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CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 5 SPECIAL LOADS AND COMBINATIONS

(Second Revision)

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(Second Revision)

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Indian Standard

CODE OF PRACTICE FOR DESIGN LOADS (OTHER THAN EARTHQUAKE) FOR BUILDINGS AND STRUCTURES

PART 5 SPECIAL LOADS AND LOAD COMBINATIONS

(Second Revision)

0. FOREWORD

0.1 This Indian Standard (Part 5) (Second Revision) was adopted by the Bureau of Indian Standards on 31 August 1987, after the draft finalized by the Structural Safety Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 A building has to perform many functions satisfac orily. Amongst these functions are the utility of the building for the intended use and occupancy, structural safety, fire safety; and compliance with hygienic, sanitation, ventilation and day light standards. The design of the building is dependent upon the minimum requirements prescribed for each of the above functions. The minimum requirements pertaining to the structural safety of buildings are being covered in this code by way of laying down minimum design loads which have to be assumed for dead loads, imposed loads, snow loads and other external loads, the structure would be required to bear. Strict conformity to loading standards recommended in this code, it is hoped, will not only ensure the structural safety of the buildings which are being designed and constructed in the country and thereby reduce the hazards to life and property caused by unsafe structures, but also eliminate the wastage caused by assuming unnecessarily heavy loadings. Notwithstanding what is stated regarding the structural safety of buildings, the application of the provisions should be carried out by competent and responsible structural designer who would satisfy himself that the structure designed in accordance with this code meets the desired performance requirements when the same is carried out according to specifications.

0.3 This standard code of practice was first published in 1957 for the guidance of civil engineers, designers and architects associated with planning and design of buildings. It included the provisions for basic design loads (dead loads, live loads, wind loads and seismic loads) to be assumed in the design of buildings. In its first revision in 1964, the wind pressure provisions were modified on the basis of studies of wind phenomenon and its effects on structures, undertaken by the special committee in consultation with the Indian Meteorological Department. In addition to this, new clauses on wind loads for butterfly type structures were included; wind pressure coefficients for sheeted roofs both curved and sloping were modified; seismic load provisions were deleted (separate code having been prepared) and metric system of weights and measurements was adopted.

0.3.1 With the increased adoption of the code, a number of comments were received on the provisions on live load values adopted for different occupancies. Simultaneously live load surveys have been carried out in America, Canada and other countries to arrive at realistic live loads based on actual determination of loading (movable and immovable) in different occupancies. Keeping this in view and other developments in the field of wind engineering, the committee responsible for the preparation of the standard decided to prepare second revision in the following five parts:

Part 1 Dead loads

Part 2 Imposed loads

Part 3 Wind loads

Part 4 Snow loads

Part 5 Special loads and load combinations.

Earthquake load is covered in a separate standard, namely IS : 1893-1984* which should be considered along with the above loads.

0.3.2 This code (Part 5) deals with loads and load effects (other than those covered in Parts 1 to 4, and seismic loads) due to temperature changes, internally generating stresses (due to creep, shrinkage, differential settlement, etc) in the building and its components, soil and hydrostatic pressure, accidental loads, etc. This part also includes guidance on load combinations.

0.4 The code has taken into account the prevailing practices in regard to loading standards followed in this country by the various municipal authorities and has also taken note of the developments in a number of countries abroad. In the preparation of this code, the following national standards have been examined:

a) National Building Code of Canada (1977) Supplement No. 4. Canadian Structural Design Manual.

*Criteria for earthquake resistant design of structures (*third revision*).

b) DS 410-1983 Code of practice for loads for the design of structures. Danish Standards Institution.

c) NZS 4203-1976 New Zealand Standard General structural design and design loading for building. Standards Association of New Zealand.

d) ANSI A 58.1-1982 American Standard Building code requirements for minimum design loads in buildings and other structures.

