ENGINEERING STANDARD

FOR

LOADS

ORIGINAL EDITION

AUG. 1993

This standard specification is reviewed and updated by the relevant technical committee on Mar. 1998(1) and May. 2005(2). The approved modifications are included in the present issue of IPS.

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0. INTRODUCTION

The purpose of this Standard is to specify the external forces (loads) acting on a structure, which are classified in accordance with the nature of the source and in order to provide some guidance on the fundamental characteristics of various types of loadings.

For convenience of use, this standard has been divided into two parts:

PART I DESIGN LOADS FOR ONLAND BUILDINGS AND STRUCTURES

This Part applies to loads recommended in current design specifications for conventional structural materials used in onland general buildings construction and in oil industries.

PART II DESIGN LOADS IN OFFSHORE AND ONSHORE STRUCTURES

This Part is applicable to special structures such as offshore platforms and onshore jetties etc. It consists of all loads that may influence the dimensioning of offshore and onshore structures or parts thereof during the expected life of the structure.

Note:

1) Throughout this standard, the symbol AR denotes the authorized Representative of the Owner.

PART I

DESIGN LOADS FOR ONLAND BUILDINGS AND STRUCTURES

1. SCOPE

This Standard provides minimum load requirements for the design of buildings and other structures.

The loads specified herein are suitable for use with the stresses and load factors recommended in current design specifications for concrete, steel, wood, masonry, and any other conventional structural materials used in buildings.

This Standard is also intended for use in oil refineries, chemical plants, gas plants and, where applicable, in exploration and new ventures.

This Standard also includes the design loads for buildings to resist blast forces (see Appendix IC).

Note 1:

This standard specification is reviewed and updated by the relevant technical committee on Mar. 1998. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No 29 on Mar. 1998. These modifications are included in the present issue of IPS.

Note 2:

This standard specification is reviewed and updated by the relevant technical committee on May 2006. The approved modifications by T.C. were sent to IPS users as amendment No. 2 by circular No 259 on May 2006. These modifications are included in the present issue of IPS.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

ACI (AMERICAN CONCRETE INSTITUTE)

ACI 318 — Building Code Requirements for Reinforced Concrete"

API (AMERICAN PETROLEUM INSTITUTE)

API 650 — "Welded Steel Tanks for Oil Storage"

ASCE (AMERICAN SOCIETY OF CIVIL ENGINEERS)

ASCE 7-95-1986 — "Minimum Design Loads for Building and other Structures"

BUILDING AND HOUSING RESEARCH CENTER

Iranian National Building Codes Part 6 — "Loads in Buildings"

BHRC-PNC 374

STANDARD 2800-1999 — "Iranian Code for Seismic Resistant Design of Building"

BSI (BRITISH STANDARDS INSTITUTION)

BS 6399 Part 2-1997 — "Code of Practice for Wind Loads"

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-GN-100	"Units"
IPS-E-CE-200	"Concrete Structures"
IPS-E-CE-390	"Rain and Foul Water Drainage of buildings"
IPS-G-CE-170	"Culvert Bridges and related Structures"

MCA MANUFACTURING CHEMISTS ASSOCIATION) 1978

Safety Guide, "SG-22: Siting and Construction of New Control Houses for Chemical Manufacturing Plants"

UBC (UNIFORM BUILDING CODE)

UBC-1997Chap. 16

US ARMY

Shore Protection Manual, Vol. I & II

3. DEFINITIONS & TERMINOLOGY

For the purposes of this Standard, the following definitions apply:

APPROVAL : AR's approval in writing of plans, drawings and specification, etc.

ACCEPTANCE : AR's acceptance in writing that information submitted in connection with approval, e.g. methods calculations or special investigations, has been found acceptable.

DESIGN LIFE : The period of time from commencement of construction till condemnation of structure.

DESIGN PHASES : The design life of an offshore structure is normally devised into five design phases as defined in the following:

1 - Phase C-Construction:

This phase includes construction ashore and construction afloat.

2 - Phase T-Transportation:

This phase includes transportation of the structure or a part of the structure, including transportation from shore to sea, or from shore to barge, and mooring operations in protected waters.

3 - Phase I-Installation:

This phase includes installation of the structure at its final location, i.e., the period from start of submerging from transport position or launching from barge, including piling, grouting or anchoring, until the platform is ready for normal operation.

4 - Phase O-Operation:

This phase is the period from completed installation till condemnation or removal from location.

5 - Phase R-Retrieval:

This phase includes retrieval or removal of the structure.

OFFSHORE STRUCTURE: A structure designed to remain permanently fixed to the sea bed by gravity, piles or anchors.

4. SYMBOLS AND ABBREVIATIONS

In this part of the Standard the following general symbols are used for various load classifications. Other symbols are defined in the section where they are used:

C = Crane load, see sub-clause 10.1

D = Dead load consisting of :

a) Weight of the structural member itself.

b) Weight of materials of construction incorporated into the building to be permanently supported by the structural member, including built-in partitions.

c) Weight of permanent service utilities. see 8.3.

E = Earthquake (Seismic) load, see 7.3.

F = Loads due to fluids with well-defined pressures and maximum heights.

H = Loads due to the weight and lateral pressure of soil and water in soil, see 10.8.

I = Impact load, See 10.9.

L = Live loads due to intended use and occupancy, including loads due to movable objects and movable partitions and loads temporarily supported by the structure during maintenance. L includes any permissible reduction. If resistance to impact loads is taken into account in design, such effects shall be included with the live load L, see 9.

L_r = Roof live loads, see 9.5.

M = Maintenance load, see 10.10.

P = Loads, forces and effects due to pending, see 7.2.10 and 7.2.12.

Q = Weight of equipments such as pumps, compressors, motors, etc. see 8.5.

R = Required dynamic resistance to blast loads, see Appendix IC.

r = Rain load, see 7.2.12.

S = Snow load, see 7.2.3.

T = Thermal loads;= Self starting forces and effects arising from contraction or expansion resulting from temperature changes, shrinkage, moisture changes, creep in component materials, movement due to differential settlement, or combinations thereof, see 10.11.

V = Vibration (Dynamic) load, see 10.3.

W = Wind load, see 7.1.

Ve. = Empty weight of vessels, columns, etc., see 10.12.1.

Vo. = Operating weight of vessels, columns, etc., see sub 10.12.2.

Vt. = Testing load of vessels, columns etc., see 10.12.3.

er = Erection load, see clause 10.4.

ds = Differential settlement, see 10.2.

5. UNITS

International System of Units (SI) in accordance with IPS-E-GN-100 shall be used.

6. BASIC REQUIREMENTS

6.1 Safety

Buildings or other structures, and all parts thereof, shall be designed and constructed to support safely all loads, including dead loads, without exceeding the allowable stresses (or specified strengths when appropriate load factors are applied) for the materials of construction in the structural members and connections.

6.2 Serviceability

Structural systems and components thereof shall be designed to have adequate stiffness to limit transverse deflections, lateral drift, vibration, or any other deformations that may adversely affect the serviceability of building or structure.

6.3 Self-Straining Forces

Provision shall be made for self-straining forces arising from assumed differential settlements of foundations and from restrained dimensional changes due to temperature changes, moisture expansion, shrinkage, creep and similar effects.

6.4 Analysis

Load effects on individual components and connections shall be determined by accepted methods of structural analysis, taking equilibrium, geometric compatibility, and both short and long term material properties into account. Members that tend to accumulate residual deformations under repeated service loads shall have included in their analysis the added eccentricities expected to occur during their service life.

6.5 General Structural Integrity

Through accident or misuse, structures capable of supporting safely all conventional design loads may suffer local damage, that is, the loss of load resistance in an element or small portion of the structure. In recognition of this, buildings and structural systems shall posses general structural integrity, which is the quality of being able to sustain local damage with the structure as a whole remaining stable and not being damaged to an extent disproportionate to the original local damage. The most common method of achieving general structural integrity is through an arrangement of the structural elements that gives stability to the entire structural system, combined with the provision of sufficient continuity and energy absorbing capacity (ductility) in the components and connections of the structure to transfer loads from any locally damaged region to adjacent regions capable of resisting these loads without collapse.

7. ENVIRONMENTAL LOADS

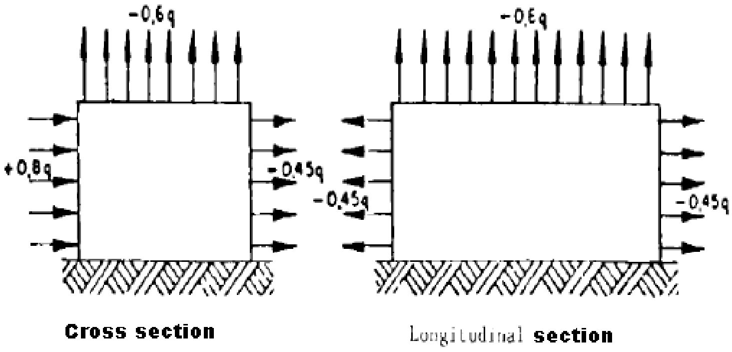
7.1 Wind Load

For requirements governing the determination of wind loads in the design of buildings and structures, reference is made to the British Standards, BS 6399 part 2.

For guidance, Table below lustrates the velocity and pressure of wind in Iran, Iranian National Building code part 6. Also as a guide, effective external and internal pressures in various structures are demonstrated in Figures 1 to 9 of this Standard.

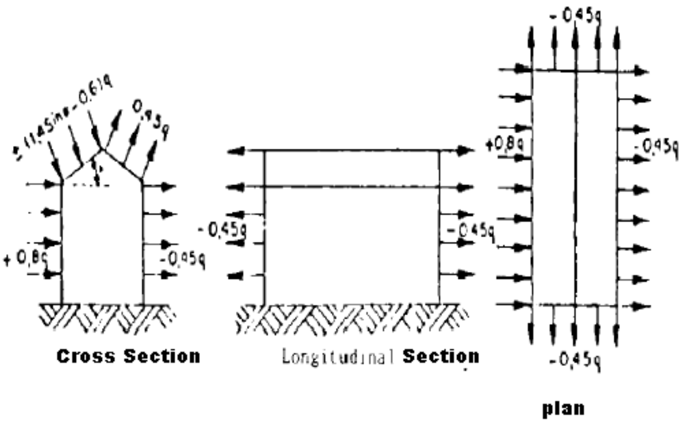
For the wind design loads of petroleum plants in Iran, this standard recommends the use of latest statistics gathered by the Iranian Meteorological Bureau, i.e., the Annual Yearbooks, and the Wind Roses.

STATION (City)		VELOCITY OF WIND (V) Km/h	
1.	Abadan	90	40.5
2.	Abadeh	100	50.0
3.	Abali	110	60.5
4.	ARAK	90	40.5
5.	ARDABIL	130	84.5
6.	URUMIYEH	90	40.5
7.	Aghajari	110	60.5
8.	ISFAHAN	110	60.5
9.	Omidiyeh	110	60.5
10.	AHWAZ	110	60.5
11.	Iran Shahr	110	60.5
12.	Babolsar	100	50.0
13.	Bojnurd	130	84.5
14.	Bam	110	60.5
15.	Bandar Anzali	110	60.5
16.	BANDAR ABBAS	100	50.0
17.	Bandar Lengeh	90	40.5
18.	BUSHEHR	100	50.0
19.	Birjand	90	40.5
20.	Parsabad Moghan	100	50.0
21.	TABRIZ	110	60.5
22.	Torbat-e-Heydarieh	80	32.0
23.	TEHRAN	100	50.0
24.	Jask	100	50.0
25.	Siri	110	60.5
26.	Kish	100	50.0
27.	Chabahar	90	40.5
28.	KHORAMABAD	80	32.0
29.	Khoy	90	40.5
30.	Dezful	110	60.5
31.	Ramsar	90	40.5
32.	RASHT	90	40.5
33.	Zabol	120	72.0
34.	ZAHEDAN	130	84.5
35.	ZANJAN	80	32.0
36.	Sabzevar	90	40.5
37.	Serakhs	110	60.5
38.	Saqez	100	50.0
39.	SEMNAN	80	32.0
40.	SANANDAJ	90	40.5
41.	Shahrud	80	32.0
42.	SHAHR-e-KORD	80	32.0
43.	SHIRAZ	80	32.0
44.	Tabas	90	40.5
45.	Fasa	90	40.5
46.	Ghaem Shahr	90	40.5
47.	QAZVIN	100	50.0
48.	QOM	90	40.5
49.	Kashan	100	50.0
50.	KERMAN	130	84.5
51.	KERMANSHAH	90	40.5
52.	GORGAN	80	32.0
53.	Maragheh	110	60.5
54.	MASHHAD	90	40.5
55.	Manjil	130	84.5
56.	Noshahr	90	40.5
57.	HAMADAN	100	50.0
58.	YAZD	110	60.5



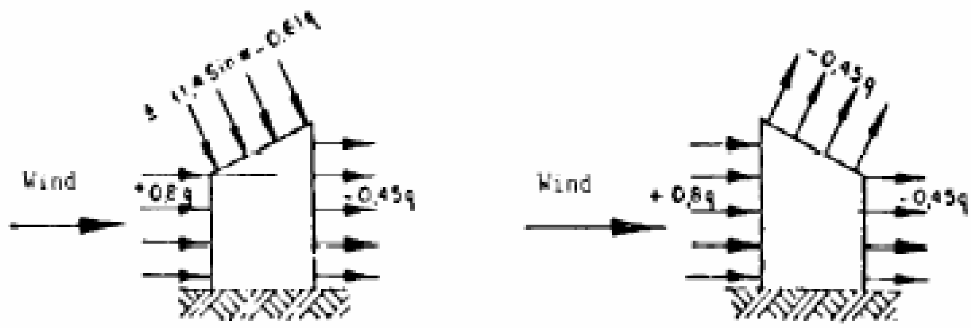
EXTERNAL ROOF STRUCTURES DESIGN WIND PRESURE IN FLAT

Fig . 1



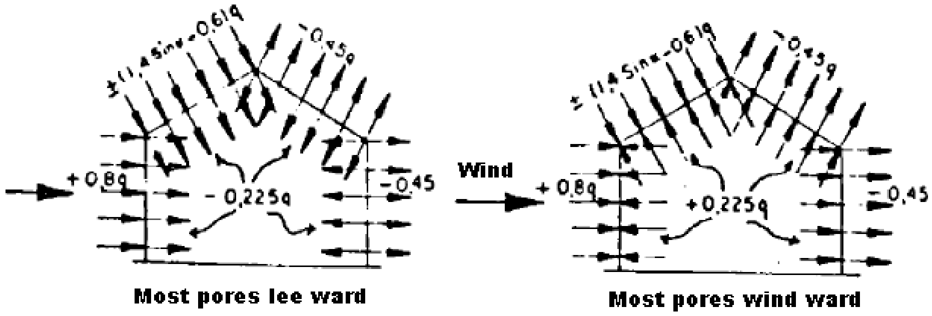
EXTERNAL PITCHED ROOF STRUCTURES DESIGN WIND PRESSURERS IN

Fig . 2



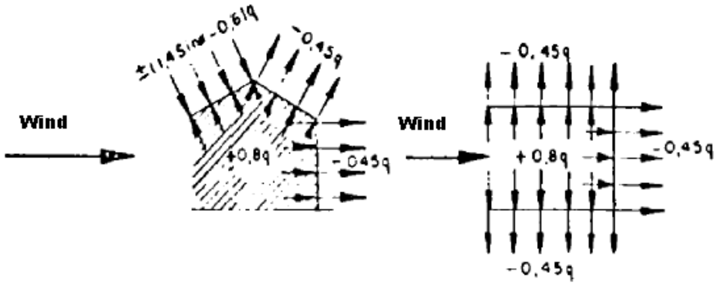
EXTERNAL DESIGN WIND PRESSURES IN MONOPITCHED ROOF STRUCTURES

Fig. 3

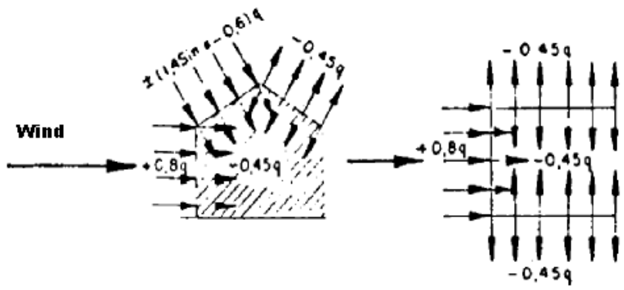


EXTERNAL AND INTERNAL DESIGN PRESSURES IN INCLOSED STRUCTURES

Fig.4



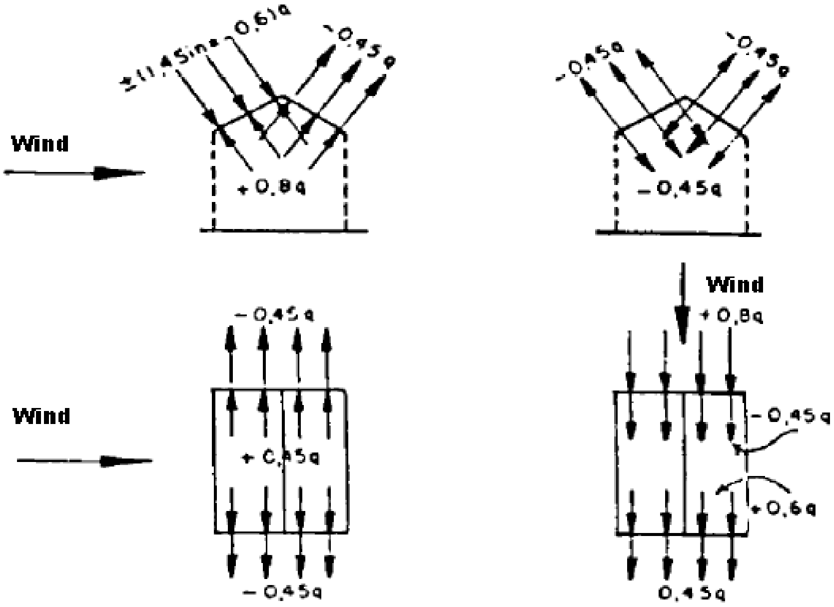
a) Open face is windward



b) Open face is Leeward

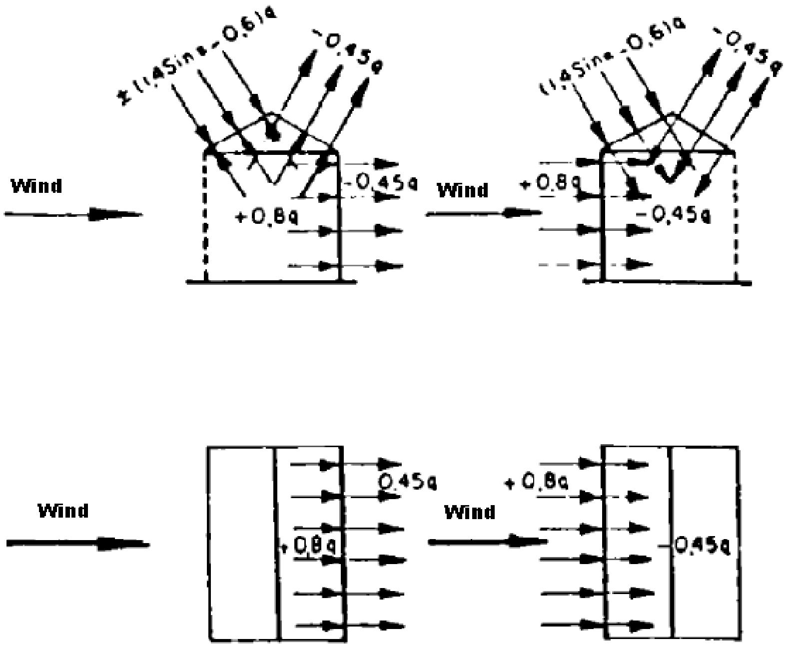
EXTERNAL AND INTERNAL DESIGN PRESSURES IN OPEN STRUCTURES

Fig.5



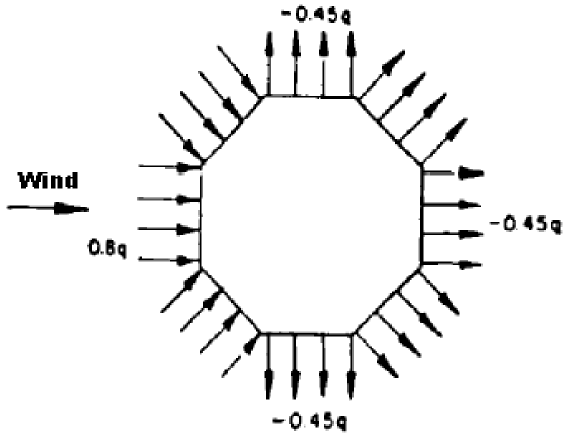
STRUCTURE WITH LONGITUDINAL WALL OPEN

Fig.6



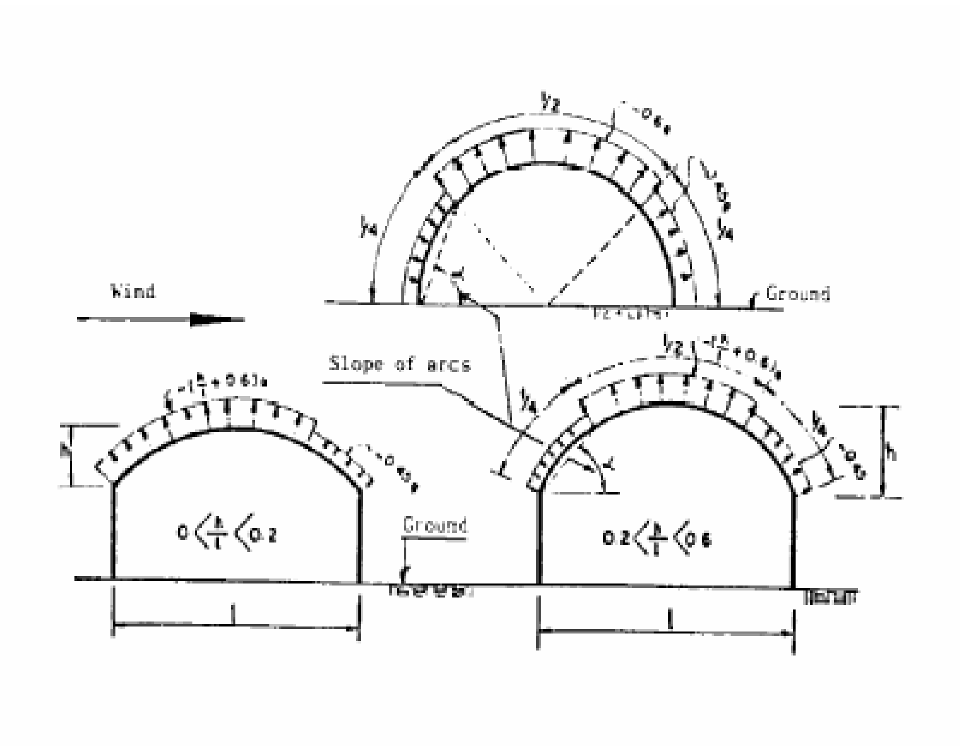
STRUCTURE WITH 3 SIDES OPEN

Fig.7



STRUCTURE WITH POLYGONAL PLAN

Fig.8



ARCHED ROOF (divided into sloped sections)

