1.1 NEED FOR PREFABRICATION

1. Prefabricated structures are used for sites which are not suitable for normal construction method such as hilly region and also when normal construction materials are not easilyavailable.

2. PFS facilities can also be created at near a site as is done to make concrete blocks usedin plane of conventionalbrick.

3. Structures which are used repeatedly and can be standardized such as mass housing storage sheds, godowns, shelter, bus stand security cabins, site offices, Fool over bridges road bridges. Tubular structures, concrete building blocks etc., are prefabricatedstructures

prefabricated systems

The first three types are mainly classified according to their degree of precast elements used in the construction. For example brick is small unit of pre casted material and used in buildings. This is called as small prefabrication and the degree of precast element is very low.

Medium prefabrication:

Suppose the roofing systems and horizontal members are provided with pre casted elements. These constructions are known as medium prefabricated construction. Here the degree of precast elements is moderate.

Large prefabrication:

In large prefabrication most of the members like wall panels, roofing / flooring systems, beams and columns are prefabricated. Here the degree of precast elements is high. One of the mainfactors which affect the factory prefabrication is transport. The width of the road, mode of transport vehicles are the factors which determines the prefabrication which is to be done on-site or in factory. Suppose the factory is situated far away from the construction site and the vehicle needs to cross congested traffic areas with heavy weighing elements the cast in- site prefabrication is preferred. Even though the same condition as the cast in site prefabrication is preferred only when umbers of houses are more for small elements the conveyance is easier with normal type of lorry and tractors. We can adopt factory or off-site prefabrication for this type of construction.

Open system of prefabrication:

In the total prefabrication systems, the space frames are casted as a single unit and erected at the site. The wall fitting and other fixing are done on site. This type of construction is known as open system of prefabrication.

Closed system of prefabrication:

In this system the whole things are casted with fixing and erected on their position.

Partial prefabrication:

In this method of construction, the building elements required are precast and then erected. Since the casting of horizontal elements (roof / floor) often take more time due to erection of frame work, the completion of the building is delayed and hence this method is restored. In most of the building sites, this method is popular, so in industrial buildings where the elements have longer spans. Use of double tees, channel units, cored stabs, slabs, hyperboloid shells, etc, are some of the horizontal elements used.

This method is efficient when the elements are readily available and the building has reached the roof level. The delay caused due to erection of framework, delay due to removal of framework is eliminated completely in this method of construction suitable for any type of building provided lifting and erection equipment's are available.

Total prefabrication:

Very high speeds can be achieved by using this method of construction. The method can be employed for frame type of construction or for panel type; the total prefabrication is done on-site or off-site. The choice of the two methods depend on the situations when the factory produced elements are transported and erected on site, we call it off-site prefabrication. If this method is to be adopted we should have a very good transportation facility for the products to be transported to the site of construction. If the elements are cast near the building site and erected, the transportation of elements can be eliminated, but we have to consider the space availability for establishing such facilities though it is temporary.

1.2 PRINCIPLES OF PREFABRICATION TECHNIQUES

Design for prefabrication, preassembly and modular

Construction. Simplify and standardize connection details.

Simplify and separate building systems.

Consider worker safety during Deconstruction Minimize building Components and materials.

Select fittings, fasteners, adhesive and sealants that allow for quicker assembly and facilitate the removal of reusable materials.
Design to accommodate deconstruction

Logistics. Reduce building complexity.

Design for reusable materials.

Design for flexibility and adaptability.

ADVANTAGES

Self supporting readymade components are used, so the need for formwork, shuttering and scaffolding is greatly reduced.
On-site construction and condition is minimized.

Less waste may occur.

Construction time is reduced and buildings are completed sooner, allowing an earlier return of the capital invested.
Quality control can be easier in a factory assembly line setting than a construction site setting.
Prefabrication can be located where skilled labour is more readily available and costs of labour, power materials, space and overheads are lower.
Time spoil in bad weather or hazardous environments at the construction site is minimized. Saving in cost, material, time & manpower. Shuttering and scaffolding is not necessary. Independent of weather condition.

DISADVANTAGES

Careful handling of prefabricated components such as concrete panels (or) steel and glass panels is reduced.

Similarly leaks can form at joints is prefabricated components.

Attention has to be paid to the strength and corrosion resistance of the joining of prefabricated sections to avoid failure of the joint.

Transportation costs may be higher for voluminous prefabricated sections than for the materials of which they are made, which can often be packed more efficiently.

Large group of buildings from the same type of prefabricated elements tend to look drab and monotonous Local jobs are lost.

1.3 MODULAR COORDINATION

Modular coordination means the interdependent arrangement of a dimension based on a primary value accepted as a module. The strict observance of rules of modular coordination facilitated,

1. Assembly of single components into large components.
2. Fewest possible different types of component.
3. Minimum wastage of cutting needed.

Modular coordination is the basis for a standardization of a mass production of component. A set of rules would be adequate for meeting the requirements of conventional and prefabricated construction.

These rules are adaptable for,

a. The planning grid in both directions of the horizontal plan shall be

1. 3m for residential and institutional buildings,
2. For industrial buildings,

- 15m for spans up to 12m
- 30m for spans between 12m and 18m
- 60m for spans over 18m

The center lines of load bearing walls shall coincide with the grid lines.

b. In case of external walls the grid lines shall coincide with the center line of the wall or a line on the wall 5 cm from the internal face of the wall.

c. The planning module in the vertical direction shall be 1m up to and including a height of 2.8m.

d. Preferred increments for the still heights, doors, windows and other fenestration shall be 1m. e. In case of internal columns the grid lines shall coincide with the center lines of columns.

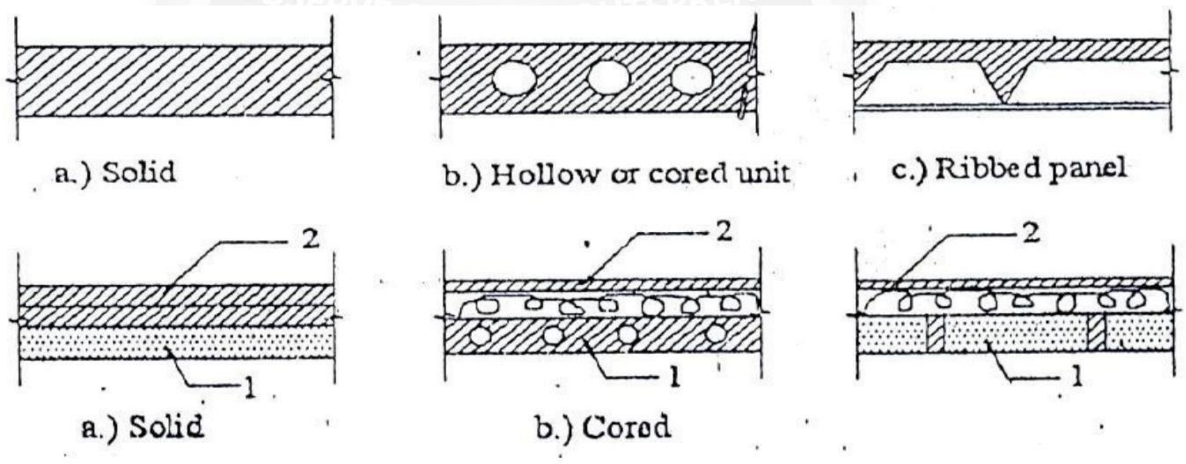
e. In case of external columns, the grid lines shall coincide with the center lines of the columns in the storey or a line in the column from the internal face of the column in the topmost storey.

A basic module can be represented as module and for larger project modules are represented Mp. For eg: For a project module in horizontal coordination, the component can be of 30cm and for vertical component size be of 10cm.

The storey height is fixed between finished floor levels as 2.8m and if the thickness of slab is<15cm storey height is fixed as 2.7m. The Centre distance between the load bearing walls can be chose from a set of modules. The use of other dimensions is not allowed.

In the design of a building, modular grid can be used consisting of parallel line spaced at a value of module M or Mp and a grid line chosen as a base for setting out a part of a building becomes a modular axis.

In the fig (a), a typical grid is chosen for load bearing walls without duct. The interior walls are placed so that their centerlines coincide with the modular axis. In the fig (b), a grid is shown for load bearing walls with hollow ducts in between. The centre line of the grid is found by deducting the size of duct.



1.4 PRODUCTION

The location of pre casting yards consist of storage facilities suitable for transporting and erection equipment's and availability of raw materials are the critical factors which should be carefully planned and provided for effective and economic use of pre-cast concrete components in construction.

The manufacture of the components can be done in a centrally located factor of in a site where pre casting yards set-up at or near the site of work.

SYSTEMS PRODUCTION

The term production of systems is describes a series of operation directly concerned In the process of making or more apply of molding precast units on the face of it there are very many techniques since almost every type prefabricates requires a Specific series of operation in its production.

These techniques however may be grouped into three basic method of production. These are

1. The stand system
2. The conveyor belt or production line system
3. The aggregate system

Stand system

In the stand system the prefabricates mature at the point where they were molded While the production team moves to successive stands the bed on which prefabricates.

Conveyor belt

The conveyor belt system of production splits the whole production process in to a series of operation carried out at a separate successive and permanent point to the heat may be by means of conveyor belt trolleys & crane etc.

Aggregate system

The word aggregates describes a large, complex permanently installed set of machines and mechanical application which can carry out most of the separate operation involved in casting concrete components.

1.4.2 FACTORY PREFABRICATION

Factory prefabrication is restored in a centrally located plant for manufacture of standardized components on a long form basis.

It is a capital intensive production where work is done throughout the year preferably under a covered shed to avoid the 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 constant team of workmen.

The basic disadvantage in factory prefabricated, is the extra cost in occurred in transportation of elements from plant to site of work sometimes the shape and size of prefabricable are to be limited due to lack of suitable transportation equipment roads controls etc.

1.4.3 SITE PREFABRICATION

In this scheme, the components are manufactured at site near the site of work as possible. This system is normally adopted for a specific job order for a short period. The work is normally carried out in open space with locally a valuable labour force. The equipment machinery and moulds are of mobile nature.

Therefore there is a definite economy with respect to cost of transportation. This system suffers from basic drawback of its non-suitability to any high degree of mechanization. It has no elaborate arrangements for quality control.

1.4.4 PROCESS OF MANUFACTURE

The various processes involved in the manufacture of precast elements are classified as follows:

1) Main process

2) Secondary (auxiliary) process

3) Subsidiary process

MAIN PROCESS

It involves the following steps.

1) Providing and assembling the moulds, placing reinforcement cage in position for reinforced concrete work, and

2) Fixing of inserts and tubes where necessary.

3) Depositing the concrete in to the moulds.

4) Vibrating the deposited concrete into the moulds.

5) Demoulding the forms.

6) Curing (steam curing if necessary)

7) Stacking the precast products.

SECONDARY (AUXILLARY) PROCESS

This process is necessary for the successful completion of the process covered by the main process.

1) Mixing or manufacture of fresh concrete (done in a mixing station or by a mixing plant).

2) Prefabrication of reinforcement cage (done in a steel yard of workshop)

3) Manufacture of inserts and other finishing items to be incorporated in the main precast products.

4) Finishing the precast products.

5) Testing the precast products.

STAGES OF PREFABRICATED CONCRETE PRODUCT

FLOW DIAGRAM OF STAGES OF PROCESSING

CONCRETE--------- MOULD------------STEEL

↓ ↓ ↓

MIXING-------- PREPARATION-------CUTTING

↓ ↓

FILLING ----------------------------- REINFORCING

↓

COMPONENT

↓

COMPACTION

↓

CURING

↓

DEMOULDING

↓

STORAGE

1.5 TRANSPORT AND ERECTION

1.5.1 TRANSPORT

Transport of prefabrication elements must be carried out and with extreme care to avoid any flock and distress in elements and handled as far as possible to be placed in final portion.

Transport of prefab elements inside the factory depends on the method of production selected for the manufacture. Transport of prefab elements from the factory to the site of action should be planned in conformity with the trafficable rules and regulations as stipulated by the authority the size of the elements is often restricted by the availability of suitable transport equipment, such as tractor-am-tailor, to suits the load and dimension of the member in addition to the load carrying capacity of the bridges on the way.

While transporting the prefab elements in various systems, such as wages, trucks, bullock cards etc. care should be taken to avoid excessive cantilever actions and desired supports are maintained. Special care should be taken in negotiating sharp beds uneven of slushy roads to avoid undesirable stresses in elements and in transport vehicles.

Before loading the elements in the transporting media, care should be taken to ensure the base packing for supporting the elements are located at specified portion only.

1.5.2 ERECTION

It is the process of assembling the Prefabrication element in the find portion as per the drawing. In the erection of prefab elements the following items of work are to be carried out.

1). Slinging of the prefabricated elements.

2). Tying up of erection slopes connecting to the erection hooks.

3). Cleaning the elements and the site of erection.

4). Cleaning the steel inserts before incorporation in the joints lifting and setting the elements to correct position.

5). Adjustments to get the stipulated level line and plumb.

6). Welding of deats.

7). Changing of the erection tackles.

8). Putting up and removing the necessary scaffolding or supports.

9). Welding the in sorts laying the reinforced in joints.

The erection work in various construction jobs by using prefab elements differs with risk condition, hence skilled foremen, and workers to be employed on the job.

Equipment's required for erection

Equipment's required for the prefab elements in industry can be classified as.

1) Machinery required for quarrying of course and fine aggregates

2) Conveying equipment, such as but conveyor, chain conveyors etc.

3) Concrete mixers

4) Vibrators

5) Erection equipment such as cranes, derricks, chain pulley etc.

6) Transport machines

7) Work shop machinery for fabricating and repairing steel.

8) Bar straitening, bending and welding machines

9) Minor tools and takes, such as concrete buckets etc…

10) Steam generation a plant for accelerated curing

Planning co-ordination

It is important to have the pre caster erector/installer and builder working together to achieve best performance.

Site Access and storage

- Check for site accessibility and precast panels delivery to site especially low bed trailers

- Check whether adequate space for temporary storage before installation and ground conditions. (firm ground & leveled)
- Uneven ground will cause overstress & crack panels.

Planning crane Arrangement

- Plan the crane capacity and lifting gears based on
- Heaviest weight of precast panels
- Lifting heights.
- Working radius
- Position of crane in relation to final panel location

Plan other equipment's

- Boom lift and scissor lift for unhooking installed panels.
- Lifting gears

Skilled personnel's

- Competent crane operators
- Rigger
- Signaled etc

General considerations for crane selection

- Total lifting weight
- Crane model
- Crane safe working load (SWL) (i.e) Based on 15% capacity build in

F.O.S. 1.33 o Lifting capacity must be 1.5 times the total weight i.e) F.O.S 1.5

- Lifting and swing radius
- Crane counter eight

- Crane boom length is relation to the vertical and horizontal clearance from the building.

