JESA

Basis Of Design_Civil & Structural

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PAT – TRACE ELEMENT

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A	IFQ	R.Ahbachou	H.FARHANE	H.FARHANE	F.EL GHAZAL	15/9/2023		
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1. Introduction

This document presents the Civil/Structural basis of design for the ***Phosphoric acid treatment – Trace element*** to be used for the design of civil, structural and building works.

Specific information to be used in conjunction with this document may be contained in the project Basis of Design.

If any conflict arises between this document and the applicable standards or codes, this shall be resolved either by application of the most severe design conditions or resolution by the Principal Civil/Structural Engineer.

The customer shall formally approve this document before commencing the design.

Note: This basis of design is intended for use on new developments and may not be appropriate for modifications to existing structures.

2. Codes and Standards

The following standards, specifications, and test methods will govern where applicable and are part of this specification, except where superseded by particular requirements of this specification.

- Technical design code BAEL 91
- Seismic Design Requirements « RPS 2000 – Version 2011 » ;
- Wind Design Requirements NV65
- Eurocode 0 : Basis of structural design (EN 1990);
- Eurocode 1 : Actions on structures (EN 1991) ;
- Eurocode 2 : Design of concrete structures (EN 1992);
- Eurocode 3 : Design of steel structures (EN 1993);
- Eurocode 7 : Geotechnical design (EN 1997);
- Eurocode 8 : Design of structures for earthquake resistance (EN 1998);
- Catalogue des structures types de chaussées neuves de la direction des routes et de la circulation routière marocaine.
- Recommended Practice for Hot Weather Concreting ACI 605
- Recommended Practice for Cold Weather Concreting ACI 306
- Building Code Requirements for Reinforced Concrete ACI 318
- Specifications for Structural Concrete ACI 301
- Sampling Fresh Concrete ASTM C172
- Making & Curing Concrete Test Specimens ASTM C31
- Method of Test for Compressive Strength of Cylindrical Concrete Specimens ASTM C39
- Method of Test for Air Content-Volumetric Method ASTM C173
- Method of Test for Air Content-Pressure Method ASTM C231
- Method of Test for Slump of Concrete ASTM C143
- Joint Sealer-Hot Poured Elastic Type ASTM D1190
- Obtaining and Testing Drilled Cores and Sawed Concrete beams ASTM C42
- Ready-Mixed Concrete ASTM C94-67
- Standard Specification for Portland Cement ASTM C150-70
- High-early Strength Cement ASTM C150-70

- Air-entraining Admixtures ASTM C260-69
- Raw or Calcined Natural Pozzolans ASTM C618-68T
- Fly Ash ASTM CISO-70
- Chemical Admixture ASTM C494-68
- Fine and Coarse Aggregate ASTM C33-67
- Testing Drilled Core Samples ASTM C42-68
- Metal reinforcement for concrete ASTM A615
- Specification for Welded Steel Wire Fabric for Concrete Reinforcement ASTM A185-73
- Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement ASTM A615-76a
- Specification for Ready-Mixed Concrete ASTM C94-74a
- Recommended Practice for Installing Vitrified Clay Pipe Sewers ASTM C12-74
- Specification for Asphalt-Saturated Roofing Felt for use in Membrane Waterproofing and Built-Up Roofing ASTM D226-75
- Tests for Moisture-Density Relations of Soils, Using 10 lb. (4.5 kg) Rammer and 18 in. (457 mm) Drop ASTM D1557-70
- AWWA Standard for Rubber Gasket Joints for Cast-Iron and Ductile Iron and Pressure Pipe Fittings AWWA C111-72
- AWWA Standard for Installation of Cast-Iron Water Mains AWWA C600-64
- AWWA Standard for Installation of Asbestos-Cement Water Pipe AWWA C603-6
- Design and Construction of Sanitary and Storm Sewers WPCF No. 9
- Structural steel channels, angles, bars, rods, plates and anchor bolts ASTM A36
- Structural steel wide flange sections A572 (Grade 50)
- High strength bolts (Including nuts and washers) All bolts shall be heavy hexagon series with heavy semi-finished hexagon series nuts. ASTM A325
- Structural steel tubing ASTM A501
- Welding electrodes E70Xx (AWS-D1-1)
- Structural steel pipe ASTM A53, Grade B.

3. Design Detail

3.1 Design Loads

3.1.1 Dead Loads (Permanent Actions)

The ‘dead loads' shall be those loads specified as such in the relevant code and shall include the following:

- Total weight of all structural and non-structural components.
- The self-weight of permanent building elements.
- Miscellaneous permanent loads.
- Fixings (including floor decking, cladding and insulating or fire proofing materials) which are permanently attached to the structure.
- Fixtures integrally constructed with the structure or forming part of the structure including empty permanently fixed equipment, cable ladders and the self-weight of piping.
- For lighting elements and utility piping allow 0.1 kN/m2 dead load.
- Process piping ducts and major electrical runs shall be assessed individually.
- Cable and cable tray loads shall also be considered as dead loads.
- Differential Settlements.
- Negative skin friction on piles.
- Hydrostatic thrust or groundwater uplift.

- Soil weight/active soil pressure.

The densities of the materials shall be in accordance with listed codes and standards and shall include:

- Reinforced Concrete - *2500 kg/m3* (for 2% reinforcement, dense aggregate).
- Steel - 7850 kg/m^3.

3.1.2 Live Loads

The weight and position of live loads shall be considered including the method of load application.

