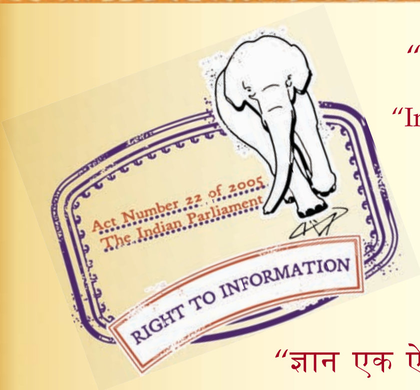
IS 15916 (2011): Building Design and Erection Using Prefabricated Concrete - Code of Practice [CED 51: Planning, Housing and pre-fabricated construction]



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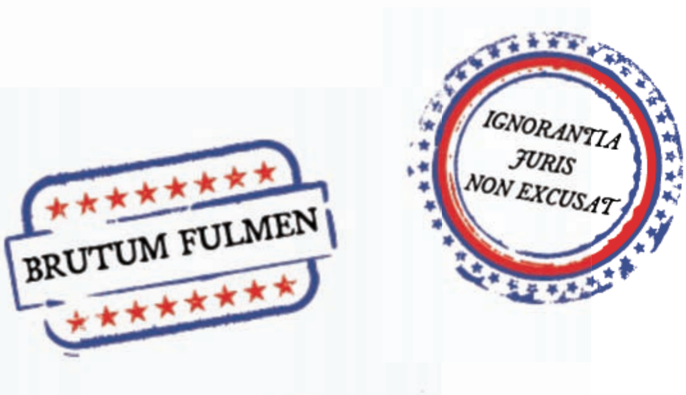

*भारतीय मानक*

# पूर्व संविरचित कंक्रीट प्रयुक्त भवन का डिजाइन और स्थापन — रीति संहिता

***Indian Standard***

# BUILDING DESIGN AND ERECTION USING PREFABRICATED CONCRETE — CODE OF PRACTICE

ICS 91.040.01



**BUREAU OF INDIAN STANDARDS**
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*May 2011* **Price Group 9**

Planning, Housing and Prefabricated Construction Sectional Committee, CED 51

## FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Planning, Housing and Prefabricated Construction Sectional Committee had been adopted by the Civil Engineering Division Council.

Prefabrication, though desirable for large scale building activities, has yet to take a firm hold in the country. Advantages of recent trends in prefabrication have been taken note of and also the hazards attended to such construction. A few recommendations on the need to avoid 'progressive collapse' of the structure have been included. This has become necessary in view of such collapses in the past. A specific point to be borne in mind, therefore, is the need to make the structure reasonably safe against such a collapse.

Prefabricated constructions being comparatively a new technique, some of the essential requirements for the manufacture of the prefabricated components and elements are also included in this standard.

Since the aim of prefabrication is to effect economy, improvement in quality and speed in construction, the selection of proper materials for prefabrication is also an important factor in the popularization of this technique. The use of locally available materials with required characteristics and those materials which, due to their innate characteristics, like light-weight, easy workability, thermal insulation and non-combustibility, effect economy and improved quality, may be tried.

It is possible to achieve or evolve aesthetically satisfying designs using prefabricated construction. A careful and judicious handling of materials and use of finishes on a prefabricated building can help the designer a great deal in ensuring that the appearance of the building is aesthetically appealing. The purpose of finishes and architectural treatment is not only to give prefabricated buildings an individual character but also to effect better performance and greater user satisfaction.

Systems building approach in construction is an upcoming field as far as its development and use in the country is concerned. Two aspects specifically to be borne in mind are the system to be adopted for the different categories of buildings and the sizes of their components. Here the principle of modular co-ordination is of value and its use is recommended.

This standard has been brought out to provide necessary guidance for design and erection of such systems. In this standard, an attempt has been made to prescribe general requirements applicable to all valid existing systems using prefabricated concrete as also to accommodate any new such system introduced in the country in future. The design of prefabricated buildings should include provision for all installations of services and their required piping, wiring and accessories to be installed in the building.

While this standard covers systems building using predominantly prefabricated concrete as material for components, for such systems approach using mixed/composite construction, a separate Indian Standard IS 15917 : 2010 'Building design and erection using mixed/composite construction — Code of practice'.

The composition of the Committee responsible for the formulation of this standard is given in Annex B.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Indian Standard*

# BUILDING DESIGN AND ERECTION USING PREFABRICATED CONCRETE — CODE OF PRACTICE

## 1 SCOPE

This standard covers provisions regarding modular planning, component sizes, prefabrication systems, design considerations, joints and manufacture, storage, transport and erection of prefabricated concrete elements for buildings and such related requirements.

## 2 REFERENCES

The standards and special publication listed in Annex A contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated in Annex A.

## 3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

**3.1 Authority Having Jurisdiction** — The authority which has been created by a statute and which, for the purpose of administering the Code, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

**3.2 Basic Module** — The fundamental module used in modular co-ordination, the size of which is selected for general application to building and its components.

NOTE — The value of the basic module has been chosen as 100 mm for the maximum flexibility and convenience. The symbol for the basic module is *M*.

**3.3 Cellular Concrete** — The material consisting of an inorganic binder (such as lime or cement or both) in combination with a finely ground material containing siliceous material (such as sand), gas generating material (for example, aluminium powder), water and harmless additives (optional); and steam cured under high pressure in autoclaves.

**3.4 Component** — A building product formed as a distinct unit having specified sizes in three dimensions.

**3.5 Composite Members** — Structural members comprising prefabricated structural units of steel, prestressed concrete or reinforced concrete and cast *in-situ* concrete connected together in such a manner that they act monolithically.

**3.6 Increments** — Difference between two homologous dimensions of components of successive sizes.

**3.7 Light-Weight Concrete** — Concrete of substantially lower unit weight than that made from gravel or crushed stone.

**3.8 Module** — A unit of size used in dimensional co-ordination.

**3.9 Modular Co-ordination** — Dimensional co-ordination employing the basic module or a multi-module.

NOTE — The purpose of modular co-ordination are,

a) to reduce the variety of component sizes produced; and
b) to allow the building designer greater flexibility in the arrangement of components.

**3.10 Modular Grid** — A rectangular coordinate reference system in which the distance between consecutive lines is the basic module or a multimodule. This multi-module may differ for each of the two dimensions of the grid.

**3.11 Multi-module** — A module whose size is a selected multiple of the basic module.

**3.12 Prefabricate** — Fabrication of components or assembled units prior to erection or installation in a building.

**3.13 Prefabricated Building** — The partly/fully assembled and erected building, of which the structural parts consist of prefabricated individual units or assemblies using ordinary or controlled materials, including service facilities; and in which the service equipment may be either prefabricated or constructed *in-situ*.

**3.14 Sandwich Reinforced Concrete Panels** — Panels made by sandwiching an insulation material between two layers of reinforced concrete to act as insulation for concrete panels.

**3.15 Self Compacting Concrete** — Concrete that is able to flow under its own weight and completely fill the voids within the formwork, even in the presence of dense reinforcement without any vibration, whilst maintaining homogeneity without segregation.

**3.16 Shear Connectors** — Structural elements, such as anchors, studs, channels and spirals, intended to transmit the horizontal shear between the prefabricated member and the cast *in-situ* concrete and also to prevent vertical separation at the interface.

**3.17 System** — It is a particular method of construction of buildings with certain order and discipline using the prefabricated components, tunnel form or large panel shutters which are inter-related in functions and are produced based on a set of instructions.

**3.18 Unit** — Building material formed as a simple article with all three dimensions specified, complete in itself but intended to be part of a compound unit or complete building. Examples are brick, block, tile, etc.

## 4 MATERIALS, PLANS AND SPECIFICATIONS

### 4.1 Materials

Use of materials for plain and reinforced concrete shall satisfy the requirements of IS 456. Connections and jointing materials shall be in accordance with **9.3**.

**4.1.1** While selecting the materials for prefabrication, the following characteristics shall be considered:

a) Easy availability;
b) Light-weight for easy handling and transport;
c) Thermal insulation property;
d) Easy workability;
e) Durability;
f) Non-combustibility;
g) Sound insulation;
h) Easy assembly and compatibility to form a complete unit;
j) Economy; and
k) Any other special requirement in a particular application.

### 4.2 Plans and Specifications

The detailed plans and specifications shall cover the following:

a) Such drawings shall describe the elements and the structure and assembly including all required data of physical properties of component materials. Material specification, age of concrete for demoulding, casting/ erection tolerance and type of curing to be followed.
b) Details of connecting joints of prefabricates shall be given to an enlarged scale.
c) Site or shop location of services, such as installation of piping, wiring or other accessories integral with the total scheme shall be shown separately.
d) Data sheet indicating the location of the inserts and acceptable tolerances for supporting the prefabricate during erection, location and position of doors/windows/ventilators, etc, if any.
e) The drawings shall also clearly indicate location of handling arrangements for lifting and handling the prefabricated elements. Sequence of erection with critical check points and measures to avoid stability failure during construction stage of the building.