1. SCOPE

1.1 This code (Part 5) deals with loads and load effects due to temperature changes, soil and hydrostatic pressures, internally generating stresses (due to creep, shrinkage, differential settlement, etc), accidental loads etc, to be considered in the design of buildings as appropriate. This part also includes guidance on load combinations. The nature of loads to be considered for a particular situation is to be based on engineering judgement.

2. TEMPERATURE EFFECTS

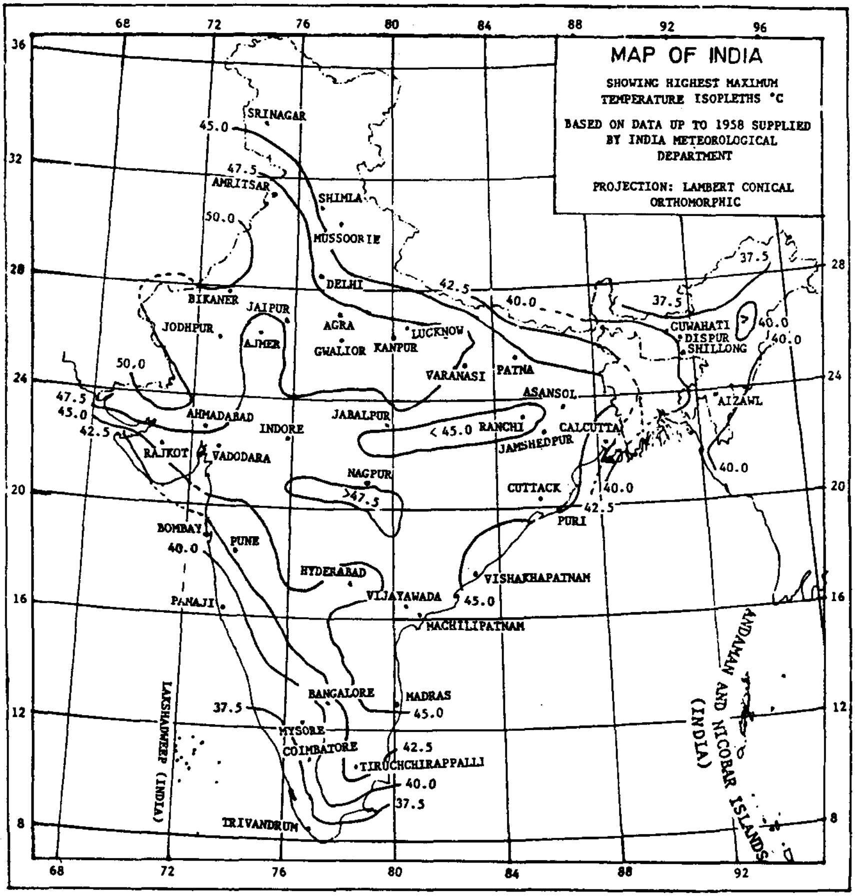
2.1 Expansion and contraction due to changes in temperature of the materials of a structure shall be considered in design. Provision shall be made either to relieve the stress by provision of expansion/contraction joints in accordance with IS : 3414-1968* or design the structure to carry additional stresses due to temperature effects as appropriate to the problem.

2.1.1 The temperature range varies for different regions and under different diurnal and seasonal conditions. The absolute maximum and minimum temperature which may be expected in different localities in the country are indicated in Fig. 1 and 2 respectively. These figures may be used for guidance in assessing the maximum variations of temperature.

2.1.2 The temperatures indicated in Fig. 1 and 2 are the air temperatures in the shade. The range of variation in temperature of the building materials may be appreciably greater or less than the variation of air temperature and is influenced by the condition of exposure and the rate at which the materials composing the structure absorb or radiate heat. This difference in temperature variations of the material and air should be given due consideration.

2.1.3 The structural analysis must take into account: (a) changes of the mean (through the section) temperature in relation to the initial temperature (st), and (b) the temperature gradient through the section.

*Code of practice for design and installation of joints in buildings.



