KARPAGAM ACADEMY OF HIGHER EDUCATION

(Established Under Section 3 of UGC Act, 1956)

COIMBATORE-641 021

FACULTY OF ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

15BECE7E03 PREFABRICATED STRUCTURES 3 0 0 3 100

OBJECTIVE:

At the end of this course students should have learnt the principles, need for prefabrication, components, design principles, joints in structural members, design for abnormal load in prefabricated structures.

UNIT I **9**

Introduction: Need for prefabrication – Principles – Materials – Modular coordination – Standardization – Systems – Production – Transportation – Erection.

UNIT II **9**

Prefabricated Components: Behavior of structural components – Large panel constructions – Construction of roof and floor slabs – Wall panels – Columns – Shear walls

UNIT III **9**

Design Principles: Disuniting of structures- Design of cross section based on efficiency of material used – Problems in design because of joint flexibility – Allowance for joint deformation.

UNIT IV **9**

Joint in Structural Members: Joints for different structural connections – Dimensions and detailing – Design of expansion joints

UNIT V **9**

Design for Abnormal Loads: Progressive collapse – Code provisions – Equivalent design loads for considering abnormal effects such as earthquakes, cyclones - Importance of avoidance of progressive collapse.

TOTAL HRS : 45

TEXT BOOKS:

Sl.No	Title of Book	Author of Book	Publisher	Year of Publishing
1	CBRI, 1990, Building materials and components, India			
2	Knowledge based process planning for construction and manufacturing	Gerostiza C.Z., Hendrikson C. and Rehat D.R	Academic Press Inc.,	2012

REFERENCES:

Sl.No	Title of Book	Author of Book	Publisher	Year of Publishing
1	Manual of precast concrete construction, Vols. I, II and III, Bauverlag, GMBH	Koncz T	Bauverlag, GMBH	1971
2	Structural design manual,Precast concrete connection details 1978.Society for the studies in the use of precast concrete Netherland Betor Verlag			

WEBSITES:

- http://www.icivilengineer.com
- http://www.engineeringcivil.com/
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- http://www.asce.org/
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- http://www.ice.org.uk/
- http://www.engineering-software.com/ce/

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COIMBATORE-641 021

15BECE7E03-PREFABRICATED STRUCTURES

Lecture Plan

Staff Name : Ms.B.PREETHIWINI, M.E,

Semester : VII (2017-18 ODD)

Course Type : Core

Number of credits : 3

LTPC : 3 0 0 3

S.No	Lecture Duration (Hour)	Topics to be covered	Support Materials
UNIT I INTRODUCTION			
1.	1	Need for prefabrication	T_1/1,2
2.	1	Principles	T_1/2,3
3.	1	Materials	T_1/5
4.	1	Modular coordination.	T_1/22
5.	1	Standardization	T_1/22
6.	1	Systems	T_1/23
7.	1	Production	T_1/25
8.	1	Transportation	T_1/30
9.	1	Erection	T_1/30
UNIT II PREFABRICATED COMPONENTS			
10.	1	Behavior of structural components	T_1/49
11.	1	Large panel constructions	T_1/44
12.	1	Construction of roof and floor slabs	T_1/22
13.	1	Construction of roof and floor slabs	T_1/213
14.	1	Wall panels	T_1/218
15.	1	Wall panels	T_1/218
16.	1	Columns	T1/52,53
17.	1	Columns	T1/53
18.	1	Shear walls	T1/55
UNIT III DESIGN PRINCIPLES			
19.	1	Disuniting of structures	T1/65
20.	1	Design of cross section based on efficiency of material used	T1/66, 72
21.	1	Design of cross section based on efficiency of material used	T1/86
22.	1	Design of cross section based on efficiency of material used	T1/55
23.	1	Problems in design because of joint flexibility	T1/ 92
24.	1	Problems in design because of joint flexibility	T1/ 84
25.	1	Problems in design because of joint flexibility	T1/ 639
26.	1	Allowance for joint deformation.	T1/ 720-724
27.	1	Allowance for joint deformation.	T1/ 500,523

UNIT IV JOINT IN STRUCTURAL MEMBERS			
28.	1	Joints for different structural connections	T1/ 84
29.	1	Joints for different structural connections	T1/ 84, 12
30.	1	Joints for different structural connections	T1/ 199
31.	1	Joints for different structural connections	T1/ 890
32.	1	Dimensions and detailing	T1/ 984, 129
33.	1	Dimensions and detailing	T1/ 145,129
34.	1	Design of expansion joints	T1/ 162
35.	1	Design of expansion joints	T1/ 127
36.	1	Design of expansion joints	T1/ 152
UNIT V DESIGN FOR ABNORMAL LOADS			
37.	1	Progressive collapse	T1/ 902, 909
38.	1	Code provisions	T1/ 910
39.	1	Equivalent design loads for considering abnormal effects such as earthquakes, cyclones	T1/ 904, 910
40.	1	Equivalent design loads for considering abnormal effects such as earthquakes, cyclones	T1/ 910, 921,
41.	1	Equivalent design loads for considering abnormal effects such as earthquakes, cyclones	T1/ 979
42.	1	Equivalent design loads for considering abnormal effects such as earthquakes, cyclones	T_1/129
43.	1	Importance of avoidance of progressive collapse	T_1/775
44.	1	Importance of avoidance of progressive collapse	T_1/1155
45.	1	Importance of avoidance of progressive collapse	T_1/1155

TEXT BOOKS:

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- nptel.ac.in/downloads/105105110
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- www.aboutcivil.org/irrigation-engineering- prefabricated -lectures.html
- https://www.vidyarthiplus.com/vp/thread-14066.html
- https://www.vidyarthiplus.com/vp/thread-21750.html
- www.purdue.edu/dp/gk12/downloads/prefabricated.pdf
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COURSE CO ORDINATOR **HOD (CIVIL)**

UNIT I

DESIGN PRINCIPLES

PREFABRICATED STRUCTURE:

Prefabricated structures are structure in which the parts are fabricated and assembled in a central assembly point.

Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located. The term is used to distinguish this process from the more conventional construction practice of transporting the basic materials to the construction site where all assembly is carried out.

NEED FOR PREFABRICATION:

- Economy in cost
- To improve the quality
- To speed up construction
- To use locally available materials with required characteristics
- To use the material which possess their characteristics like light weight, easy availability, thermal insulation, non- combustible.

ADVANTAGES:

1. Self-supporting ready-made components are used, so the need for formwork, shuttering and scaffolding is greatly reduced.
2. Construction time is reduced and buildings are completed sooner, allowing an earlier return of the capital invested.
3. On-site construction and congestion is minimized.
4. Quality control can be easier in a factory assembly line setting than a construction site setting.
5. Prefabrication can be located where skilled labour is more readily available and costs of labour, power, materials, space and overheads are lower.
6. Time spent in bad weather or hazardous environments at the construction site is minimized.
7. Less waste may occur
8. Advanced materials such as sandwich-structured composite can be easily used, improving thermal and sound insulation and airtightness

DIS- ADVANTAGES:

1. Careful handling of prefabricated components such as concrete panels or steel and glass panels is required.
2. Attention has to be paid to the strength and corrosion-resistance of the joining of prefabricated sections to avoid failure of the joint.
3. Similarly, leaks can form at joints in prefabricated components.
4. 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.
5. Large prefabricated sections require heavy-duty cranes and precision measurement and handling to place in position.
6. Larger groups of buildings from the same type of prefabricated elements tend to look drab and monotonous.
7. Local jobs may be lost, if the work done to fabricate the components being located in a place far away from the place of construction. This means that there are less locals working on any construction project at any time, because fabrication is outsourced.

STAGES INVOLVED IN PREFABRICATION:

1. The structure divided into number of units.
2. The different units are precast in permanent factories (plant fabrication) or temporary plants (site prefabrication).
3. Transported to the site.
4. Hoisted set into their final places, and assembled to form a complete structure.

PREFABRICATED SYSTEMS:

The system of prefabricated construction depends on

- The extent of the use of prefabricated components
- The materials
- Sizes

TYPES OF PREFABRICATION COMPONENTS:

- Reinforced/Pre-stressed concrete channel unit
- Reinforced/Pre-stressed concrete slab unit
- Reinforced/Pre-stressed concrete beams

- Reinforced/Pre-stressed concrete columns
- Reinforced/Pre-stressed concrete hollow core slab
- Reinforced/Pre-stressed concrete wall elements
- Reinforced concrete waffle slab/shell
- Hollow/solid blocks and battens
- Precast planks and joists for flooring and roofing
- Precast joints and trussed girder
- Light weight/cellular concrete slabs
- Precast lintel and chajjas
- Reinforced/Pre-stressed concrete trusses
- Reinforced/Pre-stressed roof purlins
- Precast concrete L-panel unit
- Prefabricated brick panel unit
- Prefabricated sandwich concrete panel
- Precast foundation

TYPES OF PREFABRICATED SYSTEMS:

- Partial Prefabricated System
- Full Prefabricated Systems
- Large Panel Prefabricated Systems
- Box type construction

PARTIAL PREFABRICATION SYSTEM:

- It should be in the form of in-situ frame work or load bearing walls
- It should be used in the roofing and flooring components

FULL PREFABRICATION:

- In this system all structural components are prefabricated
- It should be used for brick masonry or brick work

LARGE PANEL PREFABRICATION:

- This system is based on the use of large prefabricated components.
- The components used are precast concrete large panels for walls, balconies, roofs, stairs etc…

MODULAR CO-ORDINATION:

The principle object of this is to assist the building design.

OBJECTIVE :

- Facilitates co-operation b/w building designers, manufactures, distributors, contractors and authorities.
- Optimizes the number of standards sizes of buildings components.
- Simplifies site operations
- Ensures dimensional co-ordination b/w installation as well as with the rest of the building

PURPOSE OF MODULAR CO-ORDINATION:

- To reduce the variety of component sizes produced.
- To allow the building designers greater flexibility in the arrangement of the components

BASES OF MODULAR CO-ORDINATION:

MODULES (M) :

- It is a standard unit of size
- Used to co-ordinate the dimension of the buildings and components
- 1M = 100mm

MULTI MODULE:

- It's size is a selected multiple of the basin module
- The International standardizes values of the dimensions are 3M , 6M , 12M, 30M , 60M

SUB MODULE:

It is the fraction of the basic module.

B.M = 1M = 10 cm

S.M = M/4 = 10/4 = 2.5 cm

MODULAR GRID:

A rectangular co- ordinate reference system in which the distance b/w consecutive lines is the basic module or multi module.

STANDARDISATION:

Standardisation refers to the creation and use of guidelines for the production of uniform interchangeable components especially for using mass production.

ADVANTAGES OF STANDARIZATION:

- Easier in design – Elimination of unnecessary choices.
- Easier in manufacture – Limited number of variants.
- Easier in erection and completion – Repeated use of specialized equipment.

DISADVANTAGES OF STANDARIZATION:

Since the joints are at corners that are at places where the moments reach their maximum values, the forming of joints is difficult.

The forming of in-situ joints is very difficult; hence the joints must be over dimensioned.

No of joints are reduced and if larger precast members are needed.

FACTORS INFLUENCING STANDARIZATION:

- To limit the number of types of elements and to use the large quantities.
- To limit the size and a number of prefabricate by the weight.
- To use the largest sites to the extent possible, this resulting the less number of joints.
- To select the most rational type of member for each element from the point of production, assembly, serviceability and economy.

DISUNITY OF PREFABRICATD STRUCTURE:

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

The problem in prefabrication is the transportation. To avoid in this problem transportation the structure is disunited or separates into smaller elements so that the transportation becomes very easy and in the site they may be united are assembly.

This method of separating into smaller member or element is called disunity structure in prefabrication.

Instead of using the larger member as beam or girder, two or three smaller sections may be used and united together as a single member but the load carrying capacity of a single large member should be equal to sum of load carrying capacity two or three smaller members.

Normally in factories in production is done in a faster rate for many small prefabrication elements. This leads to disunity of the structures into members suitable for plant prefabrication and for shipping. There are 4 methods of disunity structures.

ADVANTAGES:

- 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.

DISADVANTAGES:

- 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.

METHODS:

(a) Systems consisting of linear members disunited at joints:

Disunity at joints gives linear members this means a great advantage at facilities in manufacturing and assembling.

Advantages:

- Scaffoldings or auxiliary scaffoldings are not necessary.
- Hoisting or lifting method is very simple.

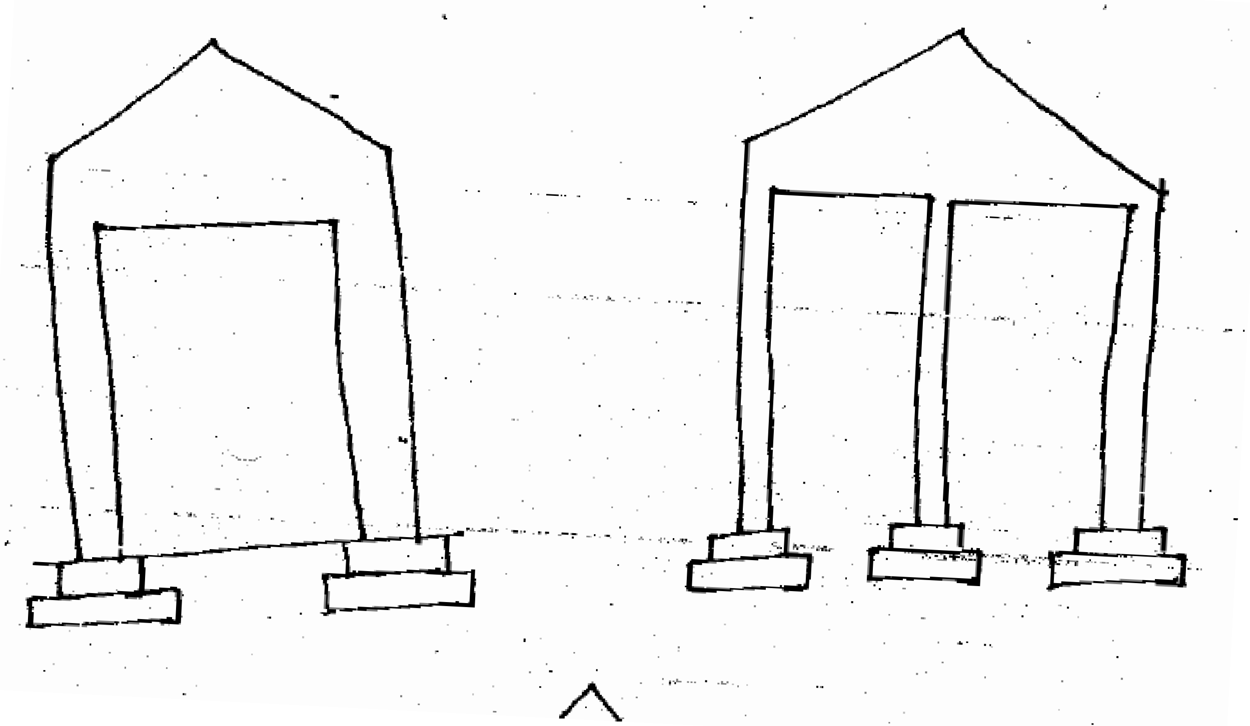
Disadvantages:

The main disadvantages the joints at the corners that is places were the moments are maximum. So the formation of joint is very difficult.

- The quality of concreting should be very high in these precast members.
- The joints must be over dimensioned.
- This makes additional materials to be used for precast members.

This disadvantage is overcome are rectified by the new trend or method of replacing moment resistance joints by hinge like structures etc...

In this method more material is required for beams the complicated construction of rigid corners can be omitted.



(b) System for the prefabrication of disuniting into entire frames:

In this method the entire frames the total structure are disunited or separated.

Advantages:

- The members of joints are reduced.
- Failures of joints are minimum.
- This disunity method is suitable for site prefabrication.
- Transportation cost for many elements to the site is reduced.

Disadvantages:

- 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.

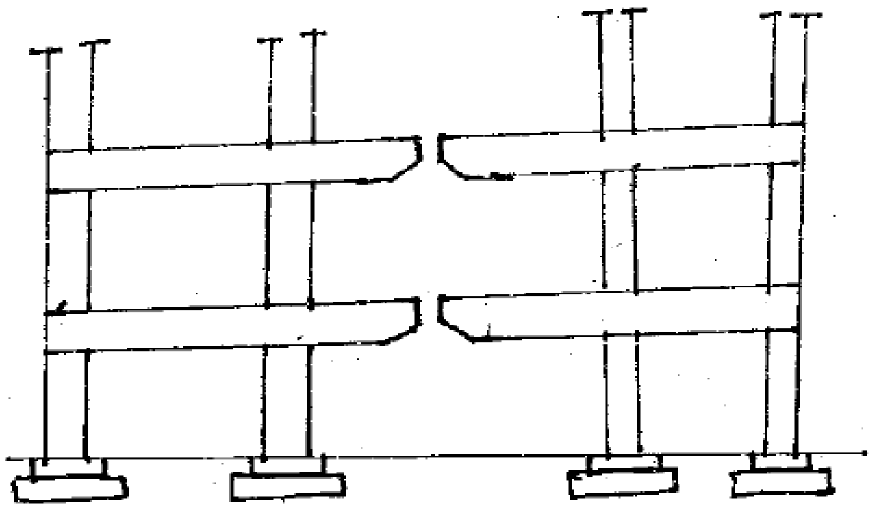
The stress distribution of straight member during lifting is to be determined. The stress distribution arising in frame during their hoisting is statically redundant.

The tilting of the frame from the horizontal into the vertical position lifted at two points two separated acting hoisting machines are the methods of lifting the frame. If these two points are lifted or hoisted at the same time uniformly, the frame will be affected by torsion.

Connecting to suspension points by the balance or a cable rocker makes the frame to be lifted at a single point. In this case also torsion occurs if the rocker is not suspended at exact point.

From this it's clear that hoisting of a frame is more complicated and difficult than hoisting a straight member.

Similarly hoisting of unsymmetrical frames is also very difficult. So this method is advantageous where small member of joints are required and where there is possibility of rapid works.



(c) Straight members disunited at points of minimum moments:

The production and placing of arches is more difficult than the straight members.

Advantages:

- Less material is required and long span structures its economical.
- Arches may be two hinged or three hinged may be fixed at footing and made up with or without ties.

The arches are usually precast assemble in the site. The middle hinge is eliminated after the placing finishing. RF bars for both the members are welded together joint between the members filled with insitu concrete. The structure is transformed to the two hinged arch rigidity is increased. The movements or motion under wind load is reduced. The method is suitable for eliminating all three hinges. In this case a arch fixed at both ends is obtained.

Arches can be precast in vertical and horizontal position. In vertical position the shuttering made up of member or concrete is required having the same curvature of the arch prefabrication is larger. Arches in the horizontal position are more economical.

The construction of arched trusses can be carried out in horizontal position only.

PRODUCTION:

- Sequence of operations
- The term production of the systems is described a series of operations directly concern in the process of making precast units.

METHODS:

There are 3 basic methods,

- Stand system
- Conveyor belt system
- Aggregate system

1) STAND SYSTEM:

In the stand system the prefabricate mature at the point where they were moulded, while the production team moves the successive stands.

2) CONVEYOR BELT SYSTEM:

This system splits the whole production process into a series of operations carried out at a separate successive and permanent by a specialized team. The movement of the mould from one point to the next may be by means of a conveyor belt, trollies and cranes.

3) AGGREGATE SYSTEM:

The word aggregate describes a large complex permanently installed set of machines and mechanical applications which can be carried out most of the separate operations involved in plastic concrete components.

TRANSPORTATION

- Transport of precast elements inside the factory and to the site of erection.
- Transport of prefabricated elements inside the factory depends on the method of production selected for manufacture.
- It must be carried out with extreme care to avoid any jerk and distress in elements and handled.
- The load carrying capacity of the bridge on the way should be checked.
- While transporting the elements care should be taken to avoid excessive cantilever actions and desired supports are maintained.
- Subsequent packing must be kept strictly.

- Care should be taken to avoid excessive cantilever action and desire supports are maintained.
- Special care should be taken at location of sharp bends and on uneven to avoid undesirable stress in the elements.
- Tower cranes are most commonly used for the vertical transportation of prefabricates

ERECTION:

Items to be included in precast elements:

- Welding of cleats
- Putting up and removing of the necessary scaffolding or supports.
- Adjustments to get the stipulated level, line and plumb.
- Tying up of erection ropes connecting to the erection hooks.
- Slinging of the precast elements.
- Transport of people , workers or visitors by using cranes and hoists should be strictly prohibited on an erection site.
- In the transverse direction the rails shall lie in a horizontal plane.
- Welding of the inserts, laying of reinforcement in joints and grouting the joints.
- Finishing the joints to bring the whole work to a work man like finished product.

Factors affecting erection

- Joints and additional erection cleats
- Structural design criteria affecting construction
- Temporary bracing,Lifting points
- Loads and conditions likely to be experienced during the lifting and erection
- Joint positions (as they affect erection sequences)
- **Accessibility** of connections
- Fixings for working platforms, hand rails etc
- Preferred **type and number of cranes** to erect members of particular size and shape, and for vertical and horizontal bracing requirements
- Capacity to withstand accidental vehicle impact

<u>Stability of structure during erection</u>

- Verifying the adequacy of the base connections
- Checking stability under construction load conditions

Erection crew

- An experienced supervisor
- Riggers
- Doggers
- Crane operator.

Sequential erection procedure

- Site limitations and Member sizes
- Access for positioning and lifting of members
- Crane size, mobility and access, and use of other large plant
- The erection sequence
- The stability requirements of the structure at all stages during erection
- Requirements for working at height
- Overhead obstructions, including overhead power lines
- Weather restrictions
- Specialty bolting or site welding requirements, included on the marking plan.

Marking plan

The marking plan includes:

- Location of each element
- Configuration of braces and any temporary bracing/supports
- Clear markings to identify each member.

Safe work method statement

The SWMS must list the high risk construction work, as a minimum and describe how the risks are to be controlled. High risk construction work in erection may include:

- A risk of falling more than two metres
- Structural alterations that may require temporary support to prevent collapse

- Working near live power lines
- Tilt-up or precast concrete (which may be part of the project).
- Working on or adjacent to roadways or railways used by road or rail traffic
- Any movement of powered mobile plant, for example, the use of EWPs.

Managing risk at the erection stage

The key risks involved in erection, and the controls for each of these are outlined below.

- Falling from a height while rigging
- Falling objects
- Collapse of the structure during construction
- Being struck by plant
- Plant contacting underground or overhead utility services
- Being struck by objects such as steel members

Risk control

The erector should reduce the need for work at height by:

- Constructing as much of the steelwork as possible (such as modules or frames)
- At ground level, or from erected floor slabs or decks in the structure, and where reasonably practicable, releasing the lifting sling or device from ground level by the use of long slings, remote release shackles or other suitable devices.
- The erector should prevent the risk of a fall of a person working at a height by using in order of effectiveness:
- Passive fall prevention devices, for example, work platforms and EWPs
- Work-positioning systems such as travel-restraint systems and industrial rope-access systems, and/or fall arrest systems such as catch platforms and safety-harness systems.

Risk control from falling objects

- Restricting access when there is overhead work by establishing, where practicable, exclusion zones
- Preventing, where practicable, loads being lifted or transported over people or amenities
- Ensuring only rigger/dogman slings loads and, where appropriate, fix tag lines
- Using lifting beams to position members where necessary to ensure the stability of the member

- Considering perimeter screens, guardrails with integral toe-boards and wire mesh, debris nets, cantilever work platforms, scaffolding sheathed with protective material and/or lanyards to secure tools and equipment
- Using materials boxes which are fully sheeted to enclose the load
- Ensuring safety helmets are worn at all times.

Risk control before erection

- Ensure a sequential erection procedure is prepared, which has been approved by the erection engineer and is consistent with the marking plans
- Ensure that an experienced steel erection supervisor is present at all times to oversee the implementation of the sequential erection procedure
- Ensure an adequate exclusion zone to prevent risk to other people not involved in the erection
- Only start the erection of a member or sub-assembly when equipment to ensure the structure's stability is available and being used
- Ensure temporary guys or bracing are securely anchored
- Place adequate visual barriers between guys and plant/vehicle movement areas.

Risk control during erection

- Verify the stability of the structure in accordance with the erection engineer's specifications:
  - at the end of each work day
  - when fastenings may be incomplete
  - during strong winds or when strong winds are forecast
- Seek approval from the builder (or erection engineer where appropriate) to cease work at unscheduled points where the structure has not been completed to the specifications of the erection engineer's design
- Obtain, from the builder, the erection engineer's written approval before loads are placed onto the structure
- Where possible, start erection in a nominated braced bay (if this is not possible, make sure that the erection engineer is involved in developing an alternative site-specific sequential erection procedure)
- Check the fittings for the support of columns during erection, to ensure adequate structural capacity for the erection conditions
- Make sure that all beams are secured before releasing the slings
- Make sure that all bolted connections are effective to ensure the stability of the steel structure.