Installation Process

Installation of vertical components Verification of Delivered Panels

- Check the panels delivered for correct marking lifting hook and position etc.
- Surface finishing condition
- Pc Dimension compliance
- Reinforcement Provision/position
- Architectural Detail compliance

1. **Setting out**

- Check the panels delivered for marking, lifting hook and condition.
- Set the reference lines & grids
- Check starter bars for vertical components before hoisting for installation

2. **Setting out Quality control point**

- Ensure correct offset line
- Check shim pedal/plate level and firm
- Rubber gasket property secured
- For external wall/column place backer rod.

3. **Hoisting, Rigging and Installation**

- While tilting provide rubber pad to avoid chip off.
- Lift and rig the panel to designated location
- Adjust the panel in position and secure
- Lifting of space adding items with balanced centre of gravity.

- Ensure horizontal alignment correct
- Ensure panel vertically to correct plumb
- Check panel to panel gap consistency
- Check stability of prop before releasing hoisting cable.

4. Grouting works

- Prepare and apply non shrink mortars to seal
- For corrugated pipe sleeve on spliced sleeve pour NSGT or proprietary grouts into pipe slab.
- Keep installed panels undisturbed for 24 hrs.
- Check joint widths are consistent before grouting
- Grout used should be same grade of components and self compacting to prevent cracking.
- Collect test cube sample for testing for critical element or load bearing elements

5. Connecting joints

- Cast in situ joints install rebars as required
- Set up forms for casting joints
- Do Concreting
- Remove forms after sufficient strength
- For external connections sealant shall be used
- Panel with welded connections welding as required

Installation of Horizontal Elements

1. Setting out

- Set reference line/offset line to required alignment and level of slab/beam during installation
- Put temporary prop to support the precast slab/beam elements
- Before Hoisting chem. Dimensions
- Check level and stability of shim
- Check protruding/ starter bars are within the Specified tolerance to prevent any observation during the erection process

2. Hoisting & Installation

- Put temporary props to support slab/beam
- Lift and rig the elements in designated location
- Align and check the level before placement
- The beams shall prop at least 2 location
- Balcony planter box and shall be supported more than 2 location based on design considerations
- Check level of precast elements

3. Connections/Jointing

- Precast with cast-in-situ joints place the lap rebars as required
- Set formwork for casting joints
- Remove formwork after concrete strength is achieved
- Supporting beams shall be designed to form part of formwork joints
- The connecting/lapping rebars tied & secured
- Same grade of concrete 10 to be used that of pa el.

4. Installation using Big canopy

- Big canopy high rise precast concrete construction system

- This is used for faster and efficient

5. Erection Purpose

- In Japan
- Used to construct the 26 storey pre-cast concrete 30,763m2
- The system realized 60% reduction in labor requirement for the frame erection.
- In Singapore
- DBS China square used the system to erect is efficient and faster

2.1 BEHAVIOUR AND TYPES OF STRUCTURAL COMPONENTS

Structural Behaviour of Precast structures

a) The design load carrying structures advantages from the viewpoint of prefabrication.

b) Principle of structural analysis

c) Various specifications

d) Dimensioning of joints

e) Elimination of handling stresses

f) Redistribution of stresses in jointed structures due to creep & shrinkage.

g) Calculation of reinforced concrete structures co-operating with strengthening concrete layer cast in situ.

h) Influence of the sequence and of the method of placing on the stress state of the structure

i) Stability of precast structural members

j) Quantity of materials used for precast reinforced concrete structures.

STRUCTURAL COMPONENTS

The following are the main components which are frequently used in building are

- Slab
- Joist
- Beams (main secondary)
- Wall panels
- Columns

The roofing/flooring system consists of R.C planks and joists. The planks are casted to a standard size and they are connected with R.C.C joist which are provided at a regular
interval. The loads from planks are transmitted to R.C joist and then to main beams.
The main beams are provided with channel sections 10 cm projections on the necessary sides with the spacing of joist. The joists are seated in the channels and bolted together. The loads from slab to the main beam will loadings are analyzed. The foundation unit is the only unit which is going to cast in site.

Slab

The roofing slab/flooring slab system consists of planks, which is supported over R.C.C Joist. The planks can be made in any one of the following form with or without prestressing.

According to the span & loads.

1. Hollow core sections
2. Double tee section\Channel sections
3. Light weight concrete roofing slab
4. Solid rectangular planks

The usual widths of these types of slabs are 0.5 m & spanning to the requirement up to a maximum limit of 5 m without prestressing. The thicknesses of planks are casted in two steps with different mould in access invisible action with adjacent slab by putting necessary reinforcement & concreting site.

Joist

The joists are designed as a small beams loaded from planks. These joists transmit the loads to the main beams through the channels provided in the main beams in this joist, triangular shaped stirrups are provided to get the proper bonding or connection with the planks. The joists are casted partially in the factory the apex portion of the triangular stirrup will be projecting from the casted top surface. In this projecting a connecting rod will be inserted and additional base from planks also inserted. This will give monolithic action as well as the plank will act as a continuous slab over the joists.

Beams (Main & Secondary)

All the main and secondary beams are the same size of 300 x 300 mm varies reinforcements are provided at varies conditions according to the moments. The beams are casted for the clear distance between the columns. A square of 10 cm x 10 cm hole or a depth of 10 cm are provided on either side to achieve the connection with other beam reinforcement or column reinforcements by proper welding. After welding the concrete has to be done at the junction with proper care.

At the junction of columns and beams it is necessary or part site controlling for this purpose the top ends of the beams are trap pored properly. So that it with give access to site concrete and for needle vibrators to get proper compaction.

Wall Panels

The wall panels are casted with all fixing like door, ventilation, window frames. These wall panels are non load bearing wall. Therefore neglect solid rectangular cross section wall panel with R.C.C. from the view of thermal effects and safety the minimum of 150 mm is provided as wall thickness. This wall is a sandwich type. That is cellular concrete blocks of 75 mm thick is sandwiched by R.C.C. M25 grade concrete to a thickness of 37,5 mm on either face with minimum reinforcement since, the walls are in steel moulds there will be no used to plastering on either face of wall.

This is one of advantage of precast wall panels. The main design factor is the handling stresses in wall panels.

The infillings may be any light weight, low cost material like brick bats, bricks light weight concrete acquainted concrete etc. Since the preparation and availability of raw materials are easy in the case of cellular concrete we are adopting cellular concrete as infill's in walls.

Columns

Many type of columns available in prefabricated system. Grooves are provided on the required faces to keep the walls in position. These grooves will act as a part of columns and since the area of column has been increased due to nibs will give addition moment carrying as well as load carrying capacity of columns. At the same time this grooves give a mild ornamental look to our building.

2.2 ROOF AND FLOOR SLABS

Behavior of roof and floor slabs:

- The roofing / flooring system consist of RC planks and joists.
- The planks are casted to a standard size and they are connected with RCC joists which are provided at a regular interval.
- The loads from planks are transmitted to RCC joists and then to main beams.
- The main beams are provided with channel sections 10cm projections on the necessary side with the spacing of joist.
- The joists are seated in the channel and bolted together.
- The loads from slabs to the main beam will come as point loads.
- The roofing / flooring slabs system consists of planks which are supported over RCC joist.
- The planks can be made in any one of the following form with or without prestressing. According to the span and loads.
- The usual width of these of slabs is 0.5m and spanning to the requirement up to a maximum limit of 5m without prestressing.
- The thicknesses of planks are casted in two steps with different mould to access monolithic action with adjacent slab by putting necessary reinforcement and concreting.

Methods Of Construction Of Roof And Floor Slab

In Floor and Roof:

- Structural floor / roof account for substantial cost of a building in normal situation. Therefore, any saving achieved in floor/roof considerably reduce the cost of building.
- Use of standardized and optimized roofing components where shuttering is avoided prove to be economical, fast and better in quality.

- Some of the prefabricated roofing/flooring components found suitable in many low-cost housing projects are
  - ❖ Precast RC planks
  - ❖ Prefabricated brick panels.
  - ❖ Precast RB curved panels.
  - ❖ Precast RC channel roofing.
  - ❖ L panel roofing.
  - ❖ Trapezon panel roofing
  - ❖ Unreinforced pyramidal brick roof.
  - ❖ Precast concrete panels.

Precast RC planks:

- This system consists of precast RC planks supporting over partially precast joist. RC planks are made with thickness party varying between 3 cm and 6 cm.
- There are haunches in the planks which are tapered.
- When the plank is put in between the joists, the space above 3 cm thickness is filled with in-situ concrete to get tee-beam effect of the joists.
- The planks are made in module width of 30 cm with maximum length of 150 cm and the maximum weight of the dry panel is 50 kg.
- Precast joists are rectangular in shape, 15 cm wide and the precast portion is 15cm deep.
- The main reinforcement of the overhang provided at the top in the in-situ concrete attains sufficient strength.
- The savings achieved in practical implementations compared with conventional RCC slab about 25%.

Prefabricated brick panel:

- The prefabricated brick panel roofing system consist of is made of first class brick reinforced with two MS bars of 6mm dia and joists filled with either 1:3 cement mortar or M15 concrete.

- A panel of 90cm length requires 16 bricks and a panel of 120cm requires 19 bricks.
- Partially precast joist it is a rectangular shaped joist 13cm wide and 10cm to 12.5cm deep.
- The overall depth of joist with in-situ concrete becomes 21cm to 23.5cm, it is designed as composite tee-beam with 3.5cm thick flange.
- The partially precast RC joist, is designed as simply supporting tee-beam with 3,5cm thick flange.

Precast curved brick arch panel:

- This roofing is same as RB panel roofing except that the panels do not have any reinforcement.
- A panel while casting is given a rise in the center and thus an arching action is created. An overall economy of 30% has been achieved in single storied building and 20% in two or three storied building.

Precast RC channel roofing:

- Precast panel channels are trough shaped with the outer side corrugated and grooved at the ends to provide shear key action and to transfer moments between adjacent units.
- The lengths of the units are adjusted to suit the span.
- The flange thickness is 30mm to 35mm.
- A savings of 14% has been achieved in actual implementation in various projects.

Precast hollow slabs roofing:

- Precast hollow slabs are panels in which voids are created by earthen kulars, without decreasing the stiffness or strength.
- These hollow slabs are lighter than solid slabs and thus save the cost of concrete, steel and the cost of walling and foundation too due to less weight.
- The width of the panel is 300mm and depth may vary from 100mm to 150mm as per the span.

- The outer sides are corrugated to provide transfer of shear between adjacent units.

L - Panel roofing:

- The precast full span RC panel is of section L.
- The L panels are supporting on parallel gable walls and are used for shaped roof of a building.
- L panel roofing is quite lighter in weight, economic in construction.
- It is panel sound performance and durability.

Trapezon panel roofing:

- Typical precast RC trapezon panel has trapezium section in orthogonal directions.
- The components are sound and can be manually handled with ease.
- These components are placed in position to from roof and haunch filling is done with in situ concrete to make a monolithic surface.

Unreinforced pyramidal brick roof:

- Unreinforced pyramidal brick roof construction system is suitable for low cost houses in cyclone affected and other coastal areas.
- Corrosion of reinforcement was found to be the major cause of failure of RCC structure in coastal area and a pyramidal roof with brick and cement concrete without reinforcement was therefore developed.
- The roofing is provided with peripheral RCC ring beam.

2.3 SHEAR WALLS

Necessity of shear wall

- When shear walls are designed and constructed properly, and they will have the strength and stiffness to resist the horizontal forces.
- In building construction, a rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes.
- Lateral forces caused by wind, earthquake and uneven settlement loads in addition to the weight of structure and occupants; create powerful twisting forces.
- These forces can literally tear a building apart reinforcing a frame by attaching or placing a rigid wall inside it maintains the shape of the frame and prevents rotation at the joints.
- Shear walls are especially important in high rise building subjected to lateral wind and seismic forces.
- Shear wall buildings are usually regular in plan and in elevation, in some building, lower floor are used for commercial purposes and the building are characterized with larger plan

Types of shear walls based on materials:

- RC shear wall
- Plywood shear wall
- RC hollow concrete brick masonry wall
- Steel plate shear wall

RC shear wall:

- It consists of reinforced concrete wall and reinforced concrete slabs.
- Wall thickness varies from 140mm to 150mm, depending on the number of stories, building age, and thermal requirement.

- In general these walls are continuous throughout the building height however, some walls are discontinuous as the street front or basement level to allow for commercial or parking spaces.

Plywood shear wall:

1. Plywood is the traditional material used in the construction of shear walls.
2. The creation of prefabricated shear panels have made it possible to inject strong shear assemblies into small walls the fall at either side of a opening in a shear wall

plywood shear wall consists of

- Plywood to transfer shear force
- Chords to resists tension / compression generated by the over turning moments.
- Base connections to transfer shear to foundation.

RC hollow concrete block masonry walls:

- This walls are constructed by reinforced the hollow concrete block masonry, by taking advantage of hollow spaces and shape of the hollow blocks.
- It requires continuous steel rods both in the vertical and horizontal directions at structurally critical locations of the wall panels.
- RHCBM element are designing both as load bearing walls for gravity loads and also shear walls for lateral seismic loads to safety withstand earthquakes.

Steel plate shear wall:

- Steel plate shear wall s stem consists of a steel plate wall, boundary columns and horizontal floor beams.
- Together the steel plate girder, the column act as a vertical plate girder and steel plate wall act as its web.
- The horizontal floor beams act more or less as transverse stiffeners in a plate girder.
- The steel plate shear wall systems have been used in recent year in highly seismic areas to resists lateral loads.

2.4 BEHAVIOR OF FRAME IN PRECAST STRUCTURES

Roof and floor slabs:

- The roofing / flooring system consist of RC planks and joists.
- The planks are casted to a standard size and they are connected with RCC joists which are provided at a regular interval.
- The loads from planks are transmitted to RCC joists and then to main beams.
- The main beams are provided with channel sections 10cm projections on the necessary side with the spacing of joist.
- The joists are seated in the channel and bolted together.
- The loads from slabs to the main beam will come as point loads.
- The roofing / flooring slabs system consists of planks which are supported over RCC joist.
- The planks can be made in any one of the following form with or without prestressing. According to the span and loads.
- The usual widths of these of slabs are 0.5m and spanning to the requirement up to a maximum limit of 5m without prestressing.
- The thicknesses of planks are casted in two steps with different mould to access monolithic action with adjacent slab by putting necessary reinforcement and concreting.

Beams:

- All the main and secondary beams are the same size of 300 mm x 300 mm varies reinforcement are provided at various conditions according to the moments.
- The beams are casted for the clear distance between the columns.
- A square of 10 cm x 10 cm hole for a depth of 10 cm are provided on either sides to achieve the connection with other beam reinforcement or column reinforcement by proper welding.