The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

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FIG. 1 CHART SHOWING HIGHEST MAXIMUM TEMPERATURE

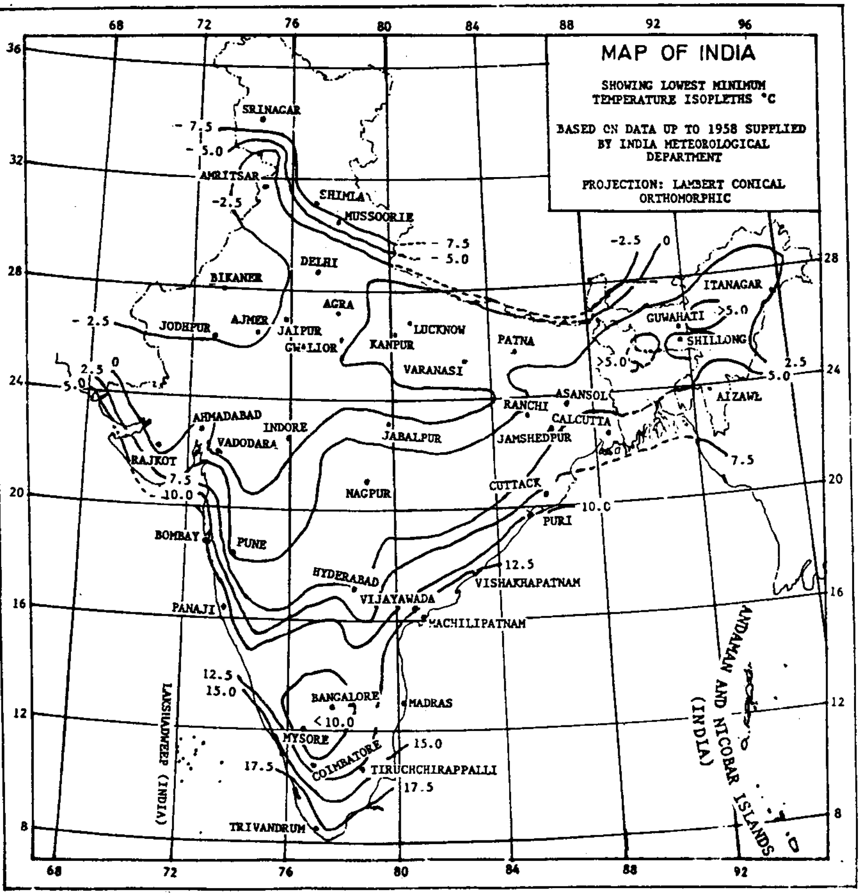

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FIG. 2 CHART SHOWING LOWEST MINIMUM TEMPERATURE

2.1.3.1 It should be borne in mind that the changes of mean temperature in relation to the initial are liable to differ as between one structural element and another in buildings or structures, as for example, between the external walls and the internal elements of a building. The distribution of temperature through section of single-leaf structural elements may be assumed linear for the purpose of analysis.

2.1.3.2 The effect of mean temperature changes t_1, and t_2, and the temperature gradients v_1 and v_2 in the hot and cold seasons for single-leaf structural elements shall be evaluated on the basis of analytical principles.

NOTE 1 — For portions of the structure below ground level, the variation of temperature is generally insignificant. However, during the period of construction when the portions of the structure are exposed to weather elements, adequate provision should be made to encounter adverse effects, if any.

NOTE 2 — If it can be shown by engineering principles, or if it is known from experience, that neglect of some or all the effects of temperature do not affect the structural safety and serviceability, they need not be considered in design.

3. HYDROSTATIC AND SOIL PRESSURE

3.1 In the design of structures or parts of structures below ground level, such as retaining walls and other walls in basement floors, the pressure exerted by soil or water or both shall be duly accounted for on the basis of established theories. Due allowance shall be made for possible surcharge from stationary or moving loads. When a portion or whole of the soil is below the free water surface, the lateral earth pressure shall be evaluated for weight of soil diminished by buoyancy and the full hydrostatic pressure.

