



GENERAL DESIGN CRITERIA AND TECHNICAL GUIDELINES

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ENGINEERING DEPARTMENT

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SECTION 1

INTRODUCTION

1.1 GENERAL

General Design Criteria and Technical Guidelines provide general requirements applicable to the development of design and the preparation of contract documents for the Royal Commission for Madinat Yanbu Al-Sinaiyah (MYAS).

This edition (4th) of the design guide was developed on the 3rd edition. In this edition, most of the design criteria were updated to reflect current international standards with emphasis on Saudi Building Codes. Also, this edition refers to specifications organized according to MasterFormat 2004. Given the extensive nature of newly added content, guidelines for each engineering discipline are presented dedicated sections.

Civil Design Section has been updated to reflect the latest storm drainage, roads, and utility design practices suitable for MYAS.

Structural Design Section has been extensively updated to reflect the current engineering and construction practices. Specific guidelines for photovoltaic system support, pipes and utilities, concrete anchorage and, heavy cargo transport are some of the most significant additions to the Structural Design Section.

Architectural Design Section has been updated to incorporate the most current building technologies, the latest Saudi Arabian Standards Organization (SASO) standards, and the latest requirements by the Royal Commission of Jubail and Yanbu. In addition, sustainability aspects were added to the Architectural Design Section.

Mechanical Design Section has been updated to incorporate the latest Saudi Arabian Standards Organization (SASO) and Saudi Building Code (SBC) requirements with emphasis on energy conservation, water conservation, and sustainability.

Electrical Design Section, has been updated to include a sub-section on HV Transmission and Substations. The Medium Voltage Distribution sub-section has been revised to incorporate the latest Marafiq network requirements.

Telecommunication Design Section, has been updated to include sub-sections on Structured Cabling, Public Address, Security, Fire Alarms, Access Control, and Intrusion Detection Systems. Telecommunication Design has also been revised to incorporate the latest Smart City requirements.

Included in this 4th Edition is a new chapter entitled “Corrosion Protection and Control”. The exposure conditions here in MYAS are very severe exasperated by our climate and our proximity to the coast where premature corrosion is a constant threat to the durability of buildings and infrastructure. This section provides much need design guidance when selecting steel and concrete materials, both above and below ground, and provides parameters for the use of impressed current cathodic protection.

Contents of the Landscape Design Section remains unchanged from the 3rd Edition.

Computer aided drafting (CAD) standards are no longer addressed in this guide but, presented as a standalone document.

1.2 APPLICABILITY

Not all sections and subsections contained herein are applicable to each project. Applicability will be determined by individual project requirements.

1.3 ORGANIZATION OF DESIGN DOCUMENTS

The general requirements herein have been organized by design discipline for ease of reference and review. Construction drawings shall be similarly organized while the developed construction specifications shall follow the Construction Specification Institute (CSI) format.

1.4 DOCUMENTS REFERENCED IN TEXT

References to the Madinat Yanbu Al-Sinaiyah (MYAS) Master Plan, soils investigation data, and other documents are contained herein. These documents furnish supplemental information and are available for inspection and/or issue from the Royal Commission.

SECTION 2

APPLICABLE CODES AND STANDARDS

2.1 CODES, STANDARDS, AND MANUALS

The applicable international codes, standards and regulations, and manuals of Madinat Yanbu Al-Sinaiyah (MYAS), shall apply to the design and construction of all facilities comprising the infrastructure and community for MYAS. Because the Kingdom is in the process of developing many of these codes and standards, certain design or construction work may not yet be governed by Saudi Arabian regulations. In the absence of such regulations, the applicable standards and building & life Safety Codes listed in Subsection 2.2 shall apply. A current list of Saudi Arabian standards, and the standards themselves, may be obtained from the Saudi Arabian Standards Organization in Riyadh, Kingdom of Saudi Arabia (K.S.A).

2.2 CRITERIA SOURCES

The following organizations that publish codes, standards, and manuals are referenced herein. The latest edition of these documents at the time of contract award shall apply.

AA	Aluminum Association, Inc. 900 19th Street NW, Washington, DC 20006
AABC	Associated Air Balance Council 1133 15th Street N.W., Washington, DC 20005
AAMA	Architectural Aluminum Manufacturers Association 2700 River Road, Suite 118, Des Plaines, IL 60018
AAN	American Association of Nurserymen, Inc. 230 Southern Building; Washington, DC 20005
AASHTO	American Association of State Highway and Transportation Officials 444 North Capitol St., N.W., Suite 249 Washington, DC 20001
ABPA	Acoustical and Board Products Association 205 West Touhy Avenue; Park Ridge, IL 60068
ACI	American Concrete Institute Box 19150 Redford Station; Detroit, MI 48219
ACIL	American Council of Independent Laboratories, Inc. 1725 K Street, NW; Washington, DC 20006
ACPA	American Concrete Pipe Association 8320 Old Courthouse Rd. Vienna, VA. 22180
AGA	American Gas Association 8501 East Pleasant Valley Road; Cleveland, OH 44131
AI	The Asphalt Institute Asphalt Institute Building; College Park, MD 20740

AIA	American Institute of Architects 1735 New York Avenue, N.W. Washington, D.C. 20006
AISC	American Institute of Steel Construction 400 North Michigan Avenue; Chicago, IL 60611
ISI	American Iron and Steel Institute 1000 16th Street, N.W., Washington, DC 20036
AITC	American Institute of Timber Construction 11818 S.E. Mill Plain Blvd.; Vancouver, WA 98684
AMCA	Air Movement and Conditioning Association, Inc. 30 W. University Dr. Arlington Heights, IL. 60004
ANSI	American National Standards Institute, Dept. 671 1430 Broadway; New York, NY 10018
AOAC	Association of Official Analytical Chemists Box 540, Benjamin Franklin Station Washington, DC 20044
APA	American Plywood Association P.O. Box 11700, Tacoma, WA 98411
API	American Petroleum Institute 1220 L Street, Northwest; Washington D.C. 20005
ARI	Air-Conditioning and Refrigeration Institute 1501 Wilson Blvd., Suite 600 Arlington, VA 22209
ASAHC	American Society of Architectural Hardware Consultants (See Door and Hardware Institute)
ASCE	American Society of Civil Engineers 1801 Alexander Bell Drive Reston, Virginia 20191-4400
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. 1791 Tullie Circle, NE Atlanta, GA 30329
ASME	American Society of Mechanical Engineers 345 East 47th Street; New York, NY 10017
ASTM	American Society for Testing and Materials 1916 Race Street; Philadelphia, PA 19103
AWI	Architectural Woodwork Institute 2310 S. Walter Reed Dr., Arlington, VA 22206
AWPA	American Wood Preservers' Association 7735 Old Georgetown Rd., Suite 4444, Bethesda, MD 20014
AWPB	American Wood Preservers Bureau 2772 S. Randolph Street; Arlington, VA 22206
AWPI	American Wood Preservers Institute 1651 Old Meadow Road; McLean, VA 22101

AWS	American Welding Society, Inc. 550 N.W. LECTEUNE ROAD; P.O. Box 351040; Miami, FL 33135
AWWA	American Water Works Association 6666 W. Quincy Avenue; Denver, CO 80235
BHMA	Builders Hardware Manufacturers Association, Inc. 60 East 42nd Street; New York, NY 10165
BIA	Brick Institute of America 1750 Old Meadow Road; McLean, VA 22102
BS	British Standard Institution 389 Chiswick High Road London W4 4AL United Kingdom
CDA	Copper Development Association, Inc. 405 Lexington Avenue; New York, NY 10017
CE	Corps of Engineers (U.S. Dept. of the Army) Washington, DC 20315
CIM	Chlorine Institute Manual The Chlorine Institute, Inc. 342 Madison Ave, New York, N.Y. 10173
CRSI	Concrete Reinforcing Steel Institute 933 Plum Grove Road; Schaumburg, IL 60195
CS	Commercial Standards of NBS (U.S. Dept. of Commerce) - See NIST
CSI	Construction Specifications Institute, Inc. 601 Madison Street Alexandria, Virginia 22314
DHI	Door and Hardware Institute 7711 Old Springhouse Rd.; McLean, VA 22102
EIA	Electronics Industries Association
FGMA	Flat Glass Marketing Association 1325 Topeka Avenue; Topeka, KS 66612
FM	Factory Mutual Engineering Corp. 1151 Boston-Providence Turnpike; Norwood, MA 02062
FSSM	Food Services Sanitation Manual U.S. Dept of Health, Education and Welfare Washington, D.C.
GA	Gypsum Association 1603 Orrington Avenue; Evanston, IL 60201
HI	Hydronics Institute 35 Russo Place, Berkely Heights, NJ 07922
HI	Hydraulic Institute 6 Campus Drive, First Floor North Parsippany, NJ 07054

HMI	Hoists Manufacturers Institute 1326 Freeport Road Pittsburg, Pennsylvania 15238
HPMA	Hardwood Plywood Manufacturers Association P. O. Box 2789; Reston, VA 22090
ICC	International Code Council 4051 West Flossmoor Road Country Club Hills, IL, 60478-5795. Tel : 1-800-214-4321
ICEA	Insulated Cable Engineers Association
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers 345 E. 47th. St. New York, NY 10017
IES	Illuminating Engineering Society Same as IEEE.
IPCEA	Insulated Power Cable Engineers Association 192 Washington Street Belmont, MA 02178
ISA	Instrument Society of America P.O. Box 12277 Research Triangle Park, NC 27709
LIA	Lead Industries Association 292 Madison Avenue; New York NY 10017
MIA	Marble Institute of America 33505 State Street, Farmington, MI 48024
MLSFA	Metal Lath/Steel Framing Association 221 North LaSalle Street; Chicago, IL 60601
MMA	Monorail Manufacturers Assn., 326 Freeport Road Pittsburgh, PA 15238
MOT	Ministry of Transportation General Specifications for Road and Bridge Construction Riyadh, Saudi Arabia
MS	Munsell Color Macbeth Division of Kollmorgen Corporation 2441 North Calvert Street, Baltimore, Maryland 21218
MSS	Manufacturers Standardizations Society of Valve and Fittings Industry, Inc. 127 Park Street, N.E., Vienna, VA 22180
NAAMM	National Association of Architectural Metal Manufacturers 600 South Federal Street; Suite 400; Chicago, IL 60605
NACE	National Association of Corrosion Engineers Box 1499, Houston, TX 77001
NBGQA	National Building Granite Quarries Association c/o H.E. Fletcher Co., West Chelmsford, MA 01863

NBHA	National Builders' Hardware Association See Door & Hardware Institute
NBS	National Bureau of Standards (U.S. Dept. of Commerce) - See NIST
NCMA	National Concrete Masonry Association P.O. Box 781, Herndon, VA 22070
NCPWB	National Certified Pipe Welding Bureau 5530 Wisconsin Ave; Suite 750 Washington, DC
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association 2101 L Street, NW Suite 300; Washington, DC 20037
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association National Electrical Code Committee Batterymarch Park Quincy, MA 02269
NFPA	National Forest Products Association 1619 Massachusetts Avenue, NW; Washington, DC 20036
NHLA	National Hardwood Lumber Association 59 East Van Buren Street; Chicago, IL 60605
NIST	National Institute for Standards and Technology Route 270 and Quince Orchard Road Gaithersbury, MD 20899
NPA	National Particleboard Association 2306 Perkins Place; Silver Spring, MD 20910
NRMCA	National Ready Mixed Concrete Association 900 Spring Street; Silver Spring, MD 20910
NSF	National Sanitation Foundation NSF Building, Ann Arbor, Michigan 48105
NWMA	National Woodwork Manufacturers Association, Inc. - See NWWDA
NWWDA	National Wood Window and Door Association 1400 E Touhy Avenue, Suite G-54 Des Plaines, IL 60018
OSHA	Occupational Safety and Health Administration OSHA Code and Standards Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
PCA	Portland Cement Association 5420 Old Orchard Road Skokie, Illinois 60077
PCI	Prestressed Concrete Institute 201 N. Wells Street, Chicago, IL 60606
PI	Perlite Institute 45 W. 45th. St. New York, NY 10036

PS	Product Standard of NBS (U.S. Dept. of Commerce) Government Printing Office; Washington, DC 20402
RCPHC	Royal Commission Public Health Code Royal Commission for Jubail and Yanbu
RIS	Redwood Inspection Service (Grading Rules) 627 Montgomery; San Francisco, CA 94111
SAE	Society of Automotive Engineers 400 Commonwealth Dr. Warrendale, PA 15096
SASO	Saudi Arabian Standard Organization P. O. Box 3437, Riyadh, Saudi Arabia
SBC	Saudi Building Code National Committee Abi Hassan Al - Salami - Muhammadiyah Unit No. 7 Riyadh 12364-2555 Kingdom of Saudi Arabia
SDI	Steel Deck Institute 135 Addison Avenue; Elmhurst, IL 60126
SDI	Steel Door Institute 14600 Detroit Avenue; Suite 712 Lakewood Center N. Cleveland, OH 44107
SIGMA	Sealed Insulating Glass Manufacturers Association 1629 K Street, NW; Washington, DC 20006
SJI	Steel Joist Institute 1703 Parham Road; Richmond, VA 23229
SMACNA	Sheet Metal & Air Conditioning Contractors' National Association, Inc. P.O. Box 70, Merrifield, VA 22116
SPIB	Southern Pine Inspection Bureau (Grading rules) P. O. Box 846; Pensacola, FL 32594
SSPC	Steel Structures Painting Council 4400 5th Avenue; Pittsburgh, PA 15213
SWI	Steel Window Institute 1230 Keith Building; Cleveland, OH 44115
TCA	Tile Council of America P. O. Box 326; Princeton, NJ 08542
UL	Underwriters Laboratories, Inc. 333 Pfingsten Road; Northbrook, IL 60062
UPC	Uniform Plumbing Code
USAB	United States Access Board Americans with Disabilities Act and Architectural Barriers Act Accessibility Guidelines 1331 F Street, N. W. Suite 1000 Washington D. C. 2004 – 1111
WCLIB	West Coast Lumber Inspection Bureau (Grading Rules) P. O. Box 23145; Portland, OR 97223
WWPA	Western Wood Products Association (Grading Rules) 1500 Yeon Building; Portland, OR 97204

Federal specifications of the United States of America shall not be used. Where commercial standards and specifications are not applicable, use generic descriptions.

2.3 DRAFTING STANDARDS

All drawings shall meet the requirements of the latest version of the Royal Commission CAD Standards.

SECTION 3

GENERAL DESIGN CRITERIA AND STANDARDS

3.1 SITE CONDITIONS

3.1.1 GEOGRAPHICAL LOCATIONS

Yanbu: The site is located at latitude 24°00'N, longitude 38°10'E.

3.1.2 METEOROLOGY AND CLIMATOLOGY

The area has an equatorial desert climate tempered by its location on the Red Sea coast.

(1) WINDS

The wind condition at Yanbu is dominated by a local sea and land breeze system that is driven by diurnal heating and cooling of the land. The predominant sea breeze is from the northwest during the afternoon, continuing until late evening. The morning land breeze blows from the east southeast. Winds are strongest in the months of February and August when the system is combined with tradewind monsoon weather. Sand and dust storms occur occasionally, typical of a desert environment. Design wind speeds shall be obtained from the Structural Design Criteria.

(2) PRECIPITATION

Precipitation at Yanbu tends to be orographic. The coastal areas, therefore, receive considerably less rainfall than the mountains. The mountains, approximately 32 km to the northeast, occasionally produce considerable surface runoff in the local wadis. Heavy rain has been known to occur, usually between November and March, causing flooding in low-lying areas. An "Intensity-Duration-Frequency Curve" for area rain fall is indicated in Figure 3-1. More detailed data are available from the Meteorology and Environmental Protection Administration (MEPA), Kingdom of Saudi Arabia.

(3) AIR TEMPERATURE

Air Temperatures are as follows:

Condition	Temperature °C Yanbu
Range of monthly maximums	35.1 to 48.6
Monthly mean daily maximums	27.5 to 35.9
Monthly mean daily minimum	12.3 to 26.0
Range of monthly minimums	6.0 to 12.0

(4) RELATIVE HUMIDITY

The relative humidity varies from 6% minimum to 100% maximum.

3.1.3 TOPOGRAPHY

Yanbu site is relatively flat, rising only 10 m from the shoreline to the regional highway, which is the northeast boundary of the city development.

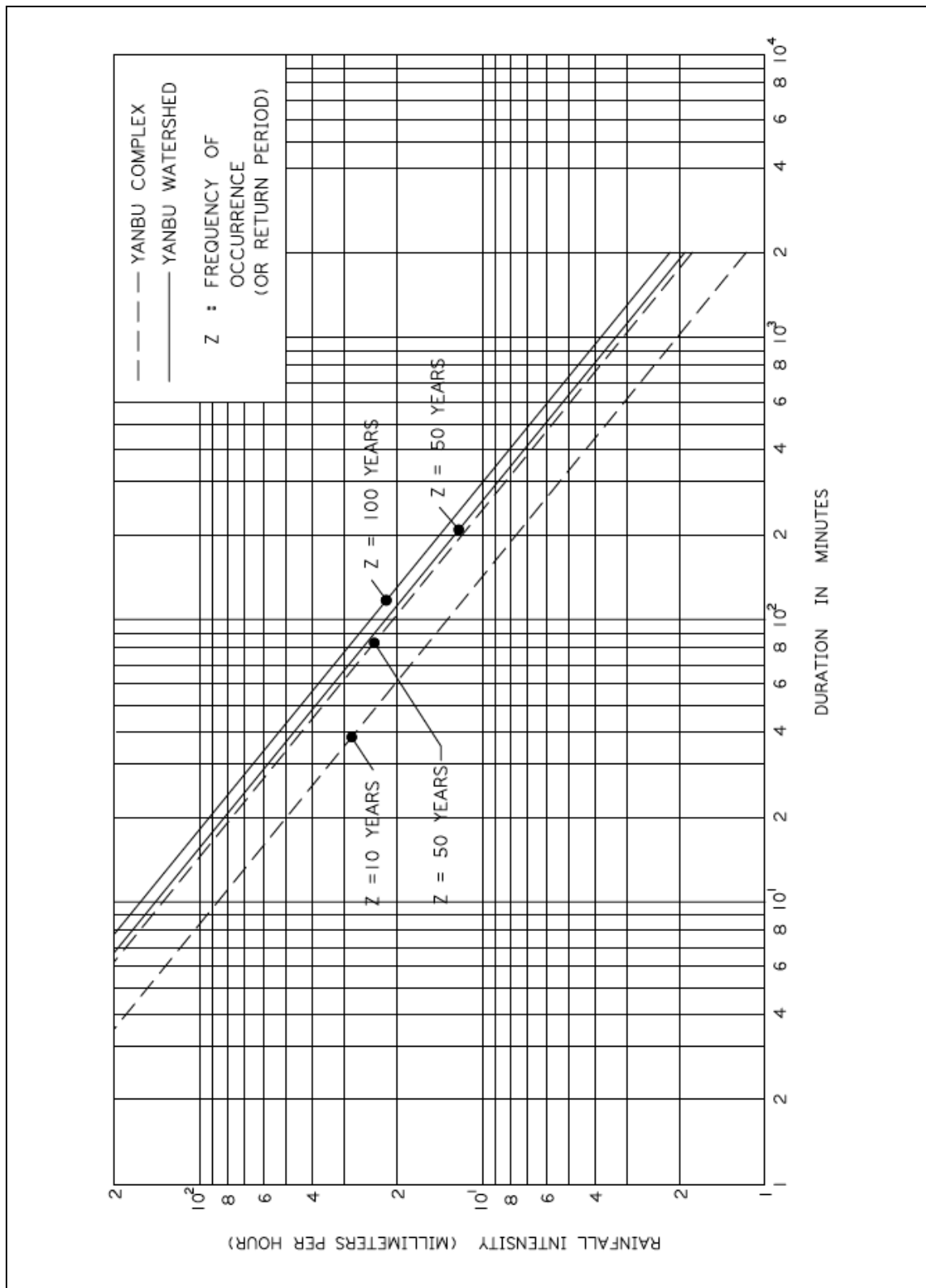


Figure 3-1 Intensity-Duration-Frequency Curve of Rainfall

3.1.4 SOIL CONDITIONS AND GEOLOGY

On the surface, the site is characterized by gravelly alluvial fans interlaced by a distributary system of wadis. The majority of the site area has dense to very dense gravel and sand, covered by up to 1 m of dense silty sands or stiff sandy silts. Wadis are generally dry year round but are subject to flooding from heavy rainfall runoff.

Soils at the site are generally corrosive due to high salt and sulfate content, as is the ground water found at relatively shallow depths.

Generalized subsurface characteristics of MYAS are available in reports entitled "General Survey of the Surface and Subsurface Conditions for Industrial Complex at Yanbu," dated March 1977, and "Subsurface Surveys for Industrial Complex at Yanbu," dated August 1976. Specific investigations have been carried out for several projects throughout the city development program and reports are available.

3.2 ENVIRONMENTAL QUALITY STANDARDS

The Environmental Protection Standards, Royal Commission, Directorate General for Yanbu Project, contains regulations and standards, as well as policy statements regarding environmental impact specific to development and operations in MYAS. These regulations and standards are to be used in conjunction with the Saudi Arabian Meteorology and Environmental Protection Administration (MEPA) Document No. 1401-01 Environmental Protection Standards.

The Environmental Protection Standards are specific to MYAS. The Royal Commission, by mutual agreement with the MEPA, acts on behalf of MEPA in monitoring and enforcing environmental standards within MYAS.

The Environmental Protection Standards may be revised and updated as the MEPA documents are revised, and as more specific requirements arise for MYAS.

SECTION 4 CIVIL DESIGN

4.1 GOVERNING CODES AND STANDARDS

The design and paving systems shall be in accordance with requirements of Ministry of Transportation (MOT), Kingdom of Saudi Arabia Manual on Uniform Traffic Control Devices (KSA MUTCD), the American Association of State Highway and Transportation Officials, the Asphalt Institute, and the Portland Cement Association. Water supply and distribution systems shall be designed in accordance with American Water Works Association (AWWA) and National Fire Protection Association (NFPA) requirements. Sanitary sewers shall conform to the design requirements of Report No. 37 of the American Society of Civil Engineers' Manuals and Reports on Engineering Practice, with consideration to the special requirements for each project.

4.2 TECHNICAL REQUIREMENTS

4.2.1 ROADS AND STREETS

(1) Grades

Road and street longitudinal grades shall not be less than 0.3% design. Ramp grades to buildings or structures and access drives to storage or parking areas shall not exceed 5%. Ramp grades at access driveways to individual dwelling shall not exceed 8%.

(2) Cross Slope

Pavement cross slope should be adequate to provide proper drainage. Normally, cross slopes range from 2% for high-type pavements and 3% for low-type pavements. In parking areas, the minimum pavement slope shall not be less than 0.5% and shall not exceed 3.5%.

High-type pavements are those that retain smooth riding qualities and good non-skid properties in all-weather with little maintenance. Low-type pavements are those with treated earth surfaces and those with loose aggregate surfaces.

(3) Super elevation

Under normal circumstances, the standard super elevation rates for various curve radii a 6% maximum rate is used to provide the maximum safety benefit while minimizing the potential low-speed operational problems. The actual super elevation provided is determined using the appropriate e max table referenced in the AASHTO GREEN BOOK. Exceptions must be approved by the RCY.

(4) Turning curves

- (a) Turning curves shall be adequate for the design truck as per RC criteria, M.O.T and AASHTO requirements, and shall comply special conditions of the project.
- (b) Standard design truck for roads shall be WB-20 in industrial area and BUS-14 in community area.
- (c) Fire truck accessibility requirements for road width and turning curve shall meet the minimum criteria as per NFPA code.
- (d) RC might require a Circulation Plan for the design truck path depending on the location of the site and the surrounding roadway network.

(5) Intersection Channelization Layout

The design layout shall conform to traffic flow requirements. Typical functional layouts are indicated in Figure 4-1 Roads or streets designated for storm drains shall require special, open- channel, invert-pavement design considerations.

(6) Curb Returns

- (a) Primary - Primary intersections use a 20 m simple curve.
- (b) Primary - Secondary intersections use a 15.0 m simple radius.
- (c) Secondary - Secondary intersections use a 10.0 m curb radius.
- (d) Secondary - Tertiary intersections use an 8.5 m curb radius.
- (e) Tertiary - Tertiary intersections use a 7.5 m curb radius.
- (f) Parking lots use a 5.0 m minimum radii at service road connections.
- (g) For Intersections design, all turning radius shall comply the minimum requirements of AASHTO 2011 tables.

(7) Sight Distance

The sight distance criteria are indicated in the Kingdom of Saudi Arabia Highway Design Standards, available from the Ministry of Transportation.

(8) Minimum clearance

The minimum vertical clearance shall be 5.50 m above crossing with roads and 7.70m above crossing with rail track.

(9) Street Signs

Street signs and other traffic control devices shall be designed in conformance with the Saudi Arabian Standards for Road Safety Features issued by the Ministry of Transportation (MOT), Manual of Uniform Traffic Control Devices by the FHWA (ANSI D 6.1) and/or standards approved by the Royal Commission in both Arabic and English.

(10) Driveways

Driveway entrances for residential and commercial units shall be reinforced concrete construction. Remote area service drives, however, may be paved with bituminous concrete. Concrete drive expansion joint spacing shall not exceed 9m. Expansion joints shall be provided along curbs and adjacent to buildings or structures.

(11) Walkways

Walkways shall be of concrete construction. Width shall not less than 1.50 m, Standard broom and float finish shall be required, except where special architectural requirements are indicated. (Expansion joint spacing shall not exceed 9.00 m). Weakened plane joint spacing shall not exceed 3 m. Expansion joints shall be provided along curbs and adjacent to buildings or structures where a walk will occupy the entire space between curbs and buildings or structures.

(12) Curbs and Gutters

Curbs and gutters shall be the integral concrete type in roads, industrial parking and paved areas. Expansion joint spacing shall not exceed 9m. Joints adjacent to concrete pavement shall match pavement joints. Weakened plane joint spacing shall not exceed 6-m. Optional use of extruded curb machines shall be provided.

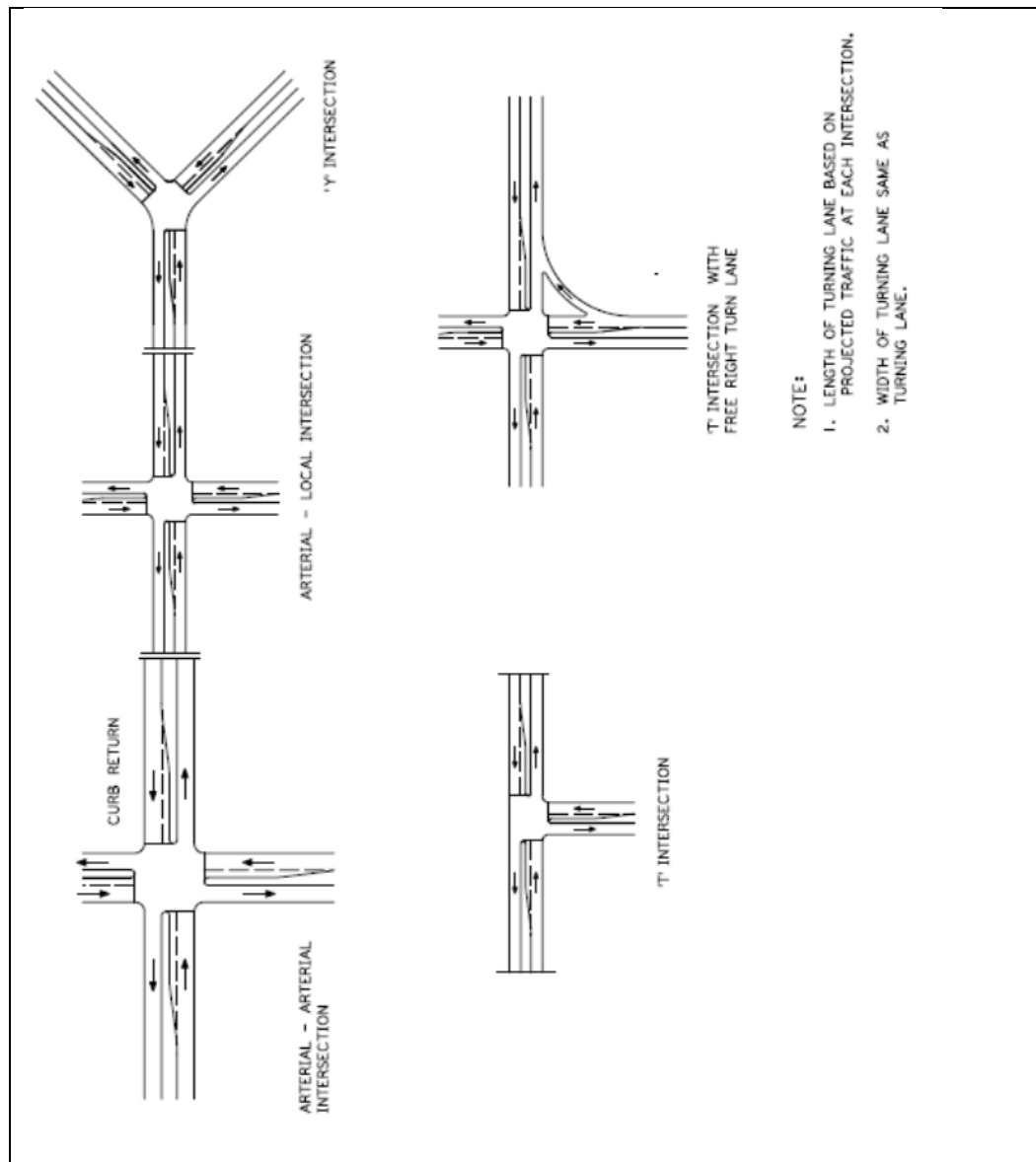


Figure 4-1. Typical Intersection Channelization

(13) Pavement Marking

Pavement Marking shall be designed in conformance with the Saudi Arabian Standards for Road Safety Features issued by The Ministry of Transportation (MOT), Manual of Uniform Traffic Control Devices by the FHWA. Colors shall be white and yellow as required for the application. Border (edge) stripes shall be solid yellow; center lines shall be white.

(14) Pavement Design

Pavement shall be of the following types.

(a) Asphalt:

- i) Primary, secondary & tertiary roads.
- ii) Public parking areas
- iii) Commercial and industrial service areas.

(b) Concrete:

- i) Residential area driveways and approaches to garages, service and parking areas.
- ii) Pedestrian walkways

(c) Concrete or Pavers:

- i) Residential courtyards
- ii) Public area parkways, courtyards and plazas.
- iii) Flexible Pavement: Use Hot Plant Mix Asphalt, super pave shall be applied for all roads categories in the industrial areas and highways. All parking and service area paving shall have fuel-resistant surface sealer.
- iv) Rigid Pavement:
 - All rigid pavement shall be reinforced concrete using Type V Portland Cement conforming to the requirements of ASTM C-150. All pavement shall be underlain with minimum 0.2 mm thick poly- ethylene sheet vapor barrier.
 - Expansion joints shall be provided between paving and buildings and structures, and at about 8.00 m centers in paving. Control joints shall be spaced at about 6 m centers in paving.
 - All paving subject to vehicular traffic shall be minimum 200 mm thick. Pedestrian walkways protected from vehicular traffic or encroachment shall be minimum 125 mm thick.

(15) Handicapped Access

- (a) The AASHTO “Guide for the Planning, Design, and Operation of Pedestrian Facilities” contains additional design guidance that may be utilized for sidewalks and sidewalk ramps.
- (b) When designing a project that includes curbs and adjacent sidewalks, proper attention should be given to the needs of persons with disabilities whose means of mobility are dependent upon wheelchairs and other devices. The street intersection with steep-faced curbs need not be an obstacle to persons with disabilities. Adequate and reasonable access shall be provided for sidewalk curb ramps.
- (c) As a result, basic curb ramp types have been established and used in accordance with the geometric characteristics of each intersection, and requires a 0.9-m minimum curb ramp width and an 8.33 percent maximum grade. Cross slopes on adjacent sidewalks should be no greater than 2 percent. A level landing area is required at the top of each curb ramp.

4.2.2 STORM DRAINAGE DESIGN

All developments shall be designed to allow safe passage of the 100 Year storm without damaging adjacent properties or infrastructure.

The drainage system for Yanbu Industrial City is organized into a major system and a minor system, as summarized in the following table:

(1) Organization of Drainage System Levels

Drainage System	Level	Design Storm	Description of Drainage Infrastructure
Major	Regional	100-year	Large open channels and detention basins that are of regional significance in that they accommodate flows originating outside the Royal Commission boundary.
Major	Primary	50-year	Storm drains of 1000 mm diameter or greater Open channels conveying flow originating outside the boundaries of a hiai.
Minor	Secondary	25-year	Storm drain using conduits smaller than 1000 mm diameter but greater than 500 mm conveying flows of a hiai.
Minor	Local	10-year	Systems using conduits smaller than 500 mm in diameter or open channel of equivalent size conveying flow of small areas or part of roadway drainage systems.

(2) Determination of Storm Surface Runoff

- (a) For catchment area less than 1 square kilometer, use the rational method.
 (b) For catchment area larger than 1 square kilometer, use the hydrograph method.
 (c) Rational Formula:

$$Q = 0.28(CIA) \text{ where}$$

$$Q = \text{Runoff in m}^3/\text{s}$$

$$I = \text{Critical rainfall intensity in mm/Hr.}$$

$$A = \text{Drainage catchment area in square kilometers.}$$

$$C = \text{Weighted runoff coefficient}$$

i) Runoff Coefficients:

The coefficient used in the rational formula is based on the weighted average. The range of coefficients classified with respect to the general character of the tributary area are as follows:

<u>Description of Area</u>	<u>Runoff Coefficient</u>
a) Business	
- Downtown	0.70 to 0.95
- Neighborhood	0.50 to 0.70

b)	Residential	
	- Single Family	0.30 to 0.50
	- Multi-units, Detached	0.40 to 0.60
	- Multi Units Attached	0.60 to 0.75
c)	Residential (suburban)	
	Apartment	0.50 to 0.70
d)	Industrial	
	- Light	0.50 to 0.80
	- Heavy	0.60 to 0.90
e)	Parks, Cemeteries	0.10 to 0.25
f)	Unimproved	0.10 to 0.30
g)	Pavement	
	- Asphaltic and Concrete	0.90 to 0.95
	- Brick	0.80 to 0.85
h)	Roofs	0.85 to 0.95
i)	Lawns, Sandy Soil	
	- Flat 2%	0.05 to 0.10
	- Average 2 to 7%	0.10 to 0.15
	- Steep 7%	0.15 to 0.20
j)	Lawns, Heavy Soil	
	- Flat 2%	0.13 to 0.17
	- Average, 2 to 7%	0.18 to 0.22
	- Steep 7%	0.25 to 0.35

- ii) The above coefficients of runoff are in accordance with the ASCE Manuals and Reports on Engineering Practice No. 37 and Page No. 212 of Hydrology for Engineers by Linsley, and modified by RC.

- iii) For different types of areas, develop a composite runoff coefficient based on the percentage of the different types of surfaces in the drainage area.

(3) Time of Concentration (T_c):

Definition: Time of concentration is the total travel time of runoff from the most remote point in the site to the discharge point or the point of interest, and it may include overland flow, shallow concentrated flow, swale/channel flow, and pipe flow. Depending on the site layout and the discharge point of interest, T_c maybe the travel time of one or more of the above flows.

T_c for the various types of flow can be calculated as follows:

(a) Sheet Flow:

Sheet flow is generally found in the upper reaches of a watershed during the rainfall event is usually 50 to 150 m in length. Sheet flow can also occur in parts of developed sites, and can be calculated as follows:

$$\text{Sheet } T_c = \frac{0.0912(nL)^{0.8}}{P_2^{0.5} S_f^{0.4}}$$

Sheet T_c = time of concentration, hours

n = surface roughness coefficient from table below

L = flow length, m

P_2 = 2-year, 24-hour rainfall, mm

S_f = land slope, m/m

Surface Description	n
Smooth Surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Short grass or Landscaping	0.150
Native desert	0.130

(b) Shallow Concentrated Flow:

Shallow concentrated flow generally consists of concentrated drainage in gutters or shallow swales/channels, and can be calculated as follows:

- i) For Unpaved surfaces:

$$\text{Shallow } T_c = \left(\frac{L_f}{4.907 S_f^{0.5}} \right) \left(\frac{1 \text{ hr}}{3600 \text{ sec}} \right)$$

- ii) For Paved surfaces:

$$\text{Shallow } T_c = \left(\frac{L_f}{6.1961 S_f^{0.5}} \right) \left(\frac{1 \text{ hr}}{3600 \text{ sec}} \right)$$

Shallow T_c = time of concentration, hours

L_f = flow length, m

$$S_f = \text{slope, m/m}$$

(c) Channel or Pipe Flow:

The travel time within channels is calculated using Manning's equation for open channel discharge:

i) Velocity is calculated using:

$$V = \frac{1}{n} \left(\frac{A}{P} \right)^{2/3} S^{1/2}$$

n = Manning's coefficient of roughness

A = Cross sectional area of flow, m²

P = wetted perimeter, m

S = slope of channel, m/m

V = average velocity of flow, m/s

ii) Channel travel time is calculated using:

$$\text{Channel } T_c = \left(\frac{L}{V} \right) \left(\frac{1 \text{ hr}}{3600 \text{ sec}} \right)$$

L = length of channel, m

V = average velocity of flow, m/s

The total time of concentration can be determined by combining (a) sheet flow, (b) shallow concentrated flow, and (c) channel / Pipe flow (if applicable) for each drainage sub-basin as shown below:

Total Time of Concentration (Total T_c) = Sheet T_c + Shallow T_c + Channel/Pipe T_c

(4) Design of the Drainage System:

The drainage system shall be designed for uniform flow. The velocity shall be calculated based on the Manning's formula as follows:

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$Q = AV = \frac{1}{n} AR^{2/3} S^{1/2}$$

Where:

Q = Discharge in m³/s.

V = Velocity in m/s

A = Cross sectional area of flow in m²

R = Hydraulic radius A/P in m

P = Wetted perimeter in m

S = Slope of the energy gradient m/m

n = Roughness coefficient

(a) Value of "n" in the Manning Equation:

Type of Material	n
i) Pipe and Boxes	
Concrete Pipe:	0.012
Concrete Box Sections:	0.012
Concrete Cast in Place:	0.014
ii) Street and Channels	
Asphalt Pavement:	0.015
Concrete Pavement:	0.015
iii) Uniform Channels	
Cobbles Flush Grouted:	0.020
Sand Fine, Silt:	0.020
Average Sand and Gravel:	0.025
Gravel - Course :	0.030
Gravel - Course with Boulders:	0.035
Rip Rap Medium Weight:	0.035
iv) Natural Wadi's	
With Light Vegetation:	0.040
With Moderate Brush and Boulders:	0.045
With Heavy Brush and Boulders:	0.070

The surface roughness is represented by the size and shape of the grains of the material forming the wetted perimeter and producing a retarding effect on the flow. This is represented by the roughness coefficient "n". Its magnitude depends on the surface condition or vegetation.

(b) Permissible Velocities in Unlined Channels:

Channel Material	Allowable Velocities (m/s)
Fine Sand-Non-Colloidal	0.46
Sandy Loam, Non-Colloidal	0.53
Silt Loam, Non-Colloidal	0.61
Alluvial Silts, Non-Colloidal	0.61
Ordinary Firm Loam	0.76
Fine Gravel	0.76
Stiff Clay Very Colloidal	1.14
Graded Silt to Cobbles	1.22
Course Gravel	1.22
Cobbles	1.52

(5) Quantities of Water to be Intercepted in Roadways:

Storm Water must be removed from road surface to provide favorable conditions for vehicles and pedestrians. For various design storm frequency, storm water shall be removed as follows:

- (a) 10-Year Storm - maintain one unflooded traffic lane.
- (b) 25-Year Storm - maintain one half of one unflooded traffic lane.
- (c) 50-Year Storm - prevent water from ponding beyond the property limit.

(6) Design of Closed Conduits:

Closed conduits are normally designed for the condition of flowing full. On steep grades, part full may occur and the conduit must be designed accordingly. Construction slopes flatter than the hydraulic slope will cause the conduit to flow under pressure for the design Q. In this case, consideration shall be given to increase the size of the conduit.

(7) General Storm Drain Design Criteria

The drainage system shall be designed in conformance with the applicable system criteria outlined below:

(a) Surface Drainage:

Surface drainage shall require maximum use of sheet flow with collection or diversion ditches. Some streets in the community and town center areas shall be designated to carry surface run-off. Runoff from adjacent areas shall be diverted, as required to minimize storm damage to the project site.

(b) Culverts:

Culverts shall be provided as required for drainage under roads. Culverts shall be designed with a minimum inside diameter of 500 mm. Concrete end walls shall be provided on all culverts with downstream channel scour protection.

(c) Storm Drain Lines:

Storm drain lines shall be designed with a minimum inside diameter of 500 mm for mainlines and 300 mm for branch lines less than 10 meters long.

(d) Storm Drain Manholes:

Storm drain manholes shall be designed for straight through flow. Manholes shall have removable cast iron covers capable of supporting a total load of 7272 kg. Grate type covers shall be used when manholes are used as required. Manholes shall be provided at changes in direction and at changes in pipe size. Manholes shall be spaced as follows:

- | | |
|---------------------------------------|------------|
| i) Conduit 750 mm in diameter or less | 90 m.o.c. |
| ii) 750 mm to 1200 mm in diameter | 120 m.o.c. |
| iii) Reinforced concrete box conduit | 150 m.o.c. |

(e) Sub-drains:

Sub-drains shall be designed with perforated pipe in collection areas and closed pipes on effluent lines. All pipe joints shall be closed.

(f) Minimum Cover:

The minimum cover over PVC/GRP the storm drain line shall be 1.20 meter. For RCP shall be designed per MOT wheel loading.

(g) Finished Floor Elevation:

Finished Floor elevations must be set above the 100-year storm elevation.

4.2.3 SEWERAGE SYSTEM DESIGN

(1) Quantity of Flow:

Average Sewage Flows

(RC assumes 5 persons per unit for residential areas)

<u>Sources</u>	<u>Liters/Day</u>
Residential Area [per capita]	340
Industrial Area (Non Residents) [per capita]	95
Hospitals [Per Bed]	760
Schools [students]	130
Hotels [per square meter]	570
Stores, Offices, and Small Business [per capita]	95
Shopping Centers [per capita]	220
Mosque [per capita]	80

(2) Groundwater Infiltration:

Groundwater Infiltration shall be calculated using the method described in “The United States Army Corp of Engineers (USACE) Sanitary and Industrial Wastewater Collection Engineer Manual”. The USACE Sanitary and Industrial Wastewater Collection Engineer Manual provide the following guidance:

“Extraneous flows from ground water infiltration will enter the sewer system and is to be accounted for by adding 500 to 1,000 gpd/per inch per mile of pipe, to the peak rate of flow. Tests required for newly constructed sewers normally limit leakage to 500 gpd/per inch per mile.”

The description provided has been converted to the metric system as follows:

Minimum, 500 gpd/inch of diameter/mile = 47 l/d/mm of diameter/km
Maximum, 1,000 gpd/inch of diameter/mile = 94 l/d/mm of diameter/km

An average of 70.5 l/d/mm of diameter/km of pipe is adopted for this design. The infiltration rates determined using this methodology has been applied as an inflow into the trunk sewers.

(3) Peak Flow Factor:

(a) The following method shall be used to determine Peak Factor (PF) for residential developments.

i) Population upto 1,000 person, PF= 5

ii) Population from 1,000 to 80,000 person, PF shall be calculated as:

$$PF = 5/p^{0.167}$$

Where P is population in thousands

iii) Population more than 80,000, PF = 2.4

(b) Residential design flow shall be calculated as:

Average Wastewater Flow x PF + Groundwater Infiltration

(c) Non-residential developments shall be evaluated as per site specific requirements.

(4) Fixture Unit Values:

For small flows from individual buildings, group of buildings or residential houses, the concept of average sewage flow has little significance. Maximum flow shall be determined by the number and type of plumbing fixtures installed. Fixture unit values are tabulated below and peak flow is determined from Figure 4-2.

Fixture Unit Per Fixture or Group

Fixture Type

Fixture Unit
Value

1 Bathroom group consisting of tank operated water closet, lavatory and bathtub or shower stall	6
Bathtub (with or without overhead shower)	2
Bidet	3
Combined sink-and-tray	3
Combined sink-and-tray with food disposal unit	4
Drinking fountain	1/2
Dishwasher domestic	2
Floor drain	1
Kitchen sink, domestic	2
Kitchen sink, domestic with food waste grinder	3
Lavatory	2
Shower stall, domestic	2
Showers (group) per head	3
Sink flushing rim (with valve)	8
Sink service (trap standard)	3
Urinal, pedestal, syphon jet, blowout	8
Urinal, wall type	4
Urinal, trough (each two feet section)	2
Wash sink (circular or multiple) each set of faucets	2
Water closet tank-operated	4
Water closet valve-operated	8

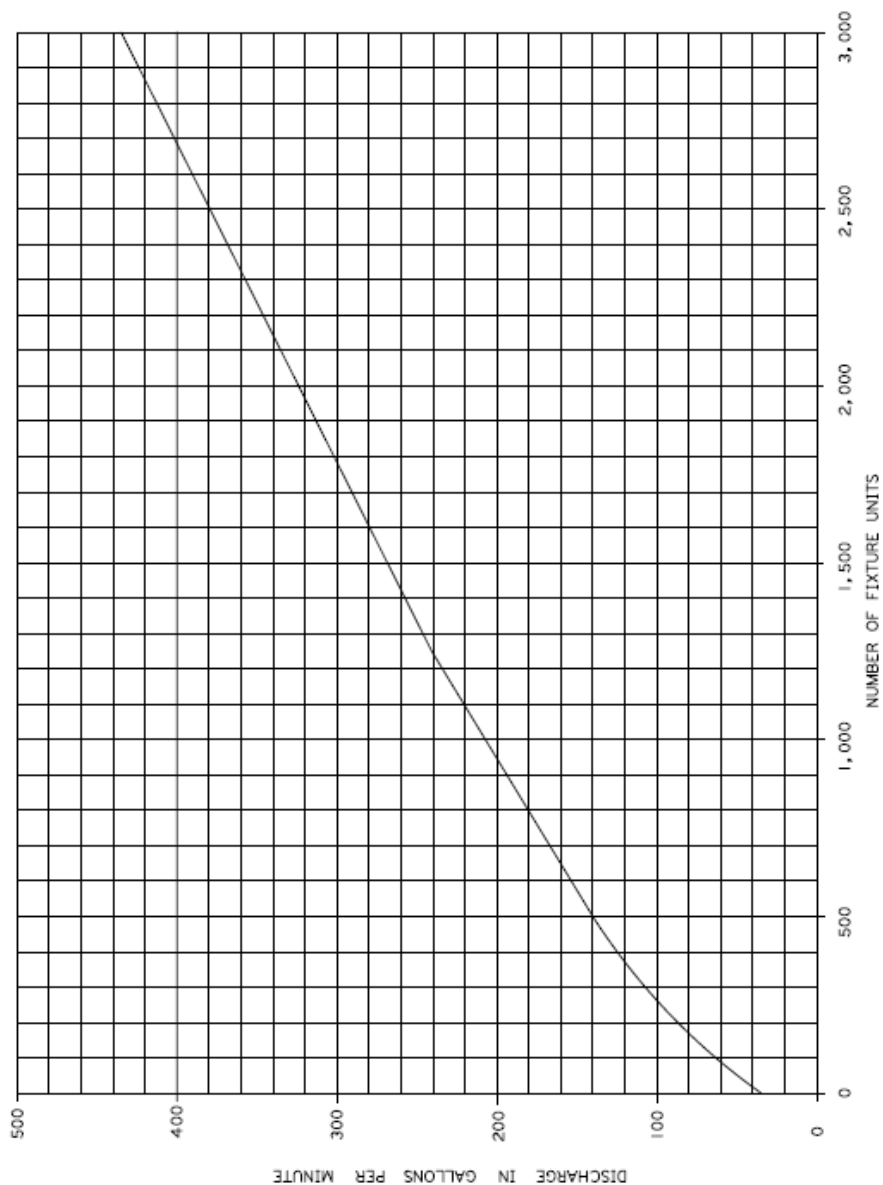


Figure 4-2. Relation of Peak Discharge to Fixture – (1 Gpm = 0.062 l/s)

(5) Hydraulic Analysis:

- (a) Manning's formula shall be used in the design of the sewer system.

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

Where:

Q = Discharge in m³/s.

V = Velocity in m/s

A = Cross sectional area of flow in m²

R = Hydraulic radius A/P in m

P = Wetted perimeter in m

S = Slope of the energy gradient m/m

n = Roughness coefficient

(b) Values of "n" to be used with Manning's equation

<u>Surface</u>	<u>"n" Value</u>
Vitrified Clay Pipe	0.013
Plastic Pipe (PVC)	0.012
Glass Reinforced Plastic Pipe (GRP)	0.012

(6) Minimum Pipe Slopes:

Minimum pipe slopes for sewer mains based on manning's formula "n" - 0.012, V = 0.70 m/sec., Class III PVC Pipe)

Pipe Size in mm	Slope m/m
160	0.0100
180	0.0050
200	0.0042
225	0.0036
250	0.0032
280	0.0027
315	0.0023
355	0.0020
400	0.0017
450	0.0015
500	0.0013
560	0.0011
630	0.0009
710 and Larger	0.0008

(7) General Sewer Line Design Criteria:

- (a) House laterals shall have a minimum pipe diameter of 160 mm to be laid to a minimum slope of 1%.
- (b) Sewer mains shall have a minimum pipe diameter of 200 mm. All sewer lines 250 mm or smaller in diameter shall be designed not more than half full at peak flow. Sewer lines larger than 250 mm in diameter shall be designed not more than 3/4 full at peak flow.
- (c) All sewer lines shall be designed to provide a minimum velocity of 0.70 m/Sec. at peak flow condition.
- (d) Manholes shall be installed at the beginning and ends of a sewer line and at all changes in pipe directions, slope or change in pipe sizes. Along straight runs, manholes shall be spaced not greater than 100 meters for pipe sizes 200 mm to 400

mm and 150 meters for larger pipes. The minimum inside diameter of manhole shall be 1.20 meters. Whenever a sewer enters a manhole, at an elevation 450 mm or more above the manhole floor, a drop type manhole shall be used.

- (e) Cleanouts (C.O.) may be used in lieu of manholes at the head end of a sewer line and along sewer laterals which are collectors for building sewers. The maximum spacing from C.O. to C.O. shall not exceed 30.00 meters and the spacing from C.O. to manhole shall not exceed 70 meters.
- (f) Minimum cover over sewer line shall not be less than 1.20 meter and shall be designed to sustain the super-imposed standard MOT wheel loading over the sewer line.
- (g) Lift Stations/pump stations:

Lift stations/pump stations shall be designed to provide adequate capacity to handle the sewage quantity at peak flow. Lift stations/pump stations shall conform to RC standard details.

- (h) Infiltration:

The infiltration of groundwater into sewer line shall not exceed 400 liters/cm of pipe diameter per kilometer per day.

- (i) Materials:

Piping shall be unplasticized polyvinyl chloride (UPVC) or fiberglass (GRP) for diameters up to 315 mm. Larger pipe over 315 mm shall be GRP. Manholes shall be fiberglass or reinforced concrete with fiberglass lining or approved protective coatings. Manhole covers shall be 600 mm diameter cast iron designed for a minimum total load of 7272 kg. All sewers shall have rubber gasket joints.

- (j) Sewer Force Mains:

- i) Force mains will be generally 200 mm in diameter or larger. For small pump stations, 160 mm may be used. For short force mains for small ejector, a 110 mm pipe may be used.
- ii) For calculating friction losses in force mains, use the Hazen Williams equation with $C = 110$ for GRP or plastic pipes.
- iii) The desired force main velocities are from 1.00 to 1.5 m/s to prevent deposition of solids at minimum flow.

4.2.4 POTABLE WATER DISTRIBUTION SYSTEM:

Potable water distribution system shall be designed in conformance with the applicable criteria outlined below.

- (1) Average Potable Water Consumptions:

(RC assumes 5 persons per unit for residential areas)

<u>Sources</u>	<u>Liters/Day</u>
Residential Area [per capita]	380
Industrial Area (Non Resident) [per capita]	105
Hospitals [Per Bed]	845
Schools [students]	145

Hotels [per square meter]	630
Stores, Offices, and Small Business [per capita]	105
Shopping Centers [per capita]	245
Mosque [per capita]	100

Water demands for non-residential developments should be evaluated based on site specific requirements as well as fire flow requirements.

For calculating Average Day Demands (ADD) on the system, population shall be based on the RC approved land use plan and 10% shall be added to account for water losses and leakage.

(2) Design Flows:

The potable water and fire systems shall be designed as per below:

(a) If potable water and fire systems are separate:

- i) Water System shall be designed to meet Peak Hour Demand (PHD)
- ii) Fire System shall be designed to meet the Fire Flow (FF) requirements

(b) If potable water and fire system is combined, then the system shall be designed for the maximum of:

- i) Peak Hour Demand
- ii) Maximum Daily Demand plus Fire Flow (MDD+FF)

(3) Flow Factors:

The maximum demand to be used in the analysis of the water network shall be determined using the Average Daily Demand multiplied by a peak flow factor as follows:

<u>Flow Condition</u>	<u>Peaking Factor</u>
Peak Hourly Demand	3.0
Maximum Daily Demand	2.5

(4) Fire Flow Requirements:

Fire Flow shall be determined on the greatest of the following demands:

- (a) In accordance with the NFPA Codes.
- (b) As specified by Project criteria
- (c) Industrial Zone = 400 m³/hr (minimum)
- (d) Residential Zone = 200 m³/hr (minimum)

(5) Hydraulic Analysis:

- (a) The hydraulic analysis of the water distribution network shall be performed by computer analysis using appropriate industry standard software. The analysis of flow in the pipe network shall assume an appropriate 'C' value depending on the pipe material to be used in the Hazen-Williams formula. Hand calculations using the Hardy Cross method are also acceptable. A minimum residual pressure in the main of 14 meters of head maintained during fire- flow analysis. The maximum velocity in the system at maximum flow shall not exceed 2.00 meters per second.

(b) Hazen-William Formula:

$$V = 0.85C \left(\frac{d}{2} \right)^{0.63} S_o^{0.54}$$

$$h_f = 6.85L \left(\frac{V}{C} \right)^{1.852} \left(\frac{1}{d^{1.17}} \right)$$

$$S = \frac{10.7}{d^{4.87}} \left(\frac{Q}{C} \right)^{1.852}$$

Where:

V = Velocity in m/s

C = Roughness coefficient of pipe

d = Pipe inside diameters in meter

L = Pipe length in meters

h_f = Hydraulic head losses in pipeline in meters

S_o = Hydraulic slope

Q = Flow rate cubic meter per second

(c) Hazen-Williams roughness coefficient 'C' value for various pipe materials.

<u>Description of Pipe</u>	<u>Value of 'C'</u>
Extremely smooth and straight pipe	140
Cast iron pipe	
New	130
5 Years Old	120
10 Years Old	110
20 Years Old	90-100
30 Years Old	75-90
Concrete or cement lined	120-140
Welded steel, as for cast iron pipe 5 Years Older	
Plastic Pipe	150
Asbestos Cement Pipe	120-140

(6) Water Meters:

- (a) Potable water meters from DN100mm and below shall be Flostar M Single-Jet Meter capable to be upgraded as a Smart Meter remote reading through Radio Frequency Wireless link (Cyble RF).
- (b) Potable water meters from DN150mm and above shall be Electromagnetic manufactured by KROHNE Waterflux 3070F battery operated.

- (c) For residential area and LIP areas where the potable water meter size is DN80mm and below, but are of high consumption, the meters shall be upgraded to Electromagnetic KROHNE Waterflux 3070F.
 - (d) For Heavy Industrial Areas and Light Industrial Areas, the process water and industrial wastewater force main meters shall be Electromagnetic manufactured by KROHNE battery operated. Potable water meter shall be Waterflux 3070F and industrial wastewater meter shall be Tidalflex 2300F.
 - (e) All Electromagnetic KROHNE meters shall be provided with data logger for sending data from the field to the Marafiq Control Room through GSM or GPRS modules.
 - (f) Water meters shall conform to RC standard specifications and drawings.
 - (g) All site test to be witness by Marafiq.
 - (h) All water meters shall be sized as per the actual demand and supported by calculations.
- (7) General Water System Design Criteria:
- (a) Sizing the Water Distribution System Network: Water main supplying fire hydrants shall not be less than 200 mm and shall be a loop distribution system. For additional technical requirements, see Subsection 7.13.
 - (b) Fire Hydrants: Fire hydrants shall be UL approved. Hydrant branch line from the water main shall be a minimum of 160 mm pipe diameter. Hydrants shall be avoided on dead end water mains. For technical requirements for fire hydrants, see Subsection 7.14.
 - (c) Loop Distribution Piping: Piping in distribution system shall be interconnected to provide a complete loop. Dead ends shall be avoided as far as possible. Water from the main distribution grid shall enter individual loop from at least two points.
 - (d) Horizontal and Vertical Pipeline Separation: A horizontal separation of 2.00 meters and a vertical separation of 0.50 m shall be maintained between water and irrigation and sewer lines, with the sewer line below the water line. A horizontal separation of 3.00 m shall be maintained where a minimum of 0.50 m vertical separation cannot be achieved. At cross overs, where the vertical separation cannot be maintained, sewer line shall be encased in concrete for a minimum length of 3.00 m on each side of the water line.
 - (e) Minimum Pipeline Cover: Pipeline shall be placed underground and designed to support the superimposed standard MOT wheel loading over the water line.
 - (f) Code and Standard: The fire protection piping system shall comply with all the applicable requirements of the National Fire Protection Association, fire underwriter and the local fire department.
 - (g) Valve Size: Gate valve shall be used for valve size of 160 mm and below, and butterfly valve with chamber shall be used for above 160 mm valve size.

SECTION 5

STRUCTURAL DESIGN

5.1 GENERAL CONDITIONS AND INITIATION OF THE STRUCTURAL DESIGN PROCESS REQUIREMENTS

- (1) Engineer, calculate, draw, detail, note, specify, cost, quantify, and describe all primary and secondary structural systems, components, and cladding including, but not limited to: buildings; other structures; transportation structures; civil-site structures; electrical and telecommunication structures; mechanical structures and above- below-ground fire, potable, and irrigation tanks.
- (2) SECTION 5 equally applies to pre-engineered buildings' and other structures' (e.g., pre-engineered metal buildings, shade structures, and porta-cabin buildings) primary and secondary structural systems, components, and elements. Refer to Subsection 5.7 "Pre-Engineered Steel Building Structure Requirements" for additional information.
 - (a) The Royal Commission does not abide by the Metal Building Manufacturers Association's structural criteria as published in their "Metal Building System Manual" and "Common Industry Practices" or their published loads, load combinations, live load reduction formulae, serviceability and deflection criteria, etcetera.
- (3) SECTION 5 "Structural Design" equally applies to the designs of primary and secondary structural systems, components, and elements by Construction Contractors. "AE Contractor" herein shall be read as "Construction Contractor" with respect to designs by Construction Contractors. Refer to Subsection 5.17 "Structural Designs by the Construction Contractor Requirements" for additional information.
- (4) Lessons Learned: It is important to the Royal Commission that past projects' errors, omissions, conflicts, and ambiguities are not repeated. In this regard, therefore, the AE Contractor shall coordinate with the Royal Commission and incorporate past projects' "lessons learned" from: (a) field-generated RFI's; (b) contractor claims and change orders; (c) addenda produced during bidding; (d) Addenda produced during construction; and (e) any other types brought to the AE Contractor's attention. Refer to Subsection 5.23 "Checklist Requirements" for additional information.
- (5) There are Royal Commission, End-User, and Third Party (e.g., Marafiq) design criteria, specifications, drawings, standards, and guidelines. The AE Contractor's structural work shall gather and incorporate the more stringent requirements from Royal Commission and Third Party sets of design criteria, specifications, drawings, standards, and guidelines, as it is required of both the design and the construction that Royal Commission and Third Party design criteria, specifications, drawings, standards, and guidelines be satisfied.
- (6) "TSS-SE" referred to herein is Royal Commission Engineering Department's Technical Support Section (TSS), Structural Engineering Unit (SE).
- (7) Bill of Quantities (BoQ) and Pay Item Description (PID) referred to herein are RFP Document F "Schedule of Prices and Quantities, Table P-2 and Specification Section 012200 "Unit Prices", respectively.

