UNIT I - INTRODUCTION

PART – A

1. **What is meant by modular co-ordination?(AUC NOV/DEC 2019,2013,APR/MAY 2018,2016)**

   Modular coordination is a concept for coordinating dimension and space for which building and component are dimensionally it used and positioned in basic units (or) modules. The standard specify that the module basic M = 100 mm. As the basic unit be used in a square of M.

2. **What are the production techniques? (AUC NOV/DEC 2018,2017)**
   - The term production techniques describe a series of operation directly concerned in the process of making or more apply of molding precast units.
   - These techniques grouped into three basic methods of production.
   - The stand system
   - The conveyor belt or production line system
   - The aggregate system

3. **List out the limitations of prefabrication.**
   - Extra reinforcement is required to take care of handling and erection stresses.
   - Temporary properties may be required in some cases before the un-site concrete joints achieve strength.
   - The cracks may develop at the joints between the precast in site concrete due to shrinkage and temperature stresses. To overcome them extra steel is required across joint.

4. **List the advantages and disadvantages of prefabricated system.**

   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.

   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 component.

5. **List the system for prefabrication.**
    - Large panel systems
    - Frame systems
    - Slab-column systems with walls
    - Mixed systems
6. **What are the methods for Manufacture of precast concrete elements (or) types of prefabrication?**
    - Factory prefabrication
    - Site prefabrication
7. **What are the classifications of prefabrication?**
    - Small prefabrication
    - Medium prefabrication
    - Large prefabrication
    - Cast in – site prefabrication
    - Off-site (or) factory prefabrication
    - Open system of prefabrication
    - Closed system of prefabrication
    - Partial prefabrication
    - Total prefabrication
8. **What is the need for pre fabricates structures?**
    - Prefabricates structures are used for sites, which are not suitable for normal construction method.
    - PFS facilities can also be created at near a site as is done to make concrete blocks used in plane of conventional brick.
    - Structures which are used repeatedly and can be standardized.
9. **What is the Production process?**

    The production of concrete blocks consists of four basic process. They are,
    - Mixing
    - Moulding
    - Curing
    - Cubing

10. Explain the conveyor belt or production line system in production technique?

The conveyor belt system of production splits the whole production process into a series of operation carried out at separate successive and permanent points, points to the next may be by means of conveyor belt, trolleys and cranes etc.

11. What are the equipments for erection and hoisting of prefabricated components? (Apr/may-2017,2016)

- Stationery cranes – Guyed Derrick and climbing cranes..
- Cranes on rails – Portal crane and tower cranes
- Mobile cranes – Truck mounted and crawler mounted.

12. What are the aims of prefabrication?

- Prefabrication is used to affect economy in cost.
- This results in improvement in quality because components can be manufactured under controlled conditions.
- The spread of construction is increased since no curing period is necessary.

13. What are the characteristics of Materials used for construction of PFS?

- Easy availability.
- Light weight for easy handling and transport.
- Thermal insulation property.
- Easy workability.
- Durability in all weather conditions.
- Economy in cost.
- Sound insulation.

14. What are the Advantages of standardization? (Apr/may-2017)

- Easier design
- Easier manufacture
- Easier erection and completion

15. What are the Factors influencing the standardization?

- The most rational type of member for each element is selected from the point of production from the assembly serviceability and economy.
- The number of types of elements will be limited and they should be used in large quantities.
- To extent possible the largest size to be used which results in less number of joints.
- The size and the number of prefabricates is limited by the weight in overall dimension that can be handled by the transportation.

16. Define prefabrication.

Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site and transporting complete assembles to the construction site where the structure is to be located.

17. Define the term Off-site fabrication.

Off-site fabrication is the process that incorporates prefabrication and preassembles the process involves the design and manufacture of units usually remote from the work site and the installation at the site to form the permanent work at the site..

18. What are all the Prefabrication materials?

- Structural insulated panels (SIPs).
- Insulating concrete forms (ICFS).
- Prefab foundation system.
- Steel framing.
- Concrete framing.
- Large - modular system

19. Write Insulating concrete forms?

Insulating concrete forms (ICE) are a prefab construction material consisting of hollow EPS foam blocks that are stacked and glued together on-site, creating the form that is filled with reinforcing bars and concrete.

20. Write short note on Principles of MC Concept?

- The basic module is small in terms of add size in order to provide design flexibility, yet large enough to promote simplification in the component variation in sizes.
- Industry friendly features that not only for manufacturing but also the transportation and assembly requirements.
- Internationally accepted to support international market.

21. What are the types of prefabricated construction systems?

- Open prefabricated system
- Partial prefabricated open system
- Full prefabricated open system
- Large panel prefabricated system

22. What are the design principles of prefabricated systems?

- Standardization
- Principle of structural design
- Connections

23. Distinguish between site prefabrication and plant prefabrication.

Site prefabrication:

- No transportation.
- The size limitation is depending on the elevation capacity only.
- Lower quality because directly affected by weather.
- Proper large free space required.

Plant prefabrication:

- Transportation and elevation capacity limits the size.
- Higher, industrialized quality – less affected by weather.
- No space requirement on the site for fabrication.
- Unlimited opportunities of architectural appearance.
- Option of standardized components.

24.Define modular grid and its types? (Apr/may-2019,2018,2017,Nov/dec-2016)

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

Types of Modular Grid

- Elements in building design
- Continuous grid
- Superimposed grid
- Displacement of grid (or) Tartan grids
- Interrupted grids as neutral zones.

25.**Define Tolerance**

It is the sum of acceptable positive and negative discrepancies of actual dimensions from the theoretical one. The limits of tolerance are based on the manufacture and erection requirements.

26. **What are the two principles of prefabrication?**(**Nov/dec-2013)**

The theory behind the method is that time and cost is saved if similar construction tasks can be grouped and assembly line techniques can be employed in prefabrication at a location where skilled labor is available while congestion at the assembly site which waste time can be reduced.

The method find application particularly where the structure is composed of repeating units or forms or where multiple copies of the same basic structure are being constructed.

27. Define standardization(Apr/may-2017,2016)

Standardization is to the creation and use of guidelines for the production of uniform interchangeable components especially for use in mass production. It also refers to the establishment and adoption of guidelines for conduct to global marketing the term is used in describes the simplification of procurement & production to achieve economy.

28.What are the prefabricated structural units?(Nov/dec -2019)

- Walls and columns
- Lintels
- Doors and window frames
- Roofing and flooring elements
- Stairs

29.List out the techniques involved in the production of prefabricated components.(Nov/dec-2017)

Stand method:

Here the moulds remain stationary at places when the various processes involved are carried out in a cyclic order at the same time.

Flow method:

Here the precast unit under consideration is in movement according to the various processes involved in the work are carried out in an assembly line method.

30. List out the limitations of modular co-ordination.

- Restricted flexibility.
- Reduced adaptability to design changes
- It is difficult to manufacture to produce components based on mm tolerance.
- Need for additional construction effort and co-ordination of activities.

PART – B

1. **What are the principles of prefabrication techniques and explain in detail and also mention its advantages and disadvantages.(NOV/DEC 2017,Apr/may-2015,2016)**

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.
- Components produced at close supervision. So quality is good.
- Possibility of alterations and reuse.
- Correct shape and dimensions and sharp edges are maintained. • Very thin sections can be entirely precast with precision

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 prefabricated structures require heavy duty cranes and precision measurement and handling to place in position.
- Large group of buildings from the same type of prefabricated elements tend to look drab and monotonous.
- Local jobs are lost.

2. Explain the erection principles of precast members with suitable sketches.

(AUC NOV/DEC 2013)

1) Planning for precast installation:

Planning co-ordination:

It is important to have the precast erector or 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.
- Uneven ground conditions will cause overstress and in cracking of the panels.

- **Planning crane arrangement:**
  - Plan the crane capacity and lifting gears based on position of panel location.
  - A boom lift and scissor lift for unhooking installed panels.
  - Lifting gears.
  - Skilled personnel, component crane operators, rigger and signaler.
- **General considerations for crane selection:**
  - Total lifting weight, crane model, swing radius and crane counter weight.
  - Lifting capacity must be 1.5 times the total weight. FOS is 1.5.

2) Installation process:

- **Installation of vertical components:**
- **Verification of delivered panels:**
  - Check the panels delivered for correct marking lifting hook and position.
  - Surface finishing condition.
  - Dimension compliance and reinforcement provision.
- **Setting out:**
  - Set the reference lines and grids.
  - Check starter bars for vertical components before hoisting for installation.
- **Setting out quality control points:**
  - Ensure correct offset line.
  - Check plate level at firm.
  - Rubber gasket properly secured.
  - Ensure panel vertically to correct plumb.

    - Check panel to panel gap connectivity.
- **Grouting works:**
    - Prepare and apply non shrink mortars to see gap.
    - Keep installed panels undisturbed for 24hrs.
    - Check joint widths are consistent before grout.
    - Grout used should be same grade of components and self compacting to prevent cracking.
- **Connecting joints:**
    - Install rebar's are required.
    - Set up for casting joints.
    - Do concreting.
    - Remove frames after sufficient strength.
    - For external connections sealant should be used.
- **Installation of horizontal elements:**
- **Setting out:**
    - Set reference line to required alignment with an level of slab during installation.
    - Put temporary properties to support the precast slab/beam elements.
    - Before hoisting check dimensions.
    - Check level and stability of shim during the erection process.
- **Hoisting and installation:**
    - Lift and rig the elements to designated location.
    - Align and check the level before placement.
    - The beams should support the properties at least two locations.
    - Check level of precast elements.
- **Connection / Jointing:**
    - Place the lap rebar's as required.
    - Set framework for casting joints.
    - Remove framework after concrete strength is achieved.
    - Supporting beams shall be designed to form part of framework joints.
    - Same grade of concrete should be used as that of the panels.

3. Explain the need for prefabrication systems. (NOV/DEC 2017,Apr/may-2015,2016)

- Prefabricated structures are used for sites which are not suitable for normal construction methods such as hilly region and also when normal construction materials are not easily available.
- Prefabricated structure facilities can also be created at near a site as is done to make concrete blocks used in plane of conventional structures.
- Structures which are used repeatedly can be standardized such as mass housing, storage sheds, godowns, shelters, bus stand, security cabins, site offices, foot over bridges, road bridges, tubular structures, concrete building blocks etc, can be made of prefabricated structures.
- Speed in construction.
- Lack of space.
- Proper utilization of space.
- Control over material.
- Mass production.
- Difficult weather condition

4.Explain the production process of prefabricated structural elements. (APR/MAY2018,2016)

The term production of systems is describes a series of operation directly concerned In the process of making or more apply of moulding precast units on the face of it there are many techniques since almost every type of 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 moulded 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.

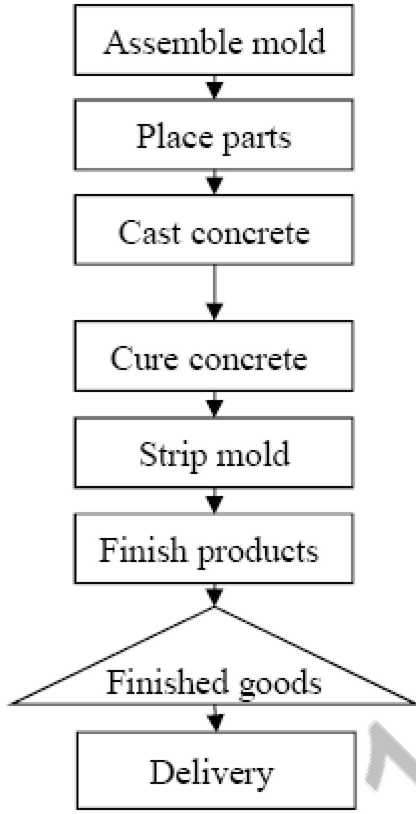


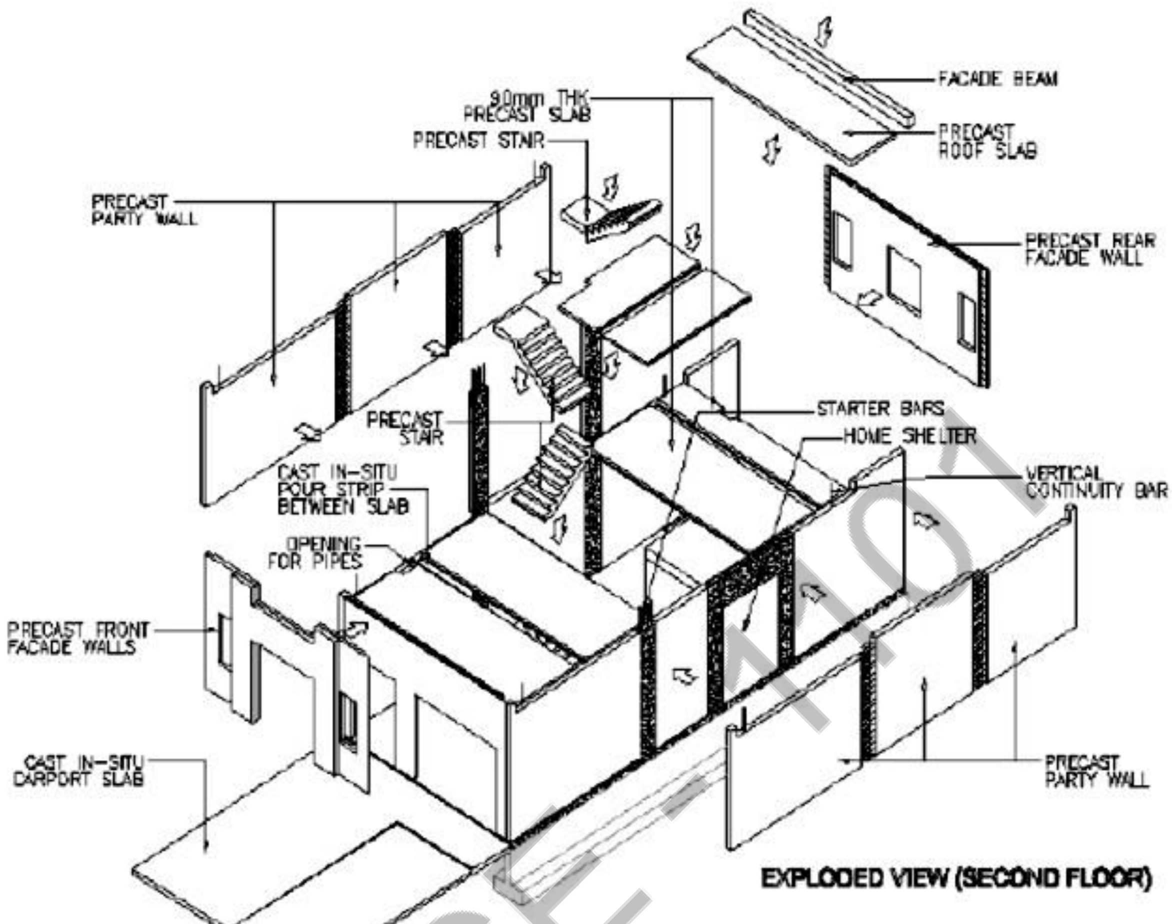
Figure 1: Precast production process

5. Discuss the concepts for precast concrete buildings. (AUC MAY/JUNE 2018)

The design concept of the precast buildings is based on the buildability, economy and standardization of precast components. In design of precast members and connections, all loading and restraint conditions from casting to end use of the structure should be considered. The stresses developed in precast elements during the period from casting to final connection may be more critical than the service load stresses. Special attention should be given to the methods of stripping, storing, transporting, and erecting precast elements.