Fig. 9

7.2 Snow Loads

This clause gives minimum imposed roof loads that may be applied by snow accumulation for use in designing buildings and building components.

7.2.1 Zoning

Various parts of the country have been classified into four zones according to the intensity of annual snowfall:

Zone I : Tropical; generally regions with no previous record of snowfall, like southern provinces.

Zone II : Fair; parts of central provinces with fair weather and relatively low rate of snowfall.

Zone III : Cold; generally northern provinces with heavy rate of snowfall.

Zone IV : Extreme cold; mountainous regions with very high rate of snowfall and intense freezing condition.

The above zones are shown in Map No. 2.

7.2.2 Calculation of snow load

Snow Load shall be determined according to the zoning and slope of the roof, as shown in Table 1 below:

TABLE 1 - SNOW LOAD, IN kPa (kN/m^2), AS APPLIED ON THE HORIZONTAL PROJECTION OF THE ROOF

ZONE	SLOPE OF THE ROOF					
	15° OR LESS	20°	25°	35°	45°	60° OR MORE
I	0.25	0.25	0.25	0.25	0.25	0.25
II	0.90	0.85	0.80	0.70	0.5	0.40
III	1.50	1.40	1.30	1.20	0.80	0.40
IV	2.00	1.85	1.70	1.50	1.00	0.40

Note 1:

Figures shown in Table 1 are the least amounts. In regions, with unusual conditions, where snowfall is more intense, loads applicable to that condition shall be used.

7.2.3 Snow loads on roofs

In the design of roofs the greater value of either snow load (as given in Table 1) or live load (as given in Table 2 and Appendix IB) shall be assumed, and these two need not be considered simultaneously.

7.2.4 Accumulation of snow

If there is a possibility of accumulation of snow in some parts of the roof due to its geometric shape, wind, etc., then the effect of this accumulation shall be considered in the calculations.

7.2.5 Unloaded portions

The effect of removing half the balanced snow load from any portion of the loaded area shall be considered.

Note 2:

In many situations a reduction in snow load on a portion of a roof by wind scour, melting, or snow-removal operations will simply reduce the stresses in the supporting members.

However, in some cases a reduction in snow load from an area will induce heavier stresses in the roof structure than occur when the entire roof is loaded. Cantilevered roof joists are a good example; removing half the snow load from the cantilevered portion will increase the bending stress and deflection of the adjacent continuous span. In other situations adverse stress reversals may result.

7.2.6 Unbalanced roof snow loads

Winds from all directions shall be considered when establishing unbalanced loads.

7.2.7 Roof projections

A continuous projection longer than 5 meters may produce a significant drift on a roof. The loads caused by such a drift shall be considered to be distributed triangularly on all sides of the obstruction that are longer than 5 meters.

The magnitude of drift surcharge loads and the width of the drift shall be determined by using the method developed for lower roofs in ANSI-A.58.1 section 7.

7.2.8 Snow sliding down roofs

Under certain conditions snow may slide down a pitched or curved roof. The force Fs (in kN per meter width) exerted by a sliding mass of snow in the direction of slide is calculated from the following equation:

$$F_s = S\,b\,\sin\alpha$$

Where:

- S is the snow load on the roof (in kN/m^2 = k Pa);
- b is the distance on plan from the gutter to the ridge (in meters).
- α is the angle of pitch of the roof measured from the horizontal.

The appropriate value for S is obtained from Table 1.

It should be the most onerous value arising from uniformly distributed snow on the roof slope under consideration. It may result from either the uniform load case or the asymmetric load case.

This force should be taken into account in the design of snowguards or snowfences if snow in likely to slide off the roof endangering people or property below. It should also be taken into account in the design of any obstruction on a roof which may prevent snow sliding off the roof.

7.2.9 Extra loads from rain-on-snow

In some areas of the country, intense rains may fall on roofs already sustaining heavy snow loads. In such areas, the application of a rain-on-snow surcharge load shall be considered.

The followings are recommendations for rain-on-snow surcharge loads in areas where intense rains are likely:

Roof Slope	Rain-On-Snow surcharge KPa
< 4.17 cm/m	0.239
$\geq$ 4.17 cm/m	0

7.2.10 Ponding loads

Roof deflections caused by snow loads shall be considered when determining the likelihood of ponding loads from rainon-snow or from snow meltwater.

7.2.11 Snow drift load calculations

This clause briefly describes the general process adopted for determining the maximum local load intensity resulting from snow in a drift. It is included for designers who wish to understand the parameters which influence the magnitude of the snow loads associated with drifting of snow. It is not intended for use in calculating snow load shape coefficients.

Basically three checks are made as follows:

a) It is first assumed that the drift forms to the top of the obstruction and the density of the snow increases from

that of the fallen snow on the ground. This check takes the general form of limiting the snow load shape coefficient to:

$$Ph_{oi} / so$$

Where:

P is the weight density of the snow in the drift (2 kN/m3 assumed);

h_{oi} is the height of the obstruction (in meters);

so is the site snow load (in kN/m2=k Pa).

b) A check is then made to ensure that there is sufficient snow available on the roof to form a drift to the top of the obstruction. This check takes the general form of limiting the snow load shape coefficient to:

$$2b_i/l_{si}$$

Where:

b_i is the length of the building from which snow will be blown into the drift (in meters);

l_{si} is the length of the drift (in meters).

c) Finally an over-riding maximum value for the amount of snow is applied by arbitrarily assuming that the local load cannot be larger than the snow load on the ground increased by a certain multiplicative factor. The factor is usually 5 or 8 depending upon the severity of drifting likely to occur for the design configuration being considered.

7.2.12 Rain loads

a) Roof drainage

Roof drainage systems shall be designed in accordance with the provisions of the IPS-E-CE-390: "Rain and Foul Water Drainage of Buildings".

Secondary (overflow) drains shall not be smaller than primary drains.

b) Ponding Loads

Roofs shall be designed to preclude instability from ponding loads.

c) Blocked drains

Each portion of a roof shall be designed to sustain the load of all rainwater that could accumulate on it if the primary system for that portion is blocked. Ponding instability shall be considered in this situation. If the overflow drainage provisions contain drain lines, such lines shall be independent of any primary drain lines.

d) Controlled drainage

Roofs equipped with controlled drainage provisions shall be equipped with a secondary drainage system at a higher elevation which prevents ponding on the roof above that elevation. Such roofs shall be designed to sustain all rainwater loads on them to the elevation of the secondary drainage system plus 0.24 k Pa. Ponding instability shall be considered in this situation.

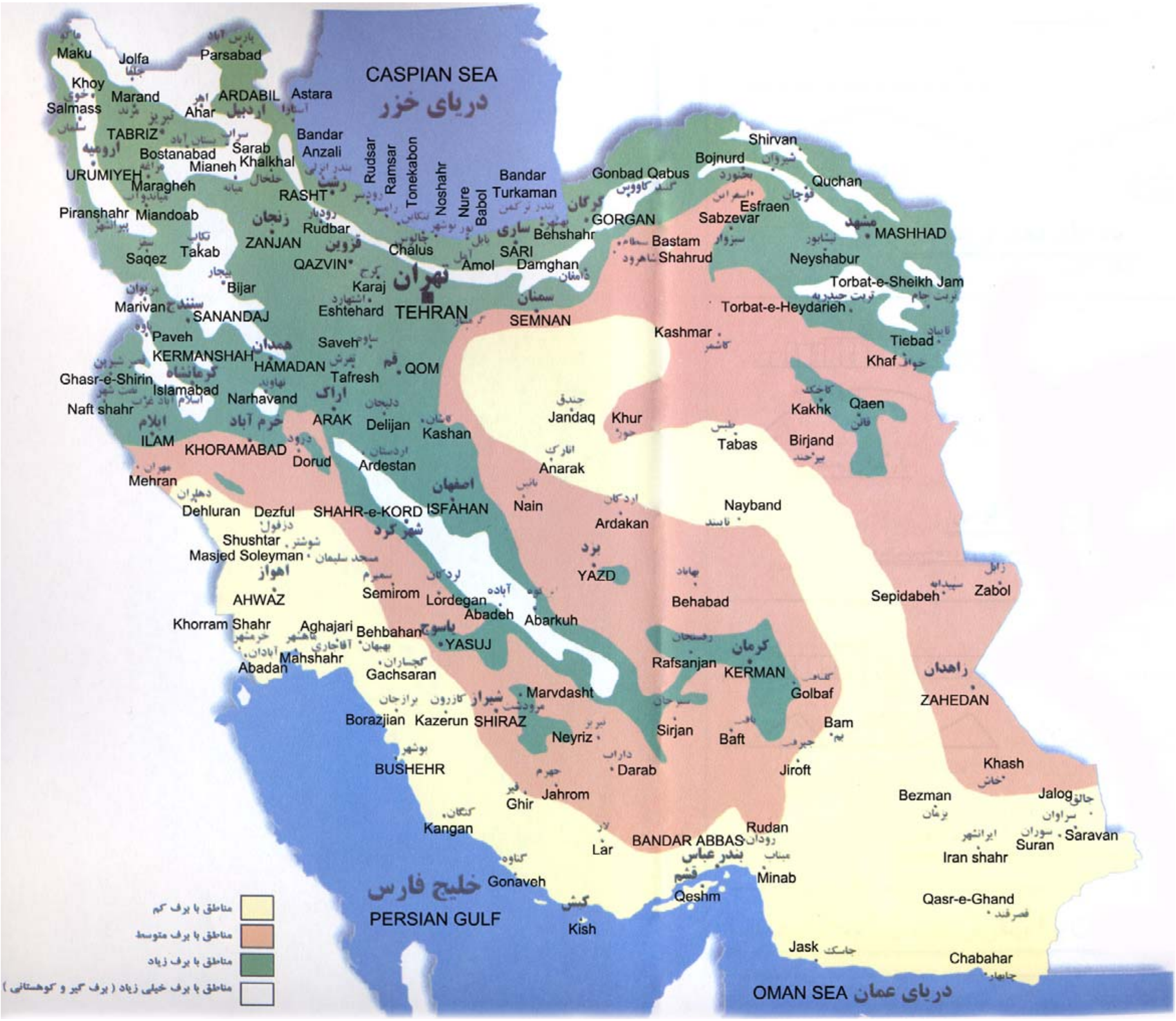
7.2.13 Snow load in special cases

Whenever snow may compile or effect the intensity of other loads (such as wind loads) not mentioned in this Standard, these effects shall be taken into account.

GROUND SNOW LOAD, FOR 50-YEAR MEAN RECURRENCE INTERVAL

FOR VARIOUS REGIONS OF IRAN

(COURTESY OF IRANIAN METEOROLOGICAL BUREAU)



7.3 Seismic (Earthquake) Loads

7.3.1 General

All buildings and structures shall be designed to withstand the effects of seismic forces as well as wind effects. Wind and seismic forces are assumed to act separately and their effects shall not be considered simultaneously.

Generally, structures and their components shall be able to thoroughly withstand the greatest stress caused by wind and earthquake.

Structures are designed individually in either one of the principal directions, without considering the other direction. Simultaneous effects of seismic forces in both directions need not be considered.

In the seismic design of structures, only the horizontal component of the seismic force shall be considered and the vertical component shall not be taken into account, except for the following cases:

- For cantilevered balconies and projections (particularly those carrying considerable dead load at the tip), and for buildings that house technical instruments or special equipments where the vertical component may cause a malfunction, then the effect of vertical component shall be considered.

7.3.2 Lateral seismic forces

The minimum lateral seismic force in each direction of a structure shall be calculated according to the provisions of "Iranian Code of Practice for Seismic Resistant Design of Buildings", BHRC–PNS 374 standard 2800-1990, (also known as Standard No. 2800) or its latter editions.

7.3.3 Earthquake loads in industrial plants

For requirements governing the designing of structures in petroleum plants, see Appendix ID.

8. DEAD LOADS

8.1 Definition

Dead loads comprise the weight of all permanent construction, including walls, floors, roofs, ceilings, stairways, and fixed service equipment, plus the net effect of prestressing.

Moreover the following complementary items shall be considered as dead load:

- fireproofing;
- sprinkler system;
- fixed partitions;
- all fixed equipment with the relevant fluid content;
- the vertical and horizontal pressures due to the stored liquid;
- insulation weight.

8.2 Weight of Materials and Constructions

In estimating dead loads for purposes of design, the actual weights of members and constructions materials shall be used, provided that in the absence of definite information, values satisfactory to the authority having jurisdiction are assumed.

Note:

For information on dead loads, see Appendix IA, tables of Annex 1 and Annex 2.

8.3 Weight of Fixed Service Utilities

In estimating dead loads for purposes of design, the weight of fixed service utilities, such as plumbing stacks and risers, electrical feeders, and heating, ventilating, and air-conditioning systems, shall be included whenever such equipment is supported by structural members. It is recommended to utilize data provided by manufacturers of such service utilities.

8.4 Special Considerations

Engineers, architects, and building owners are advised to consider factors that may result in differences between actual and calculated loads.

Experience has shown, that conditions are encountered which, if not considered in design, may reduce the future utility of a building or reduce its margin of safety. Among them are:

8.4.1 Dead loads

There have been numerous instances in which the actual weights of members and construction materials have exceeded the values used in design. Care is advised in the use of tabular values. Also, allowances should be made for such factors as the influence of formwork and support deflections on the actual thickness of a concrete slab of prescribed nominal thickness.

8.4.2 Future installations

Allowance should be made for the weight of future wearing or protective surfaces where there is a good possibility that such may be applied. Special consideration should be given to the likely types and position of partitions, as insufficient provision for partitioning may reduce the future utility of the building.

8.4.3 Occupancy changes

The possibility of later changes of occupancy involving loads heavier than originally contemplated should be considered. The lighter loading appropriate to the first occupancy should not necessarily be selected. If so chosen , considerable restrictions may be placed on the usefulness of the building at a later date.

Attention is directed also to the possibility of temporary changes in the use of a building, as in the case of clearing a dormitory for any recreational purpose.

8.4.4 Additions to existing structures

When an existing building or other structure is enlarged or otherwise altered, all portions thereof affected by such enlargement or alteration shall be strengthened, if necessary, so that all loads will be supported safely without exceeding the allowable stresses (or specified strengths, when appropriate load factors are applied) for the materials of construction in the structural members and connections.

8.4.5 Load tests

The authority having jurisdiction may require a load test of any construction whenever there is reason to question its safety for the intended occupancy or use.

8.5 Equipment Load, (Q)

The weight of equipment, such as pumps, compressors, motors, etc., shall be derived as far as possible from manufacturer’s data and shall include controls, auxiliary machinery, piping, etc.

9. LIVE LOADS

9.1 Definition

Live loads are those loads produced by the use and occupancy of the building or other structure and do not include environmental loads such as wind load, snow load, rain load, earthquake load, or dead load. Live loads on a roof are those produced (1)during maintenance by workers, equipment, and materials (2)during the life of the structure by movable objects such as planters and by people.

9.2 Load Values

9.2.1 The lowest nominal values of loads due to use and occupancy are defined as the most unfavorable values for certain (or expected) conditions of normal use of a building.

9.2.2 When designing floors for uniformly distributed loads, the lowest characteristic value shall not be prescribed less than the values given in Table 2.

9.2.3 For several floor zones which are used in conditions similar to those in production and storage buildings, loads due to use and occupancy shall be defined according to the rules for those buildings and facilities.

9.2.4 Besides uniformly distributed load, floors shall also be designed for a concentrated load applied to the element of the floor to produce the most unfavorable effects.

If detailed data for concentrated loads are not available, the load shall be considered as applied to a square area 0,1 m × 0,1 m and its value taken equal to:

a) Floors and staircases: 1,5 kN;

b) Loft space floors, roofs, terraces and balconies: 1,0 kN;

c) Roofs allowing movement of people only by footbridges: 0,5 kN.

9.2.5 The effect of significant dynamic loads shall be taken into account by dynamic factors or by special dynamic analysis. For dynamic (vibration) loads, see clause 10.3.

9.2.6 Table 2 does not contain floor loads due to partitions; these should be considered separately. If it is necessary to take into account the effect of the partitions not planned for in the design (or movable partitions), these can be considered as a uniformly distributed load with a lowest nominal value 0,5 kPa if their weight does not exceed 2,5 kN/m. In all other cases, the effect of partitions shall be determined as a function of their position, their weight and their jointing to other elements of the building.