- After welding the concrete has to be done at the column and beams, it is necessary to put site concreting.
- For the purpose the top ends of the beams are tapered so that it will give access to site concrete and for needle vibrators to get proper compaction.

Wall panels:

- The wall panels are casted with all fixing like door, ventilator, and window frames.
- These wall panel are non load bearing wall. Therefore neglect solid rectangular cross section wall panel with RCC from the view of thermal effects and safety the minimum of 150 mm is provided as wall thickness.
- This wall is a sandwich type that is cellular concrete blocks of 75 mm thick is sandwiched by RCC.
- M25 grade concrete to a thickness of 37.5 mm on either face with minimum reinforcement.
- Since, the walls are in steel moulds there will be no need for plastering on either face of wall. This is one of the advantages of precast wall panels.
- The main design factor is handling stresses in wall panels.

Columns:

- Many types of columns available in prefabricated system. Grooves are provided on the required faces to keeps the walls in position.
- This groove will act as a part of columns, and since the area of column has been increased due to tibs, will give addition moment carrying as well as load carrying capacity of columns.
- At the same time this grooves give a mild ornamental look to our building.

2.5 LARGE PANEL SYSTEMS

Large panel structure

All the main part of a building, including exterior wall and interior wall, floor slab, roofs, and staircase, may be made up from large panel structure are used in two main design schemes, frame-panel and panel building. In frame-panel building, all the base loads are borne by the building's frame, and as enclosure element. Frameless buildings are assembled from panels that perform the load bearing and enclosing functions simultaneously.

1. Large panel structure for Exterior wall
2. Large panel structure for Interior wall.
3. Large panel structure for floor slab
4. Large panel structure for Roof element.

1.Large panel structure for Exterior wall

Large panel structure for exterior walls consist of panel one or two stories in height and one or two rooms in width. The panel may be blind (without openings) or with window or door openings.

In terms of design, the wall panels may be single layer (solid) and multilayer(sand witch) Solid panels are manufactured from materials that have insulating properties and at the same time can perform supporting functions for example, light weight concrete, cellular concrete, and hollow ceramic stone.

Sandwich wall panels are made with two or three layers: their thickness depends On the climate conditions of the regions and the physic technical properties of the materials used for the insulating layer and for the exterior layer.

The surface of exterior wall panels is covered with decorative mortar or is faced with ceramic or other finishing tiles.

After assembly, the joints between panel are filled with mortar or with lightweight or ordinary concrete and then sealed with packing and special mastics.

2. Large panel structure for Interior walls

The large panel structure of interior walls may be non load bearing or load bearing.

In the first case, they are made from gypsum slag concrete or from other materials that act as enclosures. In the case of load bearing structure, the wall panels, which combine enclosing and load bearing function, are made from heavy or lightweight, silicate or cellular concrete, or vibration set brick or ceramic work.

The dimensions of the panels are determined by the dimensions of the rooms (in apartment houses), their height is equal to the height of a story, the width is equal to the depth or width of a room, and the thickness of the walls between rooms is usually 10-14 cm(between apartment 14-18 cm)

3. Large panel structure for floor slab:

- The large panel structure of floor slabs are usually made from reinforced concrete, the area of the floor slabs in apartment buildings usually equals the area of one room and be as great as 30 sq.m.
- Flagging panels have an area of 5-8 sq m. The large panel floor slabs of housing public, and administrative building are of both the solid and sandwich types in the latter, provision is made for a sound insulation layer to reduce air and impact notice.
- Composite floor panels, consisting of a load bearing reinforced concrete panel combined with a floor or ceiling panel and soundproofing, insulating, and other lay r, a e often used in housing construction.

4. Large panel structure for Roof Element:

- The large panel roof elements are used in housing and public buildings mainly in the form of combined articles roofs, and in industrial buildings the roof panels have a span of up to 12 m.
- The weight of large panel structure depends on the method of dividing the building into prefabricated element; it is usually 1.5-7.5 tons.
- Large panel structure of a high rise apartment building consist of (1) foundation slab,(2) exterior wall panel,(3) interior wall panel, (4) floor slab,(5) deck ,(6) exterior panel in the process of installation
- At the joints, the panels have to which steel connecting pieces are welded, thus linking together all the panels and providing general stability of the building.
- Large panel structures are used in the construction of high rise building.

3.1 EFFICIENCY OF MATERIAL USED

One of the principle aims of the prefabrication in general but particular of prefabrication on the site is that the dead load of precast member should be lessened to the Greater possible degree .

This also correct because the greater part of the stresses are caused by dead load is by the uses of stresses.

This was due to frequently developing cracks in the tension chords.

One can find no real reason for this aversion partly because the cracking of tension chord has no significance and partly because the possibility of cracking can be reduced by stressing the tensioned bars before there concreting.

Fibster welder used to stress the tensioned bar after the load had been applied vierendeel columns are excellent for the stanchions of frames and the columns of other reinforced concrete structures while trusses are fairly suitable for use in any kind of that structure .

They are particularly applicable for industrial buildings.

Trusses and vierendeel columns in addition to making the smallest demand in material open up new possibilities for the aesthetic forming of the interior of the building.

The structure manufactures in a horizontal position requires less material for shuttering their reinforcement and concreting is also simple.

An additional advantage of these type of columns is that tube pipes and other lines can be easily be attached to and led through the shaft.

This means that forms the standard point of operation, lost and unutilized area decrease to a minimum inside the building itself.

The problem of vierendeel column connecting to a truss is solved by using a hinge.

In comparison with a structure with moment t-bearing joints the above solution is connected with greater force effect.

If vierendeel columns and trusses are used the bearing of latter requires only a slight surplus in material.

Arched structure can be produced in the trussed form.

The spread of reinforcement concrete trusses, trussed arches and vierendeel columns has been impeded by their difficult monolithic execution complicated reinforcement as well as by the difficult calculation of secondary stresses.

3.2 JOINT FLEXIBILITY

In precast concrete construction the joint between the element are of very important.

- Dry joint
- Wet joint

The wet joints are by using mortar or in-situ concrete where as the dry joint is done by welding or bolting. The following consideration shall be taken into account.

Structural requirements: The connection must with all requirements regarding the transmission of forces, moment and permissible deformation or rotation.

Tolerances: The measure to which deviates must be taken up in the joint. It is called joint flexibility.

Aesthetical requirements : The joints remains completely or in part exposed.

Mode of Erection: With regard to available erection equipment fastest possible erection, and avoidance or minimizing ob bracing, support, etc

Necessity of checking and adjusting : The joint must be checked whether it is proper dimensioned or not . Therefore the adjustment may be possible.

Design of joint:

While designing of joints following points are considered:

It must be based on relevant standard specific codes of practice or recommendation must be relevant

- Loading under working condition
- Stability of structures
- Loading condition during construction
- Effect of shrinkage, creep and temperature
- Unequal settlement

Loading under working condition

The entire structure as well as each unit own must be designed to resist all loads, forces and moments acting there on when the structure is in the use.

Stability of structures

The overall stability of the structure must be need during each phase of construction.

Loading condition during construction

Loading condition during construction my causes higher stresses than those through normal usage. Temperature loads are erected due to erection , material and temperature supports.

Effect of shrinkage, creep and temperature

The fixed end beam connection the stresses and moments due to shrinkage , creep and temperature drop of the beam must be considered or the connection proper and for the structure as a whole.

Unequal settlement

In case of fixed end joint the possibility of settlement at the supports should be investigated.

Reinforcement anchorages:

In general the connection will require additional reinforcement bars and anchorage which must be so designed that a sound fill and proper compaction of the concrete can be realized.

Threaded and non threaded reinforcement inside :

All insert whether Threaded and non threaded reinforcement including those for the securing of piping and of erection aids must be calculated to meet the forces acting there on and must be indicated on the drawing with the relevant measurement.

Chamfers:

Square edges of all precast elements are liable to sapling or chipping and also causes accident.

Bond:

The bond surface which should transmit vertical shear must either be roughed or ribbed

Bolted Connection:

When using bolted connection , tolerance can be increased by either providing one of the plates of each pair with a slot or by drilling the bolt hole.

3.3 ALLOWANCE FOR JOINT DEFORMATION

Various structural elements are made in the plant or prefabricated when these element in their site there may be joint deformation to take it workout deformation.

An allowance is tolerance or dimensions of the pre fab units are given in the design.

This is the limiting value of the permissible or admissible deviation in the size or shape of the finished prefabricates from the design requirements.

In practice it is not possible to make products which will have the exact design dimension. Extreme precision is not possible as in accuracies or unavoidable during erection.

The designer should be able to forecast or even to tell title maximum tolerance value or the allowance which will make the correct assembly and efficient functioning of the individual prefabricates. The decreasing tolerance leads to the increased cost of protection and optimum value of permissible deviations must be established large admissible deviations which are normally made positive as a safety factors lead to waste of material in mass production.

In making large block prefabricates the average volume of concrete in their products was increased by 1.5% (the thickness of the blocks was on the average 0.5cm) with the production of 3000 m^3 of concrete per month the excessive month use of cement is nearly 15 metric tonnes.

Deviations in the dimensions of products are important to the production equipment main the frame work. The materials used in formwork and the manner in which the parts of the forms are joint together are the important face because of the deformability and their tendency to warp with moisture the timber forms can no ensure the accuracy like steel or concrete forms. Bolted connections are not recommended for formwork because of difficult of thread cleaning. The best accuracies obtained with self locking or wedged forms.

As in the machine tool industry, degree of precision is important in prelabricate building industry. There is a conventional scale defining the maximum permissible allowance or tolerance. The small is in relation to the theoretical dimension of prefabricates.

The following table gives the values degree of precision and basic tolerances or allowances (dimensions and tolerances in mm). Table 3.2.

Table 3.2 Degree of precision

Degree of precision required	Dimension of 10 m			Dimension of 60m	
	Upto 100	Upto 100 to 300	Upto 300 to 3000	3000 to 9000	Above 9000
3	0.5	1	2	3	4
4	1	2	3	4	6
5	2	3	4	6	10
6	3	4	6	10	16
7	4	6	10	10	25
8	6	10	16	25	40

In design it is advisable to design of frame work with an assumed 3rd or 4th degree of precision not less than the 5th degree.

For non-structural components 6th degree precision is sufficient if the dimensional co-ordmation is not affected.

The following rules are followed to decide the overall nominal degree of precision of a prefabricate.

From only one dimension is critical, the degree of precision corresponding to the dimension of the component.

When more than one dimension of the component are allowed tolerance or allowance of precision corresponding to the most critical or vital dimensions are calculated.

The degree of precision must be shown in the working drawings which make to know about the type of formwork for the given type of formwork the following specific ranges of precision are assigned.

- Steel or cast iron moulds = 4 to 5
- Concrete moulds = 4 to 6
- Vertical battery moulds steel = 5 to 8
- Vertical battery moulds, concrete = 6 to 8
- Collapsible steel ferrns = 5 to 8
- Timber forms bolted or welded = 7 to 8

In order to follow the design tolerances, the febricates of formwork must be accurate by at least one degree. The admissible dimensional deviation of prefabricates are

(a) Blocks:

Thickness = –0 + 5mm

Width = –5 + 8mm

Length = – 15 + 10mm

(b) Panels:

Thickness = –0 + 5mm

Width = –5 + 10mm

Length =

(c) Beam and Column:

Thickness = –3 + 5 mm

Width = –5 + 5mm

Length = –15+15mm

For the forms, the maximum allowance or tolerances are the following range.

(i) With timber forms:

Thickness = 7.5 to 14mm

Width = 6.5 to 24mm

Length = 10 to 30mm

(ii) Steel forms:

Thickness= 3 to 20m

Width = 11 to 22mm

Length = 8 to 28mm

The limiting values of allowance are calculated for the following formula.

3.4 DEMOUNTABLE PRECAST CONCRETE SYSTEMS

Methods of disuniting of structures :

- Systems consisting of linear members disunited at joints.
- System for the prefabrication of entire rigid frames.
- Straight members disunited at points of minimum moments.
- Two hinged and three hinged arches.

System consisting of linear member disunited at joints :

Disunity at joints which gives linear member, this means a great advantages and facility from the point of view both manufacture and assembly ,using this system, auxiliary scaffolding are not necessary and the hoisting process is, as a rule, very simple. In the system is that the joints are corners, so the forming of the joints are very difficult. The quality of subsequent concreting executed in-site only exceptionally and at readily accessible places as be over dimensioned. This necessities additional material for the precast member too. This, on one hand, justifies the newer precast members and , on the other hand , the newer trend of replacing moment resistant joints by hinge like ones .Although this method requires more material for the beams . The complicated construction of rigid corners can be omitted.

Advantages

- It is very simple.
- Scaffoldings are not necessary .
- Easy of hoisting process .
- Easy of assembling .

Disadvantages :

- Formation of joints is very difficult .
- Joints are at corners , where the moments usually reach their maximum values .

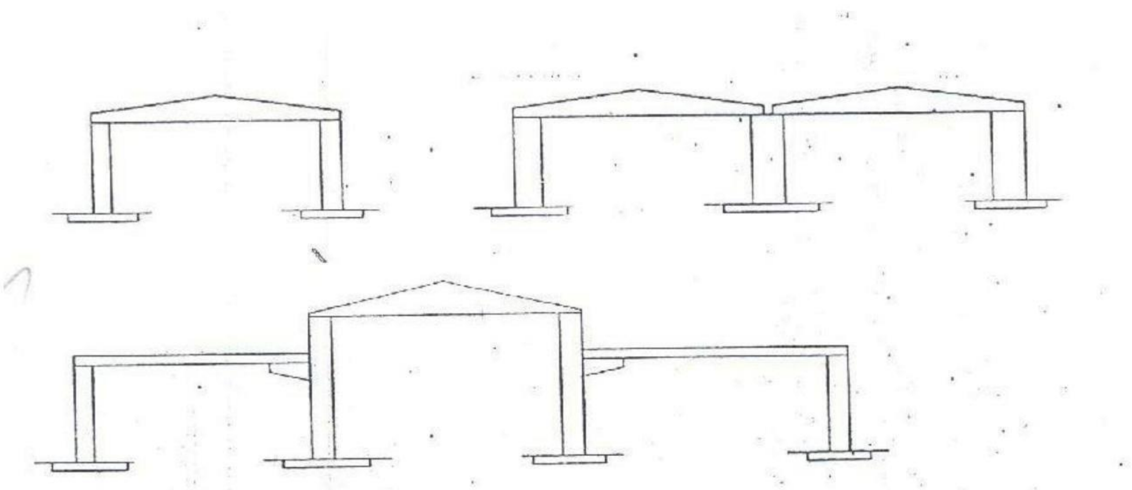


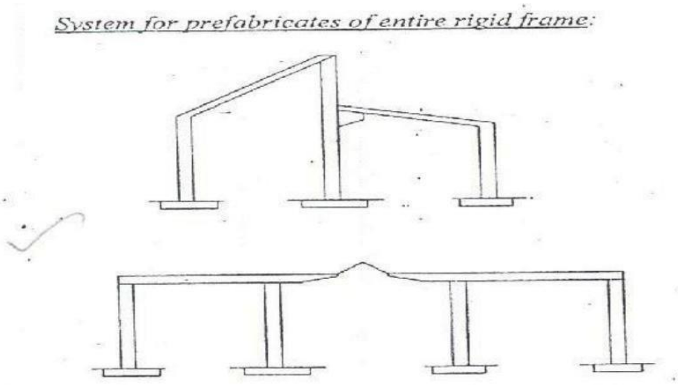
Fig 1.2.Members of frame disunited at the joints

Systems for the prefabrication of disuniting of entire rigid frames:

The trend to lesson the number of joints and to precast larger members in one piece leads to the prefabrication of entire frames . Such frames are as shown in figure , but these solutions are appropriate only for site prefabrication . The production of frames does not cause particular trouble , but their hoisting is more difficult and requires careful preparation . The stress distribution of straight members during their hoisting is, in general, statically determined . Example that of a beam lifted at two points or at more than two points when using a balance, or a cable – rocker or that of column lifted at one point and supported at its lower end.