## 5 MODULAR CO-ORDINATION, ARCHITECTURAL TREATMENT AND FINISHES

### 5.1 Modular Co-ordination

The basic module shall be adopted. After adopting this, further work is necessary to outline suitable range of multimodules with greater increments, often referred to as preferred increments. A set of rules as detailed below would be adequate for meeting the requirements of conventional and prefabricated construction.

These rules relate to the following basic elements:

a) The planning grid in both directions of the horizontal plan shall be:
   1) 15 *M* for industrial buildings, and
   2) 3 *M* for other buildings.

   The centre lines of load bearing walls should preferably coincide with the gridlines.
b) The planning module in the vertical direction shall be 2 *M for* industrial buildings and 1 *M* for other buildings.
c) Preferred increments for sill heights, doors, windows and other fenestration shall be 1 *M*.
d) In the case of internal columns, the grid lines shall coincide with the centre lines of columns. In case of external columns and columns near the lift and stair wells, the grid lines shall coincide with centre lines of the column in the topmost storey.

### 5.2 Architectural Treatment and Finishes

Treatment and finishes have to be specified keeping in view the requirements of protection, function and aesthetics of internal and external spaces and surfaces.

While deciding the type of architectural treatment and finishes for prefabricated buildings, the following points should be kept in view:

a) Suitability for mass production techniques;
b) Recognition of the constraints imposed by the level of workmanship available;
c) Possibility of using different types of finishes;

d) Use of finishes and architectural treatment for the creation of a particular architectural character in individual buildings and in groups of buildings by the use of colour, texture, projections and recesses on surfaces, etc;
e) Incorporation of structural elements like joists, columns, beams, etc, as architectural features and the treatment of these for better overall performance and appearance;
f) Satisfactory finishing of surfaces; and
g) Use of light weight materials to effect economy in the structural system.

Some of the acceptable methods of finishes integral with the precasting are,

a) concrete surface moulded to design/shape;
b) laid-on finishing tiles fixed during casting;
c) finishes obtained by washing, tooling; grinding, grooving of hardened concrete;
d) exposed aggregates; and
e) other integral finishes.

## 6 COMPONENTS

**6.1** The dimensions of precast elements shall meet the design requirements. However, the actual dimensions shall be the preferred dimensions as follows:

a) *Flooring and Roofing Scheme* — Precast slabs or other precast structural flooring units:
   1) *Length* — Nominal length shall be in multiples of 1 *M*.
   2) *Width* — Nominal width shall be in multiples of 0.5 *M*.
   3) *Overall thickness* — Overall thickness shall be in multiples of 0.1 *M*.

b) *Beams*
   1) *Length* — Nominal length shall be in multiples of 1 *M*.
   2) *Width* — Nominal width shall be in multiples of 0.1 *M*.
   3) *Overall depth* — Overall depth of the floor zone shall be in multiples of 0.1 M.

c) *Columns*
   1) *Height* — Height of columns for industrial shall be 1 *M* and other building 1 *M*.
   2) *Lateral dimensions* — Overall lateral dimension or diameter of columns shall be in multiples of 0.1 *M*.

d) *Walls*

   *Thickness* — The nominal thickness of walls shall be in multiples of 0.1 *M*.

e) *Staircase*

   *Width* — Nominal width shall be in multiples of 1 *M*.

f) *Lintels*
   1) *Length* — Nominal length shall be in multiples of 1 *M*.
   2) *Width* — Nominal width shall be in multiples of 0.1 *M*.
   3) *Depth* — Nominal depth shall be in multiples of 0.1 *M*.

g) *Sunshades/Chajja Projections*
   1) *Length* — Nominal length shall be in multiples of 1 *M*.
   2) *Projection* — Nominal length shall be in multiples of 0.5 *M*.

**6.2 Casting Tolerances of Precast Components**

| *Sl No.* (1) | *Product Tolerances* (2) | *Product (see Key No.)* (3) |
|---|---|---|
| i) | *Length:* | |
| | a) ± 5 mm | 1, 7 |
| | b) ± 5 mm or ±0.1 percent whichever is greater | 2, 3, 8 |
| | c) ±0.1 percent subject to maximum of $^{+5}_{-10}$ mm | 4 |
| | d) ±2 mm for length below and up to 500 mm<br>±5 mm for length over 500 mm | 5 |
| | e) ±10 mm | 6, 9,10 |
| ii) | *Thickness/cross-sectional dimensions:* | |
| | a) ±3 mm | 1 |
| | b) ±3 mm or 0.1 percent, whichever is greater | 2, 8 |

| *Sl No.* (1) | *Product Tolerances* (2) | *Product* (*see Key No.*) (3) |
|---|---|---|
| | c) ±2 mm up to 300 mm wide<br>±3 mm for greater than 300 mm wide | 4, 5 |
| | d) ±2 mm | 3, 7 |
| | e) ±4 mm | 6, 9, 10 |
| iii) | *Straightness/bow:* | |
| | a) ±5 mm or 1/750 of length, whichever is greater | 2, 4, 8 |
| | b) ±3 mm | 1, 5 |
| | c) ±2 mm | 7 |
| iv) | *Squareness:* | |
| | When considering the squareness of the corner, the longer of two adjacent sides being checked shall be taken as the base line | |
| | a) The shorter side shall not vary in length from the perpendicular by more than 5 mm | 2, 5, 8 |
| | b) The shorter side shall not vary in length from the perpendicular by more than 3 mm | 1, 7 |
| | c) The shorter side shall not be out of square line for more than $^{+2}_{-5}$ mm | 4 |
| v) | *Twist:* | |
| | Any corner shall not be more than the tolerance given below from the plane containing the other three corners: | |
| | a) Up to 600 mm in width and up to 6 m in length 5 mm<br>Over 600 mm in width and for any length 10 mm length | 2, 8 |
| | b) ± 1/1 500 of dimension or ± 5 mm, whichever is less | 4 |
| | c) ± 3 mm | 1 |
| | d) ± 1 mm | 7 |
| vi) | *Flatness*: | |
| | The maximum deviation from 1.5 m straight edge placed in any position on a nominal plane surface shall not exceed: | |
| | a) ± 5 mm | 2, 8 |
| | b) ± 3 mm | 4 |
| | c) ± 2 mm | 1, 7 |
| | d) ± 4 mm or maximum of 0.1 percent length | 5 |

**Key No. for product reference:**

1 Channel unit
2 Ribbed slab unit/hollow slab
3 Waffle unit
4 Large panel prefabrication
5 Cellular concrete floor/roof slabs
6 Prefabricated brick panel
7 Precast planks
8 Ribbed/plain wall panel
9 Column
10 Step unit

## 7 PREFABRICATION SYSTEMS AND STRUCTURAL SCHEMES

**7.1** The word ‘system’ refers to a particular method of construction of buildings using the prefabricated components which are inter-related in functions and are produced to a set of instructions. With certain constraints, several plans are possible, using the same set of components. The degree of flexibility varies from system to system. However, in all the systems there is a certain order and discipline.

**7.2** The following aspects, among others, are to be considered in devising a system:

a) Effective utilization of spaces;
b) Straight and simple walling scheme;
c) Limited sizes and numbers of components;
d) Limited opening in bearing walls;
e) Regulated locations of partitions;
f) Standardized service and stair units;
g) Limited sizes of doors and windows with regulated positions;
h) Structural clarity and efficiency;
j) Suitability for adoption in low rise and high rise building;
k) Ease of manufacturing, storing and transporting;
m) Speed and ease of erection; and
n) Simple jointing system.

**7.3 Prefabrication Systems**

The system of prefabricated construction depends on the extent of the use of prefabricated components, their materials, sizes and the technique adopted for their manufacture and use in building.

**7.3.1** *Types of Prefabrication Components*

The prefabricated concrete components such as those given below may be used which shall be in accordance with relevant Indian Standards, where available:

a) Reinforced/prestressed concrete channel unit,
b) Reinforced/prestressed concrete slab unit,
c) Reinforced/prestressed concrete beams,
d) Reinforced/prestressed concrete columns,
e) Reinforced/prestressed concrete hollow core slab,
f) Reinforced concrete waffle slab/shells,
g) Reinforced/prestressed concrete wall elements,
h) Hollow/solid concrete blocks and battens,
j) Precast planks and joists for flooring and roofing,
k) Precast joists and trussed girders,
m) Light-weight/cellular concrete slabs/wall panels,
n) Precast lintel and *CHAJJAS*,
p) Large panel prefabricates,
q) Reinforced/prestressed concrete trusses,
r) Reinforced/prestressed roof purlins,
s) Precast concrete L-panel unit,
t) Precast concrete double-T unit,
u) Prefabricated brick panel unit,
v) Prefabricated sandwich concrete panels,
w) Precast concrete foundation, and
y) Precast concrete staircase.

There may be other types of components which may be used with the approval of the Authority.

NOTE — The elements may be cast at the site or off the site.

**7.3.2** *Open Prefabrication system*

There are two categories of open prefab system depending on the extent of prefabrication used in the construction as given in **7.3.2.1** and **7.3.2.2**.

