ELECTRICIDADE DE PORTUGAL – EDP
SINES POWER PLANT, UNITS 1 & 2

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APPROVAL AND RELEASE

DOCUMENT: BASIC CIVIL DESIGN CRITERIA

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RESPONSIBLE ENGINEER	[signature]	26/6/81
DISCIPLINE LEADER	[signature]	1/7/81
PROJECT MANAGER	[signature]	2/7/81

ENGINEERING CONSORTIUM

MOTOR COLUMBUS
CONSULTING ENGINEERS INC
CH 5401 BADEN

PROFABRIL
CENTRO DE PROJECTOS SARL
LISBOA

LUSOTECNA
CONSULTORES TECNIÇOS
INDUSTRIAIS S. A. R. L.

Mod EC-8

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1 GENERAL

This document presents the basic assumptions for the civil design criteria of all buildings and structures for the Coal Fired Power Plant Sines.

It prescribes the properties of materials and defines the applicable loads and applicable design methods.

Codes and standards under consideration are listed and it is defined how these standards are to be applied to the Sines Site.

These criteria shall be applied at the detailed civil design of all buildings and structures of the Sines Power Plant, whenever applicable.

At the start of the detailed civil design of a particular building or structure a complete set of documentation with loads and requirements shall be issued (Design Specification).

2 CODES

The design of all structures and foundations shall be performed in agreement with the applicable portuguese building codes as a minimum requirement. The design shall also comply with all the equipment requirements, particular specifications from EDP, Gabinete da Ârea de Sines (GAS) and shall consider the site-related parameters.

Unless specifically stated otherwise, the design of structures and foundations is based upon the following codes, regulations and standards (with free translation of titles in brackets):

- Regulamento de Solicitações em Edíficios e Pontes, 1961, "RSEP" (Regulations for Loadings in Buildings and Bridges)

- Regulamento de Segurança das Construções contra os Sismos, 1958, "RSCS" (Regulations for Safety of Buildings against Seismic Actions)

- Regulamento de Estruturas de Betao Armado, 1967, "REBA" (Requirements for Reinforced Concrete Structures)

- Regulamento de Estruturas de Aço para Edíficios , 1965, "REAE". (Requirements for Steel Structures of Buildings)

- Regulamento de Betões de Ligantes Hidráulicos, 1971 "RBLH" (Requirements for Concrete Mixtures)

- Regulamento de Segurança no Trâbalho da Construção Civil, 1958 (Safety Requirements for Civil Construction)

- Normas Portuguesas - Inspecção Geral dos Produtos Agrícolas e Industriais (Portuguese Standards For Construction Materials)

For subjects omitted in the present portuguese regulations other codes and regulations can be used if they are in common use in foreign countries, but they shall be properly justified and identified.

Where contradictions occur between codes, the more stringent shall apply.

If necessary the principles of the new code, under prepara - tion, "Regulamento de Segurança e Solicitações de Estruturas de Edíficios e Pontes " (Regulations for Safety and Loading Criteria for Buildings and Bridge Structures), can be ap- plied but only as a designer's guide line.

The following codes, if necessary can also be applied:

- American Concrete Institute (ACI)
- DIN Codes
- British Standards
- French codes

For reinforced concrete structures the recommendations of the "Comite Europeen du Beton " (CEB) shall be used.

Whenever possible the SI unit system shall be considered .

3 MATERIALS

3.1 Concrete

3.1.1 Concrete Quality

The components, composition, preparation, pouring and reception of concrete shall comply with the "Regulamento de Betões de Ligantes Hidraulicos".

The following types of concrete are used:

a) Type B when strength properties are required;

b) Type BD when durability characteristics are demanded.

The quality of concrete mixtures is referred to the coefficient of variation or to the standard deviation and is divided into three groups, where the first (1) presents the lower values:

Concrete Qualities
Maximum values of parameters defining quality

Concrete quality	Parameters defining quality	Medium ultimate stress			
		Compression		Bending	
		≤ 350	>350	≤ 50	>50
1	Coefficient of variation (%)	16	-	12	-
	Standard deviation	-	55	-	6
2	Coefficient of variation (%)	20	-	16	-
	Standard deviation	-	70	-	8
3	Coefficient of variation (%)	Without Specification			
	Standard deviation				

According to REBA the following concrete classes of type B will be used:

B180, B225, B300, B350, B400

for foundations and superstructures B225 and B300 shall be specified.
B180 will be used for lean concrete (B180 shall not be used with reinforcing steel A60).