Risk control for struck by plant

- Powered mobile equipment, the erector should consider: crane selection, access and siting in accordance with AS 2550 Parts 1, 4 and 5 (cranes, hoists and winches)
- Protection of the public
- The location of any excavations or underground services that may affect a crane load
- The proximity of overhead power lines
- The capacity of the ground or supporting surface to bear the load
- Check the type and amount of packing required under the crane's outriggers to support the proposed loads
- Written procedures for setting up and dismantling of the crane and the lifting method
- Procedures for visual and audible signals between the crane operator and the erection crew
- Ground support conditions
- Selection of lifting gear
- Emergency procedures
- Prevailing or forecast weather conditions
- The need to avoid lifting loads over people.
- The weight of the load and its centre of gravity as well as the weight of the lifting gear must be carefully calculated.
- Cranes of similar characteristics should be selected.
- The position of each crane should minimise movement and slewing.
- The lifting capacity of each crane must be 20% greater than the share of the load.

Risk control near overhead lines

- Identify all power lines services before permitting any crane or other mobile plant on site
- Check that material and plant is moved or operated outside the "No Go Zone" of 3000 mm from an overhead electrical cable on a pole or 8000 mm if the electricity cable is on a tower line (If erecting scaffolding, the "No Go Zone" during this process is 4.6m distant and 5m below from the nearest power line)
- If work or plant is able to encroach on this clearance, the erector must obtain permission from the electricity company or develop a SWMS and work in accordance with it.

Risk control near underground services

Ensure that, unless permission has been obtained from the utility company, work is not carried out closer to the services than:

- 3 metres in the case of an underground asset registered under the Pipelines
- Act or an electricity cable with an in-service voltage greater than 66 kV, or in the case of other services, 500 mm for plant and equipment and 300 mm for individuals.

MATERIALS OF PREFABRICATION:

Prefabricated building materials used for small prefabricated buildings are steel, wood, fiberglass, plastic or aluminum materials. These materials are cheaper than regular brick and concrete buildings. Materials like steel, fiberglass, wood and aluminum are used as prefabricated building materials for sports buildings.

For making low cost houses, prefabricated materials like straw bale, Ferro cement, Calcium silicate products, composites and other cheap wood based materials are currently being used. Calcium silicate bricks are strong and durable. Ferro cement consists of a cement matrix reinforced with a mesh of closely-spaced iron rods or wires. In this type of construction, the techniques used are simple and quick.

While choosing the materials for prefabrication, the following special characteristics are to be considered:

a) Easy availability;

b) Light weight for easy handling and transport, and to economize on sections and sizes of foundations;

c) Thermal insulation property;

d) Easy workability;

e) Durability in all weather conditions;

f) Non-combustibility;

g) Economy in cost, and

The materials used in prefab components can be various and the modern trend is to use concrete, steel, treated wood, aluminum, cellular concrete, light weight concrete, ceramic products, etc. However, this section pertains to prefab concrete elements.

Concrete is a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregates. In hydraulic cement concrete, the binder is formed from a mixture of hydraulic cement and water.

Aggregate is the granular material, such as sand, gravel, crushed stone, or iron blast-furnace slag, used with a cementing medium to form hydraulic-cement concrete or mortar. The term **coarse aggregate** refers to aggregate particles larger than 4.75 mm (No. 4 sieve), and the term **fine** aggregate refers to aggregate size smaller than 4.75 mm.

Coarse and fine aggregates shall be batched separately.

Gravel is the coarse aggregate resulting from natural disintegration and abrasion of rock or processing of weakly bound conglomerate. The term **sand** is commonly used for fine aggregate resulting from natural disintegration and abrasion of rock or processing of friable sandstone. **Crushed stone** is the product resulting from industrial crushing of rocks, boulders, or large cobblestones. **Iron blast-furnace slag**, a by-product of the iron industry, is the material obtained by crushing blast-furnace slag that solidified under atmospheric conditions.

Mortar is a mixture of sand, cement, and water. It is essentially concrete without a coarse aggregate.

Grout is a mixture of cementitious material and aggregate, usually fine aggregate, to which sufficient water is added to produce a pouring consistency without segregation of the constituents. **Shotcrete** refers to a mortar or concrete that is pneumatically transported through a hose and projected onto a surface at a high velocity.

Cement is a finely pulverized material which by itself is not a binder, but develops the binding property as a result of hydration (i.e., from chemical reactions between cement minerals and water). Cement is called **hydraulic** when the hydration products are stable in an aqueous environment.

LOCATION AND TYPES OF SHEAR WALL:

DEFINITION:

Shear walls are the vertical elements of the horizontal force resisting systems. Shear walls are constructed to counter the effects of lateral loads acting on the structure.

In residential constructions shear walls are straight external walls that typically from a box provide all of the lateral loads of the building.

IMPORTANCE 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 transforming 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 shear a building apart. Reinforcing a frame by attaching or placing a rigid wall inside it maintains their 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.

PURPOSE OF CONSTRUCTING SHEAR WALL:

- Shear walls are not only designed to resist gravity or vertical loads (due to self wt and other living moving loads), but they are also designed for lateral loads of earthquake/wind. The walls are structurally integrated with roofs/floors and other laterals running across at right angles, thereby giving the three dimensional stability for the building structure.

- Shear wall structural systems are stable, because their supporting area with reference to total plan area of building is comparatively more, unlike in the case of RCC framed structures.
- Walls have to resist the uplift forces caused by the pull of winds. Walls have to resist the shear forces that try to push the walls over. Walls have to resist the lateral force of the wind that tries to push the walls in and pull them away from the building.

FORCES ON SHEAR WALL:

Shear wall resist two types of forces,

a) Shear forces

b) Uplift forces

a) Shear force:

Shear forces are generated in stationary buildings by accelerations resulting from ground. This action creates shear forces throughout the height of the wall between the top and bottom shear wall connection.

b) Uplift forces:

Uplift forces exist on shear walls because the horizontal forces are applied to the top of the wall. These uplift forces try to lift up one end of the wall and push the other end down. In some cases the uplift force is large enough to tip the wall over. Uplift forces are greater on tall short walls and less on low long walls. Bearing walls have less uplift. Shear walls need hold down devices at each end. When the gravity loads cannot resist all of the uplift. The hold down device then provides the necessary uplift resistance.

Types of shear walls:

1. RC shear wall
2. Plywood shear wall
3. Mid ply shear wall
4. RC hollow concrete block masonry wall
5. Steel plate shear wall.

1. RC shear wall:

It consist of reinforced concrete walls and reinforced concrete slabs. Wall thickness varies from 140mm to 500mm, depending on the number of stories, building age, and thermal insulation. In general these walls are continuous throughout the building height, however some walls are discontinued as the street front or basement level to allow for commercial or parking spaces.

Floor slabs are either cast in-situ flat slabs or less often, precast hollow core slabs. Buildings are supported by concrete strips or mat foundation, the later type is common for buildings with basement.

2. 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 that 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 or compression generated by the overturning moments
- Base connection, to transfer shear to foundation

3. Midply Shear wall:

The midply shear wall is an improved timber shear wall that was developed by redesigning the joints between sheathing and framing members, so that the failure mode observed in standard wall testing are virtually eliminated at lateral load level high enough to cause failure in standard wall.

4. **RC hollow concrete block masonry walls:**

These walls are constructed by reinforcing the hollow concrete block masonry by taking advantage of hollow space and shapes of the hollow blocks. It requires continuous steel rods both in the vertical and horizontal direction at structurally critical location of the wall panels, packed with fresh grout concrete in the hollow space of masonry blocks.

RHCBM elements designed both as load bearing walls for gravity loads and also as shear walls for lateral seismic loads to safely withstand earthquakes.

5. **Steel plate shear wall:**

In general steel plate shear wall system consists of a steel plate wall, boundary columns and horizontal floor beams. Together the steel plate wall and boundary columns act as a vertical plate girder. The columns act as a flange of the vertical plate girder and the steel plate wall act as its web. The horizontal floor beam acts more or less as transverse stiffener in the plate girder. Steel plate shear wall system has been used in recent years in high seismic areas to resist lateral loads.

UNIT 2

REINFORCED CONCRETE

PREFABRICATED STRUCTURES:

The concept of precast (also known as “prefabricated”) construction includes those buildings, where the majority of structural components are standardized and produced in plants in a location away from the building, and then transported to the site for assembly. These components are manufactured by industrial methods based on mass production in order to build a large number of buildings in a short time at low cost.

The main features of this construction process are as follows:

- The division and specialization of the human workforce
- The use of tools, machinery, and other equipment, usually automated, in the production of standard, interchangeable parts and products
- Compared to site-cast concrete, precast concrete erection is faster and less affected by adverse weather conditions.
- Plant casting allows increased efficiency, high quality control and greater contro lon finishes..
- This type of construction requires a restructuring of entire conventional construction process to enable interaction between design phase and production planning in order to improve and speed up construction.

TYPES OF PRECAST SYSTEMS

Depending on the load-bearing structure, precast systems can be divided into the following categories:

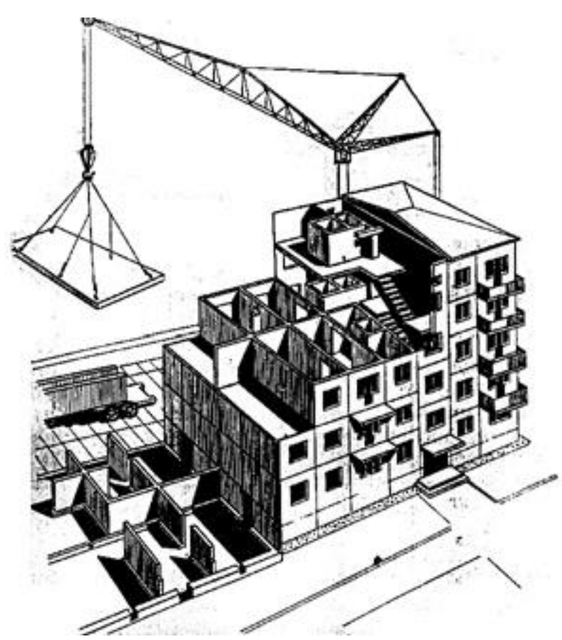
- Large-panel systems
- Frame systems
- Slab-column systems with walls
- Mixed systems

LARGE PANEL SYSTEMS

The designation “large-panel system” refers to multistory structures composed of large wall and floor concrete panels connected in the vertical and horizontal directions so that the wall panels enclose appropriate spaces for the rooms within a building.

These panels form a box-like structure. Both vertical and horizontal panels resist gravity load. Wall panels are usually one story high. Horizontal floor and roof panels span either as one-way or two-way slabs.

When properly joined together, these horizontal elements act as diaphragms that transfer the lateral loads to the walls.



Depending on wall layout, there are three basic configurations of large-panel buildings:

- Cross-wall systems
- Longitudinal wall systems
- Two-way systems

FRAME SYSTEMS

Precast frames can be constructed using either linear elements or spatial beam column sub-assemblages.

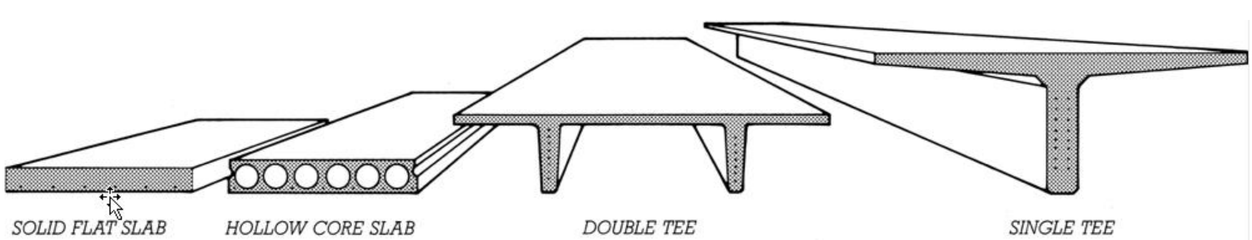
Precast beam-column sub-assemblages have the advantage that the connecting faces between the sub-assemblages can be placed away from the critical frame regions; however, linear elements are generally preferred because of the difficulties associated with forming, handling, and erecting spatial elements.

The use of linear elements generally means placing the connecting faces at the beam-column junctions. The beams can be seated on corbels at the columns, for ease of construction and to aid the shear transfer from the beam to the column.

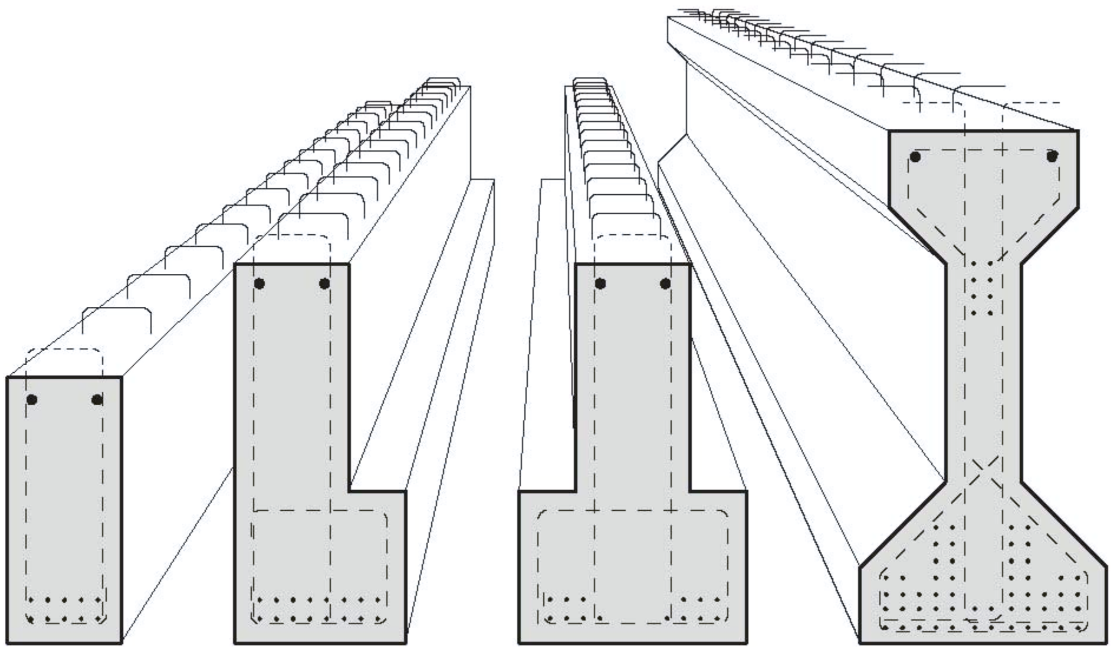
The beam-column joints accomplished in this way are hinged. However, rigid beam-column connections are used in some cases, when the continuity of longitudinal reinforcement through the beam-column joint needs to be ensured.

PRECAST CONCRETE STRUCTURAL ELEMENTS:

1) **Precast Slabs**



2)Precast Beam and Griders



2) Precast Column

3) **Precast walls**

LARGE-PANEL STRUCTURES

prefabricated elements of buildings and structures made from large factory-produced slab elements (panels) that are assembled on-site. Large-panel structures are one of the most progressive industrial types of structural elements. In modern construction they are used in building apartment houses, public and industrial buildings, roads, air-fields, dams, and canals. They have become most widespread in large-scale housing and civil construction, where the erection of buildings from large panels manufactured at housing construction combines and plants makes possible a reduction in construction time by a factor of 1.5–2.0 in comparison with erection of the buildings from brick or other traditional materials, as well as a decrease of 30–40 percent in labor expenditures at the construction site. The estimated cost of a square meter of housing space is 12–15 percent lower than in brick buildings.

The idea of large-panel housing construction—that is, the use of large panel-type elements for walls and floor slabs—was proposed by a number of engineers in the 1920's and 1930's. However, at that time such proposals were merely theoretical, as a consequence of the insufficient level of development of construction technology.

The comprehensive scientific development of the large-panel factory method of housing construction and the construction of the first experimental large-panel apartment buildings took place in the USSR in the 1940’s and 1950’s by a group of staff workers from the Institute of Construction Engineering of the former Academy of Architecture of the USSR: G. F. Kuznetsov (director), B. N. Smirnov, N. V. Morozov, T. P. Antipov, A. K. Mkrtumian, lu. B. Monfred, and N. la. Spivak

The **principles of the design theory and the system of large-panel buildings** and the design of the panels were developed, and methods of stand and multiple-form manufacturing and assembly, as well as the basic specifications, were created. The first four-story apartment house of frame-panel design (on Fifth Sokolinaia Gora Street in Moscow; 1947-48), the first three-story and four-story frameless large-panel apartment buildings (Magnitogorsk, 1949–52), and a seven-story frameless building (Sixth Oktiabr’skoe Pole Street in Moscow; 1954) were built under the direction of the institute. The construction of these apartment houses showed in practice the technical advisability and great economic efficiency of the large-panel method. The experimental construction that was undertaken in subsequent years in Moscow, Leningrad, Kiev, Cherepovets, and other cities fostered the rapid development and spread of the large-panel method.

Since 1958, large-panel housing construction in the USSR has been carried out by highly mechanized housing construction plants and combines, using standard plans and taking into account the diverse natural, climatic, and technical conditions in the various regions of the country. In 1960, large-panel construction was 1.5–2.0 percent of the total volume of housing construction in the USSR; in 1972, about 40 percent. Large-panel construction has also been widely used in the countries of the socialist community (Czechoslovakia, the German Democratic Republic, Bulgaria, and Hungary), as well as in many capitalist countries (Denmark, France, Sweden, and Great Britain).

All the main parts of a building, including exterior and interior walls, floor slabs, roofs, and staircases, may be made up from large-panel structures. Large-panel structures are used in two main design schemes, frame-panel and panel (frameless) buildings. In frame-panel buildings, all the base loads are borne by the building's frame, and the panels are usually used to fill the frame and as enclosure elements. Frameless buildings are assembled from panels that perform the load-bearing and enclosing functions simultaneously.

Large-panel structures for exterior walls consist of panels one or two stories in height and one or two rooms in width. The panels 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 (sandwich). 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 concretes, and hollow ceramic stone. Sandwich wall panels are made with two or three layers; their thickness depends on the climatic conditions of the region and the physicotechnical properties of the materials used for the insulating layer and for the exterior (supporting) layers. The exterior layers of the panels are usually made from heavy, light-weight, or solid silicate concrete or from brickwork or sheeting (asbestos cement, steel, or aluminum). Polystyrene foam, rigid and semirigid rock wool panels, or cellular concretes may be used for the insulating layer. Wall panels are produced in completely finished form, with ready-to-paint surfaces and with windows and doors; the piping for heating and other systems and for wiring may also be installed in the panels. 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 panels are filled with mortar or with lightweight or ordinary concrete and then sealed with elastic packing and special mastics.

The large-panel structures 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 structures, the wall panels, which combine enclosing and load-bearing functions, 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 apartments, 14—18 cm).

The large-panel structures 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 may 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 buildings are of both the solid and sandwich types; in the latter, provision is made for a sound-insulation layer to reduce air and impact noise. Composite floor panels, consisting of a load-bearing reinforced-concrete panel combined with a floor or ceiling panel and soundproofing, insulating, and other layers, are often used in housing construction.

The large-panel roof elements are used in housing and public buildings mainly in the form of combined atticless roofs, and in industrial buildings the roof panels have a span of up to 12 m. The weight of large-panel structures depends on the method of dividing the building into prefabricated elements; it is usually 1.5–7.5 tons.

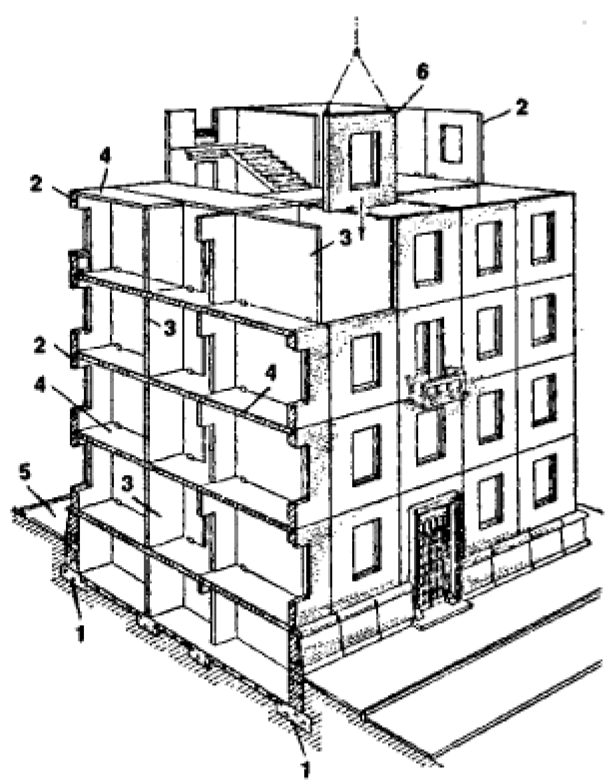


Figure 1. Large-panel structures of a high-rise apartment building: (1) foundation slab, (2) exterior wall panel, (3) interior wall panel, (4) floor slab, (5) deck (blind area), (6) exterior panel in the process of installation

In erecting a building, the large-panel structures (wall, floor, and roof panels) are placed on horizontal mortar joints; the interior vertical joints are filled with cement or concrete. At the joints, the panels have inserts to which steel connecting pieces (cover plates) are welded, thus linking together all the panels and providing general stability of the building. Spatial rigidity of the building is provided by the use of stairwell structures and butt and intersectional crosswalls. Large-panel structures are used in the construction of high-rise buildings (see Figure 1).

<u>CROSS WALL:</u>

- This system has one way slabs only the external walls in the cross direction are load bearing. the longitudinal walls are non load bearing.
- The one way floor slab have a span of 6 to 7 m , for these span, non prestressed floor slab can be used hollow cores.
- The floor slab have to be connected together to form diaphragm that transmit the horizontal

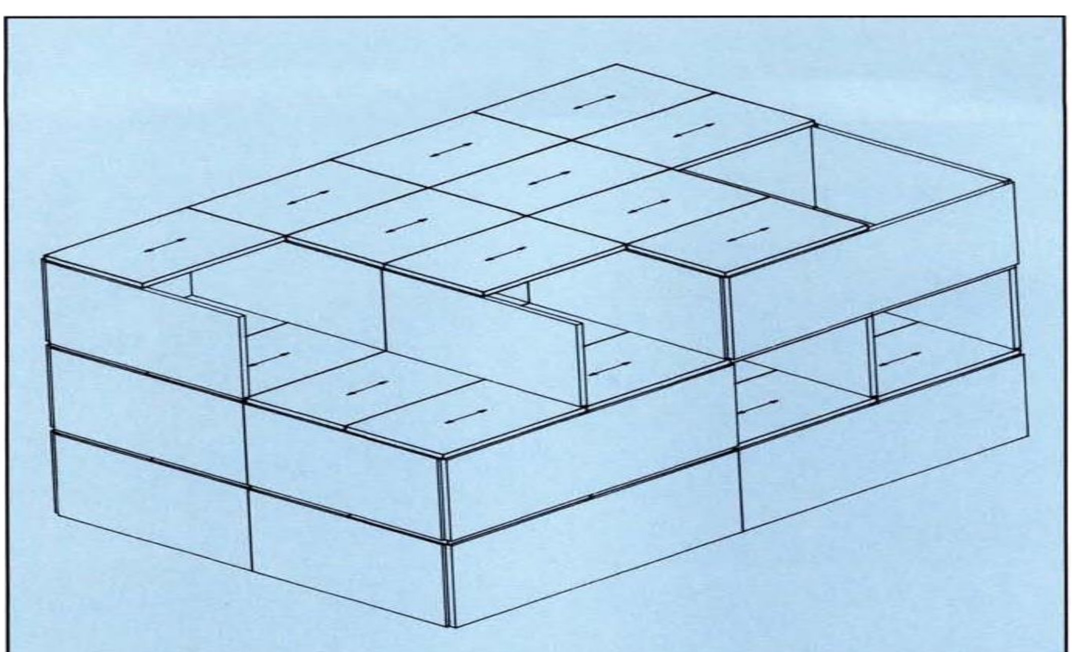


Fig. 2. Cross-wall loadbearing system — one-way slabs.

ONE WAY AND TWO WAY PREFABRICATED SLABS :

A reinforced concrete slab can be precast/prefabricated in a factory and transported to site by trucks.