TABLE 2 - LOWEST NOMINAL VALUES OF UNIFORMLY DISTRIBUTED LOADS

NO.	BUILDINGS AND PREMISES	LOWEST NOMINAL VALUES OF LOADS. kPa
1	RESIDENTIAL FLATS, BEDROOMS IN KINDERGARTENS AND SCHOOLS, DWELLINGS, HOTEL ROOMS, HOSPITAL AND SANATORIUM WARDS, ETC.	1.5
2	OFFICES FOR ADMINISTRATION, TECHNICAL AND SCIENTIFIC STAFF, CLASSROOMS IN SCHOOLS AND COLLEGES, CLOAK-ROOMS, SHOWER-BATHS, LAVATORIES IN INDUSTRIAL AND PUBLIC BUILDINGS	2.0
3	STUDYROOMS AND LABORATORIES IN HEALTH, EDUCATION OR SCIENTIFIC ESTABLISHMENTS, ROOMS WITH DATA PROCESSING EQUIPMENT, KITCHENS IN PUBLIC BUILDINGS, TECHNICAL FLOORS, BASEMENTS, ETC.	2.0
4	HALLS:	
	A) READING-ROOMS (WITHOUT BOOKSHELVES)	2.0
	B) DINING-ROOMS (IN CAFES, RESTAURANTS,ETC.)	2.0
	C) CONFERENCE-HALLS, WAITING-ROOMS, THEATRE AND CONCERT HALLS, GYMNASIA, BALL-ROOMS, ETC.	4.0
	D) DEPARTMENT STORES	4.0
	E) EXHIBITION HALLS (IN ADDITION TO EQUIPMENT AND MATERIALS)	2.5
5	SHELVING IN LIBRARIES, OFFICES WITH FILING STORAGE, STAGES IN THEATRES, ETC.	5.0
6	STANDS:	
	A) WITH FIXED SEATS	4.0
	B) WITHOUT FIXED SEATS	5.0
7	LOFT SPACE (IN ADDITION TO THE WEIGHT OF EQUIPMENT AND MATERIALS)	0.7
8	TERRACES AND ROOFS:	
	A) ZONES FOR REST	1.5
	B) ZONES CROWDED BY PEOPLE LEAVING HALLS, OFFICES, PRODUCTION BUILDINGS, ETC.	4.0
9	BALCONIES AND LOGGIAS:	
	A) STRIP UNIFORMLY LOADED IN AN AREA 0,8 m WIDE ALONG THE BARRIER	4.0
	B) UNIFORMLY LOADED OVER THE WHOLE BALCONY AREA, IF ITS EFFECT IS MORE UNFAVORABLE THAN THAT IN A)	2.0
10	LOBBIES, FOYERS, CORRIDORS, STAIRCASES (WITH ADJACENT PASSAGES), ADJOINING PREMISES SPECIFIED IN	
	A) No. 1	2.5
	B) Nos. 2 AND 3	3.0
	C) Nos. 4 AND 5	4.0
	D) No. 6	5.0
11	PLATFORMS OF RAILWAY AND SUBWAY STATIONS	4.0
12	GARAGES AND CARPARKS FOR PASSENGER CARS AND LIGHT VEHICLES (NOT FOR TRUCKS)	2.5

Notes:

1) Loads specified in No. 8 shall be taken instead of snow loads if they give more unfavorable results.

2) Loads specified in No. 9 shall be taken into account when analyzing the load-bearing elements directly supporting balconies (loggias).

3) Loads specified in the table include some allowance for impact arising from the usual movement of people and furniture.

4) If necessary, some standards may apply further subdivision to any floor zone for which a single load value is specified in this table. For example, some areas may be unloaded if this produces a more unfavorable effect.

9.3 Reduction of Uniformly Distributed Loads

9.3.1 It is recommended that uniformly distributed loads (except the loads due to stationary equipment and stocked materials) are reduced for analysis of:

a) Floor beams - as a function of floor zone dimensions supported by the beams (tributary area);

b) Columns, walls, bases and foundations, as in the previous case or as a function of the number of floors supported above the floor under consideration.

When analyzing beams with load tributary area A (in square meters), the load specified in Table 2, may be reduced:

a) For premises specified in Nos. 1 and 2 of Table 2, multiplying by the factor:

$$\alpha_1 1 = 0,3 + p \frac{3}{A} \quad \text{(if } A > 18\ m^2\text{)} \qquad (1)$$

b) for premises specified in No. 4 of Table 2, by multiplying by the factor:

$$\alpha_2 = 0,5 + p \frac{3}{A} \quad \text{(if } A > 36\ m^2\text{)} \qquad (2)$$

When analyzing columns, walls, bases and foundations, the loads given in Table 2, may be reduced:

a) For premises specified in Nos. 1 and 2 of Table 2, by multiplying by the factor:

$$\eta_1 = 0,3 + p \frac{0.6}{n} \quad \text{(for } n \geq 2\text{)} \qquad (3)$$

b) For premises specified in No. 4 of Table 2, by multiplying by the factor:

$$\eta_2 = 0,5 + p \frac{0.6}{n} \quad \text{(for } n \geq 2\text{)} \qquad (4)$$

Where:

n is the numbers of completely loaded floors considered in the analysis (over the cross-section considered):

for n =1, $\eta_1 1 = 1$, ***and*** $\eta_2 = 1.$

Note:

National standards may admit other methods of reducing the uniformly distributed loads as functions of area dimensions and number of storeys, provided the resulting load is not smaller than the reduced load derived in accordance with this Standard.

9.4 Limitations on Live-Load Reduction

For live loads of 4.8 kPa or less, no reduction shall be made for areas to be occupied as places of public assembly, for garages except as noted below, for one-way slabs, or for roofs except as permitted in Clause 9.5. For live loads that exceed 4.8 kPa and in garages for passenger cars only, design live loads on members supporting more than one floor may be reduced 20%, but live loads in other cases shall not be reduced except as permitted by the authority having jurisdiction.

9.5 Minimum Roof Live Loads (Lr)

9.5.1 General

Roofs shall sustain, within stress limitation of this standard, all dead loads, plus unit live loads as set forth in the following clauses,in which all roof slopes are measured from the horizontal and all loads are applied vertically.

9.5.2 Flat roofs

The imposed load, including snow load[(1)] on flat roofs and sloping roofs up to and including 10°, where access (in addition to that necessary for cleaning and repair) is provided to the roof, is 1.5 kN/m^2 measured on plan or a 1.8 kN concentrated load, whichever produces the greater stress. Where deflection is the design criterion, the concentrated load is assumed to act in the position which produces maximum deflection.

The imposed load, including snow load[(1)], on flat roofs and sloping roofs up to and including 10°, where no access is provided to the roof (other than that necessary for cleaning and repair), is 0.75 kN/m^2 measured on plan or a 0.9 Kn concentrated load, whichever produces the greater stress. Where deflection is the design criterion, the concentrated load is assumed to act in the position which produces maximum deflection.

9.5.3 Sloping roofs

The imposed loads, including snow load[(1)] on roofs with a slope greater than 10°, where no access is provided to the roof (other than that necessary for cleaning and repair), are as follows:

> **a)** For a roof-slope of 30° or less: 0.75 kN/m^2 measured on plan or a 0.9 kN concentrated load, whichever produces the greater stress.
>
> Where deflection is the design criterion, the concentrated-load is assumed to act in the position which produces maximum deflection.
>
> **b)** For a roof-slope of 75° or more: zero load.

For roof slopes between 30° and 75° the imposed load may be obtained by linear interpolation between 0.75 kN/m^2 for a 30° roof slope and zero for a 75° roof slope.

Note:

(1) When the depth of snow is not uniform, owing to sliding, wind, melting or the shape of the roof, the resulting load may be increased locally.

9.5.4 Curved roofs

The imposed load on a curved roof is calculated by dividing the roof into not less than five equal segments and by then calculating the load on each, appropriate to its mean slope, in accordance with sub-clauses 9.5.2 and 9.5.3.

9.5.5 Roof coverings

A load of 0.9 kN on any square with a 125 mm side provides for loads incidental to maintenance on all self-supporting roof coverings at a slope of less than 45°, i,e. those not requiring structural support over their whole area. No loads incidental to maintenance are appropriate to glazing.

9.6 Special Considerations

9.6.1 Loads not specified

For occupancies or uses not designated in clause 9.2 , the live load shall be determined in a manner satisfactory to the authority having jurisdiction.

Note:

For additional information on live loads, see the Appendix IB Tables IB/1 to IB/9.

9.6.2 Partial loading

The full intensity of the appropriately reduced live load applied only to a portion of the length of a structure or member shall be considered if it produces a more unfavorable effect than the same intensity applied over the full length of the structure or member.

9.6.3 Posting of live loads

In every building or other structure, or part thereof, used for mercantile, business, industrial, or storage purposes, the owner of the building shall ensure that the loads approved by the authority having jurisdiction are marked on plates of approved design and are securely affixed in a conspicuous place in each space to which they relate. If such plates are lost, removed, or defaced, the owner shall have them replaced.

9.6.4 Restrictions on loading

The building owner shall ensure that a live load greater than that for which a floor or roof is approved by the authority having jurisdiction shall not be placed, or caused or permitted to be placed, on any floor or roof of a building or other structure.

10. OTHER LOADS

10.1 Crane Loads and Moving Loads (C)

Crane loads shall be assumed at their maximum values including lifting capacity as well as the maximum horizontal loads caused by braking or acceleration.

For the design of each structural element the most unfavorable position of the crane or other moving loads shall be considered. For moving loads an appropriate impact factor shall be applied.

10.2 Differential Settlement, (ds)

The variability of the soil strata may result in differential settlement.

The resulting bending moments, shear and axial forces shall be considered.

10.3 Dynamic (Vibration) Loads

A detailed design and a vibration analysis shall be made in accordance with the following requirements:

10.3.1 Static deformation

The static deformation for rotating equipment foundations shall be calculated and shown to be within the limits stated by the manufacturer of the equipment. The calculations shall include, but not be limited to, the following causes of deformation:

- Shrinkage and creep of concrete.
- Temperature effects caused by radiation and convection of heat or cold generated by machinery, piping and ducting.
- Elastic deformation caused by changing vapor pressure in condensers.
- Elastic deformation caused by soil settlement or elastic compression of piles.

10.3.2 Vibration analysis

A three-dimensional vibration analysis for rotating equipment foundations shall be made and shall show that the dynamic amplitudes will not exceed the lower of the following values; see also (10.3.6):

- The maximum allowable value stated by the manufacturer of the equipment.
- The amplitude (single amplitude) which causes the effective velocity* of vibration to exceed:

  a) 2 mm/s at the location of the machine-bearing housings.

  b) 2.5 mm/s at any location of the structure.

*** The effective velocity is defined as the square root of the average of the square of the velocity. Velocity being a function of time in the case of a pure sinusoidal function the effective velocity is 0.71 times the peak value of the velocity.**

10.3.3 Exciting force

For the vibration analysis, the exciting forces shall be taken as the maximum values that according to the manufacturer of the equipment, will occur during the lifetime of the equipment.

10.3.4 Schematic mechanical model

The vibration calculation shall be based on a mechanical model wherein the weights and elasticity of both structure and foundation and the weight of the equipment are represented in an appropriate way.

10.3.5 Frequencies

All natural frequencies below 2 times the operating frequency for reciprocating equipment and below 1.5 times the operating frequency for rotating equipment shall be calculated.

Of the natural frequencies between 0.35 and 1.5 times the operating frequency, it shall be shown that the amplitudes are within the allowable values even assuming that due to differences between the actual structure and the assumed model resonance does occur. In this case a reasonable amount of damping should be estimated.

10.3.6 Dynamic amplitudes

The dynamic amplitudes of any part of the foundation including any reciprocating compressor shall be less than 80 μm single amplitude.

10.4 Erection Loads, (er)

Erection loads shall be defined as temporary forces caused by erection of structure or equipment.

All possible loading conditions during erection shall be considered and for any member of a structure the most unfavorable shall be taken into account. Heavy equipment lowered onto a supporting structure can introduce extreme point loads on structural members, exceeding any operating or test load. After placing of equipment, the exact positioning (lining out and leveling) can also introduce extreme point loads. The above should be interpreted on the basis of contractor's practical experience and manufacturer's information.

Beams and floor slabs in multi-storey structures, e.g. fire decks, shall be designed to carry the full construction loads imposed by the props supporting the structure immediately above. A note shall be added on the relevant construction drawings to inform the field engineer of the adopted design philosophy.

For floor slabs and supports whose strength during construction is less than their ultimate design strength, the following extra loads for transporting concrete or other building materials shall be added according to the volume capacity of the bucket or other means of transport:

- 0.75 kPa, for bucket of 75 lit. capacity
- 1.50 kPa, " " " 150 lit. "
- 2.50 kPa, " " " 250 lit. "

10.5 Factored Loads

Factored Loads are the product of the nominal load and a load factor.

10.6 Fluid Loads (F)

Fluid loads are the gravity loads of liquid or solid materials in equipment and piping during operation or hydrotest. They are considered live loads when establishing load factors for ultimate strength design.

10.7 Horizontal Loads

Minimal characteristic values of horizontal loads per unit length on the hand-rails and balcony barriers shall be taken as follows:

a) For residential buildings , kindergartens , hospitals and other health establishments: 0.3 kN/m;

b) For stands and gymnasia: 1.5 kN/m;

c) For other buildings and premises: 0.8 kN/m.

For service platforms, foot-bridges, roof barriers visited only by individuals, the minimum characteristic value of horizontal concentrated load on hand-rails and barriers shall be taken equal to 0,3 kN (at any point along the barrier). The same value of horizontal concentrated load should be taken for lightweight partitions.

10.8 Hydrostatic Pressure, (H)

a) Pressure on basement walls

In the design of basement walls and similar approximately vertical structures below grade, provision shall be made for the lateral pressure of adjacent soil. Due allowance shall be made for possible surcharge from fixed or moving loads. When a portion or the whole of the adjacent soil is below a free-water surface, computations shall be based on the weight of the soil diminished by buoyancy, plus full hydrostatic pressure.

b) Uplift on floors

In the design of basement floors and similar approximately horizontal construction below grade, the upward pressure of water, if any, shall be taken as the full hydrostatic pressure applied over the entire area.

The hydrostatic head shall be measured from the underside of the construction.

10.9 Impact Loads, (I)

The live loads specified in clause 9 shall be assumed to include adequate allowance for ordinary impact conditions. Provision shall be made in the structural design for uses and loads that involve unusual vibration and impact forces.

10.9.1 Elevators

All elevator loads shall be increased by 100% for impact, and the structural supports shall be designed within the limits of deflection.

10.9.2 Machinery

For the purpose of design, the weight of machinery and moving loads shall be increased as follows to allow for impact:

(1) elevator machinery, 100%; (2) light machinery, shaft or motor-driven, 20%; (3) reciprocating machinery or power driven units, 50%; (4) hangers for floors or balconies, 33%. All percentages shall be increased if so recommended by the manufacturer.

10.9.3 Craneways

All craneways except those using only manually powered cranes shall have their design loads increased for impact as follows: (1) a vertical force equal to 25% of the maximum wheel load; (2) a lateral force equal to 20% of the weight of the trolley and lifted load only, applied one-half at the top of each rail; and (3) a longitudinal force of 10% of the maximum wheel loads of the crane applied at the top of the rail.

10.9.4 Vehicle barriers for car parks

a) The horizontal force F (in kN), normal to and uniformly distributed over any length of 1.5m of a barrier for a car park, required to withstand the impact of a vehicle is given by:

$$F = \frac{0.5 m V^{2}}{\delta_c + \delta_b}$$

Where:

- ***m*** is the gross mass of the vehicle, in kg;
- ***v*** is the velocity of the vehicle, in m/s, normal to the barrier;
- δ_c is the deformation of the vehicle, in mm;
- δ_b is the deflection of the barrier, in mm.

b) Where the car park has been designed on the basis that the gross mass of the vehicles using it will not exceed 2500 kg the following values are used to determine the force F:

m **= 1500 kg***

v **= 4.5 m/s**

δ_c **= 100 mm unless better evidence is available.**

For a rigid barrier, for which äb may be taken as zero, the force F appropriate to vehicles up to 2500 kg gross mass is taken as 150 kN.

*** The mass of 1500 kg is taken as being more representative of the vehicle population than the extreme value of 2500 kg.**

c) Where the car park has been designed for vehicles whose gross mass exceeds 2500 kg the following values are used to determine the force F:

m is the actual mass of the vehicle for which the car park is designed (in kg);

v **= 4.5 m/s**

δ_c **= 100 mm unless better evidence is available.**

d) The force determined as in (b) or (c) may be considered to act at bumper height. In the case of car parks intended for motor cars whose gross mass does not exceed 2500 kg this height may be taken as 375 mm above the floor level.

e) Barriers to access ramps of car parks have to withstand one half of the force determined in (b) or (c) or acting at a height of 610 mm above the ramp.

Opposite the ends of straight ramps intended for downward travel which exceed 20 m in length the barrier has to withstand twice the force determined in (b) or (c) or acting at a height of 610 mm above the ramp.

10.10 Maintenance Loads, (M)

Maintenance loads shall be defined as temporary forces caused by the dismantling, repair or painting of equipment.

Structures and foundations supporting heat exchangers subject to bundle pulling shall be designed for a longitudinal force applied at the centroid of the tube bundle. This force shall be equal to 100% of the bundle weight (mass). The shear force due to bundle pulling shall be assumed to be transmitted solely through the fixed shell support.

10.11 Thermal Loads (T)

Thermal loads shall be defined as those forces caused by a change in temperature. Such forces shall include those by vessel or piping expansion or contraction, and expansion or contraction of structures.

10.11.1 Internal thermal forces and stresses

Foundations and structures which are subject to temperature effects shall not only be designed for the various loading conditions but also for any temperature difference that may occur in parts of structural members.

Note:

The temperature of the surface of the concrete shall not exceed 100°C.

Taking into account the wide range of temperature occurring in Iran throughout the year, expansion joints shall be provided at convenient locations and the following data shall be used in thermal loads calculation:

- Concrete and steel linear expansion factor: a = 0.000011/°C.

- Thermal variation for concrete or steel structures delta T is dependent on the maximum and minimum temperatures which should be measured at site for the period of construction.

- It shall be selected the thermal variation (positive or negative) which produces the most severe thermal load for the structure.

10.11.2 Friction due to thermal expansion

When thermal expansion results in friction between equipment and supports, the friction force shall be taken as the operating load on the support times the applicable friction coefficient given in Table 3.

TABLE 3 - FRICTION COEFFICIENT FOR VARIOUS MATERIALS

SURFACES	FRICTION COEFFICIENT
- STEEL TO STEEL (NOT CORRODED)	0.30
- TEFLON TO TEFLON	0.08
- GRAPHITE TO GRAPHITE	0.15
- STEEL TO CONCRETE	0.40
- TEFLON ON STAINLESS STEEL	0.10

In the design of pipe supporting beams, the horizontal slip forces exerted by expanding or contracting pipes on steel pipe racks shall be assumed to be 15% of the operating weight on the beam. These slip forces shall not be distributed to the foundations.

A concrete pipe rack beam shall be designed for an arbitrary horizontal pipe anchor force of 15 kN acting at midspan, which also shall not be distributed to the foundations.

For pipe anchor forces transferred by longitudinal girders to structural anchors (bracing) an arbitrary force of 5% of the total pipe load per layer shall be taken into account, unless design calculations dictate a higher force, these forces shall be distributed to the foundations.

10.12 Loads of Vessels, Columns, etc.

Apart from vessels and columns, this category also consists of filters, settlers, heat exchangers, condensers and the like complete with their piping.

In accordance with the various load combinations for the category of equipment, the following weights/loads shall be included in the calculations.

10.12.1 Empty weight, (Ve)

This is the dead weight of vessels, columns, etc. inclusive of protective layers, valves, etc., and shall be derived from manufacturer's data.

10.12.2 Operating weight, (Vo)

This is the empty weight of vessels, columns, etc., and the weight of their maximum contents which will apply during operation of the plant.

10.12.3 Hydrostatic test load, (Vt)

When hydrostatic pressure testing of equipment is required at site, the weight of this equipment completely filled with water shall be incorporated in the design of the supporting structure.

When more than one vessel, etc., is supported by one structure, the structure need only be designed on the basis that one vessel will be tested at any one time, and that the others will either be empty or still in operation.

APPENDICES

APPENDIX IA
BASES FOR DESIGN OF STRUCTURES
ACTIONS DUE TO THE SELF-WEIGHT OF STRUCTURES, NON-STRUCTURAL ELEMENTS AND STORED MATERIALS-DENSITY

IA.1 General

IA.1.1 The most important value in determining actions due to the self-weight of structures, non-structural elements and/or that of stored materials is the density.

IA.1.2 For materials having all three dimensions of the same order of magnitude, the densities are expressed in kilograms per cubic meter (kg/m^3). For roofing's (sheeting materials) having one dimension of smaller order of magnitude than the other two dimensions, the similar quantity will be surface density, expressed in kilograms per square meter (kg/m^2) (mass related to surface area).

IA.1.3 In some countries roofing's are considered to be external load, causing pressure on the structure (for example, snow load) consequently these are expressed in Newton's per square meter (N/m^2) or in PASCAL's*. For this reason, roofing's (see Annex 1 to this Appendix) are given as surface pressures, together with the values of surface density.

*** 1Pa = 1 N/m^2**

IA.1.4 Densities of stored materials substantially depend on how they are placed. Usually two methods of stocking are distinguished:

- **a)** Disorderly storage of materials;
- **b)** Orderly storage of materials.