5.2 COORDINATION AND DATA GATHERING REQUIREMENTS

- (1) Coordinate the structural work with and to: each architecture and engineering discipline; Royal Commission's outside consultants, including geotechnical; and Royal Commission's in-house architecture and engineering disciplines, including corrosion control and protection.
- (2) See also "Structural-to-Geotechnical Coordination."
- (3) Coordinate the structural work with and to: value engineering; Existing Conditions Reports (ECR); Interface Control Documents (ICD); and constructability and risk reviews.
- (4) Coordinate the structural work with and to structural fire rating requirements.
- (5) Coordinate the interfaces amongst at-grade architecture and civil engineering with structural works. As a minimum, hold coordination meetings with Architecture, Civil Engineering, and Structural Engineering, and record and publish the meeting minutes. As a minimum, coordinate existing grade levels, finish grade levels, and details at: exterior doors, stairs, and ramps; abrupt changes in grade; steep slopes; and property lines, boundaries, and limits of the land coordinate diagrams.
- (6) Ensure that the structural work thoroughly and properly interfaces with adjacent and associated contracts and site developments (i.e., primary and secondary site preparation and development Contracts; sidewalks elevations, roadway elevations, top of curb elevations, etc). Pay particular attention to the project's site grading and its impacts on and transitions to contiguous and adjacent site features and conditions.
- (7) Request those original Contract Documents, As-Built, and existing conditions documents from the Royal Commission that are necessary to thoroughly and properly coordinate the structural work with the project's contiguous and adjacent works and surroundings.
- (8) Perform the necessary data gathering activities, which are to include, but not be limited to: Research, investigate, compile, review and validate data, as-built drawings, design guidelines, specifications, studies, reports, and contract packages. Prior to the Preliminary (30%) Design Phase submittal, the AE Contractor shall confirm in writing to the Royal Commission that activities requirements have been completed.
- (9) AE Contractor is responsible to timely request documents and other data from the Royal Commission. It is not the Royal Commission's responsibility to determine which documents the AE Contractor will require or to issue documents to the AE Contractor WITHOUT THE AE CONTRACTOR'S SPECIFIC AND TIMELY REQUESTS.

5.3 ROYAL COMMISSION AND TSS-SE GUIDELINE REQUIREMENTS

- (1) The purpose of Royal Commission Guidelines and TSS-SE Guidelines is to assist the AE Contractor in establishing appropriate and consistent documents for projects within Yanbu Industrial City. Royal Commission Guidelines and TSS-SE Guidelines are not all-inclusive and the AE Contractor remains responsible to ensure that their work products comply with their contract obligations and conform to the latest adopted Royal Commission rules, regulations, codes, standards, specifications, and manuals.
- (2) Edit, modify, and incorporate the Guidelines to create project-specific documents for Drawings, Notes, Calculations, Design Analysis Reports, Specifications, Cost Estimates, Bill of Materials, and Pay Item Descriptions.
- (3) Adopt the now editing, modified, and incorporated project-specific Guidelines as their own work product.
- (4) Soft copies of the Guidelines can be provided to the AE Contractor upon their written request to the Royal Commission.

(5) TSS-SE Guidelines include, but are not limited to:

- (a) Drawings and Sketches.
- (b) Structural General Notes.
- (c) Structural Special Notes, including, but not limited to those for:
 - Architectural Precast Concrete Structural Design;
 - Architectural Cast-in-Place Concrete;
 - Concrete for Dome Structures; and
 - Interior Applied Fireproofing.
- (d) Structural Special Specifications, including, but not limited to those for:
 - Pre-Engineered Metal Buildings (PEB);
 - Pre-Engineered Steel Shade Structures (PES);
 - Stone Column Ground Improvement;
 - Drilled Piers;
 - Cranes; and
 - Interior Applied Fireproofing.

Refer to the Subsection 5.5.11 “Seismic Design Parameters” for Specification requirements particular to non-structural items.

- (e) Bill of Quantities for structural and structural-related systems and components.
- (f) Pay Item Descriptions for structural and structural-related systems and components.
- (g) Transportation Structure Aesthetics.
- (h) Transportation Structure Design Analysis Report.
- (6) Royal Commission Guidelines include, but are not limited to:
 - (a) Specifications.
 - (b) Drawings.

5.4 CORROSION PROTECTION AND CONTROL REQUIREMENTS

The atmosphere, soil, and water conditions in Madinat Yanbu Al-Sinaiyah are severely corrosive. The external atmospheric corrosivity category has been identified and classified as “C5-M” in accordance with ISO12944-2. The designs and documents shall include corrosion mitigation measures to yield high durability before the first major maintenance as defined in ISO12944-5. AE Contractor shall adopt all Royal Commission-issued corrosion related documents given in SECTION 10. In this regard, gather and incorporate the most up-to-date:

- (1) Special requirements for concrete strengths and constituents, coating systems, sheet membrane systems, increased concrete cover to reinforcing, and fusion-bonded epoxy-coated reinforcing (FBE CR) where material is at and/or below soil grades and to 1m above soil grades, and/or exposed to weather, salt, salt water, brackish water, seawater, or spray from these sources.

- (2) Special requirements for steel surface preparations and coatings where material is cast with or embedded into concrete; and/or exposed to weather, salt, salt water, brackish water, seawater, or spray from these sources.
- (3) Concrete Corrosion Protection Guideline Drawings for sheet membrane and liquid-applied protections, edited and modified by the AE Contractor so they become project-specific.
- (4) Corrosion protection-related Royal Commission Guideline Specifications, edited and modified by the AE Contractor so they become project-specific.
- (5) Table 5-1 shows requirements for concrete cover to reinforcing that may be above and beyond the requirements stated in ACI 318 and AASHTO LRFD Bridge Design Specifications:
- (6) Structural cast-in-place and precast concrete in contact with soil and to the first construction joint above top soil level; exposed to salt, salt water, brackish water, seawater, or spray from these sources; exposed to potable- and fire-water, stormwater, and sanitary- and treated waste; interior, wet, non-air-conditioned environments (e.g., inside manholes, catch basins & chambers) shall utilize $f'_c = 35$ MPa as a minimum with silica fume as pozzolanic replacement.
- (7) Structural cast-in-place and precast concrete in contact with soil and to 1 m above top soil level; exposed to salt, salt water, brackish water, seawater, or spray from these sources; exposed to potable- and fire-water, stormwater, and sanitary- and treated waste; interior, wet, non-air-conditioned environments (e.g., inside manholes, catch basins & chambers) shall utilize fusion bonded epoxy coated reinforcement (FBE CR).

5.5 STRUCTURAL DESIGN BASIS REQUIREMENTS

5.5.1 BUILDINGS AND OTHER STRUCTURES

The following code with all revisions and errata shall be used:

- (1) Saudi Building Code (SBC), 2007.
- (2) International Building Code (IBC), 2012.
- (3) American Society of Civil Engineers (ASCE), ASCE/SEI 7, 2010.
- (4) With the written approval of the Royal Commission, the International Residential Code (IRC) can be used as an alternate to IBC and SBC for single-family and duplex dwellings.
- (5) Where the editions of the codes and standards cited in these notes is not given, the editions to be used shall be those listed in the applicable and governing codes.

5.5.2 TRANSPORTATION STRUCTURES CODES

Transportation Structures Codes with all Interim Revisions up to and through 2014:

- (1) American Association of State Highway and Transportation Officials (AASHTO):
 - (a) LRFD Bridge Design Specifications, 7th Edition.
 - (b) LRFD Bridge Construction Specifications, 3rd Edition.
 - (c) Standard Specification for Highway Bridges, 17th Edition, for maintenance and rehabilitation of older, existing structures.
 - (d) Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 6th Edition.

Table 5-1. Minimum Cover for Cast-In-Place and Precast Concrete Reinforcement

Concrete Exposure	Min. Cover (mm)
In Contact with Soil and to 1 st Construction Joint Above Top Soil Level; Exposed to Salt, Salt Water, Brackish Water, Seawater, or Spray from these Sources; Exposed To Potable- and Fire-Water, Stormwater, and Sanitary- and Treated Waste; Interior, Wet, Non-Air-Conditioned Environments (e.g., Inside Manholes, Catch Basins & Chambers):	
Drilled piers; All sizes of bars	100
All other elements; All sizes of bars and WWR	75
Exposed to Weather, Above 1 st Construction Joint Above Top Soil Level, Not Exposed to Salt, Salt Water, Brackish Water, Seawater, or Spray from these Sources, and Not Exposed to Potable- and Fire-Water, Stormwater, and Sanitary- and Treated Waste:	
All sizes of bars and WWR	50
Interior, Dry, Conditioned-Air Environments Above 1 st Construction Joint Above Top Soil Level:	
Slabs, walls, and joists; All sizes of bars and WWR	20
Beams and columns; All sizes of bars	40
Shells and folded plates; 20 mm and larger	20
Smaller than 20 mm and all WWR	12

NOTE 1: Fire-rated individual members, floor and roof systems, and walls: Use the minimum concrete cover requirements specified in IBC 2012 Table 721.1 when those cover requirements exceed the cover requirements shown in this Table. Refer to Subpart 5.5.22 "Structural Fire Rating Parameters" for additional information.

- (e) As well as the Codes, AE Contractor shall use AASHTO recommendations and guides to engineer, detail, and specify transportation structures. For example, use "Bridge Aesthetics Sourcebook" and "Bridge Security Guidelines."
- (2) Precast/Prestressed Concrete Institute (PCI):
 - (a) MNL-133 Bridge Design Manual.
- (3) Saudi Ministry of Transport (MOT):

- (a) General Specifications for Road and Bridge Construction.
- (b) Special Truck Live Loads (e.g., 600 kN Trucks).

5.5.3 STRUCTURAL CONCRETE CODES

Structural Concrete Codes using the editions specified in the applicable Buildings, Other Structures, and Transportation Structures Codes:

- (1) American Concrete Institute (ACI):
 - (a) 318 for structural concrete.
 - (b) 350, 350.4R, and 350.5 for environmental structure designs and 350.1 for water-tightness testing requirements. Refer to Subsection 5.5.8 “Codes for Steel and Concrete Above- and Below-Ground Tanks” and 5.13 “Concrete Above- and Below-Ground Tank and Chamber Requirements” for additional information.
 - (c) 530 for structural masonry.
 - (d) 336.1 and 336.3R for drilled piers.
 - (e) 336.2R for combined footings and mats
 - (f) 543R for piles.
 - (g) SP-66 for reinforcement detailing.
 - (h) As well as the Codes, AE Contractor shall use ACI recommendations and guides to engineer, detail, and specify structural concrete. For example, use “ACI 360R – Guide to Design of Slabs On Ground.”
- (2) US Department of Transportation, Federal Highway Administration, National Highway Institute:
 - (a) Drilled Shafts (Piers): LRFD Design Methods, May 2010, with special adherence to Chapters 12 and 16, “Design for Lateral Loading” and “Structural Design,” respectively.
- (3) Precast/Prestressed Concrete Institute (PCI):
 - (a) MNL-120 - Design Handbook.
 - (b) MNL-121 - Manual for Structural Design of Architectural Precast Concrete.
 - (c) Thermal Design of Precast Buildings, latest edition.
 - (d) As well as the Codes, AE Contractor shall use PCI recommendations and guides to engineer, detail, and specify precast/prestressed concrete. For example, use “MNL-123 - Design and Typical Details of Connections for Precast and Prestressed Concrete.”
- (4) Post-Tensioning Institute (PTI):
 - (a) TAB.1 - Post-Tensioning Manual.
 - (b) As well as the Codes, AE Contractor shall use PTI recommendations and guides to engineer, detail, and specify post-tensioned concrete. For example, use “PTI M50.3 - Guide Specification for Grouted Post-Tensioning.”

5.5.4 STRUCTURAL STEEL CODES

Steel Codes using the editions specified in the applicable Buildings, Other Structures, and Transportation Structures Codes, except where noted:

- (1) American Institute of Steel Construction (AISC):
 - (a) Steel Construction Manual, 14 Edition.
 - (b) Seismic Design Manual.
 - (c) 360 - Specification for Structural Steel Buildings.
 - (d) 303 - Code of Standard Practice for Steel Buildings and Bridges
 - (e) As well as the Codes, AE Contractor shall use AISC recommendations and guides to engineer, detail, and specify structural steel. For example, use "Detailing for Steel Construction."
- (2) Steel Deck Institute (SDI):
 - (a) Diaphragm Design Manual.
 - (b) Roof Deck Design Manual.
 - (c) Floor Deck Design Manual.
 - (d) As well as the Codes, AE Contractor shall use SDI recommendations and guides to engineer, detail, and specify steel deck. For example, use SDI "Standard Practice Details."
- (3) Steel Joist Institute (SJI):
 - (a) Load and Weight Tables for Steel Joists and Joist Girders.
 - (b) Standard Specifications for Steel Joists and Joist Girders.
 - (c) Standard Specifications for Composite Steel Joists.
- (4) National Association of Architectural Metal Manufacturers (NAAMM):
 - (a) AMP 510 - Metal Stairs Manual.
 - (b) AMP 521 - Pipe Railing Manual.
- (5) American Iron and Steel Institute (AISI), including:
 - (a) S100 - Specification for the Design of Cold-Formed Steel Structural Members.
 - (b) S200 - Cold-Formed Steel Framing Standards.
 - (c) As well as the Codes, AE Contractor shall use AISI recommendations and guides to engineer, detail, and specify cold-formed steel. For example, use AISI "Design Guide D111 - Cold-Formed Steel Purlin Roof Framing Systems."

5.5.5 STRUCTURAL WELDING CODES

Structural Welding Codes using the editions specified in the applicable Buildings, Other Structures, and Transportation Structures Codes:

- (1) American Welding Society (AWS):
 - (a) D1.1 - Steel.
 - (b) D1.3 – Sheet Steel.
 - (c) D1.4 – Reinforcing Steel.
 - (d) D1.7 - Stainless Steel.

- (e) As well as the Codes, AE Contractor shall use AWS recommendations and guides to engineer, detail, and specify structural welding. For example, use AWS “WHB-4.9 - Welding Handbook.”

5.5.6 STRUCTURAL BOLTING CODES USING THE EDITIONS SPECIFIED IN THE APPLICABLE BUILDINGS, OTHER STRUCTURES, AND TRANSPORTATION STRUCTURES CODES

- (1) Research Council on Structural Connections (RCSC):
 - (a) Specification for Structural Joints Using High Strength Bolts.
 - (b) As well as the Code, AE Contractor shall use AISC and AASHTO recommendations and guides to engineer, detail, and specify structural bolting. For example, use AISC “Steel Construction Manual” and AASHTO “LRFD Bridge Design Specifications.”

5.5.7 STRUCTURAL MASONRY CODES

Structural Masonry Codes using the editions specified in the applicable Buildings, Other Structures, and Transportation Structures Codes:

- (1) American Concrete Institute/The Masonry Society (ACI/TMS):
 - (a) 530 - Design.
 - (b) 530.1 - Specifications.
 - (c) As well as the Codes, AE Contractor shall use ACI and TMS recommendations and guides to engineer, detail, and specify structural masonry. For example, use TMS Masonry Designers’ Guide.”
- (2) National Concrete Masonry Association (NCMA):
 - (a) TEK Manual.
 - (b) As well as the Codes, AE Contractor shall use NCMA recommendations and guides to engineer, detail, and specify structural masonry. For example, use “NCMA Concrete Masonry Walls for Metal Building Systems.”

5.5.8 CODES FOR STEEL AND CONCRETE ABOVE- AND BELOW-GROUND TANKS

Use the design codes and editions required by Marafiq for those tanks under Marafiq’s control; and the design codes required by the Royal Commission for those tanks under Royal Commission control. Refer to Subsection 5.13 “concrete above- and below-ground tank and chamber requirements” for additional information with respect to concrete above- and below-ground tanks.

- (1) American Petroleum Institute (API), including:
 - (a) 620 - Design and Construction of Large, Welded, Low-Pressure Storage Tanks.
 - (b) 650 - Welded Tanks for Oil Storage.
- (2) American Water Works Association (AWWA), including:
 - (a) D100 - Welded Carbon Steel Tanks for Water Storage.
- (3) American Concrete Institute (ACI), including:
 - (a) 350, 350.4R, and 350.5 for environmental structure designs and 350.1 for water-tightness testing requirements.
 - (b) 372R and 373R for prestressed concrete circular tanks.

- (4) Portland Cement Association (PCA), including:
 - (a) Rectangular Concrete Tanks.
 - (b) Circular Concrete Tanks Without Prestressing.
- (5) United States Department of Reclamation, including:
 - (a) Concrete Manual.

5.5.9 STRUCTURAL ALUMINUM CODES USING THE EDITIONS SPECIFIED IN THE APPLICABLE BUILDINGS, OTHER STRUCTURES, AND TRANSPORTATION STRUCTURES CODES

- (1) The Aluminum Association.
 - (a) Aluminum Design Manual.
 - (b) As well as the Codes, AE Contractor shall use The Aluminum Association recommendations and guides to engineer, detail, and specify structural aluminum. For example, use "Drafting Standards for Extruded Aluminum Products."

5.5.10 WIND DESIGN PARAMETERS

- (1) Basic Wind Speed at Ultimate Level:
 - (a) Yanbu Industrial City: V_{ult} = 51 m/s for Risk Category I; 54 m/s for Risk Category II; and 58 m/s for Risk Categories III and IV.
- (2) Surface Roughness and Exposure Category shall be taken as "C," except for structures located within 1,500 m of the Red Sea coastline, in which cases Surface Roughness and Exposure Category shall be taken as "D."
- (3) Wind Loads on Pipes and Pipe Supports:
 - (a) Pipe supports shall be designed to resist the wind effects determined in accordance with ASCE 7-10, Chapter 29. Wind loads shall be applied to the pipe supports and the pipes tributary to the pipe supports.
 - (b) The design wind load, F , on structures and elements thereof shall be assumed to act normal to the surfaces and shall be determined for any height and from any direction by the following formula:

$$F = q_z G C_f A_f, \text{ the product } q_z G C_f \text{ shall be } \geq 500 \text{ N/m}^2$$

- (c) Wind forces from piping, P_w , react eccentrically on their supports and shall be calculated using an equivalent area based on an assumed wind strip height multiplied by the length of pipe tributary to the supports determined for any height by the following formula:

$$P_w = q_z S y$$

$$S = \text{Tributary length of pipe}$$

$$y = \text{Wind strip height} = D + 0.10W$$

$$D = \text{Largest pipe diameter reacting on the pipe support}$$

$$W = \text{Width of the pipe support perpendicular to the pipe run}$$

5.5.11 SEISMIC DESIGN PARAMETERS

- (1) Mapped Maximum Considered Earthquake parameters for Short Period (S_s) and 1-Second Period (S_1) shall be taken from the site-specific Geotechnical Report, but in no case taken less than the following values:
 - (a) Yanbu Industrial City: S_s of 0.204 and S_1 of 0.058. For reference and interpolation, see SBC 2007 Figures 9.4.1(e) and 9.4.1(m), respectively.
- (2) Risk Category shall be determined from IBC, ASCE 7, or AASHTO LRFD Bridge Design Specifications, as applicable for the building, non-building, and transportation structure under design.
- (3) Soil Site Classifications shall be taken from the site-specific Geotechnical Investigation Report.
- (4) Seismic Design Category shall be determined from IBC, ASCE 7, or AASHTO LRFD Bridge Design Specifications, as applicable for the structure under design.
 - (a) Yanbu Industrial City: At the minimum Short Period (S_s) of 0.204 and 1-Second Period (S_1) of 0.058, the resulting Seismic Design Categories for Site Classifications "A" through "F" and Risk Categories I through IV are shown in Table 5-2.

Table 5-2. Min. Yanbu Industrial City Seismic Design Categories

$(S_s = 0.204, S_1 = 0.058)$						
RISK CATEGORY	SITE CLASSIFICATION					
	A	B	C	D	E	F
I	A	A	A	B	C	Note 1
II	A	A	A	B	C	
III	A	A	A	B	C	
IV	A	A	A	C	D	

Note 1: Refer To ASCE 7-2010 Section 11.4.7 and AASHTO Guide Specifications for LRFD Seismic Bridge Design.

- (5) Seismic-restraint of non-structural systems and components.
 - (a) AE Contractor shall discuss this Subpart of their work with TSS-SE Supervisor as soon as possible after given the NTP and well before the first design submittal is prepared.
 - (b) Per IBC, ASCE 7, and AASHTO, special and extraordinary designs and detailing for buildings, non-buildings, and transportation structures assigned to Seismic Design Categories "C", "D", "E", and "F" extend to non-structural components, including, but limited to: architectural components, cladding and veneers, walls and partitions, ceilings, and finishes; civil-site works and retaining walls; fire-suppression piping and equipment; plumbing piping and equipment; HVAC ductwork and equipment; process piping and equipment; and electrical and communications systems and equipment.

- (c) AE Contractor shall make note of and include seismic-restraint of non-structural systems and components in all disciplines' designs, drawings, specifications, schedules of quantities and prices, descriptions of pay items, and cost estimates for all buildings, non-buildings, and transportation structures assigned to Seismic Design Category "C", "D", "E", or "F".
- (d) With regards to Project Specifications, when any building, non-building, or transportation structure is assigned to Seismic Design Category "C", "D", "E", or "F", AE Contractor shall include one or more of the following Project Specification Sections: 130541, 210548, 220548, 230548, 260548.16, and 270548.16.
- (e) Further to Project Specifications, when any building, non-building, or transportation structure is assigned to Seismic Design Category "A" or "B", AE Contractor shall include Project Specification Sections 210548.13, 220548.13, and 230548.13, and NOT include Project Specification Sections 130541, 210548, 220548, 230548, 260548.16, and 270548.16.
- (f) With regards to Pay Items and Pay Item Descriptions, when any building, non-building, or transportation structure is assigned to Seismic Design Category "C", "D", "E", or "F", AE Contractor shall include particular Pay Items in the BoQ with particular Pay Item Descriptions in the unit prices specification, for each seismic-restraint system and type of seismic-restraint device.

5.5.12 SELF-RESTRAINING AND THERMAL EXPANSION AND CONTRACTION LOADS

- (1) Design structures for the loads and effects caused by restraining supports, contraction or expansion resulting from temperature changes, shrinkage, moisture changes, creep in component materials, differential settlement, and combinations thereof.
- (2) Ambient temperatures range from a high of 50 degrees C to a low of 0 degrees C. In direct sunlight, the temperature of structures and components shall be assumed to rise a minimum of 15 degrees C above ambient. Therefore, design structures for temperature gradients of +29 degrees C and -29 degrees C with the most severe condition governing the design.

5.5.13 SERVICEABILITY PARAMETERS

- (1) Serviceability Factors: Serviceability factors (deflection, vibration, and drift) shall be used in the design and shall be in accordance with IBC Section 1604.3 (except, Notes "a" and "g" under Table 1604.3 are not to be considered), ASCE/SEI 7 Sections 12.8.6 and 12.12, AISC Steel Design Guide No. 3 "Serviceability Design Considerations for Steel Buildings", AISC Design Guide No. 11 "Floor Vibrations Due to Human Activities", and as shown below, whichever provides for the more restrictive deflection, vibration, and drift limits. The term, "span" used herein means the dimension along the member between the centerlines of supports. For cantilevers, the "span" shall be taken as twice the length (centerline of support to end of member) of the cantilever.
- (2) The design of floors shall be in accordance with AISC Design Guide 11 "Floor Vibrations Due to Human Activities", latest edition. The following additional criteria shall be met:
 - (a) Floor natural frequency as determined from AISC Design Guide 11 procedures shall not be less than 4 Hz.
 - (b) When determining the floor natural frequency from AISC Design Guide 11 procedures, actual dead loads plus superimposed dead loads plus a maximum of 10 percent of the unreduced live load shall be used.
 - (c) The depth of steel floor framing members shall not be less than 1/20 of the span.

- (3) For design wind loads, displacement of structures shall be considered using the displacements determined in an elastic analysis. The design story drift (Δ_i) shall be computed as the difference of the displacements at the center of mass at the top and bottom of the story under consideration; and $\Delta_i/L_i < 0.0025$, where L_i = story height under consideration.
- (4) For design seismic loads, displacements of the structures and the potential for interacting effects shall be considered using the amplified displacements obtained from ASCE/SEI 7 Sections 12.8.6 and 12.12. The design story drift (Δ_i) shall be computed as the difference of the amplified displacements at the center of mass at the top and bottom of the story under consideration. In buildings with cranes, $\Delta_i/L_{cr} < 0.0025$ or 20 mm, whichever is less, where L_{cr} = height to the crane rail.
- (5) The displacements, vertical, horizontal, and drift, of the building framing shall not in any way hamper the operation of equipment, doors, mechanical devices, storage racks, cranes, and other items which may or may not be attached to the building frame.
- (6) The vertical and horizontal deflections of roof, floor, and wall framing members and crane-supporting members shall not exceed the deflection-to-span ratios shown in Table 5-3.

Table 5-3 Allowable Structural Deflections

Construction	L	W	D + L	Max. Wheel Load
Roof framing members				
Supporting plaster, stucco, or brittle ceiling or finish	1/360		1/240	
Supporting other ceiling or finish or no ceiling or finish	1/240		1/180	
Floor framing members	1/360		1/240	
Roof, floor, and wall framing members supporting masonry, skylights, overhead doors, folding partitions, and other deflection-sensitive fixtures and equipment	1/600		1/400	
Exterior wall framing members				
With interior plaster, stucco, or brittle finish		1/360		
With other interior finish or no interior finish		1/240		
Exterior wall and roof metal panels		1/360		
Crane support members				
Vertical deflection				

Light & Medium Cranes - CMAA 70 Classes A, B & C				1/600
Light & Medium Cranes - CMAA 70 Class D				1/800
Mill Cranes - CMAA 70 Classes E & F				1/1000
Horizontal deflection				
All Cranes				1/400

5.5.14 LIVE LOAD REDUCTION PARAMETERS

- (1) Apply live load reduction procedures as described in IBC Sections 1607.10 and 1607.12.2 and ASCE/SEI 7 Sections 4.7 and 4.8 to all designs, except to pre-engineered metal building roof live loads.
- (2) Roof live loads ARE NOT to be reduced in the designs of pre-engineered metal buildings nor for any of their main and secondary systems, appurtenances, components, and foundations. Live Loads for roofs in IBC Table 1607.1 and ASCE/SEI 7 Table 4-1 shall be used as stated in the designs. Roof live load reduction procedures as described in IBC Section 1607.12.2 and ASCE/SEI 7 Section 4.8 SHALL NOT be used in the designs.

5.5.15 ALTERNATING/STAGGERING LIVE LOAD APPLICATION PARAMETERS

Apply alternating/staggering of live loads as described in IBC Sections 1607.11 and 1607.12.1 and ASCE/SEI 7 Section 4.3.3 to all designs.

5.5.16 STABILITY FACTORS OF SAFETY

- (1) When using factored loads, the load combinations for stability checks (e.g., IBC 2012 Equations 16-6 and 16-7 and ASCE 7-10 Equations 2.3.2-6 and 2.3.2-7) shall be resolved such that during each stage of the construction process and through the service life of the structure, the minimum factor of safety against overturning, sliding, uplift, and buoyancy shall be 1.11.
- (2) When using service-level loads, the load combinations for stability checks (e.g., IBC 2012 Equations 16-15 and 16-6 and ASCE 7-10 Equations 2.4.1-7 and 2.4.1-8) shall be resolved such that during each stage of the construction process and through the service life of the structure, the minimum factor of safety against overturning, sliding, uplift, and buoyancy shall be 1.67.

5.5.17 FOUNDATION DESIGN PARAMETERS

- (1) Base foundation designs only on the site-specific Geotechnical Investigation Report. Do not assume geotechnical engineering data (net allowable bearing capacities, allowable drilled pier capacities, settlement values, groundwater table elevations and seasonal variance, etc.) to form the basis of any foundation design.
 - (a) Design new foundations for so-called, “site-adapted” or “go-by” structures based on the new site’s specific geotechnical engineering data, reports, conclusions, and recommendations. AE Contractor to note well that structure foundations shall never be “site-adapted”, but must always be designed particularly and specifically to the site upon which the structure is to be constructed.

- (2) Thrust Restraint designs and details shall be made for all horizontal and vertical bends, elbows, tees, wyes, dead ends, reducers, and valves.
 - (a) Design loads from fluid pressure at test levels plus changes in fluid momentum within and generated by piped fluid shall be included.
 - (b) Thrust restraint and resistance (soil and concrete mass) designs shall be based on a rational, widely accepted methodology, such as ASCE's "Design of Thrust Blocks in Buried Pipelines."
 - (c) Buoyant weights shall be utilized for those blocks and anchors and chambers wholly or partially within the Design Groundwater Table.
 - (d) Thrust restraints cast directly on and buried within soil shall be made from Type V Portland cement with minimum f'_c of 25 MPa and with ASTM A775 fusion bonded epoxy coated, ASTM A767 Class 1 (915 g/m²) hot-dip galvanized, or AISI Type 316/316L marine grade stainless steel reinforcement.
 - (e) Pipe forces shall **NOT** be transferred to walls, floors, and roofs at their penetrations. Refer to Subpart 3.5.10 "Pipe and Utility Requirements" for additional information.
- (3) Earth-retaining Structure Design Surcharge: At-grade service level (un-factored) live load shall be taken as 15 KPa minimum for the design of all structures that retain earth. This live load (surcharge) shall be incorporated in design by the AE Contractor to account for construction, backfilling, and compaction operations, direct and incidental.
- (4) Earth-retaining Structure Design Pressure and Resistance: Use the Royal Commission's standard "Soil Lateral Pressure and Resistance", Figure 1 in conjunction with the site-specific Geotechnical Investigation Report.
- (5) Design Groundwater Table (D-GWT) Elevation. Determine D-GWT elevation at each subterranean element since the D-GWT will vary within the site. Set the D-GWT elevation as the high, stabilized, local-to-the-structure groundwater table reading taken from the site-specific Geotechnical Investigation Report plus the Seasonal Variance taken from the same Report.
- (6) Footing Stability: The locus of the most eccentric points of application of the resultant vertical load, ΣV , corresponding to compression over the entire footing is defined as the "kern." Footings shall be so proportioned by the AE Contractor that there will exist compression over the entire footing base for all load combinations. That is, the eccentricity, $e = M/P$, shall remain "within the kern." e.g., for square footings, "e", therefore, must be less than or equal to the footing dimension divided by six (6).
- (7) Drilled Piers: Drilled piers are the most common, but not exclusive, deep foundations used on Royal Commission projects. Where and when used, the AE Contractor's drilled pier designs and specifications shall comply with ACI 336.1 "Specification for the Construction of Drilled Piers" and ACI 336.3R "Design and Construction of Drilled Piers." AE Contractor to note well that the correct term, and therefore the correct labeling throughout the documents, is "Drilled Piers," not piles, drilled piles, caissons, or other term.

5.5.18 STRUCTURAL CONCRETE DESIGN – GENERAL GUIDELINES

- (1) Minimum 35 MPa, Type I Portland Cement with Pozzolanic Admixtures shall be used for the following Exposure Categories:
 - (a) Concrete In Contact with Soil and to 1st Construction Joint Above Top Soil Level;
 - (b) Exposed to Salt, Salt Water, Brackish Water, Seawater, or Spray from these Sources;

- (c) Exposed To Potable- and Fire-Water, Stormwater, and Sanitary- and Treated Waste;
 - (d) Interior, Wet, Non-Air-Conditioned Environments (e.g., Inside Manholes, Catch Basins & Chambers):
- (2) Minimum 30 MPa, Type I plain Portland Cement shall be used for all other reinforced concrete categories.
 - (3) Minimum 17 MPa, Type V Portland Cement shall be used for unreinforced lean or blinding concrete only.
 - (4) Note that light weight aggregate is currently not available locally. Therefore, do not use lightweight concrete mix designs for the design of any structural or architectural concrete components.
 - (5) Vapor barriers below slabs-on-grade floors are only required if the floors are receiving moisture sensitive floor coverings or are within humidity controlled areas. When vapor barriers are used they shall be placed directly below the slab and on top of a minimum 150 mm thick free-draining granular fill.
 - (6) Durability Requirements: ACI 318-11, Chapter 4 requirements for concrete durability shall be strictly adhered to.
 - (a) The A/E design professional shall assign exposure classes based on the severity of the anticipated exposure of structural concrete members for each exposure category according to Table 4.2.1 of ACI 318.
 - (b) In the absence of specific technical data, the following exposure categories and classes listed in Table 4.2.1 of ACI 318 shall be used for concrete design in the MYAS area:
 - Category F (Freezing and Thawing): F0
 - Category S (Sulfate): Below grade applications: S3
Above grade applications: S2
 - Category P (Requiring low Permeability): P1
 - Category C (Corrosion protection of reinforcement): C2
 - (7) Crack Control. Tolerable crack widths for reinforced concrete under various exposure conditions (from ACI 224) are provided here and shall be used for design considerations (see Table 5-4).

Table 5-4. Tolerable Crack Widths

Exposure Condition	Tolerable Crack Width
Dry Air or Protective Membrane	0.40 mm
Humidity, Moist Air, Soil	0.30 mm
Sea Water and Saltwater Spray	0.15 mm
Water Retaining Structures	0.10 mm

- (a) Care should be taken to provide the proper temperature and shrinkage reinforcement for the listed exposure conditions to limit cracking.

- (b) Cracking under service loads can also be controlled by limiting the maximum stress in the reinforcing steel. Follow ACI 318-11 requirements for the distribution of flexural reinforcement in beams and slabs to control flexural and torsional cracking.
- (c) The Contract Documents shall include carefully detailed Expansion Joints, Construction Joints, Control Joints etc. where required to provide for a durable and serviceable structure.

5.5.19 STRUCTURAL STEEL DESIGN – GENERAL GUIDELINES

- (1) The A/E is responsible to design and detail all steel connections required to produce fabrication shop drawings without any additional design needed by the fabricator/detailer.
- (2) Steel structures shall be configured so that steel components are not in contact with soil.
- (3) Anchor Bolts shall be headed bolts conforming to ASTM F1554, Grade 36 or Grade 50 requirements.
- (4) Steel Structures Exposed to Weather. Steel structures designed to be permanently exposed to weather and corrosive environments should include the considerations of the following corrosion protection measures:
 - (a) In general, steel surfaces exposed to weather shall be protected by heavy duty epoxy coatings over a zinc base of either epoxy primer or hot-dipped galvanizing. (Refer to chapter titled “Corrosion Protection and Control.”)
 - (b) Hollow section members should be designed so that all inside surfaces may be readily inspected, cleaned, and painted, or should be closed entirely to prevent exposure to moisture.
 - (c) The legs of back-to-back angles, when not in contact, should have a minimum separation of 9.5mm (3/8 inch) to permit air circulation.
 - (d) Pockets or depressions in horizontal members should have drain holes greater than 10mm to prevent water and deleterious matter from accumulating in low areas. Positive drainage should be provided away from exposed steel. Column bases should be terminated on concrete curbs or pedestals a minimum of 150mm above finished grade, and tops of the curbs or pedestals should be sloped to drain away from the steel components.
 - (e) Structural members embedded in concrete and exterior railing, handrails, fences, guardrails and anchor bolts should be hot-dipped galvanized to ASTM A123M or fabricated from a suitable grade of stainless steel. After fabrication, stainless steel shall have a surface finish complying with ASTM A480 No. 6 finish or BS EN 10088 Part 2 Table 6 finish 1K or 2K (vertical) $R_a < 0.5 \mu m$.
 - (f) Risks from bimetallic corrosion of dissimilar metals shall be eliminated by conductive isolation using a suitable insulator or by choosing compatible materials.
 - (g) Confer with Royal Commission Corrosion Protection Unit to recommend material protection measures for elements exposed to environments not covered in this design criteria.
 - (h) For increased serviceability and compatibility with fireproofing use galvanized steel deck in accordance with ASTM A653/A653M.

- (i) Note that some common grades of stainless alloy are susceptible to corrosion when immersed in salt or brackish water.

5.5.20 STRUCTURAL CONCRETE MASONRY UNIT (CMU) DESIGN – GENERAL GUIDELINES

- (1) The A/E is responsible to provide, on the contract documents, all of the sizes and details of reinforcing steel required to produce bar bending shop drawings and reinforcing placement drawings.
- (2) Hollow Concrete Masonry Units shall meet the requirements of ASTM C90, Type II. CMU shall be laid in running (common) bond.
- (3) The specified design compressive strength of concrete masonry assemblies, f'_m , shall not be less than 10.5 MPa (1500 psi).
- (4) Mortar shall meet the property specifications of ASTM C270 Type “S” Mortar. Masonry cement shall not be used as mortar.
- (5) Grout shall meet the requirements of ASTM C476 and have a minimum 28-day compressive strength of 20.7 MPa (3000 psi).
- (6) All CMU walls, including exterior infill wall panels, shall be reinforced vertically and horizontally. All cells containing reinforcing are to be fully grouted.
- (7) All CMU walls shall be anchored to the roof and all floors and members that provide lateral support for the wall or which are supported by the wall. The anchorage shall provide a direct connection between the walls and the roof or floor construction. The connections shall be capable of resisting the out-of-plane (normal) wind or seismic forces set forth in ASCE 7-10, but shall not be less than 4kN/m along the length of the wall at the connection interface.
- (8) CMU is not acceptable to use for below grade applications.
- (9) Control joints shall be spaced at 10m maximum on center. Provide rubber or polyvinyl chloride control joint keys at control joint locations.

5.5.21 SUPPORTING STRUCTURES AND FOUNDATIONS FOR VIBRATING MACHINERY

- (1) Definitions:
 - (a) For civil and structural design purposes, ‘vibrating machinery’ shall be defined as any equipment having reciprocating or rotary masses as the major moving parts (e.g., compressors, horizontal pumps, engines, and turbines).
 - (b) ‘Heavy vibrating machinery’ shall be ‘vibrating machinery’ having a gross plan area of more than 2.5 m² or an operating weight greater than 2,500 kg. All reciprocating compressors shall be regarded as ‘heavy vibrating machinery’ even if their operating weight is less than 2,500 kg.
- (2) Minimum Concrete Mass:
 - (a) Minimum rigid concrete-to-equipment weight ratio for all vibrating machinery shall be three-to-one (3:1) for rotary machinery and five-to-one (5:1) for reciprocating machinery.
 - (b) Design of elevated (table) support structures for vibrating machinery shall ensure the foundation weight is not less than the combined weight of the table, machine, columns, and walls.

- (3) Loading Data; Design of structures and foundations supporting heavy vibrating machinery shall be based on dynamic analysis using manufacturers' loading data, which shall include:
 - (a) Weight of machine and ancillary equipment.
 - (b) Speed of machine.
 - (c) Position of center of gravity of machine in the three major planes.
 - (d) Out of balance forces and moments (primary and secondary speed, where needed).
 - (e) Line of action of out of balance forces.
 - (f) Inertia of driver and driven in the three major planes.
 - (g) Short circuit/emergency failure forces and moments.
- (4) Dynamic Analysis of Foundations: Shall include calculation of amplitude and frequency for all six (6) degrees of freedom (3 x translational modes + 3 x rotational modes). Foundation amplitude limits shall be as specified by the equipment vendor, but shall provide a factor of safety of not less than 1.5 compared to Figure 3 of CP 2012-1, 1974 "Code Of Practice For Foundations For Machinery. Foundations For Reciprocating Machines." Besides the above data, a static design shall take into account a static horizontal (longitudinal or transverse) force of 25 percent of a static horizontal weight acting at shaft level and a static vertical force of 110 percent of machine weight, caused by erection loading impact. These forces shall not be considered as acting simultaneously.
- (5) General Design Requirements:
 - (a) Soil bearing pressure shall not exceed 50 percent of the net allowable values (NABC) under static loads.
 - (b) The effects of shrinkage and thermal expansion shall be taken into account.
 - (c) All reinforcing shall be tri-axially arranged.
 - (d) All parts of foundations and supporting structures shall be isolated from adjacent structures, paving, and slabs.
 - (e) The thickness of the foundation in meters shall be at least $0.6 + L/9$ where L is the longest horizontal dimension of the foundation.
 - (f) The ratio machine frequency/resonance frequency shall either be less than 0.8 or greater than 1.2 in all six (6) degrees of freedom (3 x translational modes + 3 x rotational modes).
 - (g) Base and bearing plates for equipment and structures shall be specified with non-shrink, non-metallic epoxy-based grout to provide full uniform load transfer between bottom of plates and concrete foundations.

5.5.22 STRUCTURAL FIRE RATING PARAMETERS:

- (1) Determine the Code-required fire ratings structural for the structural systems and components in coordination with the Architects and the Architectural Code Analysis.
- (2) Select the means by which the required structural system and component fire ratings will be achieved via IBC Section 704 and Underwriter's Laboratories (UL) Design Numbers.

- (3) Establish and incorporate the minimum structural properties and geometries (e.g., “minimum $f'_c = 30$ MPa and cover to reinforcing = 40 mm”) to achieve the fire ratings required.
- (4) Fire-rated individual members, floor and roof systems, and walls: Use the minimum concrete cover requirements specified in IBC 2012 Table 721.1 when those cover requirements exceed the cover requirements shown in the Table in Subpart 3.5.4 “Corrosion Protection and Control.”

5.5.23 SAFETY PARAMETERS

- (1) Emphasis shall be placed on safety. Calculations and drawings shall comply with the OSHA Standards 29 CFR Parts 1910 – General Industry and 1926 – Construction Industry.
- (2) Metal Ladder: Except for elevator pit ladders, refer to and make the calculations and drawings comply with ANSI A14.3, OSHA 1910.27, and Royal Commission Guideline Specification Section 055000 “Metal Fabrications.”
 - (a) Elevator Pit Ladder: Refer to and make the drawings comply with ASME A17.1 and Royal Commission Guideline Specification Section 055000 “Metal Fabrications.”
 - (b) Ships’ Ladder: Verify that use of ships’ ladders is acceptable to Royal Commission before incorporating into the Work. Note that ANSI A14.3 and OSHA regulations discourage the use of ships’ ladders 60 degrees or steeper. Where use is acceptable, refer to and make the calculations and drawings comply with Royal Commission Guideline Specification Section 055000 “Metal Fabrications.”
- (3) Alternating Tread Devices: Refer to and make the calculations and drawings comply with ANSI A14.3, OSHA 1910.24, and Royal Commission Guideline Specification Section 055000 “Metal Fabrications.”
- (4) Pipe Crossovers: Refer to and make the calculations and drawings comply with Royal Commission Guideline Specification Section 055000 “Metal Fabrications.”

5.6 STRUCTURAL-TO-GEOTECHNICAL COORDINATION REQUIREMENTS

5.6.1 SITE SPECIFIC INVESTIGATION

AE Contractor shall note well that a site-specific Geotechnical Investigation, Engineering, and Interpretive Report is critical to the AE Contractor’s foundation engineering and related services.

5.6.2 CONTRACTUAL REQUIREMENTS:

AE Contractor shall prepare and submit Structural-to-Geotechnical Coordination Packages (S-GCP) for Royal Commission’s Engineers to be able to review the site-specific Geotechnical Investigation, Engineering, and Interpretive Report. The S-GCP shall be submitted to the Royal Commission within one (1) week of receiving the Notice to Proceed (NTP) and shall include, but not be limited to:

- (1) The geotechnical engineering reporting schedule needed, including milestone dates for the completion of the geotechnical investigation reports (drafts and final); that is, a geotechnical engineering reporting schedule that will work in tandem with the AE Contractor’s design schedule.
- (2) Drawings (four (4) hard copies and one (1) soft copy in both AutoCAD and PDF formats) showing, as a minimum:

- (a) Special ground penetration and test pit locations with their UTM and RC Datum northing and easting coordinates (e.g., locations of high column load intensities, minarets, deep foundations, etc).
- (b) Existing grade levels (EGL).
- (c) Estimated finish grade levels (FGL).
- (d) Structures, primary and secondary, located on the Site Plan(s) with their estimated bottom of foundation (BOF) elevations, including, but not limited to, BOF's for footings, mats, and u/g structures.
- (e) Substructure descriptions with their estimated foundation gross and net service loads (i.e., un-factored loads).
- (f) Project's principal features and locations of any major or special structures (e.g., presence of adjacent structures, underground utilities, retaining walls, etc).
- (g) Requests for unique and/or special studies required for the AE Contractor's foundation engineering.

5.6.3 GEOTECHNICAL INVESTIGATION REPORT REVIEW

Royal Commission will review the site-specific Geotechnical Investigation, Engineering, and Interpretive Reports (Drafts and Final) and prepare and provide written comments to the AE Contractor.

5.6.4 STRUCTURAL-TO-GEOTECHNICAL COORDINATION MEETINGS

AE Contractor shall attend, participate, record meeting minutes, submit draft meeting minutes to the Royal Commission for review, and publish the final meeting minutes.

5.7 PRE-ENGINEERED STEEL BUILDING STRUCTURE REQUIREMENTS

5.7.1 DESIGN CRITERIA

SECTION 5 "Structural Design" equally applies to pre-engineered buildings' primary and secondary structural systems, components, and elements. Refer to Subsection 5.1 "General Conditions and Initiation of the Structural Design Process" and 5.17 "Structural Designs by the Construction Contractor Requirements" for additional information.

- (1) The Royal Commission does not abide by the Metal Building Manufacturers Association's structural criteria as published in their "Metal Building System Manual" and "Common Industry Practices" or their published loads, load combinations, live load reduction formulae, serviceability and deflection criteria, etcetera.

5.7.2 PREFERRED MANUFACTURER

AE Contractor shall meet and coordinate with a KSA (local preferred) Pre-Engineered Building Manufacturer (PEBM) to define the most sound and economical superstructure layouts that satisfy the overall design program, as the Royal Commission requires PEBM expertise embedded in the Work. Submit written minutes of the meeting(s) including results, conclusions, and recommendations to the Royal Commission for discussion.

5.7.3 STRUCTURAL COORDINATION

AE Contractor shall coordinate the column reactions (6 directions, 3 translational and 3 rotational) and foundation details with the PEBM. Based on this coordination, the 6-

direction foundation loads shall be shown on the foundation and PEBM drawings. The AE Contractor shall be responsible to coordinate with the PEBM so as to properly show and design the foundations for these structures.

5.7.4 MEP COORDINATION

AE Contractor to coordinate at-, above-, and below-grade Mechanical, Electrical, Telecommunication, Plumbing, Fire protection, Piping, and Process (MEP) equipment and penetrations with PEBM.

5.7.5 ARCHITECTURAL COORDINATION

AE Contractor to coordinate the Architecture (building envelope, walls and partitions, personnel doors, OH doors, louvers, etc.) with PEBM.

5.7.6 ROYAL COMMISSION SPECIFICATIONS

AE Contractor to include Royal Commission Specification Section “Pre-Engineered Metal Buildings” (also known as “Metal Building Systems”) into the PEBM’s and their own scopes of work.

5.8 SHADE STRUCTURE REQUIREMENTS

5.8.1 DESIGN CRITERIA

Part 3.5 “Structural Design Criteria” equally applies to pre-engineered structures’ primary and secondary structural systems, components, and elements. Refer to Subsection 5.1 “General Conditions and Initiation of the Structural Design Process” and 5.17 “Structural Designs by the Construction Contractor Requirements” for additional information.

5.8.2 PREFERRED MANUFACTURER

AE Contractor shall meet and coordinate with a KSA (local preferred) Pre-Engineered Steel Shade Structure Manufacturer (PESM) to define the most sound and economical superstructure layouts that satisfy the overall design program, as the Royal Commission requires PESM expertise embedded in the Work. Submit written minutes of the meeting(s) including results, conclusions, and recommendations to the Royal Commission for discussion.

5.8.3 STRUCTURAL COORDINATION

AE Contractor shall coordinate the column reactions (6 directions, 3 translational and 3 rotational) and foundation details with the PESM. Based on this coordination, the 6-direction foundation loads shall be shown on the foundation and PESM drawings. The AE Contractor shall be responsible to coordinate with the PESM so as to properly show and design the foundations for these structures.

5.8.4 MEP COORDINATION

AE Contractor to coordinate below-grade Mechanical, Electrical, Telecommunication, Plumbing, and Fire protection equipment with PESM.

5.8.5 ARCHITECTURAL COORDINATION

AE Contractor to coordinate the Architecture (steel superstructure, roof covering, etc.) with PESM.

5.8.6 ROYAL COMMISSION SPECIFICATIONS

AE Contractor to include Royal Commission Specification Section “Pre-Engineered Steel Shade Structures” into the PESM’s and their own scopes of work.

5.8.7 ROYAL COMMISSION DRAWINGS

AE Contractor to include Royal Commission Guideline Drawings “Pre-Engineered Steel Shade Structures” into the PESM’s and their own scopes of work.

5.9 PHOTOVOLTAIC PANEL SUPPORT SYSTEMS**5.9.1 PHOTOVOLTAIC PANELS ON EXISTING ROOFS**

- (1) Existing roofs capacity shall be validated to sustain dead weights of the photovoltaic (PV) systems and support framework in addition to other loads acting on the roof such as wind loads, wind loads on PV panels, live loads, snow loads, seismic loads, seismic loads on PV panels etc.
- (2) Roof live load shall be accounted under solar panels unless the clear space between the roof top and the solar panel is less than 600 mm.
- (3) As a minimum, anchorage of the photovoltaic panels to the roof shall be designed to resist wind loads and seismic loads acting on the photovoltaic system.
- (4) Wind shielding by parapets and other surrounding structures on PV system shall be ignored in calculations.
- (5) In addition to structural drawings for PV support system and anchorage, drawings for restoration of waterproofing shall be provided.

5.9.2 PHOTOVOLTAIC PANELS ON NEW ROOFS

- (1) Roofs shall be designed to sustain dead weights of the photovoltaic (PV) systems and support framework in addition to other loads acting on the roof such as wind loads, wind loads on PV panels, live loads, snow loads, seismic loads, seismic loads on PV panels etc.
- (2) Roof live load shall be accounted under solar panels unless the clear space between the roof top and the solar panel is less than 600 mm.
- (3) As a minimum, anchorage of the photovoltaic panels to the roof shall be designed to resist wind loads and seismic loads acting on the photovoltaic system.
- (4) Wind shielding by parapets and other surrounding structures on PV system shall be ignored in calculations.

5.10 PORTA-CABIN BUILDING REQUIREMENTS**5.10.1 DESIGN CRITERIA**

Part 3.5 “Structural Design Criteria” equally applies to pre-engineered buildings' primary and secondary structural systems, components, and elements. Refer to Subsection 5.1 “General Conditions and Initiation of the Structural Design Process” and 5.17 “Structural Designs by the Construction Contractor Requirements” for additional information.

5.10.2 PREFERRED MANUFACTURER

AE Contractor shall meet and coordinate with a KSA (local preferred) Pre-Engineered Porta-Cabin Manufacturer (PEPM) to define the most sound and economical superstructure layouts that satisfy the overall design program, as the Royal Commission requires PEPM expertise embedded in the Work. Submit written minutes of the meeting(s) including results, conclusions, and recommendations to the Royal Commission for discussion.

5.10.3 STRUCTURAL COORDINATION

AE Contractor shall coordinate the foundation reactions (3 translational directions) and foundation details with the PEPM. Based on this coordination, the 3-direction foundation loads shall be shown on the foundation and PEPM drawings. The AE Contractor shall be responsible to coordinate with the PEPM so as to properly show and design the foundations for these structures.

5.10.4 MEP COORDINATION

AE Contractor to coordinate at-, above-, and below-grade Mechanical, Electrical, Telecommunication, Plumbing, Fire protection, Piping, and Process (MEP) equipment and penetrations with PEPM.

5.10.5 ARCHITECTURAL COORDINATION

AE Contractor to coordinate the Architecture (building envelope, walls and partitions, personnel doors, OH doors, louvers, etc.) with PEPM.

5.10.6 ROYAL COMMISSION SPECIFICATIONS

AE Contractor to include Royal Commission Specification Section “Pre-Engineered Porta-Cabin Buildings” into the PEPM’s and their own scopes of work.

- (1) As an alternative to the above, and at the Royal Commission’s option, the AE Contractor shall meet and coordinate with a KSA (local preferred) PEPM and develop a Specification Section “Pre-Engineered Porta-Cabin Buildings” that satisfies the overall design program. The developed Specification shall be formatted to match the Royal Commission’s Specifications.

5.11 PIPE AND UTILITY REQUIREMENTS**5.11.1 PIPING LOADS**

- (1) The following piping load conditions shall be considered:
 - (a) Hydro Test.
 - (b) Operating.
 - (c) Pipe Empty.
- (2) Vertical and horizontal loads shall be determined from detailed pipe stress analyses (e.g., Caesar II Pipe Stress Analysis).
- (3) Uniformly distributed loads shown in Table 5-5 shall be used to determine minimum design vertical load forces at each level of pipe racks.

Table 5-5. Uniformly Distributed Piping Loads

DL (Empty Pipe)	F (Fluid)	Total (Operating)
1.25 KPa	3.75 KPa	5.0 KPa

- (4) The coefficients of static friction shown in Table 5-6 shall be used to determine horizontal forces at sliding surfaces. However, due to the climate and windborne sand and dust, the coefficients of static friction utilizing Teflon coatings at exterior conditions shall not be considered:

Table 5-6. Static Friction Coefficients

Surfaces	Coefficients
Teflon on Teflon	0.10
Teflon on Steel	0.20
Steel on Steel	0.30
Concrete Cast on Soil	0.40
Steel on Concrete	0.60

- (5) Refer to Subsection 5.5 “Structural Design Basis” for additional information with respect to thrust forces.

5.11.2 FORCE TRANSFER

Pipe forces shall NOT be transferred to walls, floors, and roofs at their penetrations.

- (1) Separate pipes at wall, floor, and roof penetrations with pipe sleeves and with the annular spaces sealed all around for full moisture and weather protection.
- (2) Pipe sleeves of one pipe size larger shall be installed, centered on the penetrating pipes.
- (3) The sealing of the annular spaces shall be by:
 - (a) On the wet- or weather-side, pre-fabricated expanding rings with compressible gaskets capable of sealing all around for full moisture and weather protection (e.g., “Link-Seal”); and
 - (b) For the balance of the annular spaces, non-metallic, non-shrink grout dry-packed.
- (4) To account for pipe-and-structure differential movements, install compression couplings with thrust harnesses designed and positioned to permit potential differential movements that would otherwise damage the pipes and/or structures (e.g., “Smith-Blair Joint Restraints”).

5.11.3 GRATING AND SOLID PLATE FLOORING

- (1) Grating and solid plate flooring shall be hot-dip galvanized.
- (2) Grating shall be serrated-type and solid plate shall be checkered-type.
- (3) Provide primary, secondary, and intermediate supports as required to meet deflection and loading requirements.

- (4) Gratings shall have bolted anchorage with a minimum 4 bolts per panel using 316L stainless steel fasteners.
- (5) Connectors, accessories, and hardware shall be 316L stainless steel.
- (6) Where floor plates or grating are required to be removable, no single section shall weigh more than 60 kg.

5.11.4 PIPE TRACK EXPANSION LOOPS

Vertical expansion loops for pipes are required inside the Pipeline Tracks spaced at approximately 300 meters. The dimensions are standardized to 6 meters long by 3 meters wide (width is minimum and may increase depending on usage) by 10 meters high (from top of pedestal to top of steel). Clearance for vehicular access shall be submitted to the Royal Commission for approval.

5.11.5 PIPE TRACK CROSS ACCESS AND INTERSECTION SUPPORT STRUCTURE

These structures are not intended to support pipe anchor loads, unless directed by the Royal Commission. The dimensions are standardized to 12 meters long by 6 meters wide (width is minimum and may increase depending on usage) by 10 meters high (from top of pedestal to top of steel). Clearance for vehicular access shall be submitted to the Royal Commission for approval.

5.11.6 PIPE SHOES

Pipe shoes with a height of 100 mm are welded and required normally for insulated pipes. The length of pipe shoes are a minimum of 300 mm and are determined based on expected expansion and contraction of the pipes plus additional length to ensure that the pipe shoes will not slide off the supports. The widths of the shoes vary from 150 mm to 300 mm depending on the size of pipes. Shoe materials are the same or compatible with the pipe material. Pipes larger than 600 mm diameter are to be provided with welded reinforcing wear pads in addition to the pipe shoes.

5.11.7 PIPE SLEEPERS

Spacing is standardized to 6.0 meters. They are typically made of precast or cast-in-place reinforced concrete with embedded steel base plates. Large diameter pipes usually support adjacent small diameter pipes that cannot clear span the 6 meters by providing pipe hangers or trapeze between the pipe sleepers. However, any such pipe support scheme must be approved by the Royal Commission.

5.11.8 PIPE ANCHORS AND PIPE GUIDES

Pipe anchors and guides are provided by the end-users.

- (1) For pipe anchors with balanced and symmetrical loop configurations, an estimated friction load equal to 0.30 (friction coefficient) times the total normal force ($D + F$) shall be accumulated and applied in the direction of the piping run with a concurrent friction load equal to 0.03 (friction coefficient) times the total normal force ($D + F$) applied in the transverse direction to account for snaking forces, unless specific loads are supported by pipe stress calculations.

- (2) Loads from pipe stress calculations shall be used to design pipe anchors for unbalanced and asymmetrical loop configurations.
- (3) Pipe guides are usually provided to the sides of the pipes or pipe shoes with 2 to 3 mm clearance to maintain the vertical and horizontal alignments of the pipes and where movement of pipes must be controlled to avoid clashes.

5.12 BOUNDARY WALL REQUIREMENTS

From the Royal Commission's perspective, they note that AE Contractors are not giving boundary wall designs, drawings, specifications, BoQ and PID the time nor attention they require. Too little consideration has been given to boundary walls systems, as they are, in relative terms, simple and straightforward. However, this lack of proper time and attention has caused the Royal Commission to receive many bidder queries, addenda, contractor claims, and ultimately, construction phase change orders for both time and cost. To this end, AE Contractor's boundary wall structural engineering (designs, corrosion protections, drawings, specifications, and pay items and descriptions) is to comply with the following minimum level of work and product:

- (1) Create and submit highlighted and notated drawings and request detailed topography, existing conditions, and as-built surveys for and around the entirety of the boundary wall system. This request must include topography, existing conditions, and as-built data beyond the property line (or "LCD"), as the area that influences the designs of boundary walls obviously extends beyond its outer face.
- (2) Boundary wall designs shall take all grade differentials into account. Those are, at least: outside grade higher than inside grade; outside grade lower than inside grade; and outside grade equal to inside grade.
- (3) Boundary wall designs shall take each interfacing structure into account. Those are, at least: gates, guard houses, and fire water pump houses.
- (4) Boundary wall designs shall take each new and existing utility into account. Those are, at least: utilities passing under; and utilities running parallel.
- (5) Boundary wall structural designs, drawings, specifications, and pay items and descriptions are to receive the time and attention that is proper for structural building and foundation systems.
- (6) Boundary wall corrosion protection designs, drawings, specifications, and pay items and descriptions are to receive the time and attention that is proper for structural building and foundation systems.
- (7) Minimum boundary wall "SE" drawing set would include: Foundation Plan over the CE Grading Plan; Column and Wall Layout Plan; Sections and Details taken at and through the various topographic, existing, and as-built conditions; Sections and Details taken at and through all grade differential conditions; Sections and Details taken at and through each interfacing structure condition; Sections and Details taken at and through each new and existing utility condition; Sections and Details taken at and through the boundary wall's structure and foundation; and Sections and Details taken at and through the boundary wall's corrosion protections.
- (8) Incorporate TSS-SE's guideline pay items and descriptions. Refer to Subsection 5.18 "Bill of Quantities (BoQ) and Pay Item Description (PID) Requirements" for additional information.

5.13 CONCRETE ABOVE- AND BELOW-GROUND TANK AND CHAMBER REQUIREMENTS

- (1) Design of reinforced concrete tanks and chambers requires attention not only to strength requirements, but also to crack control and durability. AE Contractor shall design concrete liquid containing structures that will resist the extremes of seasonal temperature changes in combination with the variety of loading conditions, and remain watertight.
- (2) ACI 350 "Code Requirements for Environmental Engineering Concrete Structures" extends the basic ACI 318 "Building Code Requirements for Structural Concrete" with additional serviceability requirements for crack width control due to flexure, shrinkage of concrete, and temperature movement. ACI 350 Commentary makes it clear that ACI 318 requirements alone will not produce watertight structures.
- (3) AE Contractor's designs with respect to ACI 350 serviceability requirements shall include:
 - (a) Reduced working stresses.
 - (b) Special requirements for size and spacing of reinforcement.
 - (c) Requirements for shrinkage reinforcing at each face.
 - (d) Increased minimum reinforcement for temperature and shrinkage movement, which are dependent on the grade of reinforcing steel and the length between shrinkage-dissipating joints.
 - (e) Special waterstop requirements at all joints.
 - (f) Special concrete mix design requirements and utilizing shrinkage-compensating concrete per ACI 223. Specifying concrete mix designs that minimize shrinkage is critical to the durability of liquid containing structures.
 - (g) Increased concrete cover to reinforcement requirements.
- (4) In addition to requirements within ACI 350, 350.4R, 350.5, 372R, and 373R, AE Contractor shall utilize the following design aids:
 - (a) Portland Cement Association (PCA) "Rectangular Concrete Tanks" and "Circular Concrete Tanks Without Prestressing."
 - (b) United States Department of Reclamation "Concrete Manual."
- (5) AE Contractor shall obtain the vertical, horizontal, and vibration loads from equipment from the manufacturers, and design for possible restraint of temperature movement of supporting structures.
- (6) AE Contractor shall specify shrinkage requirements (e.g., 0.04% to 0.03%), and require the Construction Contractor to submit shrinkage test results with the associated concrete mix design submittals.