When precast members are incorporated into a structural system, the forces and deformations occurring in and adjacent to connections (in adjoining members and in the entire structure) should be considered. The structural behavior of precast elements may differ substantially from that of similar members that are monolithically cast in place. Design of connections to transmit forces due to shrinkage, creep, temperature change, elastic deformation, wind forces, and earthquake forces require special attention. Details of such connections are especially important to insure adequate performance of precast structures.

Precast members and connections should be designed to meet tolerance requirements. The behavior of precast members and connections is sensitive to tolerances. Design should provide for the effects of adverse combinations of fabrication and erection tolerances. Tolerance requirements should be listed on contract documents, and may be specified by reference to accepted standards. Tolerances that deviate from accepted standards should be so indicated.



All details of reinforcement, connections, bearing elements, inserts, anchors, concrete cover, openings and lifting devices, and specified strength of concrete at critical stages of fabrication and construction, should be shown on either the contract documents prepared by the architect/engineer of record or on the shop drawings furnished by the contractor. Whether this information is to be shown on the contract documents or shop drawings depends on the provisions of the contract documents. The shop drawings should show, as a minimum, all details of the precast concrete members and embedded items. The contract documents may specify that portions of connections exterior to the member are also to be shown on the shop drawings. The contract documents may also require the contractor to provide designs for the members and/or connections.

The contract documents should show the loads to be considered in design of the precast concrete elements of the structure, and they should indicate any special requirements or functions (for example: seismic loads, allowance for movements, etc.) that should be considered in design assigned to the contractor. In this case, the shop drawings should include complete details of the connections involved.

6. **What are the classifications of prefabricated systems?(Nov/Dec -2019,Apr/may 2016,2015,2017)**

Small prefabrication:

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 precasted 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 precasted 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 main factors 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 numbers 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 erction 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 equipments 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.

7. What is the process involved in manufacture of PFS? (MAY/JUNE 2018)

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

a. Main process:

- Providing and assembling the moulds, placing reinforcement cage in position for reinforced concrete work and stressing the wires in the cases of prestressed elements.
- Fixing of inserts and tubes where necessary.
- Pouring the concrete.
- Vibrating the concrete into the moulds.
- Demoulding the forms and stacking the precast products.
- Curing (steam curing if necessary).

b. Auxiliary process:

- Process necessary for the successful complement of the processes covered by the main process.
- Mixing and manufacture of fresh concrete (done in a mixing station or by matching plants).
- Prefabrication of reinforcement cage (done in a steel yard or workshop).
- Manufacture of inserts and other finishing items to be incorporated in the main precast products.
- Finishing the precast products.
- Testing of products.

c. Subsidiary process:

- Storage of materials.
- Transport of cement and aggregate.
- Transport of green concrete and reinforced cages.
- Transport and stacking the precast elements.
- Repairs and maintenance of tools, tackles and machines.
- Generation of steam, etc.

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

- A cycle technological method of working to bring in speed, an economy in manufacture.
- Mechanization of the process to increases productivity and to improve quality.
- The optimum production satisfying the quality requirements and to keep up the expected speed of construction aimed.
- Better working conditions for the people on the job.
- To minimize the effect of weather on the manufacturing schedule.

8. What are the methods for Manufacture of precast concrete elements and explain the factors influencing method of manufacturing.

The methods for Manufacture of precast concrete elements are stand method and flow method.

Stand method:

Here the moulds remain stationary at places when the various processes involved are carried out in a cyclic order at the same time.

Flow method:

Here the precast unit under consideration is in movement according to the various processes involved in the work are carried out in an assembly line method.

Factors influencing method of manufacturing:

- The size and the total number of elements to be produced.
  - Number of moulds required degree of mechanics.
  - Need for special curing method.
- Desired rate of output.
  - Number of moulds required degree of mechanics.
  - Need for special curing method.
- Shape type and construction features of elements.
  - Special shape (Curved or straight).
  - Required finish (single or multilayer).
  - Facilities available in production setup.
  - Accelerated curing.
  - Overhead gantry crane.
- Economic aspects.
  - Minimized cost of production.
- Vertical moulding and horizontal moulding.
  - Types of moulds.
  - Wooden moulds.

- Steel moulds.
- Concrete moulds.
- Plastic moulds.

9. Explain the precasting methods and stages of work in precasting? (Nov/dec2019)

Precasting methods:

a. Individual mould method:

- Moulds which can be easily assembled.
- Easy to transport.
- Timber or steel.
- Needle or mould vibrates.
- It is used in beams, cranes and window panels.
- Any desired dimensions weight upto 200 m.

b. Battery form method:

- The shuttering panels may be adjusted into the form of battery at the required distances equal to the thickness of concrete members.
- It is used for interior wall panels, shell elements, roof and floor slabs.
- Length 18 m, breadth 3 m, weight 5 tonnes.
- Suitable for mass production of wall panels, shuttering cost reduced, autoclave or trench steam curing.

c. Stack method:

- For casting identical reinforced or prestressed panels one over the other with separating media interposed in between.
- Used for floor and roof slab panels.
- The dimensions are any desired length, breadth is 1 to 4 m, weight 5 tonnes.

d. Tilting mould method:

- Moulds can be filled using hydraulic jacks used for exterior wall panels where special finishes are required in one face.
- The dimensions are length 6m, breadth 4m, cover 5m.

e. Long line method:

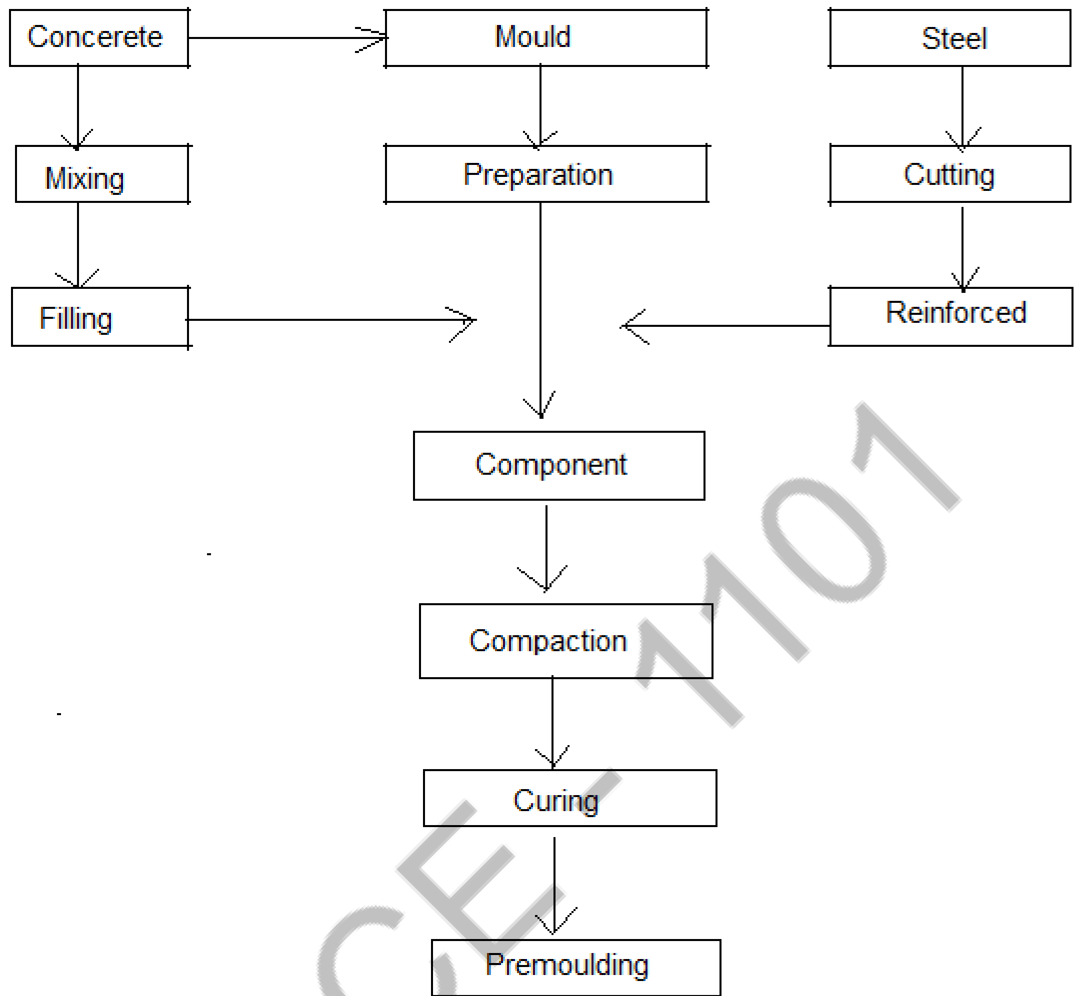
- Rib slabs, purlins, piles and beams.
- Length any desired, breadth 2m, lot upto 10 tonnes.
- Ideally suitable for pretensioned method.

f. Extrusion method:

- Long concrete mould with constant clearance concreting and vibration done automatically.
- Roof slabs, foam concrete, wall panels.
- Used for reinforced blocks, foam concrete panels.

- Used for unreinforced blocks, foam concrete panels.

Stages of working in precasting:



10. What are the importance aspects considered during hoisting, erection and transportation of precast element? (Nov/dec-2017,Apr/may-2016)

Casting:

Precast components are casted with controlled cement concrete in moulds of required shape and sizes. The vibrator is used to vibrate concrete and this removes any honeycombing inside the components.

Curing:

After 24 hours of casting, the casted components are released from the mould and transported to curing tanks. Certain special components like railway sleepers where high strength is required are steam cured.

Transportation and erection(APR/MAY-2018)

After complete curing is done the components are transported to the site with heavy trucks and erection will be done using cranes with skilled labour force.

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 authouritic 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 element are located at specified portion only.

Erection:

- Sequence of erection checking of precast elements availability.
- Precast element positions.
- Cleaning of elements and site for erection.
- Cleaning inserts before incorporation in the joints and grouting the joints.
- Crane capacity.
- Crane boom length for handling.
- Crane rotation radius.

Equipments required for erection:

- Machinery required for quarrying of coarse and fine aggregates.
- Conveying equipment such as belt conveyor, chain conveyors, screw conveyors, bucket elevator, hoists etc.
- Concrete mixers and vibrators.
- Erection equipment such as cranes, derricks, hoists, chain pulley blocks etc.
- Transport machinery such as tractor cum trailers, dumpers, lorries locomotive, motor boats and rarely even helicopters.
- Workshop machinery for fabricating and repairing steel and timber moulds.
- Bar straightening, bending and welding machines to make reinforcement cages.
- Minor tools and takes such as wheel barrows, concrete buckets etc.
- Steam generation plant for accelerated curing.

11. Explain the standardization in detail and factors influencing the standardization.

For speedy construction we have to use repetitive use of building elements. Thus standardization of prefabrication elements becomes essential.

- It will facilitate quicker construction of similar elements, avoid duplication of effort.
- To adopt prefabrication in actual practice, it is necessary that the main parameters of the whole building are standardized.
- Each and every component that forms the buildings can be standardized.
- For each standard element, a limited number of types and sizes are established with a definite gradation in geometrical dimensions and reinforcement ratio.
- Flexural elements should retain their cross sectional dimensions with change in reinforcement ratio according to length, loading.
- Columns have constant dimension change in reinforced or if needed change in grade of concrete.
- If at all there is excessive use of concrete total cost of construction will be reduced through repeated use of the forms and unification of reinforcement mats and cages.
- Unchanging dimension of column from storey to storey, one type of floor beam supported by columns can be made (some column / beam joint with slight modification can be adopted).

Advantages:

- Easier design
- Easier manufacture
- Easier erection and completion

Factors influencing the standardization:

- The most rational type of member for each element is selected from the point of product from the assembly serviceability and economy.
- The number of types of elements will be limited and they should be used in large quantities.
- To the extent possible the largest size to be used which in less number of joints.
- The size and the number of prefabricates in limited by the weight in overall dimension that can be handled by the transportation.
- Hence it is preferable to have all prefabricated approximately of same weight very near to the lifting capacity of the equipment.

12. Explain erection and equipments required for erection.

Erection:

- Sequence of erection checking of precast elements availability.
- Precast element positions.
- Cleaning of elements and site for erection.
- Cleaning inserts before incorporation in the joints and grouting the joints.

- Crane capacity.
- Crane boom length for handling.
- Crane rotation radius.

Equipments required for erection:

- Machinery required for quarrying of coarse and fine aggregates.
- Conveying equipment such as belt conveyor, chain conveyors, screw conveyors, bucket elevator, hoists etc.
- Concrete mixers.
- Concrete vibrators.
- Erection equipment such as cranes, derricks, hoists, chain pulley blocks etc.
- Transport machinery such as tractor cum trailers, dumpers, lorries locomotive, motor boats and rarely even helicopters.
- Workshop machinery for fabricating and repairing steel and timber moulds.
- Bar straightening, bending and welding machines to make reinforcement cages.
- Minor tools and takes such as wheel barrows, concrete buckets etc.
- Steam generation plant for accelerated curing.

13. Discuss in detail the concept of modular coordination .State its significance in prefabricated structures. (Apr/may-2018,2017,2016)

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 centre lines of load bearing walls shall coincide with the grid lines.

b. In case of external walls the grid lines shall coincide with the centre 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 centre lines of columns. In case of external columns, the grid lines shall coincide with the centre 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 andfor larger project modules are represented a Mp.