The stress distribution arising in frames during their hoisting. On the other hand, is frequently statically redundant. The tilting of a frame from the horizontal into the vertical position, lifted at two points by two separately acting hoisting machines, illustrates the above statement. If these two points are not hoisted exactly at the same time and with prefect uniformity , the frame itself will be affected by torsion. Connecting the two suspension points by a balance or a cable rocker enables the frame to be hoisted at one single point.

Now the stress distribution is statically determined but if the rocker is not suspended at the exact point, torsion can also arise in this case. This shows that the hoisting of a frame is far more complicated than hoisting a straight member. The hoisting of asymmetric frame is particularly difficult. In this case the force affecting the rocker does not act at the same place during the tilting up process as it does later, when the frame is already suspended. Therefore, the elimination of torsion during hoisting and placing requires either the transfer of the suspension point on the rocker after the tilting up is finished or the application of a counter weight. Entire frames are precast as a rule, in a horizontal position on the ground close to their final location. They can also be produced in a vertical position standing side by side.



Straight members disunited at point of minimum moment:

In this method is there is any deviation into member at points where the moment are smallest. This method called lambda method in some countries. The recognition of the difficulties met with when carrying out a moment-bearing junction at a place where the moment is greater led to this method. Therefore the junction must be re-sited in places where the moment is smallest.

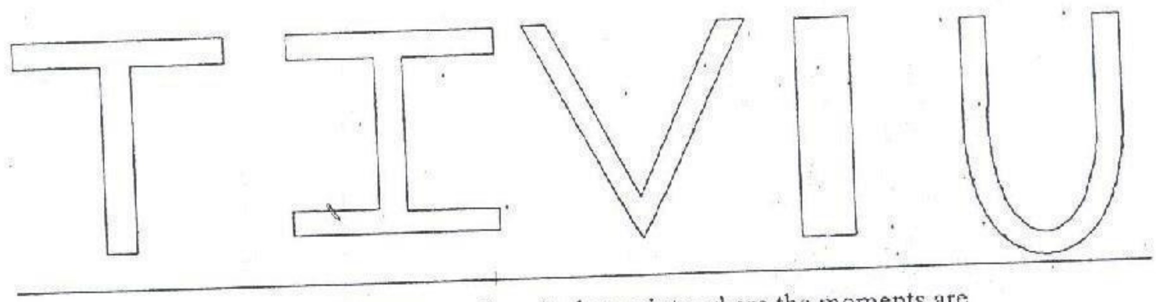


*Fig1.4*System consisting of Structures disunited at points where the moments are smallest Moments

3.5 TRANSPORT AND ERECTION

3.5.1 TRANSPORT

Transport of prefabrication elements must be carried out and with extreme care to avoid any flock and distress in elements and handled as far as possible to be placed in final portion.

Transport of prefab elements inside the factory depends on the method of production selected for the manufacture. Transport of prefab elements from the factory to the site of action should be planned in conformity with the trafficable rules and regulations as stipulated by the authority the size of the elements is often restricted by the availability of suitable transport equipment, such as tractor-am-tailor, to suits the load and dimension of the member in addition to the load carrying capacity of the bridges on the way.

While transporting the prefab elements in various systems, such as wages, trucks, bullock cards etc. care should be taken to avoid excessive cantilever actions and desired supports are maintained. Special care should be taken in negotiating sharp beds uneven of slushy roads to avoid undesirable stresses in elements and in transport vehicles.

Before loading the elements in the transporting media, care should be taken to ensure the base packing for supporting the elements are located at specified portion only.

3.5.2 ERECTION

It is the process of assembling the Prefabrication element in the find portion as per the drawing. In the erection of prefab elements the following items of work are to be carried out.

1). Slinging of the prefabricated elements.

2). Tying up of erection slopes connecting to the erection hooks.

3). Cleaning the elements and the site of erection.

4). Cleaning the steel inserts before incorporation in the joints lifting and setting the elements to correct position.

5). Adjustments to get the stipulated level line and plumb.

6). Welding of deats.

7). Changing of the erection tackles.

8). Putting up and removing the necessary scaffolding or supports.

9). Welding the in sorts laying the reinforced in joints.

The erection work in various construction jobs by using prefab elements differs with risk condition, hence skilled foremen, and workers to be employed on the job.

Equipment's required for erection

Equipment's required for the prefab elements in industry can be classified as.

1) Machinery required for quarrying of course and fine aggregates

2) Conveying equipment, such as but conveyor, chain conveyors etc.

3) Concrete mixers

4) Vibrators

5) Erection equipment such as cranes, derricks, chain pulley etc.

6) Transport machines

7) Work shop machinery for fabricating and repairing steel.

8) Bar straitening, bending and welding machines

9) Minor tools and takes, such as concrete buckets etc…

10) Steam generation a plant for accelerated curing

Planning co-ordination

It is important to have the pre caster erector/installer and builder working together to achieve best performance.

Site Access and storage

- Check for site accessibility and precast panels delivery to site especially low bed trailers

- Check whether adequate space for temporary storage before installation and ground conditions. (firm ground & leveled)
- Uneven ground will cause overstress & crack panels.

Planning crane Arrangement

- Plan the crane capacity and lifting gears based on
- Heaviest weight of precast panels
- Lifting heights.
- Working radius
- Position of crane in relation to final panel location

Plan other equipment's

- Boom lift and scissor lift for unhooking installed panels.
- Lifting gears

Skilled personnel's

- Competent crane operators
- Rigger
- Signaled etc

General considerations for crane selection

- Total lifting weight
- Crane model
- Crane safe working load (SWL) (i.e) Based on 15% capacity build in

  F.O.S. 1.33 o Lifting capacity must be 1.5 times the total weight i.e) F.O.S 1.5
- Lifting and swing radius
- Crane counter eight

- Crane boom length is relation to the vertical and horizontal clearance from the building.

Installation Process

Installation of vertical components Verification of Delivered Panels

- Check the panels delivered for correct marking lifting hook and position etc.
- Surface finishing condition
- Pc Dimension compliance
- Reinforcement Provision/position
- Architectural Detail compliance

1. Setting out

- Check the panels delivered for marking, lifting hook and condition.
- Set the reference lines & grids
- Check starter bars for vertical components before hoisting for installation

2. Setting out Quality control point

- Ensure correct offset line
- Check shim pedal/plate level and firm
- Rubber gasket property secured
- For external wall/column place backer rod.

3. Hoisting, Rigging and Installation

- While tilting provide rubber pad to avoid chip off.
- Lift and rig the panel to designated location
- Adjust the panel in position and secure
- Lifting of space adding items with balanced centre of gravity.

- Ensure horizontal alignment correct
- Ensure panel vertically to correct plumb
- Check panel to panel gap consistency
- Check stability of prop before releasing hoisting cable.

4. Grouting works

- Prepare and apply non shrink mortars to seal
- For corrugated pipe sleeve on spliced sleeve pour NSGT or proprietary grouts into pipe slab.
- Keep installed panels undisturbed for 24 hrs.
- Check joint widths are consistent before grouting
- Grout used should be same grade of components and self compacting to prevent cracking.
- Collect test cube sample for testing for critical element or load bearing elements

5. Connecting joints

- Cast in situ joints install rebars as required
- Set up forms for casting joints
- Do Concreting
- Remove forms after sufficient strength
- For external connections sealant shall be used
- Panel with welded connections welding as required

Installation of Horizontal Elements

1. Setting out

- Set reference line/offset line to required alignment and level of slab/beam during installation
- Put temporary prop to support the precast slab/beam elements
- Before Hoisting chem. Dimensions
- Check level and stability of shim
- Check protruding/ starter bars are within the Specified tolerance to prevent any observation during the erection process

2. Hoisting & Installation

- Put temporary props to support slab/beam
- Lift and rig the elements in designated location
- Align and check the level before placement
- The beams shall prop at least 2 location
- Balcony planter box and shall be supported more than 2 location based on design considerations
- Check level of precast elements

3. Connections/Jointing

- Precast with cast-in-situ joints place the lap rebars as required
- Set formwork for casting joints
- Remove formwork after concrete strength is achieved
- Supporting beams shall be designed to form part of formwork joints
- The connecting/lapping rebars tied & secured
- Same grade of concrete 10 to be used that of pa el.

4. Installation using Big canopy

- Big canopy high rise precast concrete construction system

- This is used for faster and efficient

5. Erection Purpose

- In Japan
- Used to construct the 26 storey pre-cast concrete 30,763m2
- The system realized 60% reduction in labor requirement for the frame erection.
- In Singapore
- DBS China square used the system to erect is efficient and faster

4.1 TYPES OF JOINTS BASED ON ACTION OF FORCES

4.1.1 Compression Joints

Compressive forces can be transmitted between adjacent precast components by a direct bearing or through an intermediate medium such as in-situ mortar, fine concrete, bearing pads or other bearing elements. Direct contact between the elements should be used when a great degree of accuracy in manufacturing and erection needs to be achieved and when the bearing stresses are small. Cementitious materials such as in-situ mortar, fine concrete or grouting are often used in the joints between load-bearing elements in columns and walls as well as for beam and floor elements. The nominal thickness is about 10 to 30 mm for mortar and grout and 30 to 50 mm for fine concrete.

The bedding is usually without any reinforcing bars. The mode of failure is predicated by the crushing of the mortar or splitting of the precast components in contact with it. Although the mortar, grout or fine concrete is in a highly confined state under predominantly plane stress conditions and should achieve a compressive strength higher than f_{cu}, a low design strength is normally used because the edges of the bedding tend to spall off. This will lead to a non-uniform stress distribution. The situation can be exacerbated by poor workmanship, unintentional eccentricity, spurious bending moments, and shear forces. Another fact which leads to a reduction of the joint strength is when there is a great difference in the elastic response between the bedded material and the precast concrete, which may result in localized contraction, lateral tensile stress, and splitting forces. This effect may become important when the joints thickness is greater than 50 mm.

The position of the support reaction must be accounted for eccentricities due to rotation and tolerances. The rules for this are given in Eurocode 2 (STN EN 1992-1-1, 2015). The basic dimensions of the bearing should be determined such that the stress under the bearing is limited to that of the strength of the bearing material and that of the concrete in the connected components.

Advantages

- Simple and quick to install.

- Panel edges can be plain or simple profiles.
- Economical.

Disadvantages

- Cannot be fully weatherproof, so limited to low-rise industrial buildings.
- Joint width is critical.
- Maintaining compression on the seal at the intersection of horizontal and vertical joints is difficult.
- Difficult to maintain and/or replace.
- Time-consuming while erecting.

4.1.2 Tensile Joints

The connections with the tensile capacity are often part of the overall tying system that should provide structural integrity and prevent progressive collapse. Such a connection should be designed and detailed to have a ductile behavior. Premature brittle failures must be avoided and it should be possible to obtain a rupture of the ductile components of the connections (fib Bulletin, 2008). Tensile forces are transferred between the concrete by means of various types of steel connectors that are anchored to each side of the elements at the joint with a continuity achieved by the overlapping of steel bars, dowel action, bolting or welding. The tensile capacity of the connection can be determined by either the strength of the steel elements or by the anchorage capacity.

4.1.3 Shear Joints

Shear forces can be transferred between concrete elements by adhesion or friction at a joint interface, a shear-key effect at indented joint faces, the dowel action of transverse steel bars, pins and bolts, etc. Shear keys are generally formed by providing the precast members with indented joint faces. The shear keys work as mechanical locks, thereby preventing any significant slip along the joint. Shear keys must fulfill certain minimum requirements concerning the length, depth and inclination of the tooth. Such minimum requirements are given in code and design rules (fib Bulletin, 2008).

A shear transfer by bond between precast and in-situ elements is possible, when the shear stress is low. It is not necessary to deliberately roughen the surface texture of precast units beyond the as-cast finish, which may be of a slip-forming, extrusion or tamped finish. Shear transfer by shear friction requires the presence of a permanent normal compressive force. The force may arise from permanent gravity loads, by prestressing or be artificially induced by reinforcement bars placed across the joints. Shear keys for the transfer of shear forces between elements are obtained by cast in-situ concrete or grout in joints between the elements which surface castellations. Under the action of a shear load, the shear keys act as mechanical locks that prevent significant slips at the interface.

4.2 TYPES OF JOINTS BASED ON FUNCTION

Types of joints in concrete constructions are:

1. Construction Joints
2. Expansion Joints
3. Contraction Joints
4. Isolation Joints

Construction Joints in Concrete:

Construction joints are placed in a concrete slab to define the extent of the individual placements, generally in conformity with a predetermined joint layout.

Construction joints must be designed in order to allow displacements between both sides of the slab but, at the same time, they have to transfer flexural stresses produced in the slab by external loads.

Construction joints must allow horizontal displacement right-angled to the joint surface that is normally caused by thermal and shrinkage movement. At the same time they must not allow vertical or rotational displacements. Fig.1 summarizes which displacement must be allowed or not allowed by a construction joint.