3.1.1 All foundation slabs and other footings subjected to water pressure shall be designed to resist a uniformly distributed uplift equal to the full hydrostatic pressure. Checking of overturning of foundation under submerged condition shall be done considering buoyant weight of foundation.

3.2 While determining the lateral soil pressure on column like structural members, such as pillars which rest in sloping soils, the width of the member shall be taken as follows (*see* Fig. 3):

Actual Width of Member	*Ratio of Effective Width to Actual Width*
Less than 0·5 m	3·0
Beyond 0·5 m and up to 1 m	3·0 to 2·0
Beyond 1 m	2·0

The relieving pressure of soil in front of the structural member concerned may generally not be taken into account.

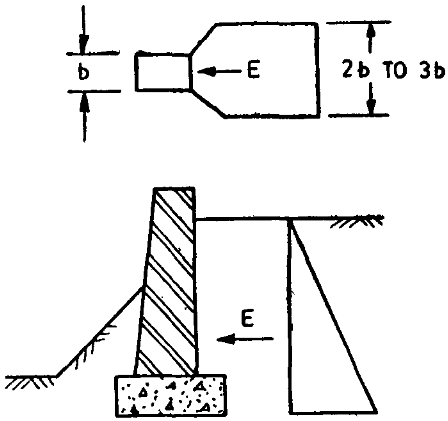

FIG. 3 SKETCH SHOWING EFFECTIVE WIDTH OF PILLAR FOR CALCULATING SOIL PRESSURE

3.3 Safe guarding of structures and structural members against over-turning and horizontal sliding shall be verified. Imposed loads having favourable effect shall be disregarded for the purpose. Due consideration shall be given to the possibility of soil being permanently or temporarily removed.

4. FATIGUE

4.1 General — Fatigue cracks are usually initiated at points of high stress concentration. These stress concentrations may be caused by or associated with holes (such as bolt or rivet holes in steel structures), welds including stray or fusions in steel structures, defects in materials, and local and general changes in geometry of members. The cracks usually propogate if loading is continuous.

Where there is such loading cycles, sudden changes of shape of a member or part of a member, specially in regions of tensile stress and/or local secondary bending, shall be avoided. Suitable steps shall be taken to avoid critical vibrations due to wind and other causes.

4.2 Where necessary, permissible stresses shall be reduced to allow for the effects of fatigue. Allowance for fatigue shall be made for combinations of stresses due to dead load and imposed load. Stresses due to wind and earthquakes may be ignored when fatigue is being considered unless otherwise specified in the relevant codes of practice.

Each element of the structure shall be designed for the number of stress cycles of each magnitude to which it is estimated that the element is liable to be subjected during the expected life of the structure. The number of cycles of each magnitude shall be estimated in the light of available data regarding the probable frequency of occurrence of each type of loading.

NOTE — Apart from the general observations made herein the code is unable to provide any precise guidance in estimating the probablistic behaviour and response of structures of various types arising out of repetitive loading approaching fatigue conditions in structural members, joints, materials, etc.

5. STRUCTURAL SAFETY DURING CONSTRUCTION

5.1 All loads required to be carried by the structures or any part of it due to storage or positioning of construction materials and erection equipment including all loads due to operation of such equipment, shall be considered as erection loads. Proper provision shall be made, including temporary bracings to take care of all stresses due to erection loads. The structure as a whole and all parts of structure in conjunction with the temporary bracings shall be capable of sustaining these erection loads without exceeding the permissible stresses specified in respective codes of practice. Dead load, wind load and such parts of imposed load as would be imposed on the structure during the period of erection shall be taken as acting together with erection loads.

6. ACCIDENTAL LOADS

6.0 General — The occurrence of accidental loads with a significant value, is unlikely on a given structure over the period of time under consideration, and also in most cases is of short duration. The occurrence of an accidental load could in many cases be expected to cause severe consequences unless special measures are taken:

The accidental loads arising out of human action include the following:

a) Impacts and collisions,

b) Explosions, and

c) Fire.