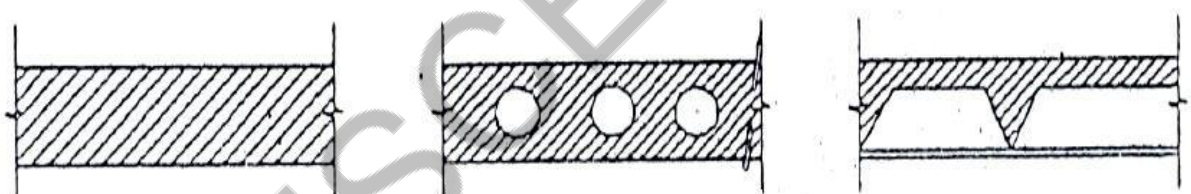
For eg: For a project module in horizontal coordination, the component can be of 30cm and for vertical component size be of 10cm.

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.

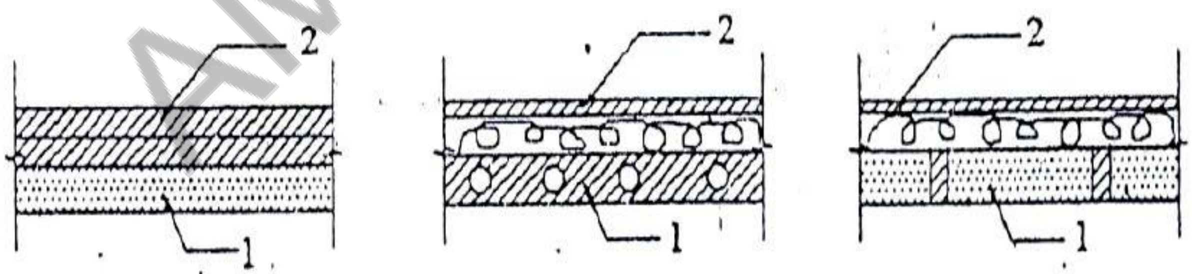
In the design of a building, modular grid can be used consisting of parallel line spaced at a value of module M or Mp and a grid line chosen as a base for setting out a part of a building becomes a modular axis.

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.

Systems of prefabrication:



a.) Solid b.) Hollow or cored unit c.) Ribbed panel



a.) Solid b.) Cored

System is referred to a particular method of construction of buildings using the prefabricated components which are inter related in functions and are produced to a set of instructions. With certain constraints, several plans are possible; using the same set of components, the degree of flexibility varies from system to system. However in all the systems there is a certain order and discipline. The system of prefabricated construction depends on the extend of the use of prefab components, their characteristics to be considered in devising a system:

- Intensified usage of spaces
- Straight and simple walling scheme
- Limited sizes and numbers of components
- Limited opening in bearing walls
- Regulated locations of partitions
- Standardized service and stair units
- Limited sizes of doors and windows with regulated positions
- Structural clarity and efficiency
- Suitability for adoption in low rise and high rise blocks
- Ease of manufacturing storing and transporting
- Speed and ease of erection
- Simple jointing system

UNIT II - PREFABRICATED COMPONENTS

PART – A

1. **What is Shear wall?(Nov/Dec 2012 & 2013,2019,2016,Apr/may-2017,2015,2016)**

   Shear walls are vertical elements which resists the horizontal forces. These walls are constructed to counter the effects of lateral load acting on a structure. In residential construction shear walls are straight external walls that typically form a box which provides all of the lateral support for the building.

2. **How prefabricated structural components are classified ?**
   - Based on the area (or) size of prefabricates.
   - Based on weight of prefabricates.
   - Based on the function.
   - Based on the shape.
   - Based on the material.

3. **What is the classification of precast large panel? (AUC May /June2013)**
   - Cross wall system
   - Longitudinal wall system
   - Two-way system

4. **What are types of Cross wall system?**
   - Longitudinal wall system
   - Homogeneous walls
   - Non-Homogeneous walls

5. **What are the prefabricated structural units?(Nov/dec -2019,2016,Apr/may-2016)**
   - Walls and columns
   - Lintels
   - Doors and window frames
   - Roofing and flooring elements
   - Stairs

6. **What is meant by box type construction?(Apr/may-2019)**

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

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

7. **Write briefly about Types of Wall Panels?**

The single way of classification of precast wall panel is based on their size or the materials of which they are made. They can be classified. According to size, as small and large, or as narrow vertical stirrups or as broad horizontal bands.

The material that are used for precast wall panel are bricks, hollow clay blocks, normal density concrete, light – weight metal, gypsum, plastic, and timber.

8. **What is the classification of precast concrete walls?**
   - Based on size
   - Based on materials used
   - Based on function
   - Based on location
   - Based on cross section
   - Based on stressing

9. **What are the types of precast floors?(Nov/dec-2019,Apr/may-2018)**
   - Depending up on the composition of units, precast flooring units could be homogeneous or non-homogeneous.
   - Homogeneous floors could be solid slabs, ribbed or waffle slabs.
   - Non homogeneous floors could be multi layered ones with combinations of light weight concrete or reinforced / prestressed concrete with filler blocks.

10. **Write about Prefabricated Roofing and flooring elements.**
    - Prefabricated reinforced concrete battens and plain concrete tiles can be used for roofing and flooring for flat, instead of wooden section and brick tiles.
    - For sloping roof, precast reinforced and prestressed concrete triangulation trusses can be used.
    - Plain concrete or lightly reinforced concrete can be used in the form of precast shells for roofing.

11. **Define Long Wall System?**

The main beam (or) load bearing wall are placed to the long axis of building. It is applied to the building with large prefabricated and similar to traditional brickwork. The longitudinal wall crosses the floor load must possess not only thermal.

12. How are roofing members in prefabricates classified?(Apr/may-2018)

- Small roofing members.
- Large roofing members.
- Reinforced planks (or) ties.
- Light weight concrete roofing members.
- Small reinforced concrete roofing members.
- Purlins.

13. What is the space bordering?

These members are used to give spaces like walls both load carrying and partition walls. This may (or) may not contain doors and windows the provision for the same is as per the requirement. Another example for the space bordering member is floor slab.

14. What is the meant by surface forming members?

In the case of surface forming members, the load carrying and surface bordering are united and a uniform load carrying surface is found loaded by complex forces and economic shapes. Example: Shell structures folded plates structures etc.

15. Differentiate between synclastic and Anticlastic?

In the case the synclastic the curve of the shell in the same side (e.g.: hemispherical shell) whereas in the case of anticlastic the curvature of the shell is in opposite direction (e.g.: hyperbolic shell (saddle shell)).

16. Write a short on dome structure?

A dome is a space structure covering a more (or) less square (or) irregular area. The best known example is the dome of revolution, and it is one of the earliest of the shell structure. Excellent examples are still is existence that were built in Roman times.

17. Different classification of shear walls.

- Plain rectangular shear wall
- Bar bell type
- Framed shear wall
- Coupled shear wall
- Care type

18. What is ring system?

Load bearing walls and beams are placed in both ways longitudinally and transversely. In the building with ring system of support floors are normally supported on all four edges and span is two direction. In skeleton construction these floors are placed directly on columns.

19. Give the classification of floor slabs.

- Precast RC Panels
- Prefabricated brick panels

- Precast RB curved panel
- Precast RC channel roofing
- Precast hollow slabs
- L panel roofing
- Trapezon panel roofing
- Un reinforced pyramidal brick roof
- Precast concrete panel

20. Explain the term lift – slab construction. (AUC May/June 2012)

- In the lift-slab system, the load bearing structure consists of precast reinforced concrete column and slab.
- Reinforced concrete slab are poured on the ground in forms one on top of the other.
- Precast concrete floor slab are lifted from the ground up to the final height by lifting cranes.
- The slab panel are lifted to the top of the column and then moved downwards to the final position.

21. What is necessity of dimensional tolerances? (AUC May /June2013)

- It is almost impossible (and sometimes uneconomical) to maintain the strict degree of accuracy as listed on a plan.
- To accommodate this, it is normal to display measurements with a plus or minus (+/-) tolerance which allows for some margin of error.
- Care needs to be taken however when determining such (+/-) tolerance, particularly where there are mating parts.

22. What are the lateral loads in a building?(Nov/dec-2013,Apr/may-2015,2017,2016)

- Live load
- Wind load
- Earthquake load

23. What are the lateral load resisting elements in a building? (AUC Nov/Dec 2013)

- Vertical Elements
  - Moment
  - Resisting Frames
  - Walls
  - Bearing walls / Shear Walls / Structural Walls
  - Gravity Frame + Walls
  - “Dual” System (Frame + Wall)
  - Vertical Truss
  - Tube System
  - Bundled
  - Tube System
- Floor/Diaphragm
- Foundation

PART – B

1. **Explain the behavior of large panel construction with suitable sketches. (Nov/Dec 2013,2017,2019,Apr/may-2019,2017,2016,2018)**

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.

- Large panel structure for Exterior wall
- Large panel structure for Interior wall.
- Large panel structure for floor slab
- Large panel structure for Roof element.

a) 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 physicotechnical 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.

b) 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)

c) 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 layer, are often used in housing construction.

d) 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.

2. Explain the behavior of roof and floor slabs construction with suitable sketches.

(Nov/Dec 2012 & 2013,2017,2018,2016)

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 upto 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.

3. **Explain the methods of construction of roof and floor slab. Also explain the precautions taken during the manufacturing process.(May/June 2015,2018,Nov/dec-2016)**

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 centre and thus an arching action is created.
- An overall economy of 30% has been achieved in single storeyed building and 20% in two or three storeyed 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 to35mm.
- 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.

4. What is the necessity of providing shear walls in the precast structures? Also discuss the different types of shear walls.(AUC May/June 2013,2017)

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:

- Plywood is the traditional material used in the construction of shear walls.
- 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 system 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.

5. Write briefly about types of wall panels. (Nov/dec -2016)

Classifications of wall panels:

- **Based on size:**
  - Large
  - Small
- **Based on materials:**
  - Bricks
  - Hollow clay blocks
  - Normal density concrete
  - Light-weight metal
  - Gypsum
  - Plastic and
  - Timber

6. **Write briefly about precast concrete columns.(Apr/may-2019)**

Precast concrete column:

- The precast concrete column elements are 1 to 3 stories high.
- The reinforced concrete floor slabs fit the clear span between columns.
- After erecting the slab and column of a story, the columns and floor slabs are prestressed by means of prestressing tendons that pass through ducts in the columns at the floor level and along the gaps left between adjacent slab are filled with in situ concrete and the tendons then become bonded with the spans.
- The prestressing slabs column system uses horizontal prestressing in two orthogonal directions to achieve continuity.
- Seismic loads are resisted mainly by the shear walls (precast or cast-in-place) positioned between the columns at appropriate locations.

7. **Write about the structural behavior of precast structure. (Nov/Dec 2017)**

Structural behavior of precast structure:

- The design load-carrying structure advantage from the viewpoint of prefabrication.
- Principles of structural analysis.
- Various specifications.
- Dimensioning of joists.
- Elimination of handling stresses.
- Redistribution of stresses in jointed structure.
- Calculation of reinforced concrete structure co-operating with strengthening concrete layer cast-in-situ.
- Influence of the sequence and the method of placing on the stress of the state of the structure.
- Stability of precast structural members.
- Quality of materials used for precast reinforced concrete structure.

8. **Differentiate the behavior of frame in precast structures. (AUC Nov/Dec 2012)**

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 upto 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.

UNIT-III

DESIGN PRINCIPLES

PART A

1. **Explain briefly the disuniting of structures? (May/June2012,2015,2016 Nov/dec 2013,2019,2017,2018,2016)**

In prefabrication many elements of prefabricated, are assembled or united or joined to form a single structures.

The problem in prefabrication is the transportation. To avoid this problem of transportation, the structure is disunited or separated into smaller or elements, so that the transportation becomes very easy.

2. **Write the advantages of disuniting structures? (Nov/Dec 2012,2017)**

- The number, of joints is reduced.
- Failure at joints is minimum
- This disuniting method is suitable for site prefabrication.
- Transportation cost for many elements to the site is reduced.

3. **Write the disadvantages of disuniting of structure?(Apr/may-2019,2017)**

- The lifting or hoisting of the entire frame is more difficult.
- Transportation of the frame from the plant is difficult
- Transport cost is high for the transport of entire frame.
- The stress distribution during lifting is a problem.

4. **How can we classify the prefabrication principles?**

Prefabricates are classified as homogeneous and composite based on the number of different material used in prefabrication

5. **Mention the design of C/S in prefabrication?**

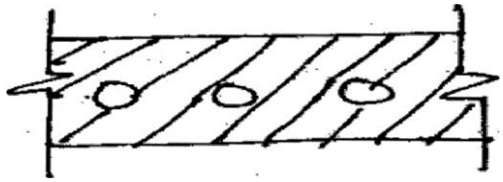
T he c/s of precast reinforced concrete structure is normally having the following.

- Tee-section
- I section
- U or v section

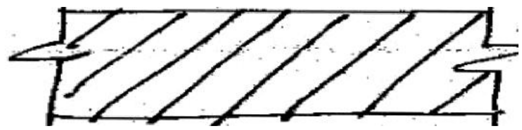
6. **Write the classification of homogeneous prefabrication?**

The homogeneous unit may be classified into 3 types.

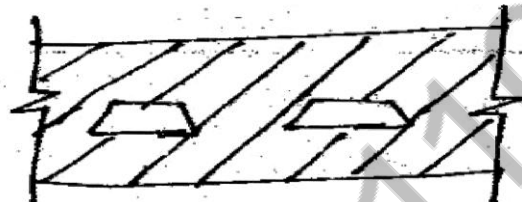
Hollow



Solid



Ribbed



7. Write the classification of composite prefabrication?

- **Cored**
- **Solid**
- **Ribbed**

8. How does the material used in construction affect the design of the element?

The materials for the construction are classified as homogeneous and composite based on the number of different material used in prefabrication.

9. Explain joint deformation?

Various structural elements are made in the plant or prefabricated when these elements in their site there May be joint deformation to take it workout deformation. Joint deformation refers to how the joint behaves in regard to the far field stresses

10. Mention some important requirements of the joint flexibility?(Nov/dec-2017)

- The construction of joint should be easy.
- The joint should require-little material..
- Joint should not consume more labour.
- Less labour is to be required.
- The cost should be minimum.

11 .Distinguish between rigid and hinged joint with reference to prefabricated construction?

The rigid joints are adequate (Sufficient) strength, in addition to bearing of tensile, compressive and shear force and for resisting bending moment.