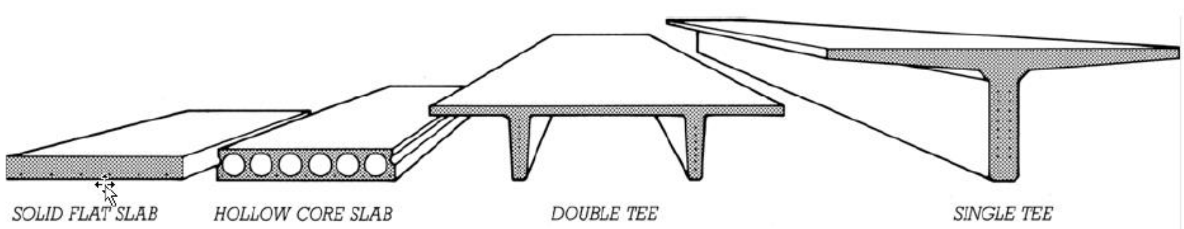
- They are lowered and erected into place between steel or concrete beams by means of crane.
- They may be prestressed (in the factory) or post tensioned (on site).

USES

- Used for floor and roof decks.
- Precast slab elements are frequently used with other vertical load bearing systems such as site cast concrete, reinforced masonry, or steel.

COMMERCIAL FORM

- The choice of roof and floor slab elements depends mainly on span requirements.
- Following are the commercial forms,



ASSEMBLING CONCEPT

Precast slab is assembled such that vertical support can be provided by,

- Precast columns and beams at bottom of slab,
- Wall panels at sides,
- or a combination of all three.

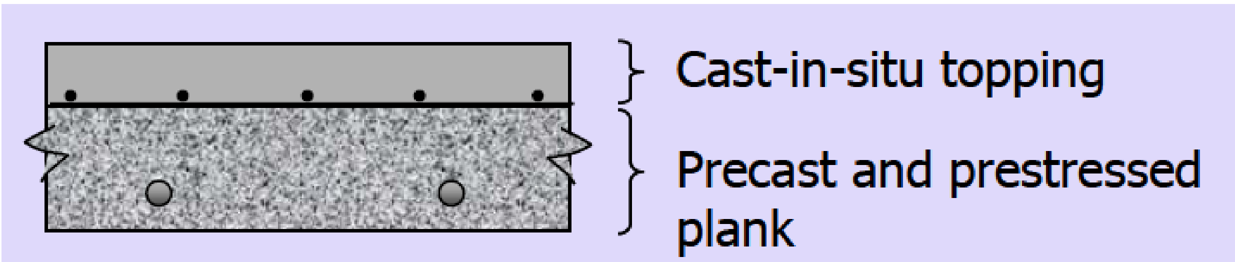
PLACING OF PRECAST CONCRETE SLAB

There are two modes of placing of precast concrete slab,

- "Half" precast slab (composite slab)
- "Full" precast slab

DEFINITION

- In half precast slab, the precast slab acts along with a topping.
- The precast slab can be prestressed and placed in the final location. After placing the precast slab, a topping slab is overlaid on the precast slab



LOADS

- The half precast slab should be designed for the loads coming from the topping slab in addition to other dead loads, live loads and impact loads.
- Treated and designed as one way slabs when the precast slab and topping concrete are lightly connected and as two way slabs when rigidly connected.

DESIGN ASPECTS

The Precast prestressed concrete slab below is provided with shear reinforcement which extends out of the slab. This extended portion of shear reinforcement is used as bottom formwork to support the cast-in-situ topping slab.

ADVANTAGES

- Greater floor strength and stiffness
- Greater fire resistance
- Greater acoustic isolation
- Allow easy integration of electrical services into floor system
- Create a smoother, flatter floor surface.
- Reduction in form work, cost and time of construction
- The grades of concrete in the two portions can be different according to strength required.

TERMINOLOGY

- In full precast slab, the precast slab acts alone
- There is no topping cast in-situ slab.
- Has very few application

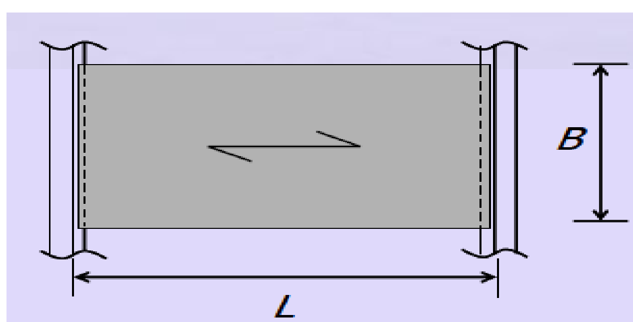
- Tight and strong connection between panels are required.
- Used when concreting is difficult, e.g., in case of steeply slanting roof
- Structural integrity can be maintained as it is monolithic

TYPES OF SLAB

- Rectangular slabs can be divided into the two groups based on the support conditions and length-to-breadth ratios.
- The slabs are presented in two groups,
- One way slab
- Two way slab

DEFINITION- One way slab

- When a slab is supported only on two opposite edges, it is a one-way slab
- It spans in the direction perpendicular to the edges. The spanning direction in each case is shown by the double headed arrow.



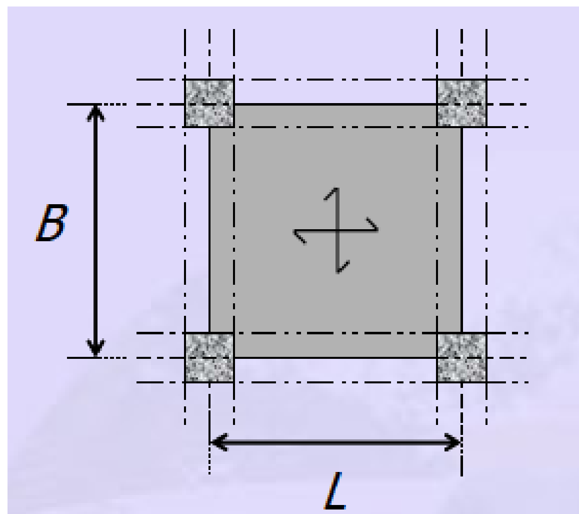
One-way slabs are analysed and designed for the spanning direction similar to rectangular beams. The analysis and design is carried out for the width of the plank or a unit width (say 1 m) of the slab.

- A **hollow core slab** is also an example of a one-way slab.
- A ribbed floor (slab with joists) made of precast **double tee** sections, is analysed as a flanged section for one-way bending.

DEFINITION – Two way slab

- The two-way action of the slab comes into play and the loads on the slab are transferred to all four supports.

- If a rectangular slab is supported on all the four sides and the length-to-breadth ratio is less than two, then it is a two-way slab.
- If a slab is supported on three edges or two adjacent edges, then also it is a two-way slab.
- The spanning direction in each case is shown by the double headed arrow.



EXAMPLE OF PRECAST SLAB

- A **circular precast slab** is also an example of a two-way slab.
- A **hollow core slab** is sometimes designed as a two-way slab due to transportation limitations of big sized one way slabs.

ADVANTAGES

- Simplified and faster construction through elimination or reduction in formwork.
- Higher strength materials and better quality.
- Reductions in depth of 20 to 40%.
- Reductions in the forces in columns and foundations.
- Considerable reductions in manual labour and therefore in labour costs.
- Elimination or reduction in the number of conventional beams.
- Simplified cutting of holes for electrical or water supply lines.

FRAMED BUILDINGS WITH PARTIAL AND CURTAIN WALLS :

Curtain Walls:

Curtain wall is the outer skin of a modern building for architectural purposes. They are non-structural walls, made of light weight materials for their minimum cost.

Evolution:

The development and use of structural steel, RCC for structural support made walls non-load bearing. This made evolution of curtain wall.

Systems and Principles:

Stick System: Long pieces of curtain walls referred to sticks are installed b/w floors vertically and b/w vertical members horizontally. The framing members are fabricated at shop and installed, glazed at site.

Unitized systems: Assembly of panels with factory glazing are used for building enclosure formation. This system is speed and have lower field installation cost. Quality control and interior climate controller are effective. They are benefited on large projects, area of high labour rates.

Rain screen Principle: Exterior walls stands off from the moisture-resistance surface of air barrier creating capillary breaks for allowing drainage and evaporation. It is called Pressure Equalized Rain screen wall, where large ventilation opening equalizes pressure on both sides of rain screen. (eg cavity wall)

Design requirements:

The curtain wall is designed to carry only its self weight. Other requirements are Thermal expansion property of materials used, contracting building sway, thermal efficiency for cost, effective heating, cooling, lighting.

Materials:

Glass, steel, wooden, aluminium members.

Loads:

Loads acting are transferred through connections at floor or column. Connections are made by anchors which attack mullion of the building.

The loads acting are dead load, wind load, seismic load, snow load(for slope > 20°), thermal load, blast load. Care should be taken for air infiltration, water penetration, deflection.

Partition wall:

A wall for the purpose of separating rooms or dividing a room is called as partition wall. The are non load bearing wall.

Partition walls are made of panels which can be of following types:

- movable
- fixed

Movable partition walls:

Walls of a room are frequently opened to form one large floor area.

Sliding - sliding systems are made using tracks at bottom to move the wall. The wall can be of frame work

Sliding and folding- screens are used as partition wall.

Fixed wall:

The walls are fixed at the bottom with the top of floor, while the top of wall is either mortared, or filled with expansible materials, or left open.

Materials:

Can be of steel, bricks, terra cotta, concrete, glass, timber

Purposes:

Partition walls have fire resistance, have good acoustic performance.\

<u>Load bearing wall:</u>

Walls bear load by its weight which conducts the load to the foundation of the structure. Depending upon the type of building, numbers of floor, load bearing walls are gauged to appropriate thickness to carry the load.

Load bearing walls sits on the sill plate bolted or connected to the concrete foundations. In tall building the base walls at bottom floor must be credibly strong. If the load exceeds the strength of material the wall becomes unstable.

Materials:

Concrete, stone blocks, bricks.

Requirements:

Proper thickness of wall, quality of bricks, concrete, quality mortar, proper laying course.

BEAM TO COLUMN CONNECTIONS:

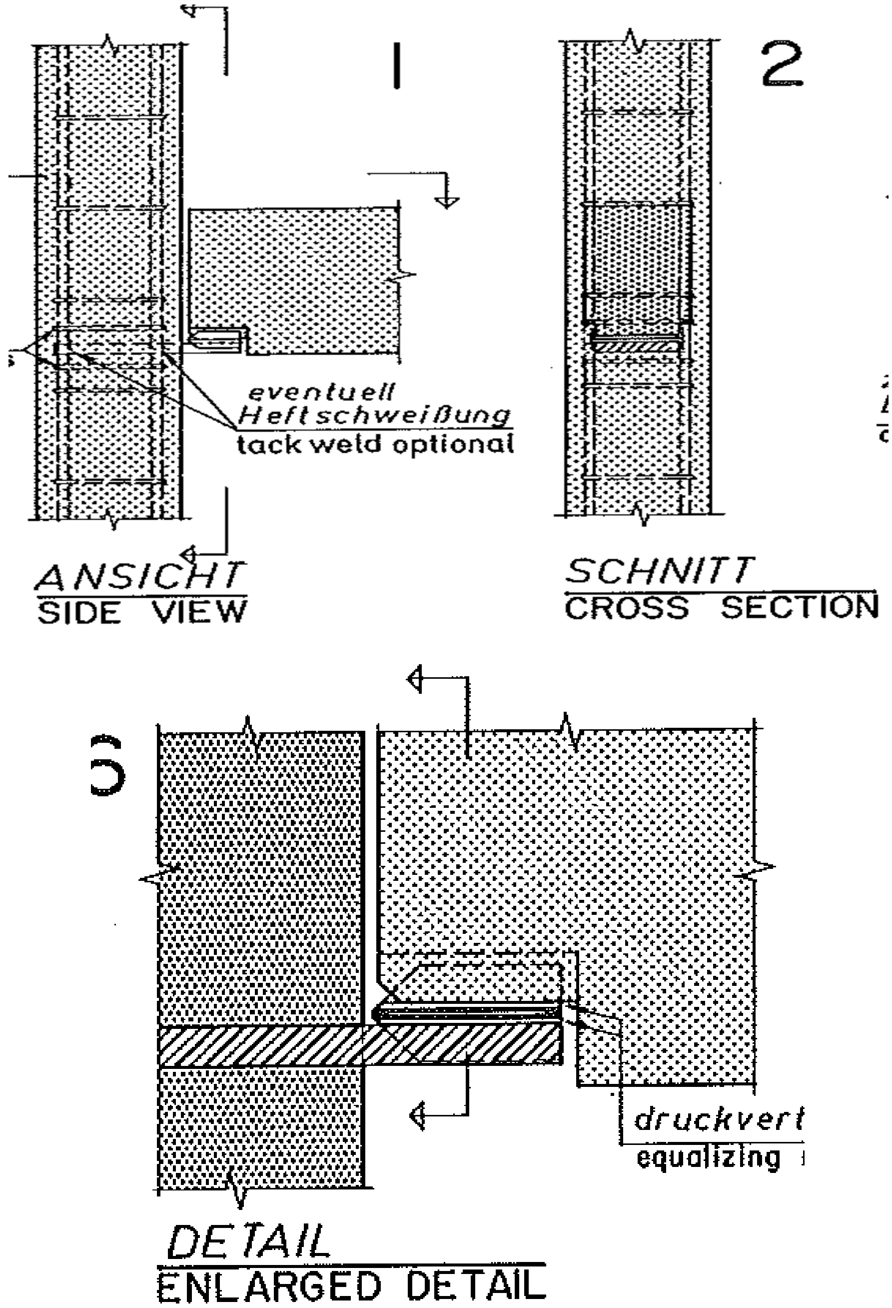
- A Beam column joint is said to be desirable if it is able to transmit large amount of vertical shear forces.
- Depending on the type of bearing and the size of the bearing surface, different beam column joints will be able to transmit various magnitudes of vertical shear force.

TYPES:

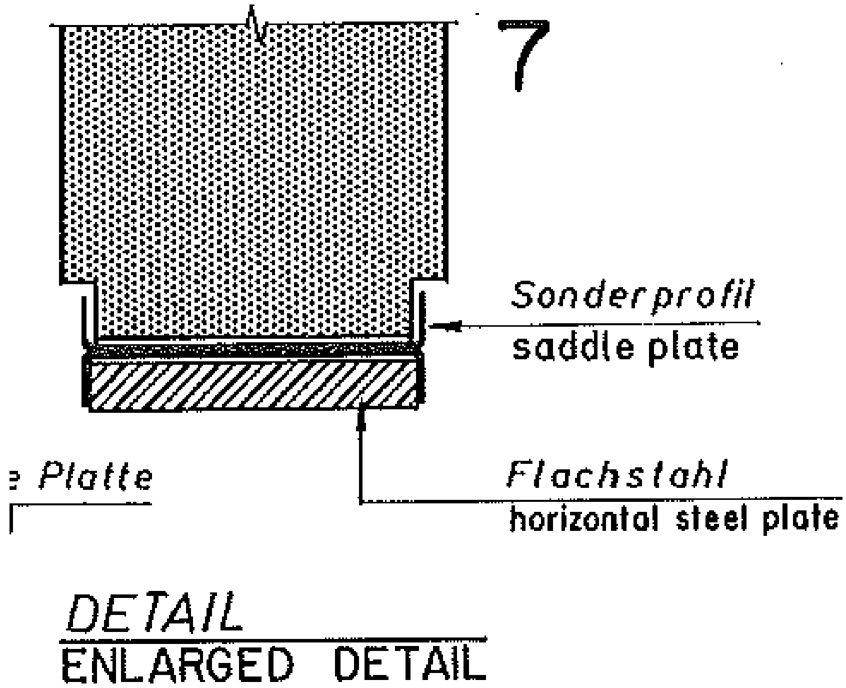
- Beam To Column Connection With Steel Plate Corbel
- Beam To Column Connection With Angle Corbel
- Beam To Column Connection With Built Up Steel Corbel
- Beam To Column Connection With Steel Joist Corbel, Encased In The Beam
- Beam To Column Connections With Vertical Steel Bearing Plates
- Beam To Column Connection With Concrete Corbel
- Beam To Column Connection With Steel Joist Hanger

1)BEAM TO COLUMN CONNECTION WITH STEEL PLATE CORBEL

- The beam is supported on a horizontal steel bearing plate which is cast into the column and is tack welded to the main reinforcing bars
- This connection for SSB beams may be considered if the vertical shear force is very small
- The plate should have sufficient thickness to prevent it from bending. In determining the thickness, the maximum cantilever moment may be assumed to occur at the column reinforcing bars.

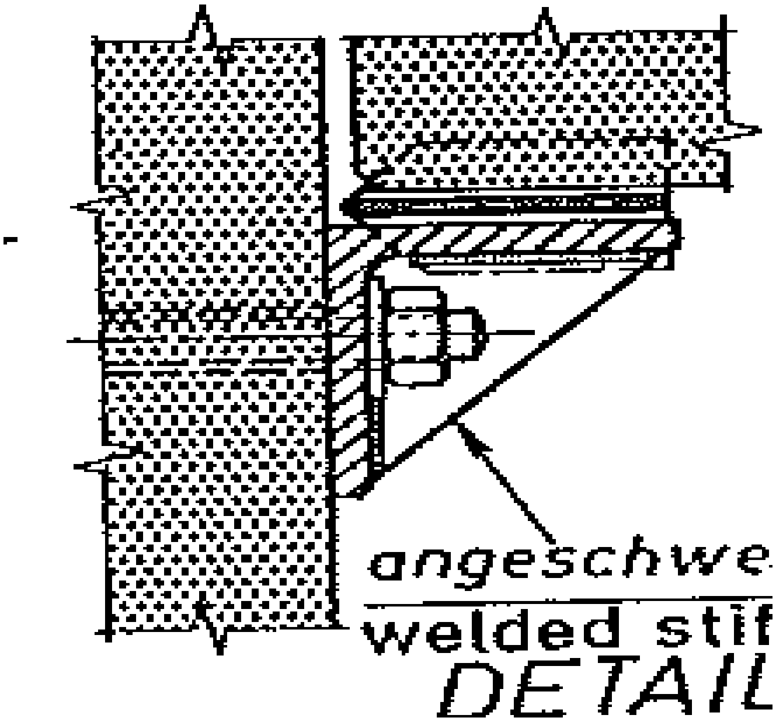


- To avoid point bearing ,special care should be taken to install the beam perpendicular to column face
- For lateral location of the beams, saddle plates may be used.
- The bearing plate must be provided with permanent protection against corrosion and against fire.

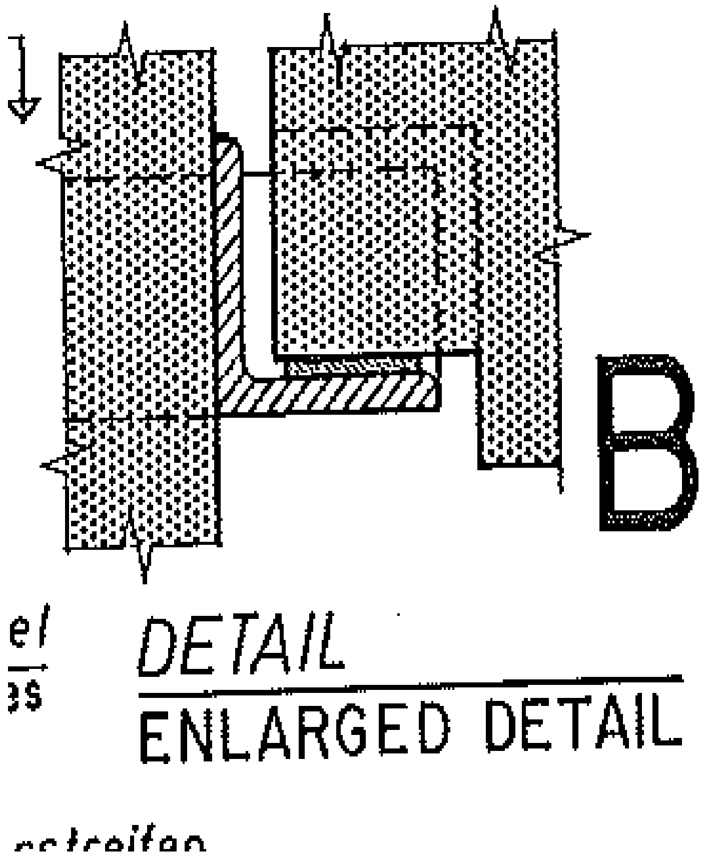


2) BEAM TO COLUMN CONNECTION WITH ANGLE CORBEL

- This connection for SSB when carried out according to variant “A” is only able to transmit small vertical shear force and could be generally considered only for temporary structures
- **VARIANT “A”**
- In variant A the angles are connected with the horizontal flange up and by mild steel bolts
- Point bearing on the column face can be avoided by applying an epoxy layer at the interface with the vertical angles just prior to placing the angles
- The entire corbel construction should be prefabricated and must be cast in which makes manufacture of corbel more complicated
- This should not be considered for fire proof buildings.



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

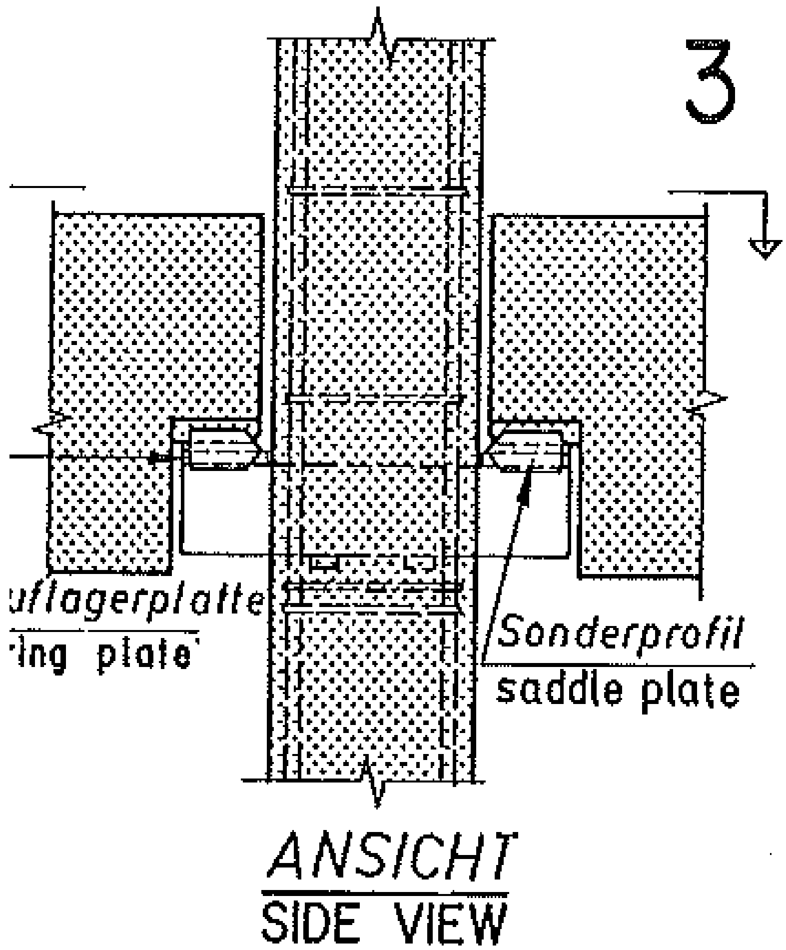


3) BEAM TO COLUMN CONNECTION WITH BUILT UP STEEL CORBEL

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

VARIANT A

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



VARIANT B

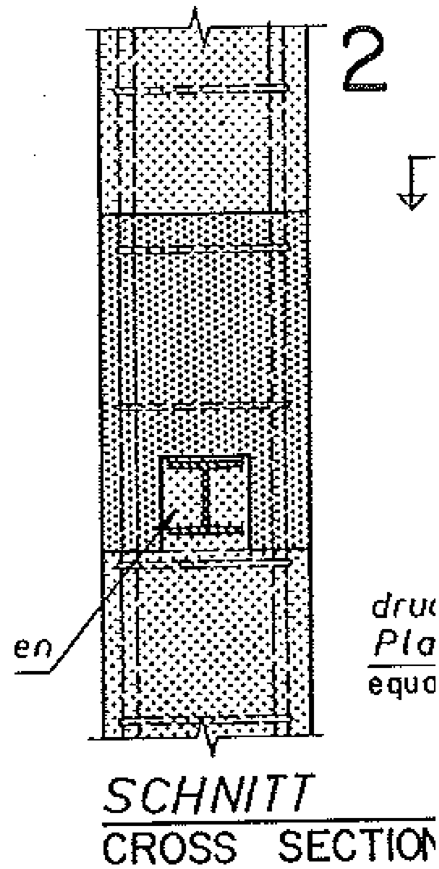
- The corbel consists of two vertically placed channels to which, outside the column horizontal bearing plates are welded
- An additional tie must be provided immediately under the corbel, in an end column also above the corbel to counteract the splitting forces