5.14 ANCHORING AND OTHER TRANSFER OF FORCE REQUIREMENTS**5.14.1 GROUTING**

- (1) Except as note below for heavy vibrating equipment, all base and bearing plates and the annular space around all sleeves shall be specified with non-shrink, non-metallic cement-based grout to provide full uniform load transfer between bottom of plates and concrete.
- (2) Base and bearing plates for heavy vibrating equipment shall be specified with non-shrink, non-metallic epoxy-based grout to provide full uniform load transfer between

bottom of plates and concrete foundations. Note that 'heavy vibrating equipment' is any equipment of operating weight greater than 2,500 kg.

5.14.2 ANCHORS

- (1) The structures, tanks, and equipment and all such related items shall be securely anchored to their foundations using cast-in-place steel anchor bolts designed to resist all induced forces.
- (2) Code-required concrete reinforcement shall be provided to transfer the design compression, tension, and shear stresses from the anchors to the foundations.
- (3) The minimum distance from base and bearing plate grout at its lower, outer edge to the closest edge of foundation, taking chamfered edges into account, shall be 75 mm.
- (4) The minimum distances from centerlines of anchors to the closest edge of foundations shall be as shown in Table 5-7. Additionally, anchors are to be dimensioned with further edge distance to make certain that the anchors' embedded parts (e.g., heads and washer) clear the foundation reinforcement plus a tolerance:

Table 5-7. Minimum Distance from Centerline of Anchors

Anchor Diameter	Minimum Edge Distance
≤ 25 mm	150 mm
> 25 mm	175 mm

- (5) Cast-in-place anchors shall be specified wherever possible. Only in unattainable situations are post-installed anchors to be specified.
- (6) When specifying post-installed expansion-, chemical-, and sleeve-type anchors, define them, "as manufactured by HILTI Corporation or approved equivalent." AE Contractor shall require the Construction Contractor to, "install anchors per the manufacturer's instructions and utilizing the manufacturer's recommended means, methods, techniques, sequences, procedures, and equipment."
- (7) AE Contractor shall not specify chemical anchors where the anchors would be:
- (8) Subjected to sustained tensile loads; or
- (9) Installed overhead.
- (10) AE Contractor shall require the Construction Contractor to test post-installed anchors before use, simulating the conditions of the intended field applications, to verify that the anchors are capable of obtaining and sustaining their design strength. Verification tests shall be conducted by independent testing agencies and shall be certified with full descriptions and details of the testing programs, procedures, results, and conclusions. Note that a minimum of 1 percent of each anchor type shall be tested and not less than 3 anchors of each type shall be tested.
- (11) AE Contractor shall specify only and require the Construction Contractor to use only post-installed anchors that have been pre-qualified by ACI 355.2 (mechanical anchors) and ACI 355.4 (chemical anchors).
- (12) AE Contractor shall design all post-installed structural anchors in accordance with Appendix D of ACI 318 and the examples given in ACI 355.3.

5.15 SITE ADAPTION PROJECT TYPE REQUIREMENTS

The following shall be used to improve the quality of site adaptation projects. Implement these requirements for each site adaptation project.

- (1) All structural-related designs, drawings, and specifications shall be reviewed, updated, and improved.
- (2) All structural-related BoQ and PID shall be reviewed, updated, and improved.
- (3) All structural-related Cost Estimate items shall be reviewed, updated, and improved.
- (4) Complete and submit at each design stage the Structural Check List specific for the site adaptation project at hand.
- (5) Coordinate with TSS-SE Supervisor, gather TSS-SE's latest guidelines, and incorporate the latest guidelines.
- (6) New sites have new soil characteristics, new groundwater table elevations, and new grade elevations, both existing and finish. Therefore, foundations are never site adaptable, and shall have full new designs, drawings, specifications, pay items and descriptions, and cost estimates.
- (7) Coordinate with TSS-SE Supervisor and incorporate "Lessons Learned." These are issues raised and documented from previous projects and that require the AE Contractor to review and update the site adaptation project at hand so that errors and omissions from prior projects are not repeated therein. Refer to Subsection 5.1 "General Conditions and Initiation of the Structural Design Process" for additional information.
- (8) Incorporate Royal Commission-, third party-, and end user-initiated modifications.
- (9) Updates to Codes, Design Criteria, Specifications, Drawings, Standards, and Guidelines shall be applied to site adaptation projects.

5.16 HEAVY CARGO (HAUL) TRANSPORT REQUIREMENTS

5.16.1 DESIGN LOADS

Roadway pavements and corresponding civil/site structures within and over such pavements are designed for HS20-44 live load, NOT the Ministry of Transportation Highway Design Manual's 3-axle 600 kN (61.2 T) truck. HS20-44 live load, then, limits heavy cargo transports to a maximum uniformly distributed pressure at the pavement surface to 1.62 T/m^2 . (Note: that this limit is derived from ASCE 7-10, Table 4-1, surfaces subject to trucking live load = 11.97 KPa ; such that, $11.97 \text{ KPa}/9.81 \times 1.33$ for temporary loading = 1.62 T/m^2)

5.16.2 MAXIMUM UDL

The heavy cargo transporter is to limit the maximum uniformly distributed pressure at the pavement surface to 1.62 T/m^2 by increasing the number of axles and wheels to enlarge the area loaded at the pavement. Where such enlargement of equipment is not possible, then the heavy cargo transporter shall prepare and submit the data prescribed in Subsection 5.16.

5.16.3 SUBMITTAL REQUIREMENTS

- (1) Tractor-Trailer Data: Prepare the following data for the tractor-trailer.
 - (a) Dimensions and geometry of the tractor-trailer and fully loaded tractor-trailer assembly. The minimum dimensions to be shown are: length, width and height of transport vehicle, dimensions between tires in length and width, wheel dimensions,

fully loaded length, width and height of load plus vehicle, number of tires, and total vertical clearances needed to transport load.

- (b) Rear, plan, and elevation views of the fully loaded tractor-trailer assembly.
 - (c) Cargo pay load and the location of the pay load center of gravity in three dimensions.
 - (d) Tractor operating weight, axle loads, and wheel loads.
 - (e) Trailer with pay load operating weight, axle loads, and wheel loads.
 - (f) Calculations showing maximum uniformly distributed pressure at the road surface under the tractor-trailer with its pay load.
 - (g) Number of heavy transport vehicles and other vehicles that will be part of the transport.
- (2) Referring to Subsection 5.16, prepare the following when it is not possible to limit the maximum uniformly distributed pressure at the pavement surface to 1.62 T/m^2 :
- (a) Diagram of the tractor-trailer turning movements: Provide a layout of the turning movements at intersections, or any area that the tractor-trailer will need to turn more than 30 degrees. The diagram shall show the turning radius of the tractor-trailer, identify the exact route of the tractor-trailer, turning movements, and identify all Royal Commission- and third party-owned appurtenances that the tractor-trailer may encounter while turning (i.e. traffic signal poles, street lights, median curbs, edge of pavement, traffic signs, etc) and that may need to be detached, relocated, or rebuilt.
 - (b) If the tractor-trailer needs to travel off the pavement, provide road profile and grades of the slopes and the characteristics of the soil that will be encountered. The heavy cargo transporter may need to prepare the ground by grading, scarifying, and compacting to ensure the ground can safely handle the tractor-trailer.
 - (c) Prepare plans showing and labeling all the Royal Commission- and third party-owned civil/site structures along the proposed route, which shall include, but not be limited to, culverts, headwalls, abutments, retaining walls, overpasses, and underground duct banks, conduits, pipes, and other utilities. Prepare the following data for each structure:
 - i) Soil overburden and paving thicknesses.
 - ii) Position of the tractor-trailer relative to the road.
 - iii) Structural existing conditions survey of the exposed primary structural components and systems.
 - (a) With due consideration for the information obtained from the existing conditions survey, prepare calculations for each structure identified and the associated soil bearing medium for the tractor-trailer and for the maximum ground bearing pressure under the trailer with pay load as per AASHTO guidelines. In the absence of structure-specific geotechnical engineering recommendations, assume an allowable soil bearing pressure of 150 KPa.

Provide temporary shoring, bracing, and support design calculations and drawings for each structure and soil bearing medium where the analysis shows the existing structure and/or soil will be overstressed.

- (b) Application Data: Prepare the following data for the Application.
- i) Completed Roads Department's Oversize/Overweight Transportation Permit Application.
 - ii) Written portal to portal route description.
 - iii) Road map highlighting the route portal to portal.
 - iv) Liability Waiver – signed Obligation Letter.
 - v) The date, time of day the transport will start, anticipated length of transport time, anticipated time of day the transport will end, and the speed of the tractor-trailer. Please note that during times of heavy traffic, the tractor-trailer may need to wait until the traffic has passed.
 - vi) Prepared data prescribed in Subsection 5.16 when the uniformly distributed pressure at the pavement surface exceeds 01.62 T/m².

5.17 STRUCTURAL DESIGNS BY THE CONSTRUCTION CONTRACTOR REQUIREMENTS

- (1) SECTION 5 equally applies to the designs of primary and secondary structural systems, components, and elements by Construction Contractors. "AE Contractor" herein shall be read as "Construction Contractor" with respect to designs by Construction Contractors. Refer to Subsection 5.1 "General Conditions and Initiation of the Structural Design Process" for additional information.
- (2) Construction Contractor to note that there are Royal Commission, End-User, and Third Party (e.g., Marafiq) design criteria, specifications, drawings, standards, and guidelines. The Construction Contractor's structural work shall gather and incorporate the more stringent requirements from Royal Commission and Third Party sets of design criteria, specifications, drawings, standards, and guidelines, as it is required of both the design and the construction that Royal Commission and Third Party design criteria, specifications, drawings, standards, and guidelines be satisfied.
- (3) Where designs are required of the Construction Contractor by the Contract Documents, the designs shall be performed by professional structural engineers.
 - (a) The governing Codes and the Contract Documents shall be referred to for determining load and serviceability requirements on main systems, sub-systems, and components and cladding, including, but not limited to: dead, live, wind, earthquake, rain, vehicle, impact, equipment, and thermal loads, and deflection and vibration limits.
 - (b) The design submittals shall indicate the loads and serviceability criteria used in the designs of the main systems, sub-systems, and components and cladding.
- (4) Designs shall be prepared in design document formats, not "shop drawing" formats; be stamped and signed by the professional structural engineers who performed the designs; have been first checked and approved by the Construction Contractor; and then submitted to the Royal Commission for review. The responsibility for structural designs required of the Construction Contractor shall remain solely with the Construction Contractor.
- (5) Refer to Subsection 5.4 "Corrosion Protection and Control" for designs involving metals in wet environments, metals attached to or embedded in concrete or masonry, metals in contact with soil, and metals exposed to weather, salt, salt water, brackish water, seawater, or spray from these sources.

- (6) Where designs are required of the Construction Contractor, note that the member and connection designs shown in the Contract Drawings are indicative and shown for illustrative, coordination, and information purposes, unless stated otherwise.
- (7) Design submittals, first checked and approved by the Construction Contractor, shall be submitted to the Royal Commission for review before fabrication or delivery of materials not requiring fabrication can proceed.
 - (a) Design submittals sent to the Royal Commission without first being stamped "checked and approved" by the Construction Contractor shall be returned without being reviewed by the Royal Commission.
 - (b) Review of design submittals by the Royal Commission shall not relieve the Construction Contractor from conforming to the requirements of the Contract Documents.
 - (c) Refer to Specification Sections for additional submittal requirements.
- (8) Design documents shall be original documents prepared by the Construction Contractor. Reproduction of the Contract Documents for use as Construction Contractor-prepared design documents is unacceptable and will be rejected for non-compliance.
- (9) Construction Contractor-proposed changes, substitutions or deletions to the Contract Documents shall be submitted to the Royal Commission for review prior to their incorporation into the project. The submission shall highlight and note the proposed change, substitution or deletion. Proposed changes, substitutions or deletions to the Contract Documents which do not follow this requirement shall be considered unacceptable.
- (10) Record sets of design submittals shall be maintained in the field office by the Construction Contractor.
- (11) Work shall only be performed from design submittals that have been checked and approved by the Construction Contractor and accepted without comment by the Royal Commission.

5.18 BILL OF QUANTITIES (BOQ) AND PAY ITEM DESCRIPTION (PID) REQUIREMENTS

- (1) Structural systems shall not have "rolled-up" pay items (e.g., excavation and backfilling + blinding + footings and pedestals + corrosion protection + etc.) or have their works rolled-up in other disciplines' pay items (e.g., structural + electrical works). But, rather structural systems' pay items shall be separated into their components and be independent of other systems' pay items. This is required because the Royal Commission uses Unit Price Construction Contracts and rolled-up pay items defeats the advantages the Royal Commission seeks by choosing to use Unit Price Construction Contracts.
 - (a) For structural works, AE Contractor shall use the TSS-SE Guideline BoQ and PID to assist the AE Contractor in establishing appropriate and consistent pay items and descriptions. TSS-SE Guidelines are not all-inclusive and the AE Contractor remains responsible to ensure that their work products are all-inclusive, comply with their contract obligations, and conform to the latest adopted Royal Commission rules, regulations, codes, standards, specifications, and manuals.
 - (b) Refer to Subsection 5.5.11 "Seismic Design Parameters" for BoQ and PID requirements particular to non-structural systems.

5.19 SPECIFICATION REQUIREMENTS

- (1) AE Contractor shall adopt the Royal Commission's Guideline Specifications.
- (2) The purpose of Royal Commission Guideline Specifications is to assist the AE Contractor in establishing appropriate and consistent documents for projects within Yanbu Industrial City. Royal Commission Guidelines are not all-inclusive and the AE Contractor remains responsible to ensure that their work products comply with their contract obligations and conform to the latest adopted Royal Commission rules, regulations, codes, standards, specifications, and manuals. Refer to Subsection 5.3 for additional information and requirements.
 - (a) AE Contractor shall edit Section 011000 "SUMMARY" and identify the relevant projects requiring coordination with this Project.
 - (b) Critical for EPC Contracts that AE Contractor edit Section 011000 and identify all professional services Contractor will be required to provide for the project.
 - (c) Critical for EPC Contracts that AE Contractor add Section 011000.16 "EPC DESIGN AND DESIGN SUBMITTAL REQUIREMENTS" to Section 011000 Part 1 within "Related Requirements."
- (3) AE Contractor to note that there are both Royal Commission, End-User, and Third Party (e.g., Marafiq) specifications. The AE Contractor's structural work shall gather and incorporate the more stringent requirements from Royal Commission, End-User, and Third Party specifications, as it is required of both the design and the construction that Royal Commission, End-User, and Third Party specifications be satisfied.
- (4) Royal Commission's Guideline Specifications, both the Division 16 and 33 versions, are the most common, frequently required specification sections, but are not all-inclusive and the AE Contractor remains responsible to produce those specification sections that are less common, less frequently required, but needed to specify the project's scope of work.
- (5) AE Contractor shall produce any and all special specifications required for the project's scope of work. Examples of special specifications are: shoreline protection, revetments, and transportation structures.
 - (a) Transportation structure specifications shall be based on AASHTO "Standard Specification for Highway Bridges" and "LRFD Bridge Construction Specifications."
- (6) Porta-Cabin Specifications: Refer to Subsection 5.10 "Porta-Cabin Building Requirements" with respect to porta-cabin specifications.
- (7) Refer to Subsection 5.5.11 "Seismic Design Parameters" for Specification requirements particular to non-structural systems.
- (8) Critical for EPC Contracts that Section 011000.16 "EPC DESIGN AND DESIGN SUBMITTAL REQUIREMENTS" be included and edited.
 - (a) Project Manager shall review it personally with each Discipline Supervisor.
 - (b) Edit the Section thoroughly and in its entirety.
 - (c) Edit for Exhibits, Architectural Models, Renderings, FFE Master Folio, and other parts highlighted.
 - (d) Project Manager and each Discipline Supervisor shall make edits to ensure that the Contractor is required to provide all required professional services for the project as summarized in Section 011000.

- (9) Royal Commission Specification format, labeling, and numbering standard shall be followed.

5.20 STRUCTURAL DESIGN CALCULATION REQUIREMENTS

- (1) The AE Contractor shall prepare and submit structural calculations in compliance the Contract provisions and with the following. Refer to Subsection 5.24 "Deliverables by Phase Requirements" for additional information.
- (2) Format: All calculations shall be presented in a professional manner. Calculations shall be grouped in accordance with the subject to which they pertain. Each group of calculations shall be preceded by a cover sheet which contains the following information:
 - (a) Name of AE Contractor preparing and submitting the calculations.
 - (b) Contract Title and Number.
 - (c) Subject.
 - (d) Calculation No.
 - (e) Sheet No. ____ of ____
 - (f) Name and signature of structural engineer and design date.
 - (g) Name and signature of structural checker and checking date.
 - (h) Name and signature of the structural supervisor and approval date.
 - (i) List of all references used, including codes, standards, textbook, etc.
 - (j) Index, which shall itemize all major parts of the design.
 - (k) Highlights of all conclusive calculation results so that the AE Contractor's checker and approver, Royal Commission TSS-SE reviewer, and third parties who are not as familiar as the preparers with the calculations can follow them without any questions.
- (3) Content: Calculations shall be prepared in SI units. The calculation sheets shall contain or present the following information:
 - (a) List of all design parameters and assumptions used.
 - (b) List of all structural design information used in the calculations with proper referencing from where it was taken (e.g., "Live Load Reduction from IBC 2012, Section 1607.10, page 342 - copy attached.").
 - (c) List of all geotechnical/foundation design information used in the calculations with proper referencing from where it was taken (e.g., soil bearing capacity = 100 kPa. See Geotechnical Investigation Report prepared by _____, dated _____, page ____).
 - (d) List of all references used, including codes, standards, textbook, etc.
 - (e) Sketches as required.
 - (f) Description of software used in the calculations.
 - (g) Explanation of any non-standard vocabulary used in the software.
 - (h) Idealization of the structure and an explanation on how the structure is mathematically modeled.

- (i) Model showing the node, member, element, and support numbering.
 - (j) Node, member, element, and support restraints.
 - (k) Loads for each load cases and all load combinations.
 - (l) Input file and output analyses showing how the joint, member, and element loads and support reactions are calculated.
 - (m) Output showing the member forces, joint displacements, and support reactions.
 - (n) Output showing the governing forces and stresses.
 - (o) Maximum member stresses.
 - (p) Column slenderness.
 - (q) Member deflections.
 - (r) Story drifts.
 - (s) Design results.
 - (t) Member sizes.
- (4) Computer Aided Engineering (CAE) Calculations: Submit all CAE input (design bases, modeling, nodes, members, numbering, etc.) and CAE output (analyses, designs, etc.) in executable (i.e., native or source) file formats in addition to bound, hard copies. All CAE calculations shall be prepared using only the latest version with latest releases and updates. Use only CAE software STAAD.Pro, STAAD.Foundation, and RAM Structure. Only commercially purchase CAE software can be used. The AE Contractor shall submit a signed and dated statement with each submittal that the software used:
- (a) Are the latest versions with latest releases and updates;
 - (b) Were purchased by and are currently licensed to the AE Contractor (the AE Contractor shall not use “pirated” or “cracked” software on any Royal Commission projects); and
 - (c) Were properly installed on all computer equipment that executes the software (individual stations and network servers) and that such equipment meets the software vendors’ requirements.
 - (d) For each CAE software used, the AE Contractor shall submit signed and dated statements of verification and validation.
 - i) Statements of verification and validation with supporting documentation are required for all design software used on Royal Commission projects.
 - ii) Signed and dated Statements Verifications and Validations shall pre-date the first use of the software on the project.
 - iii) Verification – documentation that the software gives correct answers as judged against standard problems with hand calculated solutions or against similar software that has been verified. The verification must cover all algorithms of the software.
 - iv) Validation – documentation that the software is being properly applied to the problems it was intended to solve.
- (5) Checking of Calculations: All calculations prepared by the AE Contractor shall be checked for completeness, accuracy, numerical, and geometrical correctness,

resolutions for interfaces and for any other details affecting the quality, constructability and function of the end product.

- (a) "Checking" is distinct from "review" and shall be performed by the AE Contractor for all documents regardless of whether the document is selected by Royal Commission TSS-SE for review.
 - (b) Checking is part of the regular design process and shall be performed by structural engineers, assigned by the AE Contractor's Engineering Supervisor or a Project Engineer, with senior professional experience and competence to the originator of the calculations. No calculations shall be prepared and checked by the same person.
 - (c) Originator and checker shall pay special attention to the completeness; accuracy; numerical and geometrical correctness; identification of interfaces and their coordination; interferences and to their resolutions; sequencing and phasing of construction of this Contract, with other Contracts, and with other disciplines; and for any other details affecting quality, constructability, form, and function of the project.
 - (d) Checkers shall be identified and checking shall be documented with dates.
- (6) Approval of Calculations by AE Contractor: AE Contractor shall designate an Engineering Supervisor or a Project Engineer who shall be accountable for all structural engineering work, including completeness; accuracy; numerical and geometrical correctness; coordination of interfaces; resolution of interferences; sequencing and phasing of construction of this Contract, with other Contracts, and with other disciplines; and for any other details affecting quality, constructability, form, and function of the project.
- (a) The AE Contractor's Engineering Supervisor or Project Engineer shall assign structural engineers with senior professional experience and competence to the originator of the calculations to perform all checking, supervise the checking to assure compliance with the requirements, and review the calculations, until all are to his satisfaction; and finally, approve all calculations before they are submitted to Royal Commission for review.
 - (b) Approvers shall be identified and approvals shall be documented with dates.

5.21 STRUCTURAL DESIGN ANALYSIS REPORT (DAR) REQUIREMENTS

- (1) The AE Contractor shall prepare and submit a Structural DAR in compliance the Contract provisions and with this Royal Commission TSS-SE standard for each structural system, component, and elements for buildings, civil-site structures, utilities and utility structures, and infrastructures. Refer to Subsection 5.24 "Deliverables by Phase Requirements" for additional information.
- (2) Format: The DAR shall be presented in a professional manner. The DAR shall be a controlled document that contains the signatures of all originators, reviewers, and approvers for each submittal.
- (3) The DAR shall be grouped in accordance with the subject to which it pertains. Each group within the DAR shall be preceded by a cover sheet which contains the following information:
 - (a) Name of AE Contractor preparing and submitting the DAR.
 - (b) Contract Title and Number.
 - (c) Subject.

- (d) Sheet No. ____ of ____ .
 - (e) Name and signature of structural engineer and production date.
 - (f) Name and signature of structural checker and checking date.
 - (g) Name and signature of the structural supervisor and approval date.
 - (h) Index, which shall itemize all major parts of the DAR.
 - (i) Highlights of all conclusive design analyses so that the checker, approver, Royal Commission TSS-SE reviewer, and third parties who are not familiar with the DAR can follow it without any questions.
- (4) Content: The DAR shall be prepared in SI units, except when made in compliance with a code that has not been metricated. In these cases, American units may be used but the end products shall be converted to SI units. The DAR sheets shall contain the following information:
- (a) List of all design parameters and assumptions used.
 - (b) List of all information used in the calculations with proper referencing from where it was taken (e.g., soil bearing capacity = 100 kPa. See Foundation and Subsurface Investigation Report prepared by _____, dated _____, page ____).
 - (c) List of all references used, including codes, standards, textbook, etc.
 - (d) Description of the structural systems, components, and elements.
 - (e) Sketches as required.
 - (f) Description of software used in the calculations.
 - (g) Explanation of any non-standard vocabulary used.
 - (h) Idealization of the structures.
 - (i) Loads for each load case and all load combinations.
- (5) For each DAR submitted, the AE Contractor shall demonstrate that they have:
- (a) Analyzed and defined all functional requirements.
 - (b) Analyzed and defined the performance targets.
 - (c) Considered the integration of all systems, sub-systems and components and fully identified and defined all interfaces.
 - (d) Identified and mitigated risks and constructability issues related to the design.
 - (e) Developed all relevant design drawings.
 - (f) Performed and recorded any studies required to validate the DAR.
 - (g) Identified and assessed all Safety, Health and Environmental matters.
 - (h) Included sustainability, e.g., LEED.
 - (i) Identified and considered the input of third-party stakeholders and obtained approvals as required.
- (6) The DAR shall be updated and maintained throughout the total life of the project – from inception to completion - and capture all structural engineering changes for retention as a record of the Permanent Work.

- (7) Checking of DAR: DAR shall be checked for completeness, accuracy, numerical and geometrical correctness, resolutions for interfaces and for any other details affecting the quality, constructability and function of the end product.
 - (a) “Checking” is distinct from “review” and shall be performed by the AE Contractor for all DAR documents regardless of whether the document is selected by Royal Commission TSS-SE for review.
 - (b) Checking shall be part of the AE Contractor’s regular DAR production process and shall be performed by structural engineers, assigned by the AE Contractor’s Engineering Supervisor or a Project Engineer, with senior professional experience and competence to the originator of the DAR. No DAR, in whole or in part, shall be prepared and checked by the same person.
 - (c) Originator and checker shall pay special attention to the completeness; accuracy; numerical and geometrical correctness; identification of interfaces and their coordination; interferences and to their resolutions; sequencing and phasing of construction of this Contract, with other Contracts, and with other disciplines; and for any other details affecting quality, constructability, form, and function of the project.
 - (d) Checkers shall be identified and checking shall be documented with dates.
- (8) Approval of DAR: AE Contractor shall designate an Engineering Supervisor or a Project Engineer who shall be accountable for all structural engineering work, including completeness; accuracy; numerical and geometrical correctness; coordination of interfaces; resolution of interferences; sequencing and phasing of construction of this Contract, with other Contracts, and with other disciplines; and for any other details affecting quality, constructability, form, and function of the project.
 - (a) The AE Contractor’s Engineering Supervisor or Project Engineer shall assign structural engineers with senior professional experience and competence to the originator of the DAR to perform all checking, supervise the checking to assure compliance with the requirements, and review the DAR, until all are to his satisfaction; and finally, approve all DAR before it is submitted to Royal Commission for review.
 - (b) Approvers shall be identified and approvals shall be documented with dates.

5.22 STRUCTURAL SYSTEMS COST ESTIMATE (SSCE) REQUIREMENTS

- (1) AE Contractor shall prepare and submit the SSCE in compliance the Contract provisions and with this Royal Commission TSS-SE standard for each structural system, component, and elements for buildings, civil-site structures, utilities and utility structures, and infrastructures. Refer to Subsection 5.24 “Deliverables by Phase Requirements” for additional information.
- (2) Format: The SSCE shall be presented in a professional manner. The SSCE shall be a controlled document that contains the signatures of all originators, reviewers, and approvers for each submittal.
- (3) The SSCE shall be grouped in accordance with the subject to which it pertains. Each group within the SSCE shall be preceded by a cover sheet which contains the following information:
 - (a) Name of AE Contractor preparing and submitting the SSCE.
 - (b) Contract Title and Number.

- (c) Subject.
 - (d) Sheet No. ____ of ____ .
 - (e) Name and signature of originator and production date.
 - (f) Name and signature of checker and checking date.
 - (g) Name and signature of the supervisor and approval date.
 - (h) List of all references used, including quotes, back-ups, textbooks, software, etc.
 - (i) Index, which shall itemize all each part of the SSCE.
 - (j) Highlights of all conclusive cost analyses so that the checker, approver, Royal Commission TSS-SE reviewer, and third parties who are not familiar with the SSCE can follow it without any questions.
- (4) Content: The SSCE shall be prepared in SI units and Saudi Arabian Riyal (SAR). The SSCE sheets shall contain the following information:
- (a) List of all cost and quantity parameters and assumptions used.
 - (b) List of all information used in the costing and quantities with proper referencing from where they were taken.
 - (c) Description of the costing methods and quantity take-offs for all structural systems, components, and elements.
 - (d) Description of software used in the SSCE.
 - (e) Explanation of any non-standard vocabulary used.
 - (f) Quotations and back-ups used to verify and validate the SSCE. Quotations and back-ups shall not be more than three (3) months old.
 - (g) Overhead charges that are calculated and not presumed as a lump sum or percentage.
 - (h) Reasonable and justifiable estimated costs and quantities, cross-checked for consistency and accuracy.
 - (i) Proper units of measure, cross-checked for consistency and accuracy.
 - (j) Costs associated with sustainability, e.g., LEED.
 - (k) Calculations and formulas limited to two (2) significant figures to the right of the decimal point.
 - (l) Reasonable and justifiable Contingency Factors (CF) used in the SSCE. Contingencies shall only be applied to costs, not to quantities. (Up to the 60% SSCE submittal, Consultants can use CF's to allow for lack of vendor quotations and/or back-up. The CF's shall be reduced to zero (-0-) at for the 90% SSCE submittal, as vendor quotations and back-ups shall be firm.)
 - (m) Wastage, if used in the SSCE. (Wastage shall be carried out in the costs, not in the quantities).
- (5) For each SSCE submitted, the AE Contractor shall demonstrate that they have identified, defined, and incorporated all:
- (a) Costs associated with the integration of all systems, sub-systems, and components, structural and non-structural.

- (b) Costs associated with risks and constructability issues that are outside the norm.
 - (c) Input of third-party stakeholders.
 - (d) Current market rates for labor, materials, and transportations.
 - (e) Escalation of costs to the midpoint of the construction contract.
- (6) The SSCE shall be updated and maintained throughout the total life of the project – from inception to completion - and capture all structural cost changes for retention as a record of the Permanent Work.
- (7) Checking of SSCE: SSCE shall be checked for completeness, accuracy, numerical correctness, and for any other details affecting the quality of the end product.
- (a) “Checking” is distinct from “review” and shall be performed by the AE Contractor for all SSCE documents regardless of whether the document is selected by Royal Commission TSS-SE for review.
 - (b) Checking shall be part of the AE Contractor’s regular SSCE production process and shall be performed by cost estimators with senior professional experience and competence to the originator of the SSCE. No SSCE, in whole or in part, shall be prepared and checked by the same person.
 - (c) Originator and checker shall pay special attention to the completeness; accuracy; numerical correctness; identification of interfaces and their coordination; sequencing and phasing of construction of this Contract, with other Contracts, and with other disciplines; and for any other details affecting the quality of the end product.
 - (d) Checkers shall be identified and checking shall be documented with dates.
- (8) Approval of SSCE: AE Contractor shall designate a Cost Estimating Supervisor who shall be accountable for all structural cost estimating work, including completeness; accuracy; numerical correctness; identification of interfaces and their coordination; sequencing and phasing of construction of this Contract, with other Contracts, and with other disciplines; and for any other details affecting the quality of the end product.
- (a) The AE Contractor’s Cost Estimating Supervisor shall assign cost estimators with senior professional experience and competence to the originator of the SSCE to perform all checking, supervise the checking to assure compliance with the requirements, and review the SSCE, until all are to his satisfaction; and finally, approve all SSCE’s before they are submitted to Royal Commission for review.
 - (b) Approvers shall be identified and approvals shall be documented with dates.

5.23 CHECKLIST REQUIREMENTS

- (1) AE Contractor shall complete and submit TSS-SE’s “Structural Engineering Checklist” spreadsheet for each design submittal made.
- (2) An important goal of the “Structural Engineering Checklist” is to confirm that “Lessons Learned” are incorporated in the structural work. Therefore, coordinate with TSS-SE Supervisor and incorporate “Lessons Learned.” These are issues raised and documented from previous projects and that require the AE Contractor to review and update their project so that errors and omissions from prior projects are not repeated. Refer to Subsection 5.1 “General Conditions and Initiation of the Structural Design Process” for additional information.

5.24 DELIVERABLES BY PHASE REQUIREMENTS

- (1) AE Contractor shall complete and submit TSS-SE's "Deliverables by Phase" spreadsheet for each design submittal made.
 - (a) TSS-SE reserves the right to reject incomplete submittals without review.
 - (b) Costs and delays resulting from rejected submittals are the responsibility of the AE Contractor, not TSS-SE.

SECTION 6

ARCHITECTURAL DESIGN

6.1 GENERAL

All building Design shall conform to these General Criteria, except as superseded by specific project requirement and those requirements established in the Madinat Yanbu Al-Sinaiyah Urban Design Study. In the event of conflict between the documents, the Urban Design Study shall prevail.

6.2 CODES AND STANDARDS

- (1) All Architectural Design shall incorporate the requirements of the International Building Code (IBC) and associated International Code Council (ICC) codes, National Fire Protection Association (NFPA), and Saudi Building Codes.
- (2) The International Code Council codes shall be the prevailing documents, to be used in conjunction with the Saudi Building Codes, current Design Manual, Standard Drawings and Guideline Specifications.
- (3) All construction shall conform to the adopted Building Codes. In addition, all construction shall conform to the Zoning Regulations adopted by the Royal Commission in its manual "ZONING Madinat Yanbu Al-Sinaiyah." and/or the 2030 Master Plan.
- (4) Facilities with food services, public swimming pools and other projects that would impact public health shall comply with the requirements of the Royal Commission Public Health Code.
- (5) Medical and Healthcare facilities should comply with FGI (Facility Guidelines Institute) and The Saudi Central Board for Accreditation of Healthcare Institutions (CEBAHI) requirements.
- (6) Mosques should comply with RC's publication dated 2015 and/or the 2030 Master Plan.
- (7) Gas stations and car services comply with RC's publication dated 2014 and/or 2030 Master Plan.3.1.3.

6.3 DESIGN BASIS

Designs shall combine innovative expression of current international architectural standards of practice with historic character, traditional Islamic features and patterns.

The indigenous sociocultural patterns that have promoted Islamic traditions include:

6.3.1 PRIVACY

Heightened privacy factors with particular emphasis on the segregation of male/female allocated spaces and facilities.

6.3.2 ENTERTAINMENT

Subdividing of the building (residence) to provide acceptable inter-relationships while maintaining established social criteria with regard to the "Guest" and the containment of the active family area(s).

6.3.3 RELIGION

Other than in the Mosque, the provision within diverse buildings of places devoted to daily prayers and religious instructions.

6.4 DESIGN LIFE

- (1) All permanent facilities, buildings, components and systems shall be designed to keep their structural, operational and aesthetic integrity for a minimum of 30 years. All material and systems should be efficient and cost effective.
- (2) The evaluation of life cycle costs for building materials, systems and equipment, will continue to be an issue in preparing construction drawings and specifications for the foreseeable future. Life Cycle Costing (LCC) is simply selecting the most appropriate/durable material based upon evaluation against the materials' longevity and expected maintenance costs.

6.4.1 ENERGY EFFICIENCY

- (1) The focus on energy efficient design will continue to influence the delivery of new and renovated buildings into the next century.
- (2) New and renovated buildings are major consumers of energy; therefore, implementation of strategic design approaches targeting energy conservation/energy efficiency is mandatory.
- (3) The methodology of calculation of energy performances of buildings shall include the following aspects:
 - (a) Thermal characteristics of the building (building envelope and internal partitions, etc.). These characteristics may also include air-tightness.
 - (b) Heating installation and hot water supply, including their insulation characteristics.
 - (c) Mechanical Systems.
 - (d) Electrical Lighting.
 - (e) Position and orientation of buildings, including outdoor climate.
 - (f) Selecting passive environmental control strategies.
 - (g) Natural ventilation.
 - (h) Indoor climatic conditions, including the designed indoor climate.
 - (i) Integrated control system and monitoring.
 - (j) Appliances and equipment.

6.4.2 SUSTAINABILITY

- (1) The design should be developed on environmentally friendly and ecologically sound principles with genuine commitment to sustainability issues which conserve use of energy, water and other resources.
- (2) The use of passive energy measures to achieve a comfortable internal environment shall be employed where possible. The design should also utilize the natural characteristics of the site including orientation.
- (3) Sustainable design strives to reduce negative impacts on the environment, and the health and comfort of building occupants, thereby improving building performance. The basic objectives of sustainability are to reduce consumption of non-renewable

resources, minimize waste, and create healthy, productive environments. Sustainable design principles include the ability to:

- (a) optimize site potential;
 - (b) minimize non-renewable energy consumption;
 - (c) use environmentally preferable products;
 - (d) protect and conserve water;
 - (e) encourage use of renewable or recyclable materials
 - (f) enhance indoor environmental quality; and
 - (g) optimize operational and maintenance practices.
- (4) Utilizing a sustainable design philosophy encourages decisions at each phase of the design process that will reduce negative impacts on the environment and the health of the occupants, without compromising the bottom line.

6.4.3 STANDARDIZATION

The design of all buildings and facilities shall promote:

- (1) Maximum uniformity and standardization of materials, equipment, hardware and finishes so as to minimize service and maintenance. Effort should be made to design structures and elements thereof to be compatible with their environment and adjoining buildings.
- (2) Design excellence reinforces and enhances the urban fabric, scale, and coherence of architectural treatments.
- (3) Implement existing provisions of its Construction Standards which address the selection of materials based upon location, quality, energy efficiency, life cycle costs, and safety statements.
- (4) Implement provisions of its Construction Standards, Exterior Signage, and Interior Signage to address the needs of both exterior and interior signage respectively.
- (5) All signs require approval from the Royal Commission as to size, material, graphics and color.

6.5 DESIGN GUIDELINES

6.5.1 FORM, DISPOSITION, AND PERFORMANCE

Site conditions are climatically harsh with generally level terrain exposed to high temperatures, high humidity levels and wind-borne sand.

The building's form, orientation and external fabrication shall be designed primarily to:

- (1) Diffuse/baffle direct sunlight and reduce glare.
- (2) Reduce solar gain and maintain comfort levels by air conditioning.
- (3) Arrange and relate areas to provide formation of sheltered spaces within and immediately external to the building(s).

6.5.2 ARCHITECTURAL STYLE AND CONSISTENCY (BUILDING DESIGN)

- (1) Facade Articulation

Ensure the appropriate use of building facade elements including architectural features, terraces and shade devices to provide horizontal and vertical articulation.

Building facades should be well articulated through the use of a variety of materials, patterns, decorative finishes, textures and colors.

Unsympathetic contrasts of scale and materials should be avoided.

(2) Scale, Massing and Details

External Walls & Screening of Exterior Infrastructure.

- (a) Walls facing a public right of way (ROW) without articulation are undesirable. Articulation, can be defined as, meeting two of the following three design features:
 - i) One plane/surface extending beyond the top of the wall.
 - ii) One plane/surface extending beyond the face of the wall or varying the setback of the wall by a minimum of 0.3 meters.
 - iii) Introduction of a second material design element other than concrete (typically wrought iron or wood).
- (b) A second design element should be durable and is typically wrought iron or other metal detail.
- (c) Articulation is typically accomplished with recesses, columns, column caps and wall caps.
- (d) Etched/recessed patterns in a wall surface are encouraged, but these do not extend beyond the wall face and therefore do not qualify as articulation.
- (e) For walls adjacent to a secondary roadway, “minimum landscape” shall consist of continuous trees, with irrigation and spaced at a maximum of 15m centers,
- (f) The color palette for walls should be white or light earth tones.
- (g) Accent colors (embedded in concrete, not painted) may be darker to contrast with wall colors.
- (h) Accent materials at the top or bottom of the wall, such as ceramic tiles or stone, may be utilized as long as such use reflects the character of the architectural style.
- (i) Wall/Privacy extension should be of a color and material compatible with the architectural style of associated built form.
- (j) External infrastructure such as AC units, solar panels, solar hot water, etc. should be screened from public street view.
- (k) Ground mounted mechanical equipment and refuse/recycling should be screened by landscape or an enclosure with a compatible material.

(3) Rooflines

Allow for variety of roof forms, creating interest and diversity, while reinforcing the identity of the City. Architectural design features to be incorporated at key entry points reinforce the character of the site, and provide landmarks for the community.

6.5.3 NATURAL VENTILATION

Operable window units shall be provided to permit natural ventilation as a preference or, in event of mechanical break-down.

6.5.4 WINDOWS AND SCREENINGS

Daylight Factor: Calculation shall be made of window sizing and setting with recessions and/or applied screenings to reduce direct light intake. Oversizing of glass area shall be avoided and east/west outlook minimized to the essential.

Glass Type: Residential – Double glazed tempered clear pane and/or tinted pane shall be utilized throughout. Public Facilities, Institutional and Commercial use double glazed tempered clear pane and/or tinted pane shall be utilized throughout.

Large expanses of reflective glass should not be used as the resultant glare and heat can create discomfort in the public realm and to occupiers of surrounding buildings.

6.5.5 MAINTENANCE

Systems and materials incorporated into all buildings should be selected on the basis of long term operations and maintenance costs. The design should incorporate ease and efficiency of operation and allow for easy and cost effective maintenance and repair. Standardization of equipment, parts, is also the key to reducing maintenance costs and allows for stocking of common replacement parts.

All material and systems should be reliable and easy to operate and maintain. Materials should be environmentally sound.

6.5.6 PROVISION FOR PEOPLE WITH DISABILITIES

Provisions for barrier free access for people with disabilities shall be included in all parking and public building areas in compliance with the International Building Code (IBC), Americans with Disabilities Act (ADA), Architectural Barriers Act Accessibility Guidelines and ANSI A117.1 standards.

- (1) "Tactile" paving for pedestrian, sidewalks, ramps and stairways, etc. and "braille" lettering on handrails for exterior must be ADA compliant.
- (2) Tactile characters shall be accompanied by English Braille. Braille dots shall have a domed or rounded shape. Braille shall be placed below the entire text
- (3) "Public Accommodations" must be readily accessible and usable by the blind, visually impaired & mobility impaired to the maximum extent feasible.

6.5.7 GRAPHICS, SIGNS, WAY FINDING AND IDENTIFYING DEVICES

Graphics, signs and identifying devices must be provided in public spaces to provide regulatory, safety, directional and interpretive information.

Ensure sign type, size and content suit viewing conditions. Sign graphics including text size, style, color and its contrast with the background should maximize legibility. (refer to Americans with Disabilities Act (ADA) for detailed guidance)

Graphics, signs, and identifying devices shall be in both Arabic and English. Arabic shall appear above and/or to the right of the English. The Arabic shall be 50% larger than the comparable English (Arabic "aleph" compared with English letter "E").

6.5.8 ENTRY DESIGN

Building entries should be prominent and easily identified and assist in the identity and legibility of the development along the streetscape and ensure the activation of the public realm are encouraged.

Every building must clearly display its street address at the main entrance (at a minimum) according to the Saudi Postal Corporation - National Address reference approved under Decree No. (252) of 24/7/1434 AH.

6.5.9 SPECIALTIES

(1) Toilet, Bath Enclosures and Accessories

- (a) To reduce water damage and provide for air circulation, doors of the compartments shall be undercut a maximum of 30 mm. adequate ventilation shall be provided in every stall.
- (b) Privacy screens shall be installed between all urinals
- (c) All fixtures such as liquid soap dispensers, paper towel dispensers, disposal units, robe hooks and framed plate glass mirrors shall be provided in public toilet facilities as required.

(2) Drinking Fountains

- (a) Drinking fountains, dispensing chilled water, shall be installed in all public areas as per International Plumbing Code.

6.5.10 FURNITURE AND FURNISHINGS

- (1) Appearance and durability shall be the primary considerations in the selection of furniture and furnishings.
- (2) Generally, such items shall be of a contemporary design, and shall utilize, wherever possible, replaceable, modular component construction.
- (3) All upholstered items, fabrics and coverings shall be of self-extinguishing or fire resistive type. Materials and finishes used should be easily and locally repairable.

6.5.11 EQUIPMENT

- (1) All equipment shall be specified only from recognized manufacturers with a proven record of reliability, service and replacement parts supply.
- (2) All equipment shall conform to applicable safety regulations and shall be installed in strict compliance with manufacturer's recommendations.
- (3) As a general rule, commercial and industrial equipment shall be designed for a longer service life.

6.5.12 SPECIAL CONSTRUCTION**(1) Prefabricated Structures**

- (a) Provide buildings constructed of sound, well designed durable materials.
Prefabricated construction will therefore be permitted, only when adequate design and high standards of materials and workmanship can be demonstrated. Particular attention shall be given to off-site quality control, joints and connections, tolerances, transportation ease and damage protection from handling and transport.
- (b) Modular construction shall provide adequate interface design between modules, properly designed support foundations eliminating problems of differential settlements between modules, adequate flashing, flexible utilities links and joint finishes. If modular construction is employed, consideration shall be given for ease of disassembly and relocation capabilities. Qualified field representation by the prefabrication manufacturers shall be provided for on-site assembly and quality control.

(2) Acoustically Sensitive Spaces

All acoustically sensitive spaces such as mosques, school music rooms, sound studios and laboratories, concert halls and auditoriums shall be designed with the aid of qualified acoustical consulting firms.

(3) Swimming Pools and Enclosures

All swimming pools and bathing facilities shall conform to the latest edition of the international swimming pool and spa code (ISPSC), Royal Commission Public Health Code and Hot Tub Code by IAPMO and local customs.

(4) Tennis Courts

Tennis court to be constructed on any lot shall be subject to approval by the Royal Commission. Any lighting shall be designed so as to buffer the surrounding residences from the lighting and must be approved by the Royal Commission.

(5) Play Surfacing Treatments

A key consideration in the design of accessible playground areas is the type of surfacing to use. It is important that play surface materials be suitable for cushioning falls, yet firm and stable enough to provide access for persons.

(6) Flagpoles

- (a) All public buildings/facilities i.e. schools, colleges, libraries, police station, fire stations and other government offices shall be provided with flagpoles. Flagpoles shall include Saudi National Flag, Royal Commission Flag and Institution flag (if any) with Saudi National Flag as the highest pole.
- (b) All flagpole positions and flag sizes / design must comply with Royal Decree No. (M / 3) dated 10/2 / 1393H Decision of the Council of Ministers No. 101 dated 2/2/1393. Refer to www.boe.gov.sa
- (c) Lowest flagpole height to be in ratio of (1:1.25) of the proposed building height (front façade) and subject to final RC approval.

- (d) Flagpole, based and anchorage devices shall be designed to withstand minimum wind velocity of the context location.
 - (e) Refer to ANSI/ NAAMM FP 1001-07 “Guide Specifications For Design of Metal Flagpoles” for metal flagpoles (stainless steel, aluminium, galvanized).
 - (f) Fiberglass or GRP (glass fiber reinforced plastics) flagpoles are not recommended for heights more than 12 meters.
- (7) Shaded parking incorporating photovoltaic panels (PV)
- (a) Where shaded parking spaces are to be provided in accordance with the Parking Standards in the Yanbu 2030 - Industrial City Master plan, incorporate photovoltaic panels (PV) into the design of the carports.
 - (b) Refer to “Solar Car parks – BRE (2016) A guide for owners and developers” by BRE National Solar Centre.
 - (c) PV panels and fixtures must be non-corrosive or have an approved anti-corrosive treatment.

6.6 DESIGN REQUIREMENTS

6.6.1 DESIGN REQUIREMENTS FOR LOCAL CONDITIONS

- (1) Design to deliver low maintenance/vandal-resistant interior finishes and building systems that are commonly available for necessary replacement.
- (2) Operation and Maintenance

All material and systems should be reliable and easy to operate and maintain. Materials should be environmentally sound.
- (3) Location
 - (a) The infrastructure shall reflect the location and surroundings in terms of color, materials, and detailing and preserve architectural themes.
 - (b) Architectural design shall result from the successful blending of local culture, function, environment, economy, durability, operation and maintenance and location.
- (4) Sand Control
 - (a) The prevention of sand and dust infiltration is essential throughout the design of a facility. Blowing dust particles tend to infiltrate through minute cracks, joints and openings. The accumulation of sand and its harmful abrasive effects must be countered. Joints and connections shall be designed to prevent dust and sand infiltration.
 - (b) All main entrances and all other entrances to public buildings, which are frequently used except emergency exits, should have vestibules with adequately separated doors to check sand accumulation. Tight weather-stripping all around all doors, windows, roll-up doors, sliding doors and other industrial doors shall be installed.

6.6.2 CULTURAL CONSIDERATIONS

- (1) All facilities shall be designed keeping in mind the Saudi Arabian heritage and culture. Architectural aesthetics and layout shall reflect traditional designs, needs, values, motifs and influences. Local materials and products shall be utilized to the greatest extent possible.

- (2) The overall facility should be sensitive to and reflect the local culture.
- (3) Architectural design shall be respectful and relate to the building location and surroundings through the use of appropriate color, materials, and detailing. Overall architecture should enhance the environment by honoring and preserving significant architectural, historical, cultural, and community themes which bring consistency.

6.6.3 ORIENTATION

- (1) Special attention shall be paid in the design of all facilities to the need for utilizing shade and natural ventilation possibilities due to frequent prevailing winds to minimize heat gain, radiation and glare.
- (2) Seasonal wind rises, showing a predominance of west-north-west to north-north-west winds both in frequency and velocities as referred in the Environmental Chapter should also be consulted when orienting facilities.

6.6.4 SAFETY STATEMENTS

The safety standards identified in the criteria reflect the most recent safety guidelines established for materials and building systems. They also recognize and reference the importance of adhering to NFPA.

6.7 DESIGN CRITERIA

6.7.1 BUILDING MATERIALS

The selection and use of material and manufactured goods from Saudi-owned companies is obligatory. Specifying materials of a proprietary nature shall be minimized and subject to verification of availability.

- (1) Exterior floors, walls, and roof systems shall achieve thermal transmittance factors not exceeding SASO standard requirements.
- (2) In walls vapor barrier shall be on the warm side of the insulation.
- (3) Interior. Material selection shall be limited only to Saudi owned companies. Suitability, durability, maintainability and irreplaceability shall be prime factors in the material selection process.
- (4) Provide roof pavers or tiles for perimeters or the whole roof or when roof top traffic requires a more durable and workable surface.

6.7.2 TOILET AND BATHING FACILITIES

- (1) Water Closet Orientation. All water closets shall be floor mounted, unless otherwise indicated; in Mosques, positioning of fixtures must be 90 degrees from the Makkah axis.
- (2) Other Fixtures.
 - (a) A hand-held perianal spray hose with wall mounted hanging hook and, tip flow control shall be installed at all water closets to the right of the user.
 - (b) Ablution Area: Near the toilet room, provide a separate area where ablution may be done. Provide one ablution seat and faucet for every 25 building occupants. The flow of water from the ablution faucets shall be restricted on troughs or channels to keep the access aisles dry.
- (3) Number of toilet fixtures. Water closets for varying occupancies shall comply with the International Building Code and International Plumbing Code.

- (4) Water closets ratio western vs. eastern style it varies and shall be as per the end user requirement

6.7.3 ACOUSTICAL REQUIREMENTS

- (1) General

All significant spaces in buildings and facilities shall be designed to provide an acoustically controlled environment in relation to exterior noise from adjacent spaces.

- (2) Sound Transmission Limitations

Mechanical equipment shall be located and installed to minimize transmission of objectionable sound. Sound Transmission Class (STC) shall be determined in accordance with ASTM E90 and E413 standards.

6.7.4 QUALITY OF MATERIAL

- (1) SASO standard and the American Society for Testing and Materials (ASTM) are recognized as the industry standard for establishing the performance requirements for various building materials.
- (2) The Architectural Design Criteria recognizes that adherence to the performance levels set forth in SASO and the internationally recognized standards of ASTM and the industry standards for design criteria, material performance and construction systems available through the various building.

6.7.5 INTERIOR WALLS AND PARTITIONS

The construction of internal walls using gypsum wall board on a metal framework, metal studs or other types of "dry wall" shall not be used where it would be subject to water penetration or physical damage due to normal activity.

6.7.6 METALS

- (1) Architectural Metalwork

All architectural metals shall be designed with considerations for the high saline atmosphere prevalent at the site.

- (2) Stairs, Ladders and Railings

Wherever possible, exterior metal stairs and ladders shall be so located as to minimize their exposure to direct sunlight.

- (3) Gratings and Cover Plates

- (a) Metal gratings and cover plates shall be flush, shall have a non-slip finish and shall be removable to allow access for adequate maintenance.

- (b) Perforated cover plates and gratings in public circulation areas shall be "heel safe."

- (c) Appropriate infill finishes shall be selected for cover plates in appropriate areas.

6.7.7 COLOR SCHEMES

- (1) Colors used on the project shall be in accordance with the overall project scheme and shall be subject to project approval prior to use on the project.

- (2) Color schemes developed as part of systems for the protection of health, safety and welfare shall be coordinated with the overall color scheme in order to maintain project continuity and maximum aesthetic impact.
- (3) The guidelines for the color and texture of new and renovated or expanded facilities have been established to provide continuity between the new and existing facilities. In addition to providing aesthetic harmony in the appearance, this approach allows more cost-efficient maintenance of all facilities.
- (4) Exception to this requirement shall be piping corridors shared by the Industries in the Industrial Area, on the Causeway and in the Port Area.

6.7.8 PLANNING FOR PUBLIC AND COMMERCIAL BUILDINGS

- (1) All public buildings with waiting rooms, such as in hospitals, doctors' offices, etc. shall have separate waiting rooms and entrances for men and women.
- (2) Building facades on District Commercial centers should be built to property boundary to preserve/ contribute to urban street character and provide customer shaded pedestrian access to maximize users comfort.
- (3) Shade is to be provided in parking lots either by purpose-built shade structures or suitable shade trees species. District Commercial parking lots should have one tree for every eight spaces, or fraction thereof.
- (4) Loading facilities should be restricted to the rear of building away from retail/commercial frontages, separate from pedestrian access points and minimized in width to a single entry.

6.7.9 PLANNING FOR MOSQUES

Please refer to the RC Mosques Book dated 1436-2015.

6.7.10 ROOFTOP EQUIPMENT

- (1) Rooftop equipment shall be screened from view from the ground near the building with vertical extensions of the building walls or with parapets or other architectural design features of the same materials used on the walls of the building.
- (2) Where the topography permits, it is desirable to screen such equipment from adjacent property, but it is not the intent of this requirement to increase the height of the screening significantly above that of the equipment in order to screen it from view from tall buildings or from higher ground.

6.7.11 SAFER DESIGN

- (1) The design and layout of buildings should enhance actual and perceived safety, and reduce the potential for crime, graffiti and vandalism. Developments should minimise potential entrapment areas such as recessed doorways and storage areas, and other semi-enclosed spaces.
- (2) Areas not intended for night-time access should be unlit or closed off to discourage use of these spaces and avoid giving a false sense of security
- (3) Public spaces should be designed to encourage pedestrian use and create a sense of public ownership, by providing landscaping, lighting, furniture, art, finishes, universal access and measures to improve environmental conditions, as well as providing a high standard of regular maintenance.

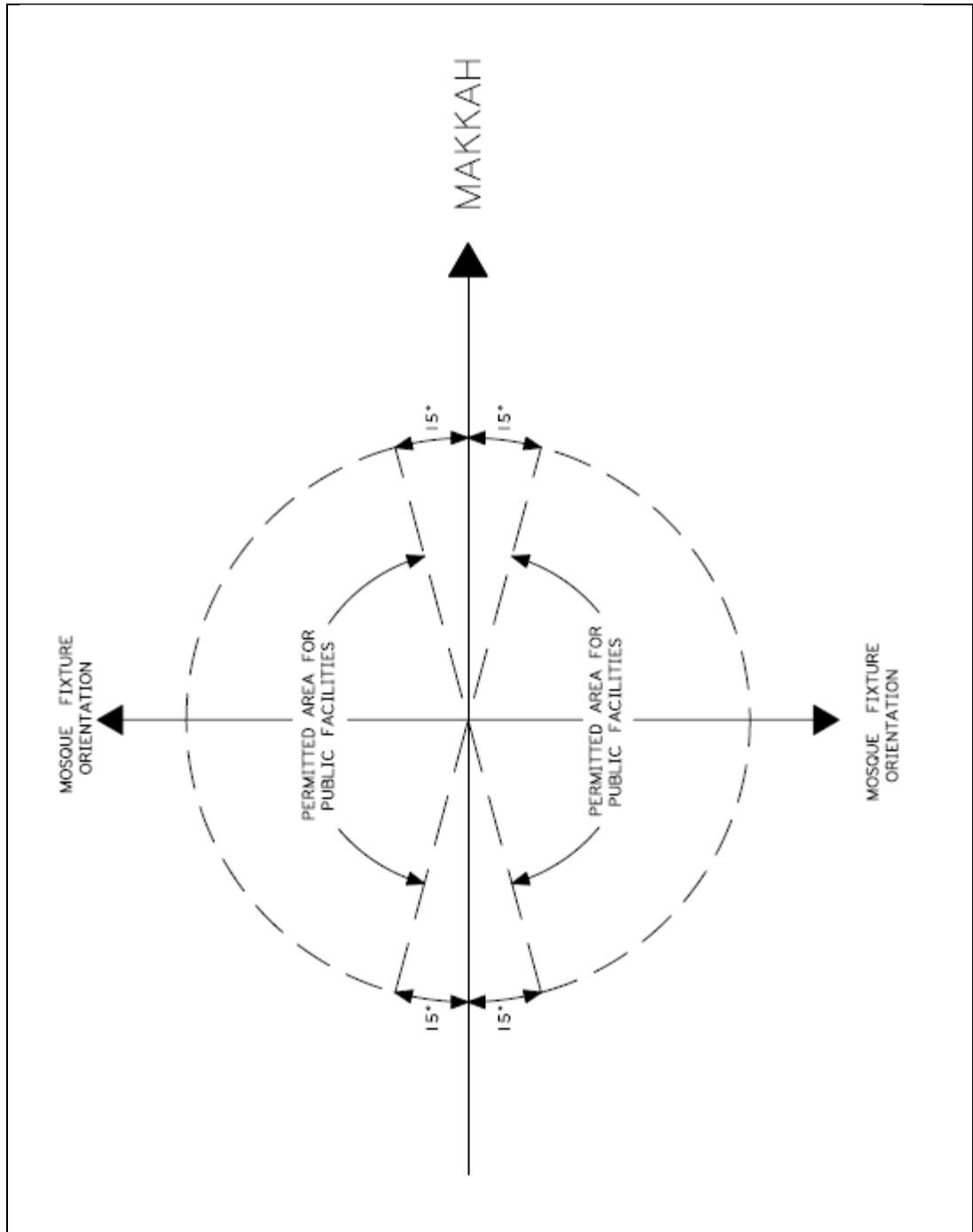


Figure 6-1. Toilet Fixture Orientation

SECTION 7

MECHANICAL SYSTEMS DESIGN

7.1 SCOPE

- (1) These criteria provide mandatory, minimally acceptable requirements for the Royal Commission new and retrofit projects.
- (2) These criteria provide the basis on which the mechanical (HVAC, Plumbing and Fire Protection) system and services shall be programmed and designed.
- (3) These criteria provide planning, design, construction, sustainment, restoration, and modernization criteria for mechanical activities.
- (4) This document contains policy and technical criteria to be used in the programming, design and documentation of the Royal Commission projects.
- (5) The provisions of this document are not intended to prohibit the use of alternative systems, methods or devices not specifically prescribed by this document, provided the Royal Commission has approved such alternatives.
- (6) Project conditions may dictate the need for design that exceeds these minimum requirements.
- (7) Any conflict between these criteria and the project specifications shall be resolved at the discretion of the Royal Commission.

7.2 DESIGN CONCEPT

- (1) All mechanical systems design shall conform to all relevant National and International Construction Codes and Standards.
- (2) Codes and Standards mentioned under Subsection 7.4 constitute an essential integrated part of this document.
- (3) All mechanical systems shall be designed to provide the following features:
 - (a) A design arrangement that allows minimum interruption to the system during maintenance of a part of the system.
 - (b) Design consideration for the system expansion.
 - (c) Economy, considering overall plant cost as well as mechanical system cost.
 - (d) System and equipment reliability, availability, and maintainability in order to obtain an optimum combination of operating and maintenance costs.
 - (e) Special attention shall be placed on material and equipment selection in order to obtain reasonably trouble free operation and economical life expectancy, especially for equipment located outdoors.
 - (f) Equipment and material installation shall be designed to provide adequate clearance area to facilitate service, maintenance, and repair or replacement of components.
 - (g) In addition, mechanical systems designs shall be compatible with other systems and shall present well integrated functional facilities.
 - (h) The design shall be as simple as possible.