The hinge joint is those which can transmit force passing through the hinge itself allow sudden motion and rotation.,

12 . List out the factors governing joint deformation.(Nov/dec-2016)

Construction of joint is easy, cost should be minimum, joint should require little material, joint should never consume more labour.

13.Explain joint flexibility.(Nov/dec-2019,2013,Apr/may-2015,2017,2018,2016)

A joint that holds two parts together so that one can swing relative to the other is called joint flexibility.

14. List the disadvantages of precast construction.(Apr/May 2011)

- Camber in beams and slabs
- Very small margin for error
- Connection's may be difficult
- Somewhat limited building design flexibility

PART–B

1. EXPLAIN ABOUT DISUNITING OF STRUCTURES ?(Nov/dec-2016,2017,2013,Apr/may-2017

The solution of problems connected with the transportation and placing of structures demands as a rule their disuniting in to smaller members. One bay frames not exceeding, 40 tonnes in weight may represent an exception because the problems of their hoisting and placing can be solved with the aid of modern available hoisting machines and equipment.

In spite of this framed are frequently disunited at their corners or points of minimum moments into members to make the hoisting of these smaller members possible, using much simpler equipment.

In general there is trend towards the use of larger members. This justified by more than one reason. One is that the bearing of a certain moment can be solved more economically by using one large girder instead of two or more smaller beams together having the same capacities.

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 .

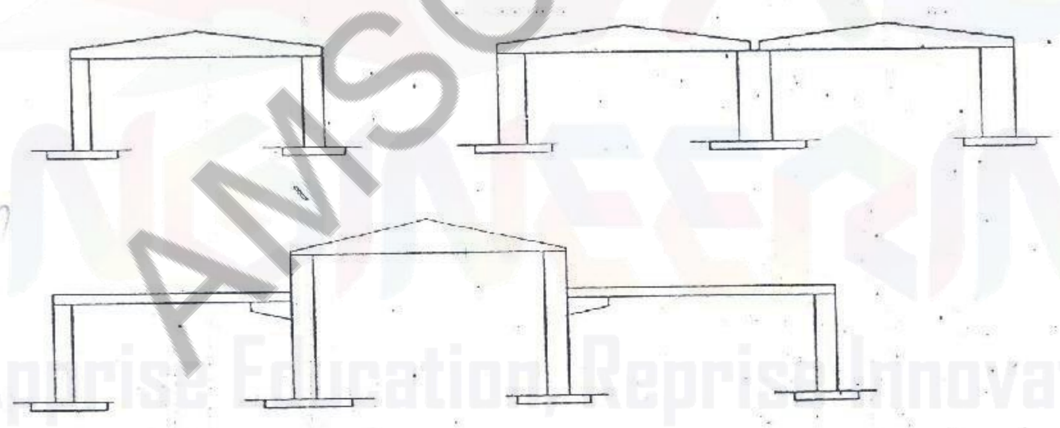


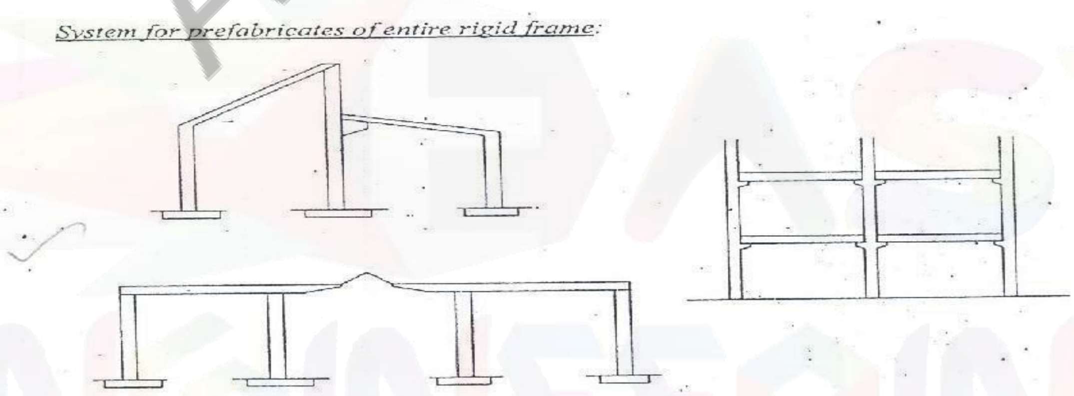
Fig 1.2.Members of frame disunited at the joints

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 itseif 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 are smallest.

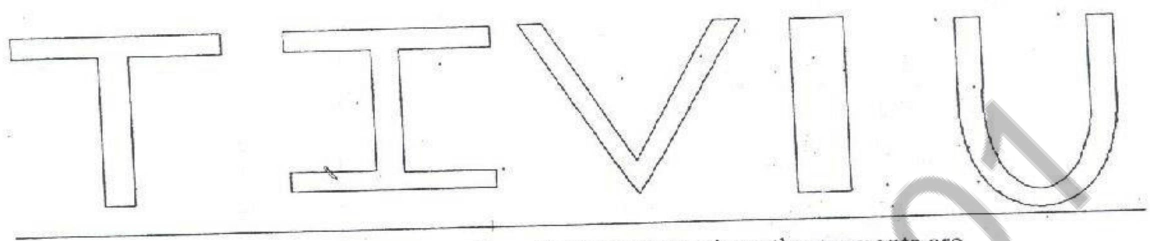


*Fig1.4*System consisting of Structures disunited at points where the moments are smallest Moments

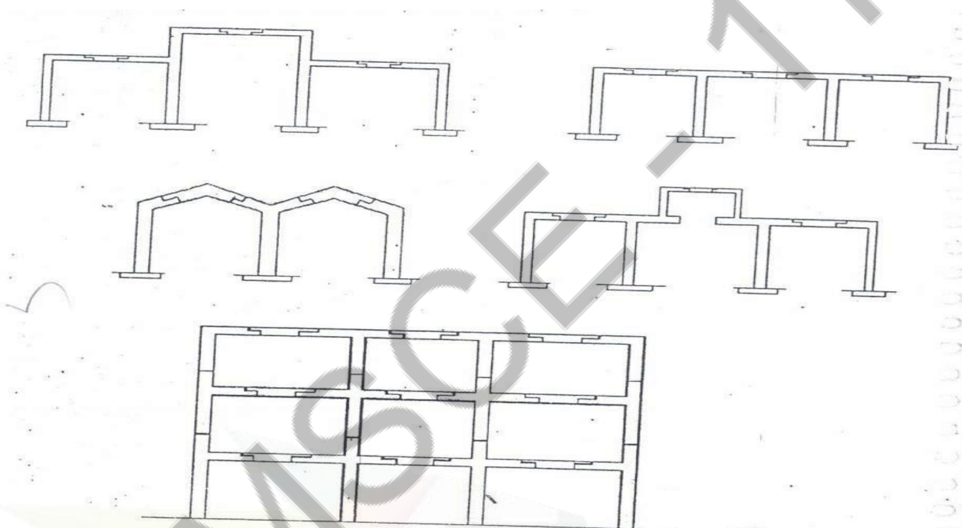


Fig 1.5 Structures disunited at points where the moments are smallest

Two hinged and three hinged arches:

Arch structures are normally used for bridging span of more than 20-25m. Their production and placing is more difficult than that of straight members but as they demand little material their use for long span structure is economical.

2. Explain About Design of Cross Section Based On Efficiency Of Material Used.(Apr/may-2015,2016,2017,2018,2019,Nov/dec-2017)

Design of cross section based on efficiency of material used:

Based on the single or more than single material, the member are classified.

The cross sections of precast reinforced concrete structure are normally having the following steps.

i. Tee section

ii. I section

iii. U or V section

The shape may be solid and their profile can be hollow or divided (practiced latticed) and vierendeel structures,

Beams:

The beasm have rectangular I, T, V shaped and hollow sections.

Rectangular Section

This is the method simple cross section of precast structure these sections to be produced is small number the advantage simple prefabricated. The disadvantage rectangular sections are hot economical.

The other section I, T, V shaped V and hollow cross section are frequently used in pre-fabrication. The advantages of these sections are

For the react c/s, F'=b.h ....(1)

$$\therefore k = \frac{b.h^2}{b} = k$$

$$\therefore k = \sqrt{\frac{6k}{b}}$$

Put 2 in 1,

$$F = b.\sqrt{\frac{6k}{b}}$$

$$F = \sqrt{6kb}$$

Hence

$$\varphi = \frac{F}{F}\frac{F}{\sqrt{6kb}}$$

For a rectangular c/s, φ = 1

For other section T, I, U and V shape etc. for this cross section φ

The smaller the values of φ, the c/s is more economical.

For ex: in case of a homogeneous of beam I shaped c/s.

They are precast RF concrete beams of equal load bearing capaci

F=2260cm²

b = 48 cm

k =48500 cm³

The depth of equivalent rectangular c/s is, h=77cm

The form factor of the the I-section is,

$$\varphi = \frac{F}{\sqrt{6kb}}$$

$$= \frac{2260}{\sqrt{6 \times 48500 \times 48}}$$

$$= 0.605$$

$$\therefore \varphi = 0.605$$

The value of $\varphi = 0.605$ means that in the case of beams made up of timber, steel are another homogeneous are same material have the same tensile strength. The application of I section is as shown in above. Instead of a red profile with the same width, makes to save in material of 39.5%.

This concept is called the design of cross section based on the efficiency of material used in prefabrication.

Fretted latticed and Vierendeet structure:

Generally, there is no difference in construction between the solid beam and a fretted section. The different openings are provided in the fretted beam only to obtain savings in materials and to reduce the dead load.

This girder or beam has openings to reduce the dead load and savings in material cost. The fretted works or fretted section, latticed truss, vierendeel structure are mainly used in prefebricatton because the dead load is very much reduced a very high material savings is achieved.

These are called as the design of different c/s based on the efficiency of material used in prefabrication structure.

3. EXPLAIN NOTES ON FLEXIBILITY JOINT(Nov/dec-2016,2019,2013,Apr/may-2016,2015)

Despite the full anchorage provided for the bars embedded in the precast and in situ, concrete bond stresses quickly break down close to the interface and the two halves of the joint may be considered separately. The flexibility of each half of the interface may be determined using the data in Table 8.36 - this is not specified in BS8110 as this type of analysis Ls not a requirement for design. However, it enables designers to calculate the total flexibility of a tension lap and determine crack widths, etc.

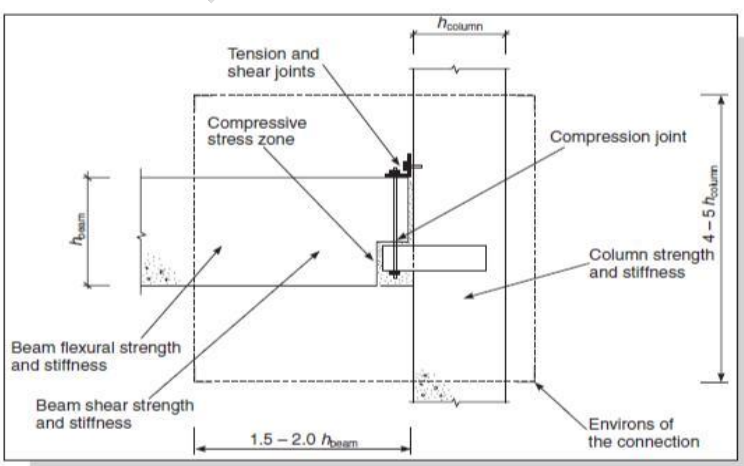


Figure Definition of 'joint' and 'connection'.

A tensile crack resulting from elastic deformation in the bar and slippage is formed in the interface and the joint's tension deformability may be calculated in the same manner as for the compression joint. The main problem with vertical lapping is to ensure that the in situ concrete forms a full and positive bond with the steel bars. Pressurized grout is inserted through a hole beneath the level of the lap, and the appearance of the grout at a vent hole above the top of the lap Ls used as an indication of complete filling as illustrated in Figure 8.22b. The annulus should be at least 6 mm clear on all sides of the bars. The grout should be non- shrinkable and be sufficiently flowable to allow pressure grouting through a 20 mm diameter nozzle using a manually powered hand pump. A 2:1 sand cement mix containing a proprietary expanding agent is used to give a 24-hour strength of 20N/mm2 and a 28-day strength of around $60 N/mm^2$

Bolting is used extensively to transfer tensile and shear forces. Anchorages such as bolts, threaded sockets, rails or captive nuts attached to the rear of plates are anchored in the precast units. Tolerances are provided using over-sized or slotted holes in the connecting member. The tensile capacity of bolted connections should be governed by the yield strength of the bolt, as this gives a ductile failure. In most types of bolted joints tension is accompanied by shear. Shear capacities are governed by the local bearing strength of the concrete in contact with the shank of the threaded socket. Shear bolt failures are brittle and should be avoided.

Welding is used to connect elements through projecting bars, fully anchored steel plates or rolled steel sections, etc. The joint can be made directly between the projecting plates or bars as shown in Figure, but is more commonly made indirectly using an intermediate bar or plate. Figure gives some guidance as to sizes, and is used to obtain the relationship between bar diameter and weld size.

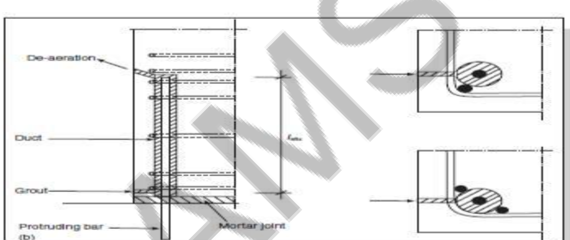
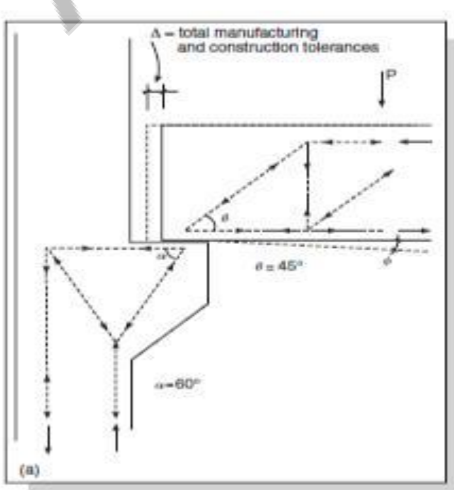


Figure 8.22b: Tension joint using bond resistance.