Fig. 1

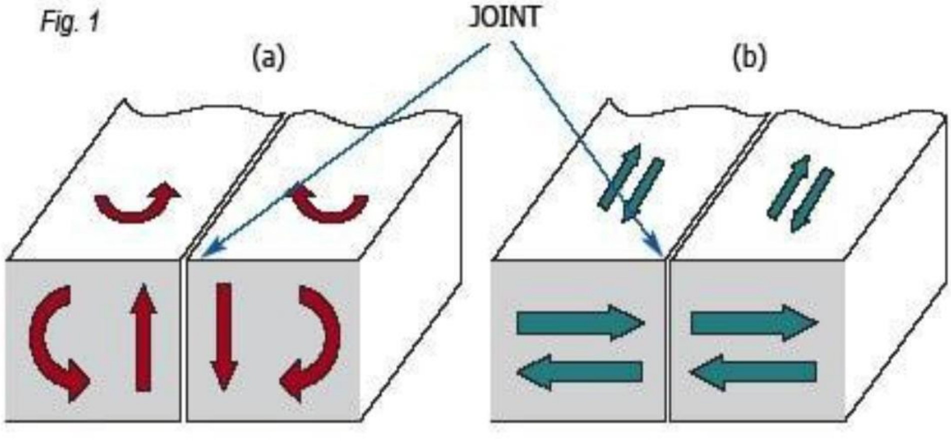
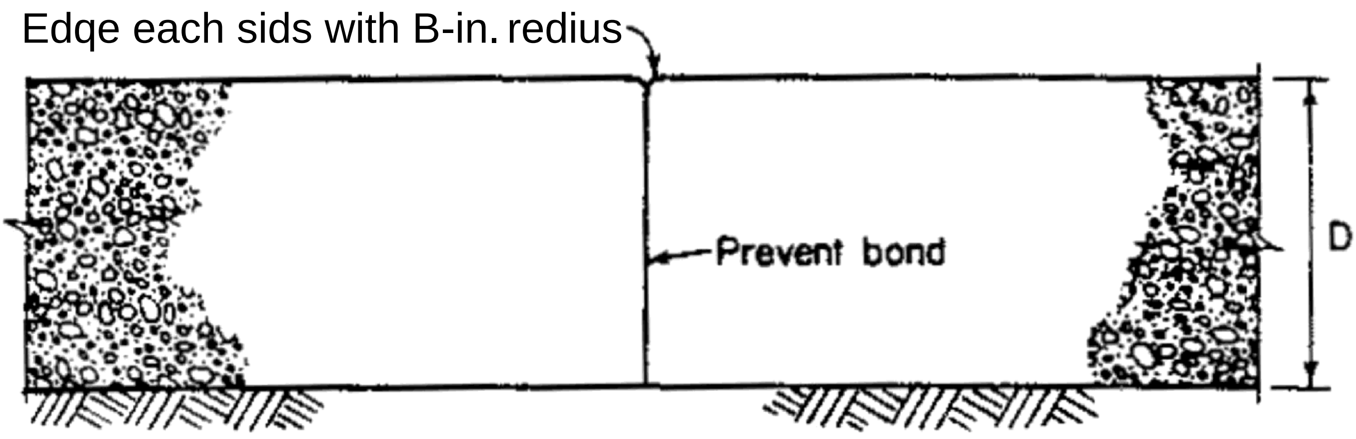
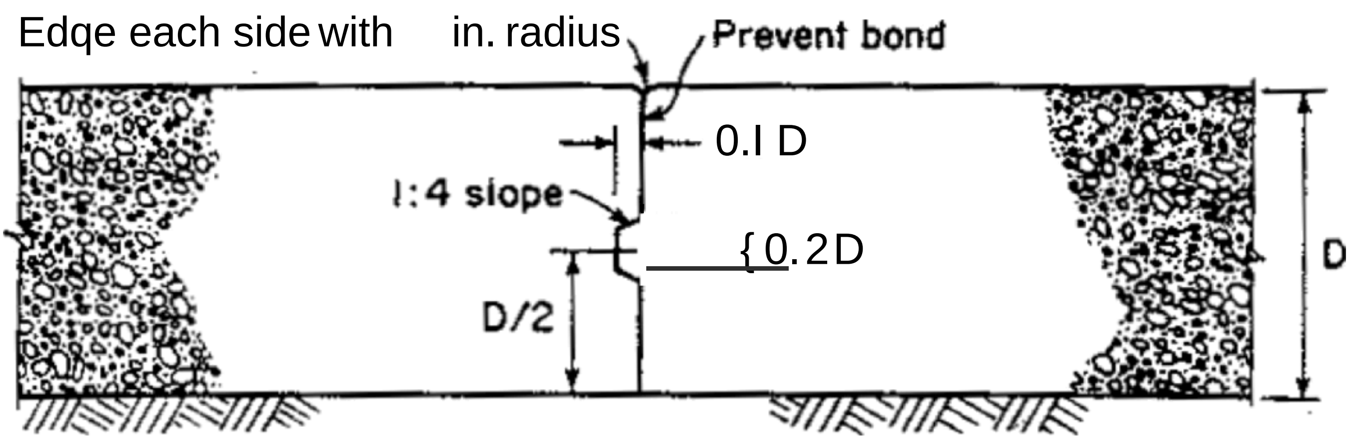


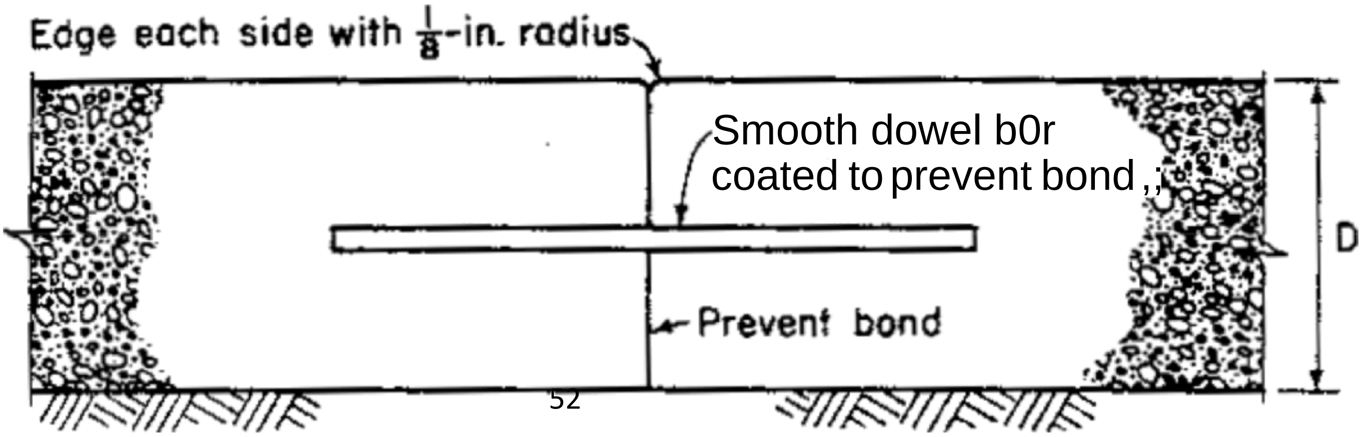
Figure 1 – Relative movements which must be (b) allowed and (a) not allowed by a con-struction joint for concrete slabs



Butt-type construction joint



Tongue-and-groove construction joint



Butt-type6 construction joint with dowels

Expansion joints in Concrete

The concrete is subjected to volume change due to many reasons. So we have to cater for this by way of joint to relieve the stress. Expansion is a function of length. The building longer than 45m are generally provided with one or more expansion joint. In India recommended c/c spacing is 30m. The joints are formed by providing a gap between the building parts.

Contraction Joints in Concrete

A contraction joint is a sawed, formed, or tooled groove in a concrete slab that creates a weakened vertical plane. It regulates the location of the cracking caused by dimensional changes in the slab.

Unregulated cracks can grow and result in an unacceptably rough surface as well as water infiltration into the base, sub base and sub grade, which can enable other types of pavement distress.

Contraction joints are the most common type of joint in concrete pavements, thus the generic term joint‖ generally refers to a contraction joint. Contraction joints are chiefly defined by their spacing and their method of load transfer. They are generally between 1/4 – 1/3 the depth of the slab and typically spaced every 3.1 – 15 m

Isolation Joints in Concrete

Joints that isolate the slab from wall, column or drainpipe

Isolation joints have one very simple purpose they completely isolate the slab from something else. That something else can be a wall or a column or a drain pipe. Here are a few things to consider with isolation joints:

- Walls and columns, which are on their own footings that are d p than the slab sub grade, are not going to move the same way a slab does as it shrinks or expands from drying or temperature changes or as the sub grade compresses a little.

Even wooden columns should be isolated from the slab.

- If slabs are connected to walls or columns or pipes, as they contract or settle there will be restraint, which usually cracks the slab—although it could also damage pipes (standpipes or floor drains).
- Expansion joints are virtually never needed with interior slabs, because the concrete doesn't expand that much—it never gets that hot.
- Expansion joints in concrete pavement are also seldom needed, since the contraction joints open enough (from drying shrinkage) to account for temperature expansion. The exception might be where a pavement or parking lot are next to a bridge or building— then we simply use a slightly wider isolation joint (maybe ¾ inch instead of ½ inch).
- Blowups, from expansion of concrete due to hot weather and sun, are more commonly caused by contraction joints that are not sealed and that then fill up with non- compressible materials (rocks, dirt). They can also be due to very long un jointed sections.
- Very long un jointed sections can expand enough from the hot sun to cause blowups, but this is rare.
- Isolation joints are formed by placing preformed joint material next to the column or wall or standpipe prior to pouring the slab. Isolation joint material is typically asphalt- impregnated fiberboard, although plastic, cork, rubber, and neoprene are also available.
- Isolation joint material should go all the way through the slab, starting at the sub base, but should not extend above the top.
- For a cleaner looking isolation joint, the top part of the preformed filler can be cut off and the space filled with elastomeric sealant. Some proprietary joints come with removable caps to form this sealant reservoir.
- Joint materials range from inexpensive asphalt-impregnated fiberboard to cork to closed cell neoprene. Cork can expand and contract with the joint, does not extrude, and seals out water. Scott White with APS Cork says that the required

performance is what determines the choice of joint materials. How much motion is expect, exposure to salts or chemicals, and the value of the structure would all come into play—and of course the cost.

- At columns, contraction joints should approach from all four directions ending at the isolation joint, which should have a circular or a diamond shaped configuration around the column. For an I-beam type steel column, a pinwheel configuration can work. Always place the slab concrete first and do not install the isolation joint material and fill around the column until the column is carrying its full dead load.

Requirements of joints

a. The joints should be leveled
b. The joints should be perfectly rigid
c. The joints should posses sufficient strength a d fitness
d. The joints should get sufficient yield strength
e. The joints should be provided rich mortar (or) concrete compared with joining member
f. The joints should be plumb checking
g. The module of the joint should be checked
h. The dowel rod must be welded with main members
i. Sufficient stirrups should be provided for beam members
j. Sufficient lateral ties should be provided for beam members

4.3 DESIGN OF EXPANSION JOINT

Joint Techniques:

The joint technique is a vital role for prefabricated structures. The joint mechanism is implemented to prefabricated elements. In case of dry joint the joint is under the category of bolting and welding .The bolted or welded connection should be designed properly with economical consideration. In case of wet joint the joint is in situ concrete. The in situ concrete should be in rich mortar.

Design of expansion joint

1. The expansion joint are provided to accommodate movements of thermal expansion
2. To avoid the cracks expansion joints should be provided
3. The thermal are formed due to summer seasons and the precast member will expand behind the original dimension. This cause the cracks will be developed in the prefabricated structures
4. Hence to avoid the formation of cracks expansion joint should be provided in the prefabricated structures

Spacing's of Expansion joints

SI.NO	TYPE OF WALL	MAX SPACING IN METRE
1	Large Block	35
2	Curtain Wall	80
3	Large panel (homogeneous)	45
4	Large panel (non-homogeneous)	60

5. AS per NBC the structures which are more than 20m the expansion joint must be provided the material are used for expansion joints bitumen with mineral , filler and cork strip. The expansion joint is protected by a sealing compound at the top against intrusion. The building is commonly separated the structure. The welded joints between the panels which permits the rotation.

The exposed roof elements are higher expansion produced the materials are also expanded. The common building material, linear co-efficient of thermal expansion are given below

SI.NO	MATERIALS	CO-EFFICIENT α ,10^{-4} PER ^{0}C
1	Gravel	13
2	Brick	5
3	Concrete	8
4	Clinker	6
5	Blast furnace slag	11
6	Expanded clay	10
7	Lime stone	10
8	Expanded shale	10
9	Prelate	11
10	Vermiculite	14

Design procedure for expansion joint

Expansion joint must be sized to accommodate the movements of several primary phenomena imposed upon the bridge following installation of its expansion joint devices. Concrete shrinkage, thermal variation, and long term creep are the three most common primary sources of movement.

Calculation of movements associated with each of these phenomena must include the effects to super structure type, tributary length , fixity condition between super structure, sub structure and pear flexibilities.

a) Shrinkage effects

Accurate calculation of shrinkage as a function of time requires that average ambient humidity, volume to surface ratios and curing methods to be taken in consideration as summarized, because expansion joint devices are generally installed in their respective block at least 30 to 60 days following concrete deck placement, they must accommodate only the shrinkage that occurs from that time onwards. For most situations, that shrinkage strain can be assumed to be 0.0002.For normal weight concrete is an unrestrained condition .This value must be corrected for restrained condition imposed by various super structure types

$\Delta shrink = \beta.\mu .Lt$

Where

L_t =Tributary length of the structure subjected to shrinkage

β = ultimate shrinkage strain after expansion joint installation estimated as 0.0002 of more refined calculations

μ = restrained factor accounting for the restraining effect imposed by superstructure element installed before the concrete slab is cast =0.1 for steel girders ,0.5 for precast prestressed concrete girders ,0.8 for concrete box girders and T beam ,1.0 for flat slabs.

b) Thermal effects:

Bridges are subjected to all modes of heat transfer, radiation, convection and conduction. Each mode affects the thermal gradients generated in a bridge superstructure differentially. Climate influences vary geographically resulting in different seasonal and average properties.

Example:

A massive concrete box girder bridge will be much slower to respond to an imposed thermal situation, particularly diurnal variation than steel plate Girder Bridge composed of many relatively thin steel elements.