The 'live loads' shall be those loads specified as such in the relevant code and shall include the following:

- Personnel, portable machinery and equipment and portable tools.
- Fluid loads caused by liquids moving in equipment, tanks or piping, including test loads as applicable.
- Moving loads caused by the non-stationary bulk materials in chutes, bins, hoppers, tanks and conveyors.
- Thermal loads due to solar or process temperature changes.
- Materials and items which could be temporarily or permanently stored during normal operation or maintenance or plant shutdown such as pallets of refractory bricks.
- Operating loads (e.g. dynamic forces, thrusts or reactions).
- Belt tension loads for conveyors during normal operation, flooded belt and at motor start up.
- Platform and flooring live load.
- Impact loads.

The design loads for flooring, platforms, walkways, stairs, and ladders shall be as follows:

3.1.2.1 Flooring

Area	Uniform[2] *(kN/m²)*	Concentrated[2] *(kN)*
Floors, platforms, walkways and staircases used for operational/ maintenance purposes	*7.5*	*7*
Floors, platforms and walkways used for access only	*7.5*	*7*
Conveyor Walkways	*2.5*	*2*[7)]
Staircases used for access only and escape routes	*5*	*4.5*[4)]
Roofs accessible for inspection and repair only	*1*	*2*[3)]
Manufacturing floors and storage areas:		
Light	*7.5*	*7*
Heavy	*7.5*	*7*
Exchanger head platform areas or similar equipment	*7.5*	*7*
Handrails[5)]:		
Heavy duty	*0.74*	*1*
Medium duty	*0.36*	*1*
Buildings		
Offices	*2.5*	*4*

Area	Uniform[2] (kN/m²)	Concentrated[2] (kN)
Areas where people may congregate (prayer rooms, corridors, canteens, etc.)	***5***	***4.5***
Areas for domestic and residential activities	***1.5***	***2***
Stairs in accommodation buildings	***2.5***	***2***
Workshops and Heavy Laydown Areas	***7.5***	***7***
Storage areas	***7.5***	***7***
Electrical Equipment Rooms [6)]	***7.5***	***7***

Notes:

1. This live load applies only on platform or floor slab of an area where the possibility exists of the platform or slab being subjected to maintenance activities.
2. Typically, concentrated loads are to be applied over a square of side ***50 mm*** and should not be applied simultaneously with the uniformly distributed load.
3. Concentrated loads applied over an area of ***200 mm x 200 mm.***
4. Concentrated loads applied over an area of ***100 mm x 100 mm.***
5. Handrail loads to be applied horizontally on the top rail.
6. Loads and distribution of load to be advised by Electrical group.
7. Material spillage load to be applied if greater and shall be calculated for the maximum burden at the full rill angle from the edge of the walkway.
8. Calculated value of stored materials to be applied if greater.

Where the storage loads, or operating loads are expected to exceed this design load then the calculated load shall be used instead, and the calculated load shall be shown on the drawings as a safe working load for the platform.

Floor live loads shall be applied to the general plant areas around equipment and all the floors of buildings or structures including maintenance platforms, mezzanine floors, control rooms, tank and thickener walkways or bridges.

3.1.2.2 Impact Loads

The forces caused by impact due to the movement of vehicles shall be in accordance with the relevant code.

For preliminary design purposes the following factors shall be applied as a multiplier to the static load of equipment to allow for impact loads caused by operating equipment.

Reciprocating machinery, crushers and pumps	***3.0***
Rotating machinery	***2.0***
Elevator supports	***2.0***
Mobile equipment	***1.25***
Hangers supporting floors and balconies	***1.35***
Cranes, monorails and hoists	***1.25***

Carry return idlers at loading points	***2.0***
Lifting lug	***2.0***
Underground piping thrust	***1.5***
Filter	***1.5***

Lifting lugs and connections shall be designed for 100% impact (2 times lifting load). Allowable stresses shall not be increased when combining impact with dead and live loads.

Impact loads for other moving equipment shall be determined in conjunction with the equipment manufacturer.

3.1.2.3 Dynamic Loads

Dynamic loads shall include vibrating or moving machinery impact forces from screens, crushers, feeders, chutes, etc. and liquid surge forces from flotation cells, aeration tanks and the like.

The magnitude of the static loads, impact forces in the horizontal and vertical directions for start-up and normal operation and the machine operating speed shall be obtained from the supplier of the equipment or from supplier data information. The final design shall be checked using certified forces shown on the drawings provided by the equipment supplier.

3.1.2.4 Crane and Davit Loads

Loads applied due to permanent mechanical lifting equipment, including overhead cranes, trolleys with hoist block, pull beams, lifting eye fixtures and moving sources shall be applied as a static load and shall be the most onerous of that which is derived from either the crane manufacturer’s data.

Handling Facility	Load Application	Additional Factors for Dynamic Loads due to IN/mm2ct and Surge Effects
Travelling Crane	1. Vertical on the supports due to impact.	Additional 25% of the maximum static wheel load.
	2. Longitudinal on the supports acting at the traction surface of the runway beam in either direction parallel to the beam.	10% of the maximum static wheel load.
	3. Lateral on the supports (surge or crabbing) acting horizontally at the traction surface of the runway beam in either direction perpendicular to the beam.	10% of the sum of the lifted load plus the weight of the crab (i.e. hoist and trolley).
Trolley Beams / Monorail	1. Vertical on runway beams / monorails.	50% of the lifted load (powered hoist). 25% of the lifted load (manual hoist).
	2. Longitudinal on runway beams / monorails.	10% of the static wheel load.
Davits*	1. Vertical on davits.	50% of the lifted load.
	2. Lateral on davits.	40% of the weight of the lifted load and moving equipment.