B350, B400 shall only be used if properly justified.

In this project all concrete type B shall be of quality group 1 (one), except B180.

Type BD concrete is divided into three classes in the RBLH, but only class 1 or 2 shall be specified.

If type BD is used, this concrete shall be of quality Group 1 (one).

Examples of concrete to be used:

```
B300.1          B225.1          B180          BD 2.1
                                                 | |quality
                                                 |  group
                                                class
```

```
B  225 · BD 1 . 1
|   |    |  |   |quality group
|   |    |  class
|   |    type BD
|   class 225
type B
```

3.1.2 Permissible Stresses

For compression, except for single compressed columns:

Concrete Permissible Stresses

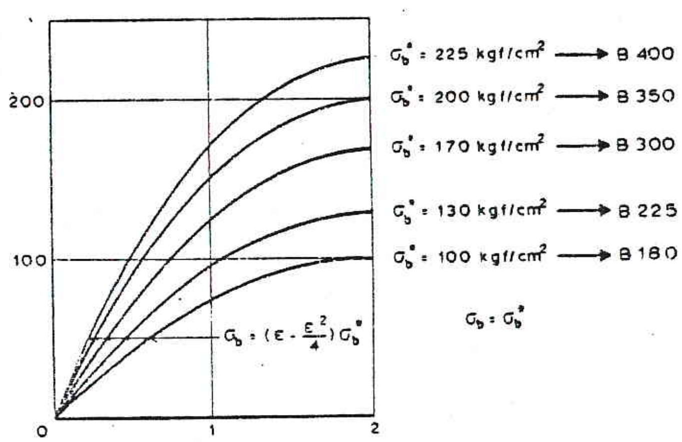
Concrete class	B180	B225	B300	B350	B400
Permissible compression stress due to bending	70	85	115	130	130

For tension : no resistance

3.1.3 Ultimate Strength

The stress-strain diagrams for ultimate analysis of reinforced concrete in compression are the following:

stresses σb (kgf/cm^2)



strain ε (‰)

3.1.4 Density

Plain concrete .... 2,4 $tf.m^{-3}$

Reinforced concrete ... 2,5 "

3.1.5 Young's Modulus

- Instantaneous deflections: E_b : 19 500 $\sqrt{\sigma_{bj}}$ ($kgf.cm^{-2}$)

  σ_{bj} - concrete cube strength at j days.

- Basically for instantaneous deflections:

Concrete Young Modules
Instantaneous Deflections

Concrete Class	B180	B225	B300	B350	B400
Young modulus	260 000	290 000	310 000	360 000	390 000

For uniform temperature variation calculations:

E_b = 140 000 kgf cm^{-2}

3.1.6 - Poisson's Ratio

ν = 0,20

3.1.7 - Dilatation Properties

Coefficient of linear thermal expansion $\alpha = 10 \times 10^{-6}$ $°C^{-1}$
see also 4.1.6

3.1.8 - Dynamic Properties

- If dynamic analysis of reinforced concrete structures will be performed a damping ratio of 5% (0,05) shall be used.

- When concrete elements are subject to vibrational loads fatigue analysis shall be considered.

  When tests are not performed for fatigue analysis, the following reducing coefficients shall be taken in concrete elements:

  0,6 - for stresses in concrete and bond stresses with high adherence bars (ribbed)

  0,4 - for bond stresses with plain bars.

- When dynamic analysis is performed an appropriate ductility factor can be used.

  In general for reinforced concrete structures with portal frames a factor of 2,0 can be used.

  For shear walls and similar structures a ductility factor of 1,0 shall be used.

3.2 - <u>Reinforcing Steel</u>

3.2.1 - <u>Reinforcing Steel Quality</u>

Reinforcing steel shall be in round bars of the classes A24, A40 and A50.

A50 steel bars shall only be used when a welded steel mesh is specified for reinforcement.