- (i) Designs shall require that systems and equipment be installed in a manner making them easily accessible and highly maintainable.
 - (j) To the maximum extent possible, designs shall incorporate all practical energy sources and design features that conserve natural resources and are environmentally friendly. This emphasis has recently become known as “sustainable designs.”
- (4) Costs and Energy Performance
- (a) The Royal Commission is committed to incorporating principles of sustainable design and energy efficiency into all of its job projects. Energy-efficient design shall be consistent with the project budget.
 - (b) The Royal Commission jobs shall be designed with the objective of achieving lowest life cycle cost.
- (5) Operations and Maintenance
- (a) Systems and materials should be selected on the basis of long-term operations and maintenance costs as those costs will be significantly higher over time than first costs.
 - (b) The design of the facility operating systems shall ensure ease and efficiency of operation and allow for easy and cost effective maintenance and repair during the job useful life.
- (6) Corrosion
- (a) Special consideration of corrosion problems shall be made for any mechanical equipment that is to be installed within 20 km of the Arabian Gulf, Red Sea or other salt water body.
 - (b) Mechanical equipment located near the coast or exposed to corrosive environment shall be provided with corrosion protection. Condenser coils shall have a factory anti-corrosion coating. Anti-corrosion coating shall be immersion applied, baked phenolic or other approved coating. Field applied coatings are not acceptable.
 - (c) Provide manufacturer's optional louvered covers or hail guards for outdoor coils to provide protection against vandalism, debris or hail.
- (7) Warranties
- (a) Special emphasis shall be placed on all mechanical equipment and systems design warranties.

7.3 DESIGN CRITERIA

7.3.1 AMBIENT CONDITIONS

The mechanical system shall be designed to satisfactorily operate under the following ambient conditions:

- (1) Temperature: 0°C to peaks of 50°C.
- (2) Humidity: 10 to 100% RH.
- (3) Sun Exposure: About 300 days per year.
- (4) Frequent high wind gusts, often of long duration and well in excess of 18 m/s, produce humid, salty, dusty and sandy atmosphere.

7.4 REGULARITY REQUIREMENTS

7.4.1 GENERAL

- (1) The referred codes and standards are intended to provide an acceptable level of quality for materials, equipment and methodologies.
- (2) The latest revision of the following codes and standards shall be used wherever applicable.
- (3) Where equipment, component or material is specified to conform to the requirements of a standard or code, the design, fabrication, installation and testing of the system shall conform to this code.
- (4) These codes and standards constitute an essential integrated part of this document.
- (5) In case of conflict between these standards and this document, the more rigorous text shall govern.

7.4.2 ROYAL COMMISSION

- (1) All applicable updated regulations and requirements.

7.4.3 CONSTRUCTION CODES AND STANDARDS

ABMA	American Boiler Manufacturers Association
ADC	Air Diffusion Council
AGA	American Gas Association
AGC	Associated General Contractors of America
AIHA	American Industrial Hygiene Association
AMCA	Air Movement and Control Association
ANSI	American National Standards Institute
API	American Petroleum Institute
ARI	Air Conditioning and Refrigeration Institute
ASA	Acoustical Society of America
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASSE	American Society of Sanitary Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Water Works Association
BOCA	Building Officials and Code Administrators International
CGA	Compressed Gas Association
CISPI	Cast Iron Soil Pipe Institute
DEMA	Diesel Engine Manufacturers Association
EPA	Environmental Protection Agency
FGI	Facility Guide Institute

HEI	Heat Exchange Institute
HI	Hydraulics Institute
HI	Hydronics Institute
IAPMO	International Association of Plumbing and Mechanical Officials
IBC	International Building Code
IEC	International Electric Code
IECC	International Energy Conservation Code
IFGC	International Fuel and Gas Code
IMC	International Mechanical Code
IPC	International Plumbing Code
ISA	Instrument Society of America
ISPSC	International Swimming Pool and Spa Code
MSS	Manufacturers Standardization Society of the Valves and Fittings Industry
NEBB	National Environmental Balancing Bureau
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NSF	National Sanitation Foundation
NWWA	National Water Well Association
OSHA	Occupational Safety and Health Administration
PDI	Plumbing and Drainage Institute
PPFA	Plastic Pipe and Fittings Association
SASO	The Saudi Standards, Quality and Metrology Organization
SBC	Saudi Building Code
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SSPC	Steel Structures Painting Council
STI	Steel Tank Institute
UEC	Uniform Electric Code
UL	Underwriters Laboratories Incorporated

7.5 REFERENCES MENTIONED IN THIS DOCUMENT

(1) ANSI - American National Standards Institute

- (a) ANSI Z358.1 Emergency Eyewash and Shower Equipment

(2) ASHRAE - American Society of Heating, Refrigeration, and Air Conditioning Engineers

- (b) ASHRAE 15 Safety Code for Mechanical Refrigeration

- (c) ASHRAE 52.2 Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size
 - (d) ASHRAE 55 Thermal Environmental Conditions for Humans
 - (e) ASHRAE 62 Ventilation for Acceptable Indoor Air Quality
 - (f) ASHRAE 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings
- (3) ASTM - American Society for Testing and Materials
 - (a) ASTM E90 Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements
 - (b) ASTM E413 Classification for Rating Sound Insulation
- (4) ASPE - American Society of Plumbing Engineers
- (5) MSS - Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.
 - (a) MSS SP69 Pipe Hangers and Supports-Selection and Application
- (6) NFPA - National Fire Protection Association
 - (a) NFPA 70 National Electrical Code
 - (b) NFPA 101 Life Safety Code
 - (c) NFPA 110 Emergency and Standby Power Systems
 - (d) NFPA 13 Standard for the Installation of Sprinkler Systems
 - (e) NFPA 14 Standard for the Installation of Standpipe and Hose Systems
 - (f) NFPA 20 Installation of Stationary Pumps for Fire Protection
 - (g) NFPA 22 Water Tanks for Private Fire Protection
 - (h) NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals.
 - (i) NFPA 92A Standard for Smoke Control Systems Utilizing Barriers and Pressure Differences
 - (j) NFPA 92B Smoke Management Systems in Malls, Atria and Large Spaces
 - (k) NFPA 99 Standard for Health Care Facilities
- (7) UL-Underwriters Laboratories Inc.
 - (a) UL 900 Test Performance of Air Filter Units

7.6 ENVIRONMENTAL

7.6.1 GENERAL

The Contractor shall comply with all the Royal Commission applicable Codes/Standard, and local laws and regulations controlling pollution of the environment.

7.6.2 ENVIRONMENTAL FRIENDLY MATERIALS

- (1) Select materials of zero or low ODP (Ozone Depletion Potential). The ODP shall be per the "Montreal Protocol on Substances that Deplete the Ozone Layer," sponsored by the United Nations Environment Program.
- (2) Select materials of zero or low GWP (Global Warming Potential).
- (3) Use Clean agent such as FM 200 and NOVEC 0123 for firefighting. Do not use Phased-out gases, like Halon.
- (4) Select air conditioning and refrigeration equipment using Eco-friendly Refrigerants such as 134a, R407 and R410 or other friendly modern accepted alternative in replacement of CFC and HCFC Refrigerant.
- (5) All specified refrigerant must comply with SASO requirements.
- (6) Gasses other than the approved ones shall not be used for testing or purging pipe system.

7.6.3 INDOOR AIR QUALITY

- (1) Indoor air quality shall comply with acceptable standard values. Refer to ASHRAE Standard 62.1 and ASHRAE Handbook Fundamentals and Systems and Equipment.
- (2) Duct liner used to attenuate sound shall be of the type that is resistant to erosion i.e. "tough skin".

7.6.4 NOISE CONTROL AND QUIET OPERATION

- (1) Systems
 - (a) Analyze mechanical system equipment sound levels to control noise transmission.
 - (b) Identify and provide acceptable measures required for piping and ductwork noise control.
 - (c) Sound shall be attenuated through the use of:
 - i) Sound attenuators.
 - ii) Duct insulation internal liner.
 - iii) Round or oval ducts, where feasible, instead of rectangular.
 - iv) Select fans at lower RPM.
- (2) Equipment
 - (a) Select all mechanical equipment to meet the noise criteria (NC) requirement of each occupied space.
 - (b) Provide acoustic treatment in mechanical room walls and ceilings if adjacent areas will be affected by noise generated in the mechanical room.
 - (c) Identify when floating slab is required for acoustical isolation and provide accordingly.
 - (d) Generator house shall be located away from quiet areas.

- (e) When generator house is located within quiet areas, the following precautions shall be taken:
 - i) A Critical Muffler Type shall be installed for engine exhaust.
 - ii) Insulate generator house walls using approved acoustics insulation type.
 - iii) Install sound attenuations on intake and exhaust louvers.

7.7 ENERGY EFFICIENCY CRITERIA

7.7.1 GENERAL

- (1) The Royal Commission is committed to sustainable design which includes engineering - efficient design within the limit of budget constraints and within the bounds of good practice and conformance with energy codes and standards.
- (2) Energy efficient design to be relevant to the design of all HVAC and Plumbing system through the use of Direct Digital Control (DDC) System.
- (3) The design and construction shall meet or exceed the energy efficiency requirements of ASHRAE 90.1.

7.7.2 APPLICATION OF ENERGY EFFICIENCY MEASURES IN MECHANICAL SYSTEM

- (1) Occupant comfort and productivity, and other functional requirements of a building shall not be adversely affected by any energy or water conservation measure. In the process of satisfying these functional requirements, designs shall include all practical energy and water conservation measures that allow for optimized life cycle cost.

7.7.3 PROPOSED ENERGY EFFICIENCY MEASURES

- (1) Compliance with Saudi Building Code Requirement (SBC 601), ASHRAE Standard 90.1 and the International Energy Conservation Code will require consideration of all or some of the following energy efficiency measures:
 - (a) Renewable Energy Systems.
 - (b) Thermal Energy Storage (TES).
 - (c) Variable frequency technologies.
 - (d) Heat Recovery
 - (e) Chilled Beam
 - (f) Gravity ventilators for storages and alike areas.
 - (g) High EER HVAC equipment
 - (h) Direct Digital Control and use of high performance sequence of operations per ASHRAE Guideline P36.
 - (i) High performance building envelope.
 - (j) Building orientation, glass to wall ratio and shading.

7.7.4 ENERGY CALCULATION / BUILDING ENERGY ANALYSIS

- (1) All energy calculations for any new building that is air conditioned and exceeds 280 m² (3000 ft²) of gross floor area shall be calculated using an internationally recognized and proven computer program that integrate architectural features with air-conditioning, heating, lighting, and other energy producing or consuming systems. These programs

shall be capable of simulating the features, systems, and thermal loads used in the design.

- (2) Operating hours shall be those actually anticipated for operation.
- (3) Where Central Plant is to be considered as a viable system, Energy Simulation Programs shall be utilized as the basis for sizing/recommending such system. Approval of the program(s) by the Royal Commission shall be obtained. In addition, input parameters to attain lower equipment and systems energy consumptions, such as the use of thermal storage tanks shall be considered
- (4) A building energy analysis shall be performed to demonstrate that the building design meets or exceeds the energy performance goals established for the project.
- (5) The building energy analysis shall be performed using the ASHRAE Standard 90.1 Energy Cost Budget methodology, and must demonstrate compliance with the latest editions of ASHRAE Standard 90.1 and/or 90.2. The analysis shall be included in each design submission.
- (6) The analysis shall evaluate the energy performance of the building design including the proposed building envelope, HVAC systems and components, the lighting systems, and domestic hot water systems, as well as the proposed control strategies for these building systems.
- (7) The analysis shall be based on actual parameters and values found in the proposed building design and not simply on defaults assigned by the simulation program.
- (8) Simulation programs shall be capable of simulating:

8,760-hours per year, hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set points, and HVAC system operation defined separately for each day of the week and holidays, thermal mass effects, the number of required HVAC zones, part load performance curves for mechanical equipment, capacity and efficiency correction curves for mechanical equipment, air-side and water-side economizers, and temperature controls.
- (9) The building energy analysis report shall include all input and output used in the simulation programs, including:

Established energy goals for the project, detailed descriptions of the budget and proposed building models, actual local utility rates, descriptions of any and all energy conservation measures, an analysis of results with final conclusions and recommendations.

7.8 LIFE CYCLE COST

- (1) As part of the mechanical systems selection, a computerized life cycle cost analysis shall be required and submitted to the Royal Commission.
- (2) Systems and equipment shall be selected from among functionally equivalent alternatives on the basis of lowest life cycle cost calculated based on the Present Worth Method.
- (3) It is an integrated, synergistic approach, in which all phases of the job lifecycle are considered to result in an optimal balance of cost, benefits while meeting the mission and function of the intended infrastructure or superstructure.

- (4) Life cycle cost analyses shall evaluate first cost, energy cost, recurring (operation and maintenance) replacement and repair costs, and other costs and benefits attributed to each alternative.
- (5) Throughout the design, the designer must make choices regarding materials, sizes, equipment and systems in order to establish the most cost effective design satisfying the Royal Commission requirements and these criteria.
- (6) The project's design program must comprehensively define reasonable scope and performance requirements, and must match those needs to an appropriate overall budget.
- (7) An ASHRAE based approved programs shall be used.
- (8) General economic study for each project must be determined individually, to ensure the cost effectiveness of the study effort itself.
- (9) Before initiating any studies, the design shall consider the following points:
 - (a) A life cycle cost analysis is likely to be cost effective when, the design feature or category to be examined is itself life cycle cost intensive relative to the project being designed. Post-occupancy continuing costs including energy, maintenance, custodial, and repair costs are especially important.
 - (b) A life cycle cost analysis is likely to be cost effective when, the design alternatives to be compared are characterized by fundamentally different cash flows.
 - (c) A life cycle cost analysis is not cost effective when, the cost of the analysis is likely to exceed any savings that could be achieved.
 - (d) A life cycle cost analysis is not cost effective when the relative economic rankings of the various alternatives have already been established for similar design conditions. This consideration encourages the use and/or revision of a previous study or analysis rather than performing a new complete analysis. The conditions and results of the previous study should be adapted and updated to the specific design alternatives being considered.
 - (e) A life cycle cost analysis of a particular design feature should not be initiated when its cost, added to the cost of life cycle cost analyses already conducted or planned for other design features of the same project, would cause the total cost to exceed 1% of the programmed amount.
- (10) The designer of a building or facility shall obtain from equipment manufacturers full and part load energy consumption data over the range which all equipment and supporting auxiliaries are expected to operate, as well as the space requirements for operation and maintenance for each component. All equipment selections shall be based on life cycle costs.

7.9 MATERIALS SELECTION

- (1) All materials used shall meet the requirements of the Contract.
- (2) All materials used shall be selected to meet applicable system requirements (temperature, pressure, etc.).
- (3) All material shall be selected in consideration of the environmental conditions.
- (4) In selecting material, special attention shall be given to corrosion resistance. Corrosion resistant material or corrosion resistant plating, coating or painting on ordinary material

shall be as specified in accordance with SECTION 10, CORROSION CONTROL AND PROTECTION.

- (5) All material shall also be selected in consideration of the ease of shipment, installation and maintenance.
- (6) Due to high ground water aggressiveness, all pipes placed underground shall have external protection by using epoxy coating, or tape wrap.
- (7) Materials shall be selected using mechanical properties and other specifications in the latest issue of ASTM Standards Specifications.

7.10 SYSTEM REDUNDANCY

7.10.1 GENERAL

- (1) Because of cost control, redundancy is mandated only in the case of critical systems and/or equipment.
- (2) When a system failure would result in unusually high repair costs or replacement of process equipment, or when activities are disrupted that is vital to an application, redundant systems or units are recommended.

7.10.2 REDUNDANCY REQUIREMENTS

- (1) Regardless of the system redundancy requirements of the program document, the design shall provide for redundancy in the following items of mechanical equipment. There is nothing in this document that prevents any equipment redundancy dictated by particular system requirements.
 - (a) Sewage Pumps
 - i) Incorporate duplex or triple pumping with automatic alternators and level alarms.
 - ii) The design shall be such that design flows will be handled by a single pump, with 33% run time.
 - (b) Chilled Water Pumps
 - i) In single chiller applications, a second, full sized pump/motor assembly shall be designed.
 - (c) Primary Chilled Water Pumps
 - i) In multiple chiller/dedicated pump applications, one spare primary chilled water pump motor shall be specified.
 - (d) Secondary Chilled Water Pumps
 - i) Where used, secondary chilled pumps shall typically be a single pump, VFD controlled.
 - ii) Unless 2 pumps are needed to handle design flow, a second, standby secondary pump is required, with a dedicated VFD.
 - (e) Condenser Water Pumps
 - i) In single chiller/tower applications, a second condenser water pump, full size shall be designed.
 - (f) Control Air Compressors

- i) A single tank is acceptable.
- ii) The design shall incorporate duplex air compressors/motors with automatic alternator.
- iii) The design shall be predicated on one-third run time for one compressor, with the second compressor designed as a full standby.

(2) Standby Air Conditioning Capacity

Redundancy of refrigeration equipment shall be provided in the following manner:

(1) Direct Expansion Systems.

- (a) Where a single refrigeration machine is proposed, a minimum of two independent compressor/condenser circuits shall be provided.
- (b) Where two refrigeration machines are proposed, each shall be sized for 50% of the system load.
- (c) Where standby requirements are specified by project criteria, chilled water systems or two self-contained package air conditioning units, each sized for 100% of the system load, shall be used.

(2) Chilled Water Systems

- (a) Where a single reciprocating refrigeration machine is proposed, two independent compressor/condenser circuits shall be provided. Two chilled water pumps (one standby) shall be selected to match the chiller.
- (b) Where 2 refrigeration machines are proposed each shall be sized for 50% of the system load. Two chilled water pumps shall be provided, each selected to match and discharge piped individually to the respective chiller.
- (c) Where 50% standby requirements are specified by project criteria, three (3) chillers, each selected for 50% of system load shall be provided. Three chilled water pumps shall be provided, each selected to match, and discharge piped individually to the respective chiller. At designer's discretion, more than three (3) chillers may be used.
- (d) Where 100% standby requirements are specified by project criteria, a minimum of two chillers shall be provided. Each chiller water pump shall be selected to match, and discharge piped individually to the respective chiller

7.11 MECHANICAL AND SERVICE SPACE REQUIREMENTS

7.11.1 GENERAL

- (1) The mechanical design shall be cognizant of the necessity to provide for the replacement of major equipment over the life of the building and shall insure that provisions are made to remove and replace, without damage to the structure, the largest and heaviest component that cannot be further broken down.
- (2) Mechanical equipment rooms shall be designed with maintenance requirements in mind.
- (3) HVAC mechanical equipment rooms shall be designed in accordance with the requirements of ASHRAE Standard 15.
- (4) Mechanical rooms shall not be used as return air, outdoor air or mixing plenums.

- (5) The plumbing design shall comply with the International Plumbing Code (IPC) and specific project criteria.
- (6) All mechanical equipment rooms shall be a minimum of 3.7 m (12 ft.) in height (clear height).

7.11.2 ACCESSIBILITY

- (1) Equipment must be fully accessible to allow for proper servicing, including adequate space to disassemble all pumps, motors and chillers.
- (2) Chillers shall be placed to permit pulling of tubes from all units.
- (3) Provide access for all required trap primers.
- (4) Access doors or panels shall be provided in ventilation equipment, ductwork and plenums as required for in-site inspection and cleaning.
- (5) The mechanical rooms shall have adequate doorways or areaways and staging areas to permit the replacement and removal of equipment without the need to demolish walls or relocate other equipment.
- (6) Sufficient service access space areas as noted by outlining manufacturer's recommendations and in compliance with applicable code requirements for routine maintenance and removal of mechanical system components shall be provided.
- (7) Equipment access doors or panels shall be readily operable and sized to allow full access.

7.11.3 CLEARANCE

- (1) Horizontal Clearances
 - (a) Mechanical rooms shall be configured with clear circulation aisles and adequate access to all equipment. Required clearance shall be in accordance to manufacturer written instructions.
- (2) Vertical Clearances
 - (a) Mechanical equipment rooms shall have clear ceiling heights of not less than 3.7 m (12 ft.) or as per manufacturer recommendation, whichever is greater.
- (3) Ceiling Clearances
 - (a) Provide adequate clearance and access for building systems installed between ceiling and structure above.

7.11.4 DRAIN PROVISION

- (1) Mechanical rooms shall have floor drains in proximity to the equipment they serve to reduce water streaks or drain lines extending into aisles.
- (2) Provide at least 1 floor drain for every 13.4 m² (144 ft²) of each equipment room.
- (3) Locate drains away from walking areas, but not beneath equipment.
- (4) Slope floor to drain.
- (5) Air handling units shall be drained considering air gap above the floor/area drain.

7.11.5 HOUSEKEEPING PADS

- (1) Housekeeping pads shall be at least 152 mm (6 in.) wider on all sides than the equipment they support and shall be 200 mm (8 in.) minimum thickness.

7.11.6 ACOUSTICAL

- (1) Walls of equipment rooms, when located on occupied floors, shall be sound proof and return air passages shall utilize sound attenuation boxes.

7.11.7 DEDICATED EQUIPMENT ROOM

- (1) Air Handling Room (AHU)
 - (a) Provide ample space on all sides of AHU for inspection and maintenance (filter removal, bearing replacement, coil replacement, cleaning, etc.).
 - (a) Suspended air handlers shall be provided with permanent platforms for maintenance including appropriate access to platforms where required.
- (2) Chiller Equipment Rooms
 - (a) All rooms for refrigerant units shall be constructed and equipped to comply with ASHRAE Standard 15, Safety Code for Mechanical Refrigeration.
- (3) Electrical Equipment Rooms
 - (a) No water lines shall be permitted in electrical rooms, except for fire sprinkler piping.
 - (b) Sprinkler piping lines must not be located directly above any electrical equipment.
 - (c) Water lines shall not be located above motor control centers or disconnect switches and shall comply with requirements of NFPA 70 Chapter 1.

7.11.8 TELECOMMUNICATIONS ROOMS

- (1) Telecommunications rooms shall be cooled. Closets which house critical communications components shall be provided with dedicated air-conditioning systems that shall be connected to the emergency power distribution system.

7.11.9 ELEVATOR MACHINE ROOMS

- (1) Elevator machines, including controls shall be specified to sustain ambient conditions, otherwise a dedicated cooling system shall be provided to maintain room mechanical conditions required by equipment specifications.

7.11.10 EMERGENCY GENERATOR ROOMS

- (1) The environmental systems shall meet the requirements of NFPA Standard 110 Emergency and Standby Power Systems, and the combustion air requirements of the equipment.
- (2) Rooms must be ventilated sufficiently to remove heat gain from equipment operation.
- (3) The supply and exhaust louvers shall be located to prevent short circuiting.
- (4) Generator exhaust shall be as per manufacturer's installation guidelines or carried up to roof level.
- (5) Horizontal exhaust through the building wall shall be avoided.
- (6) Acoustical enclosures shall be provided to maintain NC level to acceptable ASHRAE Fundamentals and ASHRAE Applications levels.

7.11.11 UPS BATTERY ROOMS

- (1) Battery rooms shall be equipped with emergency eyewash and shower equipment as per ANSI Standard Z358.1 (Emergency Eyewash and Shower Equipment).

- (2) Floor drains required at the emergency shower, within the battery room acid containment curb, shall extend with acid waste piping to an acid neutralization tank prior to discharge to the sanitary sewer or building drain.
- (3) The battery room must be ventilated/exhausted directly to the outdoors at a rate calculated to be in compliance with construction codes requirements and manufacturer's recommendations; and the exhaust system must be connected to the emergency power distribution system.
- (4) Fans shall be spark-resistant, explosion proof, with motor outdoor the air stream, ductwork to be negative pressure system of corrosion resistant material, with exhaust directly to outdoors in a dedicated system.

7.11.12 LOADING DOCKS

- (1) The entrances and exits at loading docks and service entrances shall be maintained at negative pressure relative to the rest of the building with a means to reduce infiltration and outdoor debris.

7.12 HEATING, VENTILATING AND AIR CONDITIONING (HVAC)

7.12.1 OBJECTIVES

- (1) The goal of HVAC system design is to meet occupant needs through the most efficient and environmentally positive means at the lowest initial and life-cycle costs.
- (2) All HVAC concepts shall comply with ASHRAE Handbook and Standards and International Mechanical Codes (IMC). Where provisions of ASHRAE and IMC differ, the more stringent provisions shall govern.
- (3) HVAC systems shall attain the following main objectives:
 - (a) Occupant comfort.
 - (b) Indoor air quality.
 - (c) Acceptable noise levels.
 - (d) Energy efficiency.
 - (e) Reliable operation.
 - (f) Ease of maintenance.
- (4) HVAC systems shall be specifically designed to function at the full load and part load conditions that are associated with the projected occupancies and modes of operations.
- (5) The air conditioning system shall provide comfort conditions in all rooms throughout the operating period.
- (6) HVAC for heavy or contaminated industrial applications may require specialized design considerations in dealing with the nature of a particular problem.
- (7) HVAC shall interface with fire detection system.

7.12.2 HEATING AND AIR CONDITIONING DESIGN CRITERIA

- (1) The Royal Commission Design Criteria, ASHRAE Handbook, ASHRAE Standards, International Mechanical Codes (IMC) and the applicable codes and standards listed in Section 2 along with this document shall constitute the Royal Commission HVAC Design Criteria.
- (2) Outdoor Design Criteria

- (a) The following ambient conditions shall be used when computing the heating and cooling load requirements for HVAC systems:
 - i) Summer
 - Dry bulb: 43°C (109 °F).
 - Wet bulb: 30°C (84 °F)
 - Daily Range: 14°C (25 °F).
 - ii) Winter
 - Temperature: 11°C (52 °F).
 - (b) Summer design conditions for sensible heat load calculations shall be based on the 0.4% dry bulb temperature with its mean coincident wet bulb temperature.
 - (c) Design conditions for the summer ventilation load and all dehumidification load calculations shall be based on 0.4% dew point with its mean coincident dry bulb temperature.
 - (d) Winter design conditions shall be based on the 99.6% column dry bulb temperature
 - (e) For additional local meteorological weather data, summer and winter design conditions shall be based on ASHRAE Handbook of Fundamentals, latest edition.
- (3) Indoor Design Criteria
- (a) Indoor design temperatures and relative humidity requirements in different applications shall be as stated in ASHRAE Applications Handbook.
 - (b) The space condition general datum shall comprise of the following nominal comfort conditions representative for residences and offices:
 - i) Summer
 - Dry Bulb: 24°C +/- 1°C (75°F +/- 2°F)
 - 45% - 55% Relative Humidity.
 - ii) Winter
 - Dry Bulb: 22°C (72°F)
- (4) Indoor Air Quality (IAQ)
- (a) The Royal Commission recognizes the importance of adequate ventilation to maintain indoor air quality.
 - (b) The outdoor air ventilation rates of ASHRAE Standard 62 and International Mechanical Codes (IMC) shall be the minimum acceptable in the Royal Commission buildings.
 - (c) Dilution with outside air is the primary method of maintaining acceptable indoor air quality.
 - (d) Where aspects of energy use and air quality are in conflict, air quality shall take precedence.
- (5) Derating Equipment
- (a) Capacity of all air cooled refrigeration equipment such as condensing units, packaged units and chillers shall be de-rated (reduced) based on 46°C (115°F) ambient temperatures.

- (b) Such derating of equipment capacity shall be substantiated by manufacturer's data documentation (if any) to show the effect of derating due to ambient temperature.

7.12.3 HVAC LOADS CALCULATIONS

(1) General Requirements

- (a) General: Design shall be prepared based on the building owner's requirements or in the absence of this information, it should be referred to the architectural building design brief. The design requirement must be clear for each space inside a building whether air conditioning or only ventilation is required.
- (b) The HVAC loads calculations report shall include all input and output used in the heating and cooling calculation program, and shall include zone peak heating and cooling loads results, and whole building "block" loads, air-handling unit coil selections, and psychometric process charts.
- (c) Cooling load shall be calculated for all HVAC Systems with the Summer Design Dry Bulb and Mean Coincident Wet Bulb temperatures and the supply air requirements shall be determined at these temperatures.
- (d) HVAC systems which have more than 20% outside air make-up; cooling load shall also be calculated at the Design Wet Bulb and coincident Dry Bulb temperatures in addition to the calculations performed in paragraph above, to determine which set of conditions results in larger HVAC system capacity. This will determine the cooling capacity of the refrigeration system, while the air-side capacity would have been determined from paragraph above.
- (e) Residential method shall only be used for residential application.

(2) Loads Calculations Computer-Based Program

- (a) Load and energy software programs shall be created specifically for the HVAC system design such as Trane Trace 700 or Carrier HAP.
- (b) For LEED project, the A/E shall perform High Building Performance Analysis during the early stage of the project using commonly used software such as Sefair or approved equal.
- (c) The program shall be capable of calculating each zone's peak heating and cooling load as well as the whole-building "block" loads. Each zone, room and portion of room with different load profile, orientation or sensible load shall be calculated. A separate block load for each air handling system shall also be calculated.
- (d) Hourly analysis and building block load calculations shall be prepared for sizing major HVAC equipment, as well as sizing individual space cooling units. Projects specified as proto-type shall have as minimum four (4) sets of calculations using different orientations to determine the true maximum cooling loads.
- (e) The program shall, at a minimum, calculate:
 - Solar gains through fenestration, internal gains from occupants including latent heat for cooling purposes, internal gains from lighting and equipment, outside air loads (sensible and latent) from ventilation and infiltration, and heat gains or losses through fenestration, walls, floors and roofs.

(3) Cooling Loads

- (a) During load calculations, all sensible and latent heat sources shall be considered.

- (b) Sensible cooling load shall be calculated for building envelope, people, lights, equipment, outside air that is introduced into the system by air make-up or by infiltration and duct heat loss/gain.
- (c) Latent cooling load shall be calculated for people, outside air and any process in which moisture is given up to the air.
- (d) Project specified as proto-type shall have as minimum four (4) sets of calculations using different orientations to determine the true maximum cooling loads.

7.12.4 AIR-CONDITIONING SYSTEM EQUIPMENT SELECTION

- (1) During the design conceptual phase, the A/E shall submit life cycle cost analysis of at least three (3) HVAC systems.
- (2) The A/E shall consider all air and chilled water system option as relevant to the project.
- (3) Windows A/C unit shall not be used.
- (4) All Chillers and Package Units systems and Pumps shall be provided with vibration isolators and seismic restrainers. Restrainers shall be suitable for installation in Seismic Zone 1, based on International Building Code (IBC) requirements.
- (5) Provide elastomeric isolation pads for AHU installation.
- (6) All equipment motor power rating shall be selected on the basis of the required brake power plus drive losses without any overload. All motors shall be selected with a service factor conforming to National Electrical Manufacturing Association standards. Motors shall not be selected to operate in the service factor capacity range.
- (7) All pump motors selected shall operate at 1,800 rpm or lower.
- (8) Special attention and evaluations shall be given to the mechanical equipment noise control as required for acoustic isolation treatment.
- (9) Selection on the A/C equipment shall base on T3 condition (46 °C)
- (10) Energy Efficiency Ratio (EER) for Split Units and Window Type Units shall meet SASO and SEEP requirements for T3 condition.

(11) Water Coils:

Chilled water coils shall be sized at 170 m/min (550 fpm) maximum face velocity for comfort cooling applications and 150 m/min (500 fpm) for complex and critical systems. Hot water coils shall be sized at 230 m/min (750 fpm) maximum face velocity. Coil fins shall have a spacing of not more than 4.5 fins/cm (12 fins/ in.).

(12) Air Handling Units:

Central station package- type air handling units shall be complete with filters, (replaceable pre-filter and bag filter), cooling coil, and fan sections. Air handling units should be located at floor level with adequate clearance for maintenance, testing, and equipment removal. Air handling units located above ceilings or mechanical equipment, or suspended more than 1.8 m (6 ft.) above the floor, is undesirable and should be avoided where possible. Fans, coils, and air filters of the units shall be as described in the preceding sections. Layout of rooms housing air handling units shall allow for adequate space to service valves, motors, coils and control panels and for removal and replacement of filters.

(13) Refrigeration Machines:

Air-conditioning refrigeration compressors shall be of reciprocating, scroll or screw type. Generally, compressors having a capacity greater than 450 kW (130 refrigeration tons) shall be of the centrifugal type. Individual reciprocating compressors shall not exceed 350 kW (100 tons) capacities.

All refrigeration equipment shall be electric motor driven. For centrifugal type chillers, VFD control on the compressor is required for energy efficient chiller system.

(14) Chilled Water Systems

- (a) The cooling capacity of chilled water systems of 350 kW (100 tons) and over shall be divided between 2 or more chillers to ensure reliability and constant chilled water supply without temperature fluctuations, to prevent short cycling, and to minimize hot gas by-pass.
- (b) The combined capacity of the chillers shall not exceed the total requirement, including diversity.
- (c) The selection of the number of chillers shall be based on the analysis of part load operating hours for extended periods of low load conditions.

(15) Packaged Units

- (a) Packaged unitary units with multiple reciprocating compressors (not to exceed 8) shall be used for systems between 123 and 750 kW (35 and 200 tons).
- (b) Each compressor shall have separate, independent, refrigerant circuits and cycles to provide multiple steps of capacity control.
- (c) For systems up to 123 kW (35 tons), single compressors with a minimum of 3-step capacity unloading may be used.

7.12.5 AIR AND WATER BALANCE REQUIREMENTS

- (1) The heating, ventilating and air conditioning systems shall be designed to facilitate ease of balancing both by:
 - (a) Selecting supply fans for 5% over required air, to allow for leakage and for maximum operating efficiency based on system pressure drop calculations.
 - (b) Providing means of balancing the air and water flows. All necessary air balancing dampers shall be shown on the drawings, in addition to any general requirements in the specifications. Test fittings, access holes, and access doors shall be provided where needed for balancing, as well as provisions for measuring and balancing water flows.

7.12.6 VENTILATION AND AIR FILTRATION DESIGN CRITERIA**(1) General**

- (a) Ventilation shall be in accordance with International Mechanical Code (IMC), ASHRAE Standard 62 and ASHRAE Handbooks.
- (b) Where ventilation rates are not defined in the project criteria or not listed on the ASHRAE 62 Standards or International Mechanical Codes, the minimum fresh air per person for general occupancy facilities (offices, classrooms) shall be 26 cubic meters per hour (15 CFM).

- (c) Unless otherwise specified, all ventilation systems shall be mechanically operated, and natural ventilation shall be employed only to supplement the mechanical ventilation.
- (d) Design air distribution systems for central HVAC systems to maintain a slightly positive pressure within the area served in order to reduce or eliminate infiltration unless there is a valid need to maintain a negative pressure in that area.
- (e) Ventilation for variable air volume systems shall ensure proper ventilation rates at low and high system airflow. Instrumentation and controls shall be provided to assure outdoor air intake rates are maintained during occupied hours.

(2) Ventilation Equipment

- (a) Fans shall be selected typically in the middle and most stable portion of the capacity range. Each fan shall be selected based on the recommended application and outlet velocity range indicated in the ASHRAE Handbook. Direct drive is preferred for power roof and power wall ventilators for improved reliability and reduced maintenance.

(3) Air Filter Criteria

- (a) All re-circulating and outside air systems shall be provided with air filters.
- (b) Comply with the latest edition of ASHRAE Handbooks and ASHRAE Standards guidance for selecting and specifying filters.
- (c) Filter type and efficiency shall be based on the required cleanliness of the supply air, to meet the objectives of the conditioned space.
- (d) The filter media shall be rated in accordance with ASHRAE Standard 52.2.
- (e) The pre-filters shall have a Minimum Efficiency Reporting Value (MERV) of 8 (30 to 35% efficient with a maximum allowable particle size of 10 micron), while the final filters shall have a MERV of 13 (80 to 90% efficient with a maximum particle size of 1 micron), as determined by the dust spot test specified in ASHRAE Standard 52.
- (f) Filter racks shall be designed to minimize the bypass of air around the filter media with a maximum bypass leakage of 0.5%.
- (g) Differential pressure gages shall be provided across the filter assemblies.
- (h) Safety Considerations
 - i) Combustible filtering media shall not be permitted.
 - ii) All filters shall conform to UL 900 Class 2 for combustibility and smoke generation. Systems serving areas carrying flammable gases shall have the additional fire resistance of Class 1 filters, where specified.

Refer to ASHRAE Systems and Equipment Handbook, Air Cleaners for Particulate Contaminants.

(4) Outdoor Air Intakes

- (a) Locate outdoor air intakes in areas where the potential for air contamination is lowest. Basic guidelines include the following:
 - i) Maximize distance between intakes and cooling towers, plumbing vents, loading docks, traffic, etc.
 - ii) Maintain a minimum distance of 4 m (12 ft.) between intakes and exhausts, more if possible.
 - iii) Locate intakes and exhausts on different building faces.
- (b) Where outside air is introduced into an air handling unit, for other than residential application, inertial sand filters with mechanical bleed fan shall be provided as required in the outside air duct prior to mixing with return air for systems of 235 LPS (500 CFM) and above. Systems requiring less than 235 LPS outside air may use sand trap louvers with filters.
- (c) Outside air intakes for packaged and roof-top units shall have sand trap louvers, sized at 1.25 m/s maximum face velocity.

7.12.7 HVAC APPLICATIONS

(1) Residential Applications (system considerations)

<u>Residential type</u>	<u>Type</u>
1. Public Housing	Ductless A/C Mini Split unit
2. Multi-unit residences	
a) Dormitories	A/E shall submit life cycle
b) Apartments	cost analysis of at least
	three (3) HVAC systems.

HVAC system considerations for residential buildings shall be as follows:

- (a) Stairwell in multi-unit residence (apartments) shall be provided with air conditioning system.
 - (b) Windows A/C unit shall not be used.
 - (c) Exhaust systems for bathrooms with an individual exhaust, such as in single family dwellings, shall be controlled thru light switch. Exhaust systems which have combine exhaust from more than one toilet, such as in apartment buildings and dormitories, shall have continuously running fans.
- (2) Non-Residential Facilities
- (a) General applications
 - i) During the design conceptual phase, the A/E shall submit life cycle cost analysis of at least three (3) HVAC systems.
 - ii) The A/E shall consider all air and chilled water system option as relevant to the project.
 - iii) Windows A/C unit shall not be used.

iv) As per the Royal Decree direction via CTS # 38-1000-943, District cooling shall be used if the following conditions applicable:

- New project
- Cooling load more than 15,000 TR
- High density area (land to building ratio 1.5 or more), where land to building ratio = total building floors area / land area.
- Availability of TSE water (Treated Sewage Effluent).

(b) District Cooling

District cooling project to comply with regulation instituted by Electricity & Cogeneration Regulatory Authority (ECRA)

(c) Community Facilities Applications: Mosques

i) Local Mosque and Jumma Mosque shall be designed as per the latest edition of General Design Criteria for Mosques

(d) Wet (Chemical) Laboratories:

- i) Design shall confirm to up-to-date and modern engineering practice and standards.
- ii) The following standards shall be followed and considered during the design phase:
 - NFPA 45
 - ASHRAE Handbook
- iii) Use of Auxiliary Fume Hood is prohibited.
- iv) Blower fan with vertical stack shall be used for laboratory fume hood exhaust. The exhaust velocity shall be not less than 20.32 m/s (4000 fpm).

7.12.8 VENTILATION APPLICATIONS

(1) Ventilation for Toilets and Related Areas

- (a) Toilet areas, service or janitor closets, and garbage rooms shall be exhausted mechanically.
- (b) In consideration to energy conservation, make up or supply air to these areas may use a combination of primary (conditioned) air and secondary (make-up) air from adjacent areas. The minimum primary air shall be somewhat less than exhaust air quantity and a minimum of 10%.
- (c) Makeup air shall be drawn from the adjacent areas through door undercuts or grilles, wall or ceiling mounted transfer grilles, and transfer ducts where necessary.
- (d) For transfer grilles and ducts, precautions shall be taken against transfer of noise to and from adjoining areas.
- (e) Each toilet stall shall have a separate exhaust register, and exhaust from several toilets shall not be combined in one register.

- (f) The exhaust system for toilets and related areas shall not be connected to any other ventilating system in the building.

(2) Ventilation for Commercial Kitchens, Dining Rooms and Related Areas

(a) Cooking Appliances

- i) Cooking appliances, such as ranges, deep fat fryers, broilers and roasting ovens that present a fire hazard due to grease vapor emission shall be provided with exhaust hoods, exhaust ducts, and exhaust fans.

(b) Commercial Kitchen Exhaust Hood System

- i) Commercial-type kitchen ventilation system shall be designed and installed in compliance with International Mechanical Code (IMC) and, NFPA 96. ASHRAE HVAC Application Volume or SMACNA HVAC Systems Application Manual as reference for the proper calculation of exhaust air and supply air (untreated) volumes.
- ii) The hood exhaust system shall not be connected to any other building exhaust system. Hoods shall be type I or II and shall be designed to capture and confine cooking vapors and residues
- iii) Grease exhaust ducts shall be housed in 1- or 2-hour fire-resistant rated shaft enclosures for grease ducts or 2 layers of Fire Barrier Duct Wrap (ASTM E 2336 Standard Test Methods for Fire Resistive Grease Duct Enclosure Systems).
- iv) A temperature limit thermostat shall be provided in the exhaust hood to protect the hood exhaust system against grease fires. The thermostat shall be a fixed temperature device with a setting of 175°C. The thermostat shall be connected to stop the exhaust fan, close the fire damper, and actuate the fire extinguishing system. A manual switch, easily identifiable and accessible, shall also be provided for initiating these actions.
- v) All kitchen hood exhaust fans shall be the up blast type constructed on ventilated roof curbs.

(c) Residential/Domestic Kitchen Exhaust

- i) All exhaust shall discharge to the outdoors through sheet metal ducts constructed of galvanized steel, stainless steel or aluminium. Such duct shall have smooth inner walls, air tight and equipped with backdraft damper, and shall independent of all other exhaust.
- ii) Recirculating type hood is not permitted.

(d) Dining Room (Non-residential)

- i) Outdoor air introduced into the dining rooms shall be filtered and conditioned. It shall be transferred to the kitchen through transfer grilles, and shall be considered as part of the kitchen ventilation. This will prevent transfer of food odor from the kitchen into the dining area.
- ii) Outdoor air supplied to the dining area shall be exhausted through the kitchen ventilation system. If the kitchen exhaust air volume exceeds the outdoor air requirements of the dining area, the additional air required shall be supplied directly into the kitchen and shall be filtered, conditioned and introduced horizontally at or near the ceiling, so that it will diffuse without causing drafts at the cooking level or on kitchen personnel.

(e) Dishwashing Room

- i) Dishwashing rooms shall be provided with general ventilation at a minimum rate of 5 air changes per hour. Automatic conveyor type dishwashers shall be provided with an exhaust hood having a minimum of 0.51 m/s velocity across its face at each end. In no case shall combined-general ventilation and hood exhaust air quantity be less than 30 air changes per hour.
- ii) Makeup air for the dishwashing room shall be drawn from other heated spaces in the building where outdoor air is introduced. If makeup air must be supplied directly to the dishwashing room, it shall be filtered and heated.

(3) Ventilation for Industrial Processes

- (a) The design of ventilation for Industrial Process shall comply with the Industrial Ventilation (latest edition) and shall meet the requirements of Occupational Safety and Health Administration (OSHA).

(4) Battery Room Exhaust System

- (a) Exhaust air is necessary to remove the production of hydrogen gas which is produced during the battery charging process.
- (b) For flooded lead-acid, flooded nickel-cadmium, and VRLA batteries, ventilation is necessary to remove accumulated explosive hydrogen gas produced by the battery charging process.
- (c) The ventilation fan shall be continuously on during battery charging process with a ventilation rate of not less than 1 CFM/ft² of floor area of the room, or using battery manufacturer's recommendations, whichever is more stringent.
- (d) The supply air in battery charging operations shall be approximately 95 percent of the exhaust ventilation rate to maintain slightly negative room pressure to prevent fumes and gases from migrating outside the room.
- (e) Exhaust air shall not pass over electrical equipment unless the equipment is listed for the use. Supply air inlets shall be no higher than the tops of the battery cells and exhaust outlets at the highest level in the room.
- (f) Where mechanical ventilation is installed, the following shall be required:
 - i) Interlock means shall be provided such that the initiation of battery charging process will automatically turn on the ventilation fan. A local manual override means shall be provided.
 - ii) Airflow sensors shall be installed to initiate an alarm if the ventilation fan becomes inoperative.
 - iii) Control equipment for the exhaust fan shall be located more than 6 ft. from the battery and a minimum of 4 in. below the lowest point of the highest ventilation opening.
 - iv) Where mechanical ventilation is used in a dedicated battery room, all exhaust shall be directly to the outdoors.

- (5) Fans shall be roof-mounted with an upwardly directed discharge. Fans will have non-sparking wheel and motor location outside of the air stream. Elevator Machine Room Ventilation
 - (a) Mechanical ventilation system shall be provided in Elevator Machine Room as required by ASME A 17.1 to maintain temperature limits, as recommended by elevator manufacturers.
 - (b) Air-conditioning is required in most conditions; gravity ventilation is not acceptable. Coordinate with Electrical Engineer. Provide emergency power for machine room cooling/ventilating equipment, if the elevator is on emergency power circuit.
- (6) Elevator Hoist Way (Shaft) Ventilation
 - (a) Provide exterior ventilation of hoist way, if the elevator exceeds 15 feet (4572 mm) of travel. To obtain this ventilation, provide a weatherproof louver with a minimum free area of 3 1/2 % of the hoist way horizontal cross sectional area. The louver must have a minimum free area of at least three square feet (0.3 square meters).
 - (b) Vents shall be located at the top the hoist way and shall open either directly to the outer air or through non-combustible ducts to the outer air. Non-combustible ducts shall be permitted to pass through the elevator machine room, provided that portions of the ducts located outside the hoist way or machine room are enclosed by construction having not less than the fire-resistance rating required for the Hoist way.

7.12.9 DUCT WORK AND SPACE AIR DISTRIBUTION SYSTEMS COMPONENTS

- (1) Ductwork shall be designed base on ASHRAE Fundamental Handbook (Latest edition).
- (2) Design Considerations
 - (a) Duct work design is classified in accordance with its working pressure as follows:
 - i) Low Pressure: Below 500 Pa. (0.0725 psi)
 - ii) Medium Pressure: 500 to 2500 Pa. (0.0725 to 0.3626 psi)
 - iii) High Pressure: Above 2500 Pa. (0.3626 psi)
 - (b) Ductwork shall be sized using equal friction or static regain methods. Duct velocity shall be limited to 7.6 m/s (1500 fpm) for branch ducts and 10.2 m/s (2000 fpm) for main ducts, but in no case shall the pressure drop exceed 0.82 Pa/m (0.1 in water gage/100 feet).

Ductwork Sizing Parameters:

Low Pressure Ducts:

Max. Friction Rate	: 0.08 in. WG/ 100 Ft
Max. Air Velocity	: 7.62 – 10.16 m/s (1500 - 2000 Ft/min)

Medium Pressure Ducts:

Max. Friction Rate	: 0.20 in. WG/ 100 Ft
Max. Air Velocity	: 10.16 – 12.70 m/s (2000 - 2500 Ft/min)

High Pressure Ducts:

Max. Friction Rate : 0.40 in. WG/ 100 Ft

Max. Air Velocity : 13.21 – 17.98 m/s (2600 - 3500 Ft/min)

Intake Louver and Exhaust Louver: See ASHRAE Fundamentals

Air Terminals – Diffusers or Grilles: Follow manufacturer's recommended data.

(3) Duct Design

(a) Duct design shall be in accordance with the following:

- i) The recommended minimum rectangular duct dimension shall be 150 mm. Smaller dimensions may be used only as required due to physical restrictions.
- ii) Ductwork serving or/and passing a battery rooms or other corrosive environments shall be fabricated from a corrosive resistant type material.
- iii) Aspect ratios shall not be more than 6:1, unless space consideration is a governing factor.
- iv) Where duct work is connected to any fittings or equipment such as heating coils, cooling coils or filters, the transitions shall be as smooth as possible. The slope of transition on the upstream side shall be 15° and on the downstream side not more than 30°.
- v) Increments in duct work sizes preferably shall be in one dimension only and shall not be less than 50 mm (2 in).
- vi) Access doors or panels shall be provided in duct work for maintenance and service of the following equipment:
 - Filters.
 - Cooling coil.
 - Heaters.
 - Sound absorbers.
 - Volume and splitter dampers.
 - Fire dampers.

(4) Dampers

(a) Dampers shall be provided in duct work to provide proper control, balancing, and distribution of air.

(b) Dampers shall be used as follows:

- i) Volume dampers shall be used in branch ducts only when splitter dampers cannot be used or when branches are taken from the air plenum.
- ii) Splitter dampers shall be provided at all throats at duct branches.
- iii) Automatic parallel-blade dampers shall be used for requiring two position controls. Use opposed blade dampers applications requiring modulating control.

- iv) Self-closing gravity operated louvers shall be used for applications when backflow of air is to be stopped.
- v) No damper shall be larger than 1200 mm (4 Ft). For ducts wider than 1200 mm (4 Ft), dampers shall be provided in equal sections as required. Dampers for ducts less than 350 mm (1 Ft) high shall have a single leaf. For ducts 350 mm (1 Ft) and higher, multi-leaf dampers shall be used.
- vi) The length of splitter damper shall not be smaller than the width of branch throat served. Adjusting rods shall be connected to the leading edge of damper leaves, and shall protrude through duct faces. Adjustment shall be made through lock screw fittings. One adjustment rod shall be provided for every 350 mm (1 Ft) increment in duct height.
- vii) Blades of automatic dampers shall be no wider than 225 mm (0.75 Ft) and shall have overlapping and interlocking edges lined with felt to prevent leakage of air.

7.12.10 PIPING SYSTEMS COMPONENTS

(1) Water Velocity

- (a) Water velocity in HVAC piping shall not exceed the values shown below in order to limit noise levels.

- i) Chilled Water Pipe Sizing Parameter:

50mm pipes and below:

Max. Water Velocity	:	1.2 m/s (4.0 Ft/s)
Max. Pressure Drop	:	400 Pa/m (4Ft/100Ft)

65mm and larger:

Max. Water Velocity	:	3.0 m/s (10 Ft/s)
Max. Pressure Drop	:	400 Pa/m (4Ft/100Ft)
Min. Pressure Drop	:	100 Pa/m (1.0 Ft/100 Ft)

(2) Piping Design

- (a) Piping design shall be in accordance with the following:
 - i) Long radius elbows shall be used wherever possible. For offsets, 45° elbows instead of 90° elbows shall be used.
 - ii) Unions shall be provided for screwed pipes, where equipment and piping accessories have to be disconnected for service.
 - iii) Flanges shall be provided for welded pipes, where equipment and piping accessories have to be disconnected for service.
 - iv) Recommended piping and fitting materials shall be as shown Table 7-1.

Table 7-1. Recommended Pipe and Fitting Materials For Various Services

SERVICE	PIPE	FITTINGS
Refrigerants	Copper Tube: ASTM B 88M, Type A or B ASTM B 280, Type ACR.	Wrought-Copper Fittings and Unions: ASME B16.22. Solder Filler Metals: ASTM B 32. Use 95-5 tin antimony or alloy HB solder to join copper socket fittings on copper pipe. Brazing Filler Metals: AWS A5.8/A5.8M.
Chilled Water Pipes	Aboveground: Sch. 40 Black steel pipes. Underground: Sch. 40 Black steel Pipe (Pre- insulated)	Welding, cast, malleable or black iron
Condenser or Make-Up Water	Galvanized steel pipe	Welding, galvanized, cast or malleable iron.
	Hard copper tubing	Cast brass, wrought copper or wrought brass
Drain or Condensate Lines	Galvanized steel pipe	Galvanized, cast or malleable iron
	uPVC pipe	uPVC

7.12.11 MECHANICAL PLANT INSTALLATION AND GENERAL ARRANGEMENT**(1) Chilled Water**

- (a) All constant flow system chilled water shall have 3 way motorized valves with bypass. Variable flow system chilled water shall have 2 way motorized valves with bypass.
- (b) Balancing valves shall be installed on the return lines.

(2) Chillers

- (a) Chillers shall use constant water flow or variable water flow. Chillers shall be installed in parallel to allow for ease in maintenance.

(3) Chilled Water Lines

- (a) Chilled water coil supply and return lines shall have thermowells, air release valve, pressure plug points and drain line.
- (b) Motorized butterfly valve, flow sensor, flow meter and balancing valve shall be installed at chilled water return line.
- (c) A shutoff valve shall be installed on each of the supply and return lines of each cooling coil to allow for servicing of the coil without tampering with water balance.

(4) Chilled Water Circulating Pumps

- (a) The chilled water circulating pumps shall be a 100% standby and shall have a pressure gage at the suction side, a strainer, and gate valve.
- (b) The discharge side shall have a pressure gage, a check valve and a gate valve.
- (c) Suction diffuser with strainer at suction side and triple duty valve at discharge side may be used in lieu of conventional pumps installation if the space constraint.
- (d) Where primary-secondary pumping system provided, primary pumps shall operate in constant volume and a variable volume in secondary pumps.
- (e) When parallel operating chilled water pumps are used, pumps quantity shall not be more than three (3) nos. Two (2) pumps duty and one (1) standby.
- (f) The designers are required to submit manufacturer's pump curve. Pump curve for both single pump operation and combined operation shall cross the pump system curve.
- (g) A De-Coupler pipe (neutral bridge) in primary-secondary system shall have an equal pipe size with supply and return chilled water pipe and shall have friction loss less than 1.5 ft/sec. The pipe length shall not be less than 3 diameters of chilled water pipes.

(5) Chemical Feed and Water Make-Up

- (a) The system shall also have at the suction side of the pump an air separator and closed type compression tank.
 - (b) The make-up line to the system shall have a double check valve to prevent cross-connection.
- (6) A pot feeder having a capacity of no less than 0.1% of system water volume with two shutoff valves shall be installed between the pump suction and discharge lines, in parallel with the pump.

(7) Concrete Inertia Bases

Inertia bases shall be provided for reciprocating and centrifugal chillers, air compressors, all pumps, axial fans, and centrifugal fans.

(8) Equipment Access

- (a) Where equipment or valves are situated in a high location, all necessary operating chains, service platforms and ladders with railing shall be provided.

- (b) All chilled water plants shall have adequate space for coil or tube pull-out.
- (c) Access space shall be provided for maintenance in front of motor control centers and control panels.

7.12.12 MISCELLANEOUS

- (1) Systems Pressure Loss
 - (a) Systems pressure losses shall include all pressure drops in duct work, intake louvers dampers, filters, cooling and heating coils, plenums, fire dampers, volume dampers, duct transitions, elbows, tees, other fittings, extractors, splitter dampers, equalizing grids, opposed blade volume dampers, air outlets, room overpressure, return inlets and other devices. A minimum margin of 25% shall be added to the calculated loss.
- (2) Duct Smoke Detectors
 - (a) Duct Smoke Detectors shall be installed as required by NFPA 90A and shall be interlocked with the supply fan as required by NFPA 90A.

7.12.13 VIBRATION ISOLATION AND NOISE CONTROL REQUIREMENTS

- (1) Vibration Isolation and noise:

Special attention shall be given to vibration to ensure that there is no transmission of vibration or structure-borne noise to the building and occupied spaces. Vibration isolation shall be provided for all equipment, ductwork, and piping. No rigid connections between rotating or oscillating equipment or piping and the building shall be permitted. Vibration isolators shall be selected in accordance with the weight distribution and the manufacturer's recommendations to produce uniform deflection.
- (2) Noise Control:

Fans, air devices, and sound attenuators shall be selected which do not generate within the occupied space, noise control curve ranges and decibel ranges in excess of the recommendations of ASHRAE Applications Handbooks.

7.13 PLUMBING

7.13.1 OBJECTIVES

- (1) The plumbing design shall include all plumbing (Potable water, Sanitary Drainage, Storm Drain and Vents) inside buildings and to 1.5 m outside of the buildings.
- (2) General Design Criteria for Medical Gases and Vacuum Systems

7.13.2 GENERAL CRITERIA

Comprehensive calculations shall be performed by using Plumbing Design Programs that are acceptable and/or recognized by plumbing industry to substantiate all design.

All plumbing design calculations shall utilize formats acceptable to the Royal Commission. As a minimum, the data/information as shown on Appendix PG-1, PG-2, PG-3 and PG-4 must be included as applicable.

7.13.3 WATER PRESSURE

- (1) Wherever water pressure from street main or other source of supply is insufficient to provide flow pressure at fixtures outlets as required under IPC, a water pressure booster system either by an elevated water tank, a hydro pneumatic pressure booster system or a water pressure booster pump shall be provided.
- (2) Where water pressure within building exceeds 80 psi (552 kPa) static, water pressure reducing valve with strainer shall be installed to reduce the pressure to 80 psi (552 kPa).

7.13.4 INSTALLATION

- (1) Pipe material shall conform to material listed in technical specification and the standard shall conform to one of the standards listed in table 605.4 IPC.
- (2) Headers supplying flush valve fixtures shall run full size to the last fixture.
- (3) Shutoff valve and full-open valves shall be installed at the locations listed in the IPC. The valves shall be accessible and identified. . Where valves are located in concealed spaces, metal access panels of suitable size shall be furnished.
- (4) Unless flanges are indicated, a union shall be installed on one side of all screwed shutoff valves, equipment connections, and elsewhere as indicated or required for ease of installation and servicing. Under no circumstances shall unions be installed in inaccessible locations.
- (5) The minimum branch pipe size shall be in accordance with table 604.5 IPC. .
- (6) A water-hammer arrestor shall be installed where quick closing valves are utilized on both hot and cold water lines
- (7) A potable water supply system shall be designed in such a manner so as to prevent contamination from non-potable liquids, solids or gasses being introduced into potable water supply through cross-connections or any other pipe connections to the system.

7.13.5 PLUMBING FIXTURES

- (1) All plumbing fixtures and fittings shall be of the water conservation type conforming to (SASO 1473, 1257, 1477, 1473, 2655 and NSF 61), with a maximum flow as follows:

<u>Fixture</u>	<u>Maximum Flow</u>
Eastern Water Closets	4.8 liters (1.28 gal) per flush
Western Water Closet (Dual Flush)	3.5 / 4.5 litres (0.92 / 1.2 gal) per flush
Private Faucets	6.0 liters/min (1.6 gpm)
Public Faucets	1.9 liters/min (0.5 gpm)
Showers	9.5 liters/min (2.5 gpm)
Urinal	1.0 Liters (0.26 gal) per flush
Kitchen Faucet	6.0 Liters/min (1.6 gpm)
Bidet	6.0 Liters/min (1.6 gpm)
Perineal Spray (Shattaf)	6.0 Liters/min (1.6 gpm)

- (2) In general, self-closing faucets shall be used in public facilities.

- (3) All water closets shall be equipped with flexible hoses terminating with a self-closing valve. A vacuum breaker back flow preventer shall also be provided in the hose supply line.

7.13.6 HOT WATER SUPPLY SYSTEM

- (1) Unless specified in the project specification, hot water or tempered water shall be supplied in the following premises:

(a) Residential occupancies:

- i) Hot water shall be supplied to all plumbing fixtures and equipment utilized for bathing, washing, culinary purposes, cleansing and laundry.
- ii) Each toilet with lavatory or/and shower shall have hot water source.
- iii) Water heater shall be centralized type, floor or wall mounted (depending on the tank capacity). The water heater shall not be installed above false ceiling.

(b) Non-residential occupancies:

Hot water shall be supplied to the fixtures in the non-residential occupancies listed below.

i) Schools and Kindergarten

- Lavatories (Teachers or Staff toilets)
- Janitor sink
- Shower(s)

ii) Higher Education

- Lavatories
- Janitor sink
- Shower(s)
- Fixtures required hot water for their operations.

iii) Mosque

- Lavatories
- Janitor sink

iv) Offices

- Lavatories
- Janitor sink
- Shower(s)
- Fixtures required hot water for their operations.

v) Public toilets

- Janitor sink

- (2) Water heater shall be centralized type, floor or wall mounted (depending on the tank capacity). The water heater shall not be installed above false ceiling.

- (3) Use "Point of use type" in-lieu of "Tank type" water heater if only one (1) fixture is required to be supplied with the hot water.
- (4) Water heater location (room and/or enclosure) refer to AR.
- (5) Where the developed length of hot water piping from the source of hot water supply to the farthest fixture exceeds 30 meter (100 ft), the hot water supply system shall be provided with a method of maintaining the temperature in accordance with International Energy Conservation Code.
- (6) Thermal expansion control shall be provided to control pressure due to thermal expansion.

7.13.7 MATERIALS

The plumbing specifications shall identify all types of materials, fixtures, and equipment to be used, and shall set forth explicit and concise methods of construction and installations.

7.13.8 SOLAR WATER HEATING SYSTEM

When required by specific project requirement, solar water heating systems shall be provided in buildings except where isolated lavatories and sinks are provided; (for example, guard houses and warehouses).

A solar water heating system shall include roof-mounted solar collectors, pumps, piping and accessories, insulated storage tank(s) and control devices. A roof-mounted uninsulated tank is not considered a solar collector.

Calculations shall be provided to justify equipment selection. An electric water heater (separate from the storage tank) shall be provided as a part of the system.

Solar collector panels shall be oriented due south and installed at an angle of 32° with the horizontal.

The design of solar water heating system shall comply with International Mechanical Code (latest edition).

7.13.9 WATER METERING

Design of potable water service shall include provisions for installation of metering equipment at each facility.