Disorderly or bulky stored materials are stored without bales, forming a natural heap. Orderly stored materials are stored in stocks or piles with or without bales.

IA.2 Density Values

IA.2.1 The representative value of the density of materials and/or components of structures, non-structural elements and stored materials is in general determined by the mean value.

The representative value is generally represented by a unique value. In actual design situations, densities may alter due to the difference in quality of workmanship, moisture content, etc. The representative value of the density of earth is represented in the same manner, bearing compactness in mind.

IA.2.2 The representative values of densities of structures and non-structural elements are given in a table in Annex 1; the representative values of densities of stored materials and their angles of repose are similarly given in Annex 2.

IA.2.3 Where the tables give only one density value for one material (or soil), this means that the corresponding nominal values do not normally differ significantly (up to ±5%) in different countries and the indicated mean value is the average of the nominal values. The range of two values of densities given in the Annexes for one material indicates that the mean values of densities for different countries vary between the indicated ones.

This also refers to the angles of repose. However, it should be emphasized that in accordance with the national practice of different countries, angles of repose differ up to ±30% from those indicated in Annex 2 to this Appendix. Thus values of angles of repose given in Annex 2 are approximate.

IA.2.4 For the time being, only limited statistical data are available and the values given in Annexes 1 and 2 are based on relevant national practice.

ANNEX 1 TO APPENDIX IA

REPRESENTATIVE VALUES OF DENSITIES OF STRUCTURAL AND OF NON-STRUCTURAL ELEMENTS

(THIS ANNEX FORMS AN INTEGRAL PART OF THE STANDARD)

This Annex gives representative values of the densities of structural and non-structural elements in the form of a table.

Material	Density kg/m^3	Material	Density kg/m^3
Wood and substitutes 1 (air- dried,		Building bricks and blocks	
a bout 15 % humidity)		Solid burnt clay brick	
Hardwood		up to 14 Mpa (inclusive compressive	
Beech tree (fagus sylvatica)	680	strength	1600
Oak tree (Quercus)	690	Over 14 Mpa compressive strength	1800
Peduncular oak (Quercus robur)	640	Perforated brick (holes through the brick	
Brazilian rosewood (Dalbergia nigra)	800	exceed 25 % of its volume)	
Turkey oak (Quercus cerris)	640 to 770	hollow brick	820 to 1 350
Yew tree (Taxus baccata)	640	Perforated brick	1 150 to 1 450
Australian hardwood		Lime-sand brick	1 700
Box, grey (Eucalyptus microcarpa)	1 120	Cob brick, adobe	1 600
Penda, brown (Xanthostemon chry santhus)	1 120	Refractory brick for general purposes	
Softwood		fireclay	1 850
		high-strength fireclay	2 100
Black pine (Pinus laricio)			
Larch tree (Larix decidua)	570	silica (dinas)	1 800
Norway spruce (picea)	550	magnesite	2 800
Spruce fir (Pinus eccelsa)	430	chrome magnesite	3 000
Scotch pine (Pinus silvestris)	380 to 440	corundum	2 600
White willow (Salix alba)	490	Covering bricks	
Giant poplar (Populus alba)	330	inside wall-covering	1 600
Trembling poplar (Populus tremula)	410	outside facade covering	1 800
Ocume (Ocume)	450	outside facade covering	2 000
	410	clinker brick	
Conifers		Gas silicate block	
Extrude chipboard	400 to 600	with 2 Mpa compressive strength	500
Fibreboard	500 to 750	with 5 Mpa compressive strength	700
hard		with 7,5 Mpa compressive strength	900
medium-hard	900 to 1 100	Acid-resistant brick	2 000
porous insulating	600 to 850	Tuff block with 5 Mpa compressive strength	1 100
Plywood	250 to 400	Glass brick, double-walled	870 to 1 100
	750 to 850		
Coreboard		Mortars	
	450 to 650	Lime mortar	1 200 to 1 800
Natural building stones		Lime cement mortar	1 750 to 2 000
Magmatic plutonic rocks			
	2 650 to 3 000	Cement mortar (with 2,5 Mpa or greater	
Magmatic vulcanites		compressive strength)	2 100
Volcanic tuffs	2 500 to 2 850	Rock floor mortar	1 600
Sedimentary rocks	1 400 to 2 000	Gypsum mortar	1 200 to 1 800
sandstone		Fireclay mortar	1 900
marl	2 700	Pearlite mortar	
porous limestone	2 300	lime	340
fresh-water limestone	1 700 to 2 200	gypsum	370
compact limestone	2 400	cement	440
dolomite	2 650 to 2 800	Bitumen mortar with river sand	1 700
Transformed rocks	2 800		
clay slate		Concrete2	
Marble	2 600	Gravel concrete	2 250 to 2 500
	2 700	Basalt concrete	2 300 to 2 500

(to be continued)

ANNEX 1 (continued)

Material	Density kg/m3	Material	Density kg/m3
Crushed lock concrete		Tuff concrete, medium size building block	1200
C3-C35	2300 to 2 500	Gas silicate, medium size building bloc	
Blast furnace foam slag concrete		1,5 to 2,5 Mpa compressive strength	600 to 800
C3-C10	1 600 to 1 900	2,5 to 5 Mpa compressive strength	800 to 1 400
Aerated and gas concrete		5 to 10 Mpa compressive strength	900 to 1 300
C1,5-C5	600 to 1 500	10 to 20 Mpa compressive strength	1 000 to 1 600
Expanded clay gravel concrete		Inside wall- covering brick	1 700
C1,5-C16	700 to 1 700	Outside facade brick	1 900
Perlite concrete		Clinker brick	2 000
C1,5-C2	350 to 700	Fireclay brick (in fireclay mortar)	2 000
Tuff concrete		Acid - resistant brick (in bitumen mortar)	1 900
C3-C6	1 400 to 1 600	Glass brick, double - walled	
Lightweight aggregate concrete using sintered		(in cement mortar)	1 100
Pulverized fuel ash aggregates	1 600 to 1 850	Glass brick, coupled on one side	
Heat insulating gas concrete	300 to 900	(in cement mortar)	870
Heat insulating pearlite brick and pipeshell	260		
Aggregates and fillers		Metals for structures	
Sand	1 550	Structural steel	7 850
Sand gravel of 0 to 40 mm grain size	1 700	Cast iron structure	7 100
gravel	1 500 to 1 600	Aluminium	2 700
Blast furnace foam slag	1 700		
Blast furnace slag, granulated	1 200	Covering and other building material	
Crushed slag stone of 5 to 40 mm grain size	1 500	Asphalt, pure	2 200
Aerated silicate	1 000	Bitumen	1 000 to 1 400
pulverized fuel ash (pozzolan) for use as a		Tar (pitch)	1 100 to 1 400
cementitious component in concrete (bulk		Asbestos cement roofing and covering board	1 800 to 2 100
density)	800 to 1 050	Asbestos cement corrugated board	1 600
Lightweight concrete aggregate (Lytag) (bulk		Asbestos cement pipe	1 800
density)	750 to 1 000	Cellulose acetate panel	1 300
Lightweight aggregate using sintered pulverized		Cement tile	2 400
fuel ash/natural sand	1 700 to 2 000	Mosaic tile	2 200
Masonry from natural stones		Concrete flagstone	2 200
Rocks initial setting		Tile	1 750 to 2 000
basalt malphir, diorit, gabbro	3 000	Face brick (hard facade brick)	2 500
basalt lave	2 400	Stoneware tile	2 400
diabase	2 900		
granite, syngenit, porphyt	2 800	Soft covering brick	
trachyt	2 600	holed	1 350
Sedimentary rock		solid	1 600
graywacke, sandstone, puddingstone	2 700	Epoxy resin	
dense limestone, dolomite, shell limestone		without filler	1 150
and marble	2 800	with mineral matter	2 000
limestone conglomerate		with fibreglass	1 800
limestone conglomerate		Fenoplast	1 500
(e.g. travertin, etc.)	2 600		
volcanic tuff	2 000	Rubber floor	1 800
Transformed rocks		Plastic tile	1 100
gneiss, granulite	3 000	Polyamide (e.g. diamid)	1 100
slate	2 800	Polyester resin, without filler	1 350
serpantine	2 700		
		Polyethylene	930
Brick masonry 3		Polyisobutylene- base board	1 350
Ordinary brick	1 500	Polypropylene	1 150
Solid burnt clay brick		Polypropylene	930
up to 14 Mpa (inclusive) compressive		PVC hardboard	1 400
strength	1 500 to 1 700	PVC flooring board	1 600
over 14 Mpa compressive strength	1 900		
Walls made from brick with holes		PVC flooring tile	1 700
or ceramic blocks (depending on the		Flat glass	2 600
type of brick and blocks used)	1 150 to 1 450	Armoured glass	3 000

(to be continued)

ANNEX 1 (continued)

Material	Surface Pressure N / m²	Surface density Kg / m²
Roof shells, roofings [4]		
Tile roofings		
flat tile, burnt clay	380	38
pressed tile, burnt clay	480	48
flat tile, single roofing	350	35
flat tile, double roofing	700	70
flat concrete roofing tile	600	60
concrete tile, single roofing	400 to 500	40 to 50
Metal plate roofings		
galvanized steel plate (tin plate) roofing, 0,53 mm thick, folded or battened	40	4
double standing welt roofing from galvanized steel sheet roofing, 0,63 mm thick	55	5,5
zinc-plate roofing, , 0, 75 mm thick, welded	45	4,5
double-welt copper roof covering, 0, 6 mm thick	60	6
aluminum sheet roofing		
0, 6 mm thick	20	2
0, 7 mm thick	25	2,5
lead-plate roofing, 2 mm thick, soldered	240	24
steel pantile roofing (galvanized)	150	15
sectional steel-plate roofing	75 to 240	7,5 to 24
Other plate roofings		
soft plastic roofing, 1 mm thick	90	9
bitumenized board roofing		
2 layer, nailed	80	8
3 layer with stuck gravel scattering	250	25
Asbestos cement corrugated board roofing or reinforced with other fibres		
standard roofing and corrugated board roofing	200	20
double board roofing	250	25
plastic corrugated board roofing, 1,5 mm thick	20	2
Smeared and scattered roofing		
plastic-bitumen roofing, 4 mm thick coating	50	5
synthetic glass roofing, 1 mm thick coating	60	6
flat glass roofing, 6 mm thick	200	20
armoured glass roofing, 6 mm thick	250	25
corrugated, armoured glass roofing, 6 mm thick	300	30
sectional glass roofing		
single	200	20
double	400	40

Notes:

1) The body density of the wood should be increased by 120 kg/m³ where in a state saturated with water and by 80 kg/m³ in the case of structure standing outdoors and not protected against atmospheric humidity.

2) For concrete grades (C), see IPS-E-CE-200: "Concrete & Concrete Structures".

The value of the density of reinforced concrete shall be that as given for the appropriate concrete increased by 100 kg/m³ where the reinforcement percentage is 1,25 or less. Appropriate adjustments shall be made for concrete reinforced to higher values.

3) The mass density of the masonry is taken without plaster but with mortar-filled voids. The mass density of concrete, lightweight concrete and reinforced concrete wall corresponds to the mass density value of the materials supplied.

4) The values do not include the fixing and supporting structures of the shell.

ANNEX 2 TO APPENDIX IA

REPRESENTATIVE VALUES OF DENSITIES AND ANGLES OF REPOSE OF STORED MATERIAL

(THIS ANNEX FORMS AN INTEGRAL PART OF THE STANDARD)

This Annex gives the representative values of densities and angles of repose of stored materials in the form of a table.

Material	Density [1] kg / m³		Angle of repose degrees
	natural heap [2]	stack or pile [3]	
Building and construction materials			
Basalt flagstone	—	2 750 to 3 000	—
Boulder clay	—	2 100	—
Brick sand, brick hardcore, brick chippings, moist earth	1 500	—	25 to 40
Cement	1 100 to 1 200	1 300 to 1 600	18 to 28
Clay			
fluorfine, dry	1 100	—	—
heavy, air-dried	1 600	—	—
Cork grit	—	60	—
Coke ash	750	—	25
Crushed foamed slag	900	—	35
Expanded clay gravel			
light	250	—	30 to 35
medium	400	—	30 to 35
heavy	550	—	30 to 35
Fiberglass	—	160 to 180	—
Foamed scoria, crushed, moist earth	1 000	—	35
Glass wool	—	100 to 110	—
Granite flagstone	—	2 600 to 2 800	—
Gravel and dry sand or moist earth	1 800	—	30 to 36
Heat-insulating gas concrete	—	500	—
Heat-insulating perlite brick	—	260	—
Heat-insulating perlite pipe shell	—	260	—
Lime hydrate	500	600	25
Lime			
lumps	850 to 1 300	—	45
ground	600 to 1 300	1 000 to 1 100	25
Limestone power	—	1 300	—
Magnesite (caustic magnesite), ground	—	1 200	—
Mineral wool and derivatives	—	75 to 260	—
Plaster	1 000	1 100 to 1 500	25
Plastics			
polyethylene, polystyrol, granulated	—	650	—
polyvinylchloride, powdered	—	600	—
polyester resin	—	1 200	—
Perlite	—	70 to 250	—
Reed sheet of roofing	—	150 to 220	—
Powdered coal ash	900	1 000 to 1 200	25
Silt	—	1 800	—
Slag wool	—	200 to 300	—
Slag, granulated	1 100	—	30
Slaked lime	—	1 300 to 1 400	—
Trass, ground	—	1 500	—
Wood-wool	—	300 to 380	

(to be continued)

ANNEX 2 (continued)

Material	Density [1] kg / m^3 natural heap [2]	Density [1] kg / m^3 stack or pile [3]	Angle of repose Degrees
Combustibles and fuels			
Coal			
mineral coal	900 to 1 200	—	30 to 35
coke	450 to 650	—	30 to 45
briquette			
egett	800	—	25
cornered coal	700	—	35
brown coal			
dry	800	—	35
moist earth	1 000	—	30
briquette	800	—	30
coke	1 000	—	40
brown coal dust	500	—	25
Charcoal	250	—	—
Oils			
fuel, diesel oil	800 to 1 000	—	—
crude oil	980	—	—
Petrol (gasoline)	750 to 800	—	—
Petroleum	800	—	—
Liquid gas			
propane	500	—	—
butane	580	—	—
Wood (air-dried, about 15 % moisture)			
hard wood			
chopped	400 to 600	—	45
logs	500	600 to 700	50
soft wood			
chopped	250	400	45
logs	300	400 to 600	—
fire-wood	400	—	45
Brush wood	—	200	—
Peat	300 to 600	500 to 900	—
Foodstuffs and agricultural products			
Alcohol	800	—	—
Barley	500 to 800	—	30
Barley in bags	—	650 to 750	—
Beer			
in tanks	1 050	—	—
in barrels	—	900	—
Butter			
in barrels	—	550	—
cased or boxed	—	500 to 800	—
Cocoa in bags	—	550	—
Coffee in bags	—	550 to 700	—
Cover-seed in bags	—	750	—
Conserves in bottles or boxes	—	800	—
Dry fodder			
baled	—	350	—
ensiled	1 000	—	—
Edible oil			
in barrels	—	750	—
bottled, in crates	—	550	—
Eggs in egg-stands	—	550	—
Fat, boxed	—	800	—
Fish			
in barrels	—	600	—
cased	—	800	—
Flax in bales	—	1 300	—
Flax-seed in bags	—	700	—

(to be continued)

ANNEX 2 (continued)

Material	Density [1] kg / m3		Angle of repose degrees
	natural heap [2]	stack or pile [3]	
Fruit (stored in prisms)	500 to 700	—	25
Fruit crated in boxes	—	350 to 400	—
Groundnuts	—	400	—
Hay (baled)	—	150 to 200	—
Hempseed	500	—	25
Hempseed in bags	—	450	—
Honey			
in tanks	1 300	—	—
in cans	—	1 000	—
bottled	—	600	—
Leguminous plants	850	—	—
Leguminous plants in bags	—	800	—
Maize on ear	450	—	—
Maize corn	700	—	—
Margarine			
in barrels	—	550	—
cased or boxed	—	700	—
Meal	600	—	—
Meal in bags	—	500 to 600	—
Meat, refrigerated	—	400 to 700	—
Milk			
in tanks	950 to 1 000	—	—
in cans	—	850	—
bottled (in crates)	—	700	—
Oat	450 to 600	—	—
Oat, milled	750 to 800	—	—
Onions			
in bags	—	550	—
crated	—	550	—
Pickled cucumber in cases	—	700	—
Pimiento	—	500	—
Drinks			
bottled	—	850	—
bottled in cases	—	800	—
bottled in crates	—	750	—
Potatoes	700 to 760		30
Potatoes in bags	—	500 to 700	—
Rice (unmilled)	500	—	—
Rice (unmilled) in bags (hulled)	—	800	—
Rye	750	—	—
Salt (rock-salt)	—	2 200	—
in piles (milled)	1 000	—	—
in pile, pressed cattlesalt	—	1 800	—
Starch flour in bags	—	800	—
Straw baled (standard bale)	—	170	—
Straw baled , high-density	—	600	—
Sugar powdered / granulated			
in paper bags	—	600	—
in gunny sacks	—	800	—
Lump sugar			
in paper bags	—	600	—
boxed	—	700	—
Tobacco, baled	—	300 to 500	—
Wheat	550 to 820	—	30
Wheat in bags	—	750	—
Wine			
in tanks	1 000	—	—
in barrels	—	850	—

(to be continued)

ANNEX 2 (continued)

Material	Density [1] kg / m³ natural heap [2]	Density [1] kg / m³ stack or pile [3]	Angle of repose degrees
Other materials 4			
Aluminium	2 700	—	—
Aluminium alloy	2 800	—	—
Bags, baled	—	500	500
Bone splinters	700	—	—
Books and papers in stacks	—	850	850
Brass	8 300 to 8 500	—	—
Broadcloth, in bolts	—	400	400
Bronze	8 400	—	—
Carbolineum			
in tanks	1 000	—	—
in barrels	—	800	800
Cellulose, baled	—	100	100
Cellulose filiform			
baled	—	750	750
pressed, baled	—	1 200	1 200
Cloth, baled	—	400	400
Chemical fertilizer			
phosphatic	1 200 to 1 600	—	—
kalimagnesia in bags	—	1 300 to 1 500	1 300 to 1 500
kalisulfate	1600	—	—
nitrogenous in bags	—	2 000	2 000
Compost	1 200	—	—
Copper	8 700 to 8 900	—	—
Cotton, baled	—	700 to 1 300	700 to 1 300
Excrement	1 200	—	—
Felt in piles, baled	—	500	500
Filament in piles, pressed, baled	—	1 200	1 200
Glass			
bottles, etc.	—	400	400
sheets of glass, crated	—	1 000	1 000
Hemp, baled	—	400	400
Iron, cast	7 100 to 7 250	—	—
Iron ore	3 000	—	—
Ice (from water), in blocks	—	850 to 900	850 to 900
Ice (from carbonic acid), in blocks	—	1 700	1 700
Jute, baled	—	700	700
Lead	11 400 to 12 000	—	—
Leather, in piles (curried)	—	900 to 1 000	900 to 1 000
Linen, in bolts	—	600	600
Linoleum: rolled-up flooring material	—	1 300	1 300
Magnesium	1 850	—	—
Nickel	8 900	—	—
Oil paint and lacquer, canned or boxed	—	1 100	1 100
Paper			
in stacks, in sheets	—	1 200	1 200
in rolls	—	1 100	1 100
Row hide			
in piles (dried)	—	350	350
in piles (salted)	—	1 100	1 100
Rubber			
rolled-up flooring material	—	1 300	1 300
raw, baled	—	1 000	1 000
Steel	7 850	—	—
Steel rail	2 600	—	—
Textile, in bolts	1 100	—	—

(to be continued)

ANNEX 2 (continued)

Material	Density [1] kg / m^3 natural heap [2]	Density [1] kg / m^3 stack or pile [3]	Angle of repose degrees
Tin, rolled	—	7200 to 7 400	—
Wearing apparel, cased	300	—	—
Wool			
baled	700	—	—
pressed, baled	1 300	—	—
Zinc			
cast	6 900	—	—
rolled	7 200	—	—
Soils [5]			
inorganic cohesive soils			
soft	1 800 to 2 000	—	10 to 24
stiff	1 900 to 2 050	—	12 to 26
semi-solid	2 000 to 2 100	—	17 to 27
Organic clay, soft	1 400	—	15
Organic silt	1 700	—	—
Sand			
moist earth			
loose	1 200 to 1 500	—	30
medium-dense	1 500 to 1 800	—	30
dense	1 700 to 2 000	—	35
saturated			
loose	1 500 to 1 800	—	30
medium-dense	1 700 to 2 000	—	30
dense	1 800 to 2 100	—	35
under uplift			
loose	900 to 1 000	—	30
medium-dense	1 000 to 1 200	—	30
dense	1 100 to 1 200	—	35
gravel			
moist earth			
loose	1 500 to 1 700	—	32
medium-dense	1 600 to 1 800	—	35
dense	1 900	—	37
saturated			
loose	1 900	—	32
medium-dense	2 000	—	35
dense	2 100	—	37
under uplift			
loose	900	—	—
medium-dense	1 000	—	—
dense	1 100	—	—

Notes:

1) The density of the stack and pile contains data on bales.