The mechanical properties required by REBA, as a minimum for steel bars are in the following table:

Characteristic Minimum Values of
Mechanical Properties of Steel Bars

Class	Type	Tensile Test			Bending Test	
		Yield stress at 0,2%	Ultimate stress σ_{ar}	Strain after failure ε_{ar}	Bending Equipment diameter	
		kgf/mm²	kgf/mm²	%	Ø ≤ 10mm	Ø > 10 mm
Natural Hardness Steel						
A24	Plain or Ribbed	24	37	22	2 Ø	2 Ø
A40	Ribbed	40	48	14	3 Ø	4 Ø
Cold Hardened Steel						
A40T	Plain or Ribbed	40	48	8	4 Ø	5 Ø
A50	Ribbed	50	60	8	4 Ø	6 Ø
A60	Ribbed	60	70	8	5 Ø	7 Ø

The following nominal diameters shall be used:

6, 8, 10, 12, 16, 20, 25, 32 (mm)

5 (4,8mm) only in A40.

If a welded steel mesh should be specified the following types (A50) shall be used (MALHASOL or equivalent)

Welded Steel Mesh (Malhasol type)

Mesh Type	Distance between bars		Diameters Bars (mm)		Bars Sections (cm2)		Weight by square meter (kgf/m^2)
	A	B	A	B	A	B	
AR 30	100	300	3,0	3,0	0,70	0,24	0,74
AR 34			3,4	3,4	0,91	0,30	0,95
AR 38			3,8	3,8	1,13	0,38	1,19
AR 42			4,2	4,2	1,38	0,46	1,45
AR 46			4,6	4,2	1,67	0,46	1,68
AR 50			5,0	4,2	1,96	0,46	1,90
AR 55			5,5	4,2	2,38	0,46	2,23
AR 60			6,0	4,6	2,83	0,55	2,65
AR 65			6,5	5,0	3,32	0,66	3,12
AR 70			7,0	5,5	3,85	0,79	3,65
AR 76			7,6	6,0	4,54	0,94	4,30
AR 82			8,2	6,5	5,28	1,12	5,02
CQ 30	150	150	3,0	3,0	0,47	0,47	0,74
CQ 38			3,8	3,8	0,76	0,76	1,19
DQ 25	50	50	2,5	2,5	0,98	0,98	1,54
DQ 30			3,0	3,0	1,42	1,42	2,23
AQ 25	100	100	2,5	2,5	0,49	0,49	0,77
AQ 30			3,0	3,0	0,70	0,70	1,10
AQ 38			3,8	3,8	1,13	1,13	1,77
AQ 50			5,0	5,0	1,96	1,96	3,08

A - Longitudinal bars B - Transverse bars

3.2.2 - Permissible Stresses

For tension and compression the premissible stresses are the following:

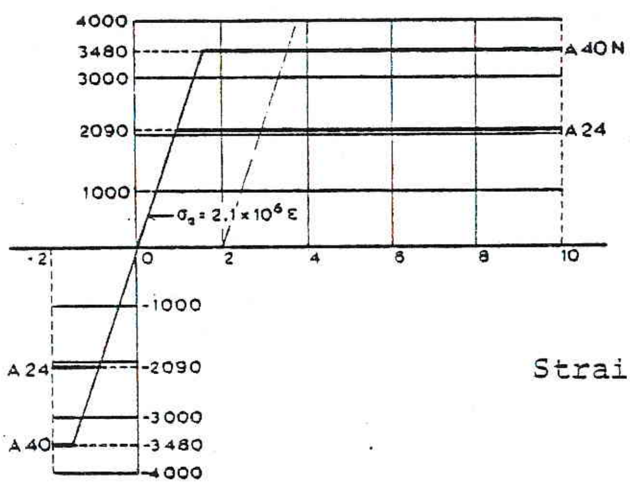
Permissible Stresses for Steel (kg/cm^2)

Steel class	A24	A40	A50
Permissible tensile and compressive stress	1 400	2 400	3 000

3.2.3 - Yield Strength, Yield Strain

- For natural hardness steel (A24, A40N) in tension or compression the following stress-strain diagrams shall be used:

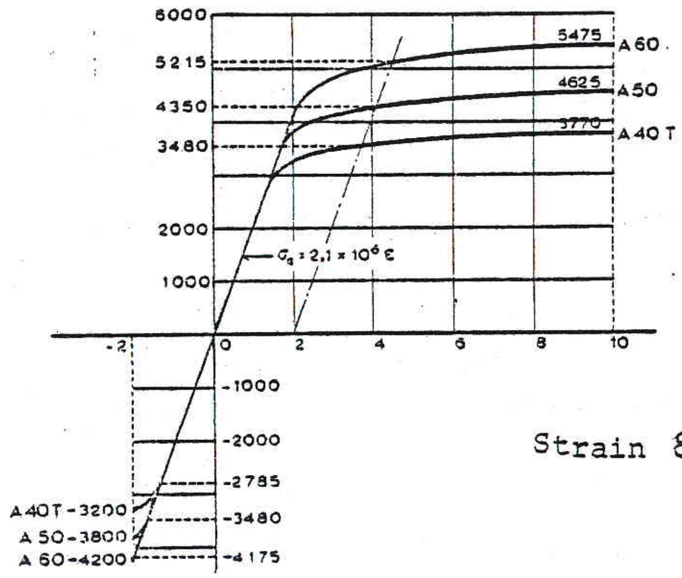
stress, σb (kgf/cm^2)



Strain, ε (‰)

- For cold hardened steel (A40T, A50) in tension or compression the following stress-strain diagrams will be used:

Stress σ_b (kgf/cm^2)



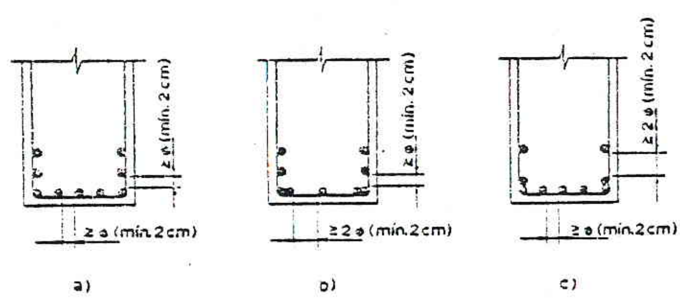
Strain ε ($^{0}/_{00}$)

3.2.4 - <u>Young's Modulus</u>

$E = 2{,}1 \times 10^6$ kg /cm^2 ($2{,}1 \times 10^8$ KN/m^2)

3.2.5 - <u>Layout of Reinforcement</u>

3.2.5.1 <u>Spacing between bars</u> shall be according to the following figures:



3.2.5.2 Covering to steel bars :

Minimum covering 2cm

Maximum covering without skin reinforcement 4 cm

3.2.5.3 Bending of bars

The minimum bending internal diameters will be as follows related to the bar diameter (Ø):

Class and type of steel bar	Hooks and stirrups		In general
	Ø ≤ 10mm	Ø > 10mm	
A24 Plain	2,5 Ø	2,5 Ø	16 Ø
A24 Ribbed	4 Ø	4 Ø	16 Ø
A40	5 Ø	6 Ø	20 Ø
A50	5 Ø	7 Ø	24 Ø
A60	6 Ø	8 Ø	28 Ø

3.2.5.4 Bar bonding lenghts

The minimum bond lengths, related to bar diameter (Ø) shall be :

Class and type steel	Concrete class	
	B180, B225	B300, B350, B400
A24 Plain and ribbed	30 Ø	30 Ø
A 10 Plain and ribbed	50 Ø	40Ø
A50	60 Ø	50 Ø

If plain bars are used, hooks must be provided according to clause 46 of REBA.

3.2.5.5 Bar overlaping

As a minimum bar overlapping lengths shall be the same as the bar bonding lengths. If plain bars are used, hooks must be provided.

Bar overlapping is not allowed for tie rods.

Stirrups must be provided in the overlapping zone.

3.2.5.6 Available bar diameter (see also 3.2.1)

The following nominal diamaters can be used:

Ø 6 - 8 - 10 - 12 - 16 - 20 - 25 - 32 (mm)

Ø 5 (4,8mm) only with A40

For welded steel meshes (A50) see 3.2.1

3.3 - Structural Steel

3.3.1 - Structural Steel Quality

Generally a steel quality 24/37 kgf/mm^2 shall be provided ("aço macio corrente")

Minimum yield stess

For elements with thickness $<$ 12mm .... 24 kgf/mm^2

For elements with thickness $\geqslant$ 12mm .... 22 kgf/mm^2

Utimate strength

Minimum .... 37 kgf/mm^2

Maximum .... 45 kgf/mm^2

If this "aço macio corrente" is not tested during fabrication and reception it is designated as "comercial". If tests are performed it is designated "garantido". Permissible stresses will be accordingly.