- (1) Meter installation shall be located adjacent to the service disconnection or regulator valve of the facility.
- (2) The meter location shall be easily accessible, identified and protected against vandalism.
- (3) Meters further than the 1.5m will be under civil site work.
- (4) Each residential unit shall have a separate water meter.

7.13.10 SANITARY DRAINAGE, STORM DRAIN AND VENTS**(1) Sanitary Drainage (Inside Building)**

- (a) The sanitary drainage system shall be designed to guard against fouling, deposit of solid, clogging, and with adequate cleanouts so arranged that the pipes may be readily cleaned.
- (b) The system shall be designed to provide an adequate circulation of air in all pipes with no danger of siphoning or forcing of trap seals under conditions of normal use.
- (c) Drainage piping shall be designed so as to afford scouring action in the piping system. A velocity of 2 ft/s (0.61 m/s) is recommended as the minimum necessary to produce scouring action in the piping conveying sewage.
- (d) Horizontal drainage piping shall be installed in practical alignment at a uniform downstream slope. For inside building horizontal drainage piping, the pipe slope shall be at least 2% (20mm/m) toward the direction of sewage flow.
- (e) Material for above ground soil, waste and vents pipe shall conform to one of the standards listed in table 702.1 IPC.
- (f) Material for underground building sanitary drainage and vents pipe shall conform to one of the standards listed in table 702.2 IPC.
- (g) Material for building sewer pipes shall conform to one of the standards listed in table 702.3 IPC.
- (h) Material for pipe fittings shall conform to applicable standards listed in table 702.4 IPC.
- (i) Cleanouts is required and shall be provided in accordance with IPC section 708.
- (j) Pipe size shall be designed in accordance with section 709 and section 710 IPC
- (k) The design of sumps and ejectors shall in accordance with section 712 IPC.

(2) Chemical/Waste

- (a) Waste containing acids or other chemicals which can adversely affect the piping system shall be subjected to treatment prior to being discharged into the sanitary drainage system.
- (b) All acids waste requires neutralization to a pH 7.5 before it is permitted to be discharged in any public sewer.
- (c) Each basin shall be designed to allow sufficient contact time for the chemical reaction to accomplish complete neutralization based on the maximum probable flow rate.
- (d) Treatment basin shall be outside of the building and shall consist of acid-resistant neutralization basin, limestone or marble chips fill the interior of the tank, and discharge pH sensor.

(3) Roof Drainage

- (a) All roofs, paved areas, courts, and courtyard shall be drained into a separate storm sewer system.
- (b) The storm drainage piping system shall be independent of any other piping systems. Storm water shall not be drained into sewer intended for sanitary drainage.

- (c) The locations and sizing of roof drains shall be coordinated with structural design and pitch of the roof.
 - (d) The size of the vertical conductors and leaders' building storm drains, building storm sewers, and any horizontal branches of such drains or sewers shall be based on the 100-year hourly rainfall rate determined from Meteorology and Environmental Protection Administration (MEPA), Kingdom of Saudi Arabia.
 - (e) Secondary (emergency) roof drains or scuppers shall be provided where the roof perimeter construction extends above the roof in such a manner that water will be entrapped if the primary drains allow buildup for any reason.
 - (f) Discharge point of secondary roof drain shall be above grade, independent from primary roof drain, in a location that would normally be observed by the building occupants or maintenance personnel.
- (4) Vents
- (a) The design of vents piping, materials and installation shall conform to chapter 9, International Plumbing Code (IPC)
- (5) Sanitary Drainage for Elevator pit (When required by Code)
- (a) Floor drain is not acceptable. Elevator pit must have floor sump pit and pump. Pump to sanitary sewer through a 2" (50 mm) air gap or directly through an oil/water separator to storm sewer, or to grade outside the building line, each in accordance with discharge permits, regulations, and statutes. Coordinate sump pit pump with the Architect, Structural Engineer, and Electrical Engineer.
 - (b) The minimum size of sump pump is 20 gallons (76 liters) per minute. Coordinate pump size with Architect to assure the pump will completely fit within the sump pump pit and function correctly.
- (6) Condensate Drain
- (a) Condensate drain shall be used as irrigation water for the landscape around the building, if applicable.

7.13.11 MEDICAL GASES AND VACUUM SYSTEMS

- (1) The design of medical gases system shall conform to NFPA 99 – Standard for Health Care Facility and NFPA 101 – Life Safety Code, International Plumbing Code (IPC) and American Society of Plumbing Engineers (ASPE). The purpose of these established criteria is to minimize the hazards of fire, explosion, and electricity in health care facilities providing services to human beings.
- (2) Each medical gas station shall provide a minimum flow rate for the proper functioning of connected equipment under design and emergency conditions.
- (3) Vacuum pumps shall be sized to evacuate the required volume of free air from a vacuum of 19 Hg. Pumps shall be provided in duplicate; each shall be capable of satisfying the demands of the system.
- (4) Units shall operate alternately and shall run simultaneously when a single unit cannot maintain the minimum vacuum of 19 Hg in the receiver.
- (5) The medical air compressors shall draw air from a source of clean air, located where no contamination anticipated from exhaust, vents, medical surgical vacuum system discharges, or odorous gas.

- (6) Medical compressed air shall be clean, oil free, and relatively dry.
- (7) Testing shall be in strict accordance with NFPA 99.

7.13.12 LIQUEFIED PETROLEUM GAS (LPG) SYSTEMS

In the absences of district natural gas mains, LPG in the portable cylinders or stationary storage tank becomes the alternatives gas fuel. Design and installation requirements shall comply with International Fuel Gas Code and NFPA 58.

- (1) Emergency shutoff valves in accordance with NFPA 58 and shall be incorporate all of the following means of closing:
 - (a) Automatic shutoff valve through thermal (fire) actuation
 - (b) Manual shutoff valve from a remote location.
 - (c) Manual shutoff valve at the installed location.
- (2) Pressure relief device in accordance with NFPA 58.
 - (a) For LPG storage tanks and equipment located inside buildings where there is a potential for loss of LPG, provide an alarm/detection system with local alarms, ventilation and a leak detector, Provide gas leak detection in accordance with SASO, AHJ and NFPA 59.

7.14 FIRE SUPPRESSION SYSTEM

7.14.1 FIRE PROTECTION DESIGN OVERVIEW

- (1) SCOPE
 - (a) This General Design Criteria and Technical Guidelines (GDCTG) applies to all designs, upgrades, and modifications to Royal Commission (RC) owned, occupied, leased, or operated facilities.
 - (b) The Industrial Security and Safety Department (ISSD), is the “Authority Having Jurisdiction” (AHJ) as defined and used in the National Fire Protection Association (NFPA).
 - (c) All Fire Protection systems shall be designed and installed in accordance with IBC, IFC and NFPA Codes and Standards.

7.14.2 PURPOSE

The purpose of this GDCTG is to establish minimum protection requirements for RC facilities. The requirements in this GDCTG reflect the need for the protection of life and property (building or contents) while taking into account the costs of implementing the criterion and risks associated with the facility. These criteria have been established in the best interest of RC.

7.14.3 CODES AND STANDARDS

- (1) RC has adopted the National Fire Codes (NFC) published by NFPA, which establish a minimum acceptable level of life safety and property protection. Life safety requirements are specifically addressed in the Life Safety Code, NFPA101. Where conflicts exist between codes, the designer shall follow the code specified in the text under the subject section of this guideline. Fire Protection design shall be based on the

latest editions of the NFC at the Date of Award of the contract to the Architectural/Engineering (A/E) firm.

(2) References:

- (a) International Code Council (ICC) Codes, latest edition
 - i) International Fire Code (IFC)
 - ii) International Building Code (IBC)
 - iii) International Mechanical Code (IMC)
 - iv) International Plumbing Code (IPC)
 - v) International Existing Building Code (IEBC)
 - vi) International Residential Code (IRC) for One & Two Family Dwellings
 - vii) International Residential Code (IRC)
 - viii) International Fuel Gas Code (IFGC)
- (b) National Fire Codes, National Fire Protection Association (NFPA), Latest Version, and their appendices

7.14.4 EQUIPMENT

All equipment shall be Underwriters Laboratories (UL), Inc. listed and/or Factory Mutual (FM) approved except that listing and labelling by similar agencies of the country where the item is manufactured will be acceptable, subject to approval by AHJ.

7.14.5 FIRE PROTECTION DESIGN ANALYSIS REPORT (DAR)

- (1) Fire protection DAR is required for all designs and must address the fire protection requirements of the project as required by this GDCTG. Summarize the fire protection design analysis and submit with the first design submission separate from other disciplines. Where applicable, discuss the following minimum fire protection provisions (include required vs. provided):
 - (a) Building code analysis (i.e., type of construction, height and area limitations, and building separation or exposure protection)
 - (b) Classification of occupancy. NFPA 13, Installation of Sprinkler Systems shall be used to determine the Occupancy Hazard Classification.
 - (c) Requirements for fire-rated walls, fire-rated doors, fire dampers with their fire-resistive ratings, smoke compartmentation, smoke barriers
 - (d) NFPA 101, Life Safety Code
 - (e) Analysis of automatic sprinkler systems and suppression systems and protected areas, including hydraulic analysis of required water demand,
 - (f) Water supplies, water distribution, location of fire hydrants
 - (g) Smoke control methods and smoke control systems
 - (h) Fire alarm and Detection system (the type of alarm and detection system and location of the fire alarm equipment, devices).
 - (i) Fire detection system (the type of detection system and location of detectors),
 - (j) Standpipe systems and fire extinguishers,

- (k) Interior finish ratings,
 - (l) Connection to and description of base fire alarm reporting system
 - (m) Identify the various occupancies and hazardous areas associated with the facility,
 - (n) Coordination with security-requirements
 - (o) Fire Department access.
- (2) Comprehensive calculations shall be performed using Fire Protection Design and Engineering Programs that are acceptable and/or recognized by NFPA Standards to substantiate all design.

7.14.6 ACCESSIBILITY REQUIREMENT

- (1) All buildings greater than 5,000 sq. ft (465 m), or more than two stories in height must have at least one means of all-weather ground access to allow emergency vehicles unimpeded access to the building. All-weather ground access must be paved, start from the road, and terminate no farther than 33 ft (10 m) from the building.
- (2) Dimensions of fire lanes and turnarounds must comply with NFPA 1, Uniform Fire Code, Chapter 18.
- (3) Facilities with fire department connections for sprinkler or standpipe systems must be provided with suitable all-weather ground access surface for pumper apparatus within 100 ft (30.5 m) of such fire department connections.

7.14.7 WATER SUPPLY FOR FIRE PROTECTION

- (1) SUPPLY DURATION.
 - (a) Requirements for fire protection water storage are based on the assumption that there will be only one fire at a time. The quantity of water required is equal to the product of the fire protection water demand and the required duration. This quantity represents fire protection requirements only, and must be available at all times.
 - (b) The total fire water supply stored for fire protection purposes must be sufficient to meet 150% of the pump's rated capacity for the durations specified in NFPA 13.

7.14.8 WATER STORAGE TANKS

- (1) Water based system that exceeds 200 gpm and/or 30 psi (31 L/s and/or 2 bars) shall be provided with a fire water storage tank and set of fire pumps. Calculation for the capacity shall be coordinated with the Industrial Security and Safety Department since the duration requirements of the storage water tank will depend on Hazard type and the location distance of a Fire Station
- (2) Provide Fire Water Storage tank installed and constructed per NFPA 22.
- (3) If water storage tank is used for both daily domestic consumption and fire water, the storage water tank shall be provided with level control device.

7.14.9 DISTRIBUTION SYSTEM

- (1) Distribution systems must be designed per NFPA 24, Installation of Private Fire Service Mains and Their Appurtenances,

- (2) Distribution must be looped to provide at least 50 percent of the required fire flow in case of a single break. Dead-end mains must be avoided.
- (3) Minimum size for underground piping supplying NFPA 13 fire sprinkler systems must be not less than 6 inches (152 mm) in diameter.
- (4) The type and class of piping used for fire mains shall be considered for its fire resistance, corrosion resistance, maximum working pressure, soil conditions and external loads due to burial. For nonmetallic and metallic pipe, NFPA Codes & Standards shall be consulted.
- (5) Fire water pipes runs under the buildings are prohibited.
- (6) Fire water mains shall not pass aboveground through fire hazardous areas.

7.14.10 HYDRANTS

Fire hydrants shall be UL listed and shall be dry barrel type, opening against the pressure and closing with the pressure.

- (1) They shall have one 4 1/2 inch pumper connection with two 2 1/2 inch outlets for hose connection. They shall be designed for 1035 kPa (150 psi) working pressure. Stem rod shall be acid resistant stainless steel conforming to AISI 316. Weather and pressure seals shall be incorporated. The pumper and hose connections shall have American National screw threads according to NFPA Standard dated 1963, the 2 1/2 inch outlet shall have 7.5 threads per inch. The operating stem nut at the top of the hydrant cap (dome) shall be a pentagon shape and measure 1 1/2 inches from point to opposite flat. The direction to open shall be counter clockwise. A minimum 150 mm auxiliary gate valve shall be provided on the hydrant branch. The hydrants shall be coated in accordance with Section 10: Corrosion Protection and Control. The finish color shall be Munsell ANSI Safety Red, 7.5R, or equivalent color approved as may be available within the Kingdom of Saudi Arabia
- (2) Fire hydrant spacing shall comply with the NFPA requirements. As a general rule the spacing in the closely built areas shall not exceed 150m.
- (3) For areas or facilities that manufacture, process, store, transport, transfer or handle bulk materials, hydrant spacing shall not exceed 328 ft (100m).
- (4) Fire hydrants shall be connected to the Potable Water network.
- (5) At least one hydrant must be located within 100 ft (30.5 m) of a Fire Department Connection (FDC).

7.14.11 FIRE EXTINGUISHING SYSTEM

(1) GENERAL

As part of fire protection design, the Designer shall determine the appropriate fire protection system to be used based on a comprehensive evaluation/analysis of latest editions of the International Fire Code (IFC) and Life Safety Code (NFPA 101) requirements

(2) SPRINKLER SYSTEM

- (a) The design of wet pipe sprinkler systems shall specifically meet, as a minimum, the requirements of NFPA 13 for the occupancies covered by this standard.

- (b) Sprinkler risers with alarm check valve and isolation valve shall be installed in a dedicated room with full height door. Locate the room along the perimeter wall of the building.

(3) STANDPIPE SYSTEM

- (a) Standpipe systems must be installed in accordance with NFPA 14, Installation of Standpipes and Hose Systems.
- (b) For Light Hazard Occupancy up to and including four stories in height, Use Class II standpipe system. A minimum 1 inch (25.4 mm) hose shall be permitted to be used for fire hose stations in light hazard occupancies where investigated and listed for this service and where approved by AHJ.
- (c) Requirements for hose stations shall include determination of which, if any, are to have foam generation capability.

(4) CLEAN AGENT EXTINGUISHING SYSTEM

The designer shall determine which facilities are to be protected by the system. Constantly attended areas, e.g. data processing and communication centres, the system shall be clean agent type and shall be designed in accordance to NFPA 2001.

- (a) Areas normally unattended but periodically serviced by one or two persons (e.g. flammable oil-insulated transformer vaults) may be protected by environmentally friendly fire suppression agent such as FM 200, FE-227, PC-410 or carbon dioxide or equivalent systems such as water mist and designed according to NFPA 12 and other relevant codes. Time delays and pre discharge alarms shall be built into the system for personnel protection and safety.
- (b) NFPA 17 and 17A shall be used as references when wet or dry chemical are used as fire extinguishing system.
- (c) Provide a manually activated exhaust system to facilitate the extraction of any remaining clean agent after the required hold time of the total flooding clean agent system. The exhaust system can be integrated into the HVAC system for the enclosure.

(5) COOKING EQUIPMENT EXTINGUISHING SYSTEMS

- (a) Cooking Facilities: Hood and duct systems for commercial cooking equipment that produces smoke and grease laden vapors must comply with NFPA 96, Ventilation Control and Fire Protection of Commercial Cooking Operations. Limit kitchen-extinguishing systems to wet chemical or automatic sprinklers installed in accordance with NFPA 96. Install fire suppression systems that sound a general building fire alarm and transmit a signal to the Fire Department or to a constantly monitored location.
- (b) Cooking Equipment: Residential type (Multi-family dwellings greater than 2 stories in height but not greater than 4 stories) range top cooking surfaces must be equipped with approved residential range top extinguishing system. The range top extinguishing system must be connected to the building fire alarm system to sound a general building fire alarm and must automatically shut off all sources of fuel and electric power that produce heat to the equipment being protected by that unit.

(6) PORTABLE FIRE EXTINGUISHERS

- (a) Portable fire extinguishers must be provided where required by NFPA 101, Life Safety Code or AHJ. Portable fire extinguishers must be located and installed in accordance with NFPA 10, Portable Fire Extinguishers
- (b) Recessed or semi-recessed enclosed cabinets must be provided in new or renovated facilities, except storage rooms, Electrical rooms, Mechanical Equipment rooms and industrial occupancies.
- (c) Selections of Fire Extinguisher type such as (A), (B), (C), (ABC) or (BC), etc. depend on type of hazard and shall meet the requirements of NFPA 10, where applicable.

(7) FIRE PUMPS

- (a) Fire pump systems shall be in complete compliance with NFPA 20. It shall consist of one (1) electric driven, one (1) diesel engine driven and one (1) jockey pump, Fire Pump Controls and other Auxiliary systems.
- (b) A fire pump may be either a horizontal or vertical shaft centrifugal pump or a vertical shaft turbine pump; whichever is most economical and appropriate for the intended use. A centrifugal pump in either the horizontal or vertical position must not be used where suction lift is required. A vertical shaft turbine pump must be used for suction lift.
- (c) Fire Pumps shall be installed in a room, fire resistant rated construction in accordance with NFPA 20, separated from other mechanical and electrical equipment. The fire pump room shall have direct access from the outside of the building.

(8) FIRE ALARM SYSTEM

The fire alarm system shall be installed where required by NFPA 101 and shall be designed to meet the requirements contained in NFPA 72, National Fire Alarm Code.

- (a) Fire Detection. The designer shall determine those buildings or portions thereof which are to have automatic fire alarm systems or individual detectors.
- (b) Buildings or portions thereof not protected by automatic extinguishing systems shall, as a minimum, be equipped with automatic fire detection systems.
- (c) The Fire Alarm and Detection system shall be of addressable type. These systems, as well as all types of extinguishing systems shall, where required, transmit alarms to a remote, constantly attended station Fire Alarm Control Panel (FACP) with 24 hours responsible supervision.
- (d) Buildings protected by automatic extinguishing systems shall also be provided with smoke detection systems as required.
- (e) Interior manual fire alarm boxes shall include an audible alarm.

Appendix PG-1

Sheet _____ of _____

Domestic Cold Water Demand Summary	Rev	Date	By	Checker	Job Number
Fixture	Number Required	Units Per Fixture		Fixture Units	Remarks
		Public	Private		
Water closet					
Urinal					
Lavatory					
Wash fountain					
Shower					
Service sink					
Mop sink					
Lab sink					
Cup Sink					
Kitchen Sink					
Electric water cooler					
Hose bibb					
Total Fixture Units				= _____ Liters per second (LPS)	
Miscellaneous Equipment Makeup				= _____ LPS	
Total				= _____ LPS	
_____ LPS = _____ mm building supply main					
_____ m per second velocity and pa friction loss					

Appendix PG-2

Sheet _____ of _____

Domestic Hot Water Demand Summary	Rev	Date	By	Checker	Job Number	
Fixture	Number Required	Units per Fixture	Fixture units	LPH at 50°C	Total LPH	Remarks
Lavatory						
Wash fountain						
Shower						
Service sink						
Mop sink						
Kitchen Sink						
Lab Sink						
Cup sink						
Bath Tub						
TOTAL			= (LPS)			
_____ LPH X _____ Demand Factor = _____ LPH						
_____ LPH X _____ Storage Factor = _____ Litters						
Legend: LPS = Liters per second LPH = Liters per hour						

Appendix PG-3

Sheet _____ of _____

Sanitary Sewer Load Summary	Rev	Date	By	Checker	Job Number
Fixture	Number Required	Units per Fixture	Fixture Units	Remarks	
Lavatory					
Wash fountain					
Shower					
Service sink					
Mop sink					
Kitchen Sink					
Lab Sink					
Cup sink					
Water Closet					
Floor Sink					
Electric Water Cooler					
Floor Drain					
Eyewash/Shower					
Total Fixture Units				.= _____ mm Building Sewer	

Appendix PG-4

Sheet _____ of _____

Potable Water System Pressure Drop Calculation		Rev	Date	By	Checker	Job Number
Item	Component Pressure Loss	Cold Water		Hot Water		
		Flush Tank	Flush Valve	46°C	60°C	82°C
1	Street Main Pressure Minimum _____ pa Maximum _____ pa					
2	Meter size _____ m for _____ LPS flow					
3	Meter loss(pa)					
4	Static loss or gain (pa)					
5	Residual pressure required (pa)					
6	Softener loss (pa)					
7	Filter or strainer loss (pa)					
8	60° mixing valve loss (pa)					
9	46° mixing valve loss					
10	Pressure regulating station					
11	Backflow preventer (main line) loss (pa)					
12	Backflow preventer (equipment) loss (pa)					
13	Subtotal losses (Item 3 to 12) (pa)					
14	Yard piping losses _____ m of _____ mm line					
15	Total losses (Item 13 and 14)(pa)					
16	Water pressure (minimum) (pa) (Item 1)					
17	Pressure available for friction (Item 16 minus 15) (pa)					
18	Actual length of system (m)					
19	Developed length _____ percent of item 18 (m)					
20	Average pressure drop (pa/100 m) Item 17 divided by 19 times 100					

SECTION 8

ELECTRICAL DESIGN

8.1 GENERAL

The Electrical Design Criteria and Guidelines provide the basis for design and installation of electrical systems, subsystems, equipment/components, and services, in Yanbu under the jurisdiction of the Royal Commission.

(1) Scope

The guidelines apply to the following systems:

- (a) High Voltage Transmission Systems (380 kV and 115 kV) & Substations
 - (b) Medium Voltage Primary Power Distribution Systems (34.5 kV and 13.8 kV)
 - (c) Low Voltage Secondary Power Distribution System (400/230 V)
 - (d) Street Lighting
 - (e) Facility / Building Electrical Systems
- (2) These guidelines shall be utilized for the design of electrical infrastructure in MYAS as well as facilities in the community and light industrial areas.
- (3) The design of electrical services within heavy industrial facilities are not included in the scope of these Design Criteria and Guidelines.
- (4) All works undertaken in relation to this Design Criteria and Guidelines shall be completed in full compliance with the respective health and safety requirements established by the following:
- (a) Kingdom of Saudi Arabia
 - (b) Legislation, Regulation, International Standards, and Codes
 - (c) Royal Commission
 - (d) Regulations, Standards, Contractual Conditions, Health and Safety Standards, and Guide Line Documentation
 - (e) Contractor Health and Safety Standards, and System as accepted by the Royal Commission.

(5) Infrastructure Scope

Substations, transmission lines, distribution networks, as used in this document, include but not limited to substation buildings, overhead transmission lines, gantries, underground cables, switchgear, transformers, distribution panels, revenue metering, measuring instrumentation, controls, street lighting, etc.

Electrical infrastructure includes the transmission lines from generation (GTG, STG, Solar, wind plants, etc.) to the transmission or distribution substations as well as the Medium Voltage (MV) and Low Voltage (LV) distribution networks to provide power to industrial and community loads, including street lighting, as shown below:

- Industrial loads: Supplied at 380, 115, 34.5, 13.8kV or 400/230V from Marafiq substations and/or Pad-Mounted Switchgear (PMS).

- Community loads (residential, commercial, governmental, etc.): Supplied at 13.8kV or 400/230V from the nearest PMS and/or distribution substations.

(6) Facilities Scope

Residential, Commercial and Institutional Facilities, as used in this document, include but not limited to Royal Commission built facilities such as villas, apartment buildings, shopping centers, parks, offices, mosques, educational facilities, healthcare facilities, sports arenas, recreational complexes etc.

(7) Equipment

Equipment shall be designed based on the following:

- System and functional requirements
- Site and environmental conditions
- Manufacturer recommendations.

All outdoor equipment enclosures/material shall be weatherproof with a minimum IP54 degree of protection as per IEC 60529 or equivalent NEMA enclosure type.

All metal parts shall be corrosion and/or abrasion resistant.

8.2 GOVERNING CODES AND STANDARDS

The electrical design shall comply with the latest edition of National Electrical Code and the latest edition of the relevant codes and standards as listed in Section 2 of the Design Guidelines.

8.3 DESIGN APPROVALS

In addition to obtaining RC approval, all designs must be reviewed and approved by Marafiq. For both PC or EPC Contracts, the A/E or Contractor must obtain Marafiq approval of the design before finalizing the IFB / IFC drawings and designs. In addition, a Utility Commitment from Marafiq is required before finalizing the IFB / IFC designs. In this respect, the A/E or Contractor must comply with the RC and Marafiq Design Checklists, copies of which are included in the Contract Documents.

8.4 DESIGN CONDITIONS

All equipment and materials shall be selected and rated for use at the following site conditions:

Underground ambient cable temperature	40°C Maximum
Outdoor design temperature	50°C Maximum
Surface temperature (direct sun exposure)	80°C Maximum
Indoor temperature in Air Conditioned Spaces	30°C Maximum
Relative humidity	100% Maximum
Blowing sand size	0.5 to 50 Micrometer
Atmosphere	Salt Spray

8.5 ELECTRICAL SERVICE CONNECTION ARRANGEMENTS

- (1) All alternating electrical power in Madinat Yanbu Al-Sinaiyah shall be 60 Hertz. 400/230 Volt service shall be 3 phase, 4 wire. 380kV, 115kV, 34.5kV and 13.8kV Volt service shall be 3 phase, 3 wire plus one ground wire.

In accordance with the Electricity & Cogeneration Regulatory Authority (ECRA) requirements, the service voltage for consumers shall be determined by the load level at the point of delivery as indicated in Table 8-1 below:

Table 8-1. Service Voltage Based on Customer Load

Type of Facility Based On Electrical Load	Voltage
Facilities with electrical loads that does not exceed 4 MVA	Low Voltage (400/230 V)
Facilities with electrical loads higher than 4 MVA and does not exceed 16 MVA	Medium Voltage (13.8 kV & 34.5 kV) *
Facilities with electrical loads higher than 16 MVA and does not exceed 25 MVA	Medium Voltage (34.5 kV)
Facilities with electrical loads higher than 25 MVA and does not exceed 120 MVA	High Voltage (115 kV)
Facilities with electrical loads higher than 120 MVA	High Voltage (115 kV) or Extra High Voltage (380 kV)

* Based on voltage availability and loop capacity.

(2) Voltage drop shall be limited to 5% from the source, as shown on Table 8-2:

Table 8-2: Allowable Voltage Drop

System	Maximum Allowable Voltage Drop
Service/Branch Feeders	2%
Branch circuits	3%

(3) High Voltage (115 kV) and Extra High Voltage (380 kV) Customer Service Connection

- (a) Customers shall construct a substation at their site where power supply feeders shall be terminated.
- (b) Customers shall provide two full capacity underground cable circuit feeders.
- (c) Marafiq shall own and operate the feeders up to the identified point of connection at the customer substation.
- (d) Operation and maintenance of the substation at the customer site is the responsibility of the customer.
- (e) Customers shall coordinate with Marafiq for their substation operation, configuration, protection schemes, relay coordination, metering, load shedding, harmonics and backup generation.

(4) Medium Voltage (13.8 kV and 34.5 kV) Customer Service Connection

- (a) Customers shall construct a medium voltage substation at their site.
- (b) When the customer load is larger than 16 MVA the customer shall provide two full capacity underground cable circuit feeders from the connection point identified by Marafiq to the medium voltage metering switchgear cabinet located at the customer site.

- (c) Marafiq shall own and operate the feeders up to the medium voltage metering switchgear cabinet.
- (d) Operation and maintenance of the substation at the customer site is the responsibility of the customer.
- (e) Customer shall coordinate with Marafiq for their substation operation, configuration, protection schemes, relay coordination, meter location, load shedding, harmonics and backup generation.

8.6 SYSTEMS PARAMETERS

Unless otherwise specified in the associated RC Standard, the equipment/material shall be designed to operate suitably under the typical system parameters tabulated, as applicable:

(1) NORMAL SYSTEM VOLTAGES:

The nominal and highest system Voltages. Equipment shall be per Table 8-3 below. Equipment shall be rated for the highest voltage values. Fault calculations and analysis shall be based on the highest voltage.

Table 8-3. Normal System Voltage

Nominal System Voltage	Highest Operating Voltage (rms)
380 kV	400 kV
115 kV	120 kV
34.5 kV	38 kV
13.8 kV	15 kV
230/400 V	240/420 V

(2) FREQUENCY:

All equipment should be designed for system frequency of 60Hz.

(3) CREEPAGE DISTANCE:

(a) Outdoor Installations: All outdoor bushings/insulators shall have a minimum creepage/leakage distance 50mm/kV based on nominal voltage, line to line.

(b) Indoor Installations: The minimum creepage/leakage distance for indoor installations shall be as follows:

12 mm/kV For enclosed insulators, such as those installed inside metal-clad switchgear or cabinet.

25 mm/kV For exposed insulators, such as wall mounted bus supports, wall bushings etc.

(c) Insulation Levels: The Basic Insulation Level (BIL) and Power Frequency withstand voltage for medium voltage equipment are per IEC 60071 and are shown on Table 8-4 below:

Table 8-4. Basic Insulation Level (BIL)

Nominal System Voltage (rms)	Power Frequency Withstand Voltage (kV rms)	BIL (kV peak)
380 kV	520	1425
115 kV	230	550
34.5 kV	70	170
13.8 kV	38	95

(4) The Basic Insulation Level (BIL) and Power Frequency withstand voltage for low system voltages are as tabulated on Table 8-5 below:

Table 8-5. Basic Insulation Level (BIL) for Low Voltage System

System Nominal Voltage (V)	BIL (kV Peak)	Power Frequency Withstand Voltage (kV rms)	
		Equipment	Panel Wiring
400/230V	6	3	2
Notes: External Insulation refers to the insulation of equipment exposed to the open air which will be influenced by atmospheric conditions, such as pollution and humidity. External insulation is further categorized into two categories. i. Outdoor insulation which is totally susceptible to atmospheric radiation pollution, humidity, sandstorms and such other vagaries of nature. ii. Indoor insulation which is installed inside a building or outside a building but inside an enclosed box such as cable box, terminal box, etc. where it is not directly subjected to outdoor atmospheric extremities. iii. Minimum protection of equipment against the ingress of solid foreign objects and ingress of water (IP code) shall be as specified in the respective materials Specification. 1. Internal insulation refers to the insulation of equipment immersed in a dielectric medium such as insulating fluid, or totally encapsulated in a solid dielectric, and not exposed to atmospheric conditions.			

(5) **SHORT CIRCUIT FAULT LEVELS:**

The maximum allowable three phase symmetrical short circuit level at the consumer connection service terminals (for one second) shall be per Table 8.8 below, unless otherwise specified in the relevant specifications. Refer to the latest edition of IEEE C37.06 and C37.13 for guidance.

Table 8-6. The Maximum Allowable Symmetrical Short Circuit Capacity at Consumer Service Terminals

Nominal System Voltage	Location	Maximum Symmetrical short Circuit kA (MVA)
400/230 V	Community and Industrial Areas	40 KA (26 MVA)
13.8 kV	Community and Industrial Areas	21 kA (500 MVA)
34.5 kV	Industrial Areas	25 kA (1500 MVA)
115 kV	Industrial Areas	40 kA (8000 MVA)
380 kV	Industrial Areas	50 kA (33000 MVA)

(6) NEUTRAL ARRANGEMENT:

Unless otherwise specified in the associated RC Standards, the neutral shall be solidly grounded for low voltage systems and solidly grounded or low resistance for medium voltage systems

(7) POWER FACTOR

The minimum power factor for the electrical installation shall be 0.9 lagging. Power factor correction capacitors shall be provided to ensure that the power factor is within the range 0.9 lagging to unity.

(8) OUTDOOR EQUIPMENT

All outdoor equipment enclosures/materials shall be harsh weatherproof and all metal parts be corrosion and /or abrasion resistant, and the minimum degree of protection shall be IP54 as per IEC 60529 standard.

8.7 HV TRANSMISSION & SUBSTATIONS**8.7.1 HIGH AND MEDIUM VOLTAGE SYSTEM PARAMETERS**

The high and medium voltage systems shall be designed per the following criteria given in Table 8-7.

Table 8-7. High Voltage and Medium Voltage System Criteria

Nominal Voltage Level (kV)	Rated Equipment Ampacity (A)	RMS 3-second Withstand Rating (kA) I''_k	Momentary Peak Withstand Rating (kA) I_p	BIL (kV Peak)	Power Frequency Withstand Voltage (kV RMS)	Creepage Distance	
						Outdoor Installations	Indoor Installations
380	2500	63	163	1425	520	50 mm/kV	12mm/kV (enclosed) 25mm/kV (exposed)
115	3150	63	163	550	230		
34.5	2500	31.5	100	170	70		
13.8	3000	31.5	100	95	38		

For short circuit calculations see IEC 60909 and Appendix 1.

- (1) **Voltage Variation:** The voltage at any point on the system shall normally remain within the nominal values (+/-5%) unless abnormal conditions prevail. Under exceptional circumstances, the maximum over voltage limits (+10%) should not be exceeded for more than thirty (30) minutes.
- (2) **Harmonic Distortion:** Equipment connected to the system shall be capable of withstanding the levels of Harmonic distortion expected to be present on the system and shall not impose voltage and current harmonics which exceed the limits specified in IEEE Standard 519.
- (3) **Voltage Unbalance:** The phase-to-phase unbalance of the system, as measured with no load and with balanced three-phase loading, shall not exceed 1% at the Connection Point (or the Point of Common Coupling).
- (4) **Voltage Fluctuation:** The voltage fluctuation at any Connection Point with a fluctuating Demand shall not exceed 1% of the nominal voltage level for step changes that may occur repetitively. Any large voltage excursions other than step changes may be allowed up to a level of 3% provided that this does not pose a risk to the system.
- (5) **Transient Voltage Variations:** The system shall be designed and operated to include equipment and devices that will mitigate the effects of transient over voltages and transient voltage dips on the grid. The effect of electrical transients shall be taken into account when specifying the insulation of the electrical equipment. The individual components in the system shall be designed to ensure proper Low Voltage Ride Through (LVRT) Capabilities as per the respective Equipment Design Specifications.
- (6) **Frequency Variations:** The system shall have a nominal frequency of 60Hz and A-B-C counter-clockwise phase rotation. During normal grid operation, the system frequency limits shall be maintained between 59.9Hz and 60.1Hz. In exceptional circumstances, the system frequency could rise to 62.5Hz or fall to 57.0Hz. In order to maintain the system frequency within the specified limits, the design of Generating Stations must enable operation in accordance with the following:

Table 8-8: Design of Generating Stations

Below Nominal Frequency (Hz)	Above Nominal Frequency (Hz)	Operation Requirement
58.8 – 60.0	60.0 – 60.5	Continuous
57.5 – 58.7	60.6 – 61.5	For a period of 30 minutes
57.0 – 57.4	61.6 – 62.5	For a period of 30 seconds

Below 57.0Hz, Automatic Load Shedding Schemes shall be implemented at the Distribution Stations where applicable, as follows. Precise set points shall be defined by the end-user.

Step 1: 10% @ ___ Hz

Step 2: 15% @ ___ Hz

Step 3: 15% @ ___ Hz

Step 4: 10% @ ___ Hz

(7) Power Factor: The system shall maintain a minimum power factor of 0.90 (lagging).

8.7.2 SUBSTATION CONFIGURATIONS

Shown below are the acceptable HV substation bus configurations.

Table 88-9: High Voltage Substation Bus Configurations

Network Category	Configuration	# of Line Bays	# of Transformer Bays	# of Line Bays (Spare)	# of Transformer Bays (Spare)
380	Breaker-and-a-Half	4	2	1	1
115	Breaker-and-a-Half or Double-Bus-Single-Breaker	5	3	1	1
34.5	Single-bus-single-breaker	10	2	1	1
13.8	Single-bus-single-breaker	10	2	1	1

Acceptable power transformer connection configurations are given below.

Table 8-10: Power Transformer Connection Configurations

Primary kV	Secondary kV	Primary Connection	Secondary Connection	Tertiary	Vector Group
380	115	Grounded-Wye	Grounded-Wye	Delta	Ynyn0
115	34.5	Delta	Grounded-Wye	N/A	Dyn1
115	13.8	Delta	Grounded-Wye	N/A	Dyn1
34.5	13.8	Delta	Grounded-Wye	N/A	Dyn1
Generator	Grid	Delta	Grounded-Wye	N/A	Dyn1

8.7.3 SUBSTATION GROUNDING

Substation grounding calculations and design shall be per the IEEE Standard 80 (latest revision), by following the 12-step iterative process given in the standard. The design process block diagram is shown in Appendix 2.

(1) TRANSFORMER NEUTRAL GROUNDING CRITERIA

The neutral connection of a Wye-connected (or Star connected) substation power transformer shall be solidly grounded or grounded via resistor depending on the application.

(2) GENERATOR NEUTRAL GROUNDING CRITERIA

Depending on the specific station requirements, the neutral of a Generating Plant can be grounded using one of the following methods.

- (a) High impedance
- (b) Low impedance
- (c) Hybrid ground

(d) Solidly grounded

8.7.4 SUBSTATION LIGHTNING PROTECTION

The lightning protection system shall be designed per IEEE Standard 998 & NFPA 780

(latest revisions), by following one of the two methods shown in Appendix 3.

8.7.5 HIGH VOLTAGE PROTECTION

The Protection schemes shall isolate the faulty section and equipment in case of fault with dependability, selectivity, speed, and sensitivity. The maximum acceptable fault clearance times are given below:

Table 8-11: The Maximum Acceptable Fault Clearance Times

Network Category (kV)	Fault Clearance Times (millisecond)
115	120
380	80

To safeguard against the failure of the Primary protection systems provided to meet the above fault clearance time requirements, Backup protection systems shall be provided, which shall have fault clearance time slower than that specified for the Primary system.

In case of the failure to trip the circuit, breaker provided to interrupt fault current interchange with the HV system, Circuit Breaker Failure Protection shall be provided to trip all necessary electrically adjacent circuit breakers within 300 milliseconds. IEEE Standard C37.119 shall be followed for breaker failure protection, as applicable.

All protective relays shall be microprocessor-based (i.e. digital type), and shall be equipped with auto self-diagnostics and failure alarms¹.

(1) TRANSMISSION LINES²

Transmission lines shall be protected by employing Communication-assisted Pilot wire relaying, as the Primary method of protection.

The following communication-assisted tripping schemes can be used for pilot protection:

- (a) Directional Comparison Blocking (DCB)
- (b) Directional Comparison Unblocking (DCUB)
- (c) Permissive Overreaching Transfer Trip (POTT)
- (d) Permissive Under-reaching Transfer Trip (PUTT)
- (e) Line Current Differential

¹ Engineering Design Specification 16390 shall be followed where applicable

² IEEE Standard C37.113 (latest version) shall be followed for transmission line protection.

(f) Line Phase Comparison

The following communication channels can be used for pilot protection:

- (a) Fibre Optics
- (b) Power Line Carrier
- (c) Audio Tone
- (d) Radio

Non-piloted relays shall be utilized as backup protection. At a minimum the following protection functions shall be implemented in both Primary and Backup systems to protect the transmission lines:

- (a) Phase Distance (21P)
- (b) Ground Distance (21G)
- (c) Phase Directional Overcurrent (67P)
- (d) Neutral Directional Overcurrent (67N)
- (e) Circuit Breaker Failure (50BF)
- (f) Synchronism Check (25)
- (g) Automatic Reclosing (79)

IEEE Standard C37.104 (latest version) shall be followed for automatic reclosing of transmission lines, as applicable. Reclosing of circuit breakers on transmission lines shall be allowed under the following conditions. Single-shot (3-pole) reclosing after 1.0 second delay shall be attempted. If the circuit breaker fails to reclose, then it shall lockout.

(h) Synchronism Check

Permissive for a breaker to close if:

- Voltage Frequency and Phase Angle are within the allowable values (Window of opportunity) OR
- HOT BUS – DEAD LINE OR
- HOT LINE – DEAD BUS

(2) TRANSFORMERS

IEEE Standard C37.91 (latest version) shall be followed for the protection of the substation power transformers. At a minimum the following protection functions shall be implemented to protect the power transformers:

Table 8-12: Protection Functions

Conditions	Protection Philosophy
Internal	
Winding Phase-Phase, Ground faults	Differential (87T), overcurrent (51, 51N) Restricted ground fault protection (87RGF)
Winding inter-turn faults	Differential (87T), Buchholz relay

Core insulation failure, shorted lamination	Differential (87T), Buchholz relay, sudden pressure relay
Tank faults	Differential (87T), Buchholz relay, tank-ground protection
Overfluxing	Volts/Hz (24)
External	
Overloads	Thermal (49)
Overvoltage	Overvoltage (59)
Overfluxing	Volts/Hz (24)
External system short circuit	Time overcurrent (51,51G), Instantaneous overcurrent (50, 50G)

(3) BUS-BAR

IEEE Standard C37.234 (latest version) shall be followed for the protection of the substation bus-bar. One of the following bus-bar protection methodologies shall be applied:

- (a) High-impedance Differential
- (b) Low-impedance Differential

(4) FEEDER

Radial and looped distribution feeders at a minimum shall have the following protection functions.

- (a) Instantaneous/Inverse Time Phase Overcurrent (50/51)
- (b) Inverse time Ground Overcurrent (51G)
- (c) Instantaneous or Definite Time Ground Directional Overcurrent (67G)
- (d) Automatic Reclosing (79) - Single-shot (3-pole) reclosing after 1.0 second delay shall be attempted. If the circuit breaker fails to reclose, then it shall lockout. Reclosing attempt shall be supervised by HOT BUS – DEAD LINE synchrocheck relay condition.

(5) GRID SEPARATION (ISLANDING)

Appropriate grid separation techniques shall be applied to prevent cascading outages and to maintain power system stability during small or large disturbances. Wide Area Measurement Systems (WAMS) with Synchrophasors (IEEE C37.118) shall be considered to reinforce the above.

(6) INSTRUMENT TRANSFORMER REQUIREMENTS

The instrument (current¹ and voltage²) transformers design and selection for protective relaying applications shall be per the IEEE Standard C57.13 (latest version), where applicable. The current transformers for protective relaying applications shall be designed and selected such that they do not saturate based on the criteria stipulated in IEEE Standard C37.110.

¹ The current transformers secondary current shall be either 1 or 5 amps. The CTs shall be connected in Wye configuration. The neutral conductor shall be effectively grounded at a single point.

² The VTs shall be connected in Grounded-wye – Grounded-wye configuration. The neutral conductor shall be effectively grounded at a single point.

8.7.6 METERING

The Metering Systems design criteria shall be based on the Saudi Arabian Grid Code Chapter 7.

The Metering equipment at the HV system shall comprise of the following:

- (1) Meters
- (2) Lightning Protection
- (3) All other interconnecting electric/telecommunication cables, wires, and associated devices, etc.

Energy and Demand metering for both Active and Reactive Power shall be required at the HV Metering point. The Meters shall have the capability to separately record the flow of Active and Reactive power and import/export of energy at each connection point on the grid. The Meters shall have the capability to measure power flows in all the quadrants in which such flow is possible. The Meters shall be configured to record/store peak demand data in 15-minute integration periods.

The Meters shall be digital, 3-element type independent for each phase, rated for the required site, comply with IEC Standards 62052-11 and 62053-21, and shall have 0.2 accuracy class. The Meters shall measure and locally display at least the kW, kWh, KVAR, KVARh, and cumulative Demand.

For each HV connection, Main and Check Metering shall be provided. Main and Check Meters shall be from different manufacturers and shall operate from separate CT and VT windings. The Main Meter, Check Meter and additional burdens shall have separately fused VT supplies. The loss of voltage to the Meters should give an alarm.

Instrument Transformer Requirements

The Voltage Transformers shall comprise of three (3) units for a 3-phase set, each of which complies with IEC Standard 60044-2, and shall be of the 0.2 accuracy class. The voltage drop in each phase of the Voltage Transformer connections of the same accuracy and class shall not exceed 0.2V. The VTs shall be connected in Grounded-wye – Grounded-wye configuration. The neutral conductor shall be effectively grounded at a single point.

The Current Transformers shall comprise of three (3) units for a 3-phase set, each of which complies with the IEC Standard 60044-1, and shall be of 0.2 accuracy class. Two (2) CT cores with corresponding number of secondary coils per phase shall be provided between the connection box and the terminal of the metering element on the Meter so that the CT connections for checking Meter pulses can be completely separated from those provided for the Meters. The CT's rated secondary current shall be either 1 or 5 amperes. The neutral conductor shall be effectively grounded at a single point.

8.7.7 SCADA/ RTU

The SCADA system shall be capable of exchanging the system status and data from the local station to the remote station(s) and vice versa. All signals shall interface via the standard

digital interfaces. Interface cabinets shall be installed in each participating station. The information exchange shall support data acquisition from remote terminal units (RTUs). The participating stations should be able to monitor the system status and data via telemetry from the RTUs connected at each site. The user shall have the capability to deactivate and reactivate the scanning of a given RTU, as well as the capability of monitoring the availability of all RTUs from a central location. SCADA/RTU systems shall be secured against unauthorized access (password protected).

8.7.8 FAULT RECORDING AND DISTURBANCE MONITORING (DFR/DDR)

Sequence of Event (SOE) recording capability shall be provided by installing SOE recorders or as part of another device, such as SCADA, RTU, generator plant Digital (or Distributed) Control System (DCS) or part of Fault recording equipment. This capability shall:

- (1) Be provided at all substations and at locations where circuit breaker operation affects continuity of service to radial loads or the operation drops generation or the operation which creates a generation/load islanding.
- (2) Be provided at generating units or series of generating units utilizing a control scheme such that the loss of 1 unit results in a greater loss and at generating plants.
- (3) Monitor the following at each location:
 - (a) Transmission and generator circuit breaker positions
 - (b) Protective relay tripping for all protection groups that operate to trip circuit breakers identified above
 - (c) Teleprotection keying and receive
- (4) Fault recording equipment is required to be installed for the following:
 - (a) All transmission lines
 - (b) All generating stations that are connected to HV network via Generator Step Up (GSU) transformer
 - (c) Autotransformers or phase-shifters connected to busses
 - (d) Shunt capacitors, shunt reactors
 - (e) Individual generator line interconnections
 - (f) Dynamic VAR devices
 - (g) HVDC terminals
- (5) Fault recording, with sufficient electrical quantities for each monitored element to determine the following:
 - (a) Three phase-to-neutral voltages (common bus-side voltages may be used for lines)
 - (b) Three phase currents and neutral currents
 - (c) Polarizing currents and voltages, if used.
 - (d) Frequency
 - (e) Real and reactive power
- (6) Provided fault recording shall have the following capabilities:

- (a) Each fault recorder record duration shall be a minimum of one (1) second
- (b) Each fault recorder shall have a minimum recording rate of 16 samples per cycle
- (c) Each fault recorder shall be set to trigger for at least the following:
 - Monitored phase overcurrents set at 1.5pu or less of rated CT secondary current or protective relay tripping for all protection groups
 - Neutral (residual) overcurrent set at 0.2pu or less of rated CT secondary current
 - Monitored phase undervoltage set at 0.85pu or greater
- (7) Provide a minimum of 1 Dynamic Disturbance Recording (DDR) for peak load, and record dynamic disturbance information with consideration of the following facilities/locations:
 - (a) Major load centers
 - (b) Major generation clusters
 - (c) Major voltage sensitive areas
 - (d) Major transmission interfaces/junctions
- (8) DDRs shall be installed with the following capabilities:
 - (a) Minimum recording time of sixty (6) seconds per trigger event
 - (b) Minimum data sample rate of 960 samples per second, and a minimum data storage rate for RMS quantities of six (6) data points per second.
- (9) DDR shall be set to trigger for at least one of the following:
 - (a) Rate of change of frequency
 - (b) Rate of change of power
 - (c) Delta frequency (recommend 20 mHz change)
 - (d) Oscillation of frequency

8.7.9 GLOBAL TIME SYSTEM

This system is provided for all computer or microprocessor-based operational devices used to monitor, control, or analyze the HV bulk power system where accurate timing has been deemed necessary is required by the application. The device applications include, but are not limited to, Power Plant Automation Systems, Substation Automation Systems, Programmable Logic Controllers (PLC), Intelligent Electronic Devices (IED), sequence of event recorders, digital fault recorders, intelligent protective relay devices, Energy Management Systems (EMS), Supervisory Control and Data Acquisition (SCADA) Systems, Plant Control Systems, routers, firewalls, Intrusion Detection Systems (IDS), remote access systems, physical security access control systems, telephone and voice recording systems, video surveillance systems, and log collection and analysis systems.

The most accurate protocols shall be utilized to implement time stamping capabilities suitable for the application. IEEE C37.118 shall be followed where applicable.

8.7.10 OVERHEAD TRANSMISSION LINE

Overhead Transmission Lines shall be designed based on the following parameters.

(1) TOWER SPECIFICATIONS

Refer to RC Specification Section 02826 and standard Structural Engineering sections.

(2) CONDUCTOR SPECIFICATIONS

IEC Standard 61089 shall be followed where applicable. For 34.5kV transmission and above both Aluminum Conductor Steel Reinforced (ACSR) and All Aluminum Alloy Conductor (AAAC) shall be considered.

(3) MINIMUM CLEARANCES

Refer to the National Electrical Code Table 490.24.

(4) INSULATORS

Suspension string insulators shall be installed in suspension towers where the line of conductors are straight. Strain string insulators shall be installed in deviation towers where the conductors change direction. Two to four insulator strings shall be used at each conductor connection point in a "V" pattern to minimize later sway.

(5) LIGHTNING PROTECTION

Shield wires (either steel or aluminum clad steel) with a diameter of approximately ½ inch shall be installed.

(6) CONDUCTOR MOTION SUPPRESSION

Dampers shall be installed to minimize the oscillatory motions of the conductors.

(7) RIGHT-OF-WAY (ROW)

Corridors for 380kV Overhead Lines double circuit – 70m

Corridors for 115kV Overhead lines double circuit – 30m

8.7.11 UNDERGROUND TRANSMISSION LINE

The cross-linked polyethylene (XLPE) cable shall be considered for underground electric transmission lines.

Higher voltages (greater than 115kV) underground transmission lines require transition stations wherever the underground cable connects to overhead transmission. For very lengthy sections of underground transmission, intermediate transition stations might be necessary. The size is governed by whether reactors or other additional components are required.

Cables shall be installed in flat formation per the approved design and shop drawings. Guidelines specified in AEIC CG4 & CS7 and IEEE Std 575 shall be followed.

Power cables adequacy calculation shall be carried out in line with IEEE Std 835 and IEC 60287.

(1) HV POWER CABLE SPECIFICATIONS

Refer to RC Specification Section 16305 and Section 02814.

(2) HV CABLE CONDUCTOR SPECIFICATIONS

Conductor shall be annealed stranded copper in accordance with ASTM B3 and ASTM B33 for coated and uncoated respectively. Conductor shall be compatible with the conductor screen.

Conductor shall be compact-round construction in accordance with IEC Standard 60228 class 2 and ASTM B496.

(3) HV POWER CABLE CORRIDORS

For direct buried power cable installation following are corridors requirement:

Corridors for 115kV underground cable – 2.5m each circuit one core per phase

Corridors for 115kV underground cable – 3.8m each circuit two cores per phase

8.8 MEDIUM VOLTAGE DISTRIBUTION SYSTEM

The medium voltage levels used in MYAS network are 34.5kV and 13.8kV. The medium voltage systems are designed to optimize equipment locations, installation cost and maximize load utilization.

8.8.1 MEDIUM VOLTAGE 34.5KV SYSTEM

Used in the industrial area to feed multiple industrial customers through a loop or a single industrial customer through a dedicated feeder as well as feeding satellite substations in both the community and industrial areas. The typical circuit breaker at the substation can accommodate up to three TR-XLPE insulated, 300mm² single copper conductors per phase.

(1) DISTRIBUTION LOOPS FOR MULTIPLE INDUSTRIAL CUSTOMERS:

Used in the industrial area only, a loop consists of two parallel 3 phase feeders from separate buses at the substation feeding multiple pad-mounted switchgears (PMSs). Each PMS can provide one, two or three radial feeders to industrial customers. One PMS in middle of the loop shall have a normally open (N.O.) switch to break the loop.

(2) DEDICATED FEEDERS TO SINGLE INDUSTRIAL CUSTOMERS:

Used in the industrial area only, two redundant 3 phase feeders from separate buses at the substation are terminated at the medium voltage metering switchgear near the customer premises.

(3) SATELLITE SUBSTATION MAIN FEEDER:

Used in both industrial and Community Area, a minimum of two redundant 3 phase feeders from separate buses at the main substation are terminated at two separate 34.5kV buses in the satellite substation.

8.8.2 MEDIUM VOLTAGE 13.8 KV SYSTEM

Used in both community and industrial areas to feed multiple customers through a loop or a single customer through a dedicated feeder. The typical circuit breaker at the substation can accommodate up to three 300mm² single conductors per phase.

(1) MAIN LOOPS FOR MULTIPLE INDUSTRIAL OR COMMUNITY CUSTOMERS:

Used in the industrial and community areas, a loop consists of two parallel 3 phase feeders from separate buses at the substation feeding multiple pad-mounted switchgears (PMSs). Each PMS can provide one, two or three feeders directly to customers or to lateral loops. One PMS in middle of the main loop shall have a normally open (N.O.) switch to break the loop.

(2) DEDICATED FEEDERS TO SINGLE RESIDENTIAL AND/OR COMMERCIAL CUSTOMER:

Used in the community area only, two redundant 3 phase feeders from separate buses at the substation are terminated at the medium voltage metering switchgear near the customer premises.

8.8.3 MEDIUM VOLTAGE DISTRIBUTION EQUIPMENT AND MATERIAL

(1) PAD-MOUNTED SWITCHGEAR (PMS)

Pad-mounted switchgear are outdoor medium voltage switches mounted on concrete pads. Each switchgear shall have two 600A load break switches and up to three vacuum circuit breakers. Load break switches shall accommodate up to three TR-XLPE, 300mm² single copper conductors per phase. One load break switch is used for the connection of the incoming feeder (from the substation or another PMS). The second load break switch is used to connect to another PMS depending on the configuration of the distribution system.

Vacuum circuit breakers are used to connect directly to customers or to form lateral loops through package substations and/or pad-mounted transformers with one normally open (N.O.) switch in the middle of the lateral loop.

(2) MEDIUM VOLTAGE PAD-MOUNTED METERING SWITCHGEAR (PMMS)

Customers provided with medium voltage supply shall require the installation of Medium Voltage Pad-Mounted Metering Switchgear outside the boundary line of their facility. These switches can be directly connected to the feeders from the substation, PMS, or from a lateral loop

(3) PACKAGE SUBSTATIONS (PSS)

The 13.8 kV - 400/230 V Package Substations consist of a MV compartment (RMU), transformer compartment, and low voltage compartment (distribution panel/board). The transformer shall be connected delta primary with 3 phase 4 wire wye secondary. All live parts shall be inaccessible to unauthorized persons.

Package substations are outdoor equipment mounted on a concrete pad.

Standard transformer capacities used in the Marafiq network are 300/500/750/1000/1500 KVA.

Package substations are designed to be connected to an MV loop with primary selective configuration on the 13.8 kV side and to a single or multiple 400/230 V loads on the low voltage distribution panel/board side.

Package substations may have the provision for connecting a revenue meter between the transformer and the low voltage panel.

(4) PAD-MOUNTED TRANSFORMER

A pad-mounted transformer is an oil filled distribution transformer in a locked steel cabinet mounted on a concrete pad based on the ANSI/IEEE and NEMA standards. It is provisioned for loop feed service.

Standard transformer capacities used in the Marafiq network are 300/500/750/1000/1500 KVA.

(5) CABLES

Cables used in the medium voltage distribution system are single conductor, TR-XLPE insulated, LDPE sheathed, unarmoured copper cables. The standard cable size used for 35kV systems is 300 mm² with insulation thickness of 8.7mm and the standard sizes used for 15kV systems are 120mm² and 300mm² with insulation thickness of 5.5mm. MV cables shall be rated for 90°C maximum conductor temperature under normal operating conditions.

All primary cables in community and industrial areas shall be installed in concrete encased duct banks. The duct banks shall be 9-way (3x3) duct banks and consist of 160 mm diameter PVC ducts.

The duct banks shall conform to the applicable Royal Commission Standard Drawing details. Duct banks shall be installed at a minimum of 1000mm below finish grade. Duct banks shall have a vertical and horizontal separation from other utilities of at least 200 mm. A bare copper ground wire shall be included in each duct bank and sized per RC Electrical Standard Drawings.

Except in simple installation configurations, ampacity ratings of cables installed in duct banks must be determined by computer calculation using simulation software, such as ETAP. Calculations must model installation conditions using 40°C earth temperature and 200 K.cm/W earth thermal resistivity. Lower earth thermal resistivity values can be used for areas near the sea coast if supported by soil tests.

As a general guideline, 300 mm² main loop cables installed in duct banks may have a capacity not exceeding 5 MVA, at 13.8 kV. However, the capacity may also be less than 5 MVA, depending on installation conditions, therefore, calculations must be performed for specific installation conditions to determine cable ampacity.

8.9 LOW VOLTAGE DISTRIBUTION SYSTEM

The low voltage system is 400/230V¹, 60Hz, 3 phase, 4-wire plus ground. There is no LV distribution system in the industrial area except for the street lighting network. Package substations feeding industrial customers with low voltage power shall have a radial supply from the main loop PMSs vacuum circuit breakers.

(1) COMMUNITY AREA LOW VOLTAGE DISTRIBUTION NETWORK

Community area power distribution lateral loops are fed from the main 13.8kV loop through two Pad-mounted switchgears and supply power to package substations, utilizing a primary selective system as shown in RC Standard drawing RC-E-13.

Each package substation shall be used to supply multiple low voltage customers or street/area lighting panels.

Low voltage Cables shall run in underground conduits from package substation to revenue metering cabinet/closet located near customer premises or street/area lighting panel.

Package substations shall be located at or near the center of the load they serve.

Transformer load shall not exceed 80% of the transformer rating to allow for future load growth.

(2) SECONDARY DISTRIBUTION

The 400/230V system cables shall feed the facility directly or feed individual buildings from a circuit breaker at the low voltage main distribution panel/board. All cables shall be sized to meet the requirements of the demand load.

Low voltage system duct banks shall conform to the Royal Commission Standard Drawing details.

(3) STREET AND AREA LIGHTING DISTRIBUTION

Street and area lighting shall be supplied from 13.8kV - 400/230V, 300 kVA distribution transformers.

The 400/230V street lighting supply shall consist of a three phase, 4 wire, plus ground 600/1000V rated, PVC sheathed direct buried cables from the street lighting distribution transformer to the street lighting pillars and lighting poles. The street lighting cables shall be TR-XLPE, multicore, 10mm² copper conductor minimum. Street and area lighting shall conform to RC Standard drawings.

Street and area lighting panels are outdoor low voltage distribution panels with a control circuits used for switching lights ON and OFF utilizing a photo electric cell and a programmable timer. Street and area lighting panels shall have a non-switchable buss for small continuous loads such as irrigation, traffic lights, etc.

¹ As per council of ministers resolution No. 324 all the existing voltage 380/220 V and 220/127 V has been changed to 400/230 V

8.10 STREET AND AREA LIGHTING**(1) GENERAL**

- (a) Luminaires shall be LED, weatherproof, heavy-duty, outdoor type.
- (b) Street and area lighting shall be designed in accordance with the latest relevant IES design requirements.
- (c) Street and area lights shall be mounted on poles of different heights based on the application and the illuminated area.
- (d) Decorative Lighting should be used sparingly, and mainly to serve aesthetic functions, rather than as prime illumination source. Typical applications are landscaped areas, shopping arcades etc.
- (e) Metallic poles, posts, luminaire housings and such non-current carrying metallic parts shall be grounded. Individual ground rod for each pole shall be provided, except in areas where concentration of poles, or bollards is heavy, in which case grounding may be accomplished with grounding conductor(s) run from the service panel, or the nearest ground rod.
- (f) Cables located under vehicular traffic such as road crossings, access roads and parking areas, shall be installed in PVC conduits encased in structural concrete.