2) Heap = disorderly or bulky stored materials and, by agreement, liquids in a tank.

3) Stack or pile = ordered and linked or ordered but not linked materials.

4) The density of stored metal products can be multiplied by a coefficient less than 1,0 according to the real situation.

5) The values given for density and angles of repose of soils which can differ from geotechnical data are only to be used if the soils present are similar to stored materials.

For soils indicated in the table, the coefficients of cohesion are to be given in relevant standards.

APPENDIX IB

DESIGN LOADS FOR BUILDINGS-LIVE LOADS

IB.1 Scope

IB.1.1 This Appendix gives minimum recommended live (imposed) loads for use in designing buildings. It applies to:

a) new buildings and new structures;

b) alterations and additions to existing buildings and existing structures;

c) existing construction on change of use.

It does not apply to the maintenance of, or the replacement of parts of, existing buildings and structures where there is no change of use.

IB.1.2 This Appendix does not cover:

a) loads on road and rail bridges; For information refer to IPS-G-CE-170: "Bridges & Related Structures";

b) wind loads. For information refer to Clause 7.1 of Part I;

c) loads on structures subject to internal pressure from their contents (e.g. bunkers, silos and water tanks), which have to be calculated individually;

d) detailed guidance on dynamic loading and loads due to machinery vibration;

e) loads due to lifts. For information refer to sub clause 10.9.1 of Part I;

f) loads incidental to construction;

g) test loads;

h) accidental loads.

IB.2 Live (Imposed) Floor and Ceiling Loads

IB.2.1 Floors. The loads appropriate to the different uses to which the portions of a building or structure may be part of, are given in Tables IB/5 to IB/9.

A key to the groups in these tables is given in Table IB/1.

The distributed loads are the uniformly distributed static loads per square meter of plan area and provide for the effects of normal use.

When partitions are indicated on the plans, their weight should be included in the dead load acting as concentrated loads in their actual positions. When the partitions are not determined on the plans, an additional live load on beams and floors (where these are capable of effective lateral distribution of the load) may be taken as a uniformly distributed load per square meter of not less than 1/3 of the weight per meter run of the finished partitions.

For floors of offices the uniformly distributed load shall not be less than 1.0 kN/m^2.

The live loads for floors are given in Tables IB/2 to IB/9.

All floors should be designed to carry the uniformly distributed or a concentrated load whichever produces the greater stresses in the part of the floor under consideration.

The live loads for beams are the distributed loads appropriate to the uses to which they are to be put, as given in Tables IB/2 to IB/9.

IB.2.2 Ceiling supports and similar structures. The following loads are appropriate to the design of frames and coverings of access hatches (other than glazing), the supports of ceilings and similar structures:

a) Without access: no live load;

b) With access: 0.25 kN/m2 uniformly distributed over the whole area, or the area supported, and a concentrated load of 0.9 kN so placed as to produce maximum stresses in the affected members.

TABLE IB/1 - OCCUPANCY CLASS INDEX

CLASS	TYPICAL STRUCTURES IN CLASS*	No. OF TABLE CONTAINING USAGES AND LOADS
RESIDENTIAL:		
TYPE 1	SELF-CONTAINED DWELLING UNITS AND COMMUNAL AREAS.	IB2
TYPE 2	BOARDING GUEST HOUSES, HOSTELS, LODGING HOUSES, RESIDENTIAL CLUBS AND COMMUNAL AREAS IN BLOCKS OF FLATS OTHER THAN TYPE 1.	IB2
TYPE 3	HOTELS AND MOTELS.	IB2
INSTITUTIONAL AND EDUCATIONAL	PRISONS, HOSPITALS, SCHOOLS, COLLEGES.	IB3
PUBLIC ASSEMBLY	HALLS, AUDITORIA, RESTAURANTS MUSEUMS, LIBRARIES, NON-RESIDENTIAL CLUBS, THEATRES BROADCASTING STUDIOS, GRANDSTANDS.	IB4
OFFICES	OFFICES, BANKS.	IB5
RETAIL	SHOPS, DEPARTMENTAL STORES, SUPERMARKETS.	IB6
INDUSTRIAL	WORKSHOPS, FACTORIES.	IB7
STORAGE	WAREHOUSES.	IB8
VEHICULAR	GARAGES, CAR PARKS, VEHICLE ACCESS RAMPS.	IB9

*** The lists are not intended to be exhaustive but merely to indicate the type of structures included in the classes.**

TABLE IB/2 - RESIDENTIAL OCCUPANCY CLASS

FLOOR AREA USAGE	INTENSITY OF DISTRIBUTED LOAD kN/m^2	CONCENTRATED LOAD KN
TYPE 1. SELF-CONTAINED DWELLING UNITS AND COMMUNAL AREAS IN BLOCKS OF FLATS NOT MORE THAN 3 STOREYS IN HEIGHT AND WITH NOT MORE THAN 4 SELF-CONTAINED DWELLINGS PER FLOOR ACCESSIBLE FROM ONE STAIRCASE.		
ALL USAGES.	1.5	1.4
TYPE 2. BOARDING AND LODGING HOUSES, GUEST HOUSES, HOSTELS, RESIDENTIAL CLUBS AND COMMUNAL AREAS IN BLOCKS OF FLATS OTHER THAN TYPE 1.		
BOILER ROOMS, MOTOR ROOMS, FAN ROOMS AND THE LIKE INCLUDING THE WEIGHT OF MACHINERY.	7.5	4.5
COMMUNAL KITCHENS, LAUNDRIES, CORRIDORS, HALLWAYS, STAIRS, LANDINGS, FOOTBRIDGES, ETC.	3.0	4.5
DINING ROOMS.	2.0	2.7
TOILET ROOMS.	2.0	—
BEDROOMS, DORMITORIES.	1.5	1.8
BALCONIES.	SAME AS ROOMS TO WHICH THEY GIVE ACCESS BUT WITH A MINIMUM OF 4.0	1.5 PER METER RUN CONCENTRATED AT THE OUTER EDGE
TYPES 3. HOTELS AND MOTELS BOILER ROOMS, MOTOR ROOMS, FAN ROOMS AND THE LIKE, INCLUDING THE WEIGHT OF MACHINERY.	7.5	4.5
ASSEMBLY AREAS WITHOUT FIXED SEATING	5.0	3.6
ASSEMBLY AREAS WITH FIXED SEATING*	4.0	—
CORRIDORS, HALLWAYS, STAIRS, LANDINGS FOOTBRIDGES, ETC.	4.0	4.5
KITCHENS, LAUNDRIES.	3.0	4.5
DINING ROOMS, LOUNGES, BILLIARD ROOMS.	2.0	2.7
BEDROOMS.	2.0	1.8
TOILET ROOMS.	2.0	—

*** Fixed seating is seating where its removal and the use of the space for other purposes is improbable.**

TABLE IB/3 - INSTITUTIONAL AND EDUCATIONAL OCCUPANCY CLASS

(PRISONS, HOSPITALS, SCHOOLS, COLLEGES)

FLOOR AREA USAGE	INTENSITY OF DISTRIBUTED LOAD KN/m^2	CONCENTRATED LOAD KN
DENSE MOBILE STACKING (BOOKS) ON MOBILE TROLLEYS.	4.8 FOR EACH METER OF STACK HEIGHT BUT WITH A MINIMUM OF 9.6	7.0
STACK ROOMS (BOOKS).	2.4 FOR EACH METER OF STACK HEIGHT BUT WITH A MINIMUM OF 6.5	7.0
STATIONERY STORES.	4.0 FOR EACH METER OF STORAGE HEIGHT 7.5	9.0
BOILER ROOMS, MOTOR ROOMS, FAN-ROOMS AND THE LIKE, INCLUDING THE WEIGHT OF MACHINERY.	7.5	4.5
CORRIDORS, HALLWAY, ETC. SUBJECT TO LOADS GREATER THAN FROM CROWDS, SUCH AS WHEELED VEHICLES, TROLLEYS AND THE LIKE.	5.0	4.5
DRILL ROOMS AND DRILL HALLS.	5.0	9.0
ASSEMBLY AREAS WITHOUT FIXED SEATING, STAGES, GYMNASIA.	5.0	3.6
PROJECTION ROOMS.	5.0	—
CORRIDORS, HALLWAYS, AISLES, STAIRS, LANDINGS, FOOTBRIDGES, ETC.	4.0	4.5
READING ROOMS WITH BOOK STORAGE, e.g. LIBRARIES.	4.0	4.5
ASSEMBLY AREAS WITH FIXED SEATING*	4.0	—
LABORATORIES(INCLUDING EQUIPMENT) KITCHENS, LAUNDRIES, CORRIDORS, HALLWAYS, AISLES, LANDINGS,STAIRS ETC. NOT SUBJECT TO CROWD LOADING	3.0	4.5
CLASSROOMS, PRAYING ROOMS.	3.0	2.7
READING ROOMS WITHOUT BOOK STORAGE.	2.5	4.5
AREAS FOR EQUIPMENT.	2.0	1.8
X-RAY ROOMS, OPERATING ROOMS, UTILITY ROOMS.	2.0	4.5
DINING ROOMS, LOUNGES	2.0	2.7
DRESSING ROOMS, HOSPITAL BEDROOMS AND WARDS.	2.0	1.8
TOILET ROOMS.	2.0	—
BEDROOMS, DORMITORIES.	1.5	1.8
BALCONIES.	SAME AS ROOMS TO WHICH THEY GIVE ACCESS BUT WITH A MINIMUM OF 4.0	1.5 PER METER RUN CONCENTRATED AT THE OUTER EDGE
FLY GALLERIES.	4.5 kN PER METER RUN DISTRIBUTED UNIFORMLY OVER THE WIDTH	—

*** Fixed seating is seating where its removal and the use of the space for other purposes is improbable.**

TABLE IB/4 - PUBLIC ASSEMBLY OCCUPANCY CLASS

(HALLS, AUDITORIA, RESTAURANTS, MUSEUMS, LIBRARIES, NON-RESIDENTIAL CLUBS, THEATRES, BROADCASTING STUDIOS, GRANDSTANDS)

FLOOR AREA USAGE	INTENSITY OF DISTRIBUTED LOAD KN/m^2	CONCENTRATED LOAD KN
DENSE MOBILE STACKING (BOOKS) ON MOBILE TRUCKS.	4.8 FOR EACH METER OF STACK HEIGHT BUT WITH A MINIMUM OF 9.6	7.0
STACK ROOMS (BOOKS).	2.4 FOR EACH METER OF STACK HEIGHT BUT WITH A MINIMUM OF 6.5	7.0
BOILER ROOMS, MOTOR ROOMS, FAN ROOMS, AND THE LIKE, INCLUDING THE WEIGHT OF MACHINERY.	7.5	4.5
STAGES.	7.5	4.5
CORRIDORS, HALLWAYS, ETC. SUBJECT TO LOADS GREATER THAN FROM CROWDS SUCH AS WHEELED VEHICLES,TROLLEYS AND THE LIKE. CORRIDORS, STAIRS, AND PASSAGEWAYS IN GRANDSTANDS.	5.0	4.5
DRILL ROOMS AND DRILL HALLS.	5.0	9.0
ASSEMBLY AREAS WITHOUT FIXED SEATING*: GYMNASIA, GRANDSTANDS.	5.0	3.6
PROJECTION ROOMS.	5.0	—
MUSEUM FLOORS AND ART GALLERIES FOR EXHIBITION PURPOSES.	4.0	4.5
CORRIDORS, HALLWAYS, STAIRS, LANDINGS, FOOTBRIDGES, ETC.	4.0	4.5
READING ROOMS WITH BOOK STORAGE, e.g. LIBRARIES.	4.0	4.5
ASSEMBLY AREAS WITH FIXED SEATING.	4.0	—
KITCHENS, LAUNDRIES.	3.0	4.5
MOSQUES, PRAYING ROOMS.	5.0	4.0
READING ROOMS WITHOUT BOOK-STORAGE.	2.5	4.5
GRIDS.	2.5	—
AREAS FOR EQUIPMENT.	2.0	1.8
DINING ROOMS, LOUNGES.	2.0	1.8
DRESSING ROOMS.	2.0	1.8
TOILET ROOMS.	2.0	—
BALCONIES.	SAME AS ROOMS TO WHICH THEY GIVE ACCESS BUT WITH A MINIMUM OF 4.0	1.5 PER METER RUN CONCENTRATED AT THE OUTER EDGE
FLY GALLERIES.	4.5 kN PER METER RUN DISTRIBUTED UNIFORMLY OVER THE WIDTH	—

*** Fixed seating is seating where its removal and the use of the space for other purposes is improbable.**

TABLE IB/5 - OFFICES OCCUPANCY CLASS (OFFICES, BANKS)

FLOOR AREA USAGE	INTENSITY OF DISTRIBUTED LOAD KN/m^2	CONCENTRATED LOAD KN
STATIONARY STORES.	4.0 FOR EACH METER OF STORAGE HEIGHT	9.0
BOILER ROOMS, MOTOR ROOMS, FAN ROOMS AND THE LIKE, INCLUDING THE WEIGHT OF MACHINERY.	7.5	4.5
CORRIDORS, HALLWAYS, ETC. SUBJECT TO LOADS GREATER THAN FROM CROWDS, SUCH AS WHEELED VEHICLES, TROLLEYS AND THE LIKE.	5.0	4.5
FILE ROOMS, FILING AND STORAGE SPACE.	5.0	4.5
CORRIDORS, HALLWAYS, STAIRS, LANDINGS, FOOTBRIDGES, ETC.	4.0	4.5
OFFICES WITH FIXED COMPUTERS OR SIMILAR EQUIPMENT.	3.5	4.5
LABORATORIES (INCLUDING EQUIPMENT) KITCHENS, LAUNDRIES.	3.0	4.5
BANKING HALLS.	3.0	—
OFFICES FOR GENERAL USE.	2.5	2.7
TOILET ROOMS.	2.0	—
BALCONIES.	SAME AS ROOMS TO WHICH THEY GIVE ACCESS BUT WITH A MINIMUM OF 4.0	1.5 PER METER RUN CONCENTRATED AT THE OUTER EDGE
CAT WALKS.	—	1.0 AT 1 m CENTER

TABLE IB/6 - RETAIL OCCUPANCY CLASS
(SHOPS, DEPARTMENTAL STORES, SUPERMARKETS)

FLOOR AREA USAGE	INTENSITY OF DISTRIBUTED LOAD KN/m^2	CONCENTRATED LOAD KN
COLD STORAGE.	5.0 FOR EACH METER OF STORAGE HEIGHT WITH A MINIMUM OF 15.0	9.0
STATIONERY STORES.	4.0 FOR EACH METER OF STORAGE HEIGHT	9.0
STORAGE, OTHER THAN TYPES LISTED SEPARATELY.	2.4 FOR EACH METER OF STORAGE HEIGHT	7.0
BOILER ROOMS, MOTOR ROOMS, FAN ROOMS AND THE LIKE, INCLUDING THE WEIGHT OF MACHINERY.	7.5	4.5
CORRIDORS, HALLWAYS, ETC. SUBJECT TO LOADS GREATER THAN FROM CROWDS, SUCH AS WHEELED VEHICLES, TROLLEYS AND THE LIKE.	5.0	4.5
CORRIDORS, HALLWAYS, STAIRS, LANDINGS, FOOTBRIDGES, ETC.	4.0	4.5
SHOP FLOORS FOR THE DISPLAY AND SALE OF MERCHANDISE.	4.0	3.6
KITCHENS, LAUNDRIES.	3.0	4.5
TOILET ROOMS.	2.0	—
BALCONIES.	SAME AS ROOMS TO WHICH THEY GIVE ACCESS BUT WITH A MINIMUM OF 4.0	1.5 PER METER RUN CONCENTRATES AT THE OUTER EDGE

TABLE IB/7 - INDUSTRIAL OCCUPANCY CLASS

(WORKSHOPS, FACTORIES)

FLOOR AREA USAGE	INTENSITY OF DISTRIBUTED LOAD KN/m^2	CONCENTRATED LOAD KN
FOUNDRIES.	20.0	—
COLD STORAGE.	5.0 FOR EACH METER OF STORAGE HEIGHT WITH A MINIMUM OF 15.0	9.0
PAPER STORAGE, FOR PRINTING PLANTS.	4.0 FOR EACH METER OF STORAGE HEIGHT	9.0
STORAGE, OTHER THAN TYPES LISTED SEPARATELY.	2.4 FOR EACH METER OF STORAGE HEIGHT	7.0
TYPE STORAGE AND OTHER AREAS IN PRINTING PLANTS.	12.5	9.0
BOILER ROOMS, MOTOR ROOMS, FAN ROOMS AND THE LIKE, INCLUDING THE WEIGHT OF MACHINERY.	7.5	4.5
FACTORIES, WORKSHOPS AND SIMILAR BUILDINGS.	5.0	4.5
CORRIDORS, HALLWAYS, FOOTBRIDGES, ETC. SUBJECT TO LOADS GREATER THAN FOR CROWDS, SUCH AS WHEELED VEHICLES, TROLLEYS AND THE LIKE.	5.0	4.5
CORRIDORS, HALLWAYS, STAIRS, LANDINGS, FOOTBRIDGES, ETC.	4.0	4.5
MACHINERY HALLS, CIRCULATION SPACES THEREIN.	4.0	4.5
LABORATORIES(INCLUDING EQUIPMENT) KITCHENS, LAUNDRIES.	3.0	4.5
WORKROOMS, LIGHT WITHOUT STORAGE.	2.5	1.8
TOILET ROOMS.	2.0	—

TABLE IB/8 - STORAGE OCCUPANCY CLASS (WAREHOUSES)

FLOOR AREA USAGE	INTENSITY OF DISTRIBUTED LOAD KN/m^2	CONCENTRATED LOAD KN
COLD STORAGE.	5.0 FOR EACH METER OF STORAGE HEIGHT WITH A MINIMUM OF 15.0	9.0
DENSE MOBILE STACKING (BOOKS) ON MOBILE TRUCKS.	4.8 FOR EACH METER OF STORAGE HEIGHT WITH A MINIMUM OF 15.0	7.0
PAPER STORAGE, FOR PRINTING PLANTS.	4.0 FOR EACH METER OF STORAGE HEIGHT	9.0
STATIONERY STORES.	4.0 FOR EACH METER OF STORAGE HEIGHT	9.0
STORAGE, OTHER THAN TYPES LISTED SEPARATELY, WAREHOUSES.	2.4 FOR EACH METER OF STORAGE HEIGHT	7.0
MOTOR ROOMS, FAN ROOMS AND THE LIKE, INCLUDING THE WEIGHT OF MACHINERY.	7.5	4.5
CORRIDORS, HALLWAYS, FOOTBRIDGES, ETC. SUBJECT TO LOADS GREATER THAN FOR CROWD, SUCH AS WHEELED VEHICLES, TROLLEYS AND THE LIKE.	5.0	4.5

TABLE IB/9 - VEHICULAR OCCUPANCY CLASS

(GARAGES, CAR PARKS, VEHICLE ACCESS RAMPS)

FLOOR AREA USAGE	INTENSITY OF DISTRIBUTED LOAD KN/m^2	CONCENTRATED LOAD KN
MOTOR ROOMS, FAN ROOMS AND THE LIKE, INCLUDING THE WEIGHT OF MACHINERY.	7.5	4.5
DRIVEWAYS AND VEHICLE RAMPS, OTHER THAN IN GARAGES FOR THE PARKING ONLY OF PASSENGER VEHICLES AND LIGHT VANS NOT EXCEEDING 2500 Kg GROSS MASS.	5.0	9.0
REPAIR WORKSHOPS FOR ALL TYPES OF VEHICLES EXCEEDING 2500 Kg GROSS MASS INCLUDING DRIVEWAYS AND RAMPS.	5.0	9.0
FOOTPATHS, TERRACES AND PLAZAS LEADING FROM GROUND LEVEL WITH NO OBSTRUCTION TO VEHICULAR TRAFFIC, PAVEMENT LIGHTS.	5.0	9.0
CORRIDORS, HALLWAYS, STAIRS, LANDINGS, FOOTBRIDGES, ETC. SUBJECT TO CROWD LOADING.	4.0	4.5
FOOTPATHS, TERRACES AND PLAZAS LEADING FROM GROUND LEVEL BUT RESTRICTED TO PEDESTRIAN TRAFFIC ONLY.	4.0	4.5
CAR PARKING ONLY, FOR PASSENGER VEHICLES AND LIGHT VANS NOT EXCEEDING 2500 Kg GROSS MASS INCLUDING GARAGES, DRIVEWAYS AND RAMPS.	2.5	9.0

APPENDIX IC

ADDITIONAL REQUIREMENTS FOR BLAST RESISTANT BUILDINGS AND STRUCTURES

IC.1 Scope

This Appendix covers minimum requirements for the design of blast resistant structures.