3.3.2 - Permissible Stresses

The normal (σ) and shear (τ) stresses for loading types I or II and steel quality "comercial" or "garantido" shall be as follows (for members not subject to buckling)

Loading Tye	Mild steel quality	Permissible Stresses (kg/cm^2)	
		Normal stress	Shear Stress
Type I	Comercial	1 400	840
	Garantido	1 600	960
Type II	Comercial	2 100	1 260
	Garantido	2 400	1 440

3.3.3 - Young's Modulus

$2{,}1 \times 10^6$ kgf/cm^2 ($2{,}1 \times 10^8$KN / m^2)

3.3.4 - Yield Strength

The characteristics yield strength for plastic analysis shall be :

" Aço macio corrente comercial" .... 2 100 kgf/cm^2
" " " " garantido .... 2 400 kgf/cm^2

3.3.5 - Bolts and Nuts

The steel quality is subdivided into two types:

normal ("corrente") and high strength ("alta resistência")

The following characteristics shall supply:

Bolt Type	Min.Ultimate Stress	Min. Yield Stress	Min. Strain after Failure	Rockwell Number
Current	37	21	25	HRB ≥62
High Resistance	80	64	12	HRC between 19 and 27
	100	90	8	HRC between 29 and 35
	120	108	8	HRC between 36 and 41

3.3.6 - Welding

Generally the welding material shall have characteristics compatible with the members to be welded.

If the members are of "aço macio corrente", the welding material shall have the following properties:

Minimum field strength .... 28 kgf/mm^2

Ultimate strength .... ≥ 44 kgf/mm^2
< 52 kgf/mm^2

If other materials are used they must be properly specified

3.4 - Subsoil

3.4.1 - Geological Investigations

Three geological investigation campaigns with different purposes were executed at Sines site. The first two investigations are completed, but the report of the third one is under execution.

The data provided below are based mainly on the LNEC report "Thermal Power Station of St. Torpes - Sines Engineering Geological Study", dated November 1979, of the second campaign. However, the figures marked with 2) are estimated values and may be used only for conceptual design purposes; the dates for the final design will be derived from the third geological campaign.

3.4.2 - Soil Layer

3.4.2.1 - Classification of the Soil

Layer	USCS Classification	Thickness m	Material
Top cover layer	SM	2 ÷ 3	loose sands
Pliocene sands	SM, SP-SM, CL	6 ÷ 15	compacted sands
Decomposed schist	-	0 ÷ 3	

The thickness of the soil layer varies significantly over the site area and can be derived from the rock contour map and the topographical map.

The decomposed schist and the ploicene sands have approximately the same soil qualities.

3.4.2.2 - Specification of the Pliocene Sand [2)]

Soil Characteristics		Unit	Above Ground Water	Below Ground Water
Net unit weight	γ_W	KN/m3	22	24
Dry unit weight	γ_D	KN/m3	19	19
Specific gravity	γ_s	KN/m3	26.5	26.5
Water content	w	%	16	16
Porosity	n	%	30	30
Internal angle of friction	ø	0	35	
Compression modulus	M_E	MPa	300	
Permeability	k	cm/s	10^{-3}	
Permissible load stress[1)]	σ_{bzul}	MPa	0.5 ÷ 0.6	

1) The detail design must be based on a calculation of the ultimate strength capacity of the particular foundation and cannot be based on permissible stresses .

The modulus of subgrade reaction - if used - can be derived according to Dimitrov:

$$C = \rho \cdot \frac{M_E}{(1-\nu^2)b}$$

Where :

ρ = according to table below

M_E = compression modulus

ν = Poisson's ratio according to ν din of chapter 3.4.4

b = width of foundation

l = length of foundation

Values for ρ :

l : b	1.0	1.5	2.0	3.0	5.0	10	20	30
ρ	1.05	0.87	0.78	0.66	0.54	0.45	0.39	0.33

3.4.3 - Rock Layer

The rock surface levels are given on the contour map of the sand schistous bedrock (Fig. 3 of geological report, dated November 1979) or in Appendix 13.