**7.3.2.1** *Partial prefabrication system*

This system basically uses precast roofing and flooring components and other minor elements like lintels, *CHAJJAS*, kitchen sills in conventional building construction. The structural system could be in the form of *in-situ* framework or load bearing walls.

**7.3.2.2** *Full prefabrication system*

In this system almost all the structural components are prefabricated. The filler walls may be of brick/block masonry or of any other locally available material.

**7.3.3** *Large Panel Prefabrication System*

This system is based on the use of large prefab components. The components used are precast concrete large panels for walls, floors, roofs, balconies, staircases, etc. The casting of the components could be at the site or off the site.

Depending upon the extent of prefabrication, this system can also lend itself to partial prefab system and full prefab system.

Structural scheme with precast large panel walls can be classified as given in **7.3.3.1** to **7.3.3.3**.

**7.3.3.1** *Precast walls*

**7.3.3.1.1** Based on the structural functions of the walls, the precast walls may be classified as:

a) Load bearing walls;
b) Non-load bearing walls; and
c) Shear walls.

**7.3.3.1.2** Based on construction, the precast walls may be classified as:

a) *Homogeneous walls* — which could be solid, hollow or ribbed; and
b) *Non-homogeneous walls* — these could be composite or sandwich panels.

**7.3.3.1.3** Based on their locations and functional requirements the precast walls may also be classified as:

a) External walls, which may be load bearing or non-load bearing depending upon the lay-out; these are usually non-homogeneous walls of sandwiched type to impart better thermal comforts; and

b) Internal walls providing resistance against vertical loads, horizontal loads, fire, etc; these are normally homogeneous walls.

**7.3.3.2** *Precast floors*

**7.3.3.2.1** Depending upon the composition of units, precast flooring units may be classified as:

a) *Homogeneous floors* — Which may be of solid slabs, cored slabs, ribbed or waffle slabs; and
b) *Non-homogeneous floors* — Which may be of multi-layered units with combinations of light-weight concrete or reinforced/ prestressed concrete, with filler blocks.

**7.3.3.2.2** Depending upon the way the loads are transferred, the precast floors may be classified as one way, two way or cantilever systems:

a) One way system transfers loads to supporting members in one direction only. The precast elements which come under this category are channel slabs, hollow core slabs, channels and ties system, light-weight/cellular concrete slabs, etc.
b) Two way systems transfer loads in both the directions imparting loads on the four edges. The precast elements under this category are room sized panels, two way ribbed or waffle slab systems, etc.
c) Cantilever components are supported on one edge or two adjacent edges and other ends without supports.

**7.3.3.3** *Staircase systems*

Staircase system may consist of single flights with in-built risers and treads in the element. The flights are normally unidirectional transferring the loads to supporting landing slabs or load bearing walls.

**7.3.4** *Box Type Construction*

In this system, room size units are prefabricated and erected at site. Toilet and kitchen blocks may also be similarly prefabricated and erected at site.

NOTE — This system derives its stability and stiffness from the box units which are formed by four adjacent walls. Walls are jointed to make rigid connections among themselves. The box unit rests on foundation which may be of conventional type or precast type.

## 8 DESIGN CONSIDERATIONS AND REQUIREMENTS

### 8.1 Design Considerations

The precast structure should be analyzed as a monolithic one and the joints in them designed to take the forces of an equivalent discrete system. Resistance to horizontal loading shall be provided by having appropriate moment and shear resisting joints or placing shear walls (in diaphragm braced frame type of construction) in two directions at right angles or otherwise. No account is to be taken of rotational stiffness, if any, of the floor-wall joint in case of precast bearing wall buildings. The individual components shall be designed, taking into consideration the appropriate end conditions and loads at various stages of construction. The components of the structure shall be designed for loads in accordance with IS 875 (Parts 1 to 5) and IS 1893 (Part 1). In addition, members shall be designed for handling, erection and impact loads that might be expected during handling and erection.

**8.1.1** In some conventional forms of construction, experience has shown that the structures are capable of safely sustaining abnormal conditions of loading and remaining stable after the removal of primary structural members. It has been shown that some forms of building structure and particularly some industrialized large panel systems have little reserve strength to resist forces not specifically catered for in the design. In the light of this, therefore, recommendations made in **8.1.2** to **8.1.9** should be kept in mind for ensuring stability of such structure.

**8.1.2** Adequate buttressing of external wall panels is important since these elements are not fully restrained on both sides by floor panels. Adequate design precautions may be taken by the designer. Experience shows that the external wall panel connections are the weakest points of a precast panel building.

**8.1.3** It is equally important to provide restraint to all load bearing elements at the corners of the building. These elements and the external ends of cross-wall units should be stiffened either by introducing columns as connecting units or by jointing them to non-structural wall units which in emergency may support the load. Jointing of these units should be done bearing in mind the need for load support in an emergency.

**8.1.4** In prefabricated construction, the possibility of gas or other explosions which can remove primary structural elements leading to progressive collapse of the structure shall be taken into account. It is, therefore, necessary to consider the possibility of progressive collapse in which the failure or displacement of one element of a structure causes the failure or displacement of another element and results in the partial or total collapse of the building.

**8.1.5** Provision in the design to reduce the probability of progressive collapse is essential in buildings of over six storeys and is of relatively higher priority than for buildings of lower height.

**8.1.6** It is necessary to ensure that any local damage to a structure does not spread to other parts of the structure remote from the point of mishap and that the overall stability is not impaired, but it may not be necessary to stiffen all parts of the structure against local damage or collapse in the immediate vicinity of a mishap, unless the design briefs specifically requires this to be done.

**8.1.7** Additional protection may be required in respect of damage from vehicles; further, it is necessary to consider the effect of damage to or displacement of a load-bearing member by an uncontrolled vehicle. It is strongly recommended that important structural members are adequately protected by concrete kerbs or similar method.

**8.1.8** In all aspects of erection that affect structural design, it is essential that the designer should maintain a close liaison with the builder/contractor regarding the erection procedures to be followed.

**8.1.9** Failures that have occurred during construction appear to be of two types. The first of these is the pack-of-cards type of collapse in which the absence of restraining elements, such as partitions, cladding or shear walls, means that the structure is not stable during the construction period. The second is the situation in which one element falls during erection and lands on an element below. The connections of the lower element then give way under the loading, both static and dynamic, and a chain reaction of further collapse is set up.

**8.1.9.1** A precaution against the first form of failure is that the overall stability of a building shall be considered in all its erection stages as well as in its completed state. All joints that may be required to resist moments and shears during the erection stage only, shall be designed with these in mind. Temporary works required to provide stability during construction shall be designed carefully.

**8.1.9.2** To guard against the second form of failure, that is, the dropping of a unit during erection, particular attention shall be given to the details of all pre-formed units and their seatings to ensure that they are sufficiently robust to withstand the maximum stresses that can arise from site conditions. Precast concrete construction generally shall be capable of withstanding the impact forces that can arise from bad workmanship on site.

**8.2 Design Requirements for Safety Against Progressive Collapse**

**8.2.1** Prefabricated buildings shall be designed with proper structural integrity to avoid situations where damage to small areas of a structure or failure of single elements may lead to collapse of major parts of the structure.

The following precaution may generally provide adequate structural integrity:

a) All buildings should be capable of safely resisting the minimum horizontal load of 1.5 percent of characteristic dead load applied at each floor or roof level simultaneously (*see* Fig. 1).
b) All buildings shall be provided with effective horizontal ties,
    1) around the periphery;
    2) internally (in both directions); and
    3) to columns and walls.
c) All buildings of five or more storeys shall be provided with vertical ties.

In proportioning the ties, it may be assumed that no other forces are acting and the reinforcement is acting at its characteristic strength.

Normal procedure may be to design the structure for the usual loads and then carry out a check for the tie forces.

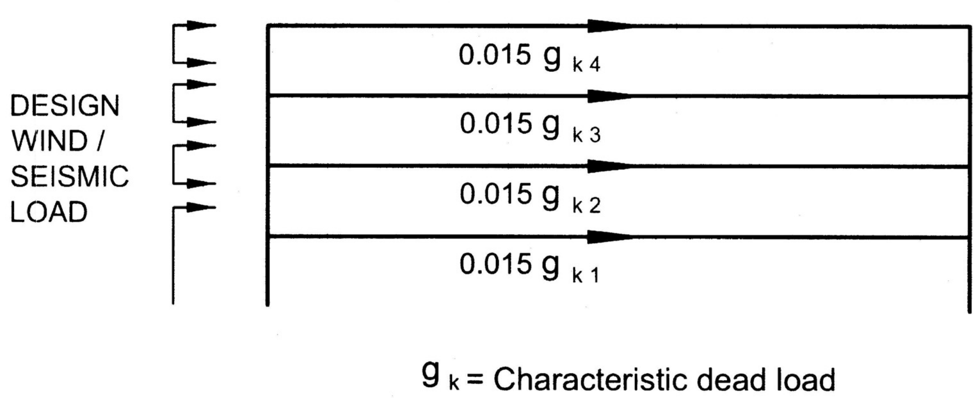



FIG. 1 HORIZONTAL LOADS

**8.2.2** *Continuity and Anchorage of Ties*

Bars shall be lapped, welded or mechanically joined in accordance with IS 456.