(2) STREET LIGHTING

- (a) Street lighting is used to refer to street and roadway lighting systems.
- (b) Street lighting shall be designed in accordance with IES RP-8 latest edition and Royal Commission standard drawings.
- (c) Based on the project specifics, the location and spacing of street lighting poles may vary. The designer shall use the minimum number of poles to achieve the specified end of life illumination.
- (d) Street lighting power shall be supplied from street lighting panels (SLP) which have two buses one for street lighting (night-time loads) and one for non-switched loads, arranged as shown in RC Standard drawings.
- (e) The street lighting bus at the panel shall provide power for lighting pole luminaires, overhead signs, and other such lighting loads required after sunset.
- (f) Traffic signals, irrigation system, variable message signs (VMS) and other continuous loads shall be fed from the non-switched bus.
- (g) Street lighting bus shall be switched by photoelectric cell and timer controlled contactor(s) with manual over-ride capabilities.
- (h) Street lighting shall be provided with dimmable and addressable capabilities in each fixture to allow remote operation from a control and monitoring system with override ON/OFF switching and dimming capabilities.
- (i) Feeder cables from the transformer to street lighting panel shall be installed in concrete encased PVC conduits.
- (j) Street lighting branch circuits to poles shall be direct buried.
- (k) Street lighting cables shall be four core, 600/1000V, copper, TR-XLPE insulated, PVC sheathed, unarmoured cables rated for 90°C maximum conductor temperature under normal operating conditions.

- (l) All 4 wires of the incoming cable shall run pole to pole and be terminated at each pole fuse box or circuit breaker terminals. Cable splices are not allowed.
- (m) Voltage drop is an important consideration in long runs associated with Street and Roadway lighting. Cables shall be sized to limit the total (feeder and branch circuit) voltage drop, at the farthest fixture to 5% or below.

Table 8-13: Street Lighting Illumination

Type of Road	Highways	Primary	Secondary	Tertiary
Illumination Level (lux)	17	17	12	9
Max. Lamp Wattage	550 Watt	220 Watt	110 Watt	55 Watt
Uniformity (E_{avg} / E_{min})	3	3	4	6
Pole Height	30 m	12 m	10 m	5or8 m
Mounting Location	Median	Median / Two sides	Two sides	One Side / Two sides

(3) AREA LIGHTING

- (a) Area lighting design includes vehicle parking areas, public areas, parks, and walkways.
- (b) Area lighting should be designed in accordance with the latest IES Handbook and the recommended practice for outdoor lighting and Royal Commission standard drawings. Table 8-14 shows typical illumination levels for Public Park areas. LED lighting shall be utilized extensively and typically 4 or 5 m pole heights shall be used, subject to achieving the required illumination and uniformity values.
- (c) Area lighting voltages should be 230V.
- (d) Area lighting power shall be supplied from Area lighting panels (ALP) which have similar configuration to street lighting panels.
- (e) Direct buried unarmoured cable shall be used for lighting circuits.
- (f) Area lighting circuits shall be switched automatically by photoelectric cell controlled contactor(s) with override capability.

Table 8-14. Public Park Lighting Illumination

Area	Av Illumination Level (lux)	Uniformity (E_{avg} / E_{min})
Main pathways	10	4
Minor pathways	5	4
Public spaces	15	3
Play Grounds	30	3
Steps & hazards	50	2
Entry / Exit areas	50	3

Footbridges	40	3
Delivery areas	30	2.5
Outside Audience areas	20	2.5
Performance / Stage Area	300	2

(4) SPORTS LIGHTING

- (a) Sports lighting should be designed in accordance with the latest edition of IES.
- (b) Lighting circuits run underground shall be direct buried unarmoured cable. Cable shall be run around, and not under sports fields and tracks to prevent disruption of playing surfaces.
- (c) Voltages for sports lighting can be 230 or 400V.
- (d) Sports field lighting shall be switched on and off at pre-set times, by photocell and timer controlled contactor(s), provided with manual override switch.

(5) SECURITY LIGHTING

- (a) Security lighting shall be provided in selected facilities, to be decided by the Royal Commission, and shall be designed according to the Directives of the High Commission for Industrial Security (HCIS), Kingdom of Saudi Arabia.
- (b) Switching shall be automatic by photocell controlled contactor(s) with manual override.
- (c) Security lighting shall be designed to be inaccessible to intruders and protected from vandalism.

(6) DECORATIVE LIGHTING

- (a) Decorative lighting should be used sparingly, and mainly to serve aesthetic functions, rather than as a prime illumination source.
- (b) Typical applications for decorative lighting are landscaped areas, shopping arcades and the waterfront.
- (c) Decorative lighting includes up lights, bollard lights, pillar/column mounted lights, and laser lights.

8.11 FACILITIES

8.11.1 GENERAL

Power distribution within facilities shall be designed for low voltage system, rated at 400/230V. The interface point with utility is the meter located at or near the boundary of the facility. Typically, facilities shall be metered at low voltage, however, if the facility has a load greater than 4 MVA then it shall be metered at higher voltages.

If several facilities are located within a single wall such as closed compounds or complexes, Marafiq shall treat them as one facility/customer for the purpose of determining service voltage and metering.

Facilities include the design of electrical systems for vertical constructions such as residential villas, apartment buildings, public facilities, commercial, institutional and office buildings.

Typically, light industrial buildings are designed based on criteria in this section.

Heavy industrial buildings and specialty buildings such as electrical substations and power plants, water treatment plants, etc. are not considered in these criteria.

8.11.2 SITE POWER

- (1) Site power is the infrastructure work outside the customer facility while within the customer boundary line.
- (2) Customers with loads higher than 4MVA, shall provide switchgears and transformers necessary to step down the service voltage to 400/230V. This equipment shall be located inside the customer boundary line and shall be owned and operated by the customer.
- (3) Customers can utilize any voltage level for industrial applications as long as the used voltage is not higher than the service voltage provided by Marafiq.
- (4) Primary power connection to facilities within customer boundary lines shall be installed in duct-banks.
- (5) Main feeders to the main distribution board shall be 600/1000V rated cables with single conductor, either cross-linked polyethylene (XLPE) or ethylene propylene rubber (EPR) insulated and PVC jacketed. Cables shall be rated for 90°C maximum conductor temperature under normal operating conditions, in accordance with IEC 60502 and shall be suitable for operation in wet or dry locations with alternately wet and dry conditions.

8.11.3 FACILITY POWER DISTRIBUTION

- (1) Facility power distribution covers the power distribution inside the facility or building from the electrical room or main distribution panel. This section is applicable only to the loads in the community area and light industrial loads.
- (2) All residential and commercial facilities shall be designed for 400/230V, 3 phase, 4-wire system.
- (3) The main 400/230V feeder to the facility shall be terminated at the main distribution board (MDB).
- (4) Based on the facility size and configuration, main distribution board may be used to feed the facility loads directly, or through sub distribution boards/panels, or a combination of both.
- (5) Each distribution board/panel shall have a minimum of 20% spare capacity.
- (6) Most facility loads such as lighting, air conditioning split units, general purpose receptacles, etc. shall be connected to 230V, single phase power supplies. Three phase loads or large loads that cannot be powered at 230V shall be powered at 400V.
- (7) For energy saving applications, relays, contactors and trip free circuit breaker shall be utilized.
- (8) For office and institutional applications, power supply to non-essential loads shall be designed to be switched off automatically after working hours.
- (9) Dedicated equipment receptacles and fixed in place loads shall not be wired to an automatic switched off circuit breaker.

- (10) For large office and institutional buildings, the general purpose receptacles can be wired in dedicated power panels and the timed switched off circuit breakers can be replaced by a main trip free circuit breaker.
- (11) Wiring shall be installed in PVC conduits concealed in walls, ceilings, or floors. PVC wires and conduits shall not be used where fire hazards may be present.
- (12) Indoor exposed conduits shall be metallic with XLPE insulated wires.
- (13) Lighting switches, sockets and other facility fixed electrical installations shall comply with the requirements of SASO/IEC 60669-1 latest revision.
- (14) All general-purpose receptacles shall be single phase, rated at 230V, 13A, in compliance with SASO 2203 / BS 1363 standard.
- (15) In wet or damp locations/areas, such as kitchens and bathrooms, receptacles shall have RCD protection with a trip current of 30mA or less.
- (16) Individual fixed loads such as air conditioning, ovens, ranges, water heaters, dish washers, dryers and washing machines shall be powered from dedicated circuits.

8.11.4 FACILITY LIGHTING

(1) GENERAL

- (a) This section covers the design of facility exterior and interior lighting systems within the facility premises.
- (b) Facility lighting systems shall be designed in accordance with the recommendations of the IES handbook latest edition.
- (c) Facility lighting systems shall be designed for optimal energy efficiency and reduction of energy waste.
- (d) The appropriate type and quantity of lamps and luminaires shall be selected based on the following:
 - Luminaire efficiency and efficacy.
 - Lamp lumen output.
 - The reflectance of the surrounding areas.
 - The effects of light losses from lamp lumen depreciation and dirt accumulation.
 - Room size and shape.
 - Availability of natural light.
- (a) The quality of light shall be improved by taking following measures:
 - The glare shall be reduced with the help of louver or lens to block direct viewing of a light source. Low glare environment can be created by using indirect lighting, or up lighting for uniform illumination of the ceiling.
 - The light shall be spread evenly over the task to maintain illumination uniformity.
 - Using a light source with Color Rendering Index (CRI) of 75 or higher.

(2) LIGHT SOURCE

Lighting systems shall be designed for energy savings while maintaining the specified lux levels. To achieve that, the following types of lamps shall be used:

- (a) LED.
- (b) Fluorescent
- (c) Compact Fluorescent lamps (CFL)

Each lamp type has particular advantages; selecting the appropriate source depends on installation requirements, life-cycle cost, color qualities, dimming capability, and the effect required. Incandescent lamps shall not be used for facility lighting.

(3) FACILITY EXTERIOR LIGHTING

Facility exterior lighting covers the design of the building exterior lighting systems exposed to weather conditions. The design of exterior area lighting and boundary wall security lighting is not considered to be a part of facility exterior lighting.

Exterior lighting requirements vary from project to project and depends upon the building type as well as other outdoor type lighting in proximity, such as area, perimeter and street lighting. IES requirement shall be followed for facility exterior lighting.

Exterior lighting shall be able to withstand the harsh environment conditions and provide easy access for maintenance. However, depending upon their location, these lights may need to be protected against vandalism.

Depending upon the application, motion detectors, occupancy sensors, timers, and photo cells, may be considered in the design to reduce energy waste.

(4) FACILITY INTERIOR LIGHTING

Facility interior lighting covers the design of fixed lighting fixtures mounted either on walls or ceiling. Task and furniture lights such as desk lights, standing lights and table lights shall not be considered in the design of interior lighting.

Interior lighting shall be designed with consideration to energy saving practices such as natural light harvesting and automatic ON/OFF switching utilizing motion detectors, occupancy sensors and timers.

Lighting systems shall be designed for illumination levels in various areas as recommended by IES.

Table 8-15 shows typical task illuminations for representative interior areas.

Table 8-15. Area Illumination

Location	Horizontal Illumination Level In Lux	Vertical Illumination Level In Lux	Elevation Of Working Plane (mm)
CONTROL AND DISPATCH ROOM			
General	550		800
Vertical Panels		550	1700
Desks	550		800
DINING FACILITIES			

Dining Areas (Leisure Service)	330		800
Dining Areas (Quick Service)	550		800
Food Preparation	770		900
Entrance Hall	330		Floor
ELECTRICAL ROOM			
Substation (General)	220		Floor
Vertical Face of Switchgear		330	1700
Battery Room	220		Floor
TELEPHONE			
Telephone Equipment Room	220		Floor
OFFICES			
Regular	770		800
Conference Room	500		800
Drafting	1650	1650	Task
Corridors	220		Floor
Stairways	330		Floor
Elevator	200		Floor
Washrooms	330		900
WARE HOUSE			
Indoor Bulk Storage	110		Floor
Indoor Barrel Storage	110		Floor
Counter Tops	300		1200
Parts Storage	330		900
RELIGIOUS PLACES			
Mosque	300		Floor
SPORTS AND RECREATION			
Volleyball	100		Floor
Basketball	300		Floor
WORK SHOPS			
General	330		Floor
Rough Machinery and Bench Work	550		900
Medium Machinery and Lathe Work	1100		900
Corridors	220		Floor
Washrooms	330		900
SCHOOLS			
Chalkboards		1650	Task
Classrooms	770		800
Manual Training	1100		900
Library	770		800
Corridors	220		Floor
HOSPITALS			

Hospital Examination Room	500		800
Hospital Waiting room	300		Floor

The most effective method for calculating illumination level for large indoor areas is the Lumen Method (Zone Cavity Method); this method is frequently used as it gives uniform distribution of light over large areas using any type of luminaires. This method shall be used for most indoor areas.

No building flood lighting shall be provided, unless specifically required by Royal Commission.

(5) RESIDENTIAL, COMMERCIAL AND INSTITUTIONAL LIGHTING

- (a) Generally, combination of LED, T5 fluorescent and compact fluorescent luminaires shall be used for residential lighting.
- (b) For decorative purposes, combination of recessed, pendant, track, portable and wall mounted luminaires is used for adequate illumination and aesthetic harmony.

(6) EMERGENCY LIGHTING

Emergency Lighting shall be provided for illumination of means of egress in accordance with life safety code (NFPA 101), to function in case of failure of power supply to the normal lighting system. In addition to egress lighting, standby lighting shall be provided in special facilities, such as hospitals, important offices, communication centers, etc. to enable normal activities to continue in case of interruption of normal supply. Emergency lighting fixtures shall, in general, be Unit-Device type, including integral rechargeable battery and charger.

(7) EXIT SIGN

Exit sign illumination shall be continuous and in accordance with life Safety Code NFPA 101. Exit signs shall be internally illuminated type with integral rechargeable battery.

8.12 EQUIPMENT DERATING

(1) GENERAL:

- (a) For the proper functioning of electrical equipment in high ambient temperature prevailing in Saudi Arabia, it is required to derate the current carrying equipment to avoid excessive heating. The ambient temperature to be used in Saudi Arabia for derating purposes is shown in Table 8-16.

Table 8-16. Recommended Ambient Temperature for Derating

Description	Construction Method	Ambient Temperature For Derating Purposes
Cable	Direct Buried – min. 460 mm below grade	40°C
	Duct bank – min. 460 mm below grade	40°C
	In air	50°C
	Directly exposed to sun	80°C
	Indoor in air conditioned spaces	30°C
	In conduit in air	50°C
Equipment	Well ventilated building – No air conditioning.	45°C
	Air conditioned for equipment, Substation, etc	30°C
	Air conditioned for comfort office etc.	25°C
	Installed outdoors	50°C

(2) HARMONIC DISTORTION

- (a) Equipment shall be derated as necessary to take cognizance of the effects of harmonics caused by non-linear loads.
- (b) The electrical installations shall be designed to ensure that the harmonic distortion does not exceed the parameters stipulated in BS EN 50160, IEC 61000 AND ENA Engineering Recommendation G5/4-1. If necessary, based on the harmonic analysis study results, filters shall be provided to mitigate the effect of harmonics to ensure that such disturbances are kept within the stipulated limits.
- (c) ANSI C57.110 provides guidelines for transformer derating due to harmonic loading.

(3) DERATING OF MOTORS:

- (a) Motors shall have Class F insulation in a Class B insulation frame (i.e., a Class F insulation motor with a Class B insulation limiting temperature of 130°C).

8.13 GROUNDING**(1) GENERAL**

All grounding shall comply with Article 250 of NEC, IEEE 80, IEEE 142 and Saudi Electric Company standards.

(2) SYSTEM GROUNDING

All low voltage power distribution systems shall have supply transformer secondary neutrals directly grounded. Medium voltage distribution systems, e.g. 13800 and 34500 V shall be resistance grounded to minimize ground fault levels.

(3) EQUIPMENT GROUNDING

The metal frames of all electrical equipment, machinery, lighting fixtures, enclosures, raceways, cable trays, outlet boxes, appliances and non-electric equipment in close proximity to electrical equipment shall be grounded for safety. Two grounding connections shall be provided to the frames of large electrical equipment such as unit substations, power transformers, motor control centers and switchgear.

(4) LIGHTNING AND STATIC ELECTRICITY PROTECTION GROUNDING

Lightning protection shall be provided for buildings and structures, including but not limited to:

- Schools.
- Hospitals.
- Buildings and Structures Over 30 m.
- Building and structures where expected lightning strike frequency to the structure exceeds tolerable lightning strike frequency as specified in Appendix H of NFPA 780.

8.14 POWER SYSTEM STUDIES

Required Power System Studies for HV Electrical Systems

(1) SHORT-CIRCUIT STUDIES**(a) Scope of Study**

Determine the short-circuit current available at each component of the electrical system and the ability of the component to withstand and/or interrupt the current. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

(b) Procedure

The short-circuit study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399 and the step-by-step procedures outlined in the short-circuit calculation chapters of IEEE 141 and ANSI/IEEE 242.

(c) Study Report

Results of the short-circuit study shall be summarized in a final report containing the following items:

- Basis, description, purpose, and scope of the study.
- Tabulations of the data used to model the system components and a corresponding one-line diagram.
- Descriptions of the scenarios evaluated and identification of the scenario used to

- evaluate equipment short-circuit ratings.
- Tabulations of equipment short-circuit ratings versus available fault duties. The tabulation shall identify percentage of rated short circuit and clearly note equipment with insufficient ratings.
- Conclusions and recommendations.

(2) COORDINATION STUDIES

(a) Scope of Study

Determine protective device characteristics, settings, or sizes that provide a balance between equipment protection and selective device operation that is optimum for the electrical system. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

(b) Procedure

The coordination study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399 and ANSI/IEEE 242. Protective device selection and settings shall comply with requirements of NFPA 70 National Electrical Code.

(c) Study Report

Results of the coordination study shall be summarized in a final report containing the following items:

- Basis, description, purpose, and scope of the study and a corresponding one-line diagram.
- Time-current curves demonstrating the coordination of time-overcurrent protective devices.
- Tabulations of protective devices identifying circuit location, manufacturer, type, range of adjustment, IEEE device number, current transformer ratios, recommended settings or device size, and referenced time-current curve.
- Conclusions and recommendations.

(3) ARC FLASH HAZARD ANALYSIS

(1) Scope of Study

Determine arc-flash incident energy levels and flash protection boundary distances based on the results of the Short-Circuit and Coordination Studies. Perform the analysis under worst-case arc-flash conditions for all modes of operation. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions to the subject system.

(2) Procedure

- (a) Identify all locations and equipment to be included in the arc-flash hazard analysis.
- (b) Prepare a one-line diagram of the power system.
- (c) Perform a short-circuit study in accordance with above section.
- (d) Perform a coordination study in accordance with above section.
- (e) Identify the possible system operating modes including tie-breaker positions, and
- (f) parallel generation.
- (g) Calculate the arcing fault current flowing through each branch for each fault location using empirical formula in accordance with NFPA, IEEE, or other standards.
- (h) Determine the time required to clear the arcing fault current using the protective device settings and associated trip curves.
- (i) Select the working distances based on system voltage and equipment class.
- (j) Calculate the incident energy at each fault location at the prescribed working distance.
- (k) Determine the hazard/risk category (HRC) for the estimated incident energy level.
- (l) Calculate the flash protection boundary at each fault location.
- (m) Document the assessment in reports and one-line diagrams. Place appropriate labels on the equipment.

(4) STUDY REPORT

Results of the arc-flash study shall be summarized in a final report containing the following items:

- (a) Basis, method of hazard assessment, description, purpose, scope, and date of the study.
- (b) Tabulations of the data used to model the system components and a corresponding one-line diagram.
- (c) Descriptions of the scenarios evaluated and identification of the scenario used to evaluate equipment ratings.
- (d) Tabulations of equipment incident energies, hazard risk categories, and flash protection boundaries. The tabulation shall identify and clearly note equipment that exceeds allowable incident energy ratings.
- (e) Required arc-flash labeling and placement of labels.
- (f) Conclusions and recommendations.

(5) LOAD-FLOW STUDIES

(a) Scope of Study

Determine active and reactive power, voltage, current, and power factor throughout the electrical system. Provide an analysis of all possible operating scenarios.

(b) Procedure

The load flow study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399.

(c) Study Report

Results of the load-flow study shall be summarized in a final report containing the following items:

- Basis, description, purpose, and scope of the study.
- Tabulations of the data used to model the system components and a corresponding one-line diagram.
- Descriptions of the scenarios evaluated and the basis for each.
- Tabulations of power and current flow versus equipment ratings. The tabulation shall identify percentage of rated load and the scenario for which the percentage is based. Overloaded equipment shall be clearly noted.
- Tabulations of system voltages versus equipment ratings. The tabulation shall identify percentage of rated voltage and the scenario for which the percentage is based. Voltage levels outside the ranges recommended by equipment manufacturers, ANSI/IEEE C84.1, or other appropriate standards shall be clearly noted.
- Tabulations of system real and reactive power losses with areas of concern clearly noted.
- Conclusions and recommendations.

(6) STABILITY STUDIES

(a) Scope of Study

Determine the ability of the electrical system's synchronous machines to remain in step with one another following a disturbance. Provide an analysis of disturbances for all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

(b) Procedure

The stability study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399.

(c) Study Report

Results of the stability study shall be summarized in a final report containing the following items:

- Basis, description, purpose, and scope of the study.
- Tabulations of the data used to model the system components and a corresponding one-line diagram.
- Descriptions of the scenarios evaluated and tabulations or graphs showing the calculation results.
- Conclusions and recommendations.

(7) HARMONIC-ANALYSIS STUDIES

(a) Scope of Study

Determine the impact of nonlinear loads and their associated harmonic contributions on the voltage and currents throughout the electrical system. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

(b) Procedure

The harmonic-analysis study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399.

(c) Study Report

Results of the harmonic-analysis study shall be summarized in a final report containing the following items:

- Basis, description, purpose, and scope of the study.
- Tabulations of the data used to model the system components and a corresponding one-line diagram.
- Descriptions of the scenarios evaluated and the basis for each.
- Tabulations of RMS voltages, peak voltages, RMS currents, and total capacitor bank loading versus associated equipment ratings. Equipment with insufficient ratings shall be clearly identified for each of the scenarios evaluated.
- Tabulations of calculated voltage-distortion factors, current-distortion factors, and individual harmonics versus the limits specified by ANSI/IEEE 519. Calculated values exceeding the limits specified in the standard shall be clearly noted.
- Plots of impedance versus frequency showing resonant frequencies to be avoided.
- Tabulations of the system transformer capabilities based on the calculated non-sinusoidal load current and the procedures set forth in ANSI/IEEE C57.110. Overloaded transformers shall be clearly noted.
- Conclusions and recommendations.

APPENDIX 1 – SHORT CIRCUIT CALCULATIONS

The initial symmetrical short circuit current is calculated from IEC 60909-0 as follows:

$$I_k'' = \frac{cV_n}{\sqrt{3}Z_k}$$

Where: I_p is the initial symmetrical short circuit current (A)

c is the voltage factor that accounts for the maximum system voltage (1.05 for voltages < 1kV, 1.1 for voltage > 1 kV)

V_n is the normal system voltage at the fault location (V)

Z_k is the equivalent positive sequence short circuit impedance (Ω)

The peak short circuit current is then calculated as follows:

$$I_p = k \times \sqrt{2}I_k'' \text{ (for non-meshed networks) or } I_p = 1.15k \times \sqrt{2}I_k'' \text{ (for meshed networks)}$$

Where: I_p is the peak short circuit current (A)

I_k'' is the initial symmetrical short circuit current (A)

k is a constant factor, $k = 1.02 + 0.98e^{-\frac{3}{X/R}}$

1. Flicker Severity: The Flicker Severity at any Connection Point in the system shall not exceed the limits of $P_{st} = 0.8$ and $P_{lt} = 0.6$, both 95th percentile values measured over a period of 1 week.

APPENDIX 2- SUBSTATION GROUNDING DESIGN

At voltage 110kV and above, the Grid is effectively grounded with specified Ground Fault Factor below 1.4. Engineering Design Specification 16450 shall be followed where applicable.

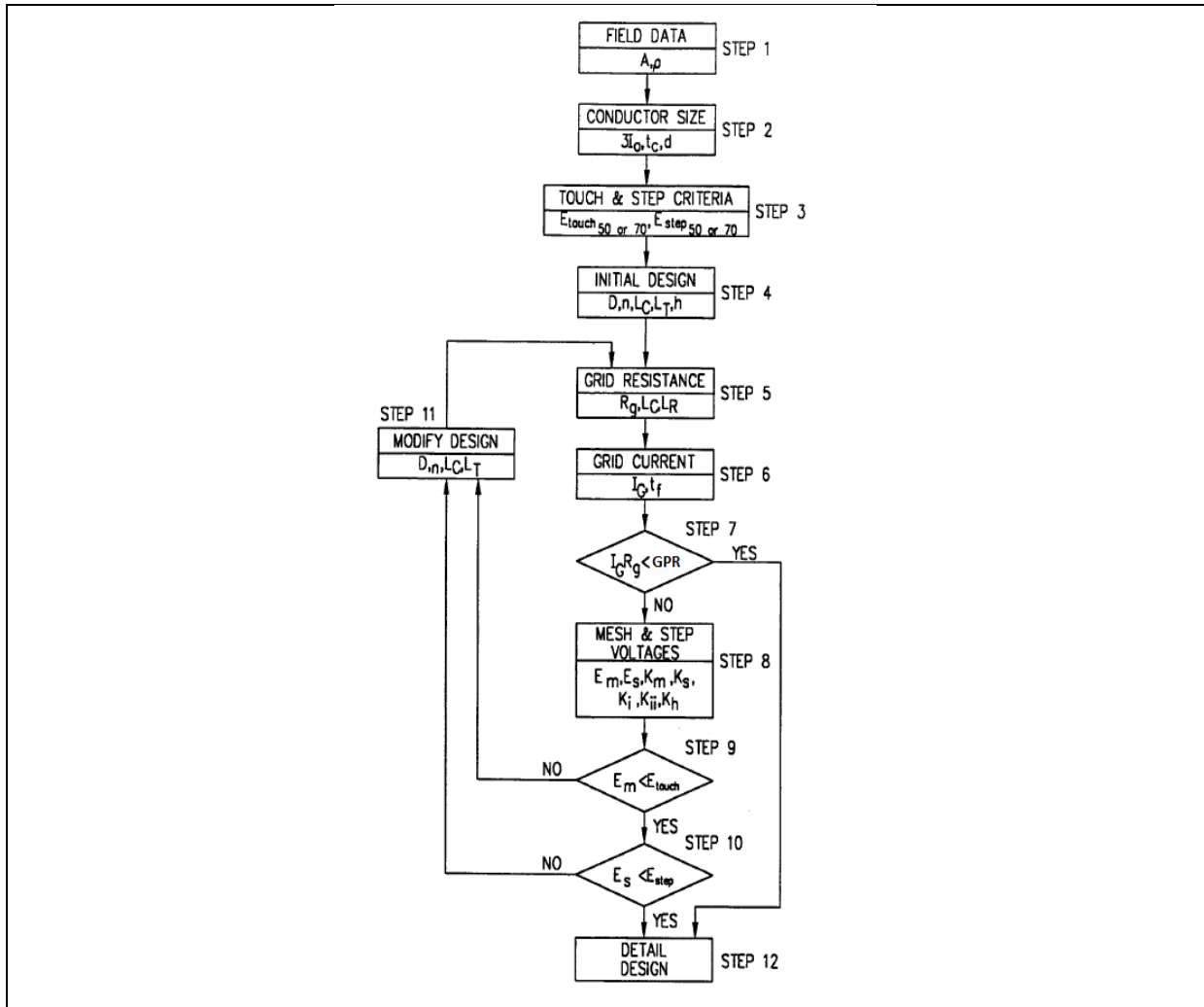


Figure 8-1: Substation Grounding Design

APPENDIX 3-SUBSTATION LIGHTNING PROTECTION**(1) Fixed Angle Method**

The fixed-angle design method uses vertical angles to determine the number, position, and height of shielding wires or masts. Figure 8-2 illustrates the method for shielding wires, and Figure 8-3 illustrates the method for shielding masts. The angles used are determined by the degree of lightning exposure, the importance of the substation being protected, and the physical area occupied by the substation. Both 30 and 45 degrees are widely used for angle Beta. Designers using the fixed angle method may want to reduce the shielding angles as the height of the structures increases in order to maintain a low failure rate.

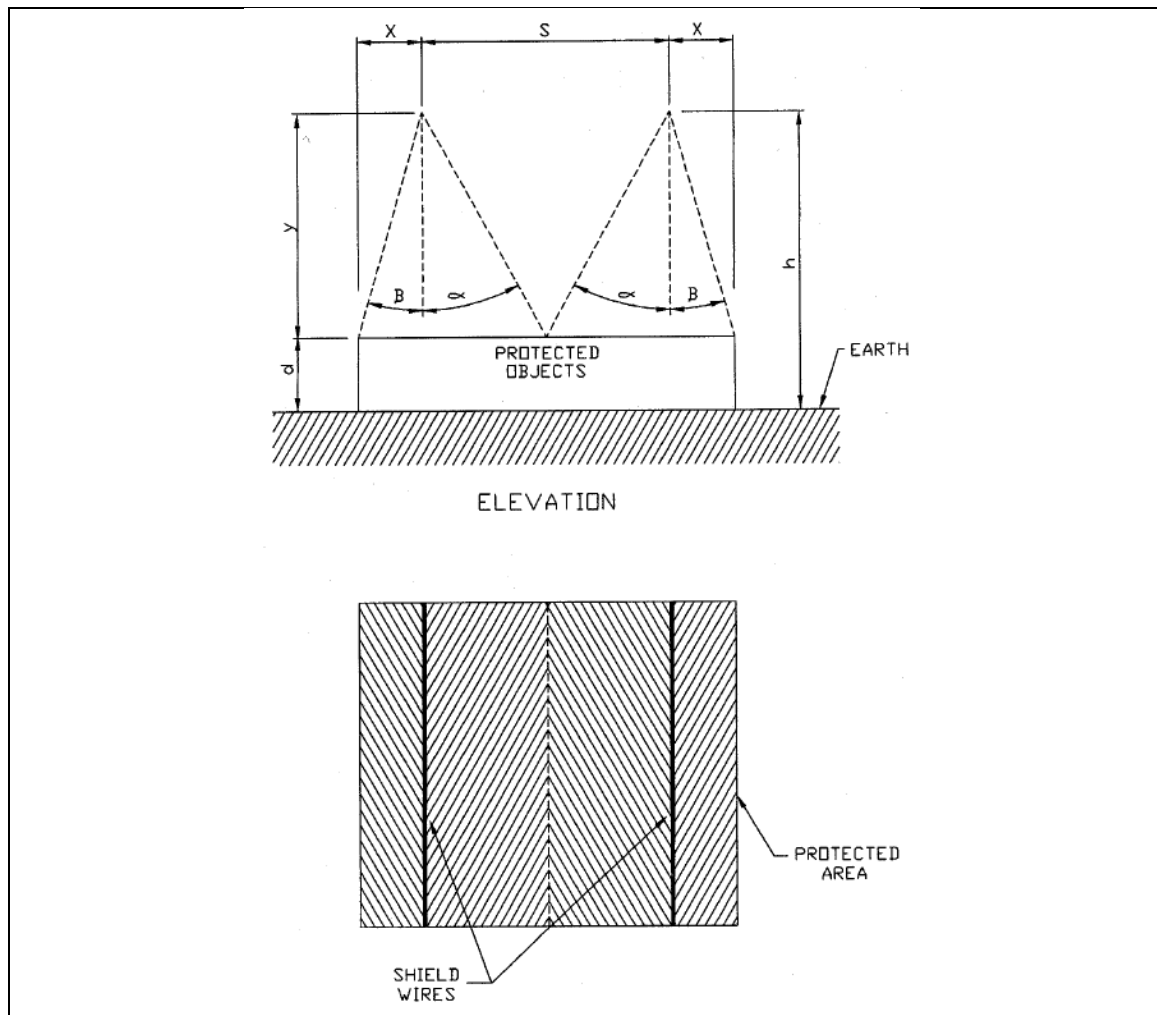


Figure 8-2: Fixed Angle for Shielding Wires

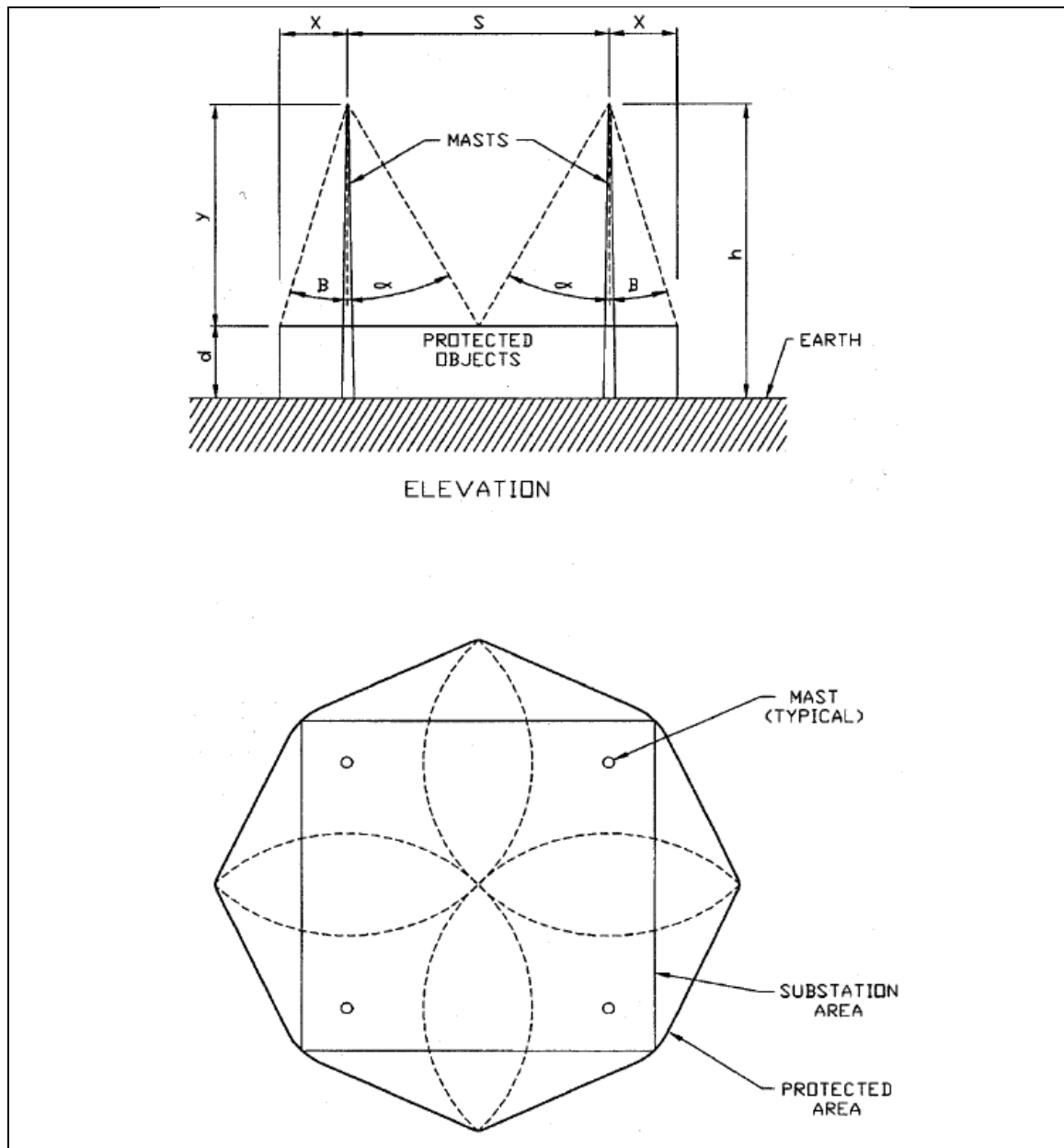


Figure 8-3: Fixed Angle for Masts

(2) Rolling Sphere Method

Use of the rolling sphere method involves rolling an imaginary sphere of radius S over the surface of a substation. The sphere rolls up and over (and is supported by) lightning masts, shield wires, substation fences, and other grounded metallic objects that can provide lightning shielding. A piece of equipment is said to be protected from a direct stroke if it remains below the curved surface of the sphere by virtue of the sphere being elevated by shield wires or other devices. Equipment that touches the sphere or penetrates its surface is not protected. The basic concept is illustrated in Figure 8-2.

SECTION 9

TELECOMMUNICATION DESIGN

9.1 GENERAL

The Telecommunications Design Criteria and Guidelines provide the basis for design and installation of electrical systems, subsystems, equipment/components, and services, in Yanbu under the jurisdiction of the Royal Commission.

(8) Scope

The guidelines apply to the following systems:

- (f) Telecommunications Networks
- (g) Voice and Data Structured Cabling Systems
- (h) Public Address System
- (i) Safety and Security System
- (j) Fire Alarm System
- (k) Access Control System
- (l) Intrusion Detection System

(9) These guidelines shall be utilized for the design of telecom infrastructure in MYAS as well as facilities in the community and light industrial areas.

(10) All works undertaken in relation to this Design Criteria and Guidelines shall be completed in full compliance with the respective health and safety requirements established by the following:

- (f) Kingdom of Saudi Arabia
- (g) Legislation, Regulation, International Standards, and Codes
- (h) Royal Commission
- (i) Regulations, Standards, Contractual Conditions, Health and Safety Standards, and Guide Line Documentation
- (j) Contractor Health and Safety Standards, and System as accepted by the Royal Commission.

9.2 GOVERNING CODES AND STANDARDS

The telecommunications and ELV systems designs shall comply with the latest edition of relevant codes and standards as listed in Section 2 of the Design Guidelines.

9.3 VOICE AND DATA STRUCTURED CABLING SYSTEM

(1) TECHNICAL REQUIREMENTS

- (a) Voice and Data structured cabling system for local area network (LAN) design shall comply with the latest revision of Telecommunication Industry Association (TIA), Electronic Industry Alliance (EIA) standard, and contract stipulation.

- (b) The A/E design contractor shall design a converged network structured cabling system for voice over IP, data, video, IPTV, IPCCTV, electronic safety/security, building automation and other system utilizing the building Ethernet TCP/IP local area network.

(2) DESIGN CONSIDERATION FOR LAN

- (a) Building networks that adhere to structured wiring specifications typically have one central wiring closet called a main distribution frame (MDF) and one or more distributed wiring closets called intermediate distribution frames (IDFs). It is highly desirable to secure the MDF and IDFs behind locked doors, and they should be large enough to support all of the equipment with sufficient room to reach all devices in them.
- (b) Each IDF should be star wired back to the MDF via fiber optic cabling. Fiber cabling supports longer distances than twisted pair copper wiring, and it is immune to electrical interference and grounding problems. It also has the potential for supporting high data transmission capacities. Twenty-four (24) strands/cores of fiber cabling should be run from MDF to each IDF to provide for future growth and redundancy.
- (c) The local area network (LAN) components of an IDF minimally consist of one or more rack mounted hubs with each hub port connecting to a port on a rack mounted patch panel via Cat 6A UTP patch cable. Each port on the patch panel is connected to an RJ-45 wall plate in an office through a solid conductor horizontal Cat 6A UTP cable running through the building infrastructure. The networked device is connected to the wall plate via Cat 6A UTP station cable.
- (d) The total cable length for Cat 6A UTP wiring is 100 m (90 m for horizontal cabling and 10 m for both station and patch cables combined). As indicated above, fixed horizontal cables must use solid copper CAT 6A wire, whereas, patch cables must be stranded copper CAT 6A cable. When designing and installing Cat 6A wiring, it is important to stay away from sources of electrical interference, e.g., 300 mm (12 in.) from light ballasts and 1.2 m (4 ft.) from electrical devices such as high-voltage transformers, electric motors, microwave ovens and copy machines.
- (e) Cable trays, which look like metal ladders, can be installed above ceilings to provide clearly defined paths for horizontal Cat 6A wiring, and can keep cables from sources of electrical interference. They also protect cables from damage by other personnel working in ceilings.
- (f) Rack mounted patch panels are ideal, direct termination points for Cat 6A wiring in the IDF and MDF.
- (g) Cable installations must comply with appropriate building codes. All penetrations through fire walls, ceilings and floors must be fire sealed. Plenum rated cable should always be utilized, but it is required when installed in air plenums. Riser rated cable should also be used where required. Furthermore, cables and hub components should be appropriately grounded.

(3) HORIZONTAL CABLING AND HARDWARE

- (a) Horizontal cable and its connecting hardware provide the means of transporting signals between the telecommunications outlet/connector and the horizontal cross-connect located in the communications equipment room. Horizontal cabling system shall comply with transmission standards in TIA/EIA-568 when tested according to test procedures of this standard. The system also includes the patch cords at the work area outlet, and patch cords in the telecommunications room.

- (b) Horizontal cabling shall be installed in a star topology, with each work area outlet being connected via the horizontal cable to the horizontal cross connect/patch panel in the telecommunications room. Each floor shall have minimum one telecommunications room, sized as per the latest revision of ANSI/TIA/EIA 569.
- (c) Category 6A cabling shall be used for data, voice, IPTV, IP security system, multimedia video streaming, and other IP based systems that utilized the building Ethernet/LAN. Appropriate cable shall be selected to meet low noise, higher bandwidth and long distance communication. It shall be solid bare copper conductor, low smoke zero halogen(LSZH) jacket material, polyolefin insulation, 4- twisted pairs and 10Gbit speed.
- (d) Telecommunications Outlet and Connectors.
 - TIA/EIA 568 requires a minimum of two telecommunication outlet in each working area. A work area is approximately 9.3 sq. meters, and includes the components that extend from the telecommunication outlet/connectors to the station equipment. Each telecom outlet in a working area shall be duplex RJ45 port-connector assemblies mounted in a single faceplate and back box, one will be associated with voice and the other data. One outlet will be a 4 pair 100 ohm UTP cable rated category 6A or higher.
 - Power receptacle outlet shall be installed near each telecommunication outlet in a work area. The power receptacle layout shall be coordinated with telecommunication outlet layout.
 - Provide also data outlets for wireless access point (WAP) in the building, such as in office rooms, corridors, hallways, waiting rooms, conference rooms, and etc. Placement of WAP's data outlets shall consider the area of coverage. Active components for WAP are not part of the scope.
- (e) Patch Panel: The patch panel shall conform to ANSI/TIA category 6A standard, and with regulatory compliance/certification from RoHS and ISO 9001. It shall be modular panels housing multiple-numbered jack units with connectors at each jack for permanent termination of pair groups of installed cables. The number of ports such as 12, 24 or 48 ports shall be as per design requirement. UTP patch panels shall be intelligent type.

(4) BACKBONE CABLING AND HARDWARE

Backbone cabling system shall provide interconnections between communications equipment rooms, main terminal space, and entrance facilities in the telecommunications cabling system structure. Cabling system consists of backbone cables, intermediate and main cross-connects mechanical terminations, and patch cords or jumpers used for backbone-to-backbone cross-connection. The back bone cable shall be laid out in a hierarchical star topology. The following cables and its associated hardware are recognized in the structured cabling system for RC Yanbu Smart City.

- (a) Single mode optical fiber, G.652D, Micro-core air blown complies with TIA/EIA-568-C.3 for performance specifications.
- (b) Multi-mode optical fiber, 50/125-micrometer, loose tube, optical fiber cable.
- (c) Optical Fiber Patch Panel. Modular panels enclosing multiple-numbered, duplex cable connectors. Patch panels shall be intelligent type.
- (d) Access terminal box (ATB). It is mainly used for Fiber to the Home Technology(FTTH) GPON technology to connect an optical cable to passive device. It provides optical ports

for optical fiber access and splicing. It is used for indoor application, wall and rack mounted in villas or residential units.

(5) VOICE AND DATA CABINET

(a) Free Standing Modular Data Cabinet

This type of data cabinet shall be used for MDF and IDF. The size of data cabinet shall be determined, sizes may vary such as 42U, 27U or other sizes depend on the quantity of voice and data outlet it serves.

(b) Wall-Surface Mounted Type Enclosure Cabinet

This type of cabinet shall be used for very small building with minimal number of voice and data outlets. This cabinet shall be a 19 inches standard rack and shall be equipped with lockable front and rear doors, louvered side panels, cable access provisions on top and bottoms, grounding lug, roof mounted fan(s), power strip cabinet keyed alike, steel or aluminum construction and treated to resist corrosion. Size may vary such as 15U and 12U size cabinet.

(c) Flush Mounted data cabinet.

Flush mounted data cabinet/enclosure shall be used for residential units with multiple voice, data and IPTV data outlet. Its main function is to enclose access terminal box/fiber patch panel, UTP Cat6a patch panel, patch cords and other components. The flush mounted data cabinet is suitable for residential type of building FTTH application because of its compact size and shape.

(6) TELECOMMUNICATION ROOM(TR) AND EQUIPMENT ROOM (ER)

- (a) These rooms are enclosed architectural spaces for housing of telecommunication equipment, cable terminations, and contain horizontal cable, backbone cable and their connecting hardware. Equipment or utilities not related to the support of the telecommunication room (e.g. piping, ductwork) shall not be installed in, pass through, or enter the space.
- (b) Comply with the latest revision of ANSI/TIA/EIA 569 for design and provisioning requirements for telecommunication rooms and equipment room. The size of TR and ER depends on the size of the building, floor space served, occupant needs, telecommunication service used, number of equipment, number of equipment racks/cabinet and projected future requirements.
- (c) There must one telecommunication room or equipment room per floor in a building. Multiple telecommunication rooms are required in a floor if: a) the cable length between the patch panel and the telecommunication outlet location is more than 90 meters, and b) usable floor space exceed 1000 m² in a floor.
- (d) Lighting System. The minimum illumination shall be equivalent to 500 lux measured one (1) meter above finish floor level. Location of lighting fixture shall be coordinated with the placement of data equipment rack/cabinet. Provide emergency lighting to ensure that the loss of power to normal lights will not hamper an emergency exit from the TR or ER.

(e) Telecommunications rooms electrical power minimum requirements are as follows:

- A minimum of two dedicated non-switched alternating current (ac) duplex electrical outlets for telecommunication/data system equipment power, each on separate branch circuits.
- Duplex convenience electrical outlet to be placed at 1.8 meters intervals around the perimeter wall.
- Additional outlets or power strips may be required, depending on the amount and type of equipment plan for the TR.

(7) GROUNDING AND BONDING:

Grounding and Bonding. Comply with the latest revision of TIA/EIA 607 for the grounding and bonding requirements of telecommunication equipment, enclosure, cabinet and other accessories.

(8) BUILDING TELECOMMUNICATION PATHWAYS SYSTEM

(a) Horizontal Pathways

- Horizontal pathways consist of structures that conceal, protect, support, and provide access to the horizontal cables between the telecommunication outlets/connectors and the floor distributor/patch panel in the serving telecommunication room or telecommunication enclosure.
- Pathways involve the containment of cables, pull boxes, splice boxes, and etc. that aid the installation and change of cable routing direction.
- Horizontal pathway design shall handle various types of telecommunication cables supporting multiple applications such as voice, data, video and building automation system.
- The conduits shall be used and considered as horizontal pathway system for telecommunication structured cabling when outlet locations are permanent, device densities are low, or flexibility is not required.
- When determining the type and size of the pathway, consider the quantity and size of cables that the pathway is intended to support, and allow for growth of the area served. The size of horizontal pathways shall be calculated with fill factor in accordance with the latest revision of ANSI/TIA 569.
- Route of pathways shall avoid the source of electromagnetic interference. Power cables shall be kept physically separated from telecommunication cables.
- All horizontal pathways that penetrate fire rated barriers must be fire stopped in accordance with applicable codes and standards.
- The maximum distance between pull box for conduit runs shall be 30 meters. No section of conduits shall contain more than two 90-degree bends or equivalent.

(b) Intra-building Backbone Pathways

- Intra-building pathways are typically consisting of ceiling pathways, conduits, sleeves or slots, cable runways, and trays. They provide the means for placing backbones cables between the entrance room or space, telecommunications closets, equipment rooms, or the main terminal space. Backbone pathways maybe either vertical or horizontal.

- When determining the size of pathway, the quantity and size of cables, with an allowance for growth, shall be provided. Where a large number of cables are expected, additional sleeves, conduits, trays, or slots shall be provided.
- The vertical backbone pathway generally routes from the main terminal space or MDF through vertically stacked telecommunication closets or telecommunication room located on each floor by means of sleeves or slots. When telecommunication closets or telecommunication rooms cannot be vertically stacked, a pathway shall be provided to link them.
- The size of backbone pathways shall be calculated with fill factor in accordance with the latest revision of ANSI/TIA-569.
- Sleeves or slots shall be provided for vertical pathways passing each floor slabs. Location and configuration of sleeves shall be approved by structural engineer.
- All intra-building backbone pathways that penetrate fire rated barriers must be fire-stopped in accordance with applicable codes and standards.

9.4 OUTSIDE PLANT (OSP) PASSIVE NETWORK INFRASTRUCTURE

(1) PASSIVE INFRASTRUCTURE DESIGN FOR FIBER TO THE HOME (FTTH)

- (a) General. The Fiber to the Home (FTTH) passive network constitutes a fiber-based access network connecting a large number of end-users to a central point known as point of presence (POP) at data center (DC). The Gigabit Passive Optical Network (GPON) based FTTH infrastructure shall cater and offer a triple play services for data (internet), voice over IP (VoIP) and IP TV system mostly for residential building.
- (b) The passive infrastructure design for Fiber to the Home (FTTH) shall constitute including, but not be limited to the following:
 - FTTH Feeder Network. The feeder network is the cable(s) feeding the fiber distribution terminal (FDT) from POP/DC. The feeder cable(s) shall be 144 fibers connected as ring topology. The FDT is usually street distribution cabinet where level-1 splitters shall be positioned, and installed in district/community area covering a radius of 500-1000 meters with sufficient connectivity points, and leaving 20% spare capacity.
 - FTTH Distribution Network. A distribution cable(s) from FDT to fiber access terminal (FAT) or joint closure (JC) installed in a manhole or hand-hole. Distribution cable shall have 144 Fiber count and 25% will be kept as spare for any future requirement.
 - User Area Drop Cables. A drop cable is from the FAT up to the optical distribution box (ODB) located at customer building premises. Each building has a drop cable 12 fibers, and the 2 fibers shall be terminated in ODB. Indoor drop cable (4 fibers) shall be from the ODB up to the access terminal box (ATB) installed in the data cabinet for each residential unit.
 - Maximum two level of splitting shall be provided; firstly, at the FDT and secondly at customer building ODB for the case of multi-dwelling unit (MDU). The maximum splitting ratio shall be 32.

(2) PASSIVE INFRASTRUCTURE DESIGN FOR ACTIVE ETHERNET FIBER TO THE X (FTTX)

- (a) General. The active Ethernet (AE) network provides each subscriber with their own fiber link to the network node switch. The passive AE FTTX network infrastructure includes, but not be limited to industrial/business and RC Yanbu facilities, and enables the

convergence of existing or creation of new value-added services.

- (b) The passive infrastructure design for active Ethernet Fiber to the X (FTTX) shall constitute, but not be limited to the following:
- FTTX Feeder Network. The feeder network is the cable(s) feeding the fiber distribution terminal (FDT) from two POP/DC with full diversity; the feeder cable(s) shall be 288 fibers.
 - FTTX Distribution Network. A distribution cable(s) from FDT to fiber access terminal (FAT) or joint closure (JC) installed in a manhole or hand-hole, and the distribution cable shall have 288 fiber counts. The FDT cross connect cabinet shall have 20% reserve capacity.
 - Drop Cables. The drop cable is the cable from FAT up to the outdoor enclosure ODB. Each ODB enclosure outdoor pedestal type shall have 24 fibers drop cable, and all fiber cores shall be terminated.
 - The ODB enclosure outdoor pedestal type shall be installed in the nearest customer tie-in/interface point or connectivity point.

9.5 TELECOMMUNICATION DUCTBANKS AND JOINING CHAMBERS

(1) GENERAL

- (a) The design contractor shall design a telecommunication conduit network or infrastructure to include manholes, hand holes, and its accessories. Include in the design continuous ducts to facilities, housing, buildings, or predetermined interface points. Include in the design task, if required, conduits or duct banks for traffic control, security systems and utilities that require cable routing through the telecommunication duct bank.
- (b) The A/E shall identify and reflect in the design the telecommunication duct bank “tie-in point” of the new design to the existing infrastructure, to other design contract, and/or to current project.
- (c) Establishment of conduit corridors and other utility locations are the responsibility of the design contractor within the parameter of these guidelines:

(2) MANHOLE AND HANDHOLE SPACING

- (a) The construction of the cable duct system shall be based upon the design cable tensile strength and the frictional resistance. Distance between manholes shall be determined accordingly.
- (b) Calculation of cable tractive force shall be designed for both possible pull-in directions. Approved pull-in length for cable to manholes shall not exceed 270 meters in any straight run.
- (c) Bends in any duct run with a radius between 2.5 meters and 80 meters reduce feasible pull-in length, this must be taken into account (Limit: 2-90° bends to a straight conduit section). To minimize cost, determine the optimal location of each manhole and hand hole for each duct route.

(3) DUCTBANK CONFIGURATION AND EXTENSION

Basic conduit sizes and minimum quantities of ducts in any bank within a neighborhood shall be as follows:

- (a) Manhole to Manhole - 4 x 110 mm diameter

- (b) Manhole to hand hole - 4 x 110 mm diameter
- (c) Hand hole to hand hole - 4 x 110 mm diameter
- (d) Hand hole to each residential site - 2 x 50 mm diameter
- (e) Hand hole to large building site (Industrial, commercial and Public Facility) - 2 x 50 mm diameter
- (f) Apartment complex - 2 x 50 mm diameter
- (g) All ducts shall have a pulling-in nylon cord left in place.
- (h) All stub-out shall be provided with end-cap or end-plug.
- (i) Duct Bending Radii Limitations:
 - 110 mm - 2.5, 5.0, 10.0 meters
 - 50 mm - 1.0, 2.5, 5.0, 10.0 meters

(4) INNER DUCTS OR MICRODUCTS

- (a) Rigid Inner duct or micro duct: Smooth HDPE duct, designed for installation within a duct or pathway. It consists of multiple variations of inner ducts in specific sizes made of factory bundled together with polyethylene outer sheath for ease of placement.
- (b) Insert 14-way micro duct having 14/11.5 mm (OD/ID) in one of the 4x110 mm diameter ducts configuration.
- (c) Insert 14-way micro duct having 14/11.5 mm (OD/ID) in two of the 8x110 mm diameter ducts configuration; one 14-way micro duct shall be located at the top portion, and another one 14-way micro duct shall be located at the bottom portion.
- (d) Insert 2-way micro duct having 14/11.5 mm (OD/ID) in one of the 2x50 mm diameter ducts configuration.
- (e) If required, other configuration of inner ducts sizes is allowed to be used to fit cable size.

(5) REQUIREMENTS FOR DUCTS AND FITTINGS

- (a) Ducts shall be polyvinyl chloride (PVC) type for communication cables. PVC conduits shall be designed to be encased in concrete, minimum of NEMA TC-6.
- (b) Ducts shall have nominal outside diameters of 50 mm and 110 mm. Outside diameter, average tolerance and minimum inside diameter shall be in accordance with NEMA TC 6.
- (c) Ducts shall have minimum wall thickness of 1.5 mm for 50 mm and 2 mm for 110 mm. The Wall thicknesses shall not exceed that of Schedule 40 (EPC-40) PVC Conduit. Conduit runs shall be at minimum of 0.80 meter below finish grade.
- (d) Fittings for joining ducts shall be made of the same material as the ducts.
- (e) Fitting shall meet the NEMA TC9 standard.
- (f) Bends shall be fabricated of the same material as the PVC ducts.
- (g) Standard bends shall be available in 45° and 90° angles and provided with a socket at one end.
- (h) Rigid hot dipped galvanized steel conduits (RGS) shall be used where duct banks cross deep wadis or areas where ground conditions are unstable. RGS-PVC adapter fittings shall be used where duct material changes occur.

- (i) Spacers shall be used to maintain a 30 mm uniform separation between assembled ducts in both the vertical and horizontal directions.
- (j) When duct banks consist of ducts with mixed sizes, appropriate spacers shall be used.
- (k) Splaying of duct bank configurations is permissible to clear obstructions or avoid right-of-way restrictions. Realignment to the original configuration must be made once the obstruction of right-of-way restriction has been cleared.
- (l) Spacers shall be made of polyethylene (PE) or polyvinyl chloride (PVC) material.
- (m) Warning tape for duct banks shall be yellow PVC tape.
- (n) The warning tape shall be 300 mm x 0.125 mm
- (o) Warning shall be printed on the warning tape in both Arabic and English and in durable black letters of 50 mm.
- (p) For telecommunication duct banks under roadways and highways, ducts shall be in structural concrete encasement.

(6) JOINTING CHAMBERS

- (a) Jointing chambers shall consist of two types:
 - Telecommunication Manhole
 - Telecommunication Hand Hole
- (b) PVC ducts shall enter jointing chambers via cable duct connection slabs fabricated from polyurethane foam for manholes/hand holes, and precast concrete or other suitable material for manholes or hand holes.

(7) TELECOMMUNICATION MANHOLES AND HAND HOLES

- (a) The size and type of manholes and hand holes shall be dependent upon the duct bank configuration and routing. Refer to Royal Commission Standard Drawings.
- (b) Manholes and hand holes shall be constructed of steel reinforced concrete.
- (c) Cable Duct Connection Slabs: Connection of PVC ducts to windows in manhole and hand hole walls shall use cable duct connection slabs. Connection slabs are required to ensure that ducts are properly terminated and watertight. Material for slabs shall be polyurethane foam or other suitable material. Sizes shall be sufficient to accommodate the number of ducts terminating in the manhole.
- (d) Manholes and hand holes shall be watertight. To ensure water tightness, all prefabricated section joints and duct entrance slab joints shall be properly sealed.
- (e) The exterior of manholes and hand holes shall be water proofed and damp proofed.
- (f) For manhole and hand hole entrance facility such as frame, cover, entrance shaft and other accessories inside the manhole, refer to Royal Commission Standard Drawings.
- (g) Fold-out details showing the configuration of ducts for telecommunication manholes and hand holes shall be provided in the design.

(8) DUCT END PLUG

- (a) All used and unused ducts terminated at jointing chambers (manhole/ hand hole) and building walls shall be sealed with duct plug sealing system. After plugging, ducts must be watertight. The plugs shall be readily removable to allow future cable installation.

- (b) Sealing bushings shall be made of plastic, neoprene rubber or heat shrinkable material and be provided at building basement wall. Sealing bushings shall be a manufactured product designed to withstand and prevent seepage of water under the pressure of at least 10m water column.

9.6 PUBLIC ADDRESS SYSTEM

9.6.1 GENERAL

- (1) The public-address system shall be designed for transmission of general announcements, emergency alarms and music in accordance with NEC Article 210, 300 and 640.
- (2) The system shall be interfaced to voice/telephone system.

9.6.2 IP PUBLIC ADDRESS SYSTEM

- (1) Internet Protocol (IP) Public Address System Speaker.
 - (a) The speaker shall be IP based and integrated with the session initiation protocol (SIP) enabled IP telephone system that makes live announcements across the PA system from the IP telephone units.
 - (b) Power over Ethernet enabled as per IEEE 802.af standard.
 - (c) Cabling system IP Public Address System shall be similar to data system structured cabling such as CAT6A cable, RJ45 connectors and UTP patch panels are being utilized.

9.6.3 CONVENTIONAL PUBLIC ADDRESS SYSTEM

- (1) The conventional Public Address System shall be used in Mosque Buildings.
- (2) Amplifier
 - (a) It is all in one solution for making announcement and background music needs in the building. The system shall consist of the pre-amplifier, power amplifier, DVD/CD player, AM/FM tuner and inputs.
 - (b) The amplifier shall be equipped with tone control facilities to tailor the audio response to suit the input signals and the required performance.
- (3) Types of speaker, where applicable, shall be used and selected based on requirement for conventional Public Address System. Performance of loudspeakers shall not be less than that specified in IEC 60581-7.
 - (a) Wall type speaker
 - (b) Ceiling type speaker
 - (c) Column type speaker
 - (d) Horn Speaker
- (4) Microphones

Microphones shall be provided with desk mount or floor mount as suitable for application.
- (5) Equipment Rack Cabinet

An enclosure for amplifiers and auxiliary equipment at each location. Comply with TIA/EIA 310-D. Size of enclosure shall be adequate to accommodate all Public Address System equipment, and it shall be provided with 20 percent spare capacity.

(6) Power Supply Back-up Unit

Provide uninterruptible power supply battery backup unit with adequate capacity to supply maximum equipment power requirements for one hour of continuous full operation.

9.7 SAFETY AND SECURITY SYSTEM

9.7.1 IP CCTV SYSTEM

(1) Technical Requirements

- (a) The IP CCTV system shall be designed, where applicable, in accordance with the latest revision of NFPA 70, TIA/EIA, IEEE, FCC, EN, PSIA, ONVIF standards and contract stipulation.
- (b) The system shall be IP based and open platform complying with the requirement of PSIA (Physical Security Interoperability Alliance) and/or ONVIF (Open Network Video Interface Forum) industry standard.
- (c) The system requirement illustrated for various types of security cameras and its application are minimum requirements and shall be subjected to bringing up to date due to the rapid change of technology.