* Davits (exclusive of manhole davits) shall be designed for the weight of the heaviest piece of equipment that they may be required to lift, plus the weight of rigging equipment, plus the impact load, but not less than a total load of 4.4 kN. Design shall be based on use of a single sheave pulley block. All davits shall be legibly marked with the safe working load (SWL).

3.1.2.5 Thermal Movements Loads

Thermal loads in piping, equipment and structural members shall include those produced by solar and process temperature change.

Where significant temperature changes occur, sliding or rolling joints will be required to allow for the dimensional change. Where sliding joints are used the following friction coefficients shall be used to determine the friction forces:

Teflon on Steel	***0.05***
Steel on Steel	***0.40***
Steel on Concrete	***0.5***

Pipe racks shall be designed to resist the horizontal transverse forces expected. Such forces may be induced by friction or thermal movements. Where structures are more than ***50m*** long, movement joints shall be provided, or specific thermal movement loads shall be applied to the structure. Movement joints or loops shall be also provided in the piping.

3.1.2.6 Pipe Loads

Pipe racks shall be designed for the applicable loading condition or a uniform distributed load of ***2.0 kN/m²*** (vertical) per deck, whichever is the greater loading. This loading is generally applicable for pipe sizes between 1" and 10" (average 8" and 350mm spacing) The pipes shall be assumed to be full. Piping loads shall include the weight of pipes plus fittings, valves, insulation, instruments and contents.

3.1.2.7 Nozzle Loads

Nozzle loads shall be based on data from piping stress or mechanical Supplier drawings. In the absence of such information the nozzle loads will be approximated using the guidelines below:

Lateral nozzle load = B x 2D kN

Where

D = Nominal size in inches

B = factor for flange rating

= 0.75 for flange rating class 150 and class 300

= 1.25 for flange rating class 600

= 1.5 for flange rating class 900

For equipment with operating temperatures lower than 100°C the nozzle loads shall not be considered critical.

Only one nozzle, producing the worst effect at the equipment support shall be considered to act at a time (for example the largest nozzle at the highest elevation).

3.1.2.8 Cable Ladder Loads

For allowable loads to be applied to proprietary cable ladders, refer to the cable ladder manufacturer. The ladder and splices shall be designed to support a ***1 kN*** point load at any position on the ladder in addition to any other loads.

Structures supporting cable ladders shall be designed for a uniform load of ***1.25*** kN/m^2 (which includes the cable ladder weight) unless a heavier load is required for a particular project.

3.1.2.9 Fluid Loads and Surge Forces

Fluid loads in tanks, thickeners, cells, etc. shall be calculated using the maximum possible liquid weight in the vessel and the maximum density of the liquid. Vessels containing liquids shall be designed for contents up to High-High Level Alarm (LAHH) for operating condition, empty for stability considerations and full of water for hydrotest condition.

3.1.2.10 Flowable Materials Loads

Fluid and moving material loads shall include loads due to liquid or bulk materials in piping, equipment, tankage, on conveyors or any other material transfer system with due allowance for increases above normal operational loads, levels or flow rates. Surge loads shall also be taken into account (see 'Fluid Loads and Surge Forces').

Fluid and moving material loads shall be the most adverse of the operating and test conditions. For well mixed contents, fluid and flowable materials loads shall be calculated using the maximum density.

3.1.2.11 Blast Loads

If deemed necessary by customer requirements and the Safety and Risk engineer, structures within the blast zone shall be checked for adequacy for the applied blast loads.

3.1.2.12 Test Loads

Test loads shall be allowed for in the design if applicable. Pipeline thrust blocks should be tested at ***twice*** the normal operating pressure. Cranes and hoists should be tested by lifting a load of ***1.1*** times the safe working load.

3.1.2.13 Erection and Construction Loads

Allowance shall be made in the design for erection and construction loads e.g., moving heavy equipment over floors, the lifting of trusses, the stacking of bricks, liners, materials, etc.

3.1.3 Wind Loads

Refer to Site Conditions ***Q3126031-00-CI-CRT-00002***.

3.1.4 Seismic Loads

Refer to Site Conditions ***Q3126031-00-CI-CRT-00002***.

3.1.5 Earth Loads

Unless advised otherwise, dry densities shall be taken as:

- *For soil, 18 kN/m^3*
- *For rock, 25 kN/m^3*

For lateral earth pressures:

- *Active earth pressures shall be used for the design of flexible structures, such as cantilever retaining wall constructed from unbraced steel sheet piling, or gravity retaining walls.*
- *At rest earth pressures shall be used for the design of rigid structures as tied retaining walls, concrete tunnels and concrete ring beams for tanks.*
- *The at rest pressure coefficient shall be taken as not less than Ko = 0.5.*
- *Passive earth pressures shall not be assumed to resist lateral forces unless substantial movement can be accommodated.*
- *The upper 300 mm of soil shall not be considered to be contributing to the passive resistance of lateral forces.*
- *Lateral earth pressure coefficients on retaining structures subject to repeated traffic loads shall take into consideration the resulting long term compaction, which in some cases has been measured as giving coefficient as high as the passive coefficient K_p.*
- *Where roads approach within half the height of the wall, the retaining wall shall be designed for a minimum surcharge of 10 kN/m^2.*
- *Compaction loads due to the compaction of backfill shall be considered on the structure where applicable.*

3.1.6 Retaining Walls (Earth Pressure Loads)

Allow for surcharge at retained ground surface in accordance relevant code:

Normal *20.0 kN/m^2*

The 'at rest' lateral earth pressure (K_o) shall be used unless calculations justify the use of 'active' pressure (K_a) by demonstrating sufficient movement to mobilize active pressure. In any case active pressure shall not be used where dynamic or vibratory loading is expected due to progressive creep required to maintain active pressures.