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

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

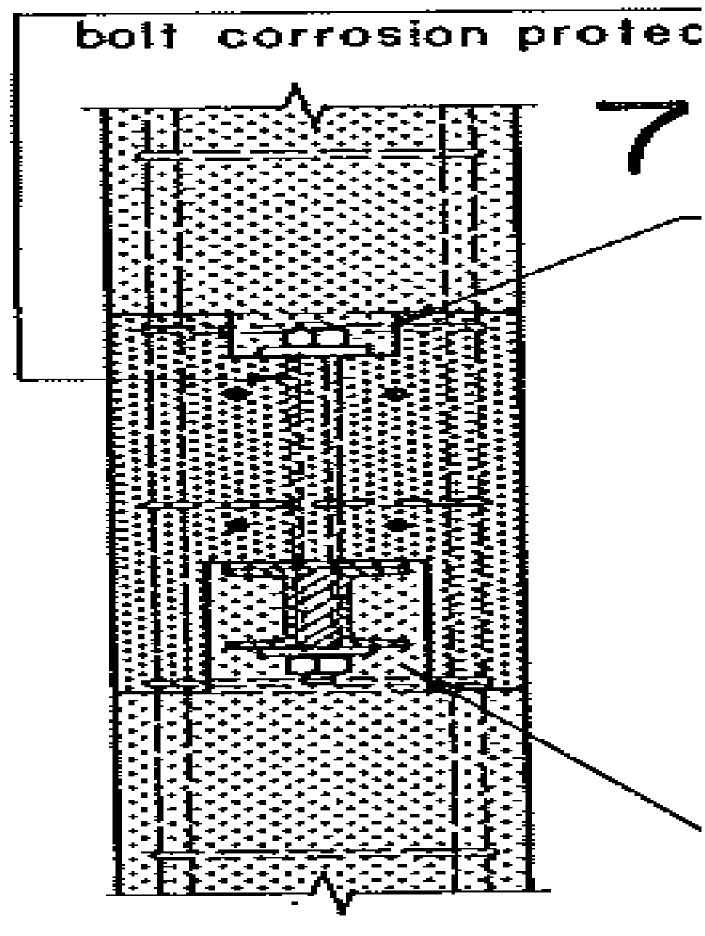
VARIANT A

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



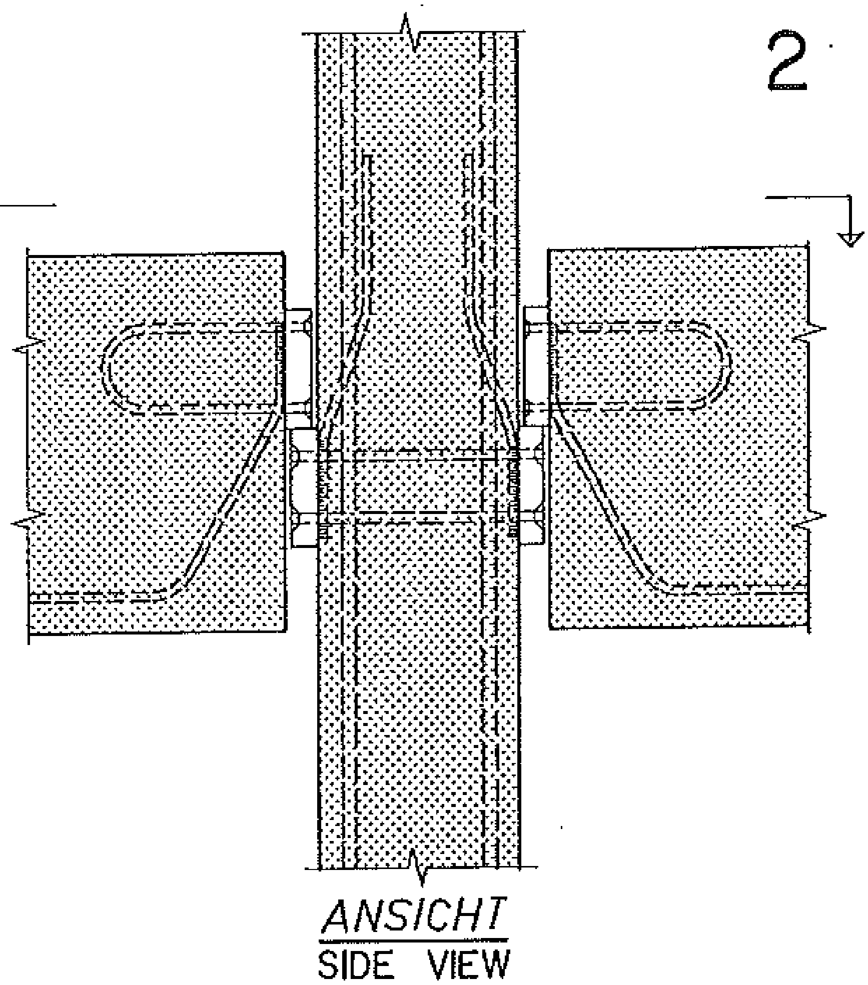
VARIANT B

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



5) **BEAM TO COLUMN CONNECTIONS WITH VERTICAL STEEL BEARING PLATES**

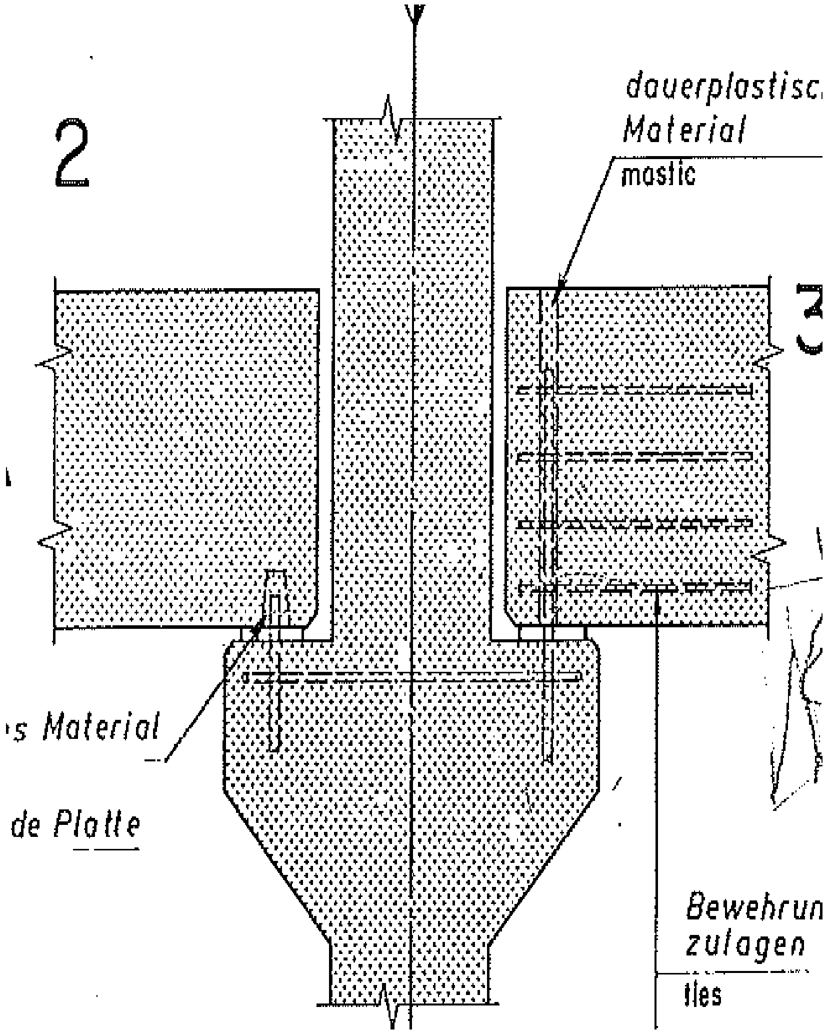
- The beams are supported on vertical steel plates against the column faces. The beam ends are also provided with a vertical steel plate.
- The entire bearing construction is contained within the beam section.
- This connection will be able to transmit large vertical shear force . Due to limited bearing surface this connection should be considered only for short beams.
- Anchorage of steel plates must not only cater for transmission of vertical shear but also prevent the plates from being pulled out.



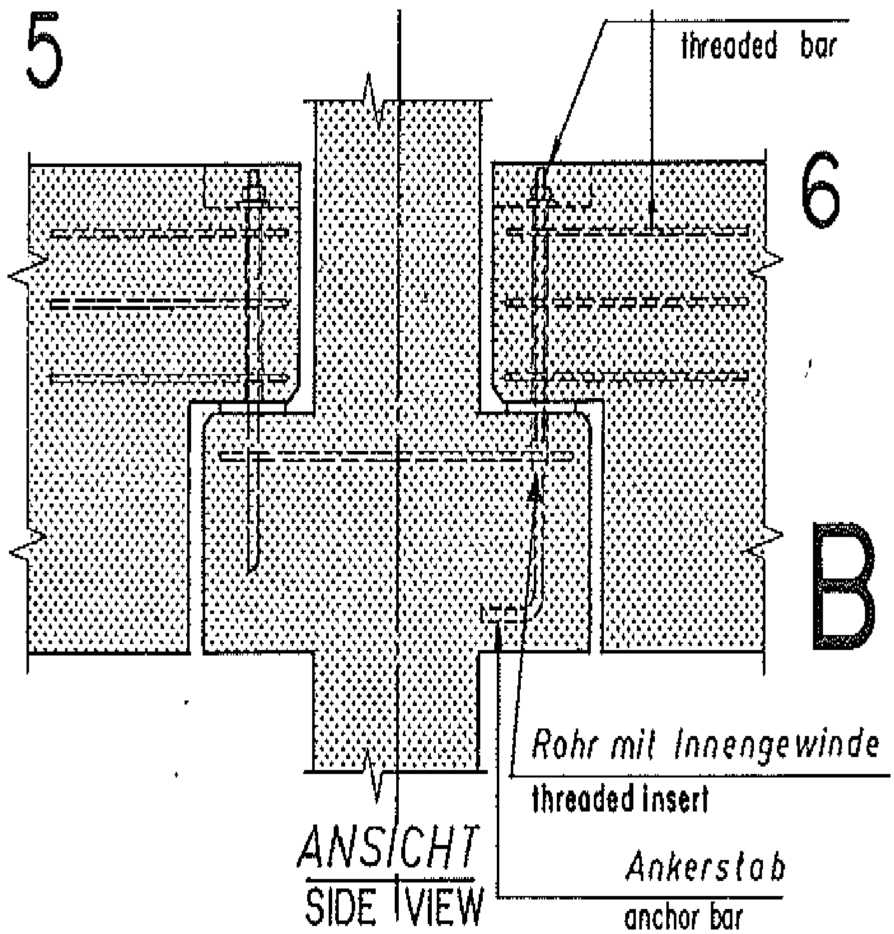
- To avoid point bearing ,care must be taken to install the bearing plates perpendicular to the column face
- Disadvantage is that only very small tolerances can be allowed.Temporary safety measures during erection are necessary and permanent stability after erection are required.

6) BEAM TO COLUMN CONNECTION WITH CONCRETE CORBEL

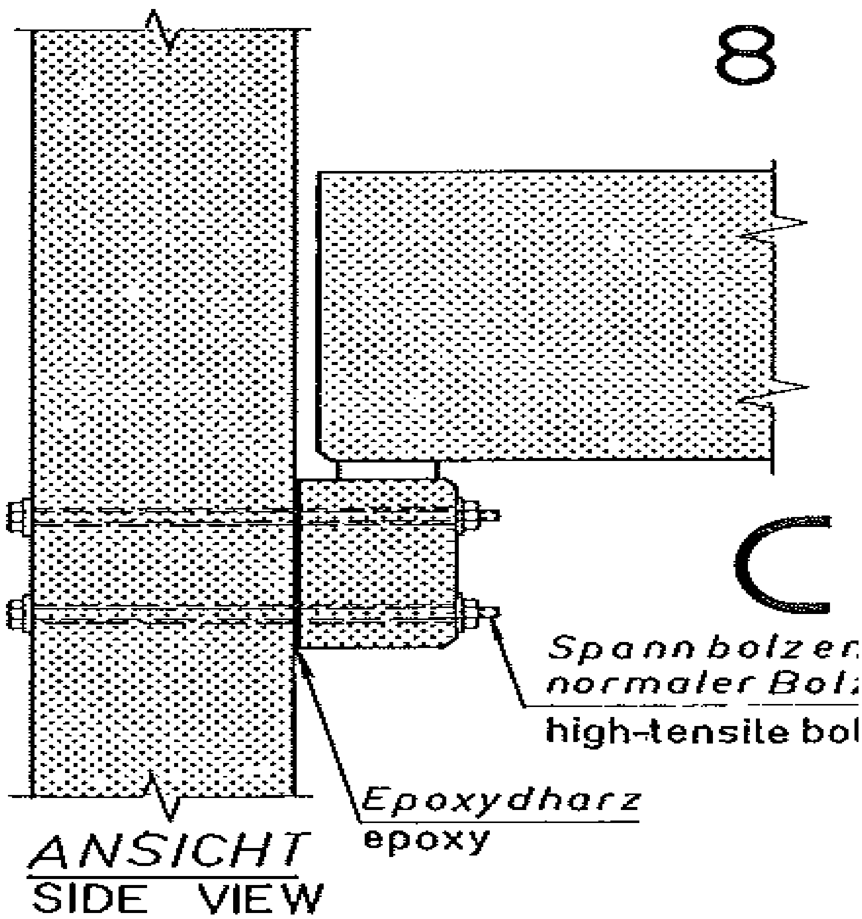
- The beams are supported on concrete corbels
- This connection is generally applied to simply supported beams
- **VARIANT A**
- The concrete corbels protrudes under the beams .



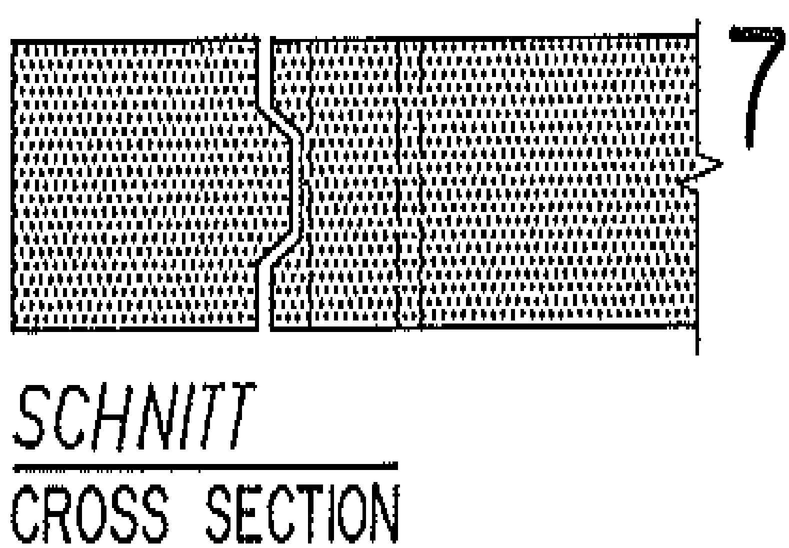
- **VARIANT B**
- The beams have notched ends and are supported on corbels.
- The notched ends must be reinforced against The vertical shear force and also against torsion if it is eccentrically loaded.



- **VARIANT C**
- Columns are provided with concrete corbels which are bolted to the column faces .
- It is advisable to use high tensile bolts and provide an Epoxy layer at the column and corbel interface. The bolts and nuts must have permanent protection against corrosion and fire.



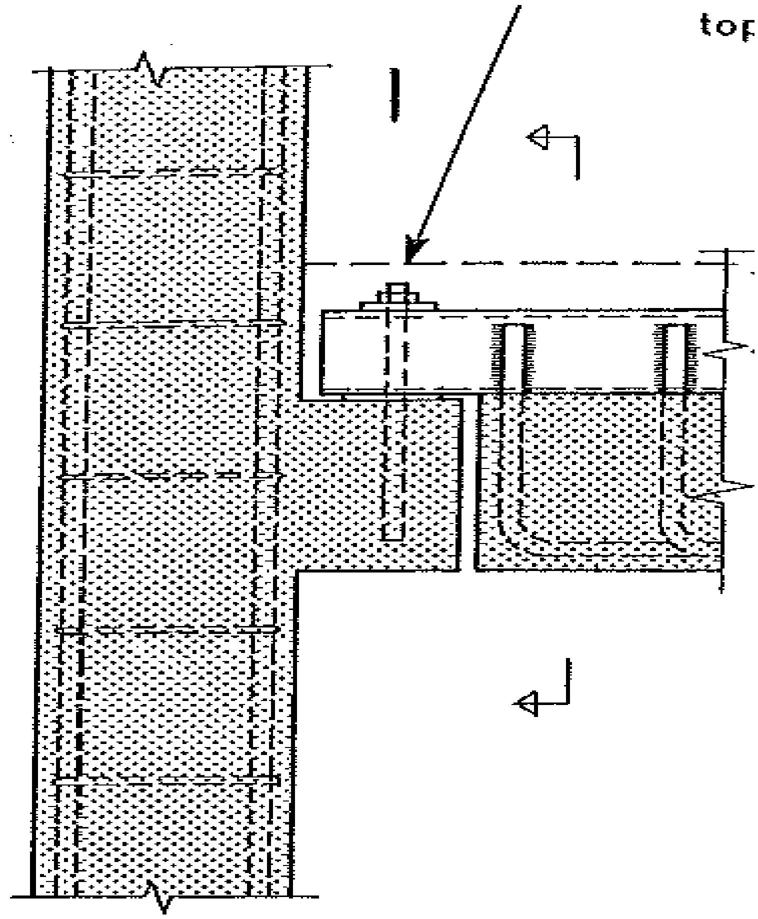
- To prevent the beams from toppling , beam and column interface could be shaped to form a tongue and groove joint.



7) BEAM TO COLUMN CONNECTION WITH STEEL JOIST HANGER

- Beams are supported by means of steel joist hangars on concrete corbels.
- This connection is suitable for limited construction depths.

- The hangar construction must be designed to transmit the total vertical shear force. Since the connection cannot transmit torsion , it is unsuitable for edge beams.



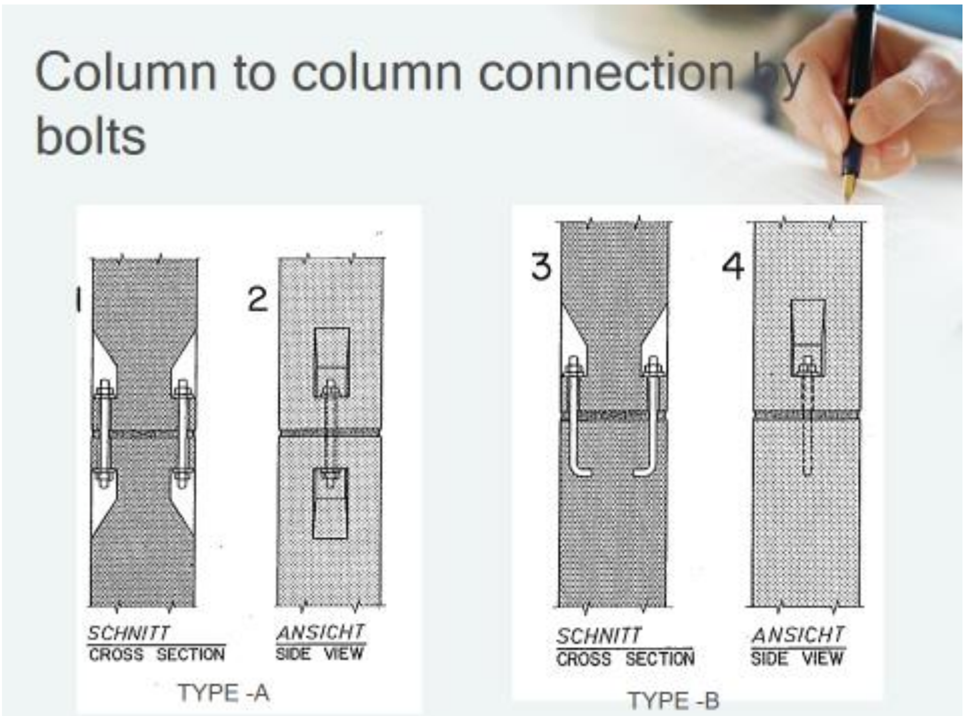
- The hanger construction consists of two vertical channels with flanges facing each other which are welded to anchor bars projecting from top of beam
- During erection , these channels are placed on an equalizing pad on top of the corbel.
- The beam is secured vertically and laterally by tightening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

COLUMN TO COLUMN CONNECTION:

- Column to column connection by bolts
- Column to column dowelled connection
- Column to column connection by welded steel bearing faces
- Column to column connection by welded-on steel flat bars
- Column to column connection by butt-welding of reinforcing bars
- Column to column connection by lap-welding of reinforcing bars
- Column to column connection by coupling of reinforcing bars
- Column to column connection by post-tensioning
- Column to column hinge connection

1) COLUMN – COLUMN CONNECTION BY BOLTS:

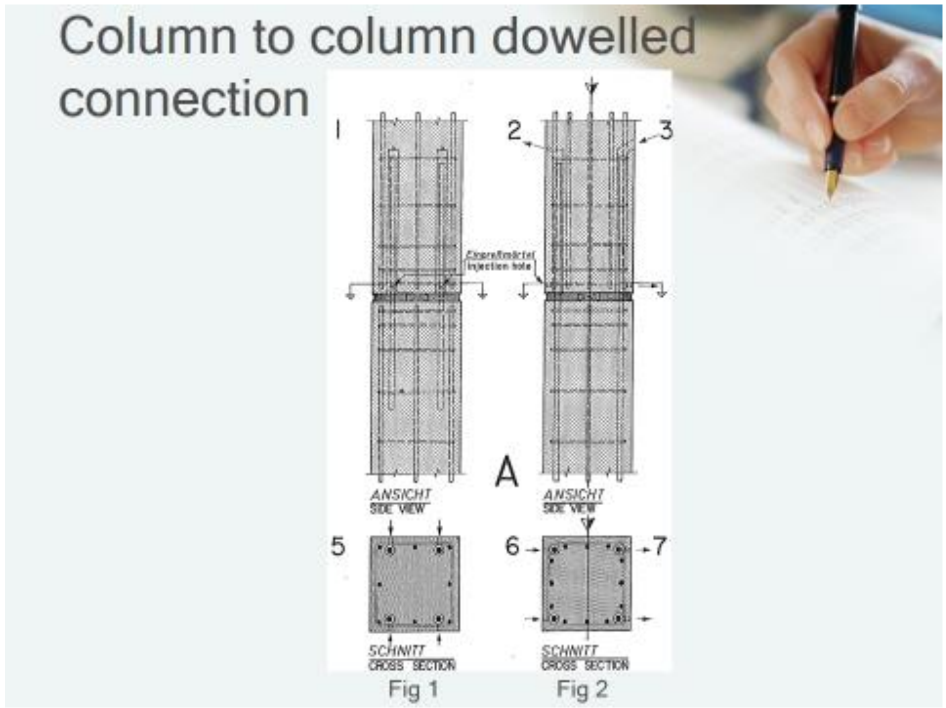
- The upper column is seated on a leveling pad of slightly flexible material.
- After plumbing and bracing the upper column, nuts with washer are tightened on bolts.
- The joint between the upper and lower column is filled with mortar.
- The upper column must remain braced until the mortar has regained sufficient strength and the nuts have been retightened.
- Type B is less complicated but care must be taken while transporting and erection against injuries.



2) COLUMN-COLUMN CONNECTION BY DOWELLED CONNECTION:

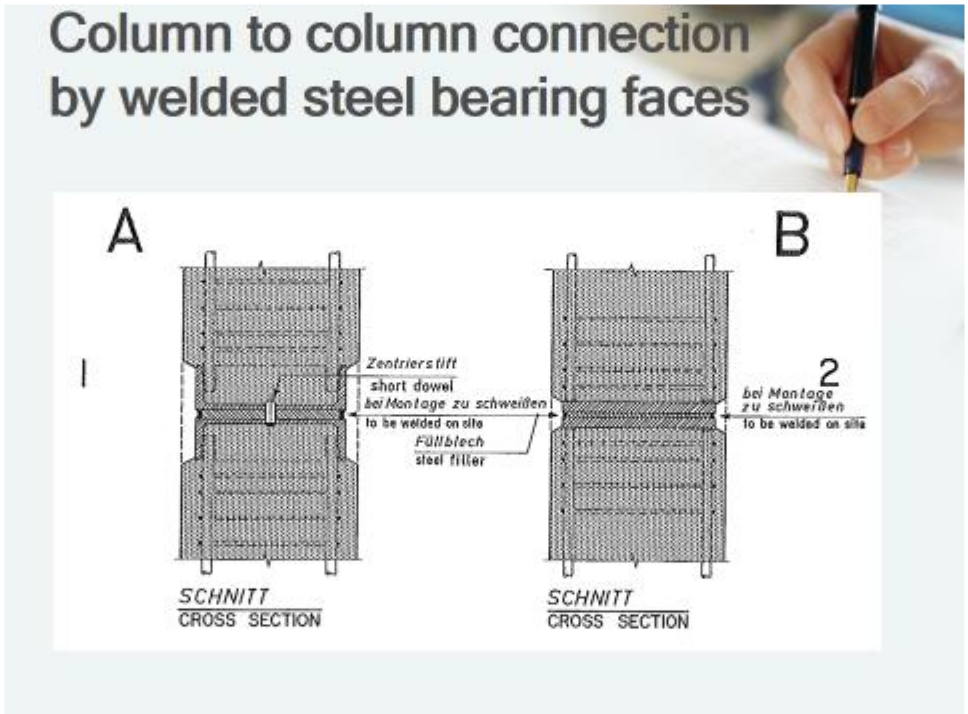
- To avoid transporting difficulties due to the long starter bars, both upper and lower column can be provided with dowel holes in which, at the time of erection, starter bars are embedded with grout.

