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5377.V.BES.1730.1	CONCRETE FOUNDATIONS & STRUCTURES (CALCULATIONS)	1	2	2/9/74.

1.00 - SCOPE -

The purpose of this specification is to define the calculations, design and construction details for reinforced concrete foundations and structure for the PETROSUI Refinery of SINES.

2.00 - GENERAL -

2.01 - Regulations -

The calculations shall be made in accordance with the requirements of the portuguese regulations, and particularly :

rev.1

- Portuguese regulations
- regulamento de betoes de ligantes hidraulicos
- regulamento des estruturas de betão armado
- regulamento des solicitacoes em edificios e pontes
- regulamento de segurança das construcoes contra os sismos

- Lummus regulations :

- Engineering specification for foundations and miscellaneous civil construction A 101 with its addendum n° 5377.V.BES.1700.1

rev.1

- Engineering specification for reinforced concrete stack C 101 with its addendum n° L.5377.V.BES.0173.1.

2.02 - TECHNIP/PROCON specifications -

5377.V.BES.1780.1 - concrete foundations and construction (material and execution)

5377.V.BES.1410.1 - soil data.

rev.2

5377.V.BES.1770.1 - roads bridges.

3.00 - DESIGN DATA -

3.01 - Load combination -

Dead weight

Dead weights to be taken into account for the calculations shall be :

1. Weight of structure itself including all accessories permanently connected to it and considered as being a part of it.
2. Fireproofing of structure
3. Equipment including all internals and fireproofing
4. Insulation of piping and equipment

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5. Weight of platform supports and plating will be estimated at 100 kg/m². Large beams and supports of loads other than platforms will be examined separately.

6. Piping

a) to take into account piping whose diameter is less than or equal to 12", framework shall be designed for uniformly distributed loads estimated as follows :

1. where there is a heavy concentration of piping, generally the case for the two lower floors of structures or columns : 100 kg/m²
2. flooring supporting a less heavy concentration of piping : 50 kg/m²
3. flooring not supporting piping : 0 kg/m²

b) all piping whose diameter is more than 12" shall be considered as loads concentrated at supporting positions

Live loads -

Live loads to be included in the calculation of each structural member shall be as follows :

1. Service platforms around compressors : exchangers or similar equipment where parts or heavy tools may be temporarily stored : 500 kg/m²
2. Operating platforms and stairways : 250 kg/m²
3. Walk ways : 125 kg/m²

Live loads for multi-level platforms may be reduced as permitted by local building codes in force.

Dynamic and vibration forces -

Dynamic and vibration forces to be taken into account in the calculations are as follows :

1. All forces produced by equipment or machines having a tendency to vibrate. If the vibration force cannot be estimated with reasonable accuracy, the design data of the manufacturer should be used insofar as they are made available to the contractor.

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2. Dynamic forces due to process operations (circulation of fluids) should be estimated

When overhead cranes are provided, their supports shall be calculated for dynamic forces as follows :

- vertical dynamic load : 25 % of lifted load
- lateral dynamic load : 20 % of lifted load + weight of crane trolley applied at the top of the runway, one half on each side and acting in either direction normal to runway
- longitudinal dynamic load : 10 % of the maximum wheel loads applied at the top of the runway.

Thermal forces -

Expansion forces exerted by hot piping shall be considered in the calculations, both in amount and direction.

Wind loads -

For standard-type constructions (buildings, control room, offices) the Portuguese regulations shall be used.

For special constructions (stack, columns, pylons, flare, high and narrow structures) the requirements defined in paragraph 5.00 shall be used.

Earthquake loads -

For standard type constructions (buildings, control room, offices, etc...) the Portuguese regulations shall be used.

For various types of equipment and structures used in a refinery, see paragraph 6.00.

Miscellaneous loads -

Miscellaneous loads such as counter-weights, spring supports, shall be included in the calculations .

3.02 - Loading combinations for design of concrete structures -

Type I -

a) erection

dead load + habitual wind

b) operating

dead load + operating load + live load + habitual wind

c) testing

dead load + test load + live load

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Type II -

a) erection

dead load + earthquake or exceptional wind

b) operating

dead load + operating load + live load + earthquake or exceptional wind

c) testing

for spheres only

dead load + test load + live load + earthquake

It is obvious that, in order to obtain the most extreme condition, (stress) calculations are to be performed for both load combination types (types I and II).