Post-tensioning is used to resist tension and shear forces by the application of damping forces across the joint. Cable ducts are inserted into the precast concrete elements, or in the spaces around the elements, and, after erection, the cables are placed in the ducts and post-tensioned. Tensile capacities are computed from the state of stress in the post-tensioned elements, and shear resistance Is calculated using the shear friction hypothesis.

4. Write the Design Considerations for prefabricated structures.(Nov/dec-2019)

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

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

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

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

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

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

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

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

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

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

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

5.Explain the problem in design because of joint flexibility. Discuss with regard to various location. (Nov/dec-2016,2019,2013,Apr/may-2016,2015)

FLEXIBILITY JOINT

Joint that holds two parts together so that one can swing relative to the other

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.

6. Discuss the necessity of disuniting of prefabricated structures and the precaution taken during disuniting of prefabricated structures?(Nov/dec-2017)

Necessity of disuniting of prefabricated structures

- Easy erection process
- Heavy tones capacity cranes are not necessary hence standard cranes are enough to hoisting of prefabricated element.
- Easy transportation because of long span girder is splitted into smaller members.
- Scaffolding work is not necessary.
- Easy handling
- The design process are very simple.
- Easy and very simple molding at the plants.
- In the production process standard system only needed
- Simple hoisting machines only required
- Hoisting process is very simple.
- Rapid hoisting work
- Simple technique are followed

Precaution taken during disuniting of prefabricated structures

All material stored in tires shall be stacked , racked, blocked, interlocked or otherwise secured safely to prevent sliding , falling or collapse and in an orderly manner to avoid obstruction of any passage way at the place of work.

- Maximum safe load limits of floor within building and structures in kg/cm2 shall be conspicuously posted in all storage areas except for floor or slab on gradient.
- Ailes and passage ways shall be kept clear to provide for the free and safe movement of material handling equipment or per-sons. such areas shall be kept in good repair.
- When a difference in road or working levels exist means such a ramp blocking or grading shall be used to ensure the safe movement of vehicles (cranes) between two

levels.

- Materials stored inside the buildings under construction shall not be placed with in two m of any hoist way or inside floor openings nor with in 3.2m of exterior wall which does not extend above the top of material stored.
- Persons employed require to work on stored material in silos , hoppers and similar storage areas shall be equipped with life lines and safety belts.
- Non compatible materials shall be segregated in storages.

7. Explain briefly about the allowance for joint deformation of precast structures.(Nov/dec-2019,2013,2016)

JOINT DEFORMATION

Joint deformation refers to how the joint behaves in regard to the far field stresses.

3.4 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 forms = 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.

UNIT IV

JOINTS IN STRUCTURAL MEMBERS

PART- A

1. **What are the importance's of joints in precast structures when compared to cast in situ structures?**

In cast in situ structures the joints are provided to relieve the stresses due to temperature and shrinkage and also to accommodate the construction sequence for placement of concrete. But in case of precast structures apart from the above reason we require joints to connect various elements of structures.

2. **What is the need for expansion joint in precast structures? (Apr/may 2015,2016, Nov/dec-2019)**

Expansion joints are necessary in precast structures in order to allow for the expansion and cooling of various members due changing in temperature. In precast structures the shrinkage takes place before the assembling of members, therefore the spacing of expansion joints may be 1.5 to 2 times greater than in monolithic structures.

Expansion joints are usually a complete gap formed at the joint of roofing members and main girders.

3. **What are connections? (May/june 2012)**

In precast members to overcome operational difficulties the member are disunited into smaller elements. Connections are used to get required structures by joining the separate smaller elements.

4. **What are the different types of connections?**

There are two types of connections

i. Wet connections (with mortar or in situ concrete)

ii. Dry connections (with welding and bolting)

S. What are the points to be considered while designing the connections?

i. Loading under working condition

ii. Stability of structures

iii. Load conditions during construction

iv. Effect of shrinkage, creep and temperature

v. Unequal settlements.

6. What are the different connections made in prefabricated structures?(Apr/may-2016,2017, Nov/dec-2019)

- **i.** Column to column connections
- ii. Beam to beam connections
- iii. Main beam to secondary beam connections.

7. **What are the different types of joints? (Nev/Dec 2016,2013,Apr/may-2017)**

- i. Expansion joints
- ii. Contraction joints
- iii. Crack control joints
- **iv.** Construction joints

8. What are the materials used for concrete joints?

- Dowels
- Sealants
- Flexible boards

9. Based on location within a 'building, how connections can *be* classified?

Based on location within a building connections arc classified into vertical and horizontal joints. .

Vertical joints connect the :vertical laces of adjoining wall **panels and** primarily resist vertical seismic shear forces.

Horizontal joints connect the horizontal laces of the adjoining wall and floor panels and resist both gravity and seismic loads.

10.What are the functions or importance of joints? (May/June 2009)

Joints between internal and external wall panels shall be designed to resist the forces acting on them without excessive deformation and cracking. They shall also be able to accommodate the deviations in the dimensions of the wall panels during production and erections.

11. Define joint. (MAY/JUNE 2012)

It is desirable for the structure should be load bearing as soon as possible, preferably, immediately after assembly.

In additional demand is that, the joint should require only a little material and should not be labour observing (i.e) cost should he minimum.

12.What are the requirements of joint's. (MAY/JUNE 2009, 2012)

- The forming and construction of joints requires greatly increased control.
- The design and construction of joints should normalise with the materials to be used
- Joints must be designed and executed to ensure dimensional tolerance.
- A relative displacement of the joint member should be impossible.

13. How wall panels are connected with frames? (Apr/may 2015,2019)

Vertical joints connect the vertical faces of adjoining wall panels and primarily resist vertical seismic shear forces.

Horizontal joints connect the horizontal faces of the adjoining wall and floor panels and resist both gravity and seismic loads.

14.State post tensioned connections.(Nov/dec-2016,2013)

Post tensioned connections can generally be joined for simpler than the usual reinforced concrete structures. In post tensioned structures, the forming of joints does not cause difficulties. In this all the joints are course rigid and moment bearing.

The post tensioned connection is one of the prestressed concrete structures. The members are prepared in the plants, then the member is erected at the site. Here the methods like Magnal Blaton Giffard Udal are used to connect the members. The tendons are tensioned after fixing the members which is commonly called as post tensioned connection.

15.State whether the precast structure needs an expansion joint.(Apr/may-2017)

In precast strures, expansion joints allow exapansion and contraction of a member without generating potential damaging forces within the member itself.

16.How will you joint precast column to the footing?(Nov/dec-2017)

Rigid joint can be made by placing the column into a calyx of the footing or by using a welded joint.

17.Describe the ductility of joint. (May/Jun 2013)

The joint which carries two or more elements fixed together. The joint should be designed to carry the loads such as dead load, live load, wind load etc. When the joint should take heavier load which is greater than the ultimate load, then the joint gets more elongated. It is called ductility of joints

18.What is meant by tolerance?(Apr/may-2018)

Tolerance is the limiting value of the admissible deviation in the size or shape of the finished prefabricate from the design requirements. In practice, it is impossible to make products which will have the exact design dimensions. The maximum tolerance values which will guarantee the correct assembly and the efficient functioning of the individual prefabricates

PART-B

1. **EXPLAIN ABOUT JOINTS FOR DIFFERENT STRUCTURAL CONNECTIONS.(Apr/may-2015,2016,2017,2018,2019,Nov/dec-2016,2019)**

One of the most intricate and most difficult problems to be solved in both design of construction of structures assembled of prefabrication members is the joining.

It is highly important that the construction of the joints should be easy that unavoidable smaller inaccuracies and deviations within dimensional tolerances should neither influence the designed stresses in a detrimental manner nor cause is admissible changes in the stress distribution of the structures.

The forming and construction of joints requires owing to their intricacy, great increased control joints which cannot be inspected should be omitted.

When solving the problem of joints the properties of reinforced concrete must be taken into consideration. This means in other words, that the design of the construction of the joint should harmonize with the materials to be used. The properties of steel of timber are quite different from those of concrete and reinforced concrete. Therefore joints similarly to those used in timber and steel construction are generally not appropriate for the purpose.

Joints of reinforced concrete structures which should be omitted are shown

These joints have to be seen. This is a solution resembling a butt joint with splayed table as used in timber construction. This doesn't comply with the nature of the material of so is not good for this purpose.

The joints can be rigid hinge-like or shed rigid joints are adequate in addition to the bearing the tensile, compressive of shear forces for resistance.

Design of class based an efficiency of the material used:

The plastic concrete can be used for the subsequent concrete of joints of the fluid cement mortar cast or pressed into the gaps less part of their water during the setting time of shrink, after setting the shrinkage of the insite concrete of mortar continue.

With respect to two phase of shrinkage same codes on reinforced concrete construction permit only reduced stresses for a subsequent insite concrete of a mortar casting. There are generally determined as a function of width of the joint on the gap to be concrete as cast.

Joints must be designed of executed so that compensation for the allowed dimensional tolerances is ensured. A relative displacement of the joined member should be impossible even as a result of a blow or of any other unfavourable force effect. The length of the section determined for the transmission of forces should be as short as possible but should excluded any excess of the permissible stress.

The joints can be rigid hinge like or shed. Rigid joints are adequate in addition to the bearing of tensile, compressive of shear forces for resisting to bending moments too. These joints make relative displacement and relative relation impossible. Hinge like joints can transmit forces passing through the hinge itself and also allow a certain motion and rotation.

Rigid joints are generally used for the junction of column to footings, but they can also be applied for joining of individual groups with one another. The joints generally used in the construction with precast members are usually hinge like. Their execution is simpler and requires less working lime than rigid joints "shed joints" are only exceptionally used in industrial construction of are justified for a long span only. These joints are chiefly used in bridge construction for long span bridges depending on the necessity of insite concreting; two kinds of joints can be distinguished.

Dry joints = joint accomplished by simple placing of two members on each other of fasting. Wet joints = joint require not only casting with cement mortar but also subsequent concreting.

Joints for different structural connections:

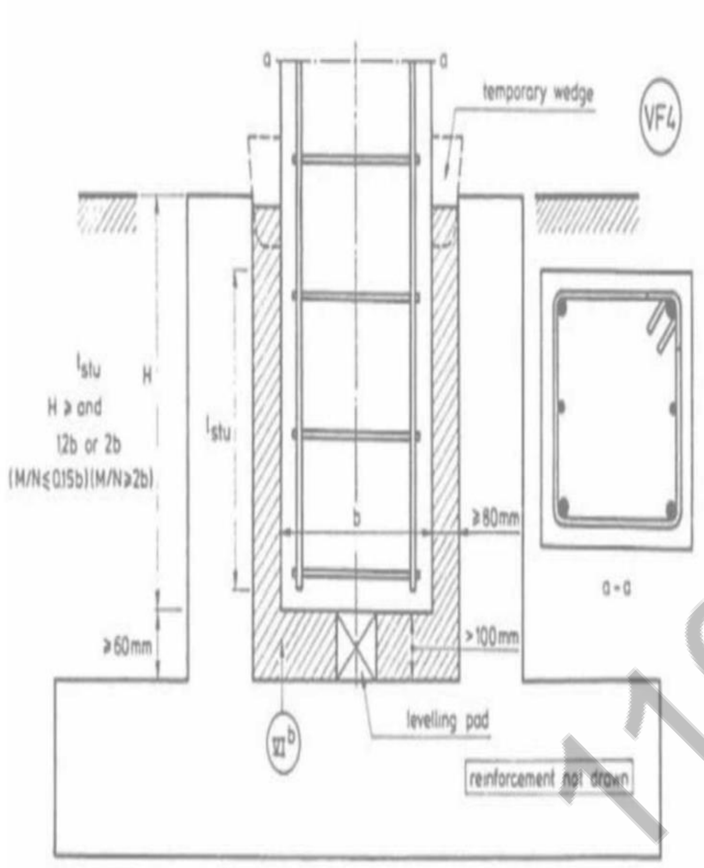
- Jointing of column to footing
- Jointing of column to beam on top of column.
- Jointing of column to beam at an intermediate functions.
- Lengthening of columns.

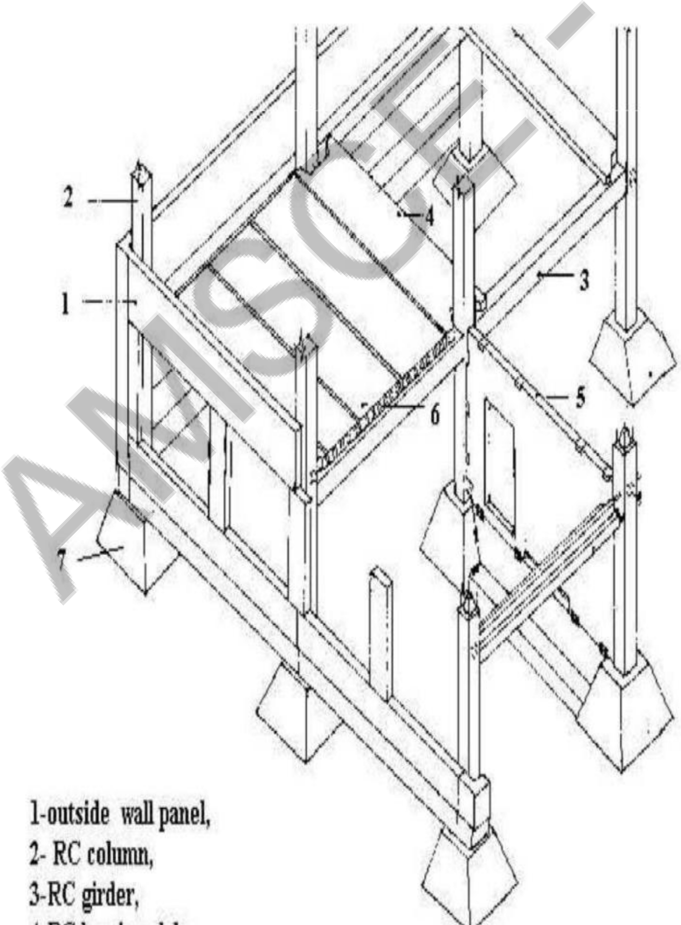
- Jointing of beams.
- Forming of joints of arched structure.
- Joining of joints f post tensioned structures.
- Joining of precast to monolithic reinforced concrete structures.