(2) FIXED DOME CAMERA INDOOR TYPE

- (a) The camera shall utilize a high sensitivity and high megapixel CMOS sensor.
- (b) The camera's power source shall be by power over Ethernet (PoE) complying with the IEEE 802.3af standard. The camera shall be equipped with LAN connector. The system shall have dual standard compression support with simultaneous streaming of both H.264 and MJPEG formats.

(3) FIXED DOME PANORAMIC INDOOR CAMERA

- (a) Panoramic cameras are suitable for locations that require a wide viewing area of coverage without adding multiple number of cameras.
- (b) Panoramic cameras shall be omnidirectional (360°) or 180° field of view, depends on the location and application. An ideal for surveillance applications that require wide area of coverage in a single view. Such cameras can be installed in places to detect activities in a large area and track the flow of people. This network camera shall be wide dynamic range (WDR) and dual encoder (H.264 & MJPEG
- (c) The camera's power source shall be powered over Ethernet (PoE) complying with the IEEE 802.3af standard, and alternative option to be powered with 12-48VDC or 24VAC. The camera shall be equipped with a 100Mbps LAN connector. The system shall have dual standard compression support with simultaneous streaming of both H.264 and MJPEG formats.

(4) FIXED DOME PANORAMIC OUTDOOR CAMERA

- (a) The camera shall utilize four high sensitivity and high megapixel CMOS sensors.
- (b) The camera power source shall be powered over Ethernet (PoE) complying with the IEEE 802.3af standard.

- (c) The camera shall have the alternative option to be powered from a 12V DC up to 48V DC or 12V AC power source.
- (d) The camera shall have combined four images for a 180 degrees horizontal field of view.
- (e) The camera shall have vandal resistant dome enclosure with rated IP66 for water and dust protection. The camera casing shall be die-cast aluminum chassis polycarbonate dome bubble with IK10 rating and POE powered fan.

(5) FIXED OUTDOOR CAMERA – BULLET TYPE

- (a) This type of camera shall provide all-in-one solution with high megapixel camera, IR illuminator, remote focus, remote zoom, p-iris IR corrected wide angel or telephoto lens and vandal resistant aluminum cylindrical (Bullet-style) enclosure with IP66 weatherproofing standard.
- (b) The camera power source shall be powered over Ethernet (PoE) complying with the IEEE 802.3af standard to support IR illuminator, blower and camera. The camera shall have also auxiliary power input, AC24V and DC12-48V to support IR illuminator, blower and camera.

(6) PAN-TILT-ZOOM (PTZ) OUTDOOR CAMERA

- (a) PTZ security camera has the ability to control the pan, tilt and zoom operations of the camera in a remote location.
- (b) PTZ shall be an IP based security camera and PoE supported complying with IEEE 802.3af. The PoE RJ45 connector kit shall be IP66 rating.
- (c) The camera shall be day and night functionality so that high image quality is maintained even in low light condition.

(7) AUTOMATIC NUMBER PLATE RECOGNITION(ANPR) OUTDOOR CAMERA

- (a) The ANPR camera is ideal for both moving traffic (motorways, enforcement, congestion, intersection, etc.), and access control (parking management) application.
- (b) The camera shall include synchronized illuminator unit providing ideal images during day and night. Extra software module is provided for easiest integration.

(8) NETWORK VIDEO RECORDER (NVR)

- (a) NVR is an internet protocol (IP) based security camera equipment, and its main function is to simultaneously record and remote access of live video streams from the IP camera located from different location. It has the features of advance recording, playback, an intuitive remote control unit, a user-friendly graphical user interface, intelligent motion detection, PTZ and virtual PTZ camera control.
- (b) NVR hardware shall be “open platform” system that allows the user to run any IP recording and control software on the market. Open platform NVRs allow for flexibility and scalability when deploying enterprise level camera system.

(9) SIGNAL TRANSMISSION MEDIA

Refer to voice/data structured cabling system for the IPCCTV converged network and cabling system. At a minimum requirement, cable shall be four pair 100 ohm UTP CAT6A cables or fiber optic cables.

9.8 FIRE ALARM SYSTEM

(1) GENERAL:

This Section applies to Fire Alarm Systems inside Residential, Commercial, Institutional and Industrial facilities.

(2) TECHNICAL REQUIREMENT:

Fire Alarm system shall be designed, where applicable, according to the latest revision of NFPA, IBC, IFC, RC standard drawings and project specification. The selection of Fire Alarm system shall be based on project assessment done by Design Engineer.

(3) DESCRIPTION OF THE SYSTEM:

Each building for which a fire alarm system is to be provided shall have an independent system. Fire alarm system shall comprise of, but not be limited to:

- (a) Addressable microprocessor based Fire Alarm Control Panel.
- (b) Microprocessor based Repeater Fire Alarm Panel.
- (c) Intelligent and addressable detectors, manual stations, bells, horns and strobes.
- (d) The system shall be electrically supervised against short, ground and open wiring faults in the detection circuit, alarm circuit, alarm and trouble relay coils and, extinguishing system release circuit (if any).
- (e) A short, ground or open wiring fault occurring in these circuits shall cause an audible and visual trouble indication at the control point.
- (f) The system shall be capable of being expanded at any time and shall have no limitations as to the number of heat detectors or manual stations per zone. The system shall be capable of having thermal, photo-electric, multi sensor and flame detecting devices connected across the same set of wires.
- (g) The alarm and trouble condition for each building shall also be relayed, through a set of controls to the main fire alarm annunciator panel where provided, and to RCY Industrial Security and Safety Department Communication and Emergency Section.
- (h) The system design should ensure that an alarm signal from any manual station (fire condition) overrides a trouble signal (fault condition).
- (i) The system shall be provided with auto dialer that activates when the alarm input is received from the fire alarm control unit.

(4) DETECTOR OPERATION PRINCIPLE:

- (a) There are three most common detectors which are generally used. Those are smoke detectors, heat detectors and flame detectors.
- (b) Smoke Detectors: Smoke detectors detect the visible or invisible smoke particles from combustion.
- (c) Photoelectric Detectors
 - In a photoelectric smoke detector, a light source and light sensor are arranged so that the rays from the light source do not hit the light sensor. When smoke particles enter the light path, some of the light is scattered and redirected onto the sensor, causing the detector to activate an alarm.

- These detectors react quickly to visible smoke particles from smoldering fires, but are less sensitive to the smaller particles associated with flaming or very hot fires.

(d) Heat Detectors

- The most common heat detectors either react to a broad temperature change or a predetermined fixed temperature.
- Heat detectors use a set of temperature-sensitive resistors called thermistors that decrease in resistance as the temperature rises. One thermistor is sealed and protected from the surrounding temperature while the other is exposed. A sharp increase in temperature reduces the resistance in the exposed thermistor, which allows a large current to activate the detector's alarm.

(e) Flame Detectors

- Flame detectors are line-of-sight devices that look for specific types of light (infrared, visible, ultraviolet) emitted by flames during combustion. When the detector recognizes this light from a fire, it sends a signal to activate an alarm.

(5) DETECTOR SELECTION:

(a) General

- Automatic detection systems will be designed and installed as required by codes, after establishing the building and occupancy type in accordance with NFPA 101, NFPA 72 and IBC.
- Some detection systems may be provided in excess of code to protect special hazards or critical equipment. In these cases, the typical operating characteristics of each detector must be compared to the proposed application. The quantity of fuel, ignition sources, size of the room, value of the contents, costs of the detectors and ambient conditions (temperature, humidity, corrosion, HVAC, etc.) must all be considered.
- Fire detectors should be selected based on the burning characteristics of the materials present and the nature of location they will be used to protect.

(b) Smoke Detectors

- Smoke detectors are usually more sensitive than heat detectors and usually detect the fire sooner during early flame stages and will meet the needs of most areas containing primarily wood, paper, fabric, and plastic materials. During combustion, these materials produce a mixture of smoke types with detectable levels of both large and small smoke particles.
- Photoelectric smoke detectors should be used in places where smoldering fires may be expected.
- The smoke detectors are suitable for:
 - Residential occupancies, computer rooms and other locations having high values.
 - Indoor areas with low ceilings such as offices, closets, and restrooms.
 - Areas those are relatively clean with minimal amounts of dust and dirt.
- The smoke detectors are not suitable for:

- Open air applications as the detectors require ceilings to direct the smoke from the plume by convection.
- Areas where ceiling heights exceed 10.5 meters.
- Rooms where cooking will take place, i.e., kitchens, or similar areas where steam and condensation are present.
- Areas where exhaust fumes are present i.e., car parks etc.

(c) Heat Detectors

- Heat detectors are normally used in dirty environments or where dense smoke is produced. Heat detectors may be less sensitive, but are more appropriate than a smoke detector in these environments.
- Heat detectors are ideal for areas where flammable gasses and liquids are handled or any area where a fire will quickly cause a large change in the surrounding temperature. Heat detectors are also suitable for:
 - Dirty, dusty or smoky environments.
 - Manufacturing areas where large quantities of vapors, gases, or fumes may be present.
 - Areas where particles of combustion are normally present, such as in kitchens, furnace rooms, utility rooms, and garages or where ovens, burners or vehicle exhaust gases are present.
- Fixed temperature detectors are suitable for the areas like boiler/plant room, kitchen and furnace/kiln rooms.
- Rate of rise of temperature detectors are suitable for areas such as car parks, loading bays etc.

(d) Flame Detectors

- Flame detectors (ultraviolet or infrared) offer the fastest response to a freely burning fire and are well suited for protecting areas involving flammable liquid fires.
- Flame detectors are best for protecting:
 - Areas with high ceilings and open-spaces, such as warehouses and auditoriums.
 - Outdoor or semi-enclosed areas, where winds or draughts can prevent smoke from reaching a heat or smoke detector.
 - Areas where rapidly developing flaming fires can occur, such as petrochemical production, fuel storage areas, paint shops, and solvent areas.
- Flame detectors are quite expensive and may be subject to false alarms from radiation such as welding, reflected sunlight, electric sparks and halogen lamps.
- Flame detectors performance is affected by thick smokes, vapors, grease, and oil deposits on the detector windows resulting in blockage of the line of sight.

(e) Duct Smoke Detectors

- Photoelectric type complying with UL standard with weatherproof duct housing enclosure and listed for use of intended application.

(f) Multi-sensor Detector: A photoelectric smoke and heat sensing device combined in one housing. Heat detection selectable as fixed temperature or fixed selectable rate of rise.

(g) Single Station and Multi Station Alarm Device

- As defined by the code, a single station alarm device is a detector comprising an assembly that incorporates a sensor, control components, and an alarm notification appliance in one unit operated from a power source either located in the unit or obtained at point of installation.
- Multiple station alarm device are two or more single station alarm devices that can be interconnected so that the actuation of one causes all integral or separate audible alarms to operate.
- This type of alarms is specifically designed for occupancies such as sleeping rooms, dormitories, family dwellings and other similar type of occupancies as defined by NFPA 72, IBC and NFPA 101.

(6) DETECTOR LOCATION:

- (a) After the detector type, has been selected, the detectors can be located within the space. The manufacturer's data and Underwriter's Laboratories listed spacing can be used as a starting point.
- (b) On smooth ceilings, detectors maximum spacing of 9.1 meter may be used as a guide and should be adjusted for other condition. NFPA 72E specifies requirements for locating detectors on ceilings with joists beams and other obstructions.
- (c) Smoke and heat detectors should also be located away from air supply vents and dead air spaces. All detectors should be located to avoid localized sources of "false" alarms.
- (d) To be most effective, both smoke and heat detectors must be located on or near the ceiling of the space to be protected because that is where smoke or hot gases initially collect. They should not be located near openable windows, supply duct outlets, or other ventilation sources that would interfere with the natural air currents nor near any obstruction that would prevent smoke or heat from reaching the detector.
- (e) In case of heating and ventilation system, where smoke detectors are used to initiate signals to shut down fans or to close dampers, they are installed in the return air ducts of heating, ventilating and air-conditioning systems, to prevent the circulation of smoke-contaminated air.
- (f) Heat detectors, though slower to respond to a fire than smoke detectors, are not as prone to false alarms. They are thus often installed in storage rooms and service rooms that are normally unoccupied.
- (g) Some consideration may also be given to architectural symmetry, provided that this does not downgrade detector function to an unacceptable level.

(7) FIRE ALARM CONTROL PANEL:

- (a) Control panels shall be designed to meet the unique requirements of each building and occupancy. The building area may be divided into zones by floors or as required to allow for accurate and rapid determination of the fire location and the type of systems being activated.
- (b) Zone configuration should consider fire zones, means of egress and areas of risk. Maximum area per zone should not exceed 2090 m². Buildings of 300 m² or less may be considered as a single zone.
- (c) Control panels should have spare zone capacity. Panels should have minimum of two zones, even though the building may be a single alarm zone.
- (d) The control panels shall be a multi-processor based networked system designed specifically for fire and smoke control. The control panels shall include all required hardware, software, and site-specific system programming to provide a complete and operational system.
- (e) The control panel shall be diagnostic type and shall be designed such that interactions between any applications can be configured and modified using software provided by a single supplier.
- (f) When the panel is used with addressable fire detectors, the panel shall be capable of providing a signal which shall indicate fire/fault zone along with the detector which has operated by means of a digital Liquid Crystal Diode (LCD) display.

(8) MANUAL PULL STATION:

A manually operated device to initiate an alarm signal to fire alarm control unit.

(9) MAGNETIC DOOR HOLDER:

Under normal conditions, the electromagnet is energized to hold open the door. In the event of the fire, the control panel will automatically interrupt the voltage to the door holder(s) releasing the door(s) to prevent the spread of smoke. The units are suitable for wall or floor mounting installation.

(10) REMOTE ANNUNCIATOR PANEL:

The remote annunciator panel provides remote annunciation and control including acknowledging, silencing, resetting, and testing. Mounting installation shall be flush or recessed mounted type.

(11) BELLS AND HORNS:

Bells or horns should normally sound throughout the building, unless specified otherwise by NFPA 101. However, in a complex of buildings connected by covered walkways open to the outside, each building may be considered separate and the system may be designed to sound only the bells in the building from which the alarm signal originated. This will minimize disturbance of everyone else in the complex.

(12) STROBES LIGHTS:

Alarm strobe light, a visible notification appliance, shall be designed to provide hearing impaired individuals with a visual warning of a fire. These strobe lights shall be installed in locations where required and specified by NFPA 72 and IBC.

(13) ANALYSIS OF FAIL-SAFE OPERATION:

An analysis of each system will be made to determine the possible effects of fail-safe operation and the system will be designed accordingly. Relays will be coordinated with the emergency power supply so that undesirable operations will not occur upon power transfer. For example, in a power failure, it may be acceptable if doors held open by magnetic devices are released, but it would be totally unacceptable if a deluge system was actuated.

(14) POWER AND WIRING DETECTORS:

- (a) Power to the control panel must be fed from a reliable source of supply which will not be disconnected for maintenance on other electrical systems. The circuit breaker should be labeled "Fire Alarm - Do Not Switch Off" and should be capable of being locked. See NFPA 72A, Section 2-3 for detailed requirements. Standby power should be available to the system in case of mains power failure. This should be from sealed gel-cell type batteries in the control panel.
- (b) Signaling line circuit/Initiating device circuits shall be Class A, Style D.

(15) MISCELLANEOUS FIRE ALARM INTERFACE DEVICES/MODULES

- (a) Interface Device/Monitor Module.
- (b) Control Module.
- (c) Relay Module.
- (d) Isolator Module.

9.9 ACCESS CONTROL SYSTEM**(1) TECHNICAL REQUIREMENTS**

- (a) Access Control system shall be IP (internet protocol) based system that consist of, but not be limited to field installed door controllers, reader, gateways, electronic escutcheon, access control software, access cards, power supply units and other system components connected by a high speed electronic data transmission.
- (b) The network based access control system shall be provided featuring expandable modular design, networking capability, user definable access and reporting functions.
- (c) The access control system shall be integrated and communicated to the existing "central station" located at Royal Commission Industrial Security and Safety Department via IT network.

(2) DOOR CONTROLLERS

- (a) Controllers shall transmit alarms, status changes, and other data to the central station when communications circuits are operable. If communications are not available, controllers shall function in a stand-alone mode; operational data, including the status and alarm data normally transmitted to the central station, shall be stored for later transmission to the central station.
- (b) Controllers shall serve as an interface between the central station and sensors and controls.
- (c) Data exchange between the central station and the controllers shall include down-line transmission of commands, software, and databases to controllers.

(d) The up-line data exchange from the controller to the central station shall include status data such as alarms, status reports, and entry-control records.

(e) Controllers are classified as alarm-annunciation or entry-control type.

(3) PROXIMITY CARD READER

(a) A contactless card reader type that allow access to a person, typically, in a locked door. Proximity card reader shall be either short range or long range; it depends on the place and required range of application. One example of requirement for the long-range card reader is on vehicle entrance gate with arm barrier.

(b) The card reader shall be compatible with the IP door controller.

(c) They shall also allow for updating of the carrier via network technology making it possible to cancel lost or stolen cards remotely.

(4) POWER SUPPLY UNIT:

Uninterruptible power source for door controller shall provide battery back-up power in the event of primary power failure and shall automatically fully recharge the batteries after primary power is restored.

(5) OTHER DEVICES.

Where applicable, other devices for access control system such as magnetic contact, electromagnetic lock, push button, door strike, and etc. are to be utilized in the system.

(6) IP NETWORK:

The IP network for access control system shall be converged on the building Ethernet LAN network.

(7) WIRELESS SYSTEM ACCESS CONTROL

(a) If required, the wireless access control system shall be applied on doors of office rooms.

(b) PoE Gateway for Wireless Escutcheon

- The gateway shall serve as the link between the PC and the wireless network (wireless escutcheons). It shall provide real-time information to the PC.

(c) RF nodes shall be provided in the network to serve as a link between the gateway and the wireless network (wireless escutcheon).

9.10 INTRUSION DETECTION SYSTEM

(1) GENERAL

(a) System components shall be continuously monitored for normal, alarm, supervisory, and trouble conditions. Indicate deviations from normal conditions at any location in system. Indication includes identification of device or circuit in which deviation has occurred and whether deviation is an alarm or malfunction.

(b) Master control unit shall directly monitor intrusion detection devices, perimeter detection units, and connecting wiring in a multiplexed distributed control system or as part of a network.

(2) MASTER CONTROL UNIT OR INTELLIGENT SYSTEM CONTROLLER

- (a) Supervise sensors and detection subsystems and their connecting communication links, status control (secure or access) of sensors and detector subsystems, activation of alarms and supervisory and trouble signals, and other indicated functions.

(3) DOOR AND WINDOW MAGNETIC SWITCHES

- (a) Description: Balanced-magnetic switch, complying with UL 634, installed on frame with integral overcurrent device to limit current of switch capacity. Bias magnet and minimum of two encapsulated reed switches shall resist compromise from introduction of foreign magnetic fields.

(4) MICROWAVE-PIR DUAL TECHNOLOGY SENSOR:

Single unit combining a sensor that detects changes in microwave signals and a PIR sensor that detects changes in ambient level of infrared emissions caused by standard-intruder movement within detection pattern.

(5) AUDIBLE AND VISUAL ALARM DEVICES

- (a) Bell: Rated to produce a minimum sound output of 84db at 3 meters from master control unit.
- (b) Strobe: Xenon light complying with UL1638, with a clear polycarbonate lens. Lighting output shall be at no less than 115 candelas with a flash rate of 60 per minute.

SECTION 10

CORROSION PROTECTION AND CONTROL

10.1 GENERAL

10.1.1 SCOPE

This section covers the corrosion control and protection guidelines for Royal Commission facilities during design, construction, operation and maintenance stages. The facilities and equipment covered by this criteria includes reinforced concrete and steel structures, bridges, culverts, marine structures, water storage tanks, wastewater handling structures, pipelines, pipe supports, pipe racks, drainage channels and all other related equipment and hardware.

10.1.2 REFERENCES

- (1) Royal Commission at Yanbu Issued Reports
 - (a) Contract POM G-2422 Geotechnical investigation services
 - (b) Contract POM G-2404 Geotechnical investigation services
 - (c) Contract POM G-2424 Geotechnical investigation services
 - (d) Contract POM G-2425 Geotechnical investigation services
 - (e) Contract PID A-0050F Geotechnical investigation services
 - (f) Update of Coastal Modeling Study, Phase I (Desk Assessment) and II (Numerical Modeling Study), Delft Hydraulics.
 - (g) Geotechnical Investigation Report for Corniche Road Link from MYAS to Yanbu Al-Bahr at Royal Commission, MYAS, Osaimi Engineering Office.
- (2) Industry Standards
 - (a) Saudi Building Code (SBC)
 - i) Chapter 304, Concrete Structures.
 - ii) Chapter 304c, Commentary for Concrete Structures.
 - (b) American Concrete Institute (ACI)
 - i) ACI 214R, Evaluation of Strength Test Results of Concrete.
 - ii) ACI 222.2R, Corrosion of Prestressing Steels.
 - iii) ACI 222.3R, Guide to Design and Construction Practices to Mitigate Corrosion of Reinforcement in Concrete Structures.
 - iv) ACI 222R, Protection of Metals in Concrete Against Corrosion.
 - v) ACI 224R, Control of Cracking in Concrete Structures.
 - vi) ACI 305, Hot Weather Concreting.
 - vii) ACI 318, Building Code Requirements for Structural Concrete and Commentary.

- (c) America Society for Testing and Materials (ASTM)
 - i) ASTM A123, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
 - ii) ASTM A153, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
 - iii) ASTM A955, Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement.
 - iv) ASTM B695, Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel.
 - v) ASTM G3, Standard Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing.
 - vi) ASTM C76, Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe.
 - vii) ASTM C876, Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete
 - viii) ASTM C150, Standard Specification for Portland Cement.
 - ix) ASTM C618, Standard Specification for Coal Fly ash and Raw or Calcined Natural Pozzolan for use in Concrete.
 - x) ASTM C1218, Standard Test Method for Water-Soluble Chloride in Mortar and Concrete.
 - xi) ASTM C1240, Standard Specification for Silica Fume Used in Cementitious Mixtures.
- (d) American Association of State Highway and Transportation Officials (AASHTO)
 - i) AASHTO T277, Standard Method of Test for Rapid Determination of the Chloride Permeability of Concrete.
- (e) America Water Works Association (AWWA)
 - i) AWWA C105, Polyethylene Encasement for Ductile-Iron Pipe Systems.
 - ii) AWWA C151, Ductile Iron Pipe, Centrifugally cast.
 - iii) AWWA C301, Prestressed Concrete Pressure Pipe, Steel-Cylinder Type.
 - iv) AWWA C303, Concrete Pressure Pipe, Bar Wrapped, Steel-Cylinder Type.
 - v) AWWA D102, Coating Steel Water-Storage Tanks.
- (f) Society for Protective Coatings (SSPC)
 - i) Good Painting Practice, SSPC Painting Manual, Volume 1.
 - ii) Systems and Specifications, SSPC Painting Manual, Volume 2.
- (g) Construction Industry Research And Information Association (CIRIA)
 - i) C577, Guide to the construction of reinforced concrete in the Arabian Peninsula.
 - ii) R174, New paint systems for the protection of construction steelwork.

- (h) BSI, EN and ISO
 - i) BS EN 12496, Galvanic anodes for cathodic protection in seawater and saline mud.
 - ii) BS EN 12499, Internal cathodic protection of metallic structures.
 - iii) BS EN 15257, Cathodic protection. Competence levels and certification of cathodic protection personnel.
 - iv) BS EN ISO 13174, Cathodic protection of harbour installations.
 - v) ISO 12473, General principles of cathodic protection in sea water
 - vi) ISO 12696, Cathodic protection of steel in concrete
 - vii) ISO 12944 part 1-8, Corrosion protection of steel structures by protective paint systems.
 - viii) ISO 1459, Metallic Coatings - Protection Against Corrosion by Hot Dip Galvanizing.
 - ix) ISO 1460, Metallic Coatings - Hot Dip Galvanized Coatings on Ferrous Metals.
 - x) ISO 14713 parts 1-3, Zinc coatings - Guidelines and recommendations for the protection against corrosion of iron and steel in structures.
 - xi) ISO 2081, Metallic Coatings - Electroplated Coatings of Zinc on Iron and Steel
- (i) National Association of Corrosion Engineers (NACE)
 - i) NACE SP0187, Design Considerations for Corrosion Control of Reinforcing Steel in Concrete.
 - ii) NACE SP0290, Impressed Current Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Concrete Structures 2007.
 - iii) NACE SP0390, Maintenance and Rehabilitation Considerations for Corrosion Control of Atmospherically Exposed Existing Steel-Reinforced Concrete Structures.
 - iv) NACE RP0395-99, Fusion-Bonded Epoxy Coating of Steel Reinforcing Bars.
 - v) NACE SP0308, Inspection Methods for Corrosion Evaluation of Conventionally Reinforced Concrete Structures.
 - vi) NACE SP0408, Cathodic Protection of Reinforcing Steel in Buried or Submerged Concrete Structures.
 - vii) NACE SP0112, Corrosion Management of Atmospherically Exposed Reinforced Concrete Structures.
 - viii) NACE 10A392, Effectiveness of Cathodic Protection.
 - ix) NACE Publication 1E100, Engineering Symbols Related to Cathodic Protection.
 - x) NACE SP0169, Control of External Corrosion on Underground or Submerged Metallic Piping Systems.

10.1.3 EXPOSURE AND ENVIRONMENTAL CONDITIONS

(1) General

Madinat Yanbu Al-Sinaiyah industrial city (MYAS) is located at latitude 24° 00' N, longitude 38° 10' E and is within the west Red Sea coastal plain of The Kingdom of Saudi

Arabia. The plain is low in elevation and is covered in many areas, by up to 1m of dense silty sands or stiff sandy silts with underlying dense to very dense granular soils (sands, gravels, boulders and cobbles) which, in turn overlay tertiary limestone, shale, siltstone and sandstone or crystalline rocks.

The Red Sea coastal zone can be broadly divided into defined zones each of which is topographically distinct. Running parallel to the coast and few, about 10 to 32 km from MYAS is a range of mountains that comprise the scarp of the Arabian Shield. The rocks are pre-Cambrian and consist of a complex set of igneous and metamorphic rocks. Materials have eroded from these mountains to form the coastal plain, which consists of gravel and silt as a network of interlinked alluvial fans and gravel mounds. At many locations along the coastline, these deposits extend from the shoreline out to the coral reef, intermixing with the reef deposits

Corrosion is further intensified in the region by the effects of high relative humidity, high temperatures and high level of particulate and pollutants so the exposure conditions in MYAS are considered to be very severe. The parameters which are relevant to ensure an adequate durability of concrete or steel and equipment are detailed below.

(a) Climatic Conditions.

The climate in MYAS is considered to be an equatorial desert tempered by its location on the Red Sea coast. Rainfall tends to be orographic; consequentially the coastal areas receives substantially less rainfall than the nearby mountain range which occasionally produce considerable surface runoff in the local wadis. Whilst precipitation levels are low there can be occasional heavy rain, usually between November and March, causing the development of water courses and flash flooding in low-lying areas. The average relative humidity ranges from 60-70%, but it can vary from 10-100% throughout the day. Local air temperatures are summarized in Table 10-1

Table 10-1. Summary of seasonal air temperature in MYAS

PARAMETER	TEMPERATURE
Range of monthly maximums	35.1°C to 48.6°C
Range of monthly minimums	6.0°C to 12.0°C
Monthly mean daily maximums	27.5°C to 35.9°C
Monthly mean daily minimums	12.3°C to 26.0°C

(b) Soil.

Soils at the site are corrosive due to a high chloride and sulfate content, as is the ground water which can be found at depths as shallow as 0.50m below existing ground level. Chloride content in the soil varies from 0.009 4.677% while sulfate content ranges from 0.004 2.750%. Soil resistivity values vary from 0.002 to 9.430Ω-m and hydrogen ion concentrations are between pH 5.7 8.3. In some

locations, salt-bearing soils are absent and instead there exist terraces of coralline limestone overlooking the Red Sea. Further inland, localized deposits of argillaceous silts and gypsum outcrops can be found. West of the coastal plains, offshore coral banks and reefal limestone can be found either outcropping or covered with mostly carbonate sands. Moisture rise of saline groundwater through the salt-laden soil under the construction site is a major concern as these conditions exasperate premature deterioration through corrosion of below and near grade construction.

(c) Coastline

i) Local Tidal Range of the Red Sea

The vertical reference level YIC which relates to Lowest Astronomical Tide (LAT) is used and the relationship is $YIC = LAT + 0.47m$. The year-average mean sea level is $YIC + 0.1m$. Seasonal fluctuations cause the mean water level in winter to be higher than in summer. In the months August and September (summer) the water level is approximately 0.30m below mean, while in the months December and January (winter) it is approximately 0.20m above mean level. The tide is semi-diurnal with a daily inequality of about 0.06m. The mean tidal range is 0.30m, the mean spring tidal range 0.40m and the mean neap tidal range is 0.20m.

ii) Ocean Currents

Recent measurements carried out at about 3.20km offshore at deep water indicate the predominance of currents due to the sea breeze cycle above tidal currents. As a result, if long-period effects are ignored, a typical current pattern has a diurnal period with a smaller semi-diurnal fluctuation. The currents are usually mild, with velocities less than 0.25 ms^{-1} . Maximum velocities recorded (offshore) are about 0.50 ms^{-1} . Computed flow velocities on the reef were generally smaller than 0.30 ms^{-1} .

iii) Wave Pattern

The prevalent wave directions are westerly and north-westerly, which corresponds with the dominant offshore wind direction. The relevant offshore wave directions are for waves with significant height, where $H_s > 0.25m$ and from directions that can actually reach the coast in the MYAS area. Such waves occur approximately 30% of the time. During the remaining part of the year, the offshore waves are weaker or moving seaward.

iv) Seawater Temperature and Salinity

The natural sea water at large water depths offshore of Yanbu Port is characterized by temperatures of 24°C in the winter and up to 31°C in the summer. In the vicinity of Yanbu Port, the yearly temperatures vary from $21\text{-}32^\circ\text{C}$ and salinity varies between 39-43‰.

(d) Wind Patterns

Strong surface winds are common during winter and summer shamals, particularly during the daily temperature peak and generally during the latter half of the day. Dust and sand that is heavily laden with various salts are carried by the winds and then this deleterious matter is deposited on the surfaces of equipment and structures. Due to the hygroscopic behavior of these contaminants, moisture is absorbed from the air allowing surfaces of structures to remain wet for longer periods of time, especially when condensation is prevalent. This renders the dust conductive and activates the corrosion of any susceptible materials that are exposed to these pollutants. Sandstorms are also common and are often strong enough to have a detrimental effect through abrasion on protective coatings and other surfaces.

(e) Atmospheric-Corrosivity Category

It has been determined that the corrosivity category for MYAS is classified as C5M VERY HIGH (MARINE) as defined in ISO12944-2. This suggests an annual mass loss of carbon steel to corrosion of $<650\text{--}1500\text{g/m}^2$ and an extremely warm dry climate where ISO9223 predicts up to 1600 hours per annum when relative humidity is above 80%.

10.2 PROTECTION OF CONCRETE STRUCTURES**10.2.1 GENERAL**

Concrete structures in MYAS are subjected to very severe exposure conditions and therefore require special considerations to achieve their intended durability. The guidelines provided herein include all reinforced concrete structures.

10.2.2 FORMS OF CONCRETE DETERIORATION**(1) Chloride Induced Corrosion of Steel Reinforcement**

This is the most prevalent cause of concrete deterioration in MYAS as the majority of concrete used in the City is reinforced with mild steel. The high alkalinity of typical concrete allows the reinforcing steel to create a self-repairing, passive layer a few microns thick which protects it from corrosion. Chloride salts (from soil, groundwater, seawater or other sources) diffuse into the concrete mass and cause a breakdown of this steel's protective film allowing the onset of active corrosion cells. Chlorides also provide a willing catalyst to the electrochemical corrosion reaction which exasperates decay of the reinforcing steel. Rust is the corrosion product and being hydrated occupies considerably more volume than the original steel. This expansion causes tensile stresses in the cover concrete and when these exceed the tensile strength of concrete, the cover concrete suffers cracking, delamination and spalling. The result is loss of serviceability leading to a reduction in the structural capacity of the reinforced concrete member.

(2) Sulfate Attack

Sulfate attack is caused in concrete exposed to soil, groundwater and seawater by chemical reaction between hydrated cement and sulfate ions. Sulfate attack results in formation of expansive products which cause expansion of concrete leading to cracking.

Sulfate attack can also cause progressive loss of strength and mass due to deterioration in the cohesiveness of the cement hydration products.

If reinforcing steel is cast in to the concrete then this form of attack is also a precursor to corrosion of the now exposed reinforcing steel.

(3) Salt Crystallization

When concrete is exposed to wetting and drying by groundwater and seawater. It is caused by ingress of salts into concrete which crystallizes on drying leading to progressive crumbling or scaling of concrete. Salt crystallization leads to erosion of concrete surface and exposes the aggregate.

(4) Thermal Cracking

Cracking of concrete may be caused due to plastic shrinkage in freshly poured concrete or drying shrinkage in hardened concrete. Plastic and drying shrinkage are physical phenomena and cause tensile strain in concrete. When the associated tensile stress in concrete exceeds its tensile strength, cracking occurs.

10.2.3 EXPOSURE CONDITIONS

- (1) Concrete structures exposed to the following conditions shall be considered as severe exposure:
 - (a) Below ground and up to half meter above ground level
 - (b) Seawater and spray from seawater (splash zone, tidal zone and structures located within 500 m from the seashore)
 - (c) Interior of chambers (valve chambers, manholes etc.)
 - (d) Wastewater and chemicals
- (2) Concrete exposed to atmosphere and interior of air conditioned areas shall not be considered as exposed to severe conditions.

10.2.4 GUIDELINES FOR PROTECTION OF CONCRETE STRUCTURES

(1) General

Design and construction of durable concrete structures involve selection of adequate materials, adoption of proper design and construction techniques and provision of additional protection measures, as required, to prolong the service life to the design service life.

(2) Material Selection

(a) Cement Type

Saudi Building Code recommends ASTM C150 Type I cement with natural pozzolan for concrete exposed to very severe chloride exposure and ASTM C150 Type V cement with natural pozzolan for concrete exposed to very severe sulfate exposure. Similarly, ACI 318 recommends ASTM C150 Type V cement with pozzolan or slag for concrete exposed to very severe sulfate exposure.

Cement with a high C3A content is more resistant to chloride exposure than that with a low C3A content. This is due to the influence of C3A in binding more chlorides and reducing chloride diffusion coefficient of concrete.

Natural pozzolans increase resistance to reinforcement corrosion as well as sulfate attack due to improvement in impermeability of concrete.

Type of cement for different exposure conditions (as defined in Subsection 2.C) shall be as follows:

- i) For reinforced concrete exposed to severe conditions, use ASTM C150 Type I with natural pozzolan.
- ii) For reinforced concrete not exposed to severe conditions, use ASTM C150 Type I cement without natural pozzolan.
- iii) For unreinforced concrete exposed to severe conditions, use ASTM C150 Type V cement with natural pozzolan⁶.

(b) Water Cementitious Materials Ratio

Water-cementitious material ratio is the ratio of water to the sum of cement and natural pozzolan. Saudi Building Code recommends maximum water- cementitious material ratio of 0.40 for concrete exposed to very severe chloride exposure and 0.45 for concrete exposed to very severe sulfate exposure. ACI 318 recommends maximum water-cementitious material ratio of 0.45 for concrete exposed to very severe sulfate exposure. To ensure concrete durability in MYAS it is recommended that the maximum water-cementitious materials ratio for all concrete shall be limited to 0.40.

(c) Compressive Strength

Saudi Building Code requires minimum compressive strength of concrete of 35MPa for concrete exposed to very severe chloride exposure and 30MPa for concrete exposed to very severe sulfate exposure. ACI 318 recommends minimum 28-day compressive strength of 35MPa or 5000psi for corrosion protection of reinforcement in concrete exposed to moisture and chlorides from chemicals, salt water, brackish water, seawater, or spray from these sources. The minimum compressive strength of 35MPa is recommended for reinforced concrete exposed to severe conditions (as defined in Subsection 2.C). For un-reinforced concrete, a lower strength can be specified.

(d) Cement Content

Minimum cement content requirement is governed by maximum water cementitious material ratio, minimum compressive strength and workability. For a required water cementitious material ratio and compressive strength, a certain amount of cement is required to obtain a workable concrete mix.

⁶ Mineral admixtures such as silica fume conforming to ASTM C 1240, Class F fly ash or Class N natural pozzolan conforming to ASTM C 618

Saudi Building Code recommends minimum cementitious material (cement plus natural pozzolan) content of 370kg/m³ for concrete exposed to very severe chloride exposure and 350kg/m³ for concrete exposed to very severe sulfate exposure. A value of 370kg/m³ can be adopted for all reinforced concrete. A lower value can be used for unreinforced concrete.

(3) Design

(a) Cover

The quality and amount of cover over the reinforcing steel plays a very important role in protection of reinforcement against corrosion. ACI 318 specifies a minimum cover of 75mm for concrete cast against and exposed to earth. For concrete exposed to severe conditions (as defined in Subsection 2.C), the minimum cover shall be 75mm.

(b) Crack Control

One of the major causes of concrete deterioration in otherwise durable concrete is cracks. The cracks allow ingress of chlorides at an accelerated rate through concrete cover. Cracks are caused by stresses in concrete due to drying shrinkage, loads and settlement.

ACI 224R "Control of Cracking in Concrete Structures" provides a general guide for tolerable crack widths in reinforced concrete for different exposure conditions. A tolerable crack width of 0.30mm is recommended for concrete structures exposed to humidity, moist air and soil, and 0.15mm for structures exposed to seawater and seawater spray. The minimum tolerable crack width shall be 0.15mm for concrete exposed severe conditions (as defined in Subsection 2.C) and 0.30mm for concrete exposed to atmosphere.

The above crack width limits shall be used during the design process. However, ACI 224R cautions that these values of crack width are not always a reliable indication of the corrosion and deterioration to be expected. In particular, a larger cover, even if it leads to a larger surface crack, may sometimes be preferable for corrosion control in certain environments. Thus, the design team must exercise engineering judgment on the extent of crack control to be used. ACI 224R also provides recommendations for controlling cracks in different structural members.

(c) Reinforcement Detailing

Good detailing also helps in minimizing reinforcement corrosion risk. Using a large number of smaller diameter bars is preferable to small number of larger diameter bars. The maximum spacing between the bars shall be limited to 300mm. Large diameter bars shall be avoided in thin sections.

(4) Construction Practice

(a) Curing

Curing is essential to develop the potential properties of concrete. Concrete containing natural pozzolan is more sensitive to curing. Strength development of fly ash blended cement concrete is slower than plain concrete and hence, a prolonged curing period is required. Silica fume blended cement concrete has higher potential of cracking due to plastic shrinkage and its strength development is sensitive to early curing. Therefore, efficient curing during early days is required. The rate of strength development of concrete containing silica fume is either equal to or better than concrete without silica fume.

The minimum curing period shall be 14 days for all reinforced concrete with and without silica fume. However, the minimum curing shall be extended to 21 days for concrete containing fly ash as natural pozzolan.

(b) Hot Weather Concreting

Precautions shall be taken for concreting during hot weather. Recommendations provided by ACI 305R "Hot Weather Concreting" shall be followed. The temperature of concrete at delivery shall be limited to 30°C.

(c) Chloride and Sulfate Limits

Saudi Building Code and ACI 318 recommends maximum water soluble chloride ion content, as measured in accordance with ASTM C1218, of 0.15% by weight of cement for reinforced concrete exposed to very severe chloride exposure. This limit is reduced to 0.06% for prestressed concrete. As the exposure conditions in MYAS are characterized by presence of sulfates in soil and high ambient temperatures, which adversely affect chloride diffusion in service and reinforcement corrosion process, a more stringent value is applicable. Therefore, a value of 0.10% water soluble chloride content is adopted for MYAS. For pre-stressed concrete, the limit shall be reduced to 0.06%.

Sulfate (SO_3) content of cement allowed by ASTM C150 is 3% for Type I cement with C3a content of 8% and less, and 3.5% for C3a content of more than 8%. This is equivalent to approximately 4% of SO_4 content. Therefore, SO_4 content of hardened concrete shall be limited to a maximum of 4% for all concrete (reinforced and unreinforced).

(d) Chloride Permeability

Chloride permeability, as measured by methods described in AASHTO T277, is a convenient quality control test for concrete durability. Typical values of chloride permeability for 0.40 water/cement ratio concrete made with ASTM C150 Type I cement varies from 3500-5000 Coulombs and values when 10% silica fume is added to concrete range from 500-1000 Coulombs. Therefore, the maximum chloride permeability for plain, fly ash or natural pozzolans and silica fume concrete shall be 4,000, 2,000 and 1,000 Coulombs respectively.

(5) Additional Protection Measures

Depending on the design service life requirement, it may be necessary to provide additional protection systems. Some of the commonly used measures are concrete surface coatings, waterproofing and tanking, cathodic protection and alternative reinforcing materials. The Designer shall assess the exposure conditions and the design life and decide upon the required additional protection measures.

10.2.5 GUIDELINES FOR PROTECTION OF CONCRETE STRUCTURES

The guidelines on water cementitious material ratio, compressive strength, cement content, cover, crack control, reinforcement detailing, curing, hot weather concreting, chloride and sulfate limits and chloride permeability shall be followed for all concrete as discussed in the above sections.

A summary of the guidelines for the protection of concrete structures are given in Table 10-2

Table 10-2. Guidelines for protection of concrete structures

STRUCTURE	EXPOSURE CONDITION	CEMENT TYPE	ADDITIONAL PROTECTION
Superstructures (located 500m away from seashore)	Atmosphere	Type I	None
Superstructures (located within 500m from seashore)	Atmosphere	Type I with natural pozzolan ⁷	Protective coatings
Superstructures	Interior of air-conditioned areas	Type I	None
Foundation of buildings, bridges, culverts and other structures (buried and up to 0.5 m above ground/finished floor level)	Buried (soil/groundwater)	Type I with natural pozzolan ⁷	Waterproofing system

⁷ Natural pozzolan at 7% silica conforming to ASTM C1142, as cement replacement.

Table 10-2. Guidelines for protection of concrete structures

STRUCTURE	EXPOSURE CONDITION	CEMENT TYPE	ADDITIONAL PROTECTION
All reinforced concrete	Immersed in seawater and Spray from seawater (splash, tidal & atmospheric zones)	Type I with natural pozzolan ⁷	Impressed current cathodic protection
Pipe supports	Partially buried and exposed to atmosphere	Type I with natural pozzolan ⁷	Waterproofing membrane for buried concrete up to 150mm above ground level and concrete surface coating for exposed concrete
Piles	Buried (soil / groundwater)	Type I with natural pozzolan ⁷	None
Chambers and manholes	Interior of non-air-conditioned areas	Type I with natural pozzolan ⁷	Protective coatings
Interior of chambers handling wastewater and chemicals	Wastewater/chemicals	Type I with natural pozzolan ⁷	Protective coatings
Tanks (internal)	Potable/reclaimed water	Type I with natural pozzolan ⁷	Protective coatings
Tanks (bottom and external)	Potable/reclaimed water	Type I with natural pozzolan ⁷	Waterproofing membrane for buried concrete up to 150mm above ground level and concrete surface coating for exposed concrete
Unreinforced concrete (blind and leading concrete, mud-mat, anchor blocks etc.)	All conditions	Type V with natural pozzolan ⁷	None

Table 10-2. Guidelines for protection of concrete structures

STRUCTURE	EXPOSURE CONDITION	CEMENT TYPE	ADDITIONAL PROTECTION
CMU	All conditions	Type V with natural pozzolan ⁷	No contact with soil +300mm above

10.3 PROTECTION OF STEEL STRUCTURES

10.3.1 GENERAL

Steel structures in MYAS Industrial City are subjected one of the most severe exposure conditions in the world and therefore, require special corrosion control measures to achieve the intended durability. The guidelines provided herein include steel framed structures (such as buildings, pipe racks, bridges etc.), tanks, vessels and piles.

10.3.2 FORMS OF CORROSION OF STEEL

(1) Galvanic Corrosion

Galvanic corrosion occurs when two dissimilar metals come in contact in a conducting corrosive environment. The corrosion is stimulated by the potential difference that exists between the two metals, the more active metal acts as anode and corrode.

Galvanic corrosion can be minimized by selecting suitable metal couples in system design. If sufficient experience is not available to select compatible couples, the selection may be confirmed through laboratory testing. Wherever dissimilar metals are used, they shall be separated electrically with an electrical insulator. When insulation is not practical, the area ratio method may be used in the design. Coating the cathode only, or coating both the anode and the cathode, is generally preferable to avoid the unfavorable area ratio effect in a galvanic corrosion situation.

(2) Pitting

Pitting corrosion is localized accelerated dissolution of metal that occurs as a result of a breakdown of the otherwise protective passive film on the metal surface. Pitting can be avoided/minimized by coating the metal surfaces, periodic cleaning and designing shapes that prevent liquids or solids to collect.

(3) Crevice Corrosion

Crevice corrosion refers to corrosion occurring in confined spaces to which the access of the working fluid from the environment is limited. These spaces are generally called crevices. Examples of crevices are gaps and contact areas between parts, under gaskets or seals, inside cracks and seams, spaces filled with deposits and under sludge piles. Crevice corrosion can be avoided by minimizing and sealing crevices and cavities where the metal is susceptible to corrosion. The use of double butt or double lap weld joints, continuous welds, or nonporous filler materials is recommended to seal the crevice openings.

(4) Intergranular Corrosion

Intergranular corrosion, also known as intergranular attack, is a form of corrosion where the boundaries of crystallites of the material are more susceptible to corrosion than their insides. This situation can happen in otherwise corrosion-resistant alloys, when the grain boundaries of the corrosion-inhibiting elements are depleted, such as chromium by some mechanism. To minimize the effects of intergranular corrosion, the base metal and weld filler material shall be selected to be compatible with the specific environment. Laboratory tests, if necessary, may be specified as part of the materials selection process. Additionally, a qualified corrosion or metallurgical engineer shall be consulted on the need of other control measures such as stress relieving and heat treatment of susceptible metals.

(5) Stray Current Corrosion

Stray current corrosion, also called interference corrosion, is corrosion caused by direct current from an external source that travels through paths other than the intended circuit. Accelerated corrosion may result if the current is collected by a structure and discharges to the soil. Preventive measures include electrical insulation of the structure, equipotential bonding, shielding or cathodic protection.

10.3.3 GENERAL GUIDELINES FOR CORROSION CONTROL OF STEEL**(1) General**

Steel structures shall be designed to resist the exposure conditions to achieve the intended design service life of the structure. The most commonly used method of design and construction of durable steel structures involve material selection, protective coatings, cathodic protection and environment treatment.

(2) Material Selection

Material selection shall consider the service conditions to which the structure will be exposed to and shall involve a qualified metallurgical engineer. Suitable corrosion protection techniques shall be selected by a qualified corrosion control and coatings specialist.

Following guidelines shall be followed in selection of materials:

(a) Materials Selection Process

Most corrosion patterns are not uniform but highly localized. Therefore, it is important that all materials be evaluated on maximum penetration rates especially when considering structures containing products. Care shall be taken when substituting more noble alloys; while general corrosion rates are substantially lower, the mode of failure can be catastrophic (i.e. stress corrosion cracking, hydrogen embrittlement etc.).

(b) Galvanic Corrosion

When selecting materials for various components of a unit (ex. body and trim materials for valves or connecting pipework), care shall be taken to ensure use of

galvanically compatible materials. Electrical insulators and insulating sleeves shall be used to separate dissimilar metals from each other. In cases where providing insulation is not feasible, more noble metals shall be used for joining or fastening.

(c) Ferrous Alloys

Ferrous alloys that are buried in soil or exposed to marine environment are expected to corrode at higher rates. Therefore, such ferrous alloys shall be protected against corrosion by coating or cathodic protection.

(d) Galvanized Steel

Galvanizing alone cannot be expected to provide adequate protection for metals in outdoor, buried, or submerged applications. Particular attention shall be given to wherever galvanized components are electrically continuous with large structure as the galvanizing will provide very little advantage. Wherever galvanized steel is buried in soil or exposed to the splash zone or below, it shall be protected against corrosion by coating or cathodic protection.

(e) Aluminum

Aluminum shall not be buried, embedded in concrete or submerged in brine or chlorinated water.

(3) Protective Coatings

Application of protective coatings is the most commonly used method for corrosion protection of steel structures. Coatings may be used in conjunction with other methods, such as cathodic protection.

(4) Cathodic Protection

Cathodic protection is one of the most effective long-term methods for corrosion protection of steel structures exposed to aggressive conditions.

(5) Environmental Treatment

The treatment of environment shall be viewed as part of an overall strategy to enhance the performance of a system. Several control methods may be adopted, depending on the type and function of the systems. Typical treatment methods are oxygen removal, pH adjustment, dehydration, water removal, velocity control, sludge removal, temperature control, pressure control, addition of inhibitors, biocides and bactericides, entrained solid removal etc.

10.3.4 GUIDELINES FOR CORROSION CONTROL OF STEEL STRUCTURES

(1) General

- (a) Steel structures exposed to atmosphere shall be protected by hot dip galvanizing and/or protective coatings. The most suitable coating system type is based on epoxy resins with a urethane acrylic finish coat.
- (b) Buried steel structures shall be protected by protective coatings and cathodic protection.

- (c) Steel structures immersed in potable and reclaimed water shall be protected by protective coatings, the most suitable coating being epoxy.
 - (d) Steel structures exposed to seawater or other corrosive environment shall be protected by protective coatings and/or cathodic protection.
 - (e) Stainless steel structures exposed to seawater shall also be protected with cathodic protection.
- (2) Steel Framed Structures
- (a) Structures shall be designed to eliminate or minimize crevices and features that trap and hold dust and water. All crevices shall be suitably sealed.
 - (b) Steel framed structures shall not be buried and shall be protected against atmospheric corrosion by protective coatings. The most suitable coating system type is based on epoxy resins with a urethane acrylic finish coat.
 - (c) Steel members shall be embedded in concrete foundation. A base plate with anchors into the concrete foundation shall be used. The exposed anchor bolts shall also be coated with protective coatings.
 - (d) Provision shall be made for inspection and re-coating of the structures after the design life of the coating is exhausted.
- (3) Tanks and Vessels
- (a) Tanks and vessels shall be protected from corrosion internally as well as externally.
 - (b) Design of vessels shall include eliminating or minimizing crevices. All crevices shall be suitably sealed.
 - (c) Internal of potable and reclaimed water storage steel tanks shall be protected by protective coatings. The most suitable coatings are based on epoxy resins.
 - (d) Internal of vessels handling corrosive media (other than potable and reclaimed water) shall be protected by coatings and/or cathodic protection.
 - (e) External of potable and reclaimed water storage steel tanks shall be protected by protective coatings. The most suitable coating system type is based on epoxy resins with a urethane acrylic finish coat.
 - (f) The underside of the tank floors shall be protected by coatings and/or impressed current cathodic protection to avoid corrosion due exposure of the steel to soil.
- (4) Piles, if approved by the RCY
- (a) Steel piles and concrete piles with steel casing driven in soil shall be protected by protective coatings and cathodic protection (coating is prone to damage during driving). Piles exposed to atmosphere shall be protected by protective coatings.
 - (b) Steel piles driven in seabed shall be protected by protective coatings and cathodic protection. The cathodic protection shall be provided to the buried as well as immersed portions of the piles.
 - (c) Piles in the splash zone shall be corrosion protection tape or protective coatings or cathodic protection (jacket-type system). Piles exposed to atmosphere shall be protected by protective coatings.

(5) Other Structures

- (a) Suitable corrosion protection shall be provided for steel structures exposed to corrosive environments.
- (b) Light poles shall be protected by hot dip galvanizing. The base plates shall be protected by protective coatings, epoxy being the most suitable.
- (c) Metallic structures in seawater intake and discharge structures shall be protected by protective coatings and/or cathodic protection.

10.4 PROTECTION OF PIPELINES**10.4.1 GENERAL**

Buried pipelines in MYAS are subjected to severe exposure conditions and therefore require adequate corrosion protection. Provisions for inspection of the corrosion control system during service must also be designed into the project. The guidelines provided herein include ductile iron, prestressed concrete, concrete cylinder, reinforced concrete, carbon steel and cement lined carbon steel pipes.

Recommendations on protection of pipelines are given in Table 10-3.

Table 10-3. Recommendations on Protection of Pipelines

DESCRIPTION	RECOMMENDED USE	EXTERNAL PROTECTION	INTERNAL PROTECTION
Ductile iron (conforming to AWWA C151)	Potable water Reclaimed water	Pure metallic zinc (200g/m ²) with bituminous paint 120µm and polyethylene sleeve 200µm	High alumina cement mortar applied centrifugally and sealed with 400µm epoxy coating
Prestressed Concrete Pipe (conforming to AWWA C301)	Potable water Reclaimed water Seawater	Modified epoxy coating 400µm and/or Cathodic protection	Epoxy coating 400µm
Concrete Cylinder Pipe (conforming to AWWA C303)	Potable water Reclaimed water Seawater	Modified epoxy coating 400µm and/or Cathodic protection	Epoxy coating 400µm

Table 10-3. Recommendations on Protection of Pipelines

DESCRIPTION	RECOMMENDED USE	EXTERNAL PROTECTION	INTERNAL PROTECTION
Reinforced Concrete Pipe (conforming to ASTM C76)	Storm drains Culvert pipe	Modified epoxy coating 400µm	Modified epoxy coating 400µm
Cement Lined Carbon Steel Pipe	Potable water Reclaimed water Seawater	Epoxy or polyethylene coating and/or Cathodic protection	Cement mortar lining plus epoxy coating 400µm
Glass-fiber Reinforced Polyester Pipe (GRP conforming to AWWA C950 and ASTM C3517)	Potable water Reclaimed water Seawater Wastewater	None	None
Plastic Pipe (PVC conforming to SASO 14)	Potable water Reclaimed water Seawater Wastewater	None	None

10.4.2 NON-METALLIC PIPING SYSTEM

The Designer shall consider the selection of non-metallic piping system wherever applicable. All factors, such as, service, exposure conditions, life, cost (initial and life-cycle cost), maintenance requirements and other factors shall be considered for selection of piping system.

10.4.3 GUIDELINES FOR CORROSION CONTROL OF PIPES

- (1) Ductile Iron Pipes (conforming to ISO 2531 and AWWA C151).
 - (a) Ductile iron pipes are recommended for potable, reclaimed and sea water. They shall not be used for wastewater.
 - (b) Ductile iron pipes have been successfully used and have good track record in MYAS .
 - (c) Ductile iron pipes and fittings shall be lined internally with high alumina cement mortar applied centrifugally and sealed with 400 µm epoxy coating.
 - (d) Buried ductile iron pipes and fittings shall be protected externally by pure metallic zinc at the rate of 200g/m² and covered by 120µm bituminous coating. Additionally, the pipes and fittings shall be wrapped in polyethylene sleeves conforming to ISO 8180 and AWWA C 105. The sleeve shall be made of 200µm thick tubular film of low density polyethylene slipped over and tightly fitted to the pipe at the time of laying.

The sleeve is fitted to the pipe by means of adhesive plastic tape at each ends and intermediate tie fasteners.

- (e) Cathodic protection is not required for internal nor external protection of ductile iron pipes.
- (2) Prestressed Concrete Cylinder Pipes (PCCP) (conforming to AWWA C301)
 - (a) PCCP are recommended for potable, reclaimed and sea water service and are suitable for large diameter pipes. they shall not be used for wastewater.
 - (b) PCCP shall be protected internally by 400µm epoxy coating.
 - (c) Buried PCCP shall be protected externally by 400µm thick coal tar epoxy and/or cathodic protection.
- (3) Concrete Cylinder Pipes (CCP) (conforming to AWWA C303).
 - (a) CCP are recommended for potable, reclaimed and sea water service and are suitable for large diameter pipes. They shall not be used for wastewater.
 - (b) CCP shall be protected internally by 400µm epoxy coating.
 - (c) Buried CCP shall be protected externally by 400µm modified epoxy and/or cathodic protection.
- (4) Reinforced Concrete Pipes (RCP) (conforming to ASTM C76).
 - (a) RCP are recommended for storm drains and culvert pipes.
 - (b) RCP shall be protected internally and externally by 400µm modified epoxy coating.
- (5) Carbon Steel Pipes.
 - (a) Carbon steel may be used for potable, reclaimed and sea water service.
 - (b) Carbon steel pipes shall be protected internally by cement mortar lining and 400µm epoxy coating.
 - (c) Buried carbon steel pipes shall be protected externally by epoxy or polyurethane coating and/or cathodic protection.

10.5 PROTECTIVE COATINGS

10.5.1 GENERAL

Protective coating is one of the most commonly used corrosion control methods. Protective coatings are used for steel as well as concrete structures. Supplemental protection, such as cathodic protection, may be required for coated steel structures. A typical coating system includes primer, intermediate coat and top coat. All components of the coating system shall be compatible and shall be obtained from the same manufacturer.

10.5.2 COATING SELECTION CRITERIA

Protective coating systems design shall take into consideration the following factors:

- (1) Analyze or estimate the corrosivity of the environment in the area where the structure is located or is to be located.
- (2) Establish any special conditions which may affect the choice of coating system to be used.
- (3) Examine the design of the structure and make sure that corrosion traps have been avoided and adequate access has been provided for corrosion protection work.

- (4) Avoid galvanic corrosion by insulating dissimilar metals from each other.
- (5) Identify a coating system with the required durability for the relevant environment or from results of laboratory performance testing if no long-term experience is available.
- (6) When designing a coating system, take into consideration the method of surface preparation which will be used.
- (7) Make sure that damage to the environment and all health and safety risks are minimized.
- (8) Draw up a plan of work and select a method of application.
- (9) Establish a program of inspections to be carried out during and after the work.
- (10) Establish a maintenance program covering the whole service life of the structure.
- (11) Consider the lifetime cost and cost of maintenance of the chosen coating system.

10.5.3 COATING SYSTEMS FOR VARIOUS STRUCTURES

Recommended coating systems for various concrete and steel structures are summarized and detailed in Table 10-4, Table 10-5, and Table 10-6.

- (1) Concrete surfaces shall be cleaned prior to coating to remove loose material, oil, grease and dust. Imperfections in the surface shall be filled with epoxy filler. The coating system shall comprise penetrating epoxy sealer, intermediate and top coat.
- (2) Steel surfaces shall be prepared to the required preparation grade then abrasive blast cleaned to the relevant surface preparation standard.
- (3) All applied coatings shall be tested for dry film thickness, integrity, appearance and adhesion.