**8.2.3** *Design of Ties*

**8.2.3.1** *Peripheral ties*

At each floor and roof level an effectively continuous tie should be provided within 1.2 m of the edge of the building or within the perimeter wall (*see* Fig. 2).

The tie should be capable to resisting a tensile force of $F_t$ equal to 60 kN or (20 + 4$N$) kN whichever is less, where $N$ is the number of storeys (including basement).

**8.2.3.2** *Internal ties*

These are to be provided at each floor and roof level in two directions approximately at right angles. Ties should be effectively continuous throughout their length and be anchored to the peripheral tie at both ends, unless continuing as horizontal ties to columns or walls (*see* Fig. 3). The tensile strength, in kN per metre width shall be the greater of

$$\frac{(g_k + q_k)}{7.5} \cdot \frac{l_r F_t}{5} \text{ and } 1.5\, F_t$$

where $(g_k + q_k)$ is the sum of average characteristic dead and imposed floor loads in kN/m$^2$ and $l_r$ is the greater of the distance between the centre of columns, frames or walls supporting any two adjacent floor spans in the direction of the tie under consideration.

The bars providing these ties may be distributed evenly in the slabs (*see* Fig. 4) or may be grouped at or in the beams, walls or other appropriate positions but at spacings generally not greater than 1.5 $l_r$.

**8.2.3.3** *Horizontal ties to column and wall*

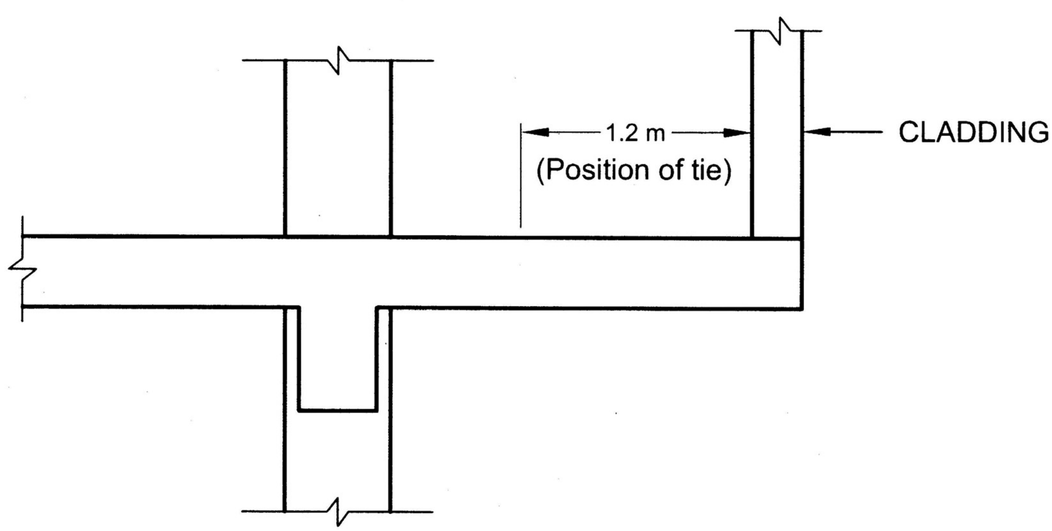
All external load-bearing members such as columns and walls should be anchored or tied horizontally into the structure at each floor and roof level. The design force for the tie is to be greater of,

a) 2 $F_t$ kN or $l_s \times F_t \times 2.5$ kN, whichever is less for a column or for each metre length if there is a wall. $l_s$ is the floor to ceiling height, in metre.
b) 3 percent of the total ultimate vertical load in the column or wall at that level.

For corner columns, this tie force should be provided in each of two directions approximately at right angles.

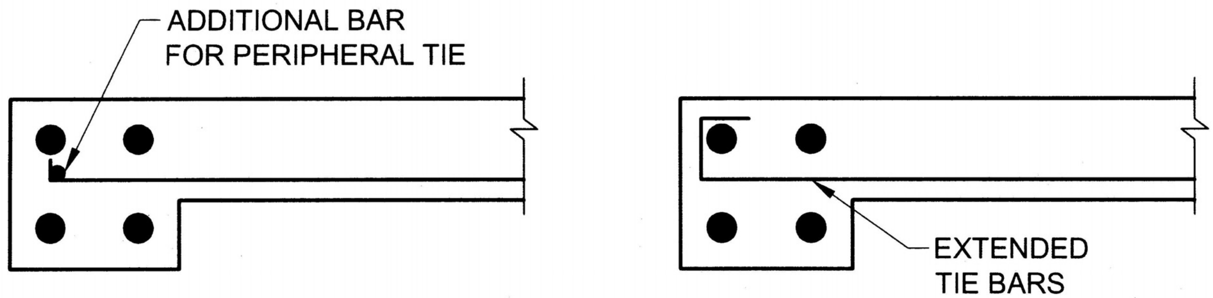
**8.2.3.4** *Vertical ties (for buildings of five or more storeys)*

Each column and each wall carrying vertical load should be tied continuously from the foundation to the roof level. The reinforcement provided is required only to resist a tensile force equal to the maximum design ultimate load (dead and imposed) received from any one storey.



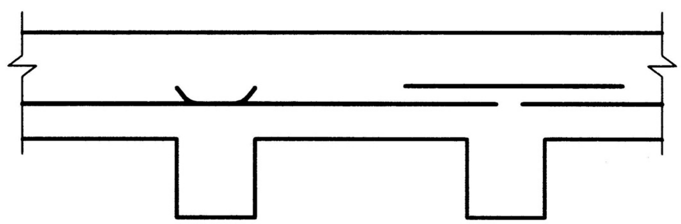

NOTE — If there are cantilever slabs, supporting external cladding, projecting in front of the columns and these are more than 1.2 m, then the peripheral tie shall go in the slab.

FIG. 2 POSITION FOR PERIPHERAL TIE




NOTE — If the peripheral tie consists of bars in an edge beam, then the bottom bars in the slabs will not be at the same level as the peripheral tie bars. It is suggested that either an additional bar be used for the peripheral tie or the internal tie bars be extended and anchored around the top bar in the beam.

FIG. 3 ANCHORING OF TIES IN SLABS



NOTE — For continuity in continuous slabs, bars are distributed evenly in a floor slab by means of lapping some bottom steel at supports, either by extending existing bars or by the addition of splice bars.

FIG. 4 CONTINUITY REQUIREMENT FOR SLAB

In situation where provision of vertical ties cannot be done, the element should be considered to be removed and the surrounding members designed to bridge the gap.

**8.2.4** *Key Elements*

For buildings of five or more storeys, the layout should be checked to identify key elements. A key element is such that its failure would cause the collapse of more than a limited area close to it.

The limited area defined above may be taken equal to 70 $m^2$ or 15 percent of the area of the storey, whichever is lesser.

If key elements exist, it is preferable to modify the layout so that the key element is avoided.

**8.3 Bearing for Precast Units**

Precast units shall have a bearing at least of 100 mm on masonry supports and of 75 mm at least on steel or concrete. Steel angle shelf bearings shall have a 100 mm horizontal leg to allow for a 50 mm bearing exclusive of fixing clearance. When deciding to what extent, if any, the bearing width may be reduced in special circumstances, factors, such as loading, span, height of wall and provision of continuity, shall be taken into consideration.

## 9 JOINTS

**9.1** The design of joints shall be made in the light of their assessment with respect to the following considerations:

a) *Feasibility* — The feasibility of a joint shall be determined by its load carrying capacity in the particular situation in which the joint is to function.
b) *Practicability* — Practicability of joint shall be determined by the amount and type of material required in construction; cost of material, fabrication and erection and the time for fabrication and erection.
c) *Serviceability* — Serviceability shall be determined by the joints/expected behaviour to repeated or possible overloading and exposure to climatic or chemical conditions.

d) *Fire rating* — The fire rating for joints of precast components shall be higher or at least equal to connecting members.

e) *Appearance* — The appearance of precast components joint shall merge with architectural aesthetic appearance and shall not be physically prominent compared to other parts of structural components.

**9.2** The following are the requirements of a structural joint:

a) It shall be capable of being designed to transfer the imposed load and moments with a known margin of safety;

b) It shall occur at logical locations in the structure and at points which may be most readily analyzed and easily reinforced;

c) It shall accept the loads without marked displacement or rotation and avoid high local stresses;

d) It shall accommodate tolerances in elements;

e) It shall require little temporary support, permit adjustment and demand only a few distinct operation to make;

f) It shall permit effective inspection and rectification;

g) It shall be reliable in service with other parts of the building; and

h) It shall enable the structure to absorb sufficient energy during earthquakes so as to avoid sudden failure of the structure.

**9.2.1** Precast structures may have continuous or hinged connections subject to providing sufficient rigidity to withstand horizontal loading. When only compressive forces are to be taken, hinged joints may be adopted. In case of prefabricated concrete elements, load is transmitted *via* the concrete. When both compressive force and bending moment are to be taken, rigid or welded joints may be adopted; the shearing force is usually small in the column and can be taken up by the friction resistance of the joint. Here load transmission is accomplished by steel inserted parts together with concrete.