3.2 Design Load Combinations

3.2.1 Loading Combinations

The loading combinations given in *relevant code* shall generally be used to determine the most severe condition for design. The design wind and earthquake loads shall not be assumed to act simultaneously.

Load combinations below give further guidance for process loads. In case of conflicts, the more severe shall govern.

3.2.1.1 Vertical and Horizontal Vessels, Horizontal Heat Exchangers

Supports and foundations for vertical and horizontal heat exchangers shall be designed on the basis of *relevant code* requirements and the following specific conditions:

	ERECTION	TEST	OPERATION	SHUTDOWN	BUNDLE PULL	ACCIDENTAL
Vessels dead weight	100 %	100 %	100 %	100 %	100 %	100 %
Internals weight	0 %	100 %	100 %	100 %	0 %	100 %
Platforms and ladders	0 %	100 %	100 %	100 %	0 %	100 %
Piping, valves	0 %	100 %	100 %	100 %	0 %	100 %
Cables	0 %	100 %	100 %	100 %	0 %	100 %
Insulation	0 %	100 %	100 %	100 %	0 %	100 %
Fire proofing	0 %	100 %	100 %	100 %	0 %	100 %

Live loads	0%/100 %	0%/100 %	0%/100 %	0%/100 %	0 %	0 %
Fluid	0 %	100 % (test)	100 % (operating)	100 %	0 %	100 % (operating)
Catalyst load	0 %	0 %	100 %	100 %	0 %	0 %
Thermal loads	0 %	0 %	100 %	100 %	0 %	0 %
IN/mm2ct loads	0 %	0 %	100 %	100 %	0 %	0 %
Vibration loads	0 %	0 %	100 %	0 %	0 %	0 %
Surge loads	0 %	0 %	0 %	100 %	0 %	100 %*
Wind	100 %	60 % ***	100 %*	0 % - 100 %	0 %	0 %
Bundle pull load	0 %	0 %	0 %	0 %	100 %	0 %
Seismic	0 % **	0 % ***	0 %*	0 % - 100 %	0 %	100 %*

* Wind and Earthquake are not considered simultaneously. Also, Surge and Earthquake are not considered simultaneously in Accidental case.

** It is assumed that erection of equipment is too short a period to take into account seismic loads.

*** It is assumed that the testing of equipment or pipes is too short a period to take into account seismic loads or the full wind loads. Reduction shown is for wind pressure, not the velocity.

3.2.2 Pipe Racks, Structures and Pipe Supports

Pipe-racks, structures and pipe supports, and their foundations shall be designed on the basis of *relevant code* requirements and the following specific conditions: Combinations shall allow for load variations, so that the most onerous load effect combinations are included.

TABLE 3.3.3-1 LOAD COMBINATIONS FOR STRUCTURES AND PIPE RACKS

	ERECTION	TEST	OPERATION	ACCIDENTAL
Structural	100 %	100 %	100 %	100 %
Piping weight	100 %##	100 %	100 %##	100 %
Cables	0 %	100 %	100 %	100 %
Fireproofing	0 %	0 %	100 %	100 %
Equipment	100 %	100 %	100 %	100 %
Live loads	0%/100 %	25 %	0%/100%	
Fluid (including surge)	0 %	100 % (test)	100 % (operating + surge)	100% (operating)*
Wind loads	100 %#	60 % ***	100 % *	0 %
Seismic loads	0 % **	0 % ***	0 % *	100 %*
Anchor and guide loads	0 %	0 %	100 %	0 %

* Wind and Earthquake are not considered simultaneously. Also, Surge and Earthquake are not considered simultaneously in Accidental case.

** It is assumed that erection of equipment is too short a period to take into account seismic loads.

*** It is assumed that the testing of equipment or pipes is too short a period to take into account seismic loads or the full wind loads.

\#   Where more severe, wind load on a single pipe, with associated weight, shall be considered.

\##   Pipe weight for Erection shall consider empty pipe weight. Pipe weight in Operation load case shall consider both empty as well as full of fluids to obtain maximum uplift and compressive forces on foundation.

3.3 Structures Supporting Vibrating Machines

An estimation of the vibratory or dynamic loads shall be made or obtained from the Supplier and the structural response of the structure shall be assessed.

The dynamic design method is to support vibrating equipment on independent structures which allow the shortest load path to the foundations. This vibration isolation technique shall result in an economic arrangement of small members for the global surrounding structure and heavy members locally supporting the vibrating equipment. The supporting members and their columns should be checked for the ratio of their natural frequency of vibration in relation to the frequency of the vibrating equipment. Tension bracing and stair stringers should also be checked for vibration. Bracing should be designed as compression bracing where possible. Lateral bracing should be provided to reduce horizontal vibrations. Stairs should be braced on the underside of the stringers to provide a lateral truss. Horizontal vibration of members shall be prevented by the use of lateral bracing.