Characteristic of the above stated loads are that they are not a consequence of normal use and that they are undesired, and that extensive efforts are made to avoid them. As a result, the probability of occurrence of an accidental load is small whereas the consequences may be severe.

The causes of accidental loads may be:

a) inadequate safety of equipment (due to poor design or poor maintenance); and
b) wrong operation (due to insufficient teaching or training, indisposition, negligence or unfavourable external circumstances).

In most cases, accidental loads only develop under a combination of several unfavourable occurrence. In practical applications, it may be necessary to neglect the most unlikely loads. The probability of occurrence of accidental loads which are neglected may differ for different consequences of a possible failure. A data base for a detailed calculation of the probability will seldom be available.

NOTE — *Determination of Accidental Loads* — Types and magnitude of accidental loads should preferably be based on a risk analysis. The analysis should consider all factors influencing the magnitude of the action, including preventive measures for accidental situations. Generally, only the principal load bearing system need be designed for relevant ultimate limit states.

6.1 Impacts and Collisions

6.1.1 *General* — During an impact, the kinetic impact energy has to be absorbed by the vehicle hitting the structure and by the structure itself. In an accurate analysis, the probability of occurrence of an impact with a certain energy and the deformation characteristics of the object hitting the structure and the structure itself at the actual place must be considered. Impact energies for dropped objects should be based on the actual loading capacity and lifting height.

Common sources of impact are:

a) vehicles;
b) dropped objects from cranes, fork lifts, etc;
c) cranes out of control, crane failures; and
d) flying fragments.

The codal requirements regarding impact from vehicles and cranes are given in **6.1.2** and **6.1.3**.

6.1.2 *Collisions Between Vehicles and Structural Elements* — In road traffic, the requirement that a structure shall be able to resist collision may be assumed to be fulfilled if it is demonstrated that the structural element is able to stop a fictitious vehicle, as described in the following. It is assumed that the vehicle strikes the structural element at height of 1·2 m in any possible direction and at a speed of 10 m/s (36 km/h).

The fictitious vehicle shall be considered to consist of two masses m_1 and m_2 which during compression of the vehicle produce an impact force increasing uniformly from zero, corresponding to the rigidities C_1 and C_2. It is assumed that the mass m_1 is breaked completely before the braking of mass m_2 begins.

The following numerical values should be used:

m_1 = 400 kg, C_1 = 10 000 kN per m the vehicle is compressed.

m_2 = 12 000 kg, C_2 = 300 kN per m the vehicle is compressed.

NOTE — The described fictitious collision corresponds in the case of a non-elastic structural element to a maximum static force of 630 kN for the mass m_1 and 600 kN for the mass m_2 irrespective of the elasticity. It will, therefore, be on the safe side to assume the static force to be 630 kN.

In addition, braking of the mass m_1 will result in an impact wave, the effect of which will depend to a great extent on the kind of structural element concerned. Consequently, it will not always be sufficient to design for the static force.

6.1.3 *Safety Railings* — With regard to safety railings put up to protect structures against collision due to road traffic, it should be shown that the railings are able to resist on impact as described in **6.1.2**.

NOTE — When a vehicle collides with safety railings, the kinetic energy of the vehicle will be absorbed in part by the deformation of the railings and, in part by the deformation of the vehicle. The part of the kinetic energy which the railings should be able to absorb without breaking down may be determined on the basis of the assumed rigidity of the vehicle during the compression.

6.1.4 *Crane Impact Load on Buffer Stop* — The basic horizontal load P_y (tonnes), acting along the crane track produced by impact of the crane on the buffer stop, is calculated by the following formula:

$$P_y = M\,V^2/F$$

where

V = speed at which the crane is travelling at the moment of impact (assumed equal to half the nominal value) (m/s);

F = maximum shortening of the buffer, assumed equal to 0·1 m for light duty, medium-duty and heavy-duty cranes with flexible load suspension and loading capacity not exceeding 50 t, and 0·2 m in every other cranes; and

M = the reduced crane mass (t.s²/m); and is obtained by the formula:

$$M = \frac{1}{g}\left[\frac{P_h}{2} + (P_t + kQ)\,\frac{L_k - l}{L_k}\right]$$

where

g = acceleration due to gravity (9·81 m/s^2);

P_h = crane bridge weight (t);

P_t = crab weight (t);

k = a coefficient, assumed equal to zero for cranes with flexible load suspension and equal to one for cranes with rigid suspension;

Q = crane loading capacity (t);

L_k = crane span (m); and

l = nearness of crab (m).