For concrete and reinforcing steel

- a) allowable units stresses shall be as stipulated in applicable Portuguese concrete codes
- b) stresses obtained by using load combination type I multiplied by a coefficient $C = 1.5$ may not exceed the yield stress
- c) stresses obtained by using load combination type II multiplied by a coefficient $C = 1$ may not exceed the yield stress.

For ground foundations

for seismic or exceptional wind loading conditions, type II, the safe allowable ground bearing pressure would be increase of 25 %.

3.03 - Anchor bolts -

Anchor bolts shall conform to ANSI namely coarse threads.

For design stress following shall be used

<u>Type of stress</u>	<u>loading type I</u>	<u>loading type II</u>
tensile	1.000 kg/cm ²	1.920 kg/cm ²
shearing	800 kg/cm ²	1.560 kg/cm ²
tensile + shearing	1.250 kg/cm ²	2.400 kg/cm ²

3.04 - Calculation of reinforced concrete constructions -

All calculation sheets shall use the terms and symbols indicated in the Portuguese regulations "regulamento des estruturas de betao armado".

Calculations shall be made in accordance with this regulation.

Mod. 132-5-74. PROCON-TECHNIP

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3.04.1 - Concrete specification -

3.04.1.1 - Concrete strength

Type	Class	compression (kg/cm ²)			tension (kg/cm ²)		
		7 d	28 d	90 d	7 d	28 d	90 d
B	180	122	180	216	13	17	20
B	225	154	225	270	16	20	23
B	300	205	300	360	20	25	30

3.04.1.2 - Type of concrete

Type	class	Quality		Class of durability	Quality	
		workshop	central		worshop	central
B	180	3	1	BD 2	2	1
B	225	2	1			
B	300	1	1			
B	180	3	1	BD 2	2	1
B	225			BD 2	2	1
B	300			BD 2	2	1

Generally concrete quality will be of quality 1.

Designation of concrete type shall be indicated on PROCON/TECHNIP drawing

Example :

B 300.1 : for B type concrete class 300 - quality 1

B 225.BD.2.1 : for B type concrete class 225 of the BD class 2 quality 1

3.04.1.3 - Using different concrete type

B 180.1 : concrete shall be used for construction of paving (with air entrainment)

B 180.BD2.1 : concrete shall be used for secondary anchor blocks of underground piping, levelling concrete, blocking or filling concrete

B 225 1 : concrete shall be used for all foundations above the paving and all elevate concrete structure

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- B 225.BD 2.1 : concrete shall be used for all foundations below the paving
- B 300.1 : concrete shall be used for piece of work above the paving, basins, high concrete structures
- B 300.BD 2.1 : concrete shall be used for piece of work below the paving, underground basins, separators, cooling tower basin

Note : concrete for cooling tower basin shall be used with supersulphated cement.

3.04.2 - Concrete breaking stress

The characteristic value of the concrete breaking stress " $\sqrt{b_K}$ " shall be taken equal to :

- $\sqrt{b_K} = 180 \text{ kg/cm}^2$ for class B 180 concrete
- $\sqrt{b_K} = 225 \text{ kg/cm}^2$ for class B 225 concrete
- $\sqrt{b_K} = 300 \text{ kg/cm}^2$ for class B 300 concrete

Concrete design stress \sqrt{b}^* shall take into account the requirements of Portuguese regulations.

3.04.3 - Concrete submitted to high temperatures

- above 100 °C allowable design stress specified by the regulations shall be reduced by applying the following formulas :

$$\sqrt{b_T}^* = \sqrt{b}^* \cdot \frac{900 - T}{800}$$

- case of stack : see specification Lummus C 101 and its addendum L 5377.V.BES.0173.1.

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3.04.4 - Reinforcing steel -

Reinforcing steel shall be in conformity with portuguese regulations "regulamento des. estruturas de betao armado".
 Reinforcing shall be ribbed grade A 40 steel and/or smooth grade A 24 steel bars shall be used for frames, pins, stirrups.
 A 50 welded wire fabric may be used for paving and trenches.

rev.2

Type of stress	A 50	A 40 T	A 24
σ_{ar} breaking stress	see	4.800 kg/cm ²	3.700 kg/cm ²
σ_{ak} yield point	homologation	4.000 "	2.400 "
elongation	chart	14 %	22 %

Steel design stress σ_a^* shall take into account requirements of Portuguese regulations.