Variation in superstructure average temperature produces elongation and shortening .Therefore thermal movement ranges calculated using a maximum and minimum anticipated bridge. Super structure average temperature anticipated during the structures life time. The consideration in the proceeding have led to the following temperature guide lines

Concrete bridges	0^0 F to 100^0 F
Steel bridges	30^0 F to 120^0 F

Total thermal movement range is calculated as

$$\Delta temp = \alpha.\ Lt.\ .\ \partial\ T$$

Where

L_t =Tributary length of the structure subjected to thermal variation

α= Co-efficient of thermal expansion 0.000006 in /^{0} F for concrete and 0.0000065 in /^{0} F

∂_{T}= Bridge superstructure average temperature ranges as a function on bridge type and location Generally these settings are specified for temperature of 40^0 F , 64^0 F and 80^0 F

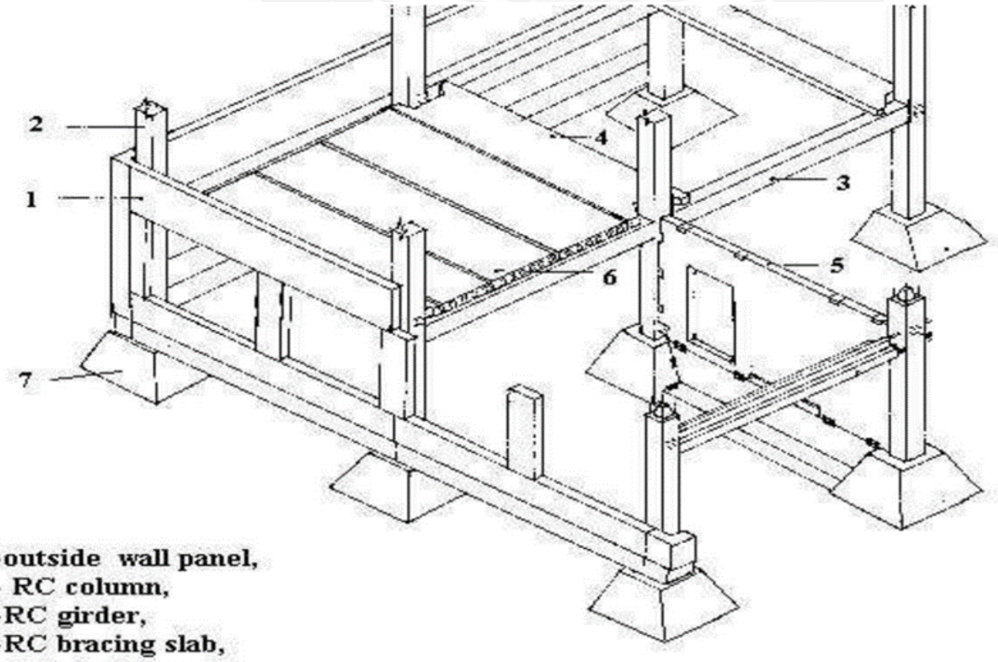
4.4 TYPES OF STRUCTURAL CONNECTIONS

Joints for different structural connections:

- Jointing of column to footing
- Jointing of column to beam on top of column.
- Jointing of column to beam at an intermediate functions.
- Lengthening of columns.
- Jointing of beams.
- Forming of joints of arched structure.
- Joining of joints of post tensioned structures.
- Joining of precast to monolithic reinforced concrete structures.

(a) JOININNG COLUMNS TO FOOTING:

This joint is usually rigid but also can be hinge. A rigid joint can be made by placing the column into a calyx of the footing or by using a welded joint. The figure shows the three variations of this method. Can be used for smaller, For average, For large footings



1-outside wall panel,
2- RC column,
3-RC girder,
4-RC bracing slab,
5- RC diaphragm,
6- RC ceiling slab,
7- RC foundation

The depth of the calyx is dimensioned according to the long or side length of the column. The depth of the calyx should be equal to 12.5% of the length of the column.

The opening of the calyx is 6-10 cm greater in all direction than the class of the column. This is enabling the vibrator to be operated while concreting at the bottom of the calyx of checked by leveling before concreting.

A similar steel plate is also put on the lower end of the column when positioning the column. These two steel plates must be on each other. The dimensions of these steel plates are frame 100x100x10 to 150x150x10 mm a chord into the concrete after the column is put in placed properly plumbed two advantages of the calyx joint should be mentioned.

1. The placing plumbing and fixing of the column as well as the subsequent filling of the calyx with concrete is for simpler and requires less time than in the case of a welded joint.
2. The method is least sensitive to inaccuracies occurring during the construction. The disadvantages of the calyx joint are more suitable for small columns. In the case of large columns requiring calyx depth of which is greater than 1 m.

(b) JOINING OF COLUMN TO BEAM AT AN INTERMEDIATE UNCTION:

One method of forming a hinge like joint consists either or placing to beam on to a small cantilever protracting frame the column or of putting it on the bottom of an adequately shaped opening left out of the column shaft.

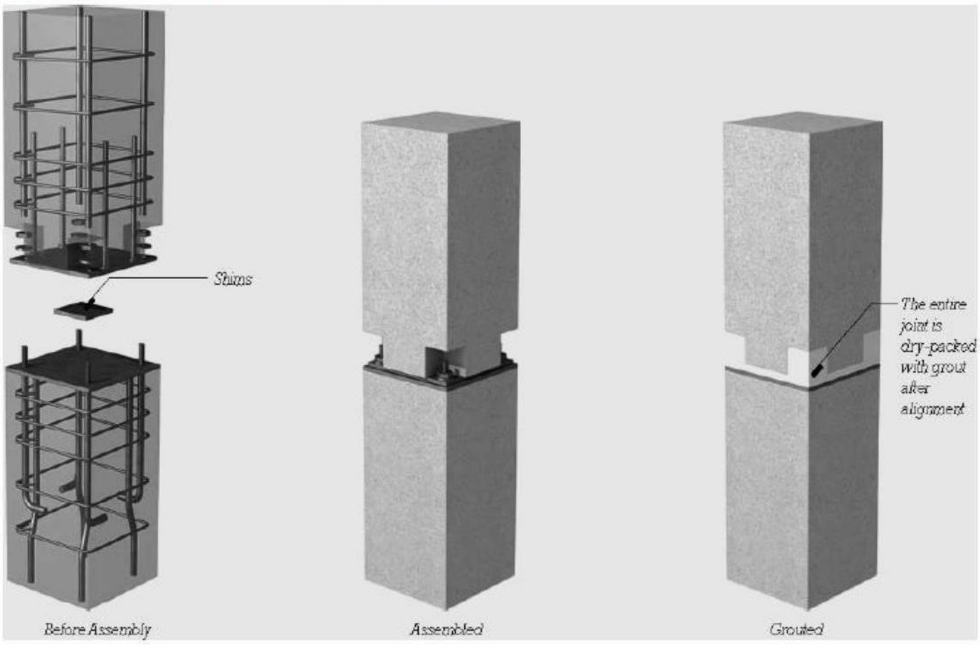
The beam rests temporarily on a tongue like extension on a steel plate placed in this opening on the supporting surface the tongue is also furnished with a steel plate anchored into the concrete The other parts of the tongue are supported after the placing has been finished with concrete cast through an opening left for this purpose.

Hinge like joining of girder to column:

1. Opening for casting.

2. Subsequent concreting.

3. Steel plate.



(c) LENGTHNING OF COLUMNS:

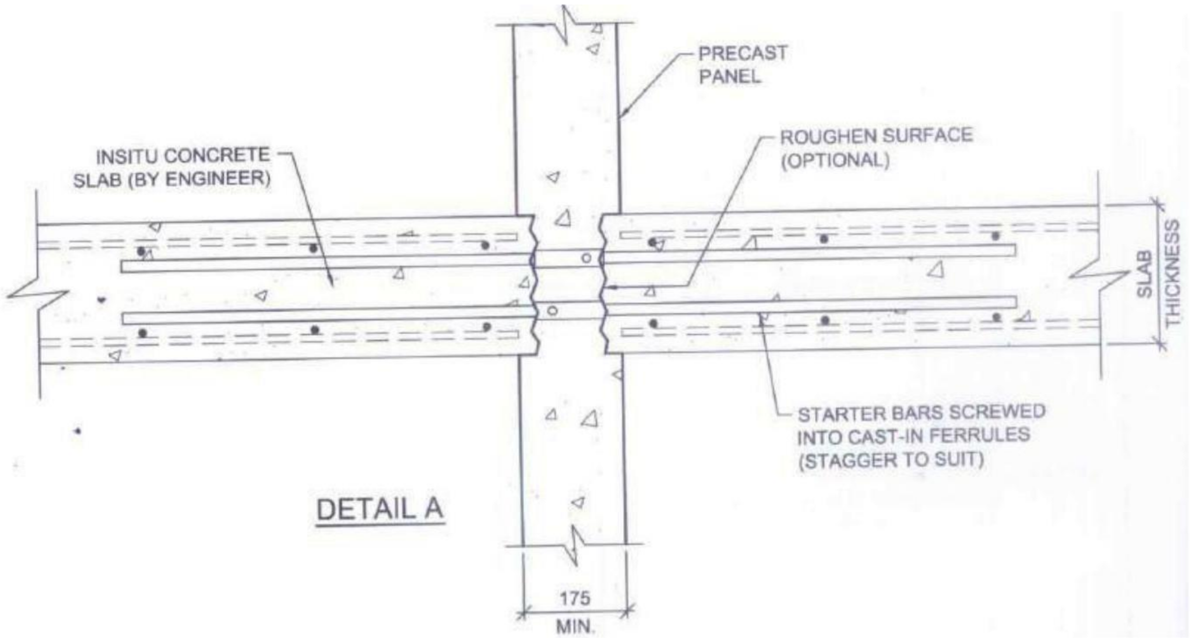
Columns are usually lengthened at floor levels. An intermediate lengthening should be avoided it possible.

The lengthening of columns can be executed similarly to the joining with footing, accordingly the upper columns rests on the lower ones by a tongue like extension. The steel bars of the main reinforcement are joined by overlapping looped steel bars a welding. There after the stirrups have to be placed of finally the joint must be concreted.

(d) JOINING OF BEAMS:

The functions of beams can be affected either by overlapping the protracting steel bars or by welding them together.

Fig. shows the hinge like joint of purlins. In this method the whole shear must be born by both cantilevers (i.e.) by two separate structures therefore it is expedient to form this joint at least for large girders.



The method illustrated in the fig presents a dry joint of beams which is called a bolted front. The advantages of this joint are immediate bearing capacity.

(e) FORMING OF FUNCTIONS OF ARCHED STRUCTURES:

Precast arches are usually produced and assembled in the form of three hinged structures. When the constant load has already been applied the centre joint is frequently eliminated. The omission of the centre joint increases the rigidity of the structures. Naturally arched structures can also be precast in a piece i.e. in the form of two hinged ones.

Hinges of arched structures can be made by using either steel shors are more expensive, but the centre transmission of forces is enhanced by their use of forming of joints on an arched structure.

The arrangement of the Centre junction and the end hinge of an arched structure. This method was used in the construction of the hall for the middle rolling train in D.O.Sgyor. The structure was precast of assembled in the form of a three-hinged arched transformed latest into a two-hinged one.

(f) DESIGN OF JOINTS FOR POST TENSIONED STRUCTURES:

Post tensioned structure can generally be joined for more simply then the usual reinforced concrete structures, by using post tensioning it can be ensured that in the entire structure. The joints included only compressive can develop consequently the problem of joining can be solved in a very easy manner namely by placing plane surfaces side by side and then filling the gaps with cement mortar by so doing longer beams can also be produced from shorter precast member. Thus is post tensioned structures the forming of joints does not cause difficulties.

Sketches on solution of principles relating to the joining of post tensioned structure are to be illustrated in the fig. all these joints are of course rigid and moment bearing. It is not permissible for the mortar which is to be poured into the ducts of the stressing cables to avoid this cable ducts are joined by placing a shore piece of tube or rubber ring into the duct itself.

(g) JOINING OF PRECAST TO MONOLITHIC REINFORCED CONCRETE STRUCTUR S:

It frequently occurs that a monolithic beam has to be joined to a precast column.

In this case the function can be established in the same way as already been described in the previous paragraph an joining namely by placing the end of the beam either on to a cantilever protruding from the column or into an opening formed i to the columns shaft.

When making the joint, first of all a 2.5 cm deep cavity is chiseled out of the sole of the precast column. The bottom of this cavity should be roughen d so as to

attain a belter band between the concrete of the monolithic beam and the precast column.

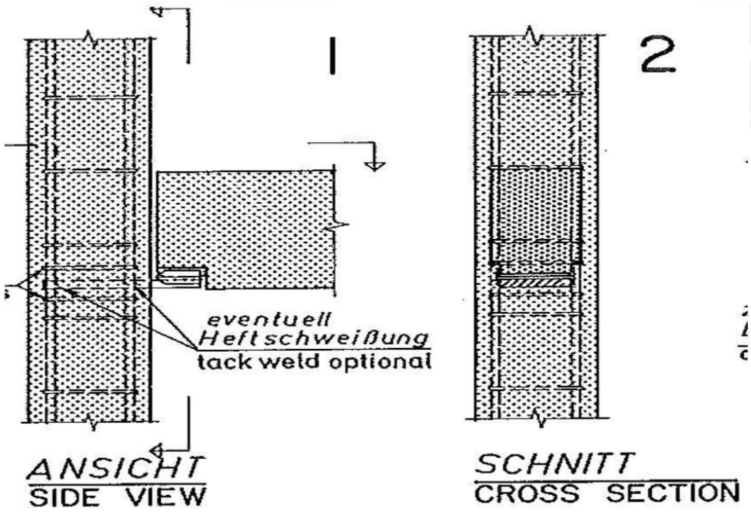
4.5 BEAM TO COLUMN CONNECTION

Various Types Of Connections

- Beam To Column Connection With Steel Plate Corbel
- Beam To Column Connection With Angle Corbel
- Beam To Column Connection With Built Up Steel Corbel
- Beam To Column Connection With Steel Joist Corbel, Encased In The Beam
- Beam To Column Connections With Vertical Steel Bearing Plates
- Beam To Column Connection With Concrete Corbel
- Beam To Column Connection With Steel Joist Hanger
- A Beam column joint is said to be desirable if it is able to transmit large amount of vertical shear forces.
- Depending on the type of bearing and the size of the bearing surface, different beam column joints will be able to transmit various magnitudes of vertical shear force.

BEAM TO COLUMN CONNECTION WITH STEEL PLATE CORBEL

- The beam is supported on a horizontal steel bearing plate which is cast into the column and is tack welded to the main reinforcing bars

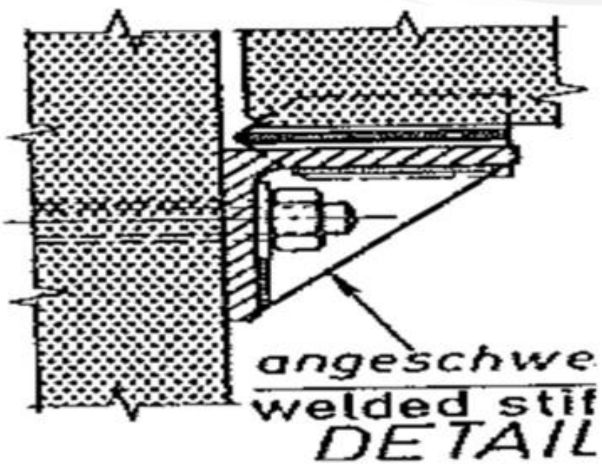


- This connection for SSB beams may be considered if the vertical shear force is very small

- The plate should have sufficient thickness to prevent it from bending. In determining the thickness, the maximum cantilever moment may be assumed to occur at the column reinforcing bars.
- To avoid point bearing ,special care should be taken to install the beam perpendicular to column face.
- For lateral location of the beams ,saddle plates may be used.
- The bearing plate must be provided with permanent protection against corrosion and against fire.