- The main column reinforcing bars may be used for starter bars (fig 2).
- The upper column is seated on a leveling pad.
- After plumbing and bracing the upper column, the joint at interface and the holes are grouted.
- To improve the shear transmission ribbed reinforcing bars should be used and the holes should have ribbed walls.
- In type B, provisions must be taken to prevent dowel holes from becoming contaminated.



3) COLUMN TO COLUMN CONNECTION BY WELDED STEEL BEARING FACES

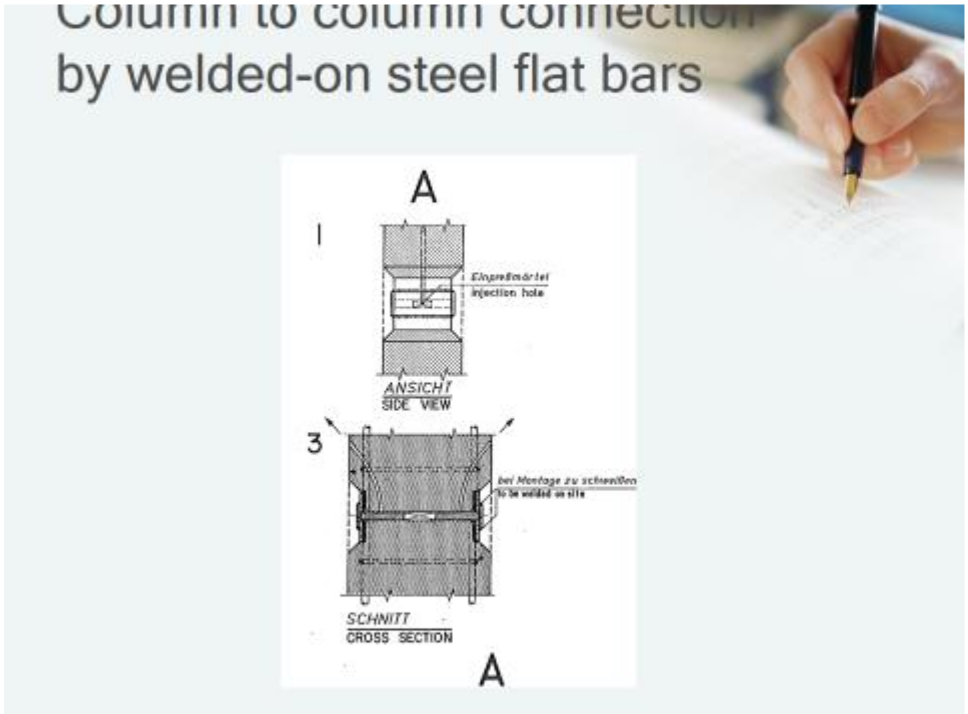
- In type A , the steel bearing faces either are built up from a channel section closed off by plates welded to it or is also formed by a plate having sides bent up and connected to welds.
- Prior to casting the column the steel bearing must be welded to the main column bars .
- This connection can be executed with a short dowel projecting centrally from lower column which fits into a hole in the bearing of the upper column.
- In type B connection the bearing surfaces are formed by steel plates these should be sufficiently heavy to keep deformations due to welding to a minimum.
- The upper column foot and lower column head should be provided over a distance with a splitting reinforcement.



4) COLUMN TO COLUMN CONNECTION BY WELDED-ON STEEL FLAT BARS

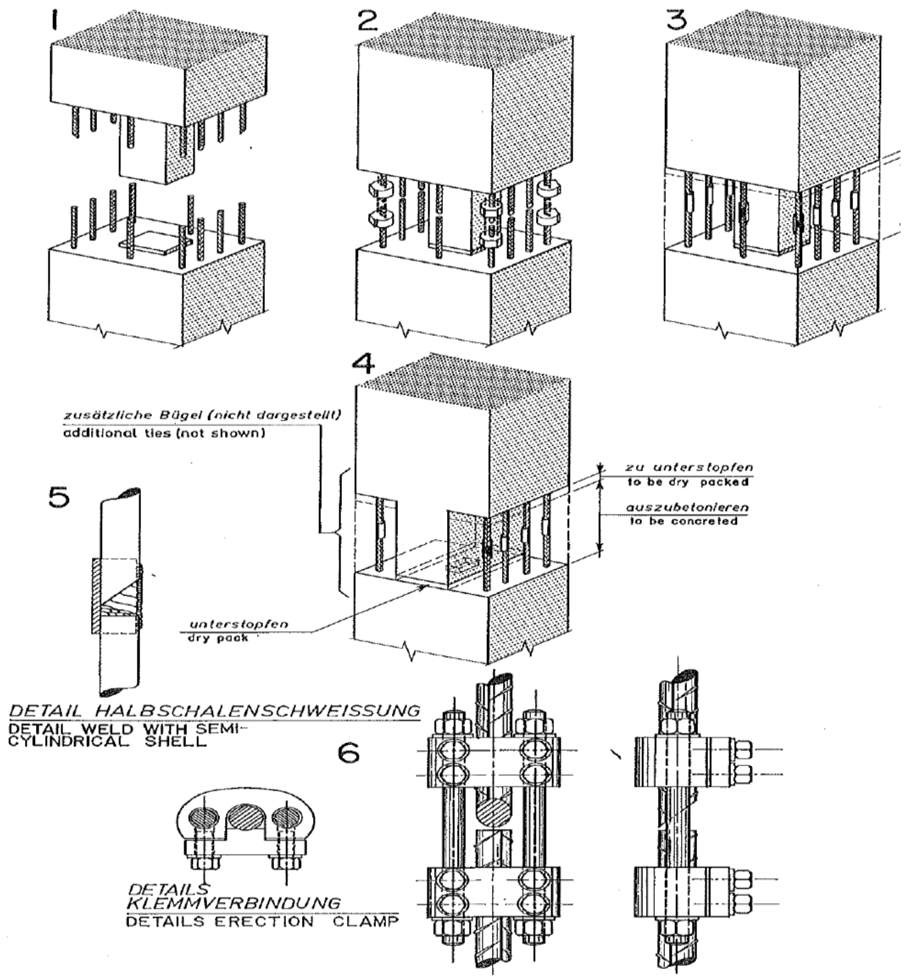
- Type A may be considered if moment transmission is required in both main directions. In this case both column ends must be recessed and steel covered on all four sides to allow the tension connections by means of vertical flat bars to be made in both directions.
- Type B is considered if moment transmission is only required in one of the main directions .in this case only two tension connections are necessary .
- Prior to casting the columns the vertical flat bars covering the column foot or head must be welded to the main column bars which form bond overlap with the main column bars.

- The upper column is seated on a leveling pad. After plumbing the upper column the connection plates are welded on.



5) COLUMN TO COLUMN CONNECTION BY BUTT WELDED REINFORCING BARS

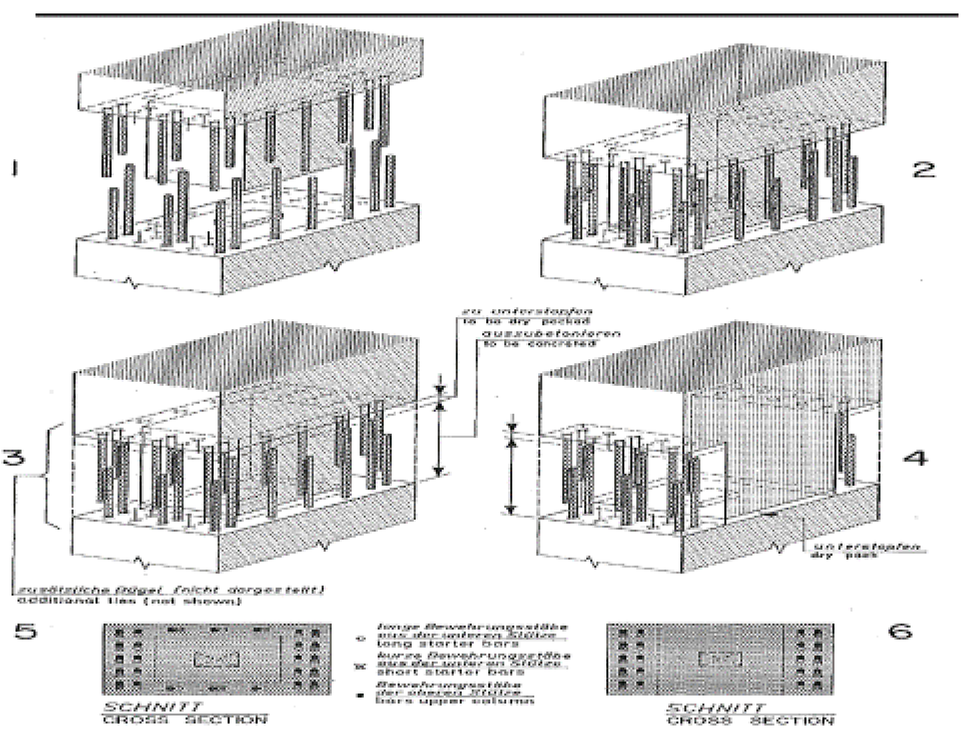
- Main column reinforcing bars of the upper column are butt welded to starter bars projecting from lower column
- Transmit large moments and resembels performance shape a monolithic constructions
- Upper column –by special designed clamp-connect the corner bars of the upper column seated on leveling pad-after plumbing corner bars clamped.
- Welding -laying the first weld bead at each one of these bars in turn after these weld have cooled - slag removed has been -lay subsequent in the same rotational order –
- upper column pulls out of true by contraction of welds in minimized. the best method is for two welders working simultaneously on two diagonally opposite bar after the welds have cooled completely remove and the column is completed with in situ concrete.
- Stub of upper column designed to carry self weight during erection
- Prevent slipping-upper column –section-insitu concrete around stub - head of the lower column –sufficient ties provided prevent slipping
- Clamp-strong-stability-erection-to resist tension by contraction of weld-butt weld semi cylindrical type
- Transmission of moment in one main direction ,upper column base need be recessed in that direction
- Welding operation-good accessibility of the weld.



6) COLUMN TO COLUMN CONNECTION BY LAP WELDING BY REINFORCING BAR

- Main column reinforcing bars of the upper column are lap welded to starter bars projecting from lower column
- Transmit large moments and resembles performance shape a monolithic constructions-suitable large column
- Upper-column braced-until welding
- Upper column –by special designed clamp-connect the corner bars of the upper column seated on leveling pad
- After plumbing and bracing- intialy tack welded –starter bar –weld continued across tack weld- executed later date-column pull out – unequal contraction of weld- the best method two welders working simultaneously on two diagonally opposite bar -welds identical out of short bead

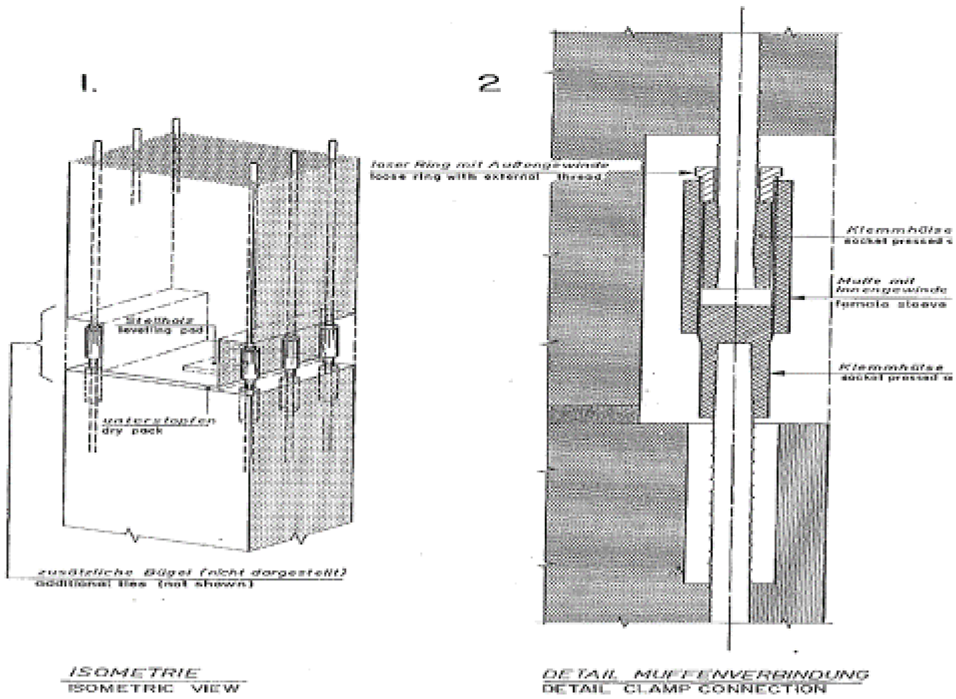
- Stub of upper column designed to carry self weight of column and erection load during erection
- Determining the length of bar it can be welded only from one side
- Main column-double rows-welds should be staggered
- Stub of upper column-section immediately above –in situ concrete around the stub-head of lower column sufficient ties should be provided
- Transmission of moment in one main direction ,upper column base need be recessed in that direction.



7) COLUMN TO COLUMN COUPLING REINFORCEMENT OF BARS

- Upper column recessed –bars are coupled to starter bars-projection from lower column-upper column completed with in-situ concrete
- Connection transmit fairly large moment-couple bar resist tension-so compressive force resist by concrete-on coupling is tightened stability is ensured

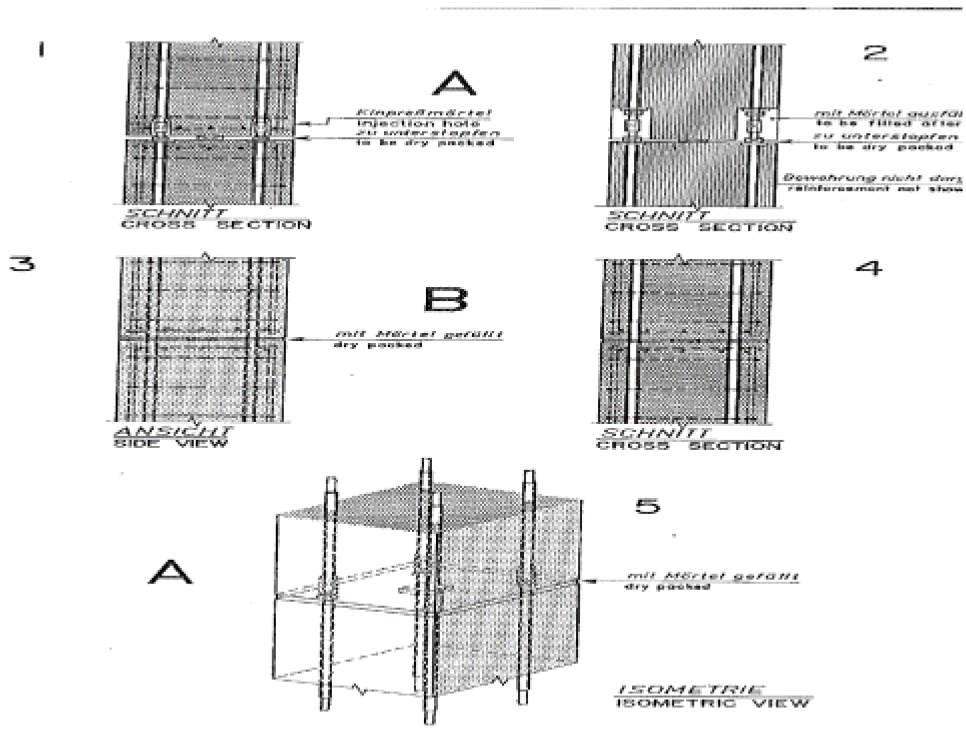
- Socket is provided before connection in main reinforcement bar-starter bar –pressed hydraulically-proper bond-
- After levelling & plumbing upper column sleeves –screwed-socket-rings tightened on the sleeve
- Tolerance- vertical-between bars are large-horizontal-starter bar should have free length allow slight bending
- upper column seated on leveling pad-after plumbing –this column and coupling reinforcement bar joint is dry packed.
- Stub of upper column designed to carry self weight of column and erection load during erection &tension caused by coupling
- Stub of upper column-section immediately above –in situ concrete around the stub-head of lower column sufficient ties should be provided Transmission of moment in one main direction ,upper column base need be recessed in that direction



8) **COLUMN TO COLUMN CONNECTION BY POST TENSIONING**

- This connection is suitable depending on the amount and the eccentricity of post-tensioning for transmitting moments of small to large magnitude in shape it resembles a monolithic construction
- Column is stressed prior to placing-upper column seated –levelling pad
- Tendons are threaded through and coupled to tendons of lower column
- Upper column is plumbed and joint at the interface of both column is filled with mortar
- mortar has sufficiently hardened the tendons - stressed at the upper end and the live end anchorages secured the upper column remain braced until pre-stressed –
- unbond tendons -additional immediate safety anchorage should be installed above the joint -ensure -connection above the joint remain intact even if lower column is destroyed -in this case these anchorage must remain accessible until the tendons and these recesses are completed with in-situ concrete after the intermediate safety anchorages are secured
- Column design must cater for additional stress due to pre-stressing
- Upper and lower column head should be provided with splitting reinforcement
- Ducts in both column –positioned-correctly to facilitate threading of tendons-ducts may be formed by cast in ribbed metal or plastic sheaths
- Joints at interface –both column must be dry packed-good performance

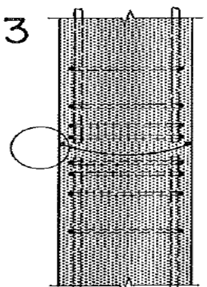
- Not required to allow tolerance at interface of both column-apply epoxy resin layer in mortar joint



9) COLUMN TO COLUMN BY HINGE JOINT

- In variation the upper column is placed over a short dowel projecting from the lower column .one no account should the incidental eccentricity fail outside the kern of the column section the short dowel caters for incident horizontal forces
- First the upper column is plumbed and levelled with the aid of erection wedges and braced then joint at the upper column and lower column interface and the dowel hole are filled with mortar
- Rotational capacity increases –elastomeric bearing-instead of mortar joint-dowel hole filled with mastic and column base shall have large chamfer
- A special construction steel hinge is fixed in between steel base plate anchored into upper column and steel head plate anchored into the lower column
- The upper column foot and lower column head should be provided with splitting reinforcement
- Steel plate must be provided with permanent protection against corrosion-reliability of latter is doubtfully.

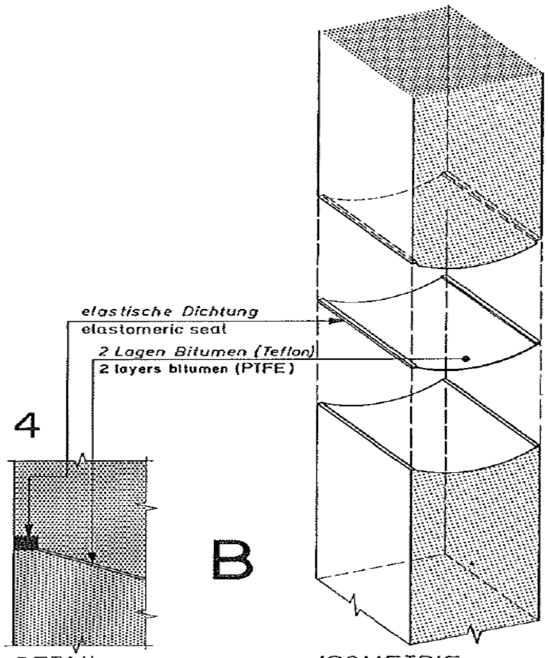
3



B

SCHNITT
CROSS SECTION

4



B

5

DETAIL
ENLARGED DETAIL

ISOMETRIE
ISOMETRIC VIEW

UNIT 3

FLOORS, STAIRS AND ROOFS

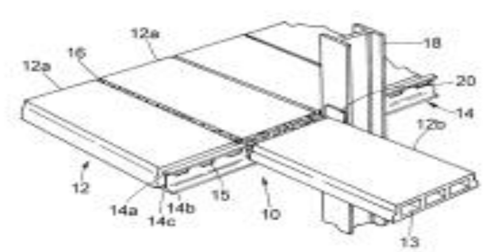
TYPES OF FLOOR SLABS :

- Precast concrete flooring is economic and versatile solution to ground and suspended flooring
- Worldwide, half of the floor slabs used in commercial and domestic building are precast concrete
- It offers both design and cost advantages over traditional methods such as cast in situ concrete, steel concrete composite and timber floors
- It give the maximum structural performance with minimum weight which can be used with or without topping.

TYPES:

- Solid flat slab
- Hollow core slab
- Double Tee slab
- Single Tee slab
- Composite beam and plank
- Bubble floor (or) Bubble deck.

1.1 Precast Slabs



Composite beam and plank flooring

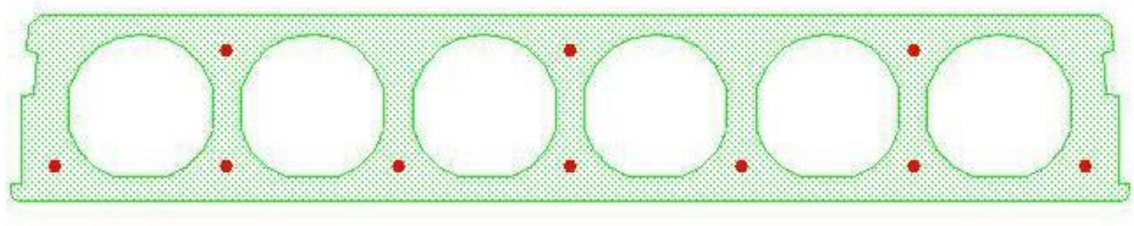
Bubble floor

1) **SOLID FLAT SLAB**

- Flat Slab is ideal for short span floors which are subjected to uniformly distributed loads.
- It is used extensively in residential buildings as well as in certain areas of commercial buildings.
- Flat Slab is manufactured using a wetpouring process.
- Generally common loadings used on residential, office and apartment buildings are suitable for Concrete Flat Slab flooring systems.
- The topping is provided over the flat slab units by placing the steel mesh above which gives the continuity and connection to various joints
- The minimum topping depth for Flat Slab at midspan is 75mm.
- Proper care should be taken in storing, handling and placing units.

2) **HOLLOW CORE SLAB**

- It is a concrete member with continuous voids provided to reduce the weight, cost and for electrical and mechanical runs
- It can also be used as a sound barriers, spandrel members and bridge deck units.



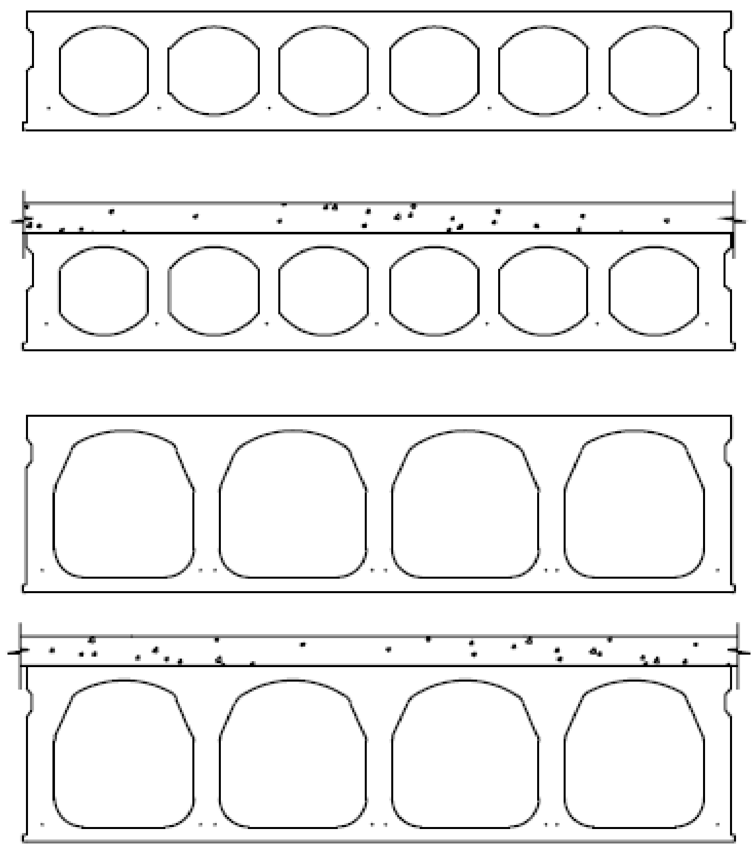
- Hollow core slabs can span up to 9 m (30 ft) or more without intermediate supports.
- Slabs can be cantilevered up to 1.8 m (6 ft) to form exterior balconies.