Welded wire

- paving th. 100 mm - 1 layer 4 x 150 x 150
- paving th. 150 mm - 2 layers 6 x 150 x 150

3.04.5 - Steel submitted to high temperatures

Above 100 °C allowable tensile and compressive stresses of reinforcing steel specified by the regulations shall be reduced by applying the following formulas :

$$\sigma_a^*(T) = \sigma_a^* \cdot \frac{700 - T}{600} \quad \text{grade A 24}$$

$$\sigma_a^*(T) = \sigma_a^* \cdot \frac{1900 - T}{1800} \quad \text{grade A 40 T}$$

rev.1 for stack see specification Lummus C 101 and addendum n° L 5377.V.BES.0173

3.04.6 - Safety of constructions

Safety of construction, for concrete and reinforcing steel shall be in conformity with portuguese regulations.

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4.00 - CALCULATIONS OF FOUNDATIONS -

4.01 - Soil allowable stress -

All foundations shall be surface footing type.
Anchorage depth shall be at about 1.5 m relative to upper level of paving (for units and major foundations).

Allowable settlement shall be checked, with loading combination without wind, and bearing capacity of foundations with normal wind.

rev.1

These nomograms (bearing pressure and allowable settlement) shall be checked after complementary soil report (July 1974) from the L.N.E.C.

4.02 - Overturning safety factor -

- overturning safety factor, during erection, shall be calculated with the minimum lowering of equipment loads, including weight of foundation minus hydrostatic pressure, and weight of immersed soil.

- safety factors shall be applied to all foundations as follows

type of foundations	loading conditions	mini factor of safety	
		type I	type II
Octogonal	normal operating	2	
rectangular	normal operating	1,75	1,5
all types	erection	1,50	

4.03 - Horizontal stresses of construction -

- horizontal stresses of construction shall be absorbed either by passive pressure, or by friction under the base of the footing taking into account a friction angle of $\varphi = 30^\circ$.

- passive pressure shall in no case be cumulated with the resistance face to horizontal friction of the foundation,

- for the passive earth pressure, the weight of the earth shall be taken into account

rev.2

. unimmersed earth $\gamma = 1,85 \text{ t/m}^3$

. immersed earth $\gamma = 0,85 \text{ t/m}^3$

However the upper 0.5 m of earth will not be included in the calculation.

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- passive pressure can be mobilized when the distance "L" between foundations is equal to, or more than :

$$L = 1,5 \text{ to } 2 H$$

H = being the anchorage depth

4.04 - Ground water -

The ground water level measured at piezometers located on the site, from LNEC is 0,5 to 1 m in the West
1,5 to 4 m in the East (report May 73)

For design, the ground water level shall be taken at a depth of 0.5 m for off-sites.

For process and water treatment areas, the ground water level shall be determined from LNEC complementary soil report (July 1974)

Calculation of underpressures due to ground water.

- foundations forming casings shall be designed to withstand any hydrostatic pressures
- effect of underpressure of ground water shall be included in the calculations of all foundations.

4.05 - Foundations of vibrating machines -

rev. 2

- foundations of vibrating machines shall be designed so that the machine center of gravity coincide with the foundation center of gravity,
- foundations for small centrifugal equipment of weight ≤ 1 t shall be supported on reinforced concrete foundations with a minimum foundation to equipment weight ration of 3/1.
- large heavy duty centrifugal pumps, centrifugal and reciprocating compressors and other equipment subject to considerable vibration shall take into account all unbalanced moments and forces, so as to avoid any resonance, and shall be supported on reinforced concrete foundation with a minimum foundation to equipment weight ratio of 5/1 ; and a maximum calculated vibration amplitude as indicated on the graph of RATHBONE under the curve "gut",
The RATHBONE graph enclosed is printed in RAUSH handbook for machinery foundations 3rd Edition 1959, page 260.

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Soil dynamic characteristics -

For dynamic calculations of foundations for vibrating machines, the allowable bearing pressure shall not be more than half the bearing pressure for statically loaded foundations

	<u>compacted back fill</u>	<u>firm natural soil</u>
modulus of elasticity Eeq	4000 kg/cm ²	8000 kg/cm ²
Poisson ratio = 0.30	damping factor = 0.20	

4.06 - Various foundations -

Exchanger foundations :

The following data shall be used in calculations for exchanger foundations:

- reaction of foundations during tube bundle extraction shall be taken on own exchanger support
- extraction force of tube bundles shall be 100 % of tube bundle weight if stresses are equal at yield point, or
50 % of tube bundle weight if stresses are equal at allowable stress

Common foundations

In the case of common foundations for several pieces of equipment, one should endeavour to coincide the general resulting load of all the operating loads with the common footing center of gravity.