Table 10-4. Recommendations for Protective Coating Systems on Concrete

TYPE OF STRUCTURE	EXPOSURE CONDITION	RECOMMENDED SURFACE PREPARATION	RECOMMENDED COATING SYSTEM
Reinforced Concrete Structures within 500m from seashore	Marine	Clean surface and fill imperfections with epoxy filler	Epoxy sealing primer Amine cured modified epoxy 400µm Urethane acrylic 60µm
Reinforced Concrete Supports	Exterior (above ground)	Clean surface and fill imperfections with epoxy filler	Epoxy sealing primer Modified epoxy 400µm
Reinforced Concrete Chambers and Manholes	Interior	Clean surface and fill imperfections with epoxy filler	Epoxy sealing primer Modified epoxy 400µm
Reinforced Concrete Chambers Handling Wastewater and Chemicals	Interior	Clean surface and fill imperfections with epoxy filler	Epoxy sealing primer Modified epoxy 400µm
Reinforced Concrete Tanks	Interior	Clean surface and fill imperfections with epoxy filler	Epoxy sealing primer Modified epoxy 400µm
	Exterior	Clean surface and fill imperfections with epoxy filler	Epoxy sealing primer Modified epoxy 400µm Urethane acrylic 60µm

Table 10-5. Recommendations for Protective Coating Systems on Ferrous Steel

Part 1 of 2

EXPOSURE	UNPOLLUTED INTERIOR ARCHITECTURAL	UNPOLLUTED INTERIOR NON ARCHITECTURAL	POLLUTED INTERIOR ARCHITECTURAL	POLLUTED INTERIOR NON ARCHITECTURAL	EXTERIOR ARCHITECTURAL	EXTERIOR NON ARCHITECTURAL	EMBEDDED IN CONCRETE OR MASONRY
ISO RATING	ISO12944-C2	ISO12944-C2	ISO12944-C4	ISO12944-C4	ISO12944-C5M	ISO12944-C5M	ISO12944-C1
SSPC ZONE	N/A	N/A	SSPC SP1	SSPC SP1	SSPC SP1	SSPC SP1	SSPC SP1
STEEL PREPARATION	ISO8501-3 P2 SSPC SP1	ISO8501-3 P2 SSPC SP1	ISO8501-3 P2 SSPC SP1	ISO8501-3 P2 SSPC SP1	"ISO8501-3 P3 SSPC SP1"	ISO8501-3 P2 SSPC SP1	ISO8501-3 P2 SSPC SP1
SURFACE PREPARATION	SSPC SP10 NACE-2 ISO8501-SA2½ PROFILE 50-75µm Rz	SSPC SP8	SSPC SP10 NACE-2 ISO8501-SA2½ PROFILE 50-75µm Rz	SSPC SP10 NACE-2 ISO8501-SA2½ PROFILE 50-75µm Rz	SSPC SP5 NACE-1 ISO8501-SA3 PROFILE 50-75µm Rz	SSPC SP10 NACE-2 ISO8501-SA2½ PROFILE 50-75µm Rz	SSPC SP10 NACE-2 ISO8501-SA2½ PROFILE 50-75µm Rz
BASE COAT	HIGH BUILD EPOXY ZINC PHOSPHATE 100µm	HOT DIPPED GALVANIZED ASTM A123 (600g/m² 85µm)	ZINC RICH COATING LEVEL 1 SSPC PAINT20 TYPE I OR TYPE II 80µm	ZINC RICH COATING LEVEL 1 SSPC PAINT20 TYPE I OR TYPE II 80µm	ZINC RICH COATING LEVEL 1 SSPC PAINT20 TYPE I OR TYPE II 80µm	HOT DIPPED GALVANIZED ASTM A123 (915g/m² 130µm)	HOT DIPPED GALVANIZED ASTM A123 (915g/m² 130µm)
TIE COAT	N/A	N/A	LOW VISCOSITY EPOXY SSPC PAINT15 20µm	N/A	LOW VISCOSITY EPOXY SSPC PAINT15 20µm	LOW VISCOSITY EPOXY SSPC PAINT15 20µm	N/A
BUILD COAT	N/A	N/A	HIGH BUILD HIGH SOLIDS EPOXY BARRIER COAT SSPC PAINT42 100µm	N/A	HIGH BUILD HIGH SOLIDS EPOXY BARRIER COAT SSPC PAINT42 200µm	HIGH BUILD HIGH SOLIDS EPOXY BARRIER COAT SSPC PAINT42 100µm	N/A
FINISH COAT	TWO COMPONENT URETHANE ACRYLIC SSPC PAINT36 60µm	N/A	TWO COMPONENT URETHANE ACRYLIC SSPC PAINT36 60µm	N/A	TWO COMPONENT URETHANE ACRYLIC SSPC PAINT36 60µm	TWO COMPONENT URETHANE ACRYLIC SSPC PAINT36 60µm	N/A
INTUMESCENT TYPE	SOLVENT OR WATER BASED ACRYLIC	N/A	SOLVENT OR WATER BASED ACRYLIC BUT WITH ADDITIONAL FINISH COAT	N/A	EPOXY BASED	N/A	N/A
SITE TOUCH UP	SSPC PA1	ASTM-A780	SSPC PA1	ASTM-A780	SSPC PA1	GALV TO ASTM-A780 PAINT TO SSPC PA1	ASTM-A780
EXAMPLE	BUILDING INTERIORS WITH LOW LEVEL OF POLLUTION. WHERE CONDENSATION MAY OCCUR E.G. OFFICES, SHOPS, SCHOOLS, HOTELS, SPORTS HALLS, HOSPITALS	BUILDING INTERIORS WITH LOW LEVEL OF POLLUTION. WHERE CONDENSATION OCCURS, E.G. DEPOTS, SWIMMING POOLS, CHEMICAL PLANTS, LAUNDRIES, PRODUCTION ROOMS.	BUILDING INTERIORS WITH LOW LEVEL OF POLLUTION. WHERE CONDENSATION OCCURS, E.G. DEPOTS, SWIMMING POOLS, CHEMICAL PLANTS, LAUNDRIES, PRODUCTION ROOMS.	BUILDING INTERIORS WITH LOW LEVEL OF POLLUTION. WHERE CONDENSATION OCCURS, E.G. DEPOTS, SWIMMING POOLS, CHEMICAL PLANTS, LAUNDRIES, PRODUCTION ROOMS.	STEEL/IRON EXPOSED TO EXTERNAL ENVIRONMENT OR OFFSHORE ABOVE SPLASHZONE WITH VERY HIGH PERMANENT [MARINE] SALINITY		

Table 10-5. Recommendations for Protective Coating Systems on Ferrous Steel

Part 2 of 2

EXPOSURE	CONTACT WITH SOIL	SPLASHZONE OR SUBMERGED IN WATER (INCLUDING SEAWATER)	HIGH TEMPERATURE SERVICE	WATER DELIVERY SERVICE	SEAWATER DELIVERY SERVICE	CHEMICAL DELIVERY SERVICE
ISO RATING	iso12944-im3	iso12944-im2	N/A	N/A	N/A	N/A
SSPC ZONE	SSPC SP1	SSPC-2d	N/A	N/A	N/A	N/A
STEEL PREPARATION	ISO8501-3 P3 SSPC SP1	ISO8501-3 P3 SSPC SP1	ISO8501-3 P3 SSPC SP1	ISO8501-3 P3 SSPC SP1	ISO8501-3 P3 SSPC SP1	ISO8501-3 P3 SSPC SP1
SURFACE PREPARATION	SSPC SP5 NACE-1 ISO8501-SA3 PROFILE 75-100µm Rz	SSPC SP5 NACE-1 ISO8501-SA3 PROFILE 75-100µm Rz	SSPC SP5 NACE-1 ISO8501-SA3 PROFILE 50-75µm Rz	SSPC SP5 NACE-1 ISO8501-SA3 PROFILE 75-100µm Rz	SSPC SP5 NACE-1 ISO8501-SA3 PROFILE 75-100µm Rz	SSPC SP5 NACE-1 ISO8501-SA3 PROFILE 75-100µm Rz
BASE COAT	HIGH SOLIDS, MODIFIED EPOXY BARRIER COAT 400µm	HIGH SOLIDS, MODIFIED EPOXY BARRIER COAT 400µm	INORGANIC ZINC COATING LEVEL 1 SSPC PAINT20 TYPE I 80µm	N/A	N/A	CONSULT WITH ROYAL COMMISSION AND PROPOSE PRODUCTS COMPATIBLE WITH CHEMICAL SUBSTANCES CONCERNED FOR RC APPROVAL. 600µm
TIE COAT	N/A	N/A	SILICONE ALUMINUM 20µm	N/A	vinyl ester PRIMER COAT	
BUILD COAT	HIGH SOLIDS, MODIFIED EPOXY BARRIER COAT 400µm	HIGH SOLIDS, MODIFIED EPOXY BARRIER COAT 400µm	N/A	SOLVENT FREE EPOXY 500µm	VINYL ESTER GLASS FLAKE EPOXY 600µm	
FINISH COAT	TWO COMPONENT URETHANE ACRYLIC SSPC PAINT36 60µm	TWO COMPONENT URETHANE ACRYLIC SSPC PAINT36 60µm	SILICONE ALUMINUM 20µm	SOLVENT FREE EPOXY 500µm	VINYL ESTER GLASS FLAKE EPOXY 600µm	
SITE TOUCH UP	SSPC-PA1	SSPC-PA1	SSPC-PA1	SSPC-PA1	SSPC-PA1	SSPC-PA1
EXAMPLE	TANKS BOTTOMS, STEEL PILES, STEEL PIPES	STEEL/IRON PIPEWORK AND SUPPORTS, SLUICE GATES, JETTIES; OFFSHORE STRUCTURES	STEEL/IRON WITH OPERATING TEMPERATURES ABOVE 150°C BUT LESS THAN 450°C	INTERNAL SURFACES OF STEEL TANKS, STEEL/IRON PIPES USED TO CONTAIN OR DELIVER FIRE, IRRIGATION OR POTABLE WATER	INTERNAL SURFACES OF STEEL TANKS, STEEL/IRON PIPES USED TO CONTAIN OR DELIVER SEAWATER	INTERNAL SURFACES OF STEEL TANKS AND STEEL/IRON PIPES USED TO CONTAIN OR DELIVER

Table 10-6. Recommendations for protective coating systems on non-ferrous metals

SUBSTRATE	STAINLESS STEEL (ALL GRADES)	HOT DIPPED GALVANIZING	ALUMINUM	COPPER	OTHER NON- FERROUS METALS
SUBSTRATE PREPARATION	SSPC-SP1	SSPC-SP1	SSPC-SP1	SSPC-SP1	SSPC-SP1
SURFACE PREPARATION	SSPC-SP2	SSPC-SP2	SSPC-SP2	SSPC-SP2	SSPC-SP2
	SSPC-SP3	SSPC-SP3	SSPC-SP3	SSPC-SP3	SSPC-SP3
	SSPC-SP16	SSPC-SP16	SSPC-SP16	SSPC-SP16	SSPC-SP16
BASE COAT	TWO PACK POLYVINYL BUTYRAL PRIMER SSPC-PAINT27	TWO PACK POLYVINYL BUTYRAL PRIMER SSPC-PAINT27	TWO PACK POLYVINYL BUTYRAL PRIMER SSPC-PAINT27	TWO PACK POLYVINYL BUTYRAL PRIMER SSPC-PAINT27	TWO PACK POLYVINYL BUTYRAL PRIMER SSPC-PAINT27
	30µm	30µm	30µm	30µm	30µm
FINISH COAT	TWO COMPONENT URETHANE ACRYLIC	TWO COMPONENT URETHANE ACRYLIC	TWO COMPONENT URETHANE ACRYLIC	TWO COMPONENT URETHANE ACRYLIC	TWO COMPONENT URETHANE ACRYLIC
	SSPC-PAINT36	SSPC-PAINT36	SSPC-PAINT36	SSPC-PAINT36	SSPC-PAINT36
	60µm	60µm	60µm	60µm	60µm
SITE TOUCH UP	SSPC-PA1	SSPC-PA1	SSPC-PA1	SSPC-PA1	SSPC-PA1

10.6 CATHODIC PROTECTION

10.6.1 GENERAL

Cathodic protection design, installation and commissioning shall be carried out by qualified engineers and contractors. Various factors to be considered prior to design of a cathodic protection system are type of structure to be protected, electrolyte resistivity, presence of other facilities and cathodic protection systems and stray current, right of way for locating cathodic protection hardware, availability of ac power and other factors. Design information provided shall include design calculations, material and installation specifications, commissioning requirements and provisions for monitoring. All cathodic protection systems shall be monitored by the installation contractor for one year prior to handing over the system to the Royal Commission.

10.6.2 CATHODIC PROTECTION SYSTEMS DESIGN CRITERIA

(1) Reinforced Concrete.

- (a) Design current density for new reinforced concrete shall at least be 5 mA/m² of steel reinforcement area.

- (b) Design current density for existing reinforced concrete shall at least be 20 mA/m² of steel reinforcement area.
 - (c) Protection criteria shall be an instant off potential of -720 mV or more negative with respect to silver-silver chloride electrode or potential decay of at least 100 mV over a period of 24 hours or 150 mV over extended period of time.
- (2) Steel Structures.
- (a) Design current density for tank bottoms, buried piles and buried bare pipeline shall at least be 20mA/m² of steel area. For coated steel piles and pipes, the value shall depend on the type of coating; a value of 0.1-1.0 mA/m² can be adopted.
 - (b) Design current density for bare steel piles exposed to seawater shall at least be 150 mA/m² (initial) and 70 mA/m² (mean) of steel area. For coated steel, the design current density can be based on a coating breakdown factor of 10%.
 - (c) Protection criteria for steel exposed to soil and seawater shall be an instant off potential of 800 mV or more negative with respect to silver-silver chloride electrode.

10.6.3 CATHODIC PROTECTION SYSTEMS FOR DIFFERENT STRUCTURES.

- (1) Reinforced Concrete.
- (a) For new reinforced concrete, mixed metal oxide coated titanium expanded mesh ribbon anodes from a qualified manufacturer with sufficient track record shall be used. The anodes shall be placed in the cover concrete or between two layers of the reinforcement. Titanium conductor bar shall be used for current distribution.
 - (b) For existing reinforced concrete, mixed metal oxide coated titanium mesh anodes from a qualified manufacturer with sufficient track record shall be used. The anodes shall be placed on the existing concrete surface and covered in a cementitious overlay. Titanium conductor bar shall be used for current distribution.
 - (c) The structure shall be divided in zones of suitable sizes and each zone shall be fed from a dedicated power supply channel.
- (2) Steel Tanks and Vessels.
- (a) For new tanks, mixed metal oxide coated titanium ribbon anodes from a qualified manufacturer with sufficient track record shall be used. The anodes shall be placed in soil under the tank in the form of parallel strips running in one direction. Titanium conductor bar shall be used for current distribution and shall be placed perpendicular to the anodes.
 - (b) For existing tanks, mixed metal oxide coated titanium tubular or high silicon cast iron anodes from a qualified manufacturer with sufficient track record shall be used. The anodes shall be placed in drilled holes around the tank. The depth of the anodes shall be determined in the design calculations.
 - (c) Each tank shall be fed from a dedicated transformer rectifier or a dedicated channel of a multi-channel transformer rectifier.
- (3) Steel Pipelines.
- (a) For new and existing pipelines, different types of anodes can be used. The type of anode shall be manufactured by from a qualified manufacturer with sufficient track record.

- (b) Use of deep well anodes may be used for cross country pipeline, however, distributed anodes shall be used for pipelines inside plants and if other structures exist in the vicinity of the pipeline.
- (4) Steel Piles.
 - (a) For new and existing steel piles buried in soil or submerged in seawater, sacrificial or impressed current anodes may be used. Sacrificial aluminum anodes shall preferred for piles in seawater. The impressed anodes may include mixed metal oxide coated titanium tubular anodes for seawater and mixed metal oxide coated titanium tubular and high silicon cast iron anodes for soil.

10.6.4 MONITORING OF CATHODIC PROTECTION SYSTEMS.

- (1) All cathodic protection systems shall be regularly monitored to ensure proper functioning of the systems and to upgrade them, as required.
- (2) The frequency of monitoring for sacrificial anode systems shall be six months. The monitoring shall include measuring anode current and structure-to-soil potentials.
- (3) The frequency of monitoring for impressed current systems shall be as follows:
 - (a) Monthly: Inspect condition of the hardware and measure transformer rectifier output.
 - (b) Semi-Annually: Inspect condition of the hardware, measure transformer rectifier output and structure-to-soil potentials (on, instant-off and decay).
 - (c) Three-years: Conduct complete system check including analysis of the monitoring data for the previous period.

SECTION 11

LANDSCAPE DESIGN

11.1 GENERAL

In order to maintain design uniformity throughout the community, landscape design shall be guided by:

- (1) Parks, Recreation & Landscape Guidelines - Vol I The Master Plan Report
- (2) Parks, Recreation & Landscape Guidelines - Vol II Landscape Design Manual.

which provide design criteria and guidelines for the landscaping of both public and private areas; provide specific requirements and recommendations regarding soil improvement and irrigation systems; identify geographic areas and recommend plant selection for specific land use within each area; and provide a maintenance program.

11.2 LANDSCAPE PLANTING

11.2.1 PLANT MATERIALS

- (1) Trees planted in linear or other geometric formations shall be specified to be matched, and planted plumb and true in complete alignment with the adjacent trees. If natural, more informal growing of trees are detailed in the design, then care shall be taken to specify various heights, multi-trunks, and low branching characteristics. Trees planted in paving shall have their clearance specified in the plant schedule from the ground to the first branch and shall be planted plumb, straight, and true in the exact center of the paving cut out.
- (2) Palm heights shall be specified as the amount of clear trunk from the ground to the base of the first frond. As for trees, matched Palms or multi-trunk Palms shall be specified depending upon the design intent. When specified as multi-trunks, the clear trunk height of each trunk shall be given.
- (3) Specification of sizes & spacing of plants shall be made so that the installation yields a fully covered planting area upon maturity.
- (4) Full Plant specifications including height, spread, caliper, number of canes, stems or trunks, container size, and pertinent remarks shall be given as applicable for each plant, and shall be shown on the plant schedule (See Subsection 11.2.3, Landscape Plant Schedule).
- (5) Minimum requirements of Plant Materials to be specified in construction bid documents are summarized as follows:

(a) Ground Cover	-	well-rooted cuttings grown in flats or young plants in 10 cm pots.
(b) Small shrubs,	-	well rooted & branched young
(up to 1.5 M		plants in 4 liter containers, once
O.C. spacing)		transplanted

- (c) Medium & - well rooted & branched plants in
Large Shrubs 19 liter containers, twice transplanted
- (d) Tree whips, trees planted - 1.75 m Hgt., 1.3 cm Caliper in
well ahead of residential 19-liter container
occupancy/ general use
- (e) Large trees, street/area - 3.0 m Hgt., 3.2 cm Caliper, with
trees where residential 30 cm root ball, well branched with
occupancy/ general use sturdy structure
in immediate vicinity.

(6) All planting materials shall be certified free of pest and diseases.

11.2.2 STANDARD PLANTING REQUIREMENTS

This section identifies required typical notes and details for landscape planting construction documents in Madinat Yanbu Al-Sinaiyah (MYAS).

- (1) Preparation of plant pits, beds, and installation of all plants shall be in accordance with the standard details and as described in the specifications. Situations requiring exceptions shall be fully detailed and documented by the landscape designer prior to the Preliminary Design submittal and shall be approved by the Royal Commission prior to design completion.
- (2) All areas to be planted shall be tested for percolation and where the penetration rate is less than 25 mm per hour, additional drainage holes shall be augured and filled with sand until the percolation rate exceeds 25 mm per hour.
- (3) Planting soil in tree and shrub areas shall always have a finish grade 50 mm below adjacent finish grades paving. Planting soil in lawn areas shall always have a finish grade 25 mm below adjacent finish grades.
- (4) The quality and size of all plants shall be fully specified. The Royal Commission may reject non-conforming plant materials at any time during the construction contract period.
- (5) All plants shall be from approved MYAS plant list, or suitable to hot arid environment with irrigation.
- (6) The construction contractor will be required to acclimate all specified species under field conditions in the MYAS climate and environment.
- (7) All planting procedures and operations shall be rigidly enforced in accordance with the specifications.
- (8) All special situations, conditions and requirements for installation or maintenance pertaining to the intended design effect shall be clearly detailed and noted on the drawings by the landscape designer.
- (9) Turf areas (grass) shall be designed in accordance with existing MYAS policy and shall be constructed according to the specifications. Where suitable and approved,

hydromulching may be specified, but shall be accomplished by personnel experienced in this technology.

(10) The following criteria for shrubs and groundcovers shall guide the placement of plants to maximize aesthetic effect and minimize maintenance.

- (a) The minimum width planting area able to accept a shrub or groundcover shall be 1 times the on-center spacing.
- (b) The minimum setback of shrubs and ground- covers from the face of buildings to free standing walls shall be the on-center spacing.
- (c) The minimum setback of shrubs and ground- covers from sidewalk edges shall be equal to the on-center spacing.
- (d) The minimum setback of shrubs and ground- covers from curb edges shall be 1 times the on-center spacing.
- (e) No shrubs or groundcovers shall be planted in primary road medians, where the planting area is less than two meters wide.

(11) Interior landscaping in controlled environments shall generally utilize hydroponic irrigation technology with careful consideration and evaluation of interior space requirements, circulation patterns, light levels and HVAC system effects. Interior tree specimens shall be grown in a 50%/50% medium of sand and organic matter.

11.2.3 LANDSCAPE PLANT SCHEDULES

- (1) Every landscape planting package (plans) shall include a lead drawing(s) containing a Master Plant Schedule as following the general format of Table 11-1
 - (a) One per construction package should be located in the front of the package following abbreviation sheet, general notes, symbols, etc
 - (b) All plants used to the contract shall be listed alphabetically within the following divisions:
 - i) Trees
 - ii) Shrubs
 - iii) Ground cover and vines
 - iv) Grass
 - (c) Typical remarks include, single trunk matched trees, clearance from ground to first branch multi-trunk, clump, number of trunks, of stems, caney or runners, flower color, single or double flower, planting/ staking detail reference, cultural notes, source of plant material, acceptable substitutions.

Table 11-1. Master Plant schedule (Example)

No.	Quantity	Symbol or Abbreviation	Botanical Name	Common Name/Color	Specification			Container or Root Ball Size	Irrigation Type (Water conserving or full value)	Remarks
					Height	Spread	Caliper Size			

- (2) Each Planting Plan shall include the following information pertaining to that specific drawing location as illustrated below.
 - (a) Location Plan
 - (b) Plant List with Quantities
 - (c) Plant Specification (height, caliper... etc.)
 - (d) Notes

Quantity	Abbreviation	Botanical Name
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11.3 IRRIGATION

11.3.1 IRRIGATION DESIGN CRITERIA

The following criteria shall be taken into consideration and incorporated into the design of the irrigation systems.

- (1) Deep watering devices utilizing drip or bubbler systems as approved shall be installed for all street trees and other trees surrounded by paving to discourage surface rooting.
- (2) As a general rule, water conserving and full value species shall not be mixed on one remote control valve. However, water conserving and full value species may be irrigated on the same remote control valve with appropriate adjustments in operational outlets to account for required irrigation regimes for the individual species in the proposed plant mix.
- (3) Due to the possibility of non-proportional irrigation rate adjustments during growth and at maturity, trees shall not be mixed with other plantings on the same remote control valve zone. Shrubs and ground cover may be irrigated on the same zone.
- (4) Multi outlet drip emitters shall be used for irrigating shrubs and ground cover only.
- (5) A minimum of two bubblers shall be used per tree.
- (6) In general non-potable water, Treated Sewage Effluent (TSE) shall be used for irrigation. For areas such as mosques, schools, hospitals and lawns potable water shall be used for irrigation with the prior approval from R.C.
- (7) Tertiary distribution design in large mass planting areas shall incorporate header mains and branches of short length where practicable in lieu of lengthy, convoluted, single distribution lines.
- (8) Where tertiary distribution design incorporates several branches, the remote control valve shall be located as close to the midpoint of the branching as is practicable to balance the distribution.
- (9) Irrigation system design(s) shall incorporate maximum adjustment flexibility at the timing controller to reduce in-field maintenance requirements and adjustment, maximum effectiveness, and efficiency of water application.

The following objectives shall be exhibited in all systems:

- (a) Suitability for use with MYAS treated sanitary effluent (TSE).

- (b) Maximum efficiency of water use (no ponding of irrigation water). Flood irrigation is not acceptable.
- (c) Salt dispersal from the soil through leaching by downward movement of soil water.
- (d) Minimizing water loss and upward salt movement by minimizing surface evaporation.
- (e) Flexibility in use to encourage slow or rapid growth, deep or shallow roots, response to high or low demand planting as appropriate to aesthetic and site related conditions.
- (f) Cost effectiveness in terms of capital investment, efficiency, life expectancy and maintenance requirements.
- (g) Operation and maintenance requirements.

11.3.2 IRRIGATION CALCULATION DATA

- (1) Calculations are to be divided into three groups.

- (a) Irrigation Demand Calculations
- (b) Hydraulic Calculations
- (c) Controller Calculations

In the design analysis submittals, the contractor shall show the relationships between these three and demonstrate how they substantiate each other.

- (2) Irrigation Demand Calculations

The following irrigation rates shall be used for demand calculations:

	FULL VALVE (FV)* PLANTINGS	WATER CONSERVING (WC)* PLANTINGS
Trees	100 litres/tree/day	60 litres/tree/day
Shrubs &	10 litres/m ² /day	6 litres/m ² /day
Grd. cover Lawn	15 litres/m ² /day	--

* Refer to MYAS Standard Plant List for FV and WC species.

These are average figures for peak demand under worst summer conditions. They also include a 15% leaching factor. Shrubs include groundcovers and vines. Large shrubs planted individually shall be treated as trees. Otherwise, all shrubs and groundcovers will be planted in beds that will be mass excavated. The irrigation demand for these shrubs and groundcovers will be based on the square meter area of bed excavated.

Irrigation demand calculations shall be supplied complete and in the following format:

TSE

Total Area allocation For each Remote m³/day

Control Valve:

_____ No. trees at 100 liters/tree/day	=	
_____ No. trees at 60 liters/tree/day	=	
_____ m ² shrubs at 10 liters/m ² /day	=	
_____ m ² shrubs at 6 liters/m ² /day	=	
Subtotal	=	liters/day ÷ 1000 = m /day

POTABLE

Total Area allocation For each Remote m³/day

Control Valve:

_____ No. trees at 100 liters/tree/day	=	
_____ No. trees at 60 liters/tree/day	=	
_____ m ² shrubs at 10 liters/m ² /day	=	
_____ m ² shrubs at 6 liters/m ² /day	=	
_____ m ² lawn at 15 liters/m ² /day	=	
Subtotal	=	liters/day ÷ 1000 = m /day

A summary calculation sheet shall identify all individual remote-controlled valves, the demand quantity (subtotal) for each valve, and shall show the accumulative valve demands compared to the total area allocation.

(3) Hydraulic Calculations

Hydraulic calculations for secondary irrigation mains from the primary distribution mains to the solenoid remote control valves shall be provided in a format approved by the Royal Commission.

- (a) Pipe size calculations for secondary irrigation mains shall include piping layout, locations, and quantity of flow through each Remote-Controlled Valve (RCV). The maximum flow from a combination of the RCV used as the basis of the design shall be clearly indicated. Secondary irrigation mains shall be designed as a loop system.

Hydraulic calculations for tertiary irrigation lines from the solenoid remote control valve to the end of the distribution system shall contain the following information for every valve.

- (a) Remote Control Valve (RCV) identity numbers.
- (b) Total quantity of sprinklers, emitters (or bubblers) and flow rate for each.
- (c) Pressure loss in system, flow rates, and length of longest run (for branched distribution).
- (d) RCV pressure setting and available pressure at the RCV inlet.

- (e) RCV size, flow rate, duration of valve operation, and total water volume through valve.
- (f) Piping diagrams for each tertiary irrigation line showing pipe sizes length, outlet spacing, and outlet discharge rate.

(4) Controller Calculations

Controller clock settings shall be given, demonstrating how each valve will efficiently supply the correct amount of water to the plants at installation and maturity. Notes shall be made regarding the adjustments required to constantly maintain efficient water application.

Additionally, controller capacity shall be maintained to provide leaching on a two week interval (if required) for each and every valve on the controller.

Efficiency is defined as applying the minimum water required to satisfy every plant type without overwatering any other plant type.

11.3.3 IRRIGATION SCHEDULES

The following schedules and diagrams shall be a part of every irrigation design:

- (1) Controller schedule settings for initial and mature plantings.
- (2) Primary wire sizing schematic diagram from power sources to field control module.
- (3) Field control module and wire size schedule.
- (4) Single line schematic diagram from field control module to remote control valves.
- (5) Irrigation Component Schedule including plan symbol, description of component, manufacturer name and part number, detail reference and specification reference.

11.3.4 IRRIGATION CABLE SYSTEM

The irrigation system controller shall be suitable for operation on 230 Vac normal power input. The remote control valve shall be capable of operating on 24 Vac.

Minimum copper conductor cable size for primary feeder and secondary irrigation control cable shall be 4 mm² and 2.5 mm², respectively.

Irrigation cables shall be installed direct-buried in accordance with Royal Commission standard drawing and specification. Secondary irrigation cable shall be bundled to irrigation water pipes. Under paved areas, cables shall be installed in conduits.

SECTION 12

INTERFACE DOCUMENTATION

12.1 GENERAL

The interface documentation requirements defined herein shall be implemented by all interfacing design agencies throughout the development of Madinat Yanbu Al-Sinaiyah. The principal objectives of this document are to: (1) establish a uniform and consistent format of interface identification, (2) provide a means for tracking and controlling interfaces, and (3) provide for the orderly and timely flow of information among interfacing design agencies.

12.2 SCOPE

The interfaces addressed herein are limited to the external interfaces with other design agencies.

12.3 INTERFACE DOCUMENTATION

An interface document shall be included with each required submission. This document shall separately address each interface identified in specific project requirements as well as all other interfaces that may result during the design phase. This document shall depict in detail all physical and functional characteristics to: (1) completely define the interfaces that are being established by this design to be extended and/or used by others and (2) define how this design conforms to the interfaces established by others that are in places to be extended by this design.

The principal means of transmitting and documenting interface information will be drawings. An alpha numeric numbering system, keyed to each discipline, shall be used to specify and identify each interface point. All interface drawings shall be identified by drawing number prefix "IF". However, to fully define and describe an interface, supplementary written technical data or instructions may be necessary. The interface document shall provide a composite drawing indicating all interfacing contracts and their related drawing numbers. Elevations of interfaces shall also be shown. The interface document shall stand alone and shall only include information that is pertinent in defining or satisfying an interface.

Interface drawings shall be standard A1 size and shall include a plan view (scale 1:200) and profile (scale 1:200 horizontal; 1:50 vertical) of the interface. All existing utilities and utilities to be installed must be differentiated. A sample format is available on request from the Royal Commission.

12.4 INTERFACE CONSIDERATIONS

The following paragraphs define considerations in establishing, describing, and depicting interfaces.

- (1) Functional Characteristics: Functional characteristics shall include, but not be limited to, such items as loads, flow rates, pressures, phasing, and percent regulation.

- (2) Physical Characteristics: Physical characteristics shall include, but not be limited to, such items as location, space requirements, size, material, and routing.
- (3) Interference: Interferences can be either physical (e.g., a waterline running into a sewerline) or functional (e.g., radio stations operating on the same frequency). It is the responsibility of the designer to lay out and design his elements or systems on a noninterference basis with other project elements or systems.

12.5 CHANGES

All changes to an established interface must have prior approval from the Royal Commission.

12.6 PROCEDURE TO SHOW NEW WORK ON EXISTING AS-BUILT DRAWINGS

In many cases, there are existing common systems and equipment that are to be shared or interfaced by the contractor's new work and the contractor may need to show either some or all of his work on the existing original "As-Built" drawings. The following criteria shall be followed.

Case 1 – When only an interface to be shown on existing As-Built drawing

- (1) When an interface is required with an existing "As-Built" drawing and the contractor's main work has to be shown on a new drawing prepared by him under the current contract, the contractor shall show an interface point on the existing "As-Built" drawing and show appropriate reference to the new contract drawing number.
- (2) The contractor shall show a new Revision in the "Revision Box" of the existing "As-Built" drawing that will indicate that the drawing has been revised under the new contract. The drawing number of the existing "As-Built" drawing shall, of course, remain unchanged and the drawing will be returned to the existing contract for filing after a Mylar copy, if available, has been made for inclusion in the set of design drawings for the new contract.
- (3) Both the existing "As-Built" drawing and the new drawing shall provide appropriate cross references as necessary.

Case 2 - When contractor's new work to be shown on existing As-Built drawing

- (1) The contractor shall obtain the existing "As-Built" drawing from the Royal Commission files. The contractor must retain the existing title block, the existing drawing number and the existing contract number.
- (2) A new revision in the Revision Box" will indicate that the drawing has been revised/modified under the new contract.
- (3) The drawing will provide appropriate reference to new contract drawings, as applicable.
- (4) The existing "As-Built" drawing must be returned to Royal Commission to be filed under the existing contract after a Mylar copy, if available, has been made for inclusion in the set of design drawings for the new contract.
- (5) The contractor's new drawing list under the current contract shall include the revised "As-Built" drawing number from the existing contract.

In many cases, the existing "As-Built" drawings are in very poor shape and barely legible. A new drawing may be required to replace the existing "As-Built" drawing. The procedure to replace an existing "signed (by RCM) and stamped As-Built" drawing may not always be

same in all cases and may require a differential treatment as noted below. The matter should be brought to the attention of the Authorized Representative (PE or RCM) for proper resolution.

- In some cases, a note and a reference in the existing “As-Built” drawing to indicate that the drawing has been replaced (or voided) with a new drawing under the current contract will suffice. A new drawing number will be assigned to the replacement drawing and the existing “As-Built” drawing will be returned to be filed with the existing contract
- But in other cases, the existing drawing number will be retained on the replaced drawing and filed with the existing contract. The contractor’s new drawing list under the new contract will include the replaced drawing from the existing contract.
- In any case, drawing sets in the new contracts must be complete with copies of affected drawings from As-Built files. The integrity of As-Built drawing files, including drawing numbering, must be preserved. Cross referencing and information documentation on affected As-Built drawings and affected drawings in new project drawing files must provide adequate direction for quick and easy assimilation of total system and/or facility design records.

12.7 SURVEY CONTROL AND DOCUMENTATION

12.7.1 SITE DESIGN AND DEVELOPMENT

- (1) All coordinates and elevations shall be based on Madinat Yanbu Al-Sinaiyah (MYAS) grid and elevation datum.
- (2) The coordinate system used is a plane rectangular in meters, based on a local arbitrary grid established by Hunting Surveys Ltd. in 1977.

12.7.2 SURVEY CONTROL AND DATUM

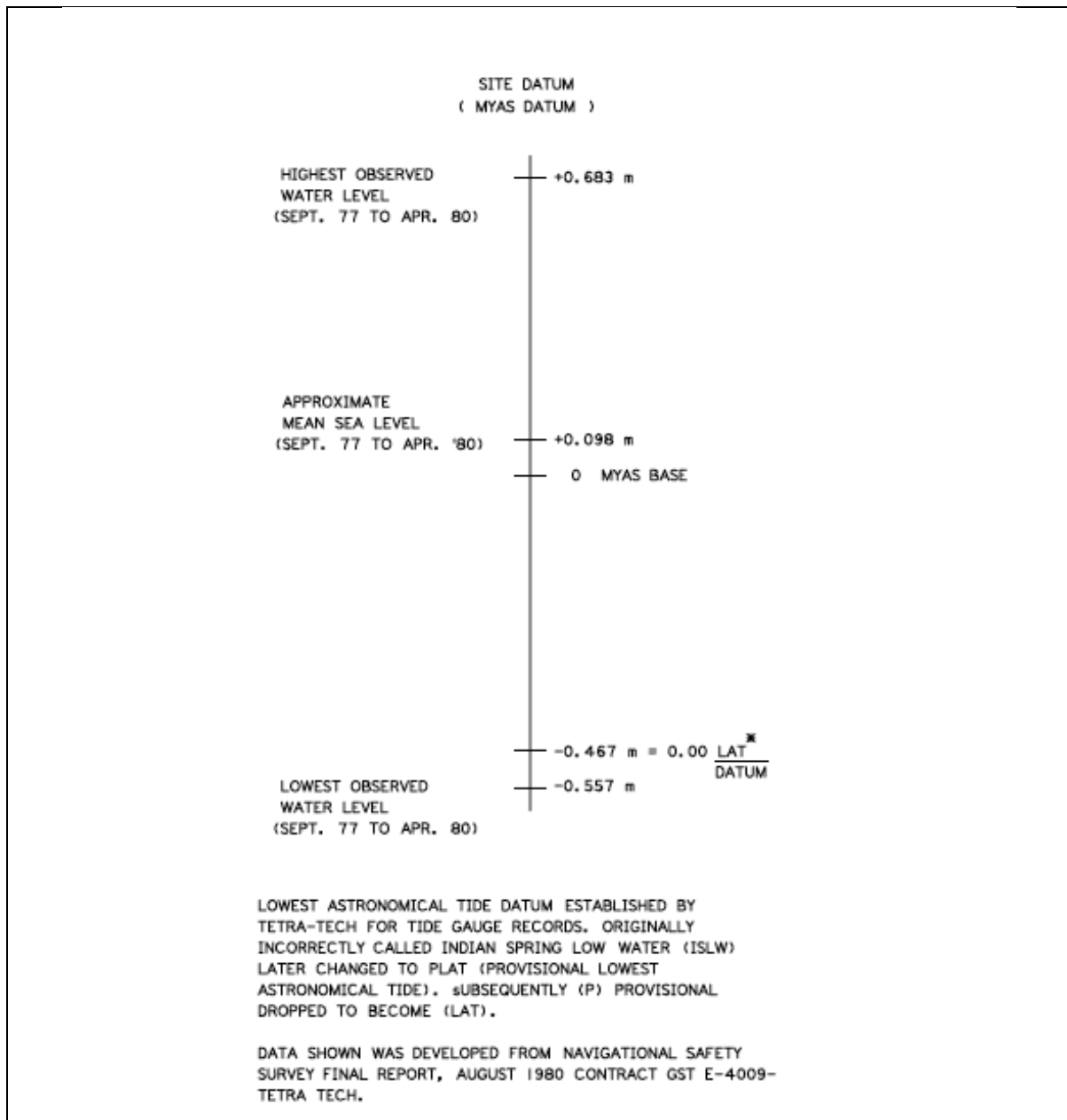
Horizontal and vertical survey data on primary survey monuments on or adjacent to work site, generally not exceeding 1 km intervals, will be furnished by the Royal Commission. Only those survey control monuments and data furnished by the Royal Commission are to be used by the Contractor in establishing additional control points and setting out for construction.

The Contractor shall make a formal application to the Royal Commission for data on survey control points in their particular project area prior to construction.

12.7.3 SURVEY CONTROL ESTABLISHED BY CONTRACTOR

The description, elevation and location (co-ordinates) of all survey control points, bench marks, and reference points established by the Contractor must be documented. Two copies of each document shall be furnished to the Royal Commission.

Documents furnished by the Contractor can be in the form of field notes, field sketches or standard plan type drawings.



SECTION 13

TECHNICAL CONSTRUCTION SPECIFICATIONS

13.1 GENERAL

Construction specifications for Madinat Yanbu Al-Sinaiyah shall be based on the format of the Royal Commission Standard Construction Guide Specifications, Divisions 00 through 50.

13.1.1 STANDARD SECTIONS

The Royal Commission will furnish standard sections to the Contractor, as requested and selected by him, from the list of standard sections. The Contractor shall edit the sections he receives, to add or delete specification data to suit the project requirements. Specification sections which are not available from the Royal Commission shall be prepared by the Contractor in the same format and depth of information as shown in the standard sections. The furnishing of a standard guide specification section by the Royal Commission shall not be construed as relieving the Contractor of his full responsibility for the adequacy and correctness of the technical and related data.

The organization and order of each section into four parts entitled General, Products, Execution and Measurement and Payment shall be followed whenever the length and subject matter require each of the parts.

The numbering of sections shall correspond to the numbering system listed in the Construction Specifications Institute's Manual of Practice.

13.1.2 GRAMMATICAL QUALITY

Ambiguities, uncertainties, and generalities shall be avoided. Construction contractors' options for type and quality of an item or material shall be minimized, and, if possible, eliminated.

The correct usage of words such as "shall," "will," "should," and "may" is of prime importance. "Shall" shall be used whenever a specification expresses a provision that is binding, and "will" to express a declaration of purpose on the part of the Royal Commission. It may be necessary to use "will" in cases where simple futurity is required (e.g., "power for the motor will be supplied by the ship"). "Should" and "may" shall be used whenever non-mandatory provisions must be expressed.

13.1.3 REFERENCES TO STANDARDS AND/OR OTHER PUBLICATIONS

References to standards and/or other publications, as listed in Subsection 2.2 or otherwise approved, pertaining to construction, materials, or tests may be specified in the construction specifications.

13.2 PROPRIETARY ITEMS AND TRADE/BRAND NAMES

The Contractor shall investigate the availability of Saudi Arabian-manufactured products for use in the Madinat Yanbu Al-Sinaiyah construction program, and where they exist these products shall be incorporated into the design and specified.

The technical specifications shall otherwise be written as performance-type specifications to allow maximum competition in bidding. If use of trade names or brand names is deemed necessary in the interest of the Royal Commission, the particular physical and functional (or other) characteristics of the item that are deemed essential shall be clearly identified and described in the appropriate technical section. Trade names with catalog numbers, or equal, may be used as an example of material or equipment meeting the specified requirements. Copies of the manufacturer's literature shall be submitted for review for all such equipment or material and shall be made a part of the construction submittal for use as a reference to evaluate submissions under the "or equal" clause.

13.3 FORM AND TYPING

The specifications shall be typed on A4 89 g white bond paper, using Calibri font, Regular, size 11. One and half-space typing shall be used for review submissions and single-space typing for the final specifications master. A minimum margin of 1 inch (25 mm) shall be maintained on left, right, top and bottom sides.

13.4 DRAWING COMPATIBILITY

Drawings and specifications shall complement each other. In general, drawings shall show the size, form, and extent of construction, and specifications shall establish the quality of materials, equipment, and workmanship. Duplication of information shall be avoided.

SECTION 14

CONSTRUCTION BID PACKAGE

14.1 SCOPE

Documents to be prepared for each construction bid package shall consist of commercial documents and technical specifications.

Commercial documents shall be divided into the following eight parts:

- Part 1 – A/E Detailed Cost Estimate
- Part 2 – Summary Breakdown of Work by Percentage / Value of Total Project
- Part 3 – FOP Section 2 – Schedule of Prices and Quantities
- Part 4 – FOP Section 3.L - List of Minimum Construction Plants and Equipment for use on this project
- Part 5 – List of Long Term Warranties (to insert in the Special Conditions)
- Part 6 – Document D – Special Specifications, including Specification Data
- Part 7 – Document E – List of Drawings
- Part 8 – Document F – Schedule of Prices and Quantities, Tables P-1, P-2

The Special Specifications shall be provided in accordance with the requirements of SECTION 13 and SECTION 15 herein, as applicable.

14.2 PREPARATION OF COMMERCIAL DOCUMENTS

Parts 1, 2, 3, 4, 5, 7 and 8 shall be completed, modified, or supplemented as required by the construction contract.

14.3 ADDITIONAL REQUIREMENTS

14.3.1 ROYAL COMMISSION-FURNISHED PROPERTY

Royal Commission-furnished property is material or equipment furnished the construction contractor without cost. If such property requires early procurement, the specifications for each item shall be prepared for approval by the Royal Commission in accordance with the requirements of Section 6 herein. Approved items will be purchased by the Royal Commission and furnished to the construction contractor for installation. A list of all Royal Commission-furnished property, if any, shall be inserted in the Special Specification.

14.3.2 LIST OF DRAWINGS

The list of drawings (Document E) shall include all contract drawings with the exact title of each drawing stated, together with the sequential number, revision number, and date and the statement "Issued for Construction" therein.

14.3.3 ASSEMBLY OF DOCUMENTS

All construction bid documents other than drawings shall be assembled (loose leaf) in one or more volumes of convenient thickness. Parts 1 through 8 shall be indexed in Volume I of the documents. The Schedule of Prices and Quantities must be provided in loose leaf hard copy and in MS Excel format on CD. The formulas must be entered on the MS Excel copy to extend the pricing and total the overall proposal price. The columns must be unlocked on the MS Excel copy. Another document must be provided in both loose leaf hard copy and MS Word format on CD.

The technical sections shall be assembled in numerical sequence as a continuation of Volume I, or assembled (loose leaf) together in Volume 2 and subsequent volumes, if required.

14.3.4 TABLE OF CONTENTS AND INDEXES

A complete table of contents shall be provided for each set of construction bid documents. This table shall follow the title page of each volume, identifying all parts, the volume in which they appear, their subsections, and the page number on which the subsections begin. Under Special Specifications, only the section numbers and title need be listed.

SECTION 15

PROCURED EQUIPMENT SPECIFICATIONS

15.1 INTRODUCTION

The following is presented as a guideline to an acceptable specification format and should not be construed as being restrictive. Other English language equipment specification formats may be used provided they contain as a minimum all items addressed herein.

15.2 FORMAT

The format, as follows, is for equipment procurement specifications and includes certain standard paragraphs considered necessary to the overall structure of the specifications.

15.2.1 SCOPE

This specification covers (Note: Insert descriptive name of equipment), furnished complete, as indicated in the design criteria and data sheets, which form a part of this specification.

15.2.2 APPLICABLE CODES AND STANDARDS

- (1) Reference publications, listed below, form a part of this specification. The applicable issue shall be the one in effect at the time of award of contract. (Note: List all standards and documents requiring compliance to ensure minimum standards of construction, materials, and performance for this equipment. List only those standards that apply.)
- (2) In the event of a conflict between this specification and any specification or document referenced herein, this specification shall govern.
- (3) This specification is based on the standards and publications referenced herein. The Seller may, upon the approval of the Purchaser, use other standards and publications, the use of which will result in equipment of comparable or better quality than that specified. The Seller shall submit, with the quotation, a copy of the applicable sections of the other standards in the English language for review by the Purchaser. Deviations which in the opinion of the Purchaser are minor will not preclude approval of the proposed alternate standard or publication.

15.2.3 GENERAL REQUIREMENTS

- (1) The design, materials and construction of this equipment shall meet or exceed all operating requirements specified in the design criteria of this specification.
 - (a) Design Capacity. The normal performance capability of the proposed equipment shall meet the requirements of the design criteria.
 - (b) Maximum Capacity. The Seller shall state the maximum capacity of the proposed equipment.
- (2) All vendor data shall be expressed in the metric system (e.g., drawings, instructions and maintenance manuals, and instrument and gauge markings). The Seller may include the engineering units he customarily uses on drawings and in documents provided the metric units are also shown.

15.2.4 DESIGN AND FABRICATION REQUIREMENTS

The design, materials, and fabrication shall be in accordance with the Seller's standard practice for the intended service, unless the requirements listed below and in the data sheets preclude their use. If these requirements limit the feasibility or suitability of the equipment, the Seller must so advise the Purchaser.

(Note: In these subsections, present those criteria that are required by the specific application of the equipment. Guards, couplings, accessories, operational efficiency, and capacities are a few of the potential entries. The following subsection topics are examples only and can be added to or deleted from as the requirements dictate.)

- (1) Structural details
- (2) Mechanical details
- (3) Electrical details
- (4) Welding procedures
- (5) Materials of construction
- (6) Instrumentation and control requirements

15.2.5 PAINTING AND PROTECTIVE COATING

Surfaces normally painted shall be cleaned and painted with a coating system which meets the requirements of ISO12944-6 C5M high durability. Other surfaces subject to corrosion in transit or storage shall be coated with a low VOC corrosion preventive that is removable with a proprietary solvent, preferably water. All machined surfaces subject to damage, and equipment openings such as pipe connections, shall be protected with suitable wooden or plastic covers, plugs, or caps.

15.2.6 INSPECTIONS AND TESTS

Testing and performance demonstration of the equipment shall include:

- (1) Quality control during manufacture
- (2) Shop assembly of total equipment item or partial assembly to prove match up and function of drives, controls, or components
- (3) Inspection of packaging for shipment
- (4) Inspection of equipment on receipt at jobsite
- (5) Supervision of installation
- (6) Acceptance test and startup

15.2.7 SELLER RESPONSIBILITY

The limits of responsibility of the Seller for each type of equipment shall be determined and defined. The value and complexity of each item will influence this requirement, from "FOB Point of Manufacture" for simple items, to "Deliver, Erect, Startup, and Test" for more complicated equipment.

15.2.8 PREPARATION FOR SHIPMENT

- (1) Packaging and shipping instructions shall be as specified in the purchase order.
- (2) The number of subassemblies shall be kept to a minimum. Disassembled units shall be marked for easy reassembly and crated for protection against exposure or damage in transit or storage, with crates identified. Uncrating, inspection, and installation instructions shall be included with each crate. Desiccant shall be provided as required.
- (3) Special erection jigs or tools and fragile, vulnerable, loose, or small parts shall be crated separately with necessary identification and instruction included.

15.2.9 SHOP DRAWINGS

- (4) Shop drawings or sketches shall be included in Seller bid packages, as required.
- (5) The Seller shall include all sizes and operational envelopes in proposal drawings or sketches, for the proposed equipment.
- (6) The Seller shall also submit all drawings containing operation and maintenance instructions. These shall be reproducible drawings showing all critical dimensions, clearances, and procedures necessary for equipment reassembly (as applicable) upon completion of maintenance work.

15.2.10 NAMEPLATES

Each item of equipment shall have a standard nameplate, securely affixed in a conspicuous location; showing the name and address of the manufacturer, serial and model number, date of manufacture, job equipment number and any other information that the Contractor may consider necessary to complete the identification of the item. Nameplate lettering shall be in the Arabic and English language on a noncorrosive metal plate.

15.2.11 EQUIPMENT NOISE CONTROL

Equipment furnished under this specification must comply with the noise control requirements of Subsection 3.2.

15.2.12 GUARANTEES

Units shall be guaranteed by the Seller against all deficiencies in performance and defects in design, materials, and workmanship for a period of 1 year after plant startup but not less than 18 months after shipment; with any corrections, adjustments, replacements, or repairs being made promptly, at no cost to the purchaser. Performance shall be guaranteed to comply with the design criteria.

15.2.13 DESIGN CRITERIA SHEET

Design criteria sheets shall be prepared for each equipment item covered by the specification. Identical items can be combined on the same sheet with separate tag or identifying numbers listed. The criteria sheet shall present in summary form the operating environments, functional and design requirements, and reference drawings and specifications for each piece of equipment.

15.2.14 DATA SHEETS

Data sheets shall be prepared for each equipment item covered by the specifications. Identical items may be included in the same data sheet with separate tag or identifying numbers listed. The data sheets shall be completed by the Seller as part of his proposal.

SECTION 16

PROJECT CONSTRUCTION BUDGETS, CONSTRUCTION COST ESTIMATES AND BILLS OF QUANTITIES

Project construction budget and construction cost estimates shall be prepared as set forth below to ensure uniformity of presentation and ease of reviewing. They will also be used as the primary tool for analyzing costs and controlling subsequent design decisions so that the project can be constructed within the project budget.

16.1 GENERAL

- (1) A project construction budget estimate shall be submitted with the program analysis submittal and shall be based on the best cost data available for the level of detail used. Once approved by the Royal Commission it will form the construction budget for this project.
- (2) Construction cost estimates for each proposed construction bid package (see SECTION 14) shall be submitted with each design submittal up to and including the pre-final design submittal. A final cost estimate, to be submitted with the final design submission, will be required whenever the Royal Commission review comments for the pre-final design submission indicate that changes and/or corrections other than minor revisions are necessary. The requirement for final construction cost estimate(s) shall be determined solely by the Royal Commission.
- (3) Bills of Quantities shall be prepared and submitted as specified in the contract. The Bills of Quantities shall be subdivided into elements in accordance with Construction Specifications Institute, 50 division format and as directed by the Royal Commission.
- (4) If the Royal Commission review of any estimate submitted indicates non-compliance with the requirements of this SECTION 16, the estimate shall be revised and resubmitted at no additional cost to the Royal Commission.
- (5) Substantial increases or decreases in total costs between each estimate submitted and the previous estimate shall be analyzed and explained as a part of the submittal.
- (6) The estimate shall be prepared in the English language and shall be clearly printed, typewritten or in computer printout form. Paper size shall be 216mm x 280mm.

16.2 DEFINITIONS

Specific terms and descriptions used in this section are as follows:

- (1) Line Items - An item described and priced on an "Estimate Worksheet" (Figure 16-2).
- (2) Manual Labor - Skilled and unskilled field labor up to and including foreman.
- (3) Non-Manual Labor - Management, construction supervision above foreman level, engineering, surveying, clerical and administrative personnel.
- (4) Small Tools - Individual hand or powered tools which have an initial cost of less than SR 2,000 each.
- (5) Construction Equipment - All plant, vehicles and equipment required in the execution of the work but excluding small tools.

- (6) Temporary Facilities - Offices, workshops, maintenance facilities, safety construction, temporary utilities, etc., which are used in the course of the construction work and subsequently removed from the jobsite.
- (7) Materials - Construction materials and permanent equipment installed or furnished for the permanent facility.
- (8) Consumables - Various and sundry purchased items which are required in the execution of the work and are either consumed or have no appreciable salvage value.
- (9) Direct Costs - Direct Costs consist of the construction costs which can be directly allocated to each specific line item of work. Direct Costs are divided into the components listed below:
 - (a) Manual Labor
 - (b) Construction Equipment
 - (c) Materials and Consumables
 - (d) Sub-contract work
- (10) General Requirements and Indirect Costs - General requirements and Indirect Costs consist of the construction contractor's costs which cannot be allocated to the direct costs. General Requirements and Indirect costs are divided into the components listed below:
 - (a) Manual Labor
 - (b) Construction Equipment
 - (c) Materials and Consumables
 - (d) Sub-contract work
 - (e) All non-manual labor
 - (f) Temporary Facilities
 - (g) Mobilization and demobilization costs.
 - (h) Other costs such as the costs of bonds, performance guarantees, taxes and insurances (excluding payroll burdens), home office costs, finance costs, etc.
- (11) Risk and Profit - Risk and Profit is the amount added to the construction contractor's costs (the sum of the direct costs and the general requirements and indirect costs), and shall include profit and when applicable, allowances for risk peculiar to the particular project.
- (12) Reimbursable Costs - Costs for which the construction contractor will be directly reimbursed in accordance with the construction contract documents.
- (13) Bid Item - An individual priced item listed in the construction contract "Form of Proposal".

16.3 FORMAT

This paragraph refers to utilization of recommended construction cost estimate sample forms (Figure 16-1 through Figure 16-2). If other estimating forms are proposed for use, they shall be submitted for prior Royal Commission approval. Each construction cost estimate shall be organized into three parts: 1) Direct costs for each bid item, 2) General

Requirements and Indirect Costs for an entire construction bid package, and 3) Risk and profit for an entire construction bid package (See Table 16-1).

- (1) Direct Costs - Direct Costs estimates for each bid item shall be prepared for each applicable section of the specifications (usually the CSI format) and summarized by specification division using the Estimate Worksheet. The specification division totals are then carried forward to the "Cost Estimate Summary - Direct Cost." The total direct costs for each bid item are the carried forward to the Direct Cost column of the Overall Summary. The amount estimated for cost reimbursable items shall be according to the terms and conditions stated in the construction contract documents. Any non-reimbursable portions of the direct costs associated with this category shall be transferred to the fixed cost category.
- (2) General Requirements and Indirect Costs - The General Requirements and Indirect Cost estimate shall be prepared using the "Estimate Worksheet" for at least each item listed on the "General Requirements and Indirect Cost Summary." The total General Requirements and Indirect Costs shall then be forwarded to the "Overall Summary," in the General Requirement and Indirect Cost Column at the total line. General Requirement and Indirect Costs can then be distributed to each bid item based on the estimator's judgement.
- (3) Risk and Profit - The total Risk and Profit mark-up shall be entered at the total line in the appropriate column of the "Overall Summary." The amounts to be used for risk and profit shall be determined on an individual job basis and distributed to each bid item in a manner similar to 16.3(2) above.

16.4 CONTENT

The construction cost estimate(s) shall contain all the line items required to adequately define the work. The number of line items will normally increase as the design work progresses. At the various design stages, the number of line items and their descriptions shall be at a level of detail commensurate with the design drawings and specifications submitted. The pre-final and the final design submittal estimate(s) shall contain line items to cover every separately identifiable part of the work.

- (1) Basis of Estimate - A narrative giving the basis of the estimate, assumptions used and special information not contained elsewhere in the estimate shall be submitted using "Construction Cost Estimate" sheet, Figure 16-1.
- (2) Quantity Take-Off - Quantity take-off shall be made for every line item. Contractor shall prepare quantity take-off on a "Estimate Quantity Worksheet." All Quantity take-off sheets shall indicate the source, procedure, and assumptions used in the take-off. All calculations shall be shown and arithmetically checked. Quantity take-off sheets shall be submitted with each estimate and shall be neatly and clearly prepared, summarized, and analyzed to permit straightforward verification/ checking by the Royal Commission. The metric system shall be used for all quantity measurement.
- (3) Costs - Costs shall be developed for each line item. Calculation sheets shall be submitted showing how the costs are developed and shall be supported by vendor/sub-contractor quotations as appropriate. These sheets shall be clearly labeled to identify the line item(s) involved. All line item costs shall be in current day Saudi Riyals. The minimum level of cost information required for each design submittal shall be as tabulated on Table 16-1.

Table 16-1. Minimum Level of Cost Information Table

		1	2	3
DESIGN SUBMISSION	CODE	DIRECT COSTS	GEN. R'MENTS & IND. COSTS	RISK AND PROFIT
Program Analysis	-	Level of detail to be defined at the post award stage and will be commensurate with the nature of the project.		
Conceptual	A	"All-in" unit rate	Included with direct costs	Included with direct costs
Preliminary	A	"All-in" unit rate	Included with direct costs	Included with direct costs
Intermediate	C	Labor mahours, labor costs, equipment, material, and sub-contract costs.	Percentage of direct costs	Percentage
Pre-final	D	Labor man-hours, labor costs, equipment, material, and sub-contract costs.	Labor man-hours, labor costs, equipment, material, sub-contract costs, and other costs.	percentage applied to sum of Cols 1 and 2.
Pre-final	E			

- (4) Cost elements to be included in the cost components listed in paragraphs 16.2 (9) and (10) shall be as follows:
- (a) Manual Labor - Man-hour unit costs used on the estimate worksheet, Figure 16-2 shall include wages, payroll burdens, housing and subsistence and small tools.
 - (b) Non-Manual Labor - Unit costs used on the estimated work sheet, Figure 16-2, shall include wages/salaries, payroll burdens and housing and subsistence.
 - (c) Construction Equipment - Costs used in developing construction equipment cost shall include operating costs, maintenance and repair costs, and equipment amortization cost. Equipment Operators shall be included in manual labor. for specialized or short term requirements, third party rental rates may be used.
 - (d) Materials - Cost of materials and consumables delivered to the jobsite.
 - (e) Sub-Contract - Total Sub-contractor's price to General Contractor. Sub-contract prices shall be backed up by cost estimates which comply with all requirements of Subsection 16.3 and 16.4. Unsubstantiated lump sum prices are not acceptable.
 - (f) Temporary Facilities - Costs for manual labor, construction equipment, materials and sub- contracts.
 - (g) Other costs – (16.2 (10) (h)) - Contractor's net costs.
 - (h) Mobilization - Labor mobilization costs, delivery and erection of construction equipment, initial costs of temporary facilities and any other requirements peculiar to the specific project.

16.5 COST ESTIMATE CONFIDENTIALITY

All cost estimates for construction projects are procurement- sensitive and shall be treated as confidential information. The responsibility for this control rests with the Contractor. Such steps shall be taken as necessary to ensure that cost information is controlled and that it is not provided to personnel outside the Contractor's office, with the exception of authorized personnel designated by the Royal Commission.

Bidder: _____

FORM OF PROPOSAL
SCHEDULE OF PRICES AND QUANTITIES

Pay Item (Refer to Section 01150)	Description of Item	Unit	Estimated Quantity	Unit Price (SR.)	Estimated Amount (SR.)
I.	<u>FIXED PRICE ITEMS</u>				
01.01.	Mobilization*				
01.02.	Demobilization				
	TOTAL AMOUNT FOR FIXED PRICE ITEMS				
	Note: *The amount proposed for mobilization by bidder shall not exceed 5% of the total contract price for pay item II.				
II.	<u>UNIT PRICE ITEMS</u>				
01.	SITE WORKS				
02.	CONCRETE WORKS				
03.	MASONRY				
04.	METALS				
05.	WOOD AND PLASTICS (NOT USED)				
06.	THERMAL AND MOISTURE PROTECTION				
07.	DOORS AND WINDOWS				
08.	FINISHES				
09.	SPECIALTIES				
10.	EQUIPMENT				
11.	FURNISHINGS				
12.	SPECIAL CONSTRUCTIONS				
13.	CONVEYING SYSTEMS				
14.	MECHANICAL				
15.	ELECTRICAL				
	TOTAL AMOUNT FOR FIXED PRICE ITEMS				
	TOTAL ESTIMATED AMOUNT FOR UNIT PRICE ITEMS				
	TOTAL CONTRACT PRICE (GRAND TOTAL) FOR (FIXED + UNIT PRICE ITEMS)				

Date: _____

Signature: _____

Contract No. _____

Figure 16-1. Sample Construction Cost Estimate Form (16 Div)

Bidder _____

FORM OF PROPOSAL
SCHEDULE OF PRICES AND QUANTITIES

Pay Item	Description	Unit	Estimated Quantity	Unit Price (SR)	Estimated Amount (SR)
01.	GENERAL REQUIREMENTS				
01.01.	Mobilization				
01.02.	Demobilization				
02.	EXISTING CONDITIONS				
03.	CONCRETE				
04.	UNIT MASONRY				
05.	METAL				
06.	WOOD AND PLASTIC				
07.	THERMAL AND MOISTURE PROTECTION				
08.	OPENINGS				
09.	FINISHES				
10.	SPECIALTIES				
11.	EQUIPMENT				
12.	FURNISHINGS				
21.	FIRE SUPPRESSION				
22.	PLUMBING				
23.	HEATING, VENTILATION & AIR-CONDITIONING (HVAC)				
26.	ELECTRICAL				
27.	COMMUNICATIONS				
28.	ELECTRONIC SAFETY AND SECURITY				
31.	SITEWORKS				
32.	EXTERIOR IMPROVEMENTS				
33.	UTILITIES				
	FIXED PRICE AMOUNT				
	UNIT PRICE ESTIMATED AMOUNT				
	TOTAL ESTIMATED CONSTRUCTION COST				
Date: _____ Signature: _____ Contract No. _____					

Figure 16-2. Sample Construction Cost Estimate Worksheet (33 Div)