MANUFACTURING

- Two basic manufacturing methods are currently in use for the production of hollow core slabs.

ADVANTAGE:

- Hollow core slabs are most widely known for providing economical, efficient floor and roofsystems.
- With proper alignment, the voids in a hollow core slab may be used for electrical or mechanical runs.
- Excellent fire resistance, Depending on thickness and strand cover, ratings up to a 4 hour endurance can be achieved.



Hollow core slab without topping

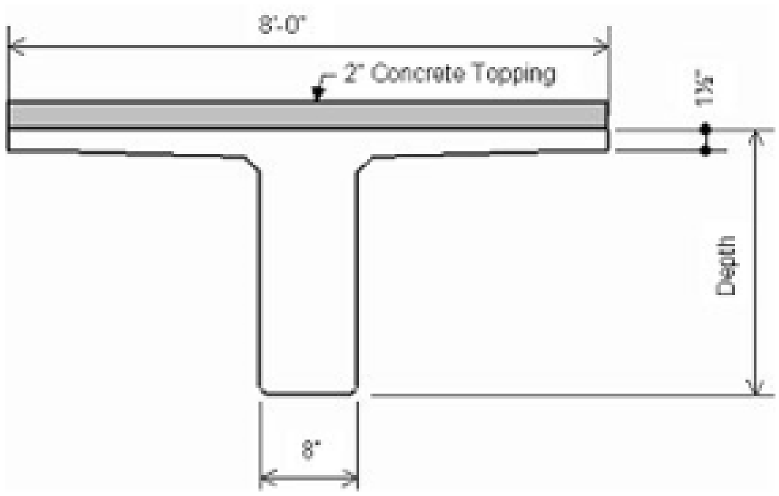
3) DOUBLE TEE SLAB

- Continued optimization of cross section by precast engineers lead to “double Tee” achieving greater spans with reduced weights when compared to the hollow core slab
- Double Tees are ideally suited for larger spanning floors with a wide variety of services suspended from the flooring system.
- Double Tees can easily accommodate large floor voids/penetrations through the slab region.
- Double Tee flooring units consist of two pre stressed ribs and a connecting top slab.
- Double Tee slabs can span up to 32 m without intermediate supports.
- The void ratio of the double tee is 70% which allows the greater span with smaller mass when compared with the 60% void ratio of the hollow core slab.
- The rate of erection is comparable with the hollow core slabs.

Structural topping over double tee slab

4) SINGLE TEE SLAB

- Single tee slab is equivalent to double tee slab where the span length is lesser than double tee slab
- It consists of single prefabricated ribs and a connecting top slab.
- The topping is provided over the slabs by placing the steel mesh above the slabs.



Typical cross section of Tee slab with topping

5) COMPOSITE BEAM & PLANK FLOOR

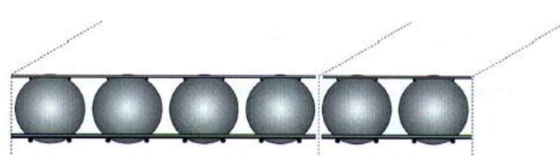
- Column or wall support long span beams, reinforced or pre stressed depending on the structural requirements, which carries a supporting beams.
- Supporting beam carry concrete planks of rectangular, non-rectangular even curved building layouts
- The planks are relatively inexpensive to produce range of moulds of different sizes than hollow core or tee slabs.
- The final constructed floor resembles a double tee floor and has similar void ratio of 70 percentage.
- Installation can be completed within very short time period.
- Slab can be utilized immediately after installation.
- Planks are designed tocarry Live Load of 2 KN/sq.m. Without any additional reinforcement.
- Planks can carry load upto 10 KN/sq.m if additional reinforcement is placed while filling up joints.

6) BUBBLE FLOOR (OR) BUBBLE DECK

- The composite slabs are made of Bubble Deck type slab elements with spherical gaps, poured in place on transversal and longitudinal directions.
- By introducing the gaps leads to a 30. . .50% lighter slab which reduces the loads on the columns, walls and foundations, and of course of the entire building.
- ”Bubble Deck” slab elements are plates with ribs on two directions made of reinforced concrete or precast concrete with spherical shaped bubbles.
- These slab elements have a bottom and an upper concrete part connected with vertical ribs that go around the gaps.
- The reinforcement of the plates is made of two meshes one at the bottom part and one at the upper part that can be tied or welded.
- The bubbles are made by high density polypropylene
- The polypropylene material is that don’t react chemically with the concrete or the reinforcement.

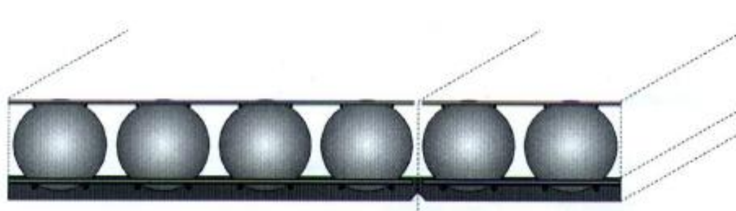
VERSION A

- Reinforcement modules in which the gaps are foreseen. Spheres of polypropylene are placed between the reinforcement at the bottom part and the reinforcement at the top part.



VERSION B

- Slab elements with Bubble Deck gaps, partially precast.



PREFABRICATED STAIR CASE

- Stairs arrangement
    - Cantilever
    - Helical
- Stairs with strings and trimmer beams
- Connection details
- Reinforcement details

SIZE

- It is entirely dependent on the available floor area.
- Usually 4 to 6 ft wide.
- Open staircases should be used in places where space is not exceeding 2,50,000 cu.ft.
- Placed in a place where natural lighting and ventilation is available.

OPEN WELL STAIRCASE

- Used mostly as fire exits in tall buildings to use lesser area.

SLOPE

- Slope of flight provided is dependent upon the safety and ease of using.
- 12in tread X 5.5in. Rise is universally adopted.
- In public buildings 14in. X 4.45 in. is adopted for tread and rise.
- For safety in indoors ,
    - Tread should not be greater than 10 in.
    - Rise should not be greater than 7.5 in.

DESIGN

- Stairs, landings and cantilever across balconies should be designed for the following imposed loads:
- For class 30 – 30 lb/sq.ft
- For class 40,50,60-60 lb/sq .ft.
- For all other classes – 100lb/sq.ft.

DISTRIBUTION OF LOAD

- In case of stairs with open wells where spans partly crossing at right angles occur,the load on the common areas is taken as one half in each direction.
- Where flights or landings are built in walls a distance of not less than 4.5in is provided.the effective breadth of beam is increased by 3 in.

EFFECTIVE SPAN OF STAIR

The effective span of stairs without stringer beams should be taken from the conditions below:

- Where supported at top and bottom risers by beams spanning parallel with the risers, the distance is centre to centre of beams
- Where spanning on to the edge of a landing slab which spans parallel with the risers a distance equal to “going “ distance plus at each end either half width of the landing or 3 ft which ever is smaller.
- Where the landing slab spans in the same direction as the stairs they should be considered as acting together to form a single slab and the span determined as in point 1 .

FLOOR INSULATED AGAINST IMPACT SOUND

Quilt

- A **quilt** is a type of bed cover, traditionally composed of three layers of fiber: a woven cloth top, a layer of batting or wadding and a woven back

Screed:

- A floor screed is usually a cementitious material made from a 1:3 or 1:4.5 ratio of cement to sharp sand.
- **Linoleum** flooring is just the normal vinyl flooring

STAIR ARRANGEMENT

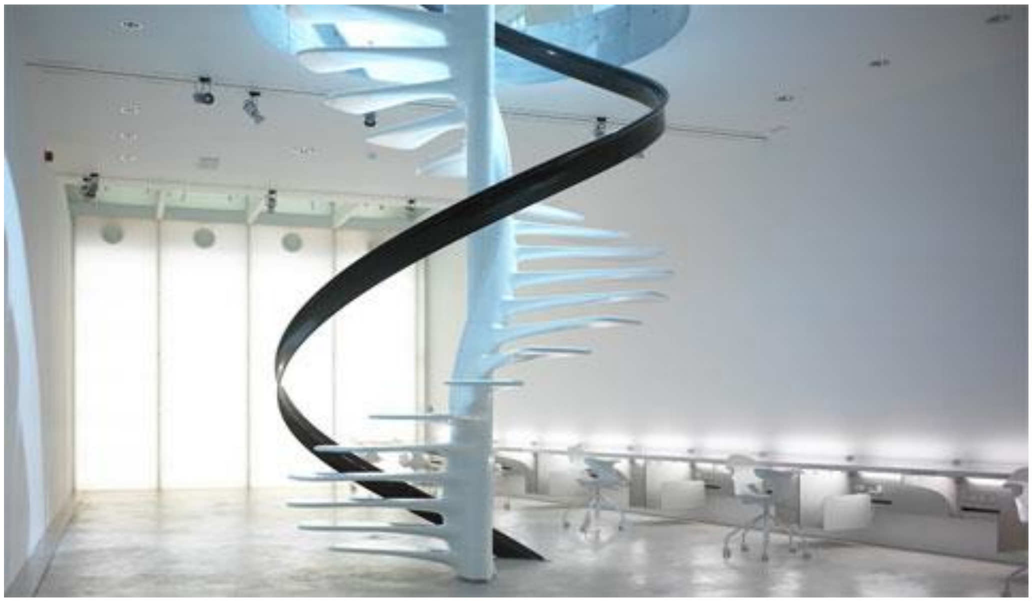
- The most common arrangement of stairs is a 3 flight stair with a open well at the centre with 2 intermediate quarter landings and a half landings and a half landing at each floor level.
- The stairs are supported in the wall at one side and the span without stringer beam to the landings and hence to the walls
- Precast stair with stringers and trimmers is a convinient design when considerable repetition is possible and the stair is in a 2 flights per storey.
- The seating recess in the trimmers are made to suit the slope of the strings upwards in one direction and downwards in the other direction.

CANTILEVERED STEPS

- cantilever stairs is a stunning feature stairs which creates an amazing impact as the steps appear to seamlessly float from the wall.
- cantilever stairs can be used in both interior and exterior applications

HELICAL STAIRS

- The design of a helical stair can be placed upon accurately precast steps post tensioned together with a number of tendons anchored in the foundation and tensioned at the top.
- Careful grouting is essential since the torsional resistance of the central string is critical.
- Some stiffening will result from hand railing and this will assist in the distribution of any concentrated eccentric load.



THE TWO-WAY WAFFLE SLAB SYSTEM

- Characterized by having transverse ribs which perform a structural function and so arranged to form a series of approx. square panels with the longitudinal ribs
- A crossing grid with large holes in the subflooring panel
- Grid provides lateral stability while the holes offer space for conduits and pipes to run beneath the main flooring

ADVANTAGES

- Actual slabs can be made very thin
- Lightweight, less foundation cost and level soffit
- Material quantities – Most economical type of roof unit
- Medium spans
- Excellent vibration control
- Good for service integration
- Durable finishes
- Fire resistant

DISADVANTAGES

- Higher formwork costs than for plain soffits
- Slow and difficuilt to prefabricate reinforcement

DIMENSIONS

- Spans from 5 – 12 m
- Width of the units range from 1 – 3 m
- Depth of longitudinal ribs - 20 to 65 cm
- Depth of transverse ribs - 15 to 20 cm
- Toppings between 50 and 150 mm thick
- Depth governed by deflection of beams, tend to be heavily reinforced.

TYPES OF ROOF SLAB

1) **WAFFLE SLAB**

   Waffle slabs designed as two way slabs with integral beams and level soffits

- Longitudinal ribs – with recesses to function as a kind of dowels that transmit shear and thus obviate any relative displacement of roof units
- Reinforcement of longitudinal ribs – ordinary bars with helical binding or ready made welded fabric mats
- Horizontal reinforcement at the corners to be provided – while lifting from the mould.

2) **RIBBED SLABS**

- Have no transverse ribs, prestressing
- Slabs to be made thicker and therefore heavier

THREE MAIN TYPES

- Channel units
- ‘T’ or “TT” units with cantilevered slabs
- Ribbed slabs with closely spaced ribs.

3) **CHANNEL UNITS OR TROUGH SLABS**

   - Omission of transverse ribs
   - Thickness 4 – 6cm
   - Width – 0.6 – 1.2m

4) PRESTRESSED CHANNEL UNITS

- Longitudinal ribs are provided with semi-circular recesses filled with concrete, function as a kind of dowels
- Equal deflection of ribs is ensured

5) PRESTRESSED “TT” ROOF UNITS

- Two ribs instead of only one and the slab does not cantilever out so far on each side
- Moulds for ‘T’ units removed sideways, ‘TT’ units in non-collapsible moulds

BEHAVIOUR AND CONSTRUCTION OF ROOF AND FLOOR SLAB:

Roofing members:

Roofing members can be divided into two groups, short span and long span roofing members. The short span members rest on purlin, while long span ones are directly supported by the main girders.

The short span roofing members are the reinforced planks made of porous hollow tiles, light weight concrete; roofing materials and small reinforced concrete roofing members will be dealt with here.

a) Reinforced planks made of porous hollow tiles:

The roofing members consist of porous tiles having longitudinal circular holes. Reinforced porous tiled planks having a length of 2.3m, thickness of 6 to 10cm and a width of 20cm can be produced. Of these tiles, two kinds exist.

The first kind is heat insulating and has a unit weight of 750 kg/m^3,the second kind is load bearing, its unit weight is 1100 kg/m^3,this is used for production of reinforced planks.

The disadvantage of using the porous hollow tiles in question for roof covering is that the material of the latter is highly moisture absorbing, and therefore not frost resistant. Thus the roof cover should protect from moisture and hence it should be rough rendered with lime cement mortar.

b) Light weight concrete roofing members:

Light weight concrete roofing members play a role, in addition to space bordering and load bearing, in heat insulating and so the application of a separate heat insulating layer is not necessary.

Light weight concrete roofing members can only be applied if there is a possibility of their reinforcement. It requires a bond between the steel and the light weight concrete for ensuring the transmission of the tensile force acting in steel bars to the concrete with the steel bars sliding; hence it is necessary to protect the reinforcement against corrosion.

c) Small reinforced concrete roofing members:

The small reinforced concrete roofing members is essentially a precast simply supported, ribbed reinforced concrete slab. A rib and block slab is composed of rectangular shaped precast concrete reinforced or prestressed ribs supporting rebated filler blocks placed between two ribs. This system is sometimes referred to as planks and block or beam and block. In - situ concrete is poured between and over the blocks. Slab depths vary from 170mm to 380mm with clear span upto 10m.

d) Large reinforced concrete roofing members:

The large reinforced concrete roofing members resting directly on the main girders of the structures represents more advanced kind of precast roofing members. These members are manufactured in a length corresponding to the spacing of the frames (6-10m). Their width is 1.30m to 1.80m. They are directly supported by the main girders so that purlins are not required.

Flooring members:

In industrial buildings the use of the prefab members, for floor consist of precast joist and flooring members.

The flooring members are designed for a span of 9m and for the bearing of a live load of 1000kg/m^2. After the members are placed in final position a longitudinal load bearing reinforcement and stirrups are placed in the trough formed between the longitudinal ribs of the adjacent members. Continuous mesh reinforcement is placed on the top of these members; there after a 5cm thick insitu concrete layer is cast on the top of the members and the trough between the longitudinal ribs are also filled up with concrete. In this way the slab is preformed as a continuous slab.

A prestressed flooring member for a span of 6.0m and live load of 5000kg/m^2 and weight of 1450kg are widely used

DESCRIPITION OF JOINTS:

i) Rigid Joints:

- Can take tensile, compressive, shear and bending moments too.
- Relative rotation and relative displacement are impossible.
- Generally used for the junction of columns to footings.
- Used for joining of individual members to each other.

Limitations:

- Requires considerable man power and hence minimum applications.

ii) Hinge like Joints:

- Can transmit forces passing through hinges itself, and also allow certain motion and rotations.
- Joints used in precast members are usually hinge like.
- Requires less working time than that of the rigid joints.
- Execution is simpler.

iii) Shod Joints:

- Used in industrial construction and used for long span only.
- Chiefly used in bridge construction for long span bridges.

iv) Dry Joints:

- A joint accomplished by simple placing of two members on each other and then fastening them is called dry joint.
- The structure becomes immediately loose bearing.

v) Wet Joints:

- The joint requiring not only a casting cement mortar, but also a subsequent concreting is called wet joint.
  Eg: when a rigid joint is formed, generally the lengthening of steel bars is by joining the members by overlapping (or) welding them while the discontinuity is avoided by a skilful subsequent concreting is called wet joint.
- Adequate for the bearing of greater force.
- Structure assembled used a wet joint have a monolithic character.

TYPES OR JUNCTIONS OF JOINTS:

i. Joining of column to footing.
ii. Joining of beam to top of column.
iii. Joining of beam at an intermediate joint.
iv. Lengthening of column.
v. Joining of beams.
vi. Forming of joints for arched structures.
vii. Joining of joints of post tension structures.
viii. Joining of precast to monolithic RC structures.

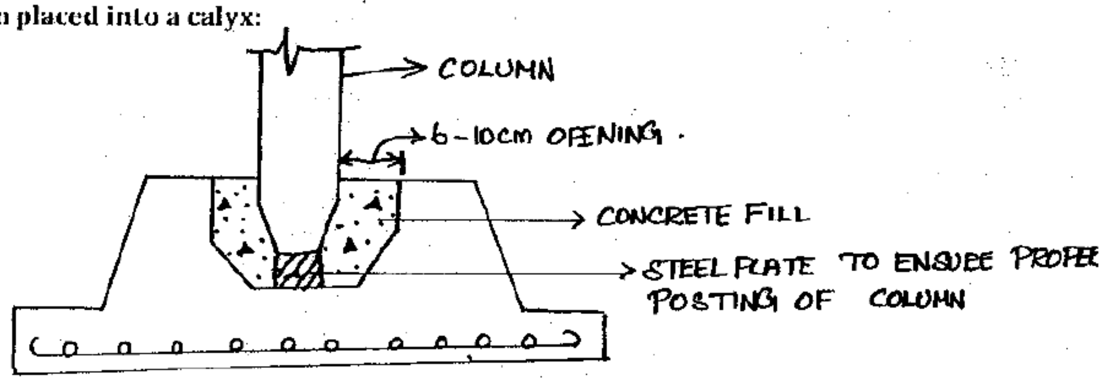
i) Joining of column to footing:

- Usually rigid.
- It may also be hinge-like.

Methods:

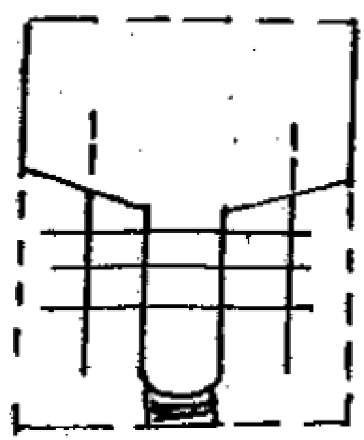
A rigid joint can be made by placing the column into calyx at the footing or by using welded joint.

a) Column placed into a calyx:

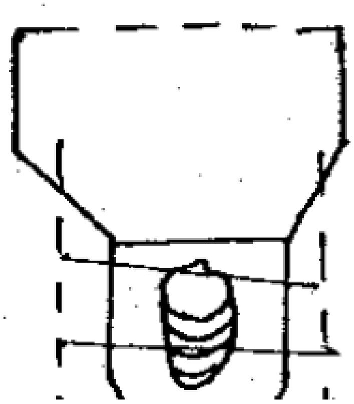


ii) Joining of column to beam on top of column:

a) By overlapping steel bars:

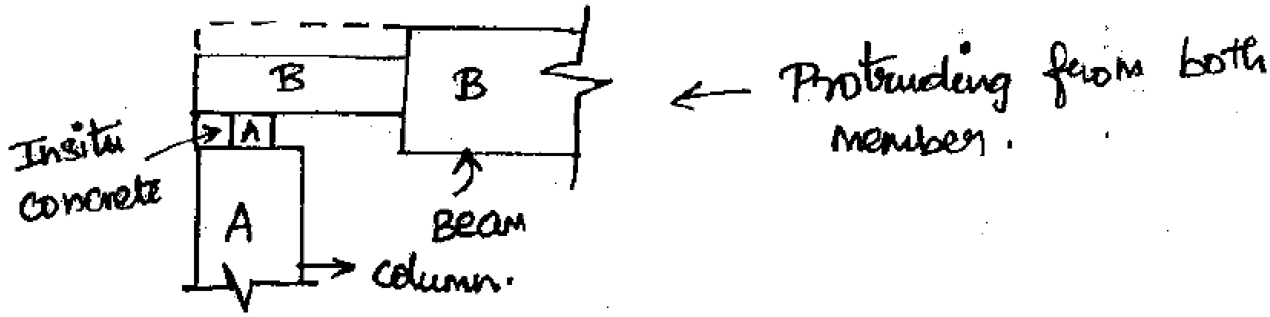


b) By hooked steel bars:

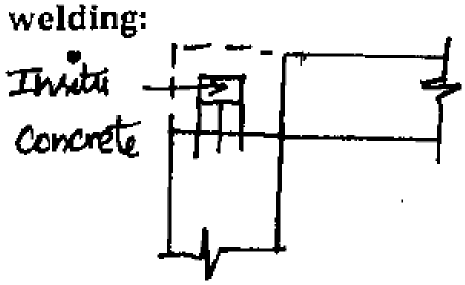


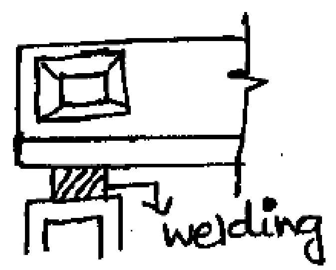
iii) **Joining of beam to column on top of column:**

a) **By overlapping steel bars:**



b) **By welding:**

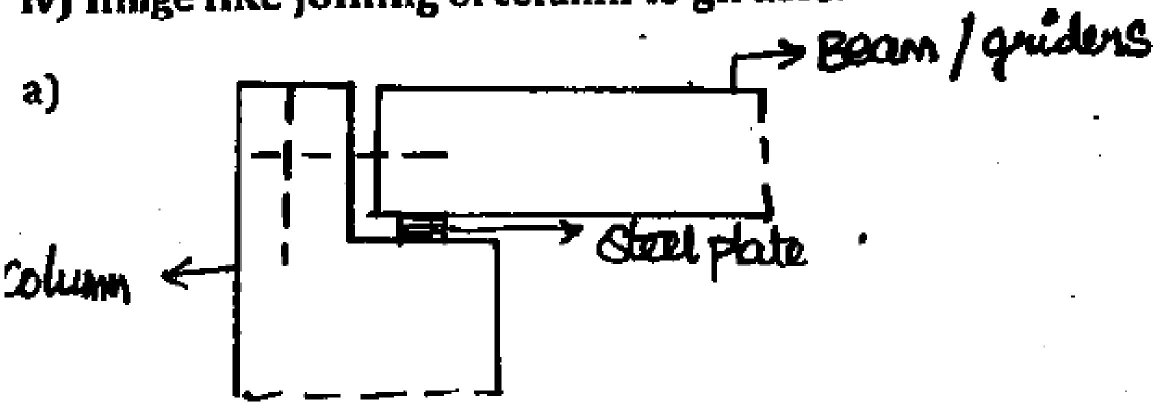




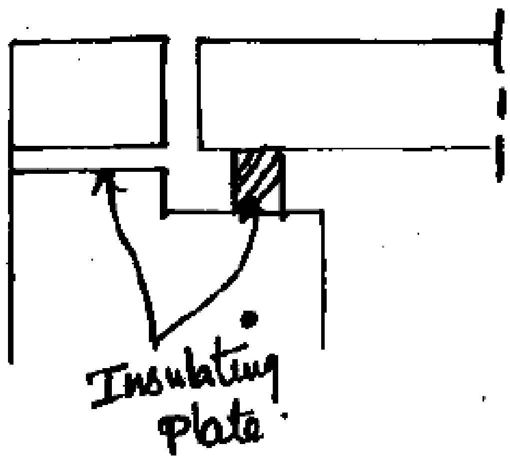
- Simple method for rigid junction fitting column with beam at girder.

iv) Hinge like joining of column to girders:

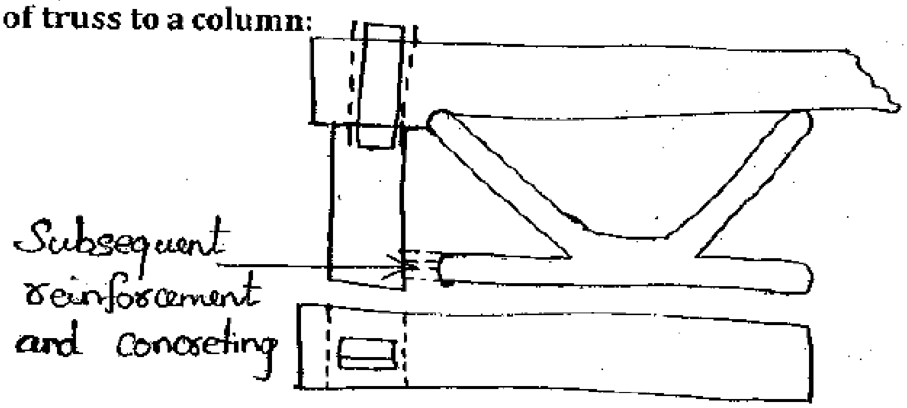
a)



b)



v) Joining of truss to a column:

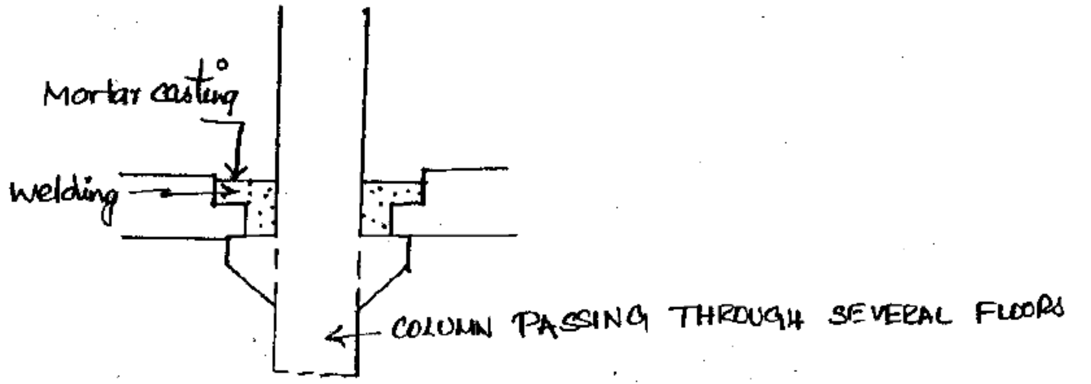


- The truss rests on the column by its cantilever like lengthened upper chord wh: the lower chord has subsequently be lengthened and joined to a column.