3.3.1 Dynamic Analysis

The following information about the equipment to be supported shall be obtained from the manufacturer prior to commencement of design:

- Weight of machine and ancillary equipment.
- Mass of rotating parts of the machine.
- Speeds of the machine including operating speed, start-up speed and shut-off speed.
- Load transfer mechanisms from machine to support or foundation.
- Position of the center of gravity in the three major planes and radius of gyration.
- Out of balance forces and moments at the primary and secondary speeds.
- Forces generated under various operating conditions.
- Forces generated under emergency or faulted conditions.
- Acceptable levels of amplitudes of vibration.
- The line of action of the out-of-balance forces.
- Suppliers damping devices.
- Footprint of machine base frame, details of holding down bolts.

Structures supporting vibrating equipment (including aeration tanks, flotation tanks and the like) shall be analyzed to ensure that the natural frequency of vibration of the support structure is sufficiently far removed from the normal operating forcing frequency of the equipment to avoid resonance and limit the dynamic magnification. The ratio of the natural frequency (f_n) to the forcing frequency (f_m) shall be either less than 0.5 or more than 1.5 (to avoid the resonance zone).

The dynamic stresses and amplitudes of vibration produced shall be acceptable in terms of metal and weld fatigue, serviceability of the structure and human comfort. TF bolting may assist in carrying fatigue loads at joints.

Energy calculation methods or computer programs may be used to determine the natural frequency of the structural support system and not just the natural frequency of the support beams.

The weight of vibrating screens supported on soft springs or isolation pads may be neglected when calculating the natural frequency of the structural support system.

3.3.2 Steel Supports for Vibrating Machines

The following guidelines should be followed for the preliminary structural layout and design of steel structures that support vibrating machines:

- Limit the span of the support beams and connect the beams directly to the columns or walls where possible.
- Limit the span to depth ratio of support beams to between 10 and 15 for steel beams and between 15 and 20 for concrete beams. This ratio depends on the support conditions and the beam continuity.
- Limit the slenderness ratio of steel columns and compression bracing to 100, where these are directly below or adjacent to vibrating machines. For members away from the source of vibration, the slenderness ratio may be increased to 180.

3.3.3 Human Sensitivity and Vibration Control

Vibration deflections should be within acceptable limits for human sensitivity and should be limited so that the operation of electronic instruments will not be hindered.

Dieckmann K-Values can be used to control the vibrations in the steel members. Dieckmann K-Values can be calculated using the formulae given in the following table.

Table 3.3.4.4-1: Formulae for Calculating Dieckmann K-Values

Vertical Vibrations		Horizontal Vibrations	
Frequency (Hz)	**K Formula**	**Frequency (Hz**	**K Formula**
< 5	$K = 0.001\ A_f^2$	< 2	$K = 0.002\ A_f^2$
5 - 40	$K = 0.005\ A_f$	2 - 25	$K = 0.004\ A_f$
> 40	K = 0.2 A	> 25	K = 0.1 A

In Table 3.3.4.4-1,

A = dynamic amplitude (microns)

f = exciting frequency (Hz)

K = Dieckmann K-Value

For design purposes the dynamic amplitude can be taken to be the product of the static amplitude and the dynamic magnification factor.

The Dieckmann K-Value should be between 0.1 and 4.0.

As a guide, the following Dieckmann K-Values can be used:

K = 0.2 for electrical control rooms and offices.

K = 1.6 for general floor areas in the process plant.

K = 4.0 for isolated pump bases.

Structural member sizes should be chosen such that the K-Value is not exceeded.

Structural member sizes should be chosen such that the K-Value is not exceeded.

3.3.4 Foundations for Vibrating Machines

Considerable rigidity of the machine foundation is essential to avoid failure of the machine bearings. The foundation must have sufficient mass to absorb the vibration. The natural frequency of the foundation should be less than 0.5 or greater than 1.5 times the operating frequency of the machine to avoid resonance. Natural frequency of the soil varies from approximately ***6 Hz for soft organic soils and loose fine sands to about 30 Hz for sedimentary rocks***. The dynamic modulus of sheer rigidity (G) ranges from about ***10 to 25 N/mm2***. By increasing the foundation weight, the natural frequency decreases. By increasing the foundation soil bearing contact area or stiffening the subsoil, the natural frequency increases.

Where structural steel associated with walkways and platforms is to be erected around the machine foundation, the attachment of the steelwork to the foundation for support should be avoided. If the steel is attached to the foundation the effect of this additional mass on the foundation response to vibration shall be included in the design.

3.4 Concrete Design

3.4.1 Concrete Strength and Durability

Design for durability shall be in accordance with *appropriate code*.

3.4.2 Concrete Compressive Strength

- Blinding ***f'c = 15 N/mm2***
- Pavement, slabs and bund walls ***f'_c = 30 N/mm2***
- Foundations ***f'_c = 30 N/mm2***
- Catch basins / manholes ***f'_c = 30 N/mm2***
- Fireproofing ***f'_c = 30 N/mm2***

Concrete compressive cylinder strength f'c quoted at 28 days.