(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 levelling before concreting. A similar steel plate is

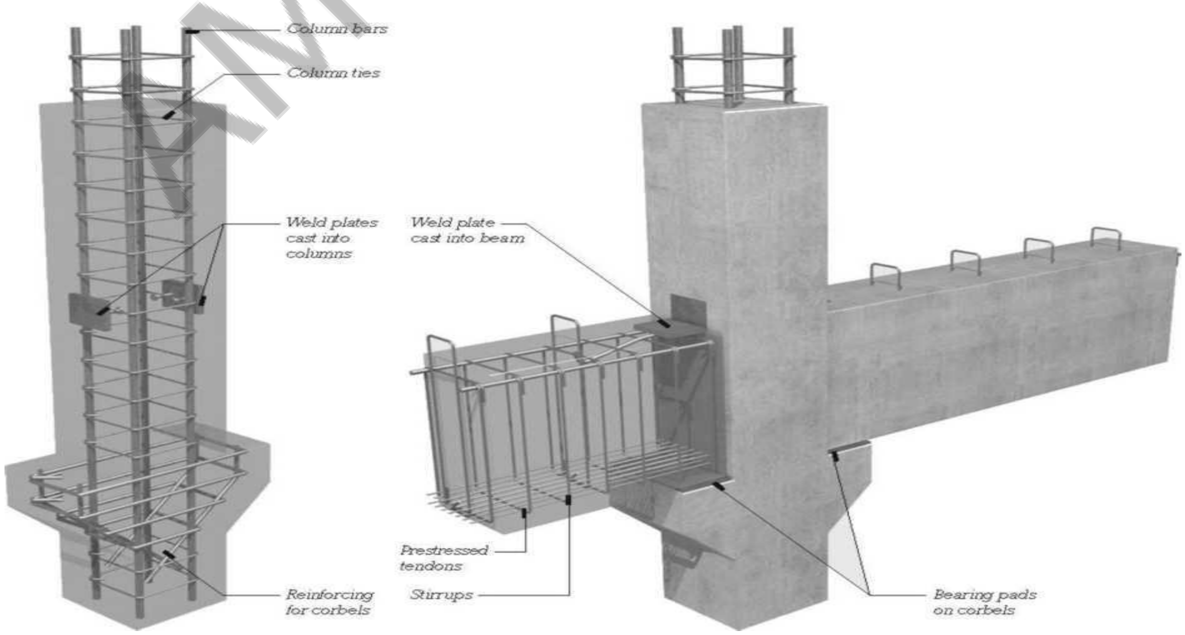
plates must be on each other. The dimensions of these steel plates are frame 100x100x10 to 150x150x10 mm a chord into the concrete after the column is put in placed properly plumbed two advantages of the calyx joint should be mentioned.

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 a calyx depth of which is greater than 1 m.

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

One method of forming a hinge like joint consists either or placing to beam on to a small cantilever protracting fram 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.

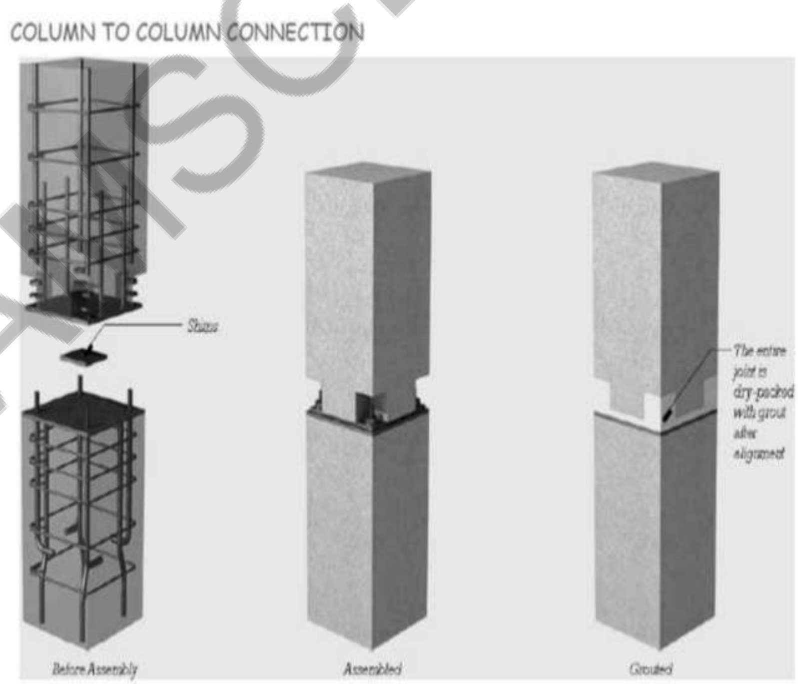


Hinge like joining of girder to column:

1. Opening for casting.
2. Subsequent concreting.
3. Steel plate.

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.

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 borm 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.

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.

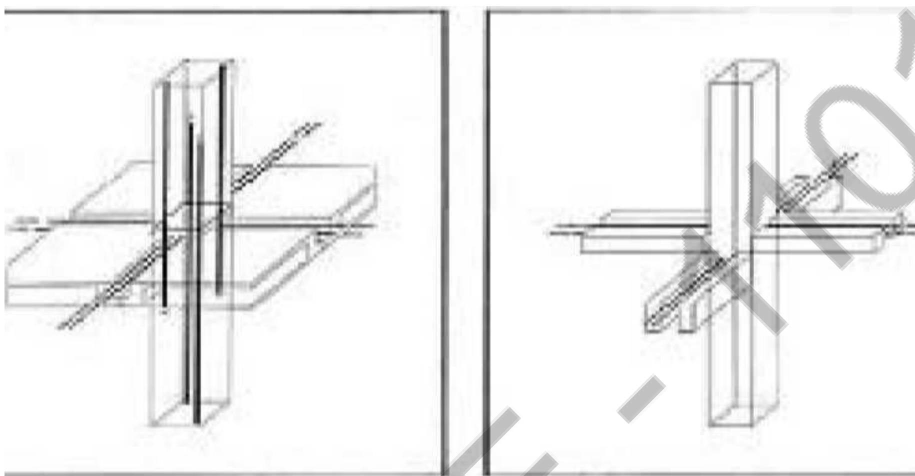
.

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.

A rigid point of these kinds established between a column two girders supported by the former after the casting of the gaps and hardening of the mortar, the short inserted cables and stressed and so rigid joint is established.



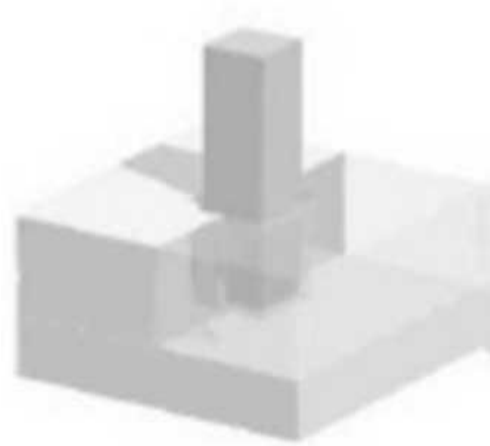
(g) **JOINING OF PRECAST TO MONOLITHIC REINFORCED CONCRETE STRUCTURES:**
It frequently occurs that a monolithic beam has to be joined to a precast column. In this casethe function can be established in the same way as already been described in the previous paragraph an joining namely by placing the end of the beam either on to a cantilever protruding from the column or into an opening formed into the columns shaft.

When making the joint, first of all a 2.5 cm deep cavity is chiselled out of the siole of the precast column. The bottom of this cavity should be roughened so as to attain a belter band between the concrete of the monolithic beam and the precast column.

2. EXPLAIN JOINING OF COLUMNS TO FOOTING(Nov/dec-2019)

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



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 levelling before concreting. A similar steel plate is

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.

3. 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.
4. 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 a calyx depth of which is greater than 1 m.

3. EXPLAIN ABOUT JOINING OF COLUMN TO BEAM AT AN INTERMEDIATE JUNCTION:

One method of forming a hinge like joint consists either or placing to beam on to a small cantilever protracting fram 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.

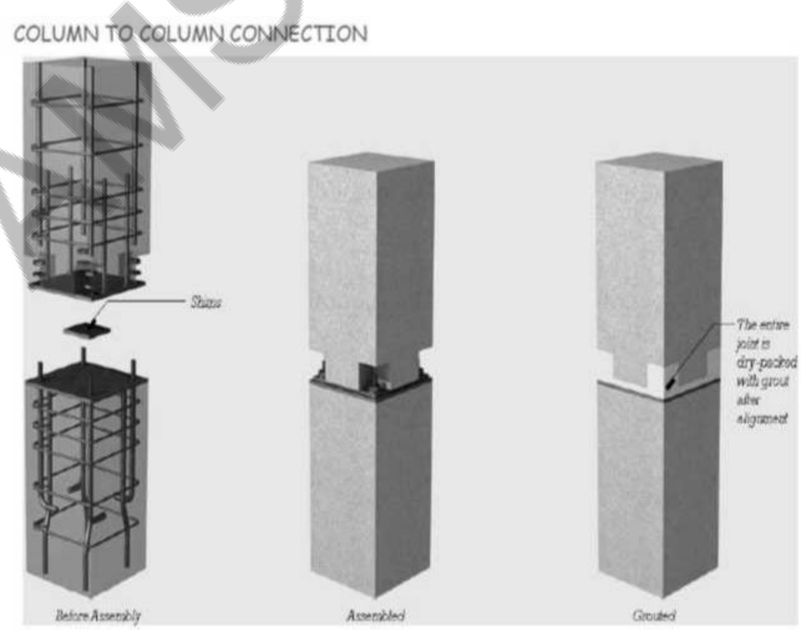
2. Subsequent concreting.

3. Steel plate.

4. EXPLAIN ABOUT LENGTHNING OF COLUMNS AND JOINING OF BEAMS

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.



(a) JOINING OF BEAMS:

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

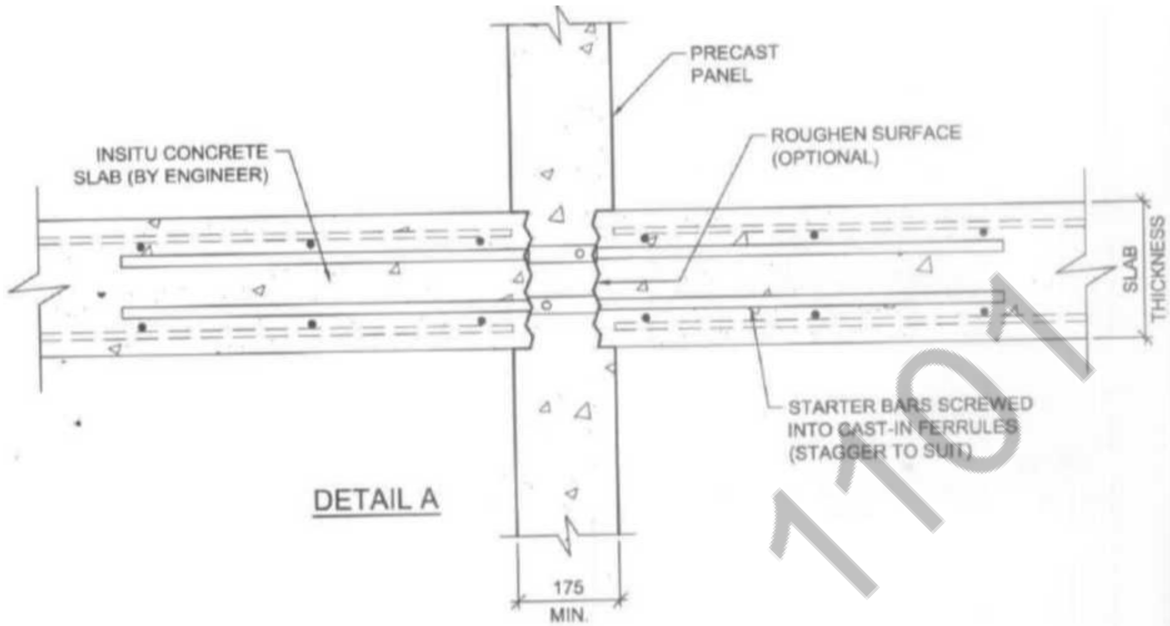


Fig. shows the hinge like joint of purlins. In this method the whole shear must be borm by both cantilevers (i.e.) by two separate structures therefore it is expedient to form this joint at least for large girders.

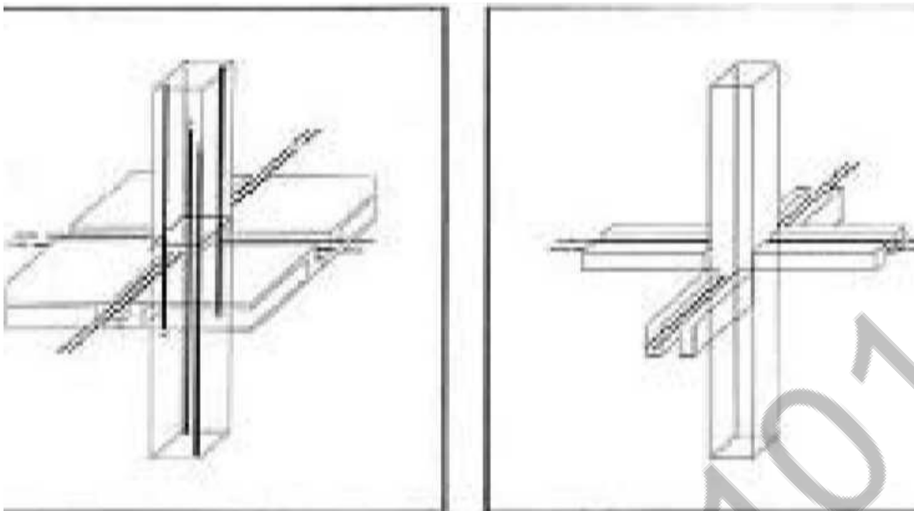
The method illustrated in the fig presents a dry joint of beams which is called a bolted front. The advantages of this joint are immediate bearing capacity.

5. WRITE ABOUT DESIGN OF JOINTS FOR POST TENSIONED STRUCTURE.

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.

A rigid point of these kinds established between a column two girders supported by the former after the casting of the gaps and hardening of the mortar, the short inserted cables and stressed and so rigid joint is established.



JOINING OF PRECAST TO MONOLITHIC REINFORCED CONCRETE STRUCTURES:

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 into the columns shaft.

When making the joint, first of all a 2.5 cm deep cavity is chiselled out of the siole of the precast column. The bottom of this cavity should be roughened so as to attain a belter band between the concrete of the monolithic beam and the precast column.