The effects of blasts and explosions induced by military weapons are not included in the scope of this Standard. These effects and design requirements of new or existing structures to resist the effects of conventional (non-nuclear) and/or nuclear weapons will be covered in IPS-E-CE-490: "Civil Defense".

Also, for appropriate precautions that may be taken in the design, siting and, particularly, the construction of new control houses to minimize damage in the event of an explosion of a vapor release or caused by a runaway reaction, reference is made to:

Safety Guide, SG-22: Siting and construction of new control houses for chemical manufacturing plants, published in 1978 by Manufacturing Chemists Association (MCA).

IC.2 References

For sources of research and reference, see Clause 2 of Part 1.

IC.3 Definitions

IC.3.1 Blast resistant structures are defined as buildings and other structures capable of withstanding an external explosion which generates an overpressure of 69 kPa for 20 milliseconds. This is roughly equivalent to the overpressure created by a free-air explosion of one metric ton of TNT at 31.5 m. In resisting such an explosion, moderate structural damage, with a margin of safety of at least 2.5 against collapse, is considered acceptable. The intent is that personnel are kept safe and facilities remain operable in such an event.

IC.4 Loads

BLAST PRESSURES AND DURATIONS

IC.4.1 Rectangular box-shaped buildings shall be designed for blast pressures as follows:

a) Each wall shall be designed for a peak reflected pressure (P_r) of 172 kPa and a duration (t_o) of 20 milliseconds.

b) Flat roof slabs and beams shall be designed for an incident overpressure (P_o) of 69 kPa and a duration (t_o) of 20 milliseconds.

c) The main structural framing shall be designed for blast pressure on any one wall in accordance with subparagraph a. above together with roof loading as follows:z

PEAK PRESSURE (P_f)

SPAN OF STRUCTURAL M	FRAME APPLIED AS UNIFORM LOAD kPa	DURATION (t_o) ms
≤ 3	69	20
6	38	40
12	31	50
18	26	60

For frame spans between those listed, pressures and durations may be interpolated linearly.

d) All blast-induced pressures shall be assumed to decrease linearly from the maximum value at time t=0 to zero at $t=t_o$.

IC.4.2 Blast pressure and durations for special structures such as arches, domes and earth-embanked structures shall receive prior approval by the AR.

STATIC LOAD EQUIVALENT OF BLAST PRESSURES AND DURATIONS

IC.4.3 Required dynamic resistance, R*, in the direction of blast loads shall be calculated in accordance with the procedure outlined in ASCE Manual 42, or an equivalent acceptable method which takes into account dynamic response. Required dynamic resistance may be calculated in accordance with the following general formula:

$$R = \frac{P}{\frac{\sqrt{\alpha}}{\pi\tau} + \frac{\alpha}{2\delta_m(\tau+0.7)}}$$

*** R. shall not be less than (13.8 kPa) and need not be greater than 86 kPa.**

Where:

R	is required dynamic resistance of structural element expressed as static load equivalent of blast pressure and duration, kPa.
P	is peak blast load = Pr or P_o or P_f .... as appropriate for the element under consideration,kPa.
α	is energy absorption factor = $2\delta_m$ -1.
δ_m	is maximum displacement factor = X_m/X_y.
τ	is duration factor = t_o/T.
X_m	is maximum dynamic displacement, mm.
X_y	is effective displacement at initial yield, mm.
t_o	is duration of blast load, milliseconds.
T	is fundamental period of vibration of structure or element under consideration, milliseconds.

IC.4.4 Maximum dynamic displacement factors shall be limited as follows:

a) For structural steel, $\delta_5 \leq 5$.

b) For reinforced concrete loaded primarily in flexure, $\delta_m \leq 3$.

c) For reinforced concrete subjected primarily to axial compression or shear, $\delta_m \leq 1.5$.

d) For a steel or reinforced concrete girder forming a part of the main structural frame which resists both vertical and lateral loads, $\delta_m \leq 1.0$..

IC.4.5 The maximum allowable plastic joint gradient, $\Delta = x_m/l$ shall be limited as follows:

a) For structural steel, $\Delta \leq .03$.

b) For reinforced concrete. $\Delta \leq .02$.

Where:

L is segment length between plastic hinges in the structural element under consideration, mm.

x_m is $\delta_m R/K_e$ mm.

K_e is effective elastic stiffness of the structural element, kPa/mm.

IC.4.6 Required rebound resistance opposite in direction to R. shall be determined in accordance with ASCE Manual 42, or an equivalent acceptable method, and shall not be less than 75 percent of undamped rebound, or 25 percent of dynamic resistance per clause IC.4.3, whichever is greater.

LOAD COMBINATIONS

IC.4.7 Required dynamic resistance (R.) to blast loads shall be combined with other loads as follows:

U = D + L + R.

Where:

U is total required resistance.

D is dead loads, or their related internal moments and forces.

L is live loads, or their related internal moments and forces.

IC.4.8 Required rebound resistance shall normally be considered in combination with dead loads only.

IC.4.9 Resistance to blast loads shall not be considered in combination with wind or earthquake.

IC.5 Structure Design

STRUCTURE DESIGN CAPACITY

IC.5.1 Dynamic capacity of any structural element shall be determined according to the plastic design method for structural steel and the ultimate strength method for reinforced concrete as provided by AISC Specification and ACI Standard, respectively, except that:

a) Dynamic strengths of materials per the Tables below shall be used.

b) Capacity reduction factors (0) can be increased by 10 percent.

c) The dynamic modulus elasticity of concrete shall be 1.25 times the static value.

DYNAMIC STRENGTHS OF STRUCTURAL AND REINFORCING STEEL (Relative to conventional specified minimum yield-strengths, f_y)	
FOR STEELS WITH $f_y \leq$ 415 MPa	
DIRECT TENSION OR FLEXURE (f_{dy})	1.2 f_y
DIRECT COMPRESSION	2 F_a (1) BUT $\leq f_{dy}$
SHEAR (f_{dy})	0.60 f_y
FOR STEELS WITH fv > 415 MPa (2)	
DIRECT TENSION OR FLEXURE (f_{dy})	1.1 f_y
DIRECT COMPRESSION	1.8 F_a (1) BUT $\leq f_{dy}$
SHEAR (f_{dv})	0.55 f_y

Notes:

1) The allowable compressive stress per Part 1 of AISC Specification.

2) Use of steels in this category requires approval by AR.

DYNAMIC STRENGTHS OF CONCRETE MPa (RELATIVE TO 28-DAY STANDARD CYLINDER COMPRESSIVE STRENGTH , f'_c in MPa) (3)	
AXIAL OR FLEXURAL COMPRESSION (f'_{dc})	1.25 f'_c
SHEAR, DIRECT (v_d)	0.20 f'_c
SHEAR, DIAGONAL TENSION (v_{dc})	0.187 $\sqrt{f'_c}$
BOND ON DEFORMED BARS (u_d)	0.15 f'_c
DIRECT TENSION (f_{dt})	0.622 $\sqrt{f'_c}$
BEARING (f_{bc})	0.85 f'_c

Note:

3) In no case shall f'_c be less than 20.7 MPa.

ADDITIONAL STRUCTURE DESIGN REQUIREMENTS

IC.5.2 The span between supports of a structural element shall be limited to 18 m.

IC.5.3 Reinforced concrete structures shall satisfy the following additional requirements:

a) Roof slabs and external walls shall be double reinforced. The amount of reinforcement on each face shall be between 0.25 percent and 2 percent of the effective cross-sectional area. Slabs and walls shall be a minimum of 125 mm and 200 mm in thickness, respectively.

b) Frames and shear walls shall be designed in accordance with Special Provisions for

Seismic Design, ACI 318 Appendix A, except as modified herein.

IC.5.4 Structures employing structural steel shapes shall satisfy the following additional requirements:

a) All members shall be designed with stiffeners and bracing to prevent local or general buckling before their full plastic capacities are developed.

b) Joints and connections shall be capable of developing the full capacities of the connected members. The allowable stresses in bolts, rivets and welds shall be as specified in the plastic design portion of the AISC Specification.

IC.5.5 Structural elements constructed of unreinforced concrete, masonry (concrete blocks, brick, etc.) prestressed concrete, or other materials of limited ductility, are not permitted.

IC.5.6 Supports for roof and floor supported equipment:

a) Supports for equipment suspended from the roof shall be designed using normal static allowable stresses to resist a horizontal or vertical force equal to three times the weight of the equipment. Provisions shall be made to accommodate horizontal movement of the roof.

b) Floor-supported equipment such as lockers, electrical cubicles, and tubing racks shall have a minimum clearance from the outside walls commensurate with the anticipated displacement of the building under blast loads, or 40 mm whichever is greater.

IC.6 Foundation Design

IC.6.1 Foundations shall be designed for the maximum values of the dynamic reactions resulting from the following taken simultaneously in combination:

a) Peak reflected pressure (P_r) acting on any one wall.

b) Roof loading (P_f).

c) Applicable dead and live loads.

The maximum value of the dynamic reaction can be considered as the reaction to the total structural resistance (U) applied as a static load. The durations and time phase relationships shall be disregarded.

In no case shall the capacity of any foundation be less than the ultimate static capacity of the structural system it supports.

IC.6.2 Allowable dynamic soil bearing pressures shall be based on the results of a soils investigation, and a consideration of permissible total and differential settlements.

IC.6.3 The foundation shall be designed so that the safety factor against overturning due to the unbalanced lateral dynamic reactions is not less than 1.2.

IC.6.4 Passive resistance of the foundation, where required in addition to friction to resist sliding, shall be at least 1.5 times the unbalanced lateral load. The unbalanced lateral load is defined as the total horizontal dynamic reaction force less the frictional resistance.

IC.6.5 For piled foundations the allowable vertical load under blast condition shall be 0.8 times the ultimate static capacity or 2.5 times the conventional allowable load, whichever is less.

IC.6.6 Where piles are required to resist lateral movements of the structure, they shall be designed as follows:

a) If only vertical piles are used, the combined ultimate lateral capacity of the piles and the passive resistance on the foundation walls and footing shall be equal to or greater than 1.5 times the full lateral resistance required.

b) Where batter piles are used, the allowable lateral resistance of the foundation shall be taken as 0.8 times the ultimate lateral load capacity of the batter piles or 0.5 times the combined ultimate lateral load capacity of the pile system plus the passive resistance, whichever is greater.

IC.7 Doors and Openings

DOORS

IC.7.1 Doors in external blast-resistant walls shall be designed statically for a pressure of 86 kPa acting inward and for a pressure of 62 kPa acting outward (rebound) using maximum design stresses equal to the dynamic yield stress of the materials being used.

IC.7.2 Doors shall open outward and shall be supported on all edges by the door frames. No door shall be recessed more than one-half its width into the building.

IC.7.3 Latch and hinge mechanisms shall be capable of withstanding the door rebound loading.

IC.7.4 Blast resistant doors and associated hardware shall be designed and fabricated by a vendor approved by the AR.

OTHER OPENINGS

IC.7.5 Openings such as vent intakes and fume hoods shall be designed for blast effects. Such openings shall by location, use of blast attenuators or other means, prevent entry of shock waves and debris into personnel and critical equipment areas.

IC.7.6 The total area of all openings, excluding doors, shall be limited to 0.0066 m2/m3 of the building volume. The total area of openings on any one side of the building shall not exceed one-half this limit.

IC.7.7 Windows are not permitted.

APPENDIX ID

EARTHQUAKE DESIGN LOADS IN PETROLEUM INDUSTRIES

ID.1 Scope

This Appendix covers requirements governing the calculation of earthquake forces for the design of buildings, open structures, storage facilities and process equipment.

ID.2 References

ID.2.1 For the codes and standards referred to in this Appendix see clause 2.

ID.2.2 Earthquake design loads for non elevated atmospheric storage tanks shall be per the following:

- API 650 Appendix E for tank designs based on that standard.
- The requirements of this Appendix for tank designs based on other standards.

ID.2.3 : Uniform building code (U.B.C) Volume2 1997 edition chapter 16.

ID.3 2.10.2 Seismic zone

seismic zone shall be considered as per IRANIAN CODE OF PRACTICE FOR SEISMIC RESISTANT DESIGN OF BUILDINGS (SEISMIC MACROZONATION HAZARD MAP OF IRAN)

ID.4 2.10.3 Loads

Every structure shall be designed and constructed to withstand minimum total lateral seismic forces assumed to act no concurrently in the direction of each of the main axes of the structure in accordance with the following formula:

Design base shear. The total design base sheer in a given direction shall be determined from the following formula:

$$V = \frac{CVI}{RT}W$$

The total design base shear need not exceed the following .

$$V = \frac{2.5CaI}{R}W$$

The total design base shear shall not less than the following :

$$V = 0.11CaIW$$

In addition, for seismic Zone 4 the total base shear shall also not be less than the following :

$$V = \frac{0.8NvI}{R}W$$

V =the total design lateral force or shear at base
Cv = seismic coefficient, as set forth in table (U.B.C)
I = important factor given in table (U.B.C)
R = numerical coefficient representative of the inherent over strength and global ductility capacity of lateral force resisting systems, as set forth in table ID.3 or 16-p (U.B.C)

T= elastic fundamental period of vibration, in seconds, of the structure in the direction under consideration
Ca=seismic coefficient, as set forth in table (U.B.C)
Z= seismic zone factor AS GIVEN IN Table ID.1
Nv= near source factor used in the determination of Cv in seismic zone 4 related to both the proximity of the building or structure to know faults with magnitudes and slip rates as set forth in Table (U.B.C) and (U.B.C)

W=the total seismic dead load
For more information and detail see U.B.C 1997 CHAP.16 . DIV.IV

ID.5.1 Structure Period. The value of T shall be determined from one of the following methods:

Method A :

$T = c_t (h_n)^{3/4}$

C_t= 0.035(0.0853) for steel moment – resisting frames.

C_t= 0.030(0.731) for reinforced concrete moment – resisting frames and eccentrically braced frames .

C_t= 0.020 (0488) for all other buildings.

Method B:

The value of fi represent any lateral force distributed approximately in accordance with the principales of above formula
For more information and detail see U.B.C. 1997 CHAP.16.DIV.IV

Rigid structures (those with period T less than 0.06 second) and their anchorages shall be designed for the lateral forced obtained from formula:

V= 0.7 Ca IW

The force V shall be distributed according to the distribution of mass and shall be assumed to act in any horizontal direction .
For more information and detail see U.B.C. code .

TABLE ID.1 SEISMIC ZONE FACTOR Z

Zone	1	2A	2B	3	A
Z	0.075	0.15	0.20	0.30	0.40

TABLE ID.2 SOIL PROFILE TYPES

SOIL PROFILE TYPE	SOIL PROFILE NAME/GENERIC DESCRIPTION	AVERAGE SOIL PROPERTIES FOR TOP 100 FEET (30480MM)0F SOIL PROFILE		
		SHAR WAVE VELOCITY ,Vs feet/second(m/s)	Standard penetration test, N [or NCH for cohesion less soil layers] (blows/foot)	Untrained shear strength's puff (kappa)
SA	HARD ROCK	> 5,000(1,500)	-	-
SB	ROCK	2,500 to 5,000 (760 to 1,500)		
SC	VERY DENCE SOIL AND SOFT ROCK	1,200 to 2,500 (360 to 760)	> 50	>2,000 (1000)
SD	SOFT SOIL PROFILE	600 to 1,200 (180 to 360)	15 to 50	1,000 to 2,000 (50 to 100)
SE	SOFT SOIL PROFILE	<600 (180)	>15	>1,000 (50)
SF	Soil Requiring site evaluation. See section 1629.3.1			

Soil profile type SE also includes any soil profile with more than 10 feet (3048mm) of soft clay defined as a soil with a plasticity index, PI>20 , Wmc> 40 percent and > 500 puff (24 kappa) The plasticity index . pi and the moisture content , Waco , shall be determined in accordance with approved national standard .

TABLE ID-3 STRUCTURAL SYSTEMS

Basic structure system [1]	Lateral force- resisting System-Description	R	Ω0	HEIGHT LIMIT FOR SEISMIC ZONES 3 AND 4 (FEET) × 304.8 for mm
1. Bearing wall system	1.Light – framed walls with shear panels		P	
	- wood structural panel walls for structures three stories or less	5.5	2.8	65
	- All other light-framed walls	4.5	2.8	65
	2.shear walls			
	-concrete	4.5	2.8	160
	-Masonry	4.5	2.8	160
	3.Light steel-framed bearing walls with tension- only bracing	2.8	2.2	65
	4.Braced frames where bracing carries gravity loads			
	-Steel	4.4	2.2	160
	-Concrete [4]	2.8	2.2	-
	- Heavy timber	2.8	2.2	65
2. Building Frame	1.Steel eccentrically braced frame (EBF)	7.0	2.8	240
System	2.Light-framed walls with sheer panels			
	-Wood structural panel walls for structures three stores or less	6.5	2.8	65
	-All other light – framed walls	5.0	2.8	65
	3.sheer walls			
	-Concrete	5.5	2.8	240
	-Masonry	5.6	2.2	160
	4.Ordinary braced frames			
	-Steel	5.6	2.2	160
	-Concrete [4]	5.6	2.2	-
	-Heavy timber	5.6	2.2	65
	5.Special concentrically braced frames			
	a.steel	6.4	2.2	240
3. Moment-resisting frame system	1.Special moment-resisting frames (SMRF)			
	-Steel	8.5	2.8	N.L.
	-Concrete	8.5	2.8	N.L.
	2.Masonry moment-resisting wall frame	6.5	2.8	160
	3.Concrete intermediate	5.2	2.8	-

	moment- resisting frames (IMRF)[5] 4.Ordinary moment-resisting frames (OMRF) -Steel[6] -Concrete[7] 5.Special truss moment frames of steel (STMF)	4.5 3.5 6.5	2.8 2.8 2.8	160 - 240
4. Dual system	1. Shear walls - Concrete with SMRF - Concrete with steel OMRF - Concrete with concrete IMRF [6] - Masonry with SMRF - Masonry with steel OMRF - Masonry with concrete IMRF[4] -Masonry with masonry MMRWF	8.5 4.2 6.5 5.5 4.2 4.2 6.0	2.8 2.8 2.8 2.8 2.8 2.8 2.8	N.L. 160 160 160 160 - 160
	2- Steel EBF - With steel SMRF - With steel OMRF 3- Ordinary braced frames - Steel with steel SMRF - Steel with steel OMRF - Concrete with concrete SMRF [4] - Concrete with concrete IMRF[4] 4. Special concentrically braced frames - Steel with steel SMRF - Steel with steel OMRF	8.5 4.2 6.5 4.2 6.5 4.2 7.5 4.2	2.8 2.8 2.8 2.8 2.8 2.8 2.8 2.8	N.L. 160 N.L. 160 - - N.L. 160
5. cantilevered column building systems	1.Cantilevered column elements	2.2	2.0	35
6.Shear wall-frame interaction system	1.Concrete	5.5	2.8	35
7.undefined systems	See Sections 1629.6.7 and 1629.9.2	-	-	-

N.L. No limit

[1] See UBC section 1630.4 for combination of structural system.

[2] Basic structural systems are defined in UBC section 1629.6.

[3] Prohibited in seismic zone 3 and 4

[4] Includes precast concrete conforming to section 1921.2.7.