Main Design Data:

Formation	Unit Weight KN/m3	Compression Modulus MPa
Weathered schistous bedrock	- same data as pliocene sand -	
Bedrock	25	2,000 2)

3.4.4 - Dynamic Properties

Seismic test inside bore holes (cross hole)
Bore holes ED1-ED2-ED3

Depth (m)	V_p (m/s)	V_s m/s)	ν din	γ (kg/m3)	G_{din} (MPa)	E_{din} (MPa)
1.00	460	240	0.31	1.68	97	253
3.00	1,600	260	0.48	2.15	145	430
5.00	-	238	-	2.15	122	360
7.00	1,540	292	0.18	2.15	183	512
9.00	1,650	268	0.48	2.15	154	457
11.00	1,700	308	0.48	2.15	204	604
13.00	1,800	410	0.47	2.20	369	1,087
15.00	1,800	610	0.43	2.40	893	2,554
17.00	2,200	1,280	0.24	2.40	3,930	9,750
19.00	2,230	1,130	0.32	2.50	3,192	8,427

Bore holes ED4-ED5-ED6

Depth (m)	V_p (m/s)	V_s (m/s)	ν din	γ (kg/m3)	G_{din} (MPa)	E_{din} (MPa)
1.00	820	220	0.46	1.68	81	237
3.00	-	274	0.46	2.15	161	471
5.00	1,600	379	0.47	2.40	345	1,031
7.00	1,700	600	0.43	2.40	864	2,470
9.00	1,820	545	0.45	2.40	713	2,067
11.00	1,620	522	0.44	2.40	654	1,857
13.00	2,100	800	0.42	2.50	1,600	1,544
14.50	2,050	706	0.43	2.50	1,246	3,563

For situation of bore holes, see Appendix 14.

Legend: V_p = pressure - wave velocity

V_s = shear wave velocity

ν din = Poisson's ratio

γ = specific weight

G_{din} = dynamic shear modulus

E_{din} = dynamic compression modulus

3.4.5 - Ground Water

3.4.5.1 - Phreatic Level

Due to several zones of surface and under ground water discharges, the phreatic level varies significantly over the site. The following data are, therefore, related to the surface level:

Maximum level 0.40 m below surface

Minimum level 4.00 m below surface

A permanent site drainage could significantly lower the phreatic level.

3.4.5.2 - Chemistry

Test Bore Hole	C	D	E
area	auxiliary buildings	main buildings	coal yard
aggressivity	low	no	no
S_{04}-concentration mg/l	251	35	152

3.5 - Bricks

All the ceramic used in masonry works shall be in accordance with portuguese standards, in particular with LNEC specification E160-1965

3.5.1 - Dimensions

Dimensions of Standard Bricks (mm)

Designation	Length			Width			Height		
	Nom.	Min.	Max.	Nom.	Min.	Max.	Nom.	Min.	Max.
22 x 11 x 7	220	214	226	107	103	111	70	66	74
30 x 20 x 7	295	288	302	70	66	74	190	185	195
30 x 20 x 11	295	288	302	110	106	114	190	185	195
20 x 20 x 7	195	190	200	70	66	74	190	185	195
20 x 20 x 11	195	190	200	110	106	114	190	185	195
30 x 20 x 15	295	288	302	150	145	155	190	185	195
30 x 22 x 20	295	288	302	220	214	226	190	185	195

3.5.2 - Density

For design purposes the following figures shall be taken:

Plain bricks 18KN/m3 (1,8 t/m3)

Hollow bricks 15KN/m3 (1,5 t/m3)

3.5.3 - Permissible stresses

Plain bricks 15kg/cm2

Hollow bricks 10kg/cm2

4 - LOADS

4.1 - Basic Load Cases

4.1.1 - Table of Effective Load Cases

Load Cases		Subload Case		Specification
Dead loads	D	Structural loads	Ds	Concrete, Steel, Pavements, Roofing, Siding, Grids, Ladders, Staircases
		Components	Dc	Boiler, Turbine, Pumps, Fans, Pipes, Controlling Equipment
		Earth pressure	De	Statical, Dynamical
		Rock pressure	Dr	
		Ground water	Dw	
Live loads	L	Live load on floors	Lf	
		Live load on roads	Lr	Heavy trasnport
		Crane loads	Lk	
		Erection loads	Le	Structural Members, Construction Equipment, Components
Vibration loads	V			Feed-Water Pumps, Coal Mills, Fans
Dilatation	C	Shrinking Creeping Temperature	Cs Cc Ct	 Differential, Uniform
Snow	S			
Settlements	F			Uniform Differential
Wind	W	Normal wind	Wn	Normal Buildings, Chimney
		Exceptional wind	We	Normal Buildings, Chimney
Earthquake	E			Normal Buildings Chimney