6. EXPLAIN ABOUT EXPANSION JOINT.(Apr/may-2015,2016, Nov/dec-2017)

An Expansion joint is an assembly designed to safely absorb the heat -induced expansion and contraction of various construction material to absorb vibration or to allow movement due to ground settlement or earthquakes they are commonly found between sections of sidewalks, bridges, railway tracks, piping systems, and other structures.

EXPANSION JOINT DESIGN

A design specification shall be prepared for each expansion joint application. Prior to writing the expansion joint design specification it is imperative that the system designer complicity review the structural system layout and other items which may affect the performance of a expansion joint particular attention shall be given to the following items the system should be reviewed to determined the local and type of expansion joint which is most suitable for the application. The availability of supporting structures of anchoring and guiding of the system and the direction and magnitude of thermal moments to be absorbed must be consider when selecting the type and location of the expansion joint.

CONVENTIONAL RUBBER EXPANSION JOINT

Expansion joints are designed to provide stress relief in piping system that are loaded by thermal movements and mechanical vibration. To deal with the various forces on the joint they require fiber reinforcement which guarantees both flexibility and strength. conventional expansion joints are reinforced using prefabricated fiber pipes, the use of these fiber pipes makes it impossible to control the orientation of the fiber on complex shape such as the below of the expansion joint. In both case the inability to use the fiber in the optimal way leads to the following disadvantages.

High material cost

- More fiber needed then necessary
- More rubber needed then necessary

(b) Additional parts such as material reinforcement rings necessary with multiple bellows Lower Performance High rubber wall thickness and fiber pack make product less flexible Undesired radial and axial expansion under pressure.

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

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

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 FTotal thermal

movement range is calculated as

Δtemp = α. $L_{t.}$. ∂_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

$\partial_{T=}$ 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

7.Explain the types of structural joints and also the requirements of joints?

(Apr/may-2019,2017,Nov/dec2013)

Types of Joints in Concrete Constructions

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

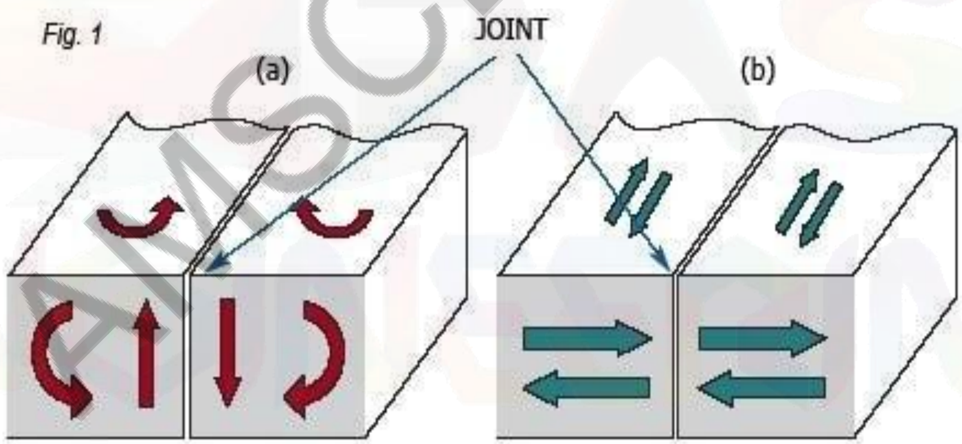


Figure 1 – Relative movements which must be (b) allowed and (a) not allowed by a con-struction joint for concrete slabs

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, subbase and subgrade, 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 a 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 deeper than the slab subgrade, are not going to move the same way a slab does as it shrinks or expands from drying or temperature changes or as the subgrade 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 unjointed sections.

- Very long unjointed 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 subbase, 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 Whitelam 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 and fitness

d. The joints should get sufficient yield strength

e. The joints should be provided rich mortar (or) concrete compared with joining member

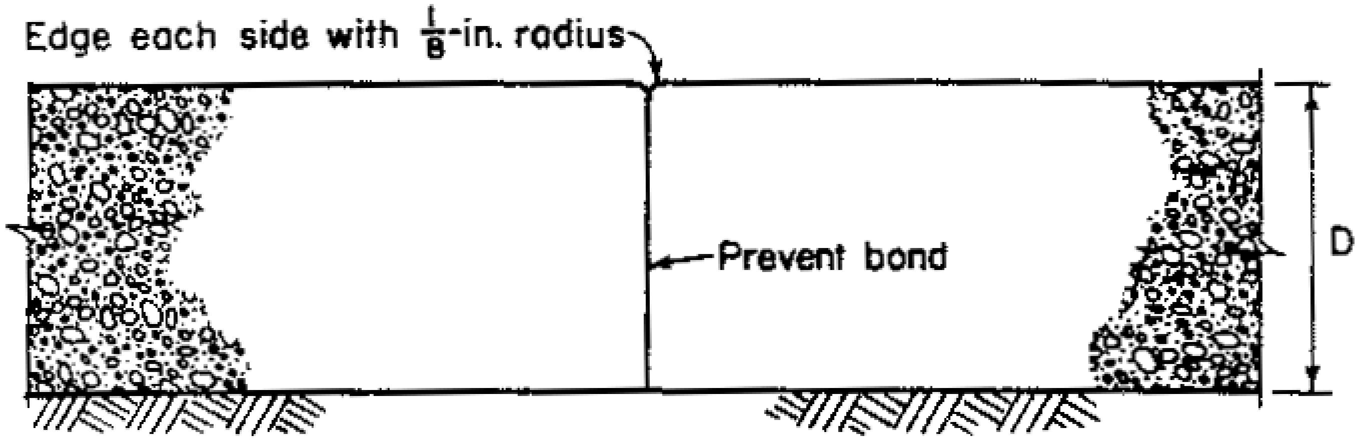
f. The joints should be plumb checking

g. The module of the joint should be checked

h. The dowel rod must be welded with main members

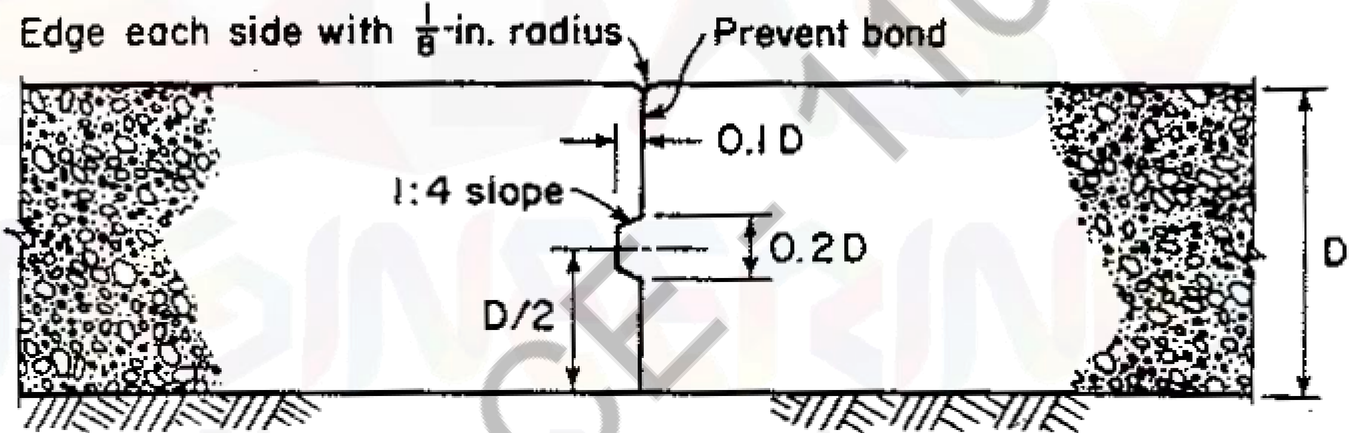
i. Sufficient stirrups should be provided for beam members

j. Sufficient lateral ties should be provided for beam members



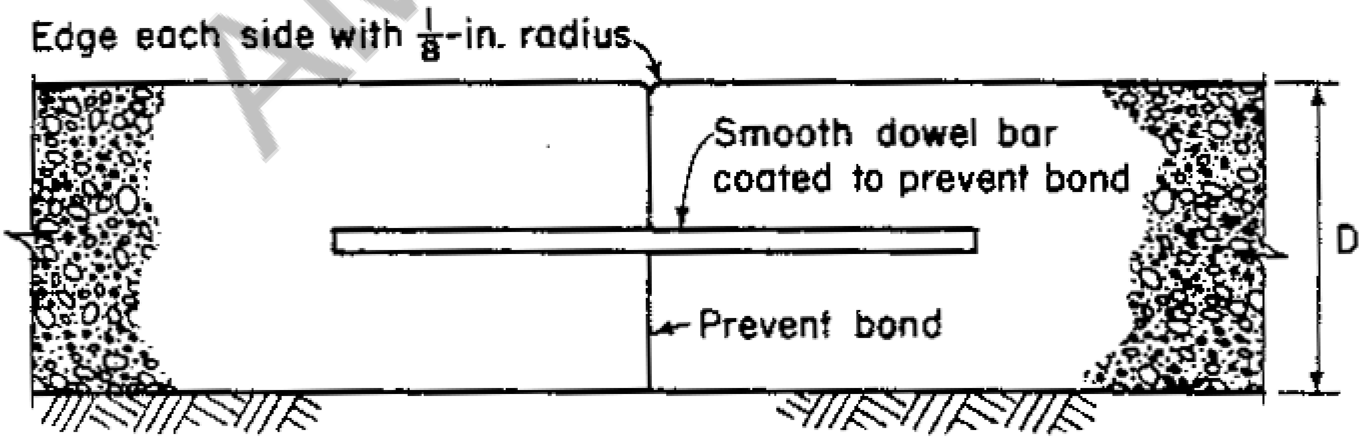
Butt-type construction joint

(a)



Tongue-and-groove construction joint

(b)



Butt-type construction joint with dowels

(c)

UNIT V

DESIGN FOR ABNORMAL LOADS

PART-A

1. What is progressive load?(Apr/may-2013,2015,2016, Nov/dec-2016)

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

2. What is 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 interconnect more effectively

3. What is 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 approach has 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

4. Explain about equivalent design loads. (Apr/may-2016,2018, Nov/dec-2013,2016)

It represents the total load which is taken as a equivalent for a given abnormal condition, D=dead load, L=live load, S=snow load, A_k =abnormal load

Load capacity = (0.9 or 1.2) D + (0.5 L or 0.2S) + A_k

5. **What are the methods of avoiding disproportionate collapse? (Apr/may-2017,2019)**

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 continue

6. **Write the Design Requirements for Safety Against Progressive Collapse**

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

7. **What is Key Elements?**

For buildings of five or more storeys, the layout should be checked to identify key elements. A key element is such that its failure would cause the collapse of more than a limited area close to it. The limited area defined above may be taken equal to 70 m2 or 15 percent of the area of the storey, whichever is lesser.

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

8. Explain abnormal loads.(Apr/may2017,Nov/dec-2017,2019)

Loads other than conventional design loads (dead, live, Wind, seismic, etc.) for structures such as air blast pressures generated by an explosion or impact by vehicles, etc.

1. Accidental impact
2. Faulty construction
3. Foundation Failure
4. Violent changes in Air pressure

9.Differentiate magnitude and intensity of earthquake.(Apr/may-2015, Nov/dec-2017)

Magnitude and Intensity measure different characteristics of earthquakes.

MAGNITUDE

- Magnitude measures the energy released at the source of the earthquake.
- Magnitude is determined from measurements on seismographs.

INTENSITY

- Intensity measures the strength of shaking produced by the earthquake at a certain location.
- Intensity is determined from effects on people, human structures, and the natural environment.

10 .Define Degree of Progressivity.(Apr/may-2019)

It is defined as the ratio of total collapsed area or volume damaged directly by the triggering event.

11. Explain the importance factor and response reduction factor used in static analysis for calculated seismic forces design. (Apr/may-2018)

Importance factor

It is a factor used to obtain the design seismic force depending on the functional use of the structure, characterized by hazardous consequences of its failure, its post-earthquake functional need, historic value, or economic importance.

Response Reduction Factor (R)

It is the factor by which the actual base shear force, that would be generated if the structure were to remain elastic during its response to the Design Basis - Earthquake (DBE) shaking shall be reduced to obtain the design lateral force

PART-B

1. **Define abnormal loads. Explain the causes of progressive collapse**? **(April/May 2011, 2015, Nov/dec-2017)**

ABNORMAL LOADS:

Loads other than conventional design loads (dead, live, Wind, seismic, etc.) for structures such as air blast pressures generated by an explosion or impact by vehicles, etc.

1. Accidental impact
2. Faulty construction
3. Foundation Failure
4. Violent changes in Air pressure.

(1) ACCIDENTAL IMPACT:

Several cases of progressive collapse have been caused by accidental impact. An example of this form of abnormal loading is an automobile striking a key member *in a* structure (i.e. buildings, bridge etc)

(ii) FAULTY CONSTRUCTION:

There have been several instances throughout history where poor construction practices have lead to progressive collapse.

A notable example of this was the skyline plaza apartment in Fairfax County,Virginia.

This failure was attributed to premature removal of supporting forms.

This lead to localized failure, followed by a progressive collapse of the northwest corner of the building.

(iii) FOUNDATION FAILURE:

Failure of a small portion of a structures foundation can result in a loss of primary support.

This failure could be the result of problems with erosion, geology, catering due to explosion etc., If the remainder of the structure is unable to redistribute this change in load caused by the loss in support, extensive damage to the structure could be much greater.

(iv) **VIOLENT CHANGES IN AIR PRESSURE:**

An extreme change in air pressure can stem from any sources such as explosions caused by gas, high explosives etc.,

Progressive collapse avoidance has several advantages:

Provides a solid exterior surface to meet blast resiliency requirements

Delivers the inherent strength of concrete tilt-up panels for overall durability

Minimizes cost to fix a damaged area compared to a steel framed building

Eliminates perimeter stell leading to greater interior space planning flexibility. 2.

2.Explain the codal provisions for Progressive collapse. (Nov/Dec 2013,2016,2019) (May/June 2012,2015,2018)

The following are the coda! provisions for progressive collapse

1. ASCE 7-02
2. AC[318-02
3. GSA PBS facilities standards 2000

4.. GSA PBS facilities standards 2003

5. GSA PBS progressive collapse guidelines 2003.

1. **ASCE 7 -02:**

The American society of civil engineers, minimum design loads for buildings and other structure (ASCE,2002) has a section on "general structure integrity" that reads thus: Building and other structures Shall be designed 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 elements 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 he accomplished by providing sufficient continuity, redundancy, or energy-dissipating capacity (ductility) or a combination there of in a members of the structure. Clearly, the focus in .the ASCE standard is on redundancy and alternate load paths over all other means of avoiding susceptibility to disproportionate collapse.