**9.2.2** When considering thermal shrinkage and heat effects, provision of freedom of movement or introduction of restraint may be considered.

**9.3** Following connections and jointing techniques/ materials may be employed:

a) Welding of cleats or projecting steel,

b) Overlapping reinforcement, loops and linking steel grouted by concrete,

c) Reinforced concrete ties all round a slab,

d) Prestressing,

e) Epoxy grouting,

f) Cement/Lime grout with non-shrink additive,

g) Polymer slurry grouting at dowel cast joint bolts and nuts connection,

h) Rebar fastener, chemical fastener and expansion fastener,

j) Reinforcement coupler,

k) A combination of the above, and

m) Any other method proven by test.

## 10 TESTS FOR COMPONENTS/STRUCTURES

### 10.1 Sampling Procedure

**10.1.1** *Lot*

All the precast units of the same size, manufactured from the same material under similar conditions of production shall be grouped together to constitute a lot.

The number of units to be selected from each lot for dimensional requirements shall depend upon the size of the lot and shall be in accordance with col 2 and col 3 of Table 1. The units shall be selected from the lot at random. In order to ensure the randomness of selection, reference may be made to IS 4905.

**10.1.2** *Number of Tests and Criteria for Conformity*

All the units selected at random in accordance with col 2 and col 3 of Table 1 shall be subjected to the dimensional requirements. A unit failing to satisfy any of the dimensional requirements shall be termed as defective. The lot shall be considered as conforming to the dimensions requirements, if no defective is found in the sample, and shall be rejected, if the number of defectives is greater than or equal to the first rejection number. If the number of defectives is less than the first rejection number the second sample of the same size as taken in the first stage shall be selected from the lot at random and subjected to the dimensional requirements. The number of defectives in the first sample and the second sample shall be combined and if the combined number of defectives is less than the second rejection number, the lot shall be considered as conforming to the dimensional requirements, otherwise not.

The lot which has been found as satisfactory with respect to the dimensional requirements shall then be tested for load test. For this purpose one unit shall be selected for every 300 units or part thereof. The lot shall be considered as conforming to the strength requirement, if all the units meet the requirement; otherwise not.

**Table 1 Sample Size and Rejection Number**
(*Clause* 10.1.1 *and* 10.1.2)

| Sl No. | Lot Size | First Sample Size | Second Sample Size | First Rejection Number | Second Rejection Number (Sum of Defectives from First and Second Sampling) |
|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) |
| i) | Up to 100 | 5 | 5 | 2 | 2 |
| ii) | 101 to 300 | 8 | 8 | 2 | 2 |
| iii) | 301 to 500 | 13 | 13 | 2 | 2 |
| iv) | 500 and above | 20 | 20 | 3 | 4 |

**10.2 Testing on Individual Components**

The component should be loaded for 1 h at its full span with a total load (including its own self weight) of 1.25 times the sum of the dead and imposed loads used in design. At the end of this time it should not show any sign of weakness, faulty construction or excessive deflection. Its recovery 1 h after the removal of the test load, should not be less than 75 percent of the maximum deflection recorded during the test. If prestressed, it should not show any visible cracks up to working load and should have a recovery of not less than 85 percent in 1 h.

**10.3 Load Testing of Structure or Part of Structure**

Loading test on a completed structure should be made, if required by the specification or if there is a reasonable doubt as to the adequacy of the strength of the structure.

**10.3.1** In such tests the structure should be subjected to full dead load of the structure plus an imposed load equal to 1.25 times the specified imposed load used in design, for a period of 24 h and then the imposed load shall be removed. During the tests, vertical struts equal in strength to take the whole load should be placed in position leaving a gap under the member.

NOTE — Dead load includes self weight of the structural members plus weight of finishes and walls or partitions, if any, as considered in the design.

**10.3.1.1** If within 24 h of the removal of the load, a reinforced concrete structure does not show a recovery of at least 75 percent of the maximum deflection shown during the 24 h under load, test loading should be repeated after a lapse of 72 h. If the recovery is less than 80 percent in second test, the structure shall be deemed to be unacceptable.

**10.3.1.2** If within 24 h of the removal of the load, prestressed concrete structure does not show a recovery of at least 85 percent of the maximum deflection shown during the 24 h under load, the test loading should be repeated. The structure should be considered to have failed, if the recovery after the second test is not at least 85 percent of the maximum deflection shown during the second test.

**10.3.1.3** If the maximum deflection, in mm, shown during 24 h under load is less than 40 $l^2/D$, where $l$ is the effective span, in m; and $D$, the overall depth of the section, in mm, it is not necessary for the recovery to be measured and the recovery provisions of **10.3.1.1** and **10.3.1.2** shall not apply.

## 11 MANUFACTURE, STORAGE, TRANSPORT AND ERECTION OF PRECAST ELEMENTS

**11.1 Manufacture of Precast Concrete Elements**

**11.1.1** A judicious location of precasting yard with concreting, initial curing (required for demoulding), storage facilities, suitable transporting and erection equipments and availability of raw materials are the crucial factors which should be carefully planned and provided for effective and economic use of precast concrete components in constructions.

**11.1.2** *Manufacture*

The manufacture of the components can be done in a factory for the commercial production established at the focal point based on the market potential or in a site precasting yard set up at or near the site of work.

**11.1.2.1** *Factory prefabrication*

Factory prefabrication is resorted to in a factory for the commercial production for the manufacture of standardized components on a long-term basis. It is a capital intensive production where work is done throughout the year preferably under a closed shed to avoid effects of seasonal variations. High level of mechanization can always be introduced in this system where the work can be organized in a factory-like manner with the help of a constant team of workmen.

**11.1.2.2** *Site prefabrication*

In this scheme, prefabricated components are produced at site or near the site of work as possible.

This system is normally adopted for a specific job order for a limited period. Though there is definite economy with respect to cost of transportation, this system suffers from basic drawback of its non-suitability to any high degree of mechanization and no elaborate arrangements for quality control. Normal benefits of continuity of work is not available in this system of construction. Under this category there are two types that is semi-mechanized and fully-mechanized.

**11.1.2.2.1** *Semi-mechanized*

The work is normally carried out in open space with locally available labour force. The equipment machinery used may be minor in nature and moulds are of mobile or stationary in nature.

**11.1.2.2.2** *Fully-mechanized*

The work carried out under shed with skilled labour. The equipments used are similar to one of factory production. This type of precast yards will be set up for the production of precast components of high quality, high rate of production.

**11.1.3** The various processes involved in the manufacture of precast elements may be classified as follows.

**11.1.3.1** *Main process*

a) Providing and assembling the moulds, placing reinforcement cage in position for reinforced concrete work, and stressing the wires in the case of prestressed elements;
b) Putting concealed service conduits/pipes;
c) Fixing of inserts and tubes, where necessary (for handling);
d) Pouring the concrete into the moulds;
e) Vibrating the concrete and finishing;
f) Curing (steam curing, if necessary); and
g) Demoulding the forms and stacking the precast products.

**11.1.3.2** *Auxiliary process*

Process, such as the following, necessary for the successful completion of the processes covered by the main process:

a) Mixing and manufacture of fresh concrete (done in a mixing station or by a batching plant);
b) Prefabrication of reinforcement cage (done in a steel yard or workshop);
c) Manufacture of inserts and other finishing items to be incorporated in the main precast products;
d) Finishing the precast products; and
e) Testing of products.

**11.1.3.3** *Subsidiary process*

All other works, such as the following, involved in keeping the main production work to a cyclic working:

a) Storage of materials;
b) Transport of cement and aggregates;
c) Transport of green concrete and reinforcement cages;
d) Transport and stacking the precast elements;
e) Repairs and maintenance of tools, tackles and machines;
f) Repair and maintenance of moulds;
g) Maintenance of curing yards; and
h) Generation of steam, etc.

**11.1.4** For the manufacture of precast elements all the above processes shall be planned in a systematic way to achieve the following:

a) A cyclic technological method of working to bring in speed and economy in manufacture;
b) Mechanization of the process to increase productivity and to improve quality;
c) The optimum production satisfying the quality control requirements and to keep up the expected speed of construction aimed;
d) Better working conditions for the people on the job; and
e) Minimizing the effect of weather on the manufacturing schedule.

**11.1.5** The various stages of precasting can be classified as in Table 2 on the basis of the equipments required for the various stages. This permits mechanization and rationalization of work in the various stages. In the precasting, stages 6 and 7 given in Table 2 form the main process in the manufacture of precast concrete elements. For these precasting stages there are many technological processes to suit the concrete product under consideration which have been proved rational, economical and time saving. The technological line or process is the theoretical solution for the method of planning the work involved by using machine complexes. Figure 5 illustrates diagramatically the various stages involved in a plant process.

**11.1.6** The various accepted methods of manufacture of precast units can be broadly classified into two methods:

a) The 'Stand Method' where the moulds remain stationary at places, when the various processes involved are carried out in a cyclic order at the same place, and
b) The 'Flow Method' where the precast unit under consideration is in movement according to the various processes involved in the work which are carried out in an assembly-line method.