3.4.3 Minimum thickness of structural elements

Footings (all types including raft foundations) – ***300 mm***

Floor or Roof Slab, Walkway, Grade Slab – ***150 mm***

Parapet – ***75 mm***

Precast Floor Slab (in contact with liquid) – ***100 mm***

Minimum dimension of Column – ***300 mm***

Minimum depth of Beams – ***300 mm***

3.4.4 Cover to reinforcement

Foundations - concrete cast against soil – ***5cm***

Foundations – concrete cast in formwork – ***3cm***

Columns and beams exposed to elements – ***3cm***

Columns and beams within buildings or sheltered from elements – ***3cm***

Floor and Roof Slabs – ***3cm***

3.4.5 Grout

- Machinery base plates — ***Non Shrink Epoxy Grout, f'_c = 40 N/mm2***
- Column base plates, vessels and non rotating equipment — ***Non Shrink Cementitious Grout, f'c = 40 N/mm2***

3.4.6 Reinforcement and Anchor Bolts

- Reinforcement — ***High Yield Strength D500N bar (fy = 500N/mm2)***
- Anchor Bolts — ***Minimum 16 mm diameter***

  Low Strength: Grade 4.6

  High Strength: Grade 8.8

  Anchor bolts to be hot dip galvanized

Modulus of elasticity of reinforcement, Es, shall be taken as 210 N/mm2.

3.4.7 General

The concrete design shall comply with ACI 318.

3.4.8 Geotechnical Properties for Foundation Design

For geotechnical data for use in the design of foundations and slabs, refer to:

- Geotechnical investigation report.

The allowable bearing pressure and other soil parameters shall be taken from the reports as listed above.

The maximum soil bearing pressure shall not exceed the allowable bearing pressure. Bearing pressures may need to be considerably less than the allowable bearing pressure for settlement sensitive structures.

3.4.9 Stability of Surrounding Structure Footings

New footings founded near existing footings, underground services or in ground at the upper edge of a batter slope should be founded at a depth such that the base of the new footing is outside the zone of influence of the existing footing, underground service or batter slope. The zone of influence of any footing, underground service or batter slope is defined as the volume of soil outside planes drawn at ***2 vertical to 3 horizontal*** (above and below) from the base of the existing footing, underground service or batter slope, unless otherwise noted in the geotechnical report.

unless otherwise noted in the geotechnical report.

3.4.10 Footing and Foundation Design

Concrete pedestals under steel column baseplates or tank rims shall have a minimum of ***50 mm*** edge distance from the baseplate or rim. Pedestals shall be made sufficiently large to accommodate the holding down bolts (and tolerance tubes) and the pedestal reinforcement.

All pedestals which are more than 150 ***mm*** high shall be reinforced. The minimum total area of main pedestal steel reinforcement provided shall be ***0.5%*** of the gross cross sectional area of the pedestal.

A ***50 mm*** thick concrete blinding layer will be required under all footings and foundations. This should be poured within 24 hours of foundation excavation.

3.4.11 Protection of Buried Concrete

All buried foundations should be protected according to appropriate code.

3.4.12 Concrete Slabs

3.4.12.1 Design Procedures

Movement joints in slabs shall be provided to control and accommodate shrinkage and thermal movement. The slab joints for general paved areas should be spaced to limit the unjointed concrete areas to 100 m^2. The ratio of the longer slab panel dimension to the shorter panel dimension should not exceed 2.0.

Where practical movement joints in slabs generally should run down the slope rather than across slope. Where joints across the slope are required, they should be located on a crest in the slab.

Movement joints in process areas which are subject to exposure of contaminants should be minimized (e.g., by using additional reinforcement, concrete additives, or low heat cement).

Concrete paving slabs for process areas subject to exposure of aggressive contaminants or containment of contaminants (e.g., acids) should be protected by a suitable chemically resistant lining system such as troweled-on epoxy, polyester, fiberglass, synthetic membrane, acid resistant tiling or stainless steel. In all cases refer to the manufacturer for specific details e.g., joints, coving, etc. to be incorporated into the detail design for the lining system selected.

Consideration should be given to integral footings and paving (i.e., localized slab thickenings with raised pedestals) to minimize isolation joints between slabs and footings. Where movement joints between slabs and footings cannot be avoided and depending on the environment in which they are to be located, consideration should be given to providing a raised curb or upstand at the isolation joint to prevent ponding over the joint. For slabs in these situations, consideration should be given to the use of low heat, low shrinkage cement and suitable reinforcement to limit the crack widths to **0.*2 mm.***

Movement joints in slab areas providing containment for contaminants should have a waterstop provided as a backup to the joint sealants and provide a continuous coating system utilizing the waterstop.

Special attention should be given to the design of slab joints to accommodate movement (including thermal effects, settlement and shrinkage). The geometry, movement allowance and chemical resistance to attack should be checked with the sealant suppliers.

Special joint sealants will be required for oxygen plants to ensure no hydrocarbons are present due to a possible reaction with liquid oxygen.

3.4.13 Holding Down Bolts for Concrete

Holding down bolts shall be designed to transfer the entire column or equipment loads to the concrete pedestal or plinth. Shear keys on the baseplate should be provided where there are large base shear loads. Holding down bolts shall be sized to take into account the effects of corrosion. The following guidelines should be adhered to:

- Engineer shall consider prestressing holding down bolts for equipment and structures subject to stress reversal or fatigue. In such cases anchor bolts to be sleeved to provide an appropriate unbonded length.
- The holding down bolt design shall be checked to ensure that the bolts, tolerance tubes, stress development sleeves and anchor plates clear the reinforcement in the pedestal, plinth or base.
- The tolerance tube set-out design shall be checked to ensure there is adequate clearance between the tubes.
- The holding down bolt length shall be checked to ensure that the bottom of the bolt has adequate concrete cover.
- Holding down bolt and pedestal reinforcement design shall be checked to ensure that there is adequate development length for each to transfer the load from the structure or equipment to the concrete.
- Holding down bolts are to be installed to match the anchor holes in the Supplier supplied equipment or supporting steelwork.