6.2 Explosions

6.2.1 *General* — Explosions may cause impulsive loading on a structure. The following types of explosions are particularly relevant:

a) Internal gas explosions which may be caused by leakage of gas piping (including piping outside the room), evaporation from volatile liquids or unintentional evaporation from surface material (for example, fire);

b) Internal dust explosions;

c) Boiler failure;

d) External gas cloud explosions; and

e) External explosions of high-explosives (TNT, dynamite).

The codal requirement regarding internal gas explosions is given in **6.2.2**.

6.2.2 *Explosion Effect in Closed Rooms* — Gas explosion may be caused, for example, by leaks in gas pipes (inclusive of pipes outside the room), evaporation from volatile liquids or unintentional evaporation of gas from wall sheathings (for example, caused by fire).

NOTE 1 — The effect of explosions depends on the exploding medium, the concentration of the explosion, the shape of the room, possibilities of ventilation of the explosion, and the ductility and dynamic properties of the structure. In rooms with little possibility for relief of the pressure from the explosion, very large pressures may occur.

Internal overpressure from an internal gas explosion in rooms of sizes comparable to residential rooms and with ventilation areas consisting of window glass breaking at a pressure of 4 kN/m^2 (3-4 mm machine made glass) may be calculated from the following method:

a) The overpressure is assumed to depend on a factor A/V, where A is the total window area in m^2, V is the volume in m^3 of the room considered.

b) The internal pressure is assumed to act simultaneously upon all walls and floors in one closed room.

c) The action q_0 may be taken as static action.

If account is taken of the time curve of action, the following (Fig. 4) schematic correspondence between pressure and time is assumed, where t_1 is the time from the start of combustion until maximum pressure is reached, and t_2 is the time from maximum pressure to the end of combustion. For t_1 and t_2, the most unfavourable values should be chosen in relation to the dynamic properties of the structures. However, the values should be chosen within the intervals as given in Fig. 5.

NOTE 2 — Figure 4 is based on tests with gas explosions in room corresponding to ordinary residential flats and should, therefore, not be applied to considerably different conditions. The figure corresponds to an explosion caused by town gas and it might therefore, be somewhat on the safe side in rooms where there is only the possibility of gases with a lower rate of combustion.

The pressure may be applied solely in one room or in more rooms at the same time. In the latter case, all rooms are incorporated in the volume V. Only windows or other similarly weak and light weight structural elements may be taken to be ventilation areas even through certain limited structural parts break at pressures less than q_0.

Figure 4 is given purely as guide and probability of occurrence of an explosion should be checked in each case using appropriate values.

6.3 Vertical Load on Air Raid Shelters

6.3.1 *Characteristic Values* — As regards buildings in which the individual floors are acted upon by a total characteristic imposed action of up to 5·0 kN/m², vertical actions on air raid shelters generally located below ground level, for example, basement, etc, should be considered to have the following characteristic values:

a) Buildings with up to 2 storeys	28 kN/m²
b) Buildings with 3 to 4 storeys	34 kN/m²
c) Buildings with more than 4 storeys	41 kN/m²
d) Buildings of particularly stable construction irrespective of the number of storeys	28 kN/m²

In the case of buildings with floors that are acted upon by a characteristic imposed action larger than 5·0 kN/m², the above values should be increased by the difference between the average imposed action on all storeys above the one concerned and 5·0 kN/m².

NOTE 1 — By storeys it is understood, every utilizable storey above the shelter.

NOTE 2 — By buildings of a particular stable construction it is understood, buildings in which the load-bearing structures are made from reinforced *in-situ* concrete.