[5] Prohibited in seismic zone 3 and 4 . except as permitted in section 1634.2

[6] Ordinary moment resisting frames in seismic one 1 meeting the requirements of section 2211.6 may use a R-value of 8 .

[7] Total height of the building including cantilevered columns.

[8] prohibited in seismic zones 2A , 2B ,and 4 see section 1631.2.7.

PART II

DESIGN LOADS IN OFFSHORE AND ONSHORE STRUCTURES

CONTENTS : PAGE No.

PART II

TABLES:

FIGURES:

1. SCOPE

All loads that may influence the dimensioning of the structure or parts of the structure are to be considered in the design. This applies for all phases of the life of the structure. (See clause 3 of Part I for definitions of phases).

The loads are to include the effects of increased dimensions and weight due to marine growth, ice accumulation etc.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

API (AMERICAN PETROLEUM INSTITUTE)

API RP 2A-LRFD-1993 "Recommended Practice for Planning and Constructing Fixed Offshore Platforms"

DNV (DET NORSKE VERITAS)

"Rules for the Design, Construction and Inspection of Offshore Structures" -1977

3. SYMBOLS AND NOTATIONS

NOTATION

The following general symbols are used. Other symbols are defined in the Sections where they are used.

Note:

For definitions, see clause 3 of Part I.

D = dead load,

L = live (imposed) load,

H = hydrostatic pressure,

Df = deformation load,

Env = environmental loads,

W = wind load,

F_w = wind force,

WV = wave and current load,

F_{wv} = force per unit length of member,

I = impulsive loads,

V_x = vortex shedding,

S = snow and ice loads,

E = earthquake (seismic) load,

C = construction and installation load,

A = accidental loads.

4. BASIC REQUIREMENT

4.1 Safety Considerations

The safety of life and property depends upon the ability of the structure to support the loads for which it was designed and to survive the environmental conditions which may occur. Over and above this overall concept, good practice dictates use of certain structural additions, equipment and procedures on a platform so that injuries to personnel will be minimized and the risk of collision from ships reduce. Governmental regulations stipulating such requirements and all other applicable regulations should be carried out.

5. FIXED PLATFORM TYPES

5.1 Template

A template-type platform consists of:

1) The jacket or welded tubular space frame which is designed to serve as a template for pile driving, and as lateral bracing for the piles.

2) Piles which permanently anchor the platform to the ocean floor, and carry both lateral and vertical loads.

3) A superstructure consisting of the necessary trusses and deck space for supporting operational and other loads.

5.2 Tower

A tower platform is one which has relatively few large diameter, e.g. 5 m legs. The tower may be floated to location and placed in position by selective flooding. Tower platforms may or may not be supported by piling. Where piles are used, they are driven through sleeves inside or attached to the outside of the legs. The piling may also serve as well conductors. If the tower's support is furnished by spread footings instead of by piling, the well conductors may be installed either inside or outside the legs.

5.3 Gravity Structures

A gravity structure is one that relies on the weight of the structure rather than piling to resist environmental loads.

5.4 Caisson

A caisson platform is one whose foundation support consists of one large member. These structures range from freestanding caissons which support only one well 762 mm OD to large structures several meters in diameter.

5.5 Guyed Tower

A guyed tower is a structure with a tubular steel frame supported vertically by piles or by a shallow bearing foundation. Primary lateral support is provided by a guyline system.

5.6 Tension Leg Platform

A tension leg platform is a buoyant platform connected by vertical tethers to a template on the sea floor.

5.7 Others

Other structures include underwater oil storage tanks, bridges connecting platforms, etc.

6. APPLICATION OF ENVIRONMENTAL INFORMATION

6.1 Values for Design

- The extreme values of environmental factors to be taken into account in design, are in general to be not less than those likely to be exceeded on average, once only in a period of 100 years. In regions where environmental data is well established an average return period of 50 years may be accepted by AR.

- For simplicity this Standard has been written in terms of the 100 year return period. Where a 50 year return period is accepted reference to 100 years should be replaced by 50 years.

- The joint probability of occurrence of extreme values of individual design factors may be taken into account where sufficiently accurate data exists.

- Where installations are intended for exceptionally long service lives then the average return period on which the design criteria are based is to be specially considered.

6.2 Characteristic Values

For loads that may be considered as random, the characteristic value Fk is defined as the most probable largest value in a time period equal to the design period. Where a reduction in load may result in a reduced safety of the structure, the characteristic value is to be taken as the most probable lowest value in a time period equal to the design period. The basis for the choice of characteristic value for different load categories is given in clause 7.

7. DESIGN CRITERIA AND PROCEDURES

7.1 General

The design of the installation is to be considered for all loads expected during its service life.

7.1.1 Load cases

The following loads and their appropriate combinations are to be considered in the design of the installation:

a) Functional loads.

b) Environmental loads.

c) Loads in combination.

d) Construction and installation loads.

e) Accidental loads.

f) Deformation loads.

7.1.2 Load factors

Working stress methods are acceptable. Where limit state or plastic design methods are employed the load factors will be specially considered.

7.2 Functional Loads

7.2.1 Introduction

The loads applied to the installation during its service life, except the environmental loads, are considered in this Clause.

7.2.2 Dead loads, (D)

7.2.2.1 Dead loads are the weights in air of the installation structures together with all permanently installed utilities and facilities which do not change with the mode of operation. Examples of typical loads are:

a) The weight of the structure including where necessary the weight of piles, pile sleeves, pile guides, grout , grout lines and permanent ballast.

b) The weight of equipment and machinery not associated with drilling or processes and appurtenances (e.g. boat landings, barge bumpers, risers, caissons and J-tubes, etc.,) which are permanently fixed to the installation.

7.2.3 Imposed (Live) loads, (L)

7.2.3.1 Imposed loads are all those loads which the installation is expected to withstand during its service life, other than dead loads and environmental loads.

These loads are inherently variable in their magnitude and/or disposition. Typical imposed loads are:

a) The weight of drilling, production and process equipment. These loads are to be assessed by the operator, and any limits or precautions recorded in the Operations Manual.

b) The weight of all variable and consumable items, bulk storage, and mud, cement and liquids in storage tanks. These are to be assessed as in sub-clause 7.2.3.1 (a), above.

c) The weight of liquid in piping.

d) The forces resulting from operations such as drilling, material handling and transfer of personnel and stores by the use of cranes or other means.

e) The forces resulting from vessels mooring (i.e. berthing loads) and helicopters landing and taking-off.

f) Live loads on areas such as living quarters, walkways and access platforms. The following loadings are to be used for the local design of deck plating and stiffeners and are to be not less than:

i) Cabin spaces, 3,25 kN/m^2.

ii) Crew spaces, (Walkways, general traffic areas, etc.), 4,5 kN/m^2.

iii) Work areas, 9 kN/m^2.

iv) Storage areas, 13 kN/m^2.

The blanket loadings to be used for the design of primary structure are to be specified by the designer.

g) The weight of life support, diving and utilities equipment.

h) The weight of marine growth.

7.2.3.2 On large complex offshore installations weight growth has been a problem. On this type of installation the methods of weight control and monitoring weight growth are to be included in the Operations Manual.

7.2.4 Hydrostatic loads, (H)

Hydrostatic loads are the forces exerted on the members of the installation below the water line which include external pressure and buoyancy.

7.2.5 Deformation loads, (df)

The deformation loads are loads associated with imposed deformation, such as:

- prestressing
- temperature (including sea and air temperature)
- creep
- shrinkage
- absorption
- differential settlements

The characteristic value of a deformation load is normally evaluated on the basis of prescribed maximum and minimum values for the parameters governing its magnitude.

8. ENVIRONMENTAL LOADS

- Environmental loads due to wind, waves, current, ice, snow, earthquake and similar environmental actions.
- The characteristic value of an environmental load is normally to be established in accordance with clause 6.2. The design period is generally to be taken equal to 100 years for phase O.
- For the phases C,T,I and R the design period is to be considered in each case taking into account location, seasons of the year and the consequences of the predicted values of the environmental loads being exceeded. Normally a design period equal three times the duration of the phase may be used.
- Characteristic values of environmental loads to be considered for operations or phases of short duration may be based on reliable weather predictions. In such cases, the characteristic values of the environmental loads to be considered and the criteria for starting operation are subject to approval.
- The combination and severity of the environmental loads used in design may be determined taking into account the probability of their simultaneous occurrence.

Loads due to earthquake normally need not be considered to act simultaneously with other environmental loads.

8.1 Wind

8.1.1 General

- The wind forces developed on an installation and its structural members are to be determined by part I of this Standard or on the basis of reliable wind tunnel tests. Also, reference to the Persian Gulf Pilot published by the Ports and Shipping Authority of Iran is recommended.

- A method for determining wind loads is given in clause 9.

- Blockage:

If several members are located close together in a plane normal to the wind direction, the solidification effect is to be taken into account.

- Shielding:

Shielding may be taken into account when a member or object lies closely enough behind another to have this effect. Procedures for determining the loading are to be acceptable to the AR.

8.1.2 Environmental factors to be considered in the wind load

Account is to be taken of the wind forces acting on that part of the installation which is above water and of the followings:

a) Consideration is to be given to gusts, which are of brief duration, and sustained winds which act over intervals of time equal to or greater than one minute.

Specific categories of structural element and wind speed averaging time intervals to be used for design are shown in Table 1.

b) Windspeeds are to be specified relative to a standard reference height, usually taken to be 10 m above sea level.

c) The variation of windspeed with height is to be specified. If this is not available for the location of the installation, then the following expression may be used:

$$V_H = V_R{}^{2} \frac{H}{H_R}^{3n}$$

Where:

V_H = windspeed at specified height.

V_R = windspeed at specified reference height HR.

H = specified height above sea level.

H_R = reference height.

n = power-low exponent

for 3 second gust	n = 0,077
for 5 second mean	n = 0,08
for 15 second mean	n = 0,09
for 1 minute mean	n = 0,125

TABLE 1 - STRUCTURAL PARTS TO BE CONSIDERED FOR WIND LOADING

WINDSPEED AVERAGING TIME-INTERVAL	STRUCTURAL CATEGORY
3 SECOND GUST	INDIVIDUAL MEMBERS AND EQUIPMENT SECURED TO THEM
5 SECOND MEAN	PART OR WHOLE OF A STRUCTURE WHOSE GREATEST HORIZONTAL OR VERTICAL DIMENSION DOES NOT EXCEED 50 m
15 SECOND MEAN	PART OR WHOLE, OF A STRUCTURE WHOSE GREATEST HORIZONTAL OR VERTICAL DIMENSION EXCEEDS 50 m
1 MINUTE MEAN	THE WHOLE TOPSIDE STRUCTURE REGARDLESS OF DIMENSION FOR USE WITH THE MAXIMUM WAVE OR CURRENT LOADING

8.2 Wave and Current

8.2.1 General

8.2.1.1 The forces produced by the action of waves on the installation are to be taken into account in the structural design.

8.2.1.2 Where current acts simultaneously with waves the effect of the current is to be included. The current velocity is to be added vectorally to the wave particle velocity. The resultant velocity is to be used to calculate the total force.

8.2.1.3 Wave theories used for the calculation of water particle motions are to be acceptable to the AR.

Regions of validity that may be taken for various wave theories are shown in Fig. 1. For more information on wave theories reference is made to: The Shore Protection Manual, Volumes I and II by U.S. Army; and the Shlezinger Theory.

8.2.1.4 Account is to be taken of the increase of overall size and roughness of submerged members due to marine growth when calculating loads due to wave and current.

8.2.1.5 The following methods may be used for load estimation:

a) Morison’s equation , see Clause 10 , may be used to determine wave and current loading on structural members with dimensions less than 0,2 of the wave length.

b) Overall loading on an offshore structure is determined from the summation of loads on individual members at a particular time. The proper values of C_D and Cm for individual members to use with Morison’s equation will depend on a number of variables for example, Reynolds Number, Keulegan Carpenter Number, inclination of the member to local flow and effective roughness of marine growth.

Therefore fixed values for all conditions cannot be given. Typical values for circular cylindrical members will range from 0,6 to 1,4 for C_D and 1,3, to 2,0 for C_m. The values selected are not to be smaller than the lower limits of these ranges.

For inclined members the drag forces in Morison’s equation are to be calculated using the normal component of the resultant velocity vector.

c) General values of hydrodynamic coefficients may be used in the Morison equation for the calculation of overall loading on the structure, namely:

i) For circular cylinders covered by hard marine growth C_D is to be not less than 0,7.

ii) For circular cylinders not covered by hard marine growth C_D is to be not less than 0,6.

iii) For circular cylinders C_m is to be not less than 1.7.

d) The lowest values of C_D and Cm shown in 8.2.1.5(c) may only be used for calculating the overall loading for the extreme design wave, see Clause 8.2.2 when the calculations include the assumptions that:

i) The design wave is long crested.

ii) The motions are calculated by normal wave theories.

iii) No shielding effects on the structure are included see Sub-clause 8.2.1.11.

iv) The particle velocities due to extreme independent values of wave and current are combined, see Clause 11.3, unless otherwise agreed.

If joint probability predictions of wave and current are included in the design procedure or if the conservatism is reduced in any part , consideration is to be given to increasing the drag coefficient associated with hard marine growth. Where local loading governs, e.g. vertical loading on conductor frames, the force coefficients are to be specially considered.

e) The lowest values of C_D shown in 8.2.1.5 (c) may be used for calculating fatigue loading but unless otherwise approved C_m is to be increased to 2.

8.2.1.6 Diffraction theory is to be used to determine wave loads where the member is large enough to modify the flow field (i.e. dimensions greater than 0,2 of the wave length).

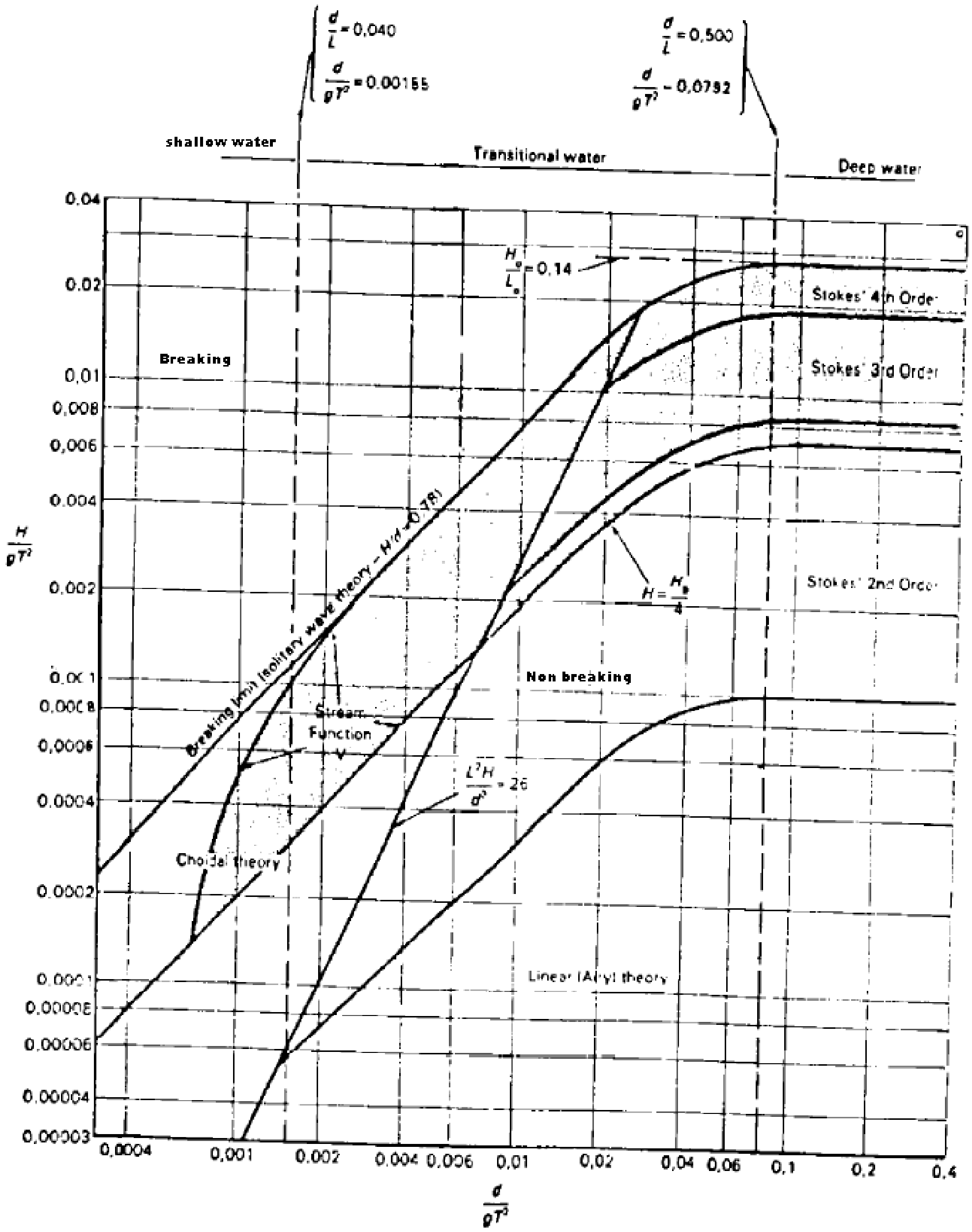
8.2.1.7 Changes in wave load, phase and direction due to interference of closely spaced columns are to be taken into account.

8.2.1.8 Any increase of loading due to wave making resistance or "run up" which may occur on surface piercing members is to be assessed.

8.2.1.9 Account is to be taken of the increase of loading on members due to attachments such as sacrificial anodes and pile guides.

8.2.1.10 If several members are closely located in a plane normal to the wave direction the solidification effect is to be taken into account.

8.2.1.11 Shielding may be taken into account when a member or object lies closely enough behind another to have this effect. Where shielding is taken into account CD and Cm values appropriate to local conditions are to be used. Procedures for determining the loading are to be acceptable to the AR.



REGIONS OF VALIDITY FOR VARIOUS WAVE THEORIES

Fig. 1

8.2.2 Environmental factors to be Considered for the wave and current loads

The information to be submitted relating to waves used in the design is to include heights, periods and where available, directions.

The following factors should also be taken into account:

a) Design wave

The extreme wave with return period specified for design will normally give rise to the maximum loads on the installation as a whole and on most of its principal elements. The maximum crest elevation of this wave will be required to calculate the clearance height of the superstructure. However consideration is to be given to other waves if these are likely to give rise to maximum loads.

b) Wave encounters

An estimate is to be made of the probable wave encounters that the installation is likely to experience during its service life in order to assess fatigue effects on its structural elements.

c) Wave energy spectra

Alternative methods of carrying out maximum loads and fatigue analyses may be based on the use of wave energy spectra. Theoretical wave spectra may be used for design purposes. The Pierson-Moskowitz spectrum is normally used for oceanic locations and fully developed seas. The Jonswap spectrum is normally used for fetchlimited growing seas and without swell. Proposed use of wave spectra is to be agreed with the AR.

d) Shallow water

In intermediate and shallow water, the effect on wave heights and periods, of the water depth and of refraction due to seabed topography, is to be taken into account.

8.3 Impulsive loads, (I)

8.3.1 Consideration is to be given to the effect of wave impact on the static, dynamic and fatigue loading of structural members in the splash zone.

8.3.2 Slamming affects local loading only and does not usually increase the overall loading significantly.

8.3.3 The slamming force per unit length, Fs, on a member (or part of a member) may be determined from the expression:

$$F_s = 1/2pC_SDU^2$$

Where:

P	is water density
C_S	is slamming coefficient
D	is member local effective diameter
U	is velocity of the water normal to the surface.

A typical value for C_S is 3,5. AR may give consideration to other rational methods for the calculation of slam loads.

8.3.4 If the axis of the member is parallel to the wave crest, wave slam can give rise to a dynamic response from the high loading momentarily incurred. Account is to be taken of any dynamic effects.

8.3.5 Loads on members due to the change in buoyancy which occurs with the passing of a wave are also to be considered. Provision of free flooding is not to be automatically considered to alleviate this effect.