3.5 Steelwork Design

Structural steel design shall generally comply with *relevant code*.

3.5.1 Structural Steel

Structural steel characteristics shall comply with relevant standard.

All steel profile shall comply with OTUA catalogue. The grades to be considered are the followings:

Rolled Open Sections	***Grade S275***
Structural Hollow Sections	***Grade S235***
Plate	***Grade 235***

The minimum thickness of any part of structural sections shall be ***6mm.***

The minimum thickness of plates used for structural connections shall be ***10mm.***

All structural steel to be ***hot dip galvanized***, unless noted otherwise on project documents.

3.5.2 Bolts and Masonry Anchors

Minimum Size	- structural connection	***M20 (20 mm diameter)***
	- non structural connections	***M16 (16 mm diameter)***
Grade	***8.8 high strength fuf = 830 N/mm2***	
Tightening	- Standard	***S - Snug Tight***
	prevent loosening (bearing type)	***TB - Fully Tensioned***
	- Slip Critical	***TF – Fully Tensioned***
Masonry Anchors	***M20 Chemical Set Anchors (minimum)***	

All bolts and masonry anchors to be hot dipped spun galvanized.

Lock nuts or approved equivalent shall be used for connections subject to vibration and/or supporting hanging (tension) loads.

3.5.3 Specific Serviceability Requirements

In addition to the design requirements of the design code used, the following design requirements shall be adhered to:

- Where K-bracing is used, the bracing members should be restricted to angles of between 30° and 60° to the vertical.
- Machine guards should be planned into the design of the equipment and should not in themselves constitute a hazard. Further, they shall be easily removable/replaceable to facilitate maintenance of the equipment. Guards shall be constructed of appropriate material of adequate strength and shall be effectively attached and maintained. Such guards should not be capable of removal or adjustment without the use of tools.

3.5.4 Environment

Structural steel members shall be adequately protected from the environment with a suitable surface protective coating system.

The allowable stress or limit state stress of structural members which are subjected to temperatures above 270°C shall be reduced from that given in the design code. Structural steel members which are subjected to temperatures below 0°C shall also be given special consideration.

Purlins and girts used in a highly corrosive environment shall be made from hot-rolled structural steel sections and not cold- formed thin gauge sections.

3.5.5 Structural Member Sizes

The designer shall establish the size of each structural member and bolted connection required for each of the design drawings for the project. For bolt design, the shear plane shall be taken to be through the threaded part of the bolt. The Design Engineer shall:

- Check that the member, fastener and weld sizes are shown correctly on the design drawing and the stiffener and baseplate details are adequate.

3.5.6 Connection Details

If available, the customer standard steel connection drawings shall be used where practicable and are fit for purpose.

The following information is given for the standard pinned type connection details:

- For beam to column connections, flexible end-plates should generally be used. For beam to beam connections, web side plates should generally be used. For beam to beam connections with horizontal bracing in place, flexible end plate connection shall be used with web side plate connection at the far end of the member.
- The Design Engineer should check that any customer standard connections will be adequate for the project design loads. Should the standard connection be unsuitable or inadequate, the Design Engineer shall provide the appropriate detail for a suitable connection for the design drawings.
- Flexible end-plate connections which are subject to axial tension should have a detail design check done.

Where braces lying in the vertical share gravity loads the connections should be:

a. Snug tightening for small brace members.
b. TF tightening where significant load sharing and slip free performance is indicated in the analysis.

- It is important to note that compression braces carrying gravity dead loads will exhibit a lower natural frequency.
- Proprietary structural analysis programs do not usually account for the increase in torsion stiffness of open sections which results from twin-beam flange action. This can affect load paths and joint forces in particular for lifting analyses of flat grillages.

3.5.7 Constructability and Transport

At the design stage, special consideration shall be given to prefabrication in shop and pre-assembly on the ground prior to erection for structures, vessels, tanks, equipment, etc. The location of splices should be designed to suit the transport limitations. Welded cleats which project proud of the overall member should be avoided where possible.

3.5.8 Deflection Limitations

Structures should be designed such that the structural deflections at [SM] serviceability limit state load combinations are limited to:

Vertical Deflection:

- Floor beams, walkways, platforms, stairs L/200
- Equipment supporting beam L/400
- Trolley beams, crane gantry beams L/400
- Monorails L/400
- Pipe racks (pipe support beams) L/400
- Main roof beams with non-brittle finishes L/200
- Main roof beams with brittle finishes L/200
- Purlins and side rails L/200
- where

L = span of beam or twice the length of a cantilever

Maximum permissible horizontal displacement for structures and columns are noted below:

- Industrial building without monorail and open structures, H <30m H/200
- Industrial building without monorail and open structures, H >30m H/300
- Tops of columns in single-storey buildings without monorail H/150
- Crane beams (deflection of beam due to lateral loads) L/300
- Structures supporting gantry cranes Hc/400

  where:

  H = total height of the structure

Maximum permissible horizontal displacement for each storey in an industrial building without monorail is noted below:

- Multi-storey building Hi/200

  where:

  Hi = Height of storey

3.5.9 Corrosion Considerations

At the design stage the following should be considered:

- An adequate space between the structural components should be provided to facilitate painting.

- Where possible, orientate structural sections in such a way as to avoid the collection of water or dust or spillage materials.
- Provide adequate drain holes in the members where required.
- Welds which are exposed to the elements or to a corrosive environment should be continuous welds.