But the degree of redundancy is not specified and the requirements are entirely threat -independent

2. **ACI 310 -02:**

The American concrete institution building code requirements for structural concrete (Adl, 2002) include extensive "Requirement for structural integrity" in the chapter on reinforcing steel details.

is Though the commentary states that it Is an intend of this section to improve redundancy "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 tying together of precast structural components.

:• None of the ACI provisions are threat specific in anyway.

3. GSA PBS Facilities Standards 2000:

The 2000 edition of the GSA's facilities standards for the public building service (GSA 2000) included the following statement under the "progressive Collapse" heading in the "Structural Considerations" section. "The structure must be able to sustain local damage without destabilizing the whole structure. The failure of beam, slab, or column shall not result in failure of the structural 55'stc.T,ii below, above, or in adjacent bays. in case of column failure, damage hi the beams and girder above the column shall be limited to large deflections.

This is an absolute and unequivocal requirement for one-member (beam, slab or column) redundancy, unrelated to degree of vulnerability of the member or the level of treat to the structure.

4. GSA PBS facilities standards 2003:

The 2003 edition of the GSA's facilities standards for the public buildings service (GSA, 2003) retained the "Progressive Collapse" heading from the 2000 edition, but replaced all of the words reproduced above with this short statement [41] Security Design".

The structural provisions apply only to buildings deemed to be at risk of blast attack.

For such buildings, the chapter provides general performance guidelines and references to various technical manuals for the study of blasts effects.

This represents a complete change of approval from the 2000 version of the same document.

S. GSA PBS Progressive Collapse Guidelines 2003:

The GSA *Progressive* collapse analysis and design guidelines for new federal

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 nonexempt) 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.

In some ways, these guidelines appear to be a throw-back to the GSA's PBS.
Facilities standards of 2000 in that their central provision is a requirement for one-member redundancy, unrelated to the degree of vulnerability of the member or the level of threat of the structure.

3. Explain the methods of preventing disproportionate collapse.(Apr/may-2019,2018 2015)

METHODS OF PREVENTING DISPROPORTIONATE COLLAPSE:

There are three alternative approaches in designing the structure to reduce their susceptibility to disproportionate collapse.

1 **Redundancy or Alternate load paths.**

2. **Local resistance**

3. **Interconnection or continuity.**

1. **Redundancy or Alternate load 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 a general collapse do not occur,

This approach has benefit of simplicity and directness.

In most common applications, design of redundancy requires that a building structure he able to tolerate loss of any one column with collapse. This is an objective, easily -understood performance requirement.

The problem with the redundancy approach, as typically practiced, is that it does not account for differences in vulnerability.

Clearly, one - column redundancy when each column is a W8 X35 does not provide the same level of safety as when each column is a 20001b/ft built up section.

Indeed, *an* explosion that could take out the 20001b/ft column would likely to destroy several of the W8 columns, making one-column redundancy inadequate to prevent collapse in that case.

And, yet codes and standards that mandate redundancy of small and lightly loaded column, redundancy requirements may have the unfortunate consequence of encouraging designs with many small columns rather than fewer larger columns.

2 Local Resistance:

In this approach, susceptibility to progressive collapse is reduced by providing critical components that might he 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 objective way.

3. **Interconnection or Continuity:**

This method of approach is a mean of improving either redundancy or local resistance or both.

Studies of many recent building collapses have shown that the failure could lio.ve been avoided or at least reduced in scale, at. fairly small additional cost, if the structural components are interconnected more effectively.

This is the basis of the "Structural Integrity" requirements in the ACI 318 specifications.

4. **Explain the *Guidelines* for achieving Structural integrity.**

1. Connections between structural components should be ductile and have a capacity for relatively large deformations and energy absorption under the effect of abnormal conditions.

2. Good Plan Layout:

An important factor in achieving structural integrity is the proper plan layout of walls and columns,

- In bearing walls structures there should be an arrangement of interior longitudinal walls to support and reduce the span of long sections of cross wall. Thus enhancing stab ill ty of individual walls and of the structure as a whole.

3. An integrated System:

Provide an integrated system of ties among the principal elements of the structural systems. These ties may be designed specifically as components of secondary load-carrying.

4. Return on Walls:

Returns of interior and exterior walls will make them more stable.

5. Interior Explosion.

When explosions occur within structures pressures can build up within confined spaces, causing lightly attached wall, floor and roof surfaces to be blown away.

6. Changing directions of span of floor slab:

Where a one way floor slab is reinforced to span in main direction, provided spanning capability in its secondary direction also perhaps using a lower safety factor.

With this approach, the collapse of the slab will be prevented and the debris loading of other parts of the structure will be minimized_

Often. shrinkage and temperature steel may be enough to enable the slab to span in the secondary direction.

5. *Give* some examples of Progressive Disproportionate collapse.(Apr/may-2017)

1. Ronan Point:

In May 19613, a gas explosion occurred in the newly occupied 24-storey Ronan Point apartment building, located in London, England. The explosion took place in an apartment kitchen near one corner of the building at 18th floor level. The blast blew out a primary supporting exterior bearing panel which led to loss of support for the floors above. This in turn began a chain reaction of collapse, upwards to the roof level. As a result of the loading generated by falling debris, lower floor also collapsed.

Construction of the Ronan point complex primarily consisted of precast panels. While this type of construction can be designed to avoid progressive collapse from abnormal loading conditions. The Ronan Point complex lacked the connection details necessary to effectively redistribute load. The essential training detail from this England apartment building was reinforcement continuity between panels. Because of this there was no mechanism in place for achieving alternatives load paths once failure began to propagate.

2.In the morning of April 19,1995, a terrorist bombing was directly at the. 9-storey A.P. Murrah Federal Building in Oklahoma city. This attack significant loss of life and inflicted many injuries to the occupants of this GSA facilities. The vast majority of the deaths were attributed to falling debris generated by the progressive collapse that the structure underwent. When the bomb detonated, primary support columns along the perimeter were locally damaged. The localized doge of these bearing members initiated a series o failures that extended across much of the north *face* and though the width of the building in the eastern part of the structure.

The primary structure of the A.R Murrah Federal Building consisted of c reinforced concrete ordinary moment frame with typical bay size of 20ft by 351t An important structural feature of the building was the use of transfer girder at the 3rd floor level. The girder provided support for intermediate columns that extended from the 3rd flour to the roof level. However, from the first floor to the third floor, there was a 40ft column spacing (as opposed to the 20ft spacing above the 3rd floor level. Hence, the loss of a column along the ground level created an 80ft unsupported length. It is believed that this was a primary mechanism that caused the progressive collapse of the building. This type of a structural feature is typically avoided when considering abnormal loads, since the use of transfer girder can potentially limit the building ability to effectively redistribute load. The GSA security criteria explicitly prohibit the use of transfer girders in the design of GSA facilities.

3. World trade centre 1 and 2:

Each of the twin towers of the world trade centre 1&2 collapsed on 11th September 2011 following this sequence of events: A Boeing 767 jetliner crashed into the tower at high speed. The crash caused structural damage at and near the point impact zone lost its ability to support the load above it, as a result of some combination of impact damage and fire damage. The structure above collapsed, having lost its support, the weight and impact of the collapsing upper part of the tower caused a progression of failures extending downward all the way to the ground.

Clearly, this was a "progressive collapse" by any definition. But it cannot labeled a " Disproportionate Collapse".lt was a very large collapse caused by very large impact and fire.And unlike the case with Murrah building, simple changes in the structural design that might have greatly reduced the scale of the collapse have not yet been identified.

5. **Write the design criteria for 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

Design strategies

c. 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 immateri al 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).

6. Explain the procedure for calculating equivalent design loads when the structure is subjected to earthquake loading. (May/June2013,2017,2018,2019,Nov/dec-2016,2017)

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.

7, Define equivalent static loads analysis in progressive collapse. (Nov/*Dec* 2013)

Equivalent Static Analysis

The equivalent static analysis procedure is also essentially an elastic design technique, although some consideration of the post-elastic response enters into the selection of the determination of the lateral force coefficient (item 2 below). It is, however, simple to apply than the multi-model response method, with the implicit simplifying assumptions being arguably more consistent with other assumptions implicit elsewhere in the design procedure.

The equivalent static analysis procedure involves the following steps:

1.Estimate the first mode response period of the building from the design spectra.

2. Use the specific design response spectra to determine that the lateral base shear of the complete building is consistent with the level of post-elastic (ductility) response assumed.

3. Distribute the base shear between the various lumped mass levels usually based on an inverted triangular shear distribution of 90% of the base shear commonly, with 10% of the base shear being imposed at the top level to allow for higher mode effects.

4. Analyse the resulting structure under the assumed distribution of lateral forces and determine the member actions and loads.

5. Determine the overall structural response, particularly regarding the inter-storey drifts assessed for the elastically responding structure. (For the assessment of the post-elastic deformation, design standards typically magnify the elastic deformed shape by the structural ductility to determine the overall maximum deformation-typically at roof level. The introduction of a non-linear response profile to allow for local rotation at plastic hinge zones is often required when determining the inter-storey drifts.)

B. Mention some case study for building code approaches to progressive collapse.

Most structural design standards in North America and in Western Europe have acknowledged the existence and Potential consequences of abnormal loads and progressive collapse for some time.

Ne**f** Most standards contain a statement. of required structural performance, to the effect that local damage to the structure shall not have catastrophic consequences. In some codes, accidental loads are acknowledged explicitly (e.g,, United Kingdom, Sweden, The Netherlands).

✓ Most recognize the desirability for continuity between structural elements, and several specify minimum tie forces to achieve continuity. Some specify the "notional removal" of an external load bearing element; others, a floor area or volume of damage that the remaining structure is required to bridge.

The applicability of provisions varies from country to country - in some, they apply to practically all buildings, while in others only to certain forms of construction or buildings over a certain minimum height (typically 5 to 6 stories).

ASCE 7/ANSI A58 first introduced a requirement for progressive collapse due to "local failure caused by severe overloads" in Section 1.3.1 of ANSI Standard A58.1- 1972, the first edition following the 1968 Ronan Point collapse. No commentary or other guidance was provided. ANSI Standard A58.1-19432. Section 1.3, retiled General Structural, Integrity, contained a more comprehensive performance statement, and referred to a greatly expanded commentary section and references

for guidance.

The 1988 and 1993 editions (now titled ASCE Standard 7) illustrated several

structural system layouts that would lead to development of alternate load paths. Section 1.4 of ASCE 7-95 retained the performance requirement that a building be designed to sustain local damage, with the structural system as a whole remaining

Stable. However, the commentary was shortened, keeping the discussion of general Design approaches to general structural integrity but eliminating the figures and

other specific guidance. At the same time, a new Section 2.5 was added that required a check of strength and stability of structural systems under low-probability events, where required by the authority having jurisdiction (AHD.

The provisions in ASCE 7-98 and ASCE 7-02 are essentially the same as in the 1995 edition. The (non-mandatory) Commentary C2.5 recommends the following load combination for checking the ability of a damaged structure to maintain its overall stability for a short time following an abnormal load event:

(0.9 or 1.2)10.5 L or 0.2 S) $- 0.2 W (1a)

in which 0, i., W and S ;:ire specified dead, live, snow and wind loads determined according to Sections 3, 4, 6 and 7 of ASCE 7-02. This check suggests the notional removal of selected (presumably damaged) load-bearing elements at the discretion *of* the engineer without stipulating tolerable damage. If certain key elements in the structural system must be designed to withstand the effects of the accident (perhaps to allow the development of alternate load paths), they should be designed using the combination,

(0.9 or 1.2) D A_k (0, 5 1, or 0.2 S) (1 b)

in which A_k is the postulated action due to the abnormal load. Normally, only the main load-bearing structure would be checked using these equations.

Building code officials in the United States have not been enthusiastic about provisions related to general structural -integrity because they are difficult to cast in prescriptive code language and to enforce.

Most building codes in the United States have not contained such provisions. Whether the new paradigm of performance-based engineering and the related new initiatives will impact this resistance remains to be seen.

Eurocode I - The general design requirements in Section 2 of Eurocode 1 -Actions on Structures, Part 1 - Basis of Design (CEN 250 1994) state that a structures shall be "designed in such a way that it will not be damaged by events like fire, explosions, impact or consequences of human errors. to an extern disproportionate to the original cause."

The engineer is permitted to choose a design method that eliminates or reduces the hazard, uses a structural system. that is insensitive to the hazard, ties the system together, or to design so that the system can tolerate accidental removal of an element. The design load combination used to demonstrate compliance using a specific "accidental" action, A_K. is specified as,

1.)1.-+1.1_1 Q_1+ E k.)1_{2i} Q_i (2a)

in which $*_1$ and 113_{2i} are companion action factors for "frequent" and "quasi-

permanent" values of load, which depend on the load and are presented in a table. As an illustration for combinations of dead, live and snow load for light occupancies, we would have,

A_k 0.5 (2b)

A_k 1- 0.2 S + 0.3 I, (2c)

A_k + 0.5W + 0,3 L (2d)

Specific local resistance - In this approach, "hard spots" are designed in the structure, at areas that are believed to be prone to accidental loads (e.g., exterior columns at risk from vehicular collision or sabotage) or that may be required to develop alternate load paths. One such requirement that was proposed subsequent to Ronan Point was that key load-bearing elements surrounding residential compartments served with natural gas be designed to withstand a pressure of 34 kPa (720 psi).

This enormous pressure was based on a series of tests that measured explosion pressures in residential compartments. One unattractive feature of such an approach is that it provides resistance to only one hazard.

A second is that specifying such a load provides exactly the sort of information that one might require to defeat the design.

Specific abnormal loads seldom can be designed against economically; it is better to eliminate the hazard or control the consequence of local damage (Breen and Siess 1979).

7. How to design the progressive collapse against abnormal loading?

Progressive collapse has attracted the attention of engineers since the structural failure of Ronan Point apartments, London, UK in 1968. Progressive collapse and robustness have become important issues in precast concrete cross wall construct i

V Due to the importance of this type of collapse, a number of researchers have attempted to conduct studies to develop design guidelines 'that would reduce or eliminate the susceptibility fit buildings to this form of failure. Today there are three methods to design against progressive collapse, which are:

Indirect method. In this method, the overall robustness of the structure will be increased through tie reinforcements. Specific local resistance method. This method requirrLF the designed elements to be able to resist a sudden accident which can lead to a removal of one member or more.