8.4 Vortex Shedding, (V_x)

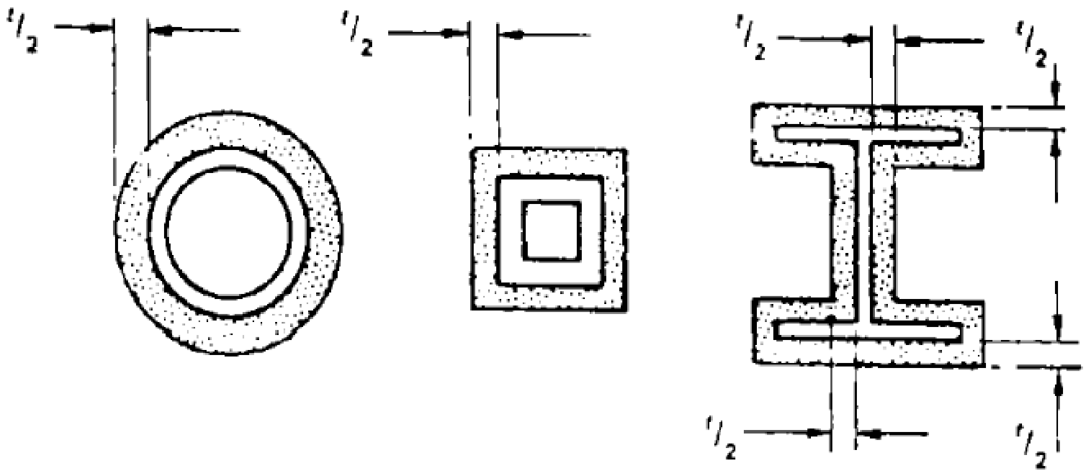
8.4.1 Consideration is to be given to the possibility of oscillating forces produced by the shedding of vertices in wind, wave and current flow.

8.5 Snow and Ice

8.5.1 The increased loading caused by the accumulation of snow and ice on the topside structure is to be taken into account.

8.5.2 Values for the thickness, density and variation with height of accumulated snow and ice are to be derived from meteorological data acceptable to the AR.

8.5.3 The overall distribution of snow and/or ice on topside structure is to be taken as a thickness t on the upper and windward faces of the module or member under consideration, where t is the basic thickness obtained from the meteorological data. The distribution of ice on individual members may be assumed to be as shown in Fig. 2.



ASSUMED DISTRIBUTION OF ICE ON INDIVIDUAL MEMBERS FOR CALCULATION PURPOSE

Fig. 2

8.5.4 It may be assumed that there is no increase of drag coefficient in the presence of ice.

8.5.5 For the appropriate combinations of snow and/or ice accumulations and wind speeds see Clauses 11.2. and 11.3.

8.6 Earthquake Loads

8.6.1 General

The effects of earthquakes are to be considered in phase O for structures to be located in seismically active areas. In special cases earthquake effects may need to be considered in phase C.

Two level of earthquake activity are normally to be considered in phase O, i.e. the design level and the exceptional level.

a) The design (strength/operating) level, corresponding to the design earthquake which is defined as the most probable severest earthquake expected to occur at the site during the design period. The design earthquake is to be considered in the loading condition "extreme".

b) The exceptional (ductility/safety) level, corresponding to the maximum credible earthquake which could be expected to occur at the site. The maximum credible earthquake is considered as an accidental load, see clause 13.

Guidance: The intent of the exceptional level is to ensure that the structure has sufficient energy absorbing capacity against reaching a progressive collapse limit state during rare intense earthquake motions. Normally, the maximum credible earthquake is not taken less than twice the ground motion of the design earthquake.

8.6.2 Ground motion

The ground motions used as basis for design shall adequately represent the expected conditions at the site, both in terms of frequency content and energy distribution.

The effects of local soil conditions in amplifying or attenuating the ground motion and in altering the frequency content are to be studied in order to determine appropriate horizontal and vertical characteristic values of the ground motion.

The ground motion may be described either in terms of time histories or in terms of response spectra.

Standard spectra generally recognized as being valid for the region and the site conditions considered, may be considered when describing the ground motion.

The ground motion is normally to consist of three components (see .6.4) which are to be applied simultaneously, i.e. in the two horizontal directions and in the vertical direction.

When the response spectra method (see 8.6.5) is used the minimum values of ground acceleration in the three directions are;

- 100% in the horizontal direction (i.e. the principal axis) considered most unfavorable to the structure.
- 70% in the orthogonal horizontal direction.
- 50% in the vertical direction.

Where deemed necessary, appropriate higher percentages are to be used.

The ground motion components to be used in time history analysis are to be derived using recognized procedures.

The statistics and procedures used, and the investigations made for establishing the characteristic of the ground motion to be used as basis for design are subject to acceptance.

The characteristic values of the ground motion are subject to approval.

8.6.3 Other effects

The effects of tsunamis are to be considered for structures located in shallow water. The effects of earthquake generated acoustic shock waves are to be considered where such effects will result in additional loads, e.g. sub-sea compartments that are not fully flooded.

8.6.4 Structure analytical model

The analytical models used for determination of earthquake response should represent the structure-soil-water system in a realistic manner as regards distribution of stiffness, mass and damping.

Assumptions made as regards nonlinear behavior are to be carefully examined with respect to material properties and structural detailing.

Normally, the dynamic characteristics of the structure and its foundation should be determined using a three dimensional analytical model. A two dimensional model may be used provided the torsional response and the response of cantilevered structures, e.g. decks on gravity structures, are properly accounted for.

Parameter studies are to be carried out where deemed necessary for proper determination of loading effects. The use of partitioned damping is recommended for parts of the structure-soil-water system having relatively large damping compared to the damping in the structure, e.g. the material and radiation damping in the soil.

8.6.5 Methods of analysis

The response analysis may be accomplished using any recognized method applicable for offshore structures e.g. response spectrum methods or time history methods.

When using the response spectrum method as many modes should be considered as required to provide at least 90 percent of the total energy of all modes. A minimum of six modes with the highest energy content should be considered. Unless otherwise agreed, the maximum total response S is not to be taken less than:

$$S = S_n + \sqrt{\sum S_i^2}$$

Where:

- ***s_n*** is the modal response yielding the largest contribution and
- ***s_i*** the individual modal response of the other modes.

When the response is carried into the inelastic range, time history methods are normally to be used.

Static equivalent methods are not to be used as the basis for design of structures for which sufficiently accurate dynamic analyses can be carried out.

Guidance: For structures for which a meaningful dynamic analysis can not be carried out for the maximum credible earthquake, acceptable safety against progressive collapse may normally be assumed if it can be verified that the structure remains stable when subjected to a quasistatic loading that yields deformations approximately twice those of the design earthquake.

8.6.6 Equipment response

The purpose of equipment response analysis is to determine the loads to be used in the design of the equipment support structures and the fastening arrangements, and in the checking of the safety of equipment.

The dynamic response of equipment and equipment supports is to be analyzed using recognized procedures and methods. The vertical and horizontal support accelerations should be combined in a rational manner so as to arrive at realistic loading effects.

9. GUIDANCE NOTES ON THE CALCULATION OF WIND AND CURRENT FORCES

9.1 Wind Force Calculation

9.1.1 The wind force on a structural member or surface may be calculated according to:

$$F_W = C_f \tfrac{1}{2} p V^2 A$$

Where:

- ***F_W*** = the wind force.
- ***C_f*** = the force coefficient, see 9.1.2 and 9.1.3.
- ***p*** = the air mass density; to be taken as 1,255 kg/m^3 for dry air.
- ***V*** = the wind velocity, see 8.1.2.
- ***A*** = the projected area of the exposed surfaces of the member.

9.1.2 In the absence of data indicating otherwise the force coefficients tabulated in Table 2 may be used:

TABLE 2 - WIND FORCE COEFFICIENTS

Form	Cf
SPHERICAL	0,4
LARGE FLAT SURFACES (MODULES, SMOOTH UNDERSIDES OF MODULES OR DECKS)	1,0
DRILLING DERRICKS	1,25
WIRES	1,2
EXPOSED BEAMS AND GIRDERS UNDER MODULES OR DECKS	1,3
SMALL PARTS	1,4
ISOLATED SHAPES (CRANES, BEAMS, ETC.,)	1,5
CLUSTERED MODULES OR SIMILAR STRUCTURES	1,1

9.1.3 The force coefficient, Cf for circular cylinders as a function of Reynold's Number is given in Fig. 3. Reynold's Number Re is defined as:

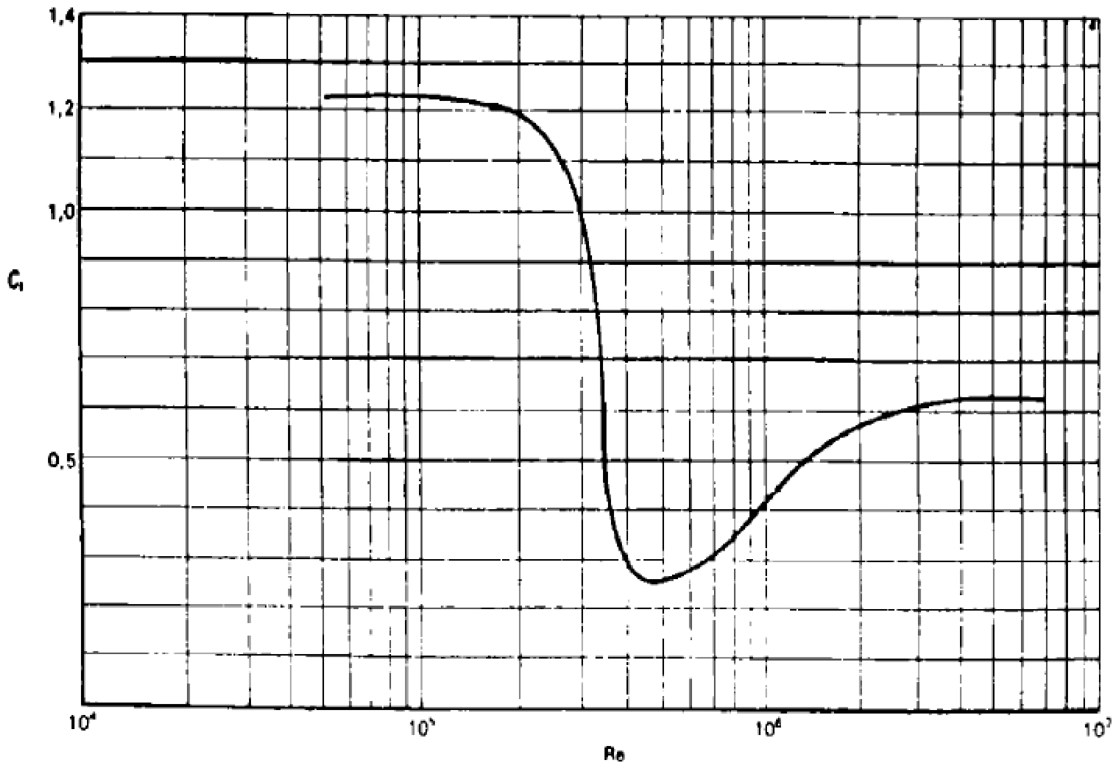
$$R_e = \frac{DV}{V}$$

Where:

D = diameter of member.

V = wind speed.

v = Kinematic viscosity of air , may be taken as $1{,}46 \times 10^{-5}$ m^2/sec. at 15°C and standard atmospheric pressure.



FORCE COEFFICIENT VERSUS REYNOLD'S NUMBER FOR SMOOTH CYLINDERS IN STEADY UNIFORM FLOW

Fig. 3

10. GUIDANCE NOTES ON THE CALCULATION OF THE WAVE AND CURRENT FORCES

10.1 Drag and Inertia Loading

The forces on members in the drag/inertia loading regime due to wave and current motions can be calculated by the equation:

$$F_{wv} = C_D \tfrac{1}{2}\, p\, A\, u\, |u| + C_m\, p\, V\, _u$$

Where:

F_{wv} = force per unit length of member.

C_D = drag coefficient.

p = density of water.

A = projected area of member per unit length.

u = component of the water particle velocity at the axis of the member and normal to it (calculated as if the member were not there).

$|u|$ = modulus of u.

C_m = inertia coefficient.

V = volume of member per unit length.

u = component of the water particle acceleration at the axis of the member and normal to it (calculated as if the member was not there).

11. LOADS IN COMBINATION

11.1 General

11.1.1 The design of the installation, is to be investigated for all possible combinations of loads which will produce the most severe effects on the structure.

11.1.2 The load combinations to be considered in both the operating and extreme storm conditions are described in 11.2 and 11.3.

11.1.3 In seismically active areas earthquake loads in combination with other loads, as described in 11.4 are to be considered. For this load combination, environmental loads such as wave, wind and current need not be considered.

11.1.4 The magnitude and distribution of the minimum imposed loads, for load combinations described in 11.2.4(a), 11.3.5(a) and 11.4.3 are to be such that they maximize design loadings in the members.

11.1.5 The magnitude and distribution of the minimum imposed loads, for load combinations described in 11.2.4(b), 11.3.5(b) and 11.4.4, are also to be considered in a manner which maximizes design loadings in members. This case is particularly important in determining the maximum tension loads in the piles.

11.2 Operating Conditions

11.2.1 Those parts of the structure subject to wave loading are to be designed for an environmental condition which occurs frequently during the service life of the installation, but is not severe enough to limit its normal operation.

11.2.2 The operator is to specify the wave, wind and current to be used and these criteria are to be submitted for approval. A still water condition is acceptable using the maximum dead and imposed loads if these loads are also used in the extreme storm condition and a rigorous fatigue analysis is carried out.

11.2.3 For those parts of the structure not subject to wave loading, see 11.2.5.

11.2.4 The operating environmental loads are to be combined with dead, imposed and hydrostatic loads as follows:

> **a)** The operating environmental loads are to be combined with dead loads, maximum consistent imposed loads and hydrostatic loads as appropriate to the normal operations of the installation.
>
> **b)** The operating environmental loads are to be combined with dead loads, minimum consistent imposed loads and hydrostatic loads as appropriate to the normal operations of the installation.

11.2.5 The load combinations to be considered for those parts of the structure not subject to wave loading are as detailed in Table 3.

TABLE 3 - LOAD COMBINATIONS, OPERATING CONDITIONS

CASE	LOADS TO BE COMBINED		
	GRAVITY	WIND SEE 8.1.2	ICE/SNOW SEE 11.2.6
1	YES	MEAN WIND WITH 1 YEAR RETURN	NO
2	YES	MEAN WIND WITH 3 MONTH RETURN	100 YEAR RETURN VALUE SEE 8.5

11.2.6 Where ice loading effects are considered as in Table 3 case 2, account is to be taken of both the increased gravity loading and the increase in wind loading.

11.2.7 Mean wind speeds are defined in clause 8.1.2.

11.3 Extreme Storm Conditions

11.3.1 The installation is to be designed for the extreme storm condition as defined in clause 6.

11.3.2 All combinations of environmental factors to which the installation may foreseeably be subjected are to be taken into account.

11.3.3 When minimum values of C_D and C_m are used for calculating overall loading, see 8.2.1.5, the extreme combination of environmental factors to be taken into account is to be not less severe than the following:

a) The maximum wave height with a mean return period of 100 years, see 6.1. A range of wave periods for this wave should be considered.

b) The one minute mean wind speed with a mean return period of 100 years.

c) The maximum storm and tidal current with a return period of 100 years, acting in the same direction as the design wave. Directional current associated with the 100 year design wave may be used if such data is available.

d) The most critical water depth between the following levels:

i) Mean low water springs.

ii) Mean high water springs plus maximum storm surge with a mean return period of 100 years.

11.3.4 Any other combination of environmental factors are to be taken into account which may cause greater stresses either in the structure as a whole or in any element of the primary structure.

11.3.5 The extreme storm environmental loads are to be combined with dead, maximum and minimum imposed and hydrostatic loads as follows:

a) The extreme storm environmental loads are to be combined with dead loads , maximum consistent imposed loads and hydrostatic loads as appropriate to the extreme storm operations of the installation.

b) The extreme storm environmental loads are to be combined with dead loads , minimum consistent imposed loads and hydrostatic loads as appropriate to the extreme storm operations of the installation.

11.3.6 The load combinations to be considered for those parts of the structure not subject to wave loading are as detailed in Table 4.

TABLE 4 - LOAD COMBINATIONS, EXTREME STORM CONDITIONS

CASE	LOADS TO BE COMBINED		
	GRAVITY	WIND SEE 8.1.2	ICE/SNOW SEE 11.3.7
1	YES	MEAN WIND WITH 100 YEAR RETURN	NO
2	YES	MEAN WIND WITH 10 YEAR RETURN	100 YEAR RETURN VALUE SEE 8.5

11.3.7 Where ice loading effects are added, as in Table 4 case 2, account is to be taken of both the increased gravity loading and the increase in wind loading.

11.3.8 Mean wind speeds are defined in Clause 8.1.2.

11.4 Earthquake Loading Conditions

11.4.1 In seismically active areas, the installation is to be designed to withstand earthquake loadings. Two levels of earthquake loadings are to be considered, the "strength" (design/operating) and the "ductility" (extreme/safety) levels.

The definitions of these two levels of earthquake loading are given in Clause 8.6.

11.4.2 The earthquake loadings, for both 'strength' and 'ductility' levels, are to be combined with dead, imposed and hydrostatic loads as detailed in 11.4.3 and 11.4.4.

11.4.3 For maximum imposed loads earthquake loadings are to be combined with dead loads, maximum consistent imposed loads (i.e. live loads), hydrostatic loads and 75 percent of the maximum supply and storage loads as appropriate to the normal operations of the installation.

11.4.4 For minimum imposed loads earthquake loadings are to be combined with dead loads, minimum consistent imposed loads and hydrostatic loads as appropriate to the normal operations of the installation.

11.4.5 Both of the maximum and minimum imposed load combinations are to be considered for the installation where the earthquake loadings govern the design. However, only the maximum imposed load combination need be considered if the earthquake loadings are less critical than the extreme storm environmental loadings.

11.5 Other Load Combination Cases

11.5.1 Other load combinations to account for the effects of loads such as ice force, berthing loads, etc., where applicable, are to be specially considered .

12. CONSTRUCTION AND INSTALLATION LOADS, (C)

12.1 General

The design of the installation is to take account of the loads imposed during fabrication, load-out, transportation, launching and installation at the site.

For detailed information on construction and installation loads, reference shall be made to API, RP-2A LRFD-1993 "Recommended Practice for Planing, Designing and Constructing Fixed Offshore Platforms".

13. ACCIDENTAL LOADS

13.1 Boat Impact

13.1.1 The loads imposed by supply boats while approaching, mooring and lying alongside the installation are to be considered in the design. The platform is to be designed to withstand accidental impacts between supply boats and the jacket structure.

13.1.2 If fendering is fitted the combined structure/fender system is to be capable of absorbing the energy of impact from vessels without overstressing the jacket.

13.1.3 Where fending is not fitted the structure itself is to be designed to be capable of absorbing the energy of impact.

13.1.4 The level of energy selected for vessel impact design is dependent on the size of supply boat used, the prevailing environmental conditions and the type of platform. Unmanned wellhead platforms, etc., not requiring supply boat operations, may be designed to very much lower levels of impact energy. Proposed design for boat impacts is to be submitted for consideration. Where there is doubt regarding design requirements the following is recommended:

> **a)** In general, for platforms in calm protected environments the level of energy of impact recommended is 0,5 MJ or otherwise approved.
>
> **b)** For exposed locations and where large supply vessels are used the recommended level of impact energy is 2 MJ.

13.1.5 The jacket is to be so designed that the energy can be totally absorbed in deformation of the member or members concerned. No account is to be taken of energy absorbed in the vessel. Both elastic and plastic deformation may be considered .

13.1.6 In many cases the jacket bracing members may not be capable of absorbing the impact energy. Where the boat impact analysis shows that a member or group of members becomes ineffective it is essential to show that the installation will not collapse as a consequence. In this case a redundancy analysis with the members concerned removed, or a non-linear analysis of the damaged structure, may be required to demonstrate that the structure has adequate reserve strength.

13.1.7 For non redundant members such as the main legs, the energy of impact is generally mainly absorbed by denting. The possibility of total collapse, due to impact, of such non-redundant members is to be considered in the design.

13.1.8 The damaged platform should be capable of withstanding a minimum of a one month storm without collapse. The member forces are to be determined for the damaged condition in combination with dead loads, maximum consistent imposed loads and hydrostatic loads as appropriate to the operations of the installation.

14. ADDENDUM

For additional information on environmental conditions and loads refer to Appendices A and B respectively of Det Norske Veritas "Rules for the Design, Construction and Inspection of Offshore Structures",(1981 Reprint).