BEAM TO COLUMN CONNECTION WITH ANGLE CORBEL

- This connection for SSB when carried out according to variant ―A‖ is only able to transmit small vertical shear force and could be generally considered only for temporary structures
- **VARIANT "A"**
- In variant A the angles are connected with the horizontal flange up and by mild steel bolts
- Point bearing on the column face can be avoided by applying an epoxy layer at the interface with the vertical angles just prior to placing the angles

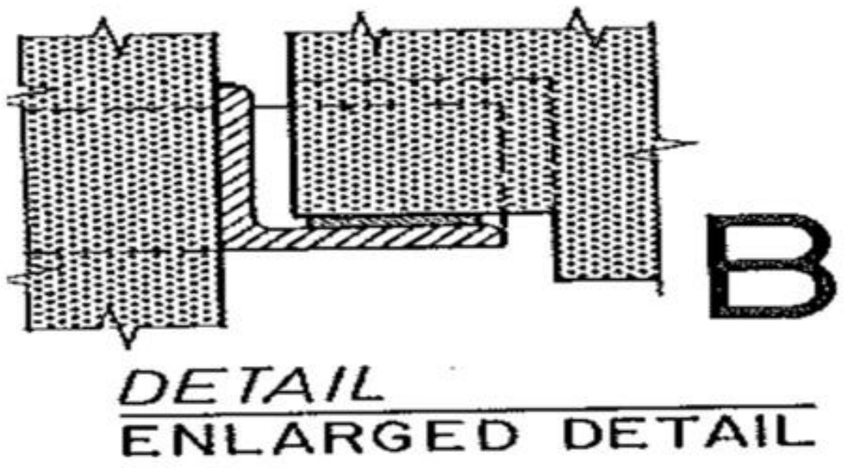


- The entire corbel construction should be prefabricated and must be cast in which makes manufacture of corbel more complicated

- This should not be considered for fire proof buildings.

VARIANT “B”

- In variant B ,the angles with the horizontal flange down are connected by vertical flat bars welded to the ends of the angles.
- In the column ,the bearing surface is increased by horizontal flat bars welded to the undersides of vertical flat bars.
- Ensures a better anchorage and greater stiffness of the corbel and lateral location of the beams.



BEAM TO COLUMN CONNECTION WITH BUILT UP STEEL CORBEL

- This connection for SSB will be able to transmit a large vertical shear force.
- The beams are supported on a built up steel corbel which is cast into the column.

VARIANT A

- In variant A the corbel consists of two vertical flat bars to which the horizontal bearing plates are welded
- In column the bearing surface is increased by horizontal flat bars welded to the undersides of the vertical flat bars.
- The max B.M in the vertical flat bars is assumed to occur over the centre of the horizontal connection plates.

VARIANT B

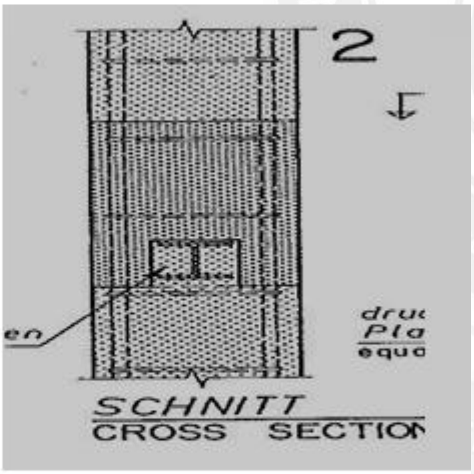
- The corbel consists of two vertically placed channels to which, outside the column horizontal bearing plates are welded
- An additional tie must be provided immediately under the corbel, in an end column also above the corbel to counteract the splitting forces

BEAM TO COLUMN CONNECTION WITH STEEL JOIST CORBEL, ENCASED IN THE BEAM

- This connection for SSB can depend the size of the bearing surface, transmit a fairly large vertical shear force.
- In this case the beams are supported on a steel joist corbel which extends into a recess in the end of the beam.

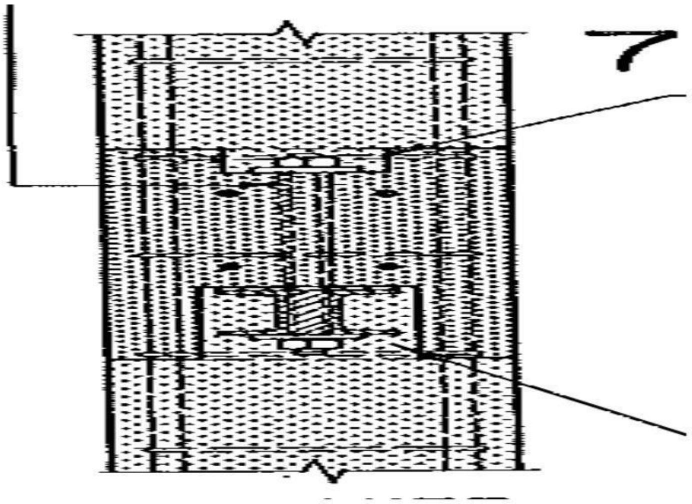
VARIANT A

- The corbel is formed by a cast-in broad flange rolled steel I section.
- Additional tie is provided to counteract the splitting forces.



VARIANT B

- Could be considered if the beams must also be located vertically.
- The corbel consists of two rolled steel I sections with splice plates welded in between the webs, so that the bolts can pass through a hole in the beam.
- Additional tie under the corbel to counteract the splitting forces.
- Corbel must be provided with a permanent protection against corrosion and fire



BEAM TO COLUMN CONNECTIONS WITH VERTICAL STEEL BEARING PLATES

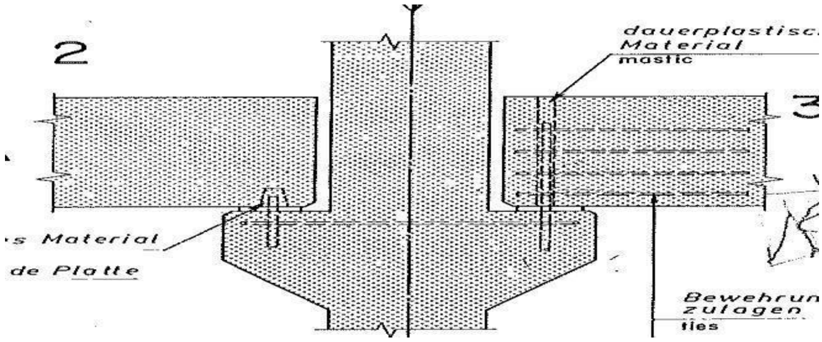
- The beams are supported on vertical steel plates against the column faces. The beam ends are also provided with a vertical steel plate.
- The entire bearing construction is contained within the beam section.
- This connection will be able to transmit large vertical shear force. Due to limited bearing surface this connection should be considered only for short beams.
- Anchorage of steel plates must not only cater for transmission of vertical shear but also prevent the plates from being pulled out.
- To avoid point bearing ,care must be taken to install the bearing plates perpendicular to the column face
- Disadvantage is that only very small tolerances can be allowed. Temporary safety measures during erection are necessary and permanent stability after erection is required.

BEAM TO COLUMN CONNECTION WITH CONCRETE CORBEL

- The beams are supported on concrete corbels
- This connection is generally applied to simply supported beams

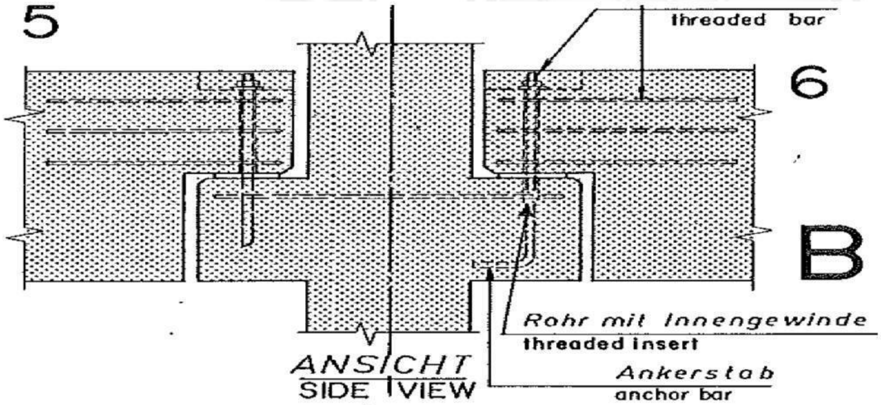
VARIANT A

- The concrete corbels protrude under the beams.



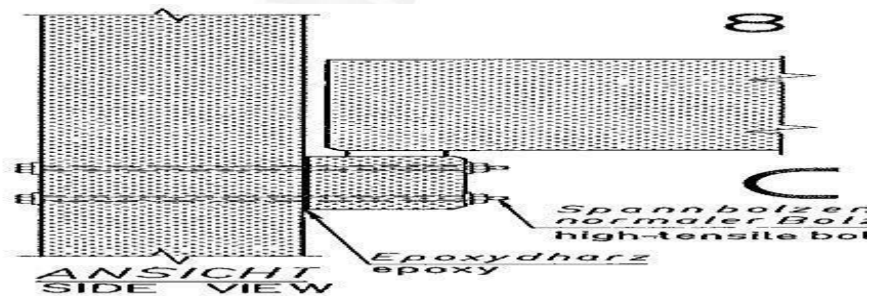
VARIANT B

- The beams have notched ends and are supported on corbels.
- The notched ends must be reinforced against the vertical shear force and also against torsion if it is eccentrically loaded.



VARIANT C

- Columns are provided with concrete corbels which are bolted to the column



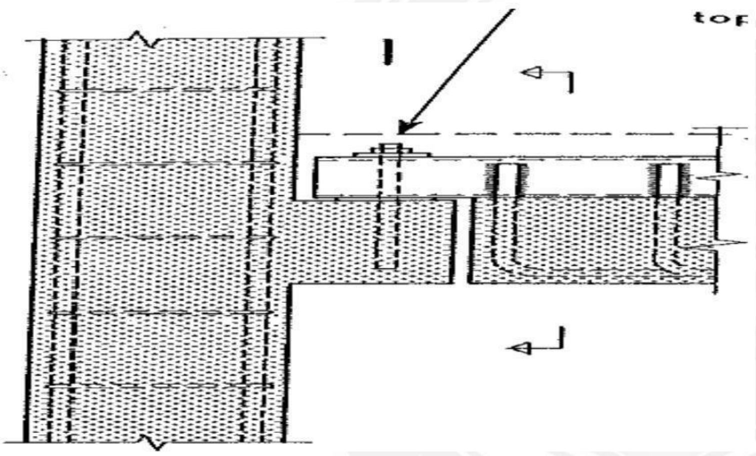
faces.

- It is advisable to use high tensile bolts and provide an Epoxy layer at the column a d corbel interface. The bolts and nuts must have permanent protection against corrosion and fire.

- To prevent the beams from toppling, beam and column interface could be shaped to form a tongue and groove joint.

BEAM TO COLUMN CONNECTION WITH STEEL JOIST HANGER

- Beams are supported by means of steel joist hangars on concrete corbels.
- This connection is suitable for limited construction depths.
- The hangar construction must be designed to transmit the total vertical shear force. Since the connection cannot transmit torsion, it is unsuitable for edge beams.



- The hanger construction consists of two vertical channels with flanges facing each other which are welded to anchor bars projecting from top of beam
- During erection, these channels are placed on an equalizing pad on top of the corbel.
- The beam is secured vertically and laterally by tightening a nut with washer on a bolt which projects from the corbel through the slot in between the channel flanges.

5.1 PROGRESSIVE COLLAPSE

Progressive collapse can be defined as collapse of all or a large part of a structure by failure or damage of a relatively small part of it.

The general services administration (GSA, 2003b) offers a somewhat more specific description of the phenomenon progressive collapse is a situation where local failure of a primary structural component leads to the collapse of adjoining member which in turn leads to additional collapse.

It has also been suggested that the degree of progressivity in a collapse be defined as the ratio of total collapsed area or volume to the area or volume damaged or destroyed directly by the triggering event.

Avoidance of progressive collapse.

- Progressive collapse occurs when a key member or member of a structure fail.
- The isolated failure of this key member or section then initiates a sequence of events, coursing failure of the entire structure
- Provides a solid exterior surface to meet blast resilience requirements. Minimizes cost to fix a damaged area compared to a steel framed building.
- Eliminates perimeter stell leading to greater interior space planning flexibility.

progressive collapse in abnormal loads.

In the assessment of a particular structure with regard to its collapse resistance, the following design criteria are of importance;

a. Requirements
b. Design objectives
c. Design strategies
d. Verification procedures

First the requirements, particularly the question if collapse resistance is necessary.

should he clarified. The necessity depends on the structure's significance with respect to the consequences of a collapse, including the immediate material and immaterial losses but also indirect effects, e.g., the possible impairment of the infrastructure and of civil and national defense_ Another criterion for the determination of requirements is the structure's degree of Exposure to hazards of war, malicious action, and natural disasters. The exposure can be considered particularly high for public buildings, major bridges, and other lifeline structures, If collapse resistance is deemed necessary, the following design objectives must be specified:

1. Assumable extent of accidental circumstances
2. Assumable extent of initial local failure
3. Acceptable extent of collapse progression
4. Acceptable extent of damage to the remaining structure
5. Applicable load combinations and safety factors

The following design strategies to prevent progressive collapse are mentioned in the literature and have at least partially made their way into-the design codes:

1.High safety against local failure

1.1. Specific local resistance of key elements (direct design)

1.2. Non-structural protective measures (event control)

2. Design for load case "local failure' (direct design)

2.1. Alternate load paths

2,2. Isolation by compartmentalization

3. Prescriptive design rules (indirect design)

These methods are further discussed in Section 4 below. The prediction of the structural behavior following a local failure requires suitable verification procedures Accurate analysis will require a high degree of expertise and modeling effort. Thus, development and validation of simplified but admissible verification methods would be a worthwhile undertaking. The design criteria I. to IV. Listed above are to date only partially addressed in codes and guidelines. As far as applicable design criteria are not available in codified form, they should be agreed upon by the contracting and other affected parties or established by the building authorities. It is anticipated that the design criteria can only partly be developed from first principles and reliability theory.

There will remain necessity for judgment and a decision-making process, most notably when stipulating the acceptable extent of collapse progression. On the other hand, the choices to he made here are relatively transparent—at least when compared to the choice of a safety index 13 so that an informed societal consensus is in principle possible (even when that consensus leads to the conclusion that certain kinds of structures should better not be build).

5.2 CODAL PROVISIONS

CODES AND STANDARDS

ASCE 7-02

The American society of civil engineers minimum design load for buildings and other structure (ASCE,2002) has a section on general structure integrity that reads thus building and other structures Shall be design d to sustain local Damage with the structural system as a whole remaining stable and not being damaged to an extent disproportionate to the original local damage.