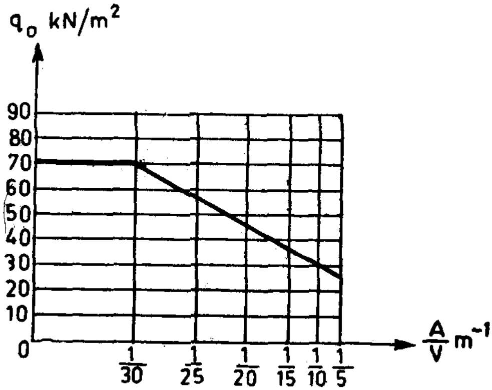

FIG. 4 SKETCH SHOWING RELATION BETWEEN PRESSURE AND TIME

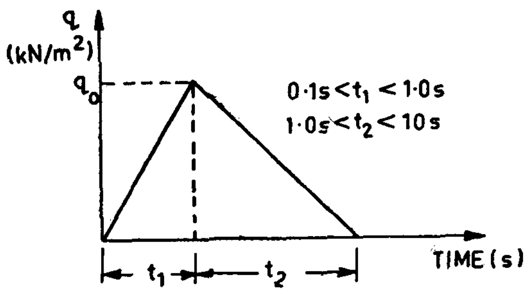

FIG. 5 SKETCH SHOWING TIME INTERVAL AND PRESSURE

6.4 Fire

6.4.1 *General* — Possible extraordinary loads during a fire may be considered as accidental actions. Examples are loads from people along escape routes and loads on another structure from structure failing because of a fire.

6.4.2 *Thermal Effect During Fire* — The thermal effect during fire may be determined from one of the following methods:

a) Time-temperature curve and the required fire resistance (minutes), or

b) Energy balance method.

If the thermal effect during fire is determined from energy balance method, the fire load is taken to be:

$$q = 12\, t_b$$

where

q = fire action (KJ per m² floor), and

t_b = required fire resistance (minutes) (*see* IS : 1642-1960*).

NOTE — The fire action is defined as the total quantity of heat produced by complete combustion of all combustible material in the fire compartment, inclusive of stored goods and equipment together with building structures and building materials.

7. OTHER LOADS

7.1 Other loads not included in the present code such as special loads due to technical process, moisture and shrinkage effects, etc, should be taken into account where stipulated by building design codes or established in accordance with the performance requirement of the structure.

8. LOAD COMBINATIONS

8.0 General — A judicious combination of the loads (specified in Parts 1 to 4 of this standard and earthquake), keeping in view the probability of:

a) their acting together, and

b) their disposition in relation to other loads and severity of stresses or deformations caused by combinations of the various loads is necessary to ensure the required safety and economy in the design of a structure.

8.1 Load Combinations — Keeping the aspect specified in **8.0**, the various loads should, therefore, be combined in accordance with the stipulations in the relevant design codes. In the absence of such recommendations, the following loading combinations, whichever combination produces the most unfavourable effect in the building, foundation or structural member concerned may be adopted (as a general guidance). It should also be recognized in load combinations that the simultaneous occurrence of maximum values of wind, earthquake, imposed and snow loads is not likely.

a) DL

b) $DL+IL$

c) $DL+WL$

d) $DL+EL$

e) $DL+TL$

f) $DL+IL+WL$

g) $DL+IL+EL$

*Code of practice for safety of buildings (general) : Materials and details of construction.

h) $DL + IL + TL$

j) $DL + WL + TL$

k) $DL + EL + TL$

m) $DL + IL + WL + TL$

n) $DL + IL + EL + TL$

(DL = dead load, IL = imposed load, WL = wind load, EL = earthquake load, TL = temperature load).

NOTE 1 — When snow load is present on roofs, replace imposed load by snow load for the purpose of above load combinations.

NOTE 2 — The relevant design codes shall be followed for permissible stresses when the structure is designed by working stress method and for partial safety factors when the structure is designed by limit state design method for each of the above load combinations.