The various accepted precasting methods are listed in Table 3 with details regarding the elements that can be manufactured by these methods.

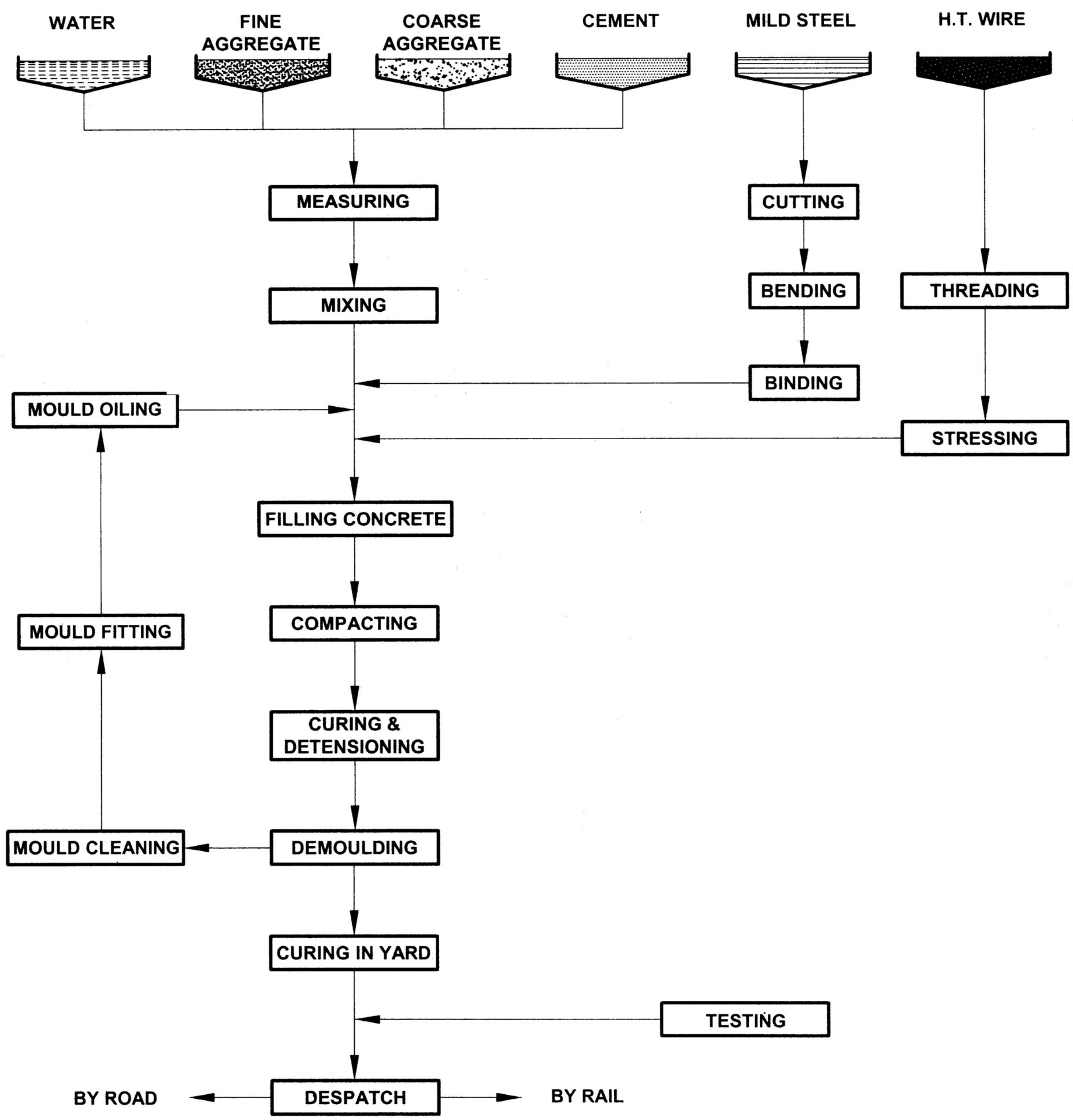



FIG. 5 PLANT PROCESS

**Table 2 Stages of Precasting of Concrete Products**

(*Clause* 11.1.5)

| Sl No. | Precasting Stage No. | Name of Process | Operations Involved |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| i) | 1 | Procurement and storage of construction materials | Unloading and transport of cement, coarse and aggregates, and steel, and storing them in bins, silos or storage sheds |
| ii) | 2 | Testing of materials | Testing of all materials including steel |
| iii) | 3 | Design of concrete mix | Testing of raw materials, plotting of grading curves and trial of mixes in laboratory |
| iv) | 4 | Making of reinforcement cages | Unloading of reinforcement bars from wagons or lorries and stacking them in the steel yard, cutting, bending, tying or welding the reinforcements and making in the form of a cage, which can be directly introduced into the mould |
| v) | 5 | Applying form release agent and laying of moulds in position | Moulds are cleaned, applied with form release agent and assembled and placed at the right place |
| vi) | 6 | Placing of reinforcement cages, inserts and fixtures | The reinforcement cages are placed in the moulds with spacers, etc as per data sheet prepared for the particular prefabricate |
| vii) | 7 | Preparation of green concrete | Taking out aggregates and cement from bins, silos, etc, batching and mixing |
| viii) | 8 | Transport of green concrete | Transport of green concrete from the mixer to the moulds. In the case of precast method involving direct transfer of concrete from mixer to the mould or a concrete hopper attached to the mould this prefabrication stage is not necessary |
| ix) | 9 | Pouring and consolidation of concrete | Concrete is poured and vibrated to a good finish |
| x) | 10 | Curing of concrete and demoulding | Either a natural curing with water or an accelerated curing using steam curing and other techniques. In the case of steam curing using trenches or autoclaves, this stage involves transport of moulds with the green concrete into the trench or autoclave and taking them out after the curing and demoulding elements. Cutting of protruding wires also falls in this stage. In certain cases the moulds have to be partly removed and inserts have to be removed after initial set. The total demoulding is done after a certain period and the components are then allowed to be cured. All these fall in this operation |
| xi) | 11 | Stacking of precast elements | Lifting of precast elements from the mould and transporting to the stacking yard for further transport by trailer or rail is part of this stage |
| xii) | 12 | Testing of finished components | Tests are carried out on the components individually and in combination to ensure the adequacy of their strength |
| xiii) | 13 | Miscellaneous | a) Generation of steam involving storing of coal or oil necessary for generation of steam and providing insulated steam pipe connection up to the various technological lines<br>b) Repair of machines used in the production |

**11.2 Preparation and Storage of Materials**

Storage of materials is of considerable importance in the precasting industry, as a mistake in planning in this aspect can greatly influence the economics of production. From experience in construction, it is clear that there will be very high percentages of loss of materials as well as poor quality due to improper storage and transport. So, in a precast factory where everything is produced with special emphasis on quality, proper storage and preservation of building materials, especially cement, coarse and fine aggregates, is of prime importance. Storage of materials shall be done in accordance with IS 4082.

**11.3 Moulds**

**11.3.1** Moulds for the manufacture of precast elements may be of steel, timber, concrete and plastic or a combination thereof. For the design of moulds for the various elements, special importance should be given to easy demoulding and assembly of the various parts. At the same time rigidity, strength and watertightness of the mould, taking into consideration forces due to pouring of green concrete and vibrating, are also important.

**11.3.2** *Tolerances*

The moulds have to be designed in such a way to take into consideration the tolerances given in **6.2**.

**11.3.3** *Slopes of the Mould Walls*

For easy demoulding of the elements from the mould with fixed sides, the required slopes have to be maintained. Otherwise there is a possibility of the elements getting stuck up with the mould at the time of demoulding.