5.00 - WIND LOAD -

Wind loads shall be calculated with portuguese regulations.
The dynamic pressure acting at height H = shall be

<u>height</u>	<u>normal wind</u>	<u>extreme wind</u>
0 to 15 m	90 kg/m ²	150 kg/m ²
15 to 40 m	105 "	180 "
40 to 120 m	120 "	210 "
120 to 200 m	135 "	240 "

Reduction factor for circular shapes = 0.6

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Appurtenance coefficient (K_o)

This increase coefficient shall use only for towers and columns. It corresponds to equipment existing on columns and towers such as ladders, platforms, piping.

rev.1 $K_o = \phi$ columns + 2 insulation thickness + 0,6 m for platforms and ladders
+ diameter of talgest pipe running down column
where: ϕ = outside diameter of column

For slender vessels, structures and stacks, the possibility of wind excited oscillations must be investigated.

6.00 - EARTHQUAKE -

Action earthquake shall be calculated as follows :

$$F = W \cdot C$$

where F = overturning force at level in question
W = weight of each element located at center of gravity
C = seismic coefficient

SINES site shall be considered as zone A.

Since the soil at the Sines refinery site can be considered as being soft foundation soil, the coefficient shall be taken as follows :

- column 2 for Portugueses rules for buildings
- conditions b for equipment and structures commonly used in a refinery (enclosed)

7.00 - CONSTRUCTION - DETAILS -

7.01 - Reinforcing steel -

Unless otherwise stated from portuguese regulation, thickness of concrete protecting the reinforcing bars shall be :

a) for foundations

- . 75 mm for concrete poured directly on ground for concrete poured in forms.
- . 50 mm for bars larger than 16 mm dia
- . 40 mm for bars less than and including 16 mm dia.

b) for above ground structures

- . 40 mm for beams and pillars
- . 25 mm for walls and paving

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This concrete thickness is the net thickness. The above thicknesses should be increased by half a diameter when measured from longitudinal bar centerline. Minimum bar diameter for reinforcing bars shall be :

- rev.1
- 6 mm for paving reinforcing and for stirrups
 - 10 mm (A 40T)
 - 12 mm (A 24) } for pillar main reinforcing bars

7.02 - Troughs and paving -

- small constructions such as inspection chambers, troughs situated within circulation zones shall be able to bear the weight transmitted by a 12 t axle.

- for inspection chambers and troughs situated outside traffic areas the weight shall be 1 t/m².

- areas where tanks filled with corrosive products are to be erected shall be dyked ; the dike shall have a capacity at least equal to that of the tank.

Paving and dyke sides shall be made of materials resisting to the corrosive action of the products concerned, or shall be coated with a sufficiently thick layer of such materials.

- paving can be locally reinforced to support small foundations having a weight less than 2.5 tons and provided that their bearing surface on paving does not exert a load exceeding 0.5 kg/cm².

This concerns supports for ladders, stairways and small equipment.

- the following joints shall be provided in concrete paving :

- . slots shall be provided as shrinkage joints in the paving every 7.5 meters in both directions,
- . free expansion joints 15 mm wide every 30 m max.
- . free expansion joints 15 mm wide shall also be provided :
 - around foundations
 - around walls of buildings
 - around basins
 - around troughs

Expansion joint shall be 25 mm wide around foundations of vibrating machines.

Filling compound shall consist of a product not liable to be dissolved or attacked by hydrocarbons.

As far as possible, expansion joints shall be located at high points of paving.

Reinforcing steel shall in no case traverse expansion joints.

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7.05 - Miscellaneous -

- 1/ To allow adjustment of pumps, exchangers, drums, columns, steel structures, etc... the upper surface of concrete blocks and cradles built to bear this equipment shall first be levelled at 0.025 m below final level.
- 2/ The dimensions of the concrete base shall be at least 0.050 m larger than dimensions of the equipment base plate.
- 3/ All edges above grade and structures shall be chamfered 25 mm down to 150 mm below paving top surface.
- 4/ Solid blocks supporting vessels by means of skirts shall have drain pipe as shown on PROCON/TECHNIP standard dwg.