NOTE 3 — Whenever imposed load (IL) is combined with earthquake load (EL), the appropriate part of imposed load as specified in IS : 1893-1984* should be used both for evaluating earthquake effect and for combined load effects used in such combination.

NOTE 4 — For the purpose of stability of the structure as a whole against overturning, the restoring moment shall be not less than 1·2 times the maximum overturning moment due to dead load plus 1·4 times the maximum overturning moment due to imposed loads. In cases where dead load provides the restoring moment, only 0·9 times the dead load shall be considered. The restoring moments due to imposed loads shall be ignored.

NOTE 5 — The structure shall have a factor against sliding of not less than 1·4 under the most adverse combination of the applied loads/forces. In this case, only 0·9 times the dead load shall be taken into account.

NOTE 6 — Where the bearing pressure on soil due to wind alone is less than 25 percent of that due to dead load and imposed load, it may be neglected in design. Where this exceeds 25 percent foundation may be so proportioned that the pressure due to combined effect of dead load, imposed load and wind load does not exceed the allowable bearing pressure by more than 25 percent. When earthquake effect is included, the permissible increase is allowable bearing pressure in the soil shall be in accordance with IS : 1893-1984*.

Reduced imposed load (IL) specified in Part 2 of this standard for the design of supporting structures should not be applied in combination with earthquake forces.

NOTE 7 — Other loads and accidental load combinations not included should be dealt with appropriately.

NOTE 8 — Crane load combinations are covered under Part 2 of this standard (*see* **6.4** of Part 2 of this standard).

*Criteria for earthquake resistant design of structures (*fourth revision*).

(Continued from page 2)

Panel on Loads (Other than Wind Loads), BDC 37 : P3

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Plot No. 20/9, Site IV, Sahibabad Industrial Area, Sahibabad 201010	8-77 00 32
Regional Offices:	
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002	323 76 17
*Eastern : 1/14 CIT Scheme VII M, V.I.P. Road, Maniktola, CALCUTTA 700054	337 86 62
Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160022	60 38 43
Southern : C.I.T. Campus, IV Cross Road, CHENNAI 600113	235 23 15
†Western : Manakalaya, E9, Behind Marol Telephone Exchange, Andheri (East), MUMBAI 400093	832 92 95
Branch Offices:	
'Pushpak', Nurmohamed Shaikh Marg, Khanpur, AHMEDABAD 380001	550 13 48
‡Peenya Industrial Area, 1st Stage, Bangalore-Tumkur Road, BANGALORE 560058	839 49 55
Gangotri Complex, 5th Floor, Bhadbhada Road, T.T. Nagar, BHOPAL 462003	55 40 21
Plot No. 62-63, Unit VI, Ganga Nagar, BHUBANESHWAR 751001	40 36 27
Kalaikathir Buildings, 670 Avinashi Road, COIMBATORE 641037	21 01 41
Plot No. 43, Sector 16 A, Mathura Road, FARIDABAD 121001	8-28 88 01
Savitri Complex, 116 G.T. Road, GHAZIABAD 201001	8-71 19 96
53/5 Ward No. 29, R.G. Barua Road, 5th By-lane, GUWAHATI 781003	54 11 37
5-8-56C, L.N. Gupta Marg, Nampally Station Road, HYDERABAD 500001	20 10 83
E-52, Chitaranjan Marg, C-Scheme, JAIPUR 302001	37 29 25
117/418 B, Sarvodaya Nagar, KANPUR 208005	21 68 76
Seth Bhawan, 2nd Floor, Behind Leela Cinema, Naval Kishore Road, LUCKNOW 226001	23 89 23
NIT Building, Second Floor, Gokulpat Market, NAGPUR 440010	52 51 71
Patliputra Industrial Estate, PATNA 800013	26 23 05
Institution of Engineers (India) Building 1332 Shivaji Nagar, PUNE 411005	32 36 35
T.C. No. 14/1421, University P.O. Palayam, THIRUVANANTHAPURAM 695034	6 21 17

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