**11.4 Accelerated Hardening**

In most of the precasting factories, it is economical to use faster curing methods or artificial curing methods, which in turn will allow the elements to be demoulded

**Table 3 Precasting Methods**
(*Clauses* 11.1.6 *and* 11.9.1)

| Sl No. | Precasting Method | Where Used | Recommended Dimensions and Weights | Advantages and Remarks |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| i) | *Individual mould method* (Precasting method using mould which may be easily assembled out of bottom and sides, transportable, if necessary. This may be either in timber or in steel using needle or mould vibrators and capable of taking prestressing forces) | a) Ribbed slabs, beams, girders, window panels, box type units and special elements<br>b) Prestressed railway sleepers, parts of prestressed girders, etc | No limit in size and weight. Depends on the equipment used for demoulding, transporting and placing | a) Strengthening of the cross-section possible<br>b) Openings are possible in two planes |
| ii) | *Battery form method* (The shuttering panels may be adjusted into the form of a battery at the required distances equal to the thickness of the concrete member) | Interior wall panels, shell elements, reinforced concrete battens, rafters, purlins and, roof and floor slabs | Length : 18 m<br>Breadth : 3 m<br>Mass : 5 t | Specially suitable for mass production of wall panels where shuttering cost is reduced to a large extent and autoclave or trench steam curing may be adopted by taking the steam pipes through the shuttering panels |
| iii) | *Stack method* | Floor and roof slab panels | Length : Any desired length<br>Breadth : 1 to 4 m<br>Mass : 5 t | For casting identical reinforced or prestressed panels one over the other with separating media interposed in between |
| iv) | *Tilting mould method* (This method is capable of being skipped vertically using hydraulic jacks) | Exterior wall panels where special finishes are required on one face or for sandwich panel. | Length : 6 m<br>Breadth : 4 m<br>Mass : 5 t | Suitable for manufacturing the external wall panels |
| v) | *Long line prestressing bed method* | Double tees, ribbed slabs, purlins, piles and beams | Length : Any desired<br>Breadth : 2 m<br>Height : 2 m<br>Mass : Up to 10 t | Ideally suited for pretension members |
| vi) | *Extrusion method* (Long concrete mould with constant cross-section where concreting and vibration are done automatically just as in hollow cored slab casting) | Roof slabs, foam concrete wall panels and beams cross-section where concreting and vibration are done automatically just as in hollow cored slab casting | Length : Any desired<br>Breadth : Less than 2 m<br>Height : Less than 3 m | May be used with advantage in the case of un-reinforced blocks, foam concrete panels |

much earlier permitting early re-use of the forms. Any of the following methods may be adopted:

a) *By heating the aggregates and water before mixing the concrete* — By heating of the aggregates as well as water to about 70°C to 80° C before making the concrete mix and placing the same in the moulds, sufficiently high earlier strengths are developed to allow the elements to be stripped and transported.

b) *Steam curing* — Steam curing may be done under high pressure and high temperature in an autoclave. This technique is more suited to smaller elements. Alternatively, this could be done using low pressure steam having temperature around 80°C. This type of curing shall be done as specified in **11.5.2**. For light weight concrete products when steam cured under high pressure, the drying shrinkage is reduced considerably. Due to this reason, high pressure steam curing in autoclave is specified for light weight low densities ranging from 300 to 1 000 kg/m$^3$. For normal (heavy) concretes as well as light weight concretes of higher densities, low pressure steam curing may be desirable as it does not involve using high pressures and temperatures requiring high investment in an autoclave (*see also* **11.5.2**).

c) *Steam injection during mixing of concrete* — In this method low pressure saturated steam is injected into the mixer while the aggregates are being mixed. This enables the heating up of concrete to approximately 60° C. Such a concrete after being placed in the moulds attains high early strength.

d) *Heated air method* — In this method, the concrete elements are kept in contact with hot air with a relative humidity not less than

80 percent. This method is specially useful for light weight concrete products using porous coarse aggregates.

e) *Hot water method* — In this method, the concrete elements are kept in a bath of hot water around 50 °C to 80 °C. The general principles of this type of curing are not much different from steam curing.

f) *Electrical method* — The passage of current through the concrete panels generates heat through its electro-resistivity and accelerates curing. In this method, the concrete is heated up by an alternating current ranging from 50 V for a plastic concrete and gradually increasing to 230 V for the set concrete. This method is normally used for massive concrete products.

**11.4.1** After the accelerated hardening of the above products by any of the above accepted methods, the elements shall be cured further by normal curing methods to attain full final strength.

**11.4.2** Accelerated hardening may also be achieved by the following techniques:

a) *Construction chemicals* — Suitable construction chemicals may be used.

b) *Consolidation by spinning* — Such a method is generally used in the centrifugal moulding of pipes and such units. The spinning motion removes excess water, effects consolidation and permits earlier demoulding.

c) *Pressed concrete* — This method is suitable for fabrication of small or large products at high speed of production. A 100-200 t press compresses the wet concrete in rigid moulds and expels water. Early handling and a dense wear resistant concrete is obtained.

d) *Vacuum treatment* — This method removes the surplus air and water from the newly placed concrete as in slabs and similar elements. A suction up to about 70 percent of an atmosphere is applied for 20 to 30 min/cm thickness of the units.

e) *Consolidation by shock* — This method is suitable for small concrete units dropped repeatedly from a height in strong moulds. The number of shocks required to remove excess water and air may vary from 6 to 20 and the height of lift may be up to as much as half the depth of the mould.

**11.4.3** After the accelerated curing of the above products by any of the above accepted methods, the elements shall be cured further by normal curing methods to attain full final strength.

**11.5 Curing**

**11.5.1** The curing of the prefabricated elements can be effected by the normal methods of curing by sprinkling water and keeping the elements moist. This can also be done in the case of smaller elements by immersing them in a specially made water tanks.

**11.5.2** *Steam Curing*

**11.5.2.1** The steam curing of concrete products shall take place under tarpaulin in tents, under hoods, under chambers, in tunnels or in special autoclaves. The steam shall have a uniform quality throughout the length of the member. The precast elements shall be so stacked, with sufficient clearance between each other and the bounding enclosure, so as to allow proper circulation of steam.

Before the concrete products are subjected to any accelerated method of curing, the cement to be used shall be tested in accordance with relevant Indian Standards especially for soundness, setting time and suitability for steam curing.

In the case of elements manufactured by accelerated curing methods, concrete admixtures to reduce the water content may be allowed to be used. The normal aeration agents used to increase the workability of concrete should not be allowed to be used. Use of calcium chloride based admixtures should not be used for reinforced concrete elements so as to meet the chloride limits prescribed in IS 456.

**11.5.2.2** The surrounding walls, the top cover and the floor of steam curing chamber or tunnel or hood shall be so designed as not to allow more than 1 kcal/m$^2$/h/°C.

**11.5.2.3** The inside face of the steam curing chamber, tunnel or hood shall have a damp-proof layer to maintain the humidity of steam. Moreover, proper slope shall be given to the floor and the roof to allow the condensed water to be easily drained away. At first, when steam is let into the curing chambers, the air inside shall be allowed to go out through openings provided in the hoods or side walls which shall be closed soon after moist steam is seen jetting out.

**11.5.2.4** It is preferable to let in steam at the top of the chamber through perforated pipelines to allow uniform entry of steam throughout the chamber.

**11.5.2.5** The fresh concrete in the moulds should be allowed to get the initial set before allowing the concrete to come into contact with steam. The regular heating up of fresh concrete product from about 20 °C to 35 °C should start only after a waiting period ranging from 2 to 5 h depending on the setting time of cement used. It may be further noted that steam can be let in earlier than this waiting period provided the temperature of the concrete product does not rise beyond 35°C within this waiting period.

**11.5.2.6** The second stage in steam curing process is to heat up the concrete elements, moulds and the surroundings in the chamber,

a) in the low pressure steam curing the airspace around the member is heated up to a temperature of 75°C to 80°C at a gradual rate, usually not faster than 30°C/h (this process takes around 1 h to 1½ h depending upon outside temperature); and
b) in the case of curing under high pressure steam in autoclaves, the temperature and pressure are gradually built up during a period of about 4 h.

**11.5.2.7** The third stage of steam curing is to maintain the uniform temperature and pressure for a duration depending upon thickness of the section. This may vary from 3 h to 5½ h in the case of low pressure steam curing and 4 h to 7 h in the case of high pressure steam curing.

**11.5.2.8** The fourth stage of steam curing is the gradual cooling down of concrete products and surroundings in the chamber and normalization of the pressure to bring it at par with outside air. The maximum cooling rate, which is dependent on the thickness of the member, should normally not exceed 30°C/h.

**11.5.3** In all these cases, the difference between the temperature of the concrete product and the outside temperature should not be more than 60°C for concretes up to M30 and 75°C for concretes greater than M45. In the case of light weight concrete, the difference in temperature should not be more than 60°C for concretes less than M25. For concretes greater than M50, the temperature differences can go up to 75°C.

**11.6 Stacking During Transport and Storage**

Every precaution shall be taken against overstress or damage, by the provision of suitable packings at agreed points of support. Particular attention is directed to the inherent dangers of breakage and damage caused by supporting other than at two positions, and also by the careless placing of packings (for example, not vertically one above the other). Ribs, corners and intricate projections from solid section should be adequately protected. Packing pieces shall not discolour, disfigure or otherwise permanently cause mark on units or members. Stacking shall be arranged or the precast units should be protected, so as to prevent the accumulation of trapped water or rubbish, and if necessary to reduce the risk of efflorescence.

**11.6.1** The following points shall be kept in view during stacking:

a) Care should be taken to ensure that the flat elements are stacked with right side up. For identification, top surfaces should be clearly marked.
b) Stacking should be done on a hard and suitable ground to avoid any sinking of support when elements are stacked.
c) In case of horizontal stacking, packing materials shall be at specified locations and shall be exactly one over the other to avoid cantilever stress in panels.
d) Components should be packed in a uniform way to avoid any undue projection of elements in the stack which normally is a source of accident.

**11.7 Handling Arrangements**

**11.7.1** Lifting and handling positions shall be clearly defined particularly where these sections are critical. Where necessary special facilities, such as bolt holes or projecting loops, shall be provided in the units and full instructions supplied for handling. For the purpose of testing the bolts/hooks, bond strength shall be the criteria for embedded bolts and bearing strength for through bolts. For bond strength, pull out test of concrete shall be carried out.