For vertical loads → The joint should be Hinge-like.

For horizontal loads → The joint should be Rigid.

vi) **Joining of column to a beam at an intermediate level:**



Joint techniques normally employed are:

- Welding if cleats or projecting steel
- Overlapping reinforcement, loops and linking steel grouted by concrete.
- Reinforced concrete ties all round a slab
- Prestressing
- Epoxy grouting
- Bolts and nuts connection, and
- A combination of the above.

Materials for concrete joints:

There are numerous different materials used in forming joints in concrete slabs, but the most common are

- Flexible board
- Dowels
- Sealants

Flexible board:

- A fibrous, compressible, flexible board such as flexcell, it is cheap and readily available from builder's merchants in pre-cut strips of the required depth, especially for creating expansion joints.
- It is typically 12mm, 20mm or 25mm thick and right thickness for the joint should be chosen.
- No joint should be wider than 30mm.

Dowels:

- 400 – 600mm long, 20 – 32mm in diameter and manufactured from grade 250 steel.

Sealants:

There are three main types

- Hot poured, usually bituminous in origin. Not as widely used now a days as they once were.
- Cold applied, often a two part poly sulphide mix incorporating resins and curing agent. Usually applied via a mastic gun and smoothed with a putty knife.
- Preformed elastomeric, expensive and need to be squeezed and inserted into a scrupulously clean and well lubricated perfectly formed joint.

DEFLECTION CONTROL FOR SHORT TERM AND LONG TERM LOADS:

The deflection of a flexural member is calculated to satisfy a limit state of serviceability. Since a prestressed concrete member is smaller in depth than an equivalent reinforced concrete member, the deflection of a prestressed concrete member tends to be larger.

The total deflection is a resultant of the upward deflection due to prestressing force and downward deflection due to the gravity loads. Only the flexural deformation is considered and any shear deformation is neglected in the calculation of deflection.

Shear deformation is included in members such as deep beams and wall type of structures.

The deflection of a member is calculated at least for two cases.

1) Short term deflection **at transfer**

2) Long term deflection under **service loads**

The short term deflection at transfer is due to the prestressing force (before long term losses) and self-weight. The effect of creep and shrinkage of concrete are not considered.

The long term deflection under service loads is due to the effective prestressing force (after long term losses) and the gravity loads. The permanent components of the gravity loads are considered in the effect of creep. These components are dead load and sustained live load.

The total deflection is calculated for the following two cases.

1) Short term deflection at transfer

2) Long term deflection under service loads

The short term deflection at transfer (Δst) is given as follows.

$$\Delta st = -\Delta P0 + \Delta SW$$

Here,

$\Delta P0$ = magnitude of deflection due to $P0$

Δsw = deflection due to self-weight

$P0$ = prestressing force before long term losses.

The long term deflection under service loads is difficult to calculate because the prestressing force and creep strain influence each other. Creep of concrete is defined as the increase in deformation with time under constant load.

The ultimate creep strain is found to be proportional to the elastic strain. The ratio of the ultimate creep strain to the elastic strain is called the creep coefficient θ.

The following expression of the long term deflection under service loads (Δlt) is a simplified form, where an average prestressing force is considered to generate the creep strain. The effect of shrinkage on the prestressing force is neglected in the expression.

$$\Delta_{lt} = -\Delta_{Pe} - \left(\frac{\Delta_{P0} + \Delta_{Pe}}{2} \right)\theta + (\Delta_{DL} + \Delta_{SL})(1+\theta) + \Delta_{LL}$$

The notations in the previous equations are as follows.

$\Delta P0$ = magnitude of deflection due to $P0$

ΔPe = magnitude of deflection due to Pe

Pe = effective prestressing force after long term losses.

ΔDL = deflection due to dead load (including self-weight)

ΔSL = deflection due to sustained live load

ΔLL = deflection due to additional live load

A more rigorous calculation of total deflection can be done using the **incremental timestep method**. It is a step-by-step procedure, where the change in prestressing force due to creep and shrinkage strains is calculated at the end of each time step.

The results at the end of each time step are used for the next time step. This procedure was suggested by the Precast / Prestressed Concrete Institute (PCI) committee and is also called the **General method.**

LIMITS OF DEFLECTION

The limits of deflection are summarised next.

1) The total deflection due to all loads, including the effects of temperature, creep and shrinkage, should not exceed span / 250.

2) The deflection after erection of partitions or application of finishes, including the effects of temperature, creep and shrinkage, should not exceed span/350 or 20 mm, whichever is less.

3) If finishes are applied, total upward deflection due to prestressing force should not exceed span / 300.

LIMITS OF L/D RATIO

The limits of L/d ratios, are as follows.

- For $L \leq 10$ m

  For cantilever beams $L/d \leq 7$

  For simply supported beams $L/d \leq 20$

  For continuous beams $L/d \leq 26$

- For $L > 10$ m

  For simply supported beams $L/d \leq (20 \times 10/L)$

  For continuous beams $L/d \leq (26 \times 10/L)$

  Here, L is in metres.

Deflection calculations are necessary for cantilevers with $L > 10$ m

UNIT IV

WALLS

WALL PANELS:

- **Structural insulated panels** (or *structural insulating panels*), SIPs, are a composite building material. They consist of an insulating layer of rigid polymer foam sandwiched between two layers of structural board.
- The board can be sheet metal, plywood, cement or oriented strand board(OSB) and the foam either expanded polystyrene foam(EPS),extruded polystyrene foam (XPS), polyisocyanurate foam, or polyurethane foam.
- SIPs share the same structural properties as an I-beam or I-column. The rigid insulation core of the SIP acts as a web, while the OSB sheathing exhibits the same properties as the flanges.
- SIPs combine several components of conventional building, such as studs and joists, insulation, vapour barrier and air barrier.
- They can be used for many different applications, such as exterior wall, roof, floor and foundation systems.

MATERIALS

- SIPs are most commonly made of OSB panels sandwiched around a foam core made of expanded polystyrene (EPS), extruded polystyrene (XPS) or rigid polyurethane foam, but other materials can be used, such as plywood, pressure-treated plywood for below-grade foundation walls, steel, aluminum, cement board such as Hardibacker, and even exotic materials like stainless steel, fiber-reinforced plastic, and magnesium oxide.
- Some SIPs use fiber-cement or plywood sheets for the panels, and agricultural fiber, such as wheat straw, for the core.
- The third component in SIPs is the spline or connector piece between SIP panels. Dimensional lumber is commonly used but creates thermal bridging and lowers insulation values.
- To maintain higher insulation values through the spline, manufacturers use Insulated Lumber, Composite Splines, Mechanical Locks, Overlapping OSB Panels, or other creative methods.
- Depending on the method selected, other advantages such as full nailing surfaces or increased structural strength may become available.

BENEFITS AND DRAWBACKS

- The use of SIPs brings many benefits and some drawbacks compared to a conventional framed building.
- A well-built home using SIPs will have a tighter building envelope and the walls will have higher insulating properties, which leads to fewer drafts and a decrease in operating costs.

- Also, due to the standardized and all-in-one nature of SIPs, construction time can be less than for a frame home, as well as requiring fewer tradesmen.
- The panels can be used as floor, wall, and roof, with the use of the panels as floors being of particular benefit when used an uninsulated space. As a result, the **total life-cycle cost** of a SIP-constructed building will, in general, be lower than for a conventional framed one—by as much as **40%.**
- Whether the total construction cost (materials and labour) is lower than for conventional framing appears to depend on the circumstances, including local labour conditions and the degree to which the building design is optimized for one or the other technology.

DIMENSION AND CHARACTERISTICS

- In the United States, SIPs tend to come in sizes from 4 feet (1.22 m) to 24 feet (7.32 m) in width. Elsewhere, typical product dimensions are 300, 600, or 1,200 mm wide and 2.4, 2.7, and 3 m long, with roof SIPs up to 6 m long. Smaller sections ease transportation and handling, but the use of the largest panel possible will create the best insulated building.
- At 15−20 kg/m^2, longer panels can become difficult to handle without the use of a crane to position them, and this is a consideration that must be taken into account due to cost and site limitations. Also of note is that when needed for special circumstances longer spans can often be requested, such as for a long roof span.
- Typical U.S. height for panels is eight or nine feet (2.44 to 2.75 m). Panels come in widths ranging from 4 to 12 inches thick and a rough cost is 200-300 rs/ft^2 in the U.S. In 4Q 2010, new methods of forming radius, sine curve, arches and tubular SIPs were commercialized.
- Due to the custom nature and technical difficulty of forming and curing specialty shapes, pricing is typically three or four times that of standard panels per foot.

PLASTIC SECTION

- The Plastic Sections are fabricated using quality raw material in accordance with international quality standards.
- These easy to install sections are light in weight and do not require any painting or varnishing.
- Available in wide color range, these are highly durable and there is no chance of cracking, splitting, rotting or warping.
- For thermal or sound insulation, the sections are available with glass wool or polyurethane foam.
- The range is resistance to termite and borer and is reusable.

UNIQUE FEATURES

- No splitting, cracking, warping or rotting
- No painting or varnishing
- Light-in-weight and high durability
- Consistency in quality
- Easy to install and reusable
- Time and labour saving
- Wide colour range
- High aesthetic appeal
- Available with Polyurethane Foam or glass wool for improved thermal and sound insulation properties in selected sizes.

LARGE PANEL PRECAST CONCRETE BUILDINGS

STRUCTURAL CONSIDERATION

- Load bearing wall system
- Structural integrity
- Design computations
- Connections
- Production technology
- Erection & installation
- Architectural treatment

LOAD BEARING SYSTEM

- The structural solution of the large panel buildings are characterized by the orientation of the load bearing walls & whether the slab are one way or two way slabs.
- There are three basic structural solutions,
    - 1.Cross wall load bearing systems.
    - 2.Long wall load bearing system.
    - 3.All wall load bearing system

CROSS WALL LOAD BEARING SYSTEM

- This system has one way slabs. only the external walls in the cross direction are load bearing.the longitudinal walls are non load bearing.
- The one way floor slab have a span of 6 to 7 m ,for these span, non prestressed floor slab can be used hollow cores.
- The floor slab have to be connected together to form diaphram that transmit the horizontal forces to the walls.

LONGITUDINAL WALL LOAD BEARING SYSTEMS

- This system has one way slabs. only the external walls in the longitudinal direction are load bearing.
- The one way floor slab have a longer span of 9 to 12 m
- For these span, non prestressed floor slab can be used hollow cores.

ALL WALL LOAD BEARING SYSTEM

- These system has two way floor slab.
- The floor slabs are generally room size,with a thickness of 150 mm.
- This is sufficent for span 4 to 4.2 m
- This is used for all wall load bearing system, especially for high rise buildings,because it is easier to achieve stability in both directions.

STRUCTURAL INTEGRITY

- Structural integrity means that the stress normally carried in any one structural component can be safely transferred to adjacent components without overloading them & causing them to fail.
- It is more difficult to achieve with the cross wall and longitudinal wall systems,because the one way slab will collapse when there is no supports unless special connections are provided.
- The all wall load bearing system only easy to achieve structural stability.

CONNECTIONS

- The quality of the large panel is mainly depending upon the connections.
- Ideally,The connections should be simple ,installed quickly& efficently.
- Welded,bolted connections are eleminated,only concrete grouting is used in this system.
- There are two types connections,
    - horizontal connection and vertical connection

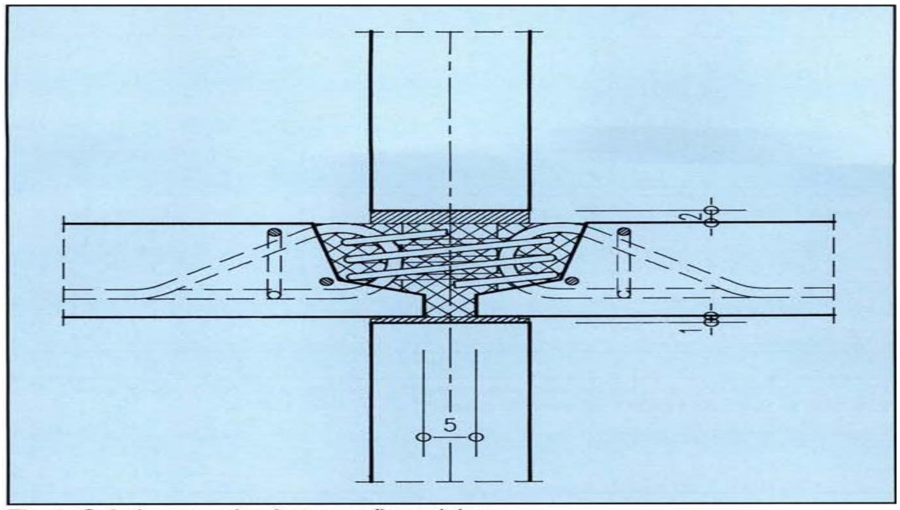


Fig. 9. Spiral connection between floor slabs.

horizontal

VERTICAL

- Corrugated tubes forms the holes in the top & bottom of the walls
- After the bottom wall is erected the bar is placed into the tube, then filled with the concrete .
- After the upper wall is erected over the reinforcing bars. then the upper part tube is filled with concrete.

PRODUCTION TECHNOLOGY

- Prefabricated elements are casted in factory or field, the factory is divided into production lines.
- Production technology is based on the circulating system, such as, Horizontal production: external sandwich walls are produced on horizontal production.

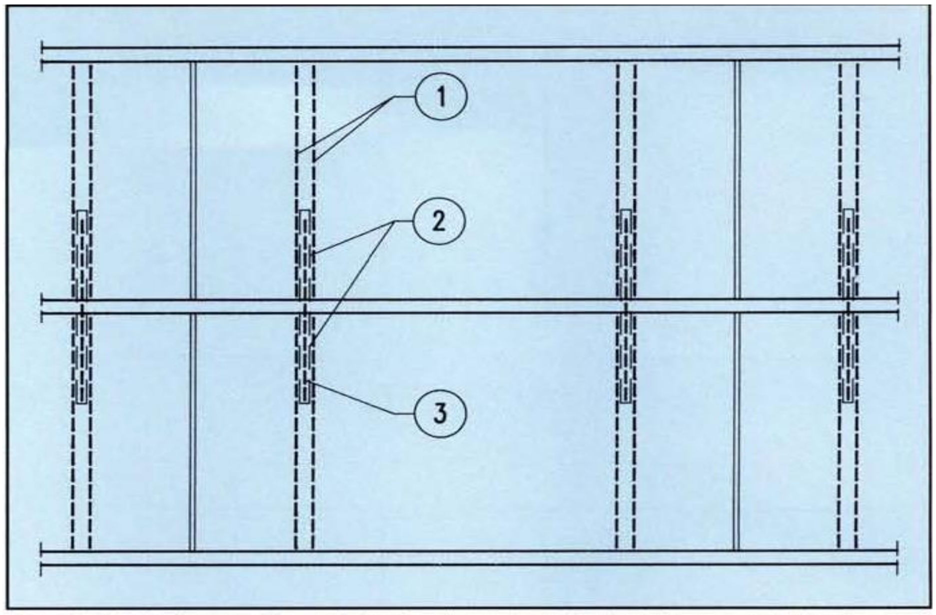


Fig. 12. Vertical connection reinforcing bars: **1.** vertical reinforcement of wall; **2.** tubes in top and bottom of wall; **3.** lapped bar in filled tubes.

- Vertical production: internal walls, partitions &floor slabs are produced vertical production.

ERECTION AND INSTALLATION

- Erection in building is done by tower craness.
- The crane erects 30 to 50 elements per gay.
- The weight of the element in all wall load bearing system does not exceed 10 metric tonnes.
- In all wall load bearing system the electrical,plumping accessories are embedded in the floor slab & walls.it difficult in hollow core,one way slab.
- Doors,& windows are embedded during the precasting.
- Finishing is simplified,wall paper can be directly applied on the walls without preliminary plastering.

ARCHITECTURAL TREATMENT

- Architectural treatment are given for achieving the good appearnce.
- It means arrangement of balconies, windows, doors and use of colors and texture on the surface of external elements my using new technology.
- It gives a verity of architectural expressions.

WALL PANEL JOINTS:

For the purpose of this Note, a *joint* is an intentional gap between adjoining elements (typically cladding) or between an element and some other portion of the structure. Joints may be horizontal, vertical or inclined.

The function of a joint between precast elements is to provide physical separation between the units and, in conjunction with joint sealants, prevent the ingress of water and air into the building; and, if required, fire resistance.

Two aspects of joint selection need to be emphasised:

- The positioning of joints in relation to windows and to the structure can affect the serviceability, construction and maintenance of the building envelope. Poor joint location will lead to problems which cannot be overcome by joint detailing (see **Figure 1**)
- Careful control of construction tolerances is necessary to ensure the integrity of the cladding system.

TYPES OF WALL PANEL JOINTS

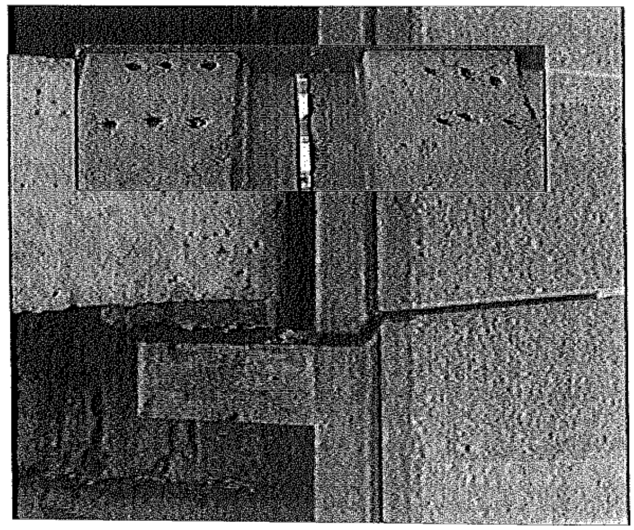
The most common types of joint between precast concrete cladding and/or wall panels are:

- open-drained;
- face-sealed; and
- compression-seal.

1) OPEN DRAINED JOINTS

The open-drained joint is recommended for **high-rise construction.** It consists of a rain barrier in the form of an expansion chamber with a loose-fitting baffle and an air-seal at the interior face of the panel (see

The baffle prevents direct entry of the wind-driven rainwater. The pressure in the chamber between the baffle and the internal air seal is at external air pressure. There is, therefore, no pressure differential to drive rain past the baffle. The air-seal is the demarcation barrier between outside and internal air pressures.



Advantages

- Can tolerate relatively large movements.
- The rear sealant is protected from UV light and weather.
- Can be installed from inside the building (no scaffold required).
- Long maintenance-free life.
- Best for medium- and high-rise construction.

Disadvantages

- Careful supervision is required during installation as i is difficult to remedy defects due to poor workmanshi
- Not suitable for tall vertical panels (> 9.0 m in height)
- Cannot accommodate joint gap tolerances > 5 mm.

2) FACE SEALED JOINTS

These joints are simple, economical and are most suited to low-rise construction (see Figure 3). They are sealed by a single run of gun-applied sealant close to the exterior surface of the joint. A backing-rod forms the rear of the sealant. The external face seal should, where practical, be supplemented by a seal near the inside face of the panel.

ADVANTAGES

Panel edges can have simple profile, no grooves required.

Can be used for complex panel shapes (angled or curved).

Can have a rear seal as a second line of defence.

Lowest first cost.

Can be readily inspected, repaired or replaced.

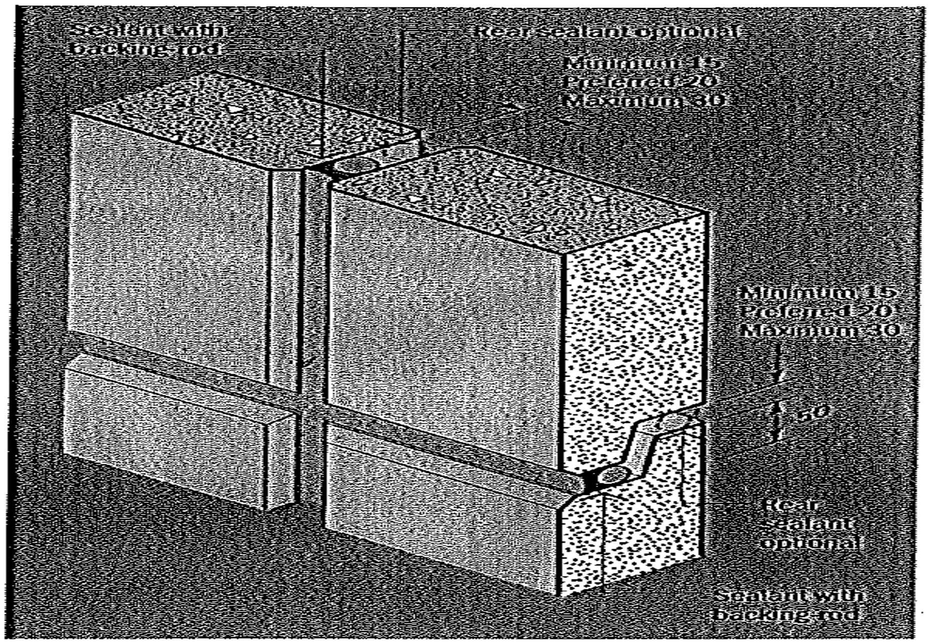
Best for low-rise construction.

DISADVANTAGES

Must be applied from external scaffolding or other form of access.

Sealant is exposed to UV light and weather – needs more maintenance.