3.6 Earthworks

3.6.1 Clearing and Grubbing

Clearing shall be undertaken to remove all existing surface and subsurface vegetation. Grubbing shall include removal of all obstructions, including small rocks, tree stumps and roots and artificial obstructions to a depth of at least 200 mm below existing ground surface.

Only trees actually obstructing proposed permanent works should be removed.

3.6.2 Bulk Earthworks and Batter Slopes

At all times batter slopes shall be maintained in a safe and stable condition.

3.6.3 Design

The design of bulk earthworks shall take into account the finished geometry of the facilities, roads, hardstanding or other works to be constructed over the earthworks.

Material properties shall be considered when determining the final batter slopes. The design shall consider long term slope stability and erosion control.

Where fill contains rock or rubble then zoning should be considered to prevent the use of this material in areas to be re-excavated, such as for footings, service trenches and liner anchor trenches. Project specific standards may be required for other than general fill.

3.6.4 Construction Phase Feedback

Where the material properties as constructed are critical to the function of the works or the intent of the design, (such as a dam liner or base permeability) then field soil testing shall be carried out on the completed works to ensure that the design criteria have been achieved. Should lower soil property values be achieved on site than those assumed at the design stage, the design shall be re-assessed using as constructed soil properties.

3.7 Drainage and Spillage Containment

3.7.1 Design Basis

Drainage design shall be carried out on a rational basis in accordance with *appropriate code*.

The Average Recurrence Interval (ARI) for design storms shall be:

- 500 years: Diversion drains around open cuts mine, shafts and portal entrances.
- 100 years: Global diversion drains around plant sites and major facilities.
- 50 years: Plant facilities and permanent all weather roads and airstrips.
- 20 years: In-plant local drainage, building drainage.

Notwithstanding the above, runoff from events of greater return periods should be provided for by provision of alternative flood routes and sensible provision of freeboard to all bunding and diversion channels, designed in accordance with the above criteria. The minimum freeboard provided should be

500 mm, except for mines which have an expected life of less than 10 years, in which case, the freeboard may be reduced to 300 mm.

3.7.2 Drainage Containment

In-plant stormwater runoff should be totally contained during the initial flush of the first storm or rainfall.

3.7.3 Spillage Containment Bunds

In-plant drainage design shall allow for the containment and recycling or treatment of day-to-day washdown runoff, accidental spillages and plant excursions.

Spillages shall be confined to the smallest practicable area by use of appropriate bunding.

Bunding should also be used to ensure adequate segregation of incompatible process streams.

Any earthen bunds must be suitable for the material being contained, suitably compacted and/or sealed to required permeability standards and remain clear of vegetation.

Concrete paving slabs for process areas subject to exposure of aggressive contaminants or containment of contaminants (e.g. acids) should be protected by a suitable chemically resistant covering.

3.7.4 Piped Drainage

In-plant drainage should avoid the use of piped drains where possible.

For preliminary design the following information shall be used unless specified otherwise.

Roughness factors ‘n’ to be used in Manning’s formula:

▪ Concrete pipe	0.12
▪ HDPE pipe	0.009 – 0.015
▪ Unlined channels	0.020 - 0.040
▪ Concrete lined channels	0.011 - 0.020
▪ Rubble or rip rap lined channels	0.020 - 0.040

Culvert and open channel velocity:

▪ Unlined channel	0.8 m/s maximum
▪ Lined channels	4.0 m/s maximum
	0.7 m/s minimum

General:

- Permanent culverts shall have concrete headwalls.
- Drainage channel outfalls shall have protection (stone pitching or lining) as required.

3.7.5 Floodways

Floodway design shall be based on maintaining the design flow velocity at less than 2 m/s. Pavement protection shall be achieved by cement stabilized road base course with a bitumen seal over the section of pavement. The base course shall be constructed from road base material stabilized with nominally 2% cement by weight. Bituminous seal shall extend for the full width of the pavement layer with the edges protected by rock armor where provided.

3.8 Sewerage

3.8.1 Design

The design of a sewer system (inclusive of collection, treatment and disposal of effluent and sludge) shall comply with the provisions of *appropriate codes and standards.*

Unless specified otherwise the design flows in sewers shall be based upon a daily average dry weather flow rate of **40 liters/person/day** for persons showering at the plant site. For day staff at the plant site (non-showering) an allowance of **70 liters/person/day** shall be made.

Peak flow rate shall be assessed on specific analysis. If this is not possible a peak flow rate of 4 times the average dry weather flow should be used.

3.9 Potable Water Supply

3.9.1 General

Design of a potable water supply system shall generally comply with the provisions of *appropriate codes*.

These documents cover current industry practice with respect to materials and workmanship of municipal water supply.

3.9.2 Specific Criteria

Where supply is to be provided to an urban or town situation then the design should conform more appropriately to the Water Supply Reticulation Construction Manual:

- Allow 450 liters per person per day as the minimum water supply.
- Water quality shall be tested for compliance with Health Department public drinking water criteria and treated accordingly. System design shall include documentation for conformance monitoring of the water supply during operation.
- All potable water supplies shall be chlorinated. Dosing with liquid sodium hypochlorite is recommended.

3.10 Roadworks and Paving

Geometric design of roadways shall comply with the current *Catalogue des structures types de chaussées neuves de la direction des routes et de la circulation routière marocaine.*

Within the plant, hardstanding areas should be graded to a minimum grade of *1.0% if sealed or 1.5% if unsealed. Roads should have a cross fall of 2.5% and road drains falling at least 0.66%. The valleys and spoon drains in the plant should be graded at a minimum of 0.66%.*