This shall be achieved through an arrangement of the structural element That provides stability to the entire structural system by transferring loads from Any locally damaged region to adjacent regions capable of resisting those Loads without collapse.

This shall be accomplished by providing sufficient continuity , redundancy, or energy-dissipating capacity (ductility) or a combination there of in a members of the structure clearly the focused in the ASCE standard is on redundancy and alternate load paths overall other means of avoiding susceptibility to disproportionate collapse. But the degree of redundancy is not specified and the requirements or entirely threat - independent

ACI 318-02

The American concrete institution building code requirement for structural concrete (ACI, 2002) include extensive requirement for structural integrity in the chapter on reinforcing steel details. Though the commentary states that it is an intend of This section...to improve 6 redundancies there is no explicit mention of redundancy or alternate load paths in the code.

The code provisions include a general statement that "In the detailing of reinforcement and connections members of a structure shall be effectively tied together to improve integrity of overall structure" and many specific prescriptive requirements for continuity of reinforcing steel and interconnection of components.

There are additional requirements for the typing together of precast structural components. None of the ACI provisions are threat specific in anyway.

GSA PBS Facilities Standards 2003

The 2003 edition of the GSA'"s facilities standards for the public buildings service (GSA, 2003 a) retained the "Progressive Collapse" heading from the 2000 edition.

GSA Progressive Collapse Guidelines 2003 GSA Progressive Collapse Analysis and Design Guidelines for new federal of his buildings and major Modernization Projects (GSA, 2003b) begin with a process for determining whether a building is exempt from progressive collapse considerations.

Exemptions based on the type and size of the structure (for instance, any building of over 10 stories is non- exempt) and is unrelated to the level of threat.

Typical non-exempt buildings in steel are concrete have to be shown by analysis to be able to tolerate removal of one column of o e-30 ft length of bearing wall without collapse. Considerable detail is provided regarding the features of the analysis and the acceptance criteria.

GSA Progressive Collapse Guidelines 200

The GSA Progressive collapse analysis and design guidelines for new federal office buildings and major modernization projects(GSA,2003b) begins with a process for determining whether a building is exempt from Progressive Collapse considerations. Exemption is based on the type and size of the structure (for instance any building of over 10 stories is non-exempt) and is unrelated to the level of threat.

Typical non-exempt buildings in steel or concrete have to be shown by analysis to be able to tolerate removal of one column or one-30 ft length of bearing wall without collapse.

Considerable detail is provided regarding the features of the analysis and the acceptance criteria.

5.3 EQUIVALENT DESIGN LOADS WHEN THE STRUCTURE IS SUBJECTED TO EARTHQUAKE LOADING.

The seismic loads on the structure during an earthquake result from inertia forces which were created by ground accelerations. The magnitude of these loads is a function of the following factors: mass of the building, the dynamic properties of the building, the intensity, duration, and frequency content of the ground motion, and soil-structure interaction.

In recent years, a lot of achievements have been made to incorporate these influential factors into building codes accurately as well as practically. The basis for IBC 2000 seismic provisions is the 1997 NEHRP "Recommended Provisions for the Development of Seismic Regulations for New Buildings and Other Structures" (FEMA 302).

The National Earthquake Hazard Reduction Program (NEHRP) is managed by the Federal Emergency Management Agency (FEMA),In IBC 2000, the seismic loads are on a strength level limit state rather than on a service load level, which was used in UBC 94 and prior versions. The seismic limit state is based upon system performance, not member performance, and considerable energy dissipation through repeated cycles of inelastic straining is assumed.

Criteria Selection

In IBC 2000, the following basic information is required to determine the seismic loads:

I. Seismic Use Group According to the nature of Building Occupancy, each structure is assigned a Seismic Use Group (I, II, or III) and a corresponding Occupancy Importance (1) factor (1 E 1.0, 1.25, or 1.5).Seismic Use Group I structures are those not assigned to either Seismic Use Group H or III. Seismic Use Group 11 are structures whose- failure would result- in a substantial public hazard due to occupancy or use. Seismic Use Group III is assigned to structures for which failure would result in loss of essential facilities required liar post earthquake recovery and those containing substantial quantities of hazardous substances.

2. Site Class eased on the soil properties, the site of building is classified as A, B, C, D, E and F to reflect the soil-structure interaction. Refer to 113C 2000. for Site Class definition.

3. Spectral Response Accelerations SS and S1 The spectral response seismic design maps reflect seismic hazards on the basis of contours. They provide the maximum considered earthquake spectral response acceleration at short period SS and at 1-second period Sl. They are for Site Class B, with 5% of critical damping. Refer to the maps in IBC 2000.

4. Basic Seismic-Force-Resisting System Different types of structural system have different energy-absorbing characteristics. The response modification coefficient R in Table 5.9 is used to account for these characteristics. Systems with higher ductility have higher R values.

With the above basic parameters available, the following design and analysis criteria can be determined. Seismic Design Category. The Seismic Design Category is based on the seismic group and the design spectral response acceleration coefficients, SDS and SDI, which will be explained later.

The Seismic Design Category for a structure can be determined in accordance} Seismic Design Categories are used to determine the permissible structural systems, the limitations on height and irregularity of the structural components that must be designed for seismic resistance and the types of lateral force analysis that must be performed.

Seismic Use Groups I and II structures located on sites with mapped maximum considered earthquake spectral response acceleration at 3.-second period SI, equal to or greater than 0.75g, shall be assigned to Seismic Design Category E. Seismic Use Group IIl structures located on such sites shall be assigned to Seismic Design Category F. A structure assigned to Seismic Design Category E or F shall not be sited where there is the potential for an active Fault to cause rupture of the ground surface at the structure. Building Irregularity. Building with irregular shapes, changes in mass from floor to floor, variable stiffness with height, and unusual setbacks do not perform well during earthquakes.

Thus, for each type of these irregularities, additional design requirements shall be followed to maintain seismic-resisting capacity. IIIC 2000 requires that all buildings be classified as regular or irregular based on the plan and vertical configuration.

Structures assigned to Seismic Design Category A need only comply with the following:

Structure shall be provided With a complete lateral-force-resisting system designed to – resist the minimum lateral force, of 1% floor gravity load. The gravity load should include the total dead load and other loads listed below.

In areas used for storage, a minimum of 25% Of the reduced floor live load [floor live load in public garages and open parking structures need not be included)

Where an allowance for partition load is included in the floor load design, the actual partition weight or a minimum weight of 10 psf of floor area (whichever is greater)

Total operating weight of permanent equipment

= 20% of flat roof snow load where flat roof snow load exceeds 30 psf

The direction of application of seismic forces used in design shall be that which will produce the most critical load effect in each component. The design seismic forces are permitted to be applied separately in each of two orthogonal directions and orthogonal effects are permitted to be neglected.

The effect of this lateral force shall be taken as E in the load combinations.

Special seismic load combinations that include Em need not to be considered, The primary objective of earthquake resistant design is to prevent building collapse during earthquakes thus minimizing the risk of death or injury to people in or around those buildings. Because damaging earthquakes are care, economics dictate that damage to buildings !s expected and acceptable provided collapse is avoided.

Earthquake forces are generated by the inertia of buildings as they dynamically respond to ground motion. The dynamic liatuve of the response makes earthquake loadings markedly different from other building loads.

5.4 AVOIDING DISPROPORTIONATE COLLAPSE

There are in general three alternate approaches to designing structures to reduce their susceptibility to disproportionate collapse:

- Redundancy or alternate load paths
- Local Resistance
- Interior or continuity

Redundancy or Alternate paths:

- In this approach the structure is designed such that if any one component fails, alternate paths are available for the load in that component and the general collapse does not occur.
- This approaches the benefit of simplicity and directness in its most common applications, design for redundancy requires that a building structure be able to tolerate loss of any one column without collapse this is an objective easily understood performance requirements the problem with the redundancy approach as typically practiced is that it does not account for difference in vulnerability .
- Clearly one column redundancy when each column is a W8x35 does not provide the same level of safety as when each column is a 2000 I/ft build up section.
- Indeed and explosion that cloud take out the 2000 I/ft column would likely destroy several of the W8 columns making one column redundancy inadequate to prevent collapse in that case.
- And ate codes and standards mandate redundancy do not distinguish between two situation they threat every column as equally likely to be destroy d in fact since it is generally much easier to design for redundancy of a small and lightly loaded column redundancy requirements may have the unfortunate consequence of encouraging design with small(and vulnerable) columns rather than fewer larger column.
- For safety against deliberate attacks (as opposed to random accidence) this may

be a step in wrong direction.

Local Residence

In this approach susceptibility to progressive /disproportionate collapse is reduced by providing critical compound dence that might be subject to attack with additional resistance to such attacks this requires some knowledge of the nature of potential attacks. And it is very difficult to codify in a simple and object way.

Interconnection or continuity

This is strictly speaking not a third approach separate from redundancy and local residence. But a means of improving either redundancy of or local residence (or both).Studies of many recent building collapses have shown that the figure could have been Avoided or at least reduced in scale, at fairly small additional cost if structural components had been interconnecting more effectively. This is the basis of the structural integrity requirement in the ACI 318 specification (ACI 2002)

5.5 CASE STUDY OF EARTHQUAKE RESISTANT STRUCTURE

An earthquake is the sudden shaking of the surface of the earth caused by the passage of seismic waves through the earth's crust. During the earthquake, vibrations occur in all directions radiating from the epicenter. The sudden release of energy cause structure to vibrate and inertia forces are acting on them. Most of the earthquakes are result from tectonic events, primarily movements on the faults, and remaining related to the manmade. The lack of earthquake knowledge and its incorporation in the building design and execution leads to the failure of structures.

Some of the reasons behind building failures are

- Vertical and horizontal movement and the inertia of buildings cause frequent changes in buildings' weight.
- Use of poor-quality material.
- Massive structure (greater the mass of the structure, more the lateral force is exerted on the building).
- More the height of building, lesser its stability.

There are 9 severe earthquakes has witnessed by India in the last 3 decades between 1990 to 2020 and reports claim the number of causalities approx. 30500. Although, certain parts of the country are more prone to earthquakes (seismic zone V of IS 1893(Part 1)-2016) than the others [4]. No region can be considered free from earthquakes. In the Indian scenario, minor earthquakes are reported near the seduction zone (Himalayan belt) on a daily basis, whereas in the interpolate region (Deccan plateau) few major earthquakes have been observed over the years. The performance of the built environment during the past earthquakes has shown its brittle nature and has created an itch among the engineers and architects to move towards seismically efficient buildings.

- Analysis of earthquake resistant Design structures against natural earthquakes he said that buildings can effectively protect against earthquake using multiple design options[3].Load factors of earthquake designing structures where a number of options, details for earthquake types can be found[9].

- About 60 % of the Indian landmass, is susceptible to moderate to very severe earthquakes. A great earthquake in an unoccupied area may produce minimum damage when compared to a moderate earthquake in a densely populated area. All the field survey studies conducted after a major earthquake suggested that the maximum casualties reported were caused by structure collapse.The seismic performance of a building during an earthquake depends on its shape, size, geometry, and the nature of the load path. The aim of seismic design philosophy is to ensure the safety of structural components and human life. Design philosophies state that the load-bearing structural elements must suffer no damage in the case of a minor shaking, sustain repairable damage in the case of moderate shaking and sustain severe damage without collapse under strong shaking.

OBJECTIVE

The main aim of a structural engineer is to prevent the structural damages that are caused due to earthquakes.

So, the main objective of this paper is to fulfil the following.

- To increase the stability of structures against inertial forces using modern techniques
- To know about new and advanced methods for earthquake-resistant structures.
- To prevent deflection of structure which causes failure by using new and advanced methods.

METHODOLOGY

Since it is clear that our main reason for this research is to make the public aware and improve towards this ruinous phenomenon that is Earthquake matter. We have decided to research new technologies for the construction of earthquake-resistant structures, starting with local On the other hand, up to more percentage of housing reserves in rural areas, the urban population grew rapidly during last decade. The growth of the urban population in building projects, and then discovered and cited new approaches that the world is still using right now.

Thus, the methodology process is given below

- Creating idea
- Evaluation for its necessity
- Supervising projects
- Researching website
- Collecting information
- Conclusion

NECESSITY FOR EARTHQUAKE-RESISTANT CONSTRUCTION

As per census 2011 India, there are more than 330 million dwelling units in the country, two-thirds out of which are rural households. According to India's geological survey, the country has been classified into four seismic zones having different seismic capabilities the Indian census by 32% has increased from 286 million in 2001 to 377 million in 2011.

About 30% constitute residential units of seismic zone IV and V.These rural building units are mainly made by the use of locally available materials like mud and unburnt bricks, stone walls, or walls made of burnt bricks, all these are very poor in construction and maintenance. Besides a large percentage of housing facilities in rural areas, the urban population has increased rapidly during the last decade. The growth of the urban population in the Indian census by 32% has increased from 286 million in 2001 to 377 million in 2011. The urban population is estimated to be around 590 million by the end of 2030.As per the statistics, 50% of the demand for construction work in India comes from infrastructure. Sector, the rest comes from industrial activities, residential and commercial development, etc [1][6]. Due to this rapid urbanization, demand for infrastructure, essential infrastructure, residential layout, and community development has increased.

The occurrence of earthquakes in (day time or night time) plays a major role as they have a direct impact on the occupancy of buildings. for example. The Latur earthquake (1993) took place in the early hours around 3:53 AM most people were sleeping in the affected area. On the contrary, the Bhuj earthquake (2001) occurred around 8.46 AM, in which most people woke up and there was minimal interference in the building. The two earthquakes showed poor performance of non - engineered building units such as random rubble masonry in mud mortar with heavy roofs as well as modern multi-story RC framed buildings (Figure 2).

Figure. 2: Apartment collapse in Bhuj

The Last seismic experience shows that modern residential buildings lack seismic designs. Further, the importance of incorporating seismic principles in the structural design of the building to function as a single unit during the earthquake has become clear. Empowering rural communities to ensure seismic safety of building stock by generating awareness about earthquakes and the significance of earthquake-resistant buildings. The environment built in urban areas should be planned and has to be carefully prepared in the initial stages so that the constructing layout is suited for seismic performance.

BUILDING TYPOLOGIES

The classification of the building is based on the material used in the building such as

- Type of mortar used
- Concrete used in the structure
- Reinforcement
- Wooden structures

A. Classification of masonry units -

Stonemasonry - doing stonework

Wooden masonry - doing wooden work

Reinforcement masonry - doing steelwork

Brick masonry - doing brickwork

B. Classification of load-bearing units in structures-

Reinforced walls - the walls can be made load bearable

Trusses- H shaped girders made of steel

Braces- made of steel

Columns - vertical reinforced concrete bars

Beams - horizontal reinforced concrete.