**11.7.2** For precast prestressed concrete members, the residual prestress at the age of particular operation of handling and erection shall be considered in conjunction with any stresses caused by the handling or erection of member. The compressive stress thus computed shall not exceed 50 percent of the cube strength of the concrete at the time of handling and erection. Tensile stresses up to a limit of 50 percent above those specified in IS 456 shall be permissible.

**11.8 Identification and Marking**

All precast units shall bear an indelible identification, location and orientation marks as and where necessary. The date of manufacture shall also be marked on the units.

**11.8.1** The identification markings on the drawings shall be the same as that indicated in the manufacturer's literature and shall be shown in a table on the setting schedule together with the length, type, size of the unit and the sizes and arrangement of all reinforcement.

**11.9 Transport**

Transport of precast elements inside the factory and to the site of erection is of considerable importance not only from the point of view of economy but also from the point of view of design and efficient management. Transport of precast elements must be carried out with extreme care to avoid any jerk and distress in elements and handled as far as possible in the same orientation as it is to be placed in final position.

**11.9.1** *Transport Inside the Factory*

Transport of precast elements moulded inside the factory depends on the method of production, selected for the manufacture as given in Table 3.

**11.9.2** *Transport from Stacking Yard Inside the Factory to the Site of Erection*

Transport of precast concrete elements from the factory to the site of erection should be planned in such a way so as to be in conformity with the traffic rules and regulations as stipulated by the Authorities. The size of the elements is often restricted by the availability of suitable transport equipment, such as tractor-*cum*-trailers, to suit the load and dimensions of the member in addition to the opening dimensions under the bridge and load carrying capacity while transporting the elements over the bridge.

**11.9.2.1** While transporting elements in various systems, that is, wagons, trucks, bullock carts, etc, care should be taken to avoid excessive cantilever actions and desired supports are maintained. Transportation of prefabricated element should be done with safety ties and vibrations to the elements in transit should be minimum. Special care should be taken at location of sharp bends and on uneven or slushy roads to avoid undesirable stresses in elements.

**11.9.2.2** Before loading the elements in the transporting media, care shall be taken to ensure that the base packing for supporting the elements are located at specified positions only. Subsequent packings shall be kept strictly one over the other.

## 11.10 Erection

In the erection of precast elements, all the following items of work shall be included:

a) Slinging of the precast element;
b) Tying up of erection ropes connecting to the erection hooks;
c) Cleaning of the elements and the site of erection;
d) Cleaning of the steel inserts before incorporation in the joints, lifting up of the elements, setting them down into the correct envisaged position;
e) Adjustment to get the stipulated level, line and plumb;
f) Welding of cleats;
g) Changing of the erection tackles;
h) Putting up and removing of the necessary scaffolding or supports;
j) Welding of the inserts, laying of reinforcements in joints and grouting the joints; and
k) Finishing the joints to bring the whole work to a workmanlike finished product.

**11.10.1** In view of the fact that the erection work in various construction jobs using prefabricated concrete elements differs from place to place depending on the site conditions, safety precautions in the work are of utmost importance. Hence only those skilled foremen, trained workers and fitters who have been properly instructed about the safety precautions to be taken should be employed on the job. For additional information, *see* SP 7 (Part 7).

**11.10.2** Transport of people, workers or visitors, by using cranes and hoists should be strictly prohibited on an erection site.

**11.10.3** In the case of tower cranes running on rails, the track shall not have a slope more than 0.2 percent in the longitudinal direction. In the transverse direction the rails shall lie in a horizontal plane.

**11.10.4** The track of the crane should be checked daily to see that all fish plates and bolts connecting them to the sleepers are in place and in good condition.

**11.10.5** The operation of all equipment used for handling and erection shall follow the operations manual provided by the manufacturer. All safety precautions shall be taken in the operations of handling and erection.

**11.10.6** For the design and construction of composite structures made up of prefabricated structural units and cast *in-situ* concrete, reference may be made to IS 3935.

For design and construction of precast reinforced and prestressed concrete triangulated trusses reference may be made to IS 3201.

For design and construction of floors and roofs using various precast units, reference may be made to IS 6332, IS 10297, IS 10505, IS 13994, IS 14142, IS 14215 and IS 14242.

For construction with large panel prefabricates, reference may be made to IS 11447.

For construction of floors and roofs with joists and filler blocks, reference may be made to IS 6061 (Parts 1 and 2).

# 12 EQUIPMENT

## 12.1 General

The equipment used in the precast concrete industry/

construction may be classified into the following categories:

a) Machinery required for quarrying of coarse and fine aggregates;
b) Conveying equipment, such as belt conveyors, chain conveyors, screw conveyors, bucket elevators, hoists, etc;
c) Concrete mixing machines;
d) Concrete vibrating machines;
e) Erection equipment, such as cranes, derricks, hoists, chain pulley blocks, etc;
f) Transport machinery, such as tractor-*cum*-trailers, dumpers, lorries, locomotives, motor boats and rarely even helicopters;
g) Workshop machinery for making and repairing steel and timber moulds;
h) Bar straightening, bending and welding machines to make reinforcement cages;
j) Minor tools and tackles, such as wheel barrows, concrete buckets, etc; and
k) Steam generation plant for accelerated curing.

In addition to the above, pumps and soil compacting machinery are required at the building site for the execution of civil engineering projects involving prefabricated components.

Each of the above groups may further be classified into various categories of machines and further to various other types depending on the source of power and capacity.

**12.2 Mechanization of the Construction and Erection Processes**

The various processes can be mechanized as in any other industry for attaining the advantages of mass production of identical elements which in turn will increase productivity and reduce the cost of production in the long run, at the same time guaranteeing quality for the end-product. On the basis of the degree of mechanization used, the various precasting factories can be divided into three categories:

a) With simple mechanization;
b) With partial mechanization; and
c) With complex mechanization leading to automation.

**12.2.1** In simple mechanization, simple mechanically operated implements are used to reduce the manual labour and increase the speed.

**12.2.2** In partial mechanization, the manual work is more or less eliminated in the part of a process. For example, the batching plant for mixing concrete, hoists to lift materials to a great height and bagger and bulldozer to do earthwork come under this category.

**12.2.3** In the case of complex mechanization leading to automation, a number of processes leading to the end-product are all mechanized to a large extent (without or with a little manual or human element involved). This type of mechanization reduces manual work to the absolute minimum and guarantees the mass production at a very fast rate and minimum cost.

**12.2.4** For equipments relevant Indian Standards.

## ANNEX A

(*Clause* 2)

### LIST OF REFERRED INDIAN STANDARDS

| *IS No.* | *Title* |
|---|---|
| 456 : 2000 | Code of practice for plain and reinforced concrete (*fourth revision*) |
| 875 | Code of practice for design loads (other than earthquake) for buildings and structures: |
| (Part 1) : 1987 | Dead loads — Unit weights of building materials and stored materials (*second revision*) |
| (Part 2) : 1987 | Imposed loads (*second revision*) |
| (Part 3) : 1987 | Wind loads (*second revision*) |
| (Part 4) : 1987 | Snow loads (*second revision*) |
| (Part 5) : 1987 | Special loads and load combinations (*second revision*) |
| 1893 (Part 1) : 2002 | Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*fifth revision*) |
| 3201 : 1988 | Criteria for design and construction of precast trusses and purlins (*first revision*) |
| 3935 : 1966 | Code of practice for composite construction |

| *IS No.* | *Title* |
|---|---|
| 4082 : 1996 | Recommendation on stacking and storage of construction materials and components at site (*second revision*) |
| 6061 | Code of practice for construction of floor and roof with joists and hollow filler blocks : |
| (Part 1) : 1971 | With hollow concrete filler blocks |
| (Part 2) : 1981 | With hollow clay filler blocks (*first revision*) |
| 6332 : 1984 | Code of practice for construction of floor and roofs using precast doubly-curved shell units (*first revision*) |
| 10297 : 1982 | Code of practice for design and construction of floors and roofs using precast reinforced/prestressed concrete ribbed or cored slab units |
| 10505`: 1983 | Code of practice for construction of floors and roofs using precast reinforced concrete waffle units |
| 13994 : 1994 | Code of practice for design and construction of floor and roof with precast reinforced concrete planks and RC joists |
| 14142 : 1994 | Code of practice for design and construction of floors and roofs with prefabricated brick panel |
| 14215 : 1994 | Code of practice for construction of floor and roof with RC channel units |
| 14242 : 1994 | Code of practice for design and construction of roof with L-Panel units |
| 11447 : 1985 | Code of practice for construction with large panel prefabricates |
| SP 7 (Part 7) : 2005 | National Building Code of India 2005: Part 7 Constructional practices and safety |

# ANNEX B
(*Foreword*)

## COMMITTEE COMPOSITION

Planning, Housing and Prefabricated Construction Sectional Committee, CED 51

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This Indian Standard has been developed from Doc No.: CED 51 (7567).

**Amendments Issued Since Publication**

| Amend No. | Date of Issue | Text Affected |
|---|---|---|
| | | |
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