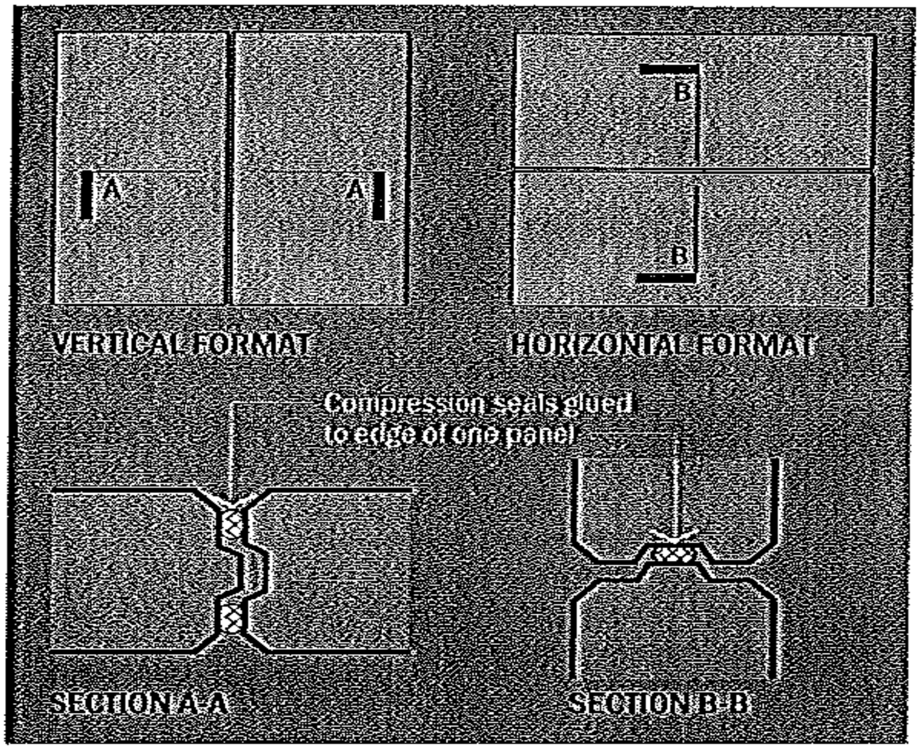
In a single-seal system even a small failure may allow water penetration due to capillary effects and pressure differentials.



3) COMPRESSION SEAL JOINTS

This type of joint utilises a compressible impregnated polyethylene or polyurethane foam strip. The strip is pre-compressed and inserted into the joint after the panels are erected or it is glued in position before placement of the second panel, **Figure 4**. It then expands to fill the joint.

The use of this type of joint seal is usually limited to **low-rise buildings** such as factories and warehouses where wind pressures are low. It can be used where spandrel beams, downturns or columns restrict the access required for placement of gun-applied sealants.



ADVANTAGES

- Simple and quick to install.
- Panel edges can be plain or simple profile.
- Economical.

DISADVANTAGES

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

4) HOLLOW CORE WALL JOINTS

Hollowcore wall units are primarily used on **low-rise** commercial and industrial buildings. The joints between panels are normally 10 mm wide and are sealed with a two-part polyurethane sealant placed against a closed-cell backing rod.

JOINT SEALANTS:

Factors to be considered by the designer when choosing a suitable sealant material include:

- The sealant should be impermeable to water.
- It should have a low elastic modulus to accommodate strain due to joint movement without significant stress, with the shape of the sealant influencing the stress in the sealant.
- It should be able to recover its original shape after cyclic deformation.
- It must bond firmly to the joint face without failing in adhesion nor splitting or peeling under the anticipated joint movements.
- It must not soften or flow at higher service temperatures and should not harden and become brittle at low temperatures.
- It should not be adversely affected by ageing or weathering and should be stable when exposed to UV light.
- For face-sealed joints the sealant should have a stable colour, be non-staining and resistant to pickup of dirt.

TYPES OF SEALANTS

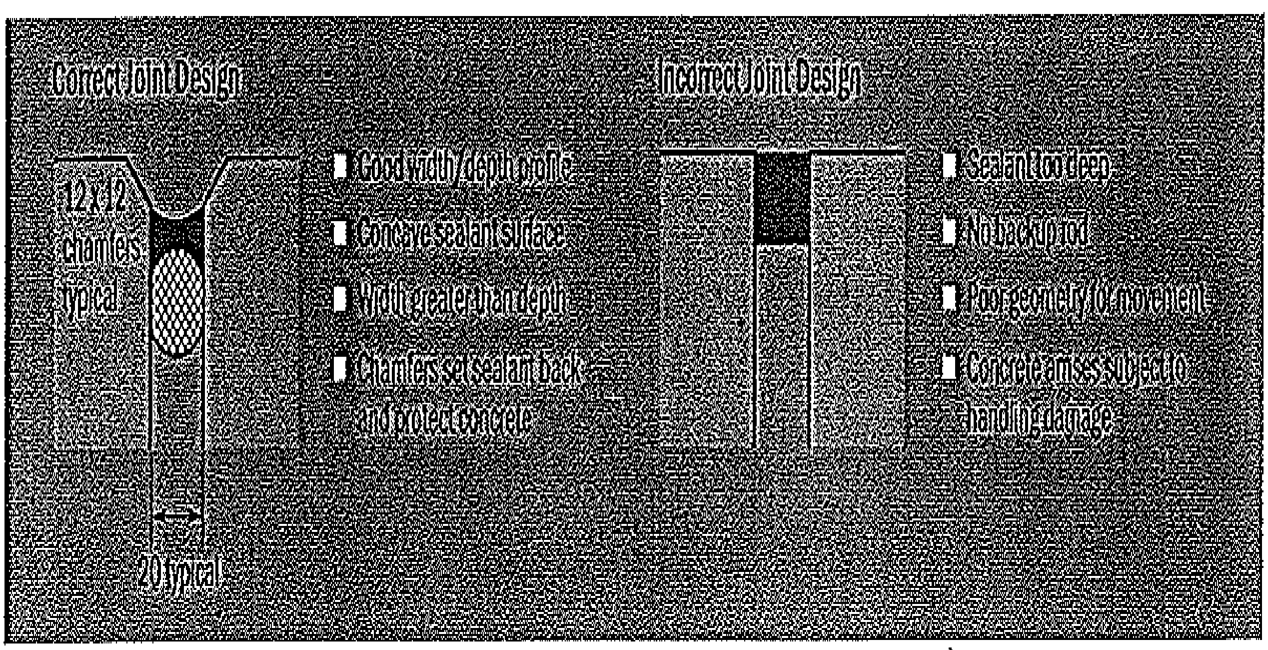
Field-moulded sealants are available in the following types:

- Polysulphide sealants (two-part)
- Polyurethane sealants (one- or two-part)
- Acrylic sealants
- Butyl sealants
- Silicone sealants.

JOINT SEALANT APPLICATION

- Correct joint preparation
- Correct sealant-backing systems
- Correct joint geometry
- Sufficient curing time.

<u>JOINT DESIGN:</u>



Poured Sealant Joints

- Durable low-modulus sealants, poured cold to provide watertight expansion joint seals have been used in new construction and in rehabilitation projects. Properties and application procedures vary between products.

- Most silicone sealants possess good elastic performance over a wide range of temperatures while demonstrating high levels of resistance to ultraviolet and ozone degradation.
- Rapid-curing sealants are ideal candidates for rehabilitation in situations where significant traffic disruption from extended traffic lane closure is unacceptable. Other desirable properties include self-leveling and self-bonding capabilities.
- Installation procedures vary among different products, with some products requiring specialized equipment for mixing individual components. Designers must assess the design and construction requirements, weighing desirable properties against material costs for alternative sealants

Strip Seal Joints

- An elastomeric strip seal expansion joint system, consists of a preformed elastomeric gland mechanically locked into metallic edge rails embedded into concrete on each side of an expansion joint gap.
- Movement is accommodated by unfolding of the elastomeric gland. Steel studs or reinforcing bars are generally welded to the edge rails to facilitate bonding with the concrete in formed block outs.
- In some instances the edge rails are bolted in place. Edge rails also furnish armoring for the adjacent bridge deck concrete.
- Properly installed strip seals have demonstrated relatively good performance. Damaged or worn glands can be replaced with minimal traffic disruptions.

UNIT V

INDUSTRIAL BUILDINGS AND SHELL ROOFS

R.C. ROOF TRUSSES:

A roof truss may be defined as being: '*an unyielding frame designed to span or transfer loads between supports.*'

Truss Types

Trusses are categorised into 3 groups depending on the shape of the top chord

- Triangular Roof Trusses
- Crescent roof Trusses
- Other Types

Triangular Roof Trusses

- Simple Triangular geometric shape
- Web Bracing
- Straight Top Chord

Crescent Roof Trusses

- Top Chord is manufactured with a curved top chord
- The Harbour bridge is a good example

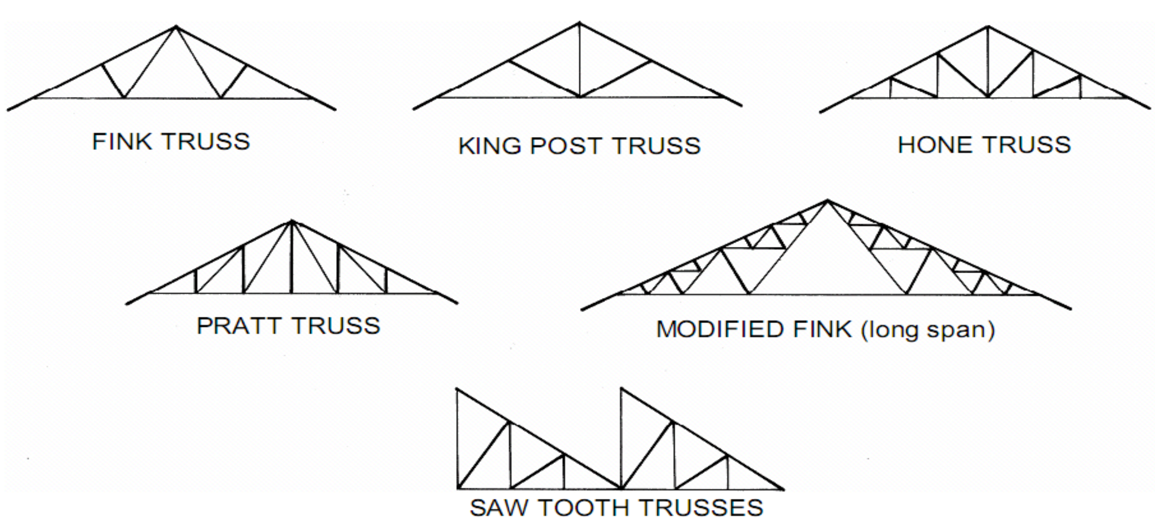
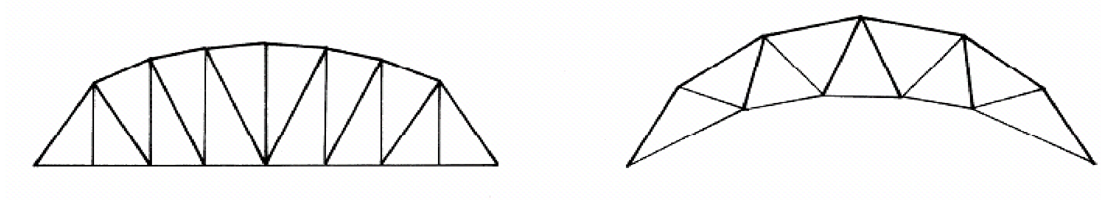


Fig. 13.4 Typical triangular roof trusses



CRESCENT TRUSSES

Other Types

- Top Chords may be parallel – such as floor joist trusses
- Or they may be nearly parallel – such as bridges

Parallel Chord Trusses

- Used as Rafters

Advantages

- Lighter
- Larger Spans
- Allow for easy access for services

Disadvantages

- Cannot be site modified

TRUSS MANUFACTURE

- Designed by Structural Engineer
- No Site Modification or repair without engineer supervision
- Trusses manufactured in controlled factory conditions to ensure design is strictly followed
- Nailing Plates
  - Claw Type, only suitable for use with a press
  - Knuckle type, can be nailed with a hammer or pressed
- Member Sizes must be specified by engineer
- Trusses Manufactured in factory in controlled environment
- Members are assembled and cut in jigs and presses

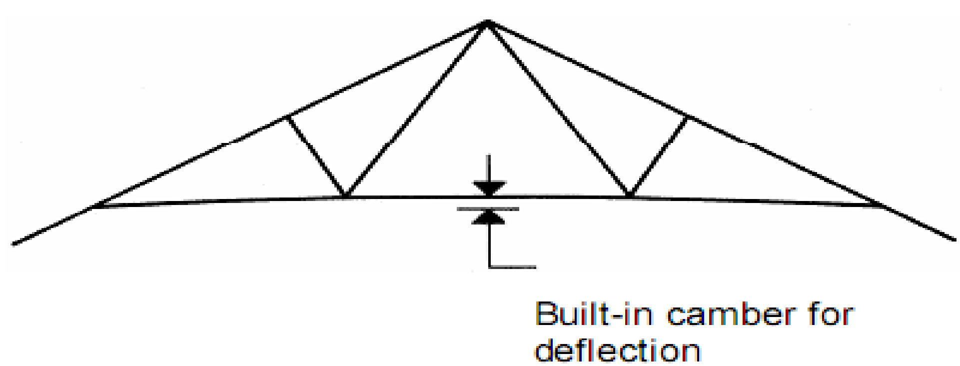
Camber

Trusses are manufactured with camber in the bottom chord

- To allow for calculated deflection while dead loads such as Roof Covering & Ceiling Linings
- Bottom chord should not be supported between supports, unless specifically designed.

Support to Trusses

- Top Plates Based on AS 1684 Span Tables
- As no internal support walls, spans are large
- Loads imposed on top plates are greater than conventional roofs



Top Plates

- Using Nominal Thickness Top Plates (i.e. 90 x 35)
- Place Studs directly under trusses
- If Trusses are not placed directly over studs
- Top Plates may be overloaded and deflect and/or fail

Lintels

- Similarly Lintels should be sized according to AS 1684
- As the spans are larger than a conventional roofs , large members may be required
- An options may be to use C & Z metal lintels

Lifting Roof Trusses

- Never lift by the Apex
- This will damage the roof trusses

Storage of Trusses

- ➢ Trusses should be inspected on delivery
- ➢ No site repairs without design engineers supervision
- ➢ Stored flat on timber dunnage
- ➢ Carrying of Trusses
- ➢ Erection of Trusses

- Note – All Trusses need to Temporarily Braced during Installation

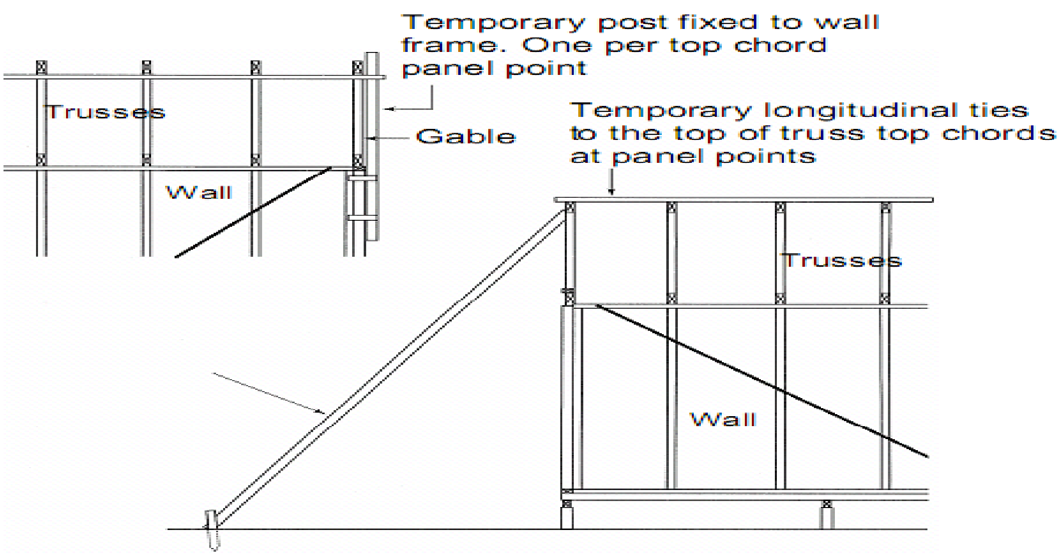


Fig. 52 Methods of temporary bracing first truss

The purpose of temporary bracing is to hold the trusses plumb & true until permanent bracing is installed.

<u>ROOF PANELS :</u>

The fully standardized precast concrete elements are those used for making floor and roof slabs. These may be supported by bearing walls of precast concrete or masonry or by frames of steel, in-situ concrete, or precast concrete. Roof panels of lightweight precast-concrete panels typically span 5 to 10 ft between supports. Panel thicknesses range from 2 to 4 in, and widths are usually 16 to 24 in. Depending on the product, concrete density can vary from 50 to 115 lb per ft3.

Four kinds of precast slab elements are commonly produced for:

- ➢ For short spans, minimum slab depths of solid slabs are appropriate.

- For intermediate spans, hollow-core precast elements suitable, internal longitudinal voids replace much of the non-working concrete.
- For longer spans, deeper elements single Tee must be used, but sometimes site cast counterparts, become inefficient because they contain too much dead weight of nonworking concrete.
- For the longest spans, still deeper elements are required (double tees and single tees).This eliminate still more nonworking concrete.

MANUFACTURE AND ERECTION PROCESS

- Precast floors are composed of units, which are totally cast at the plant.
- After erection, the units are **connected** to the structure & the longitudinal joints are grouted. In some cases a cast in-situ structural **topping** screed is added.
- Partially precast floors are composed of a **precast part** & a **cast in-situ part.** Both parts are **working together** at the final stage to achieve the composite structural capacity.
- A concrete topping is poured over them and finished to a smooth surface.
- The topping, usually 2 inches (50 mm) in thickness, **bonds** during curing to the rough top of the precast elements and becomes a working part of their structural action.
- The topping helps the precast elements **to act together as a composite structural** unit rather than as individual planks in resisting concentrated loads and diaphragm loads.
- **Structural continuity** across a number of spans can be achieved by casting **reinforcing bars** into the topping over the supporting beams or walls. Underfloor electrical conduits may also be embedded in the topping.
- Greater floor strength and stiffness
- Greater fire resistance
- Greater acoustic isolation
- Allow easy integration of electrical services into floor system

ADVANTAGES

- Prefabricated construction, as the slab components are readymade, self supporting, **shuttering and scaffolding** is eliminated with a saving in shuttering cost.

- In traditional construction, the repetitive use of **shuttering is limited,** as it gets damaged due to frequent cutting, nailing etc.
- After laying slab, the **finishes and services** can be done below the slab immediately. While in the conventional in-situ RCC slabs, due to props and shuttering, the work cannot be done, till they are removed. Saving of time means saving of money.

LIMITATIONS OF PREFABRICATED SLABS

- As the precast elements have to behave monolithic on erections, **extra reinforcement** may be necessary in some cases.
- Extra reinforcement is required to take care of **handling and erection stresses**.
- Temporary props may be required in some cases, before the in-situ concrete joints achieve strength.
- The cracks may develop at the joints between the precast and in-situ concrete due to shrinkage and temperature stresses. To overcome them, extra steel is required across the joint.
- As there are chances of **leakage/seepage** through the **joints** between the precast components, extra care is required to make them leak proof.

PREFAB COLUMN

- Columns are *vertical load carrying members* in a framed structure.
- A prefabricated column can be manufactured in various cross sections like *square, rectangular and circular.*
- The *minimum cross section* depends on the type of beam column connection employed, typically it ranges between *250 to 300mm*.
- *Maximum dimension* is limited to *600mm x1200mm*.
- The characteristic *compressive strength* of concrete should be above *50N/mm²* because of the early strength required for lifting the prefabricated column in factory.

DIMENSIONS

- <u>Height</u>
  - Floor to floor clear height shall be,
- Multiples of 1M – For height ≤ 2.8m
- Multiples of 2M – For height > 2.8m
- <u>Lateral Dimension</u>
  - Overall lateral dimension or diameter of column shall be, multiples of M/4

DESIGN

- The structural design of precast columns is similar to that of ordinary reinforced concrete.
- The main difference is that the ultimate *<u>failure load</u>* is a function of *<u>cross section</u>* of the precast component and the *<u>type of connections</u>*, while it depends on cross section alone in case of RC columns.
- A impact allowance of 50% should be provided while designing.

Following are the points to be considered while designing the column section,

- The size of section should be predetermined in accordance to *<u>factory handling and transportation.</u>*
- Design should be carried out such that *<u>safety</u>* is ensured *<u>during frame erection</u>* and its stability,
- Ultimate limit state calculations should be carried out to satisfy the *<u>service requirements</u>* of each project.

MANUFACTURING

- Most of the columns are manufactured horizontally.
- Columns upto 3m length with complex profiles are cast vertically.
- The moulds are made of steel accurately with dimensional tolerances of < ±3mm.
- Main bar diameter – Minimum -12mm Maximum - 40mm
- Links – Diameter not less than ¼ of size of main bars. Spacing not more than 12 times diameter the main bar.

LIFTING AND ERECTION

- Generally columns are manufactured in largest possible length that can be erected in site.
- *Maximum lengths* of *25-30m* are possible.
- The maximum length of the column depends on the lifting capacity of the crane.
- The *maximum length to depth ratio* suitable for lifting purposes is *50:1*. Such slender columns needs to be *prestressed* axially to about $3N/mm^2$ to prevent damage due to flexural cracking.
- The lifting point are positioned at 0.2L from the ends of the column.

CONNECTIONS

- The connection between two precast columns and also between precast column and beam are designed according to manner in which *moments and shear forces* are transferred through them.
- The connections can be achieved by,
- Placing in-situ concrete at junctions with overlapping reinforcing bars
- Providing steel inserts and concreting the joints thus formed.
- Bolted connections can also be used to connect the precast columns and beams together which are covered by in-situ concrete.

CORBELS

- Corbels are *short cantilever brackets* projecting from columns.
- They are generally *provided to support rails*, which transmit heavy loads from moving cranes in heavy duty factory workshops.

DIMENSIONS

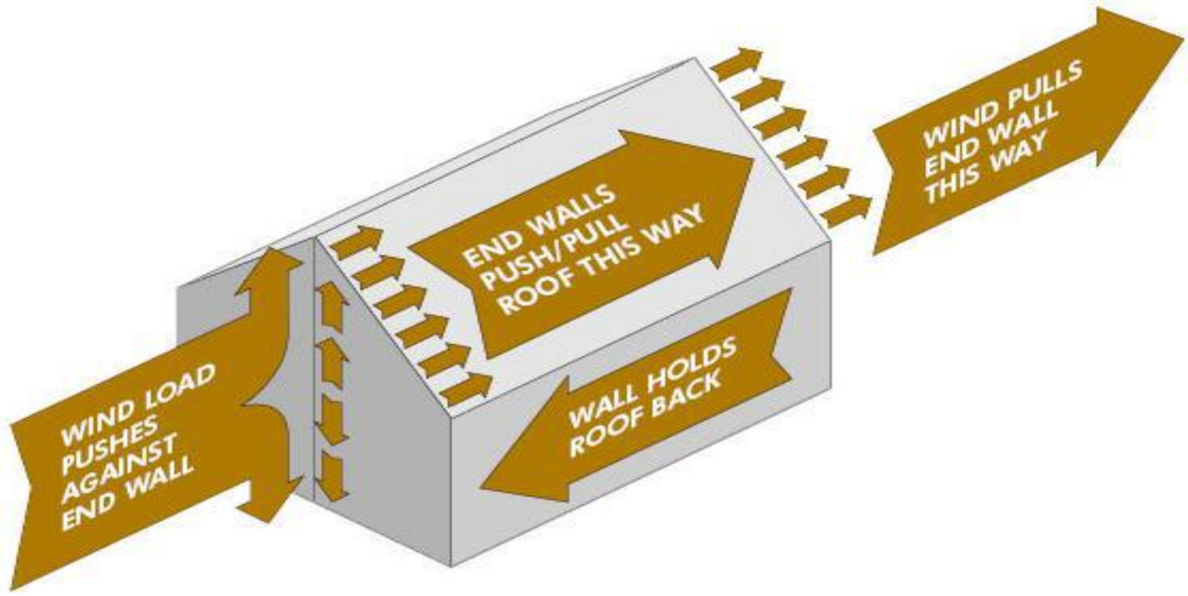
- They can also be used *for fixing false ceiling panels*.
- The dimensions of corbel should be such that,
- span/depth(a_v/d) ratio is less than 1.0
- Depth (D_f) at the end face is not less than one half of the depth D_s at support.

CORBEL

WIND BRACING DESIGN:

All buildings must be designed to resist wind load. Unlike snow load which acts vertically and downward only, wind load acts horizontally and in any direction.
The design wind load on a structure is based on the local wind speed which is 90 mph for Fairfax County. Due to the way wind is measured, this translates to a Category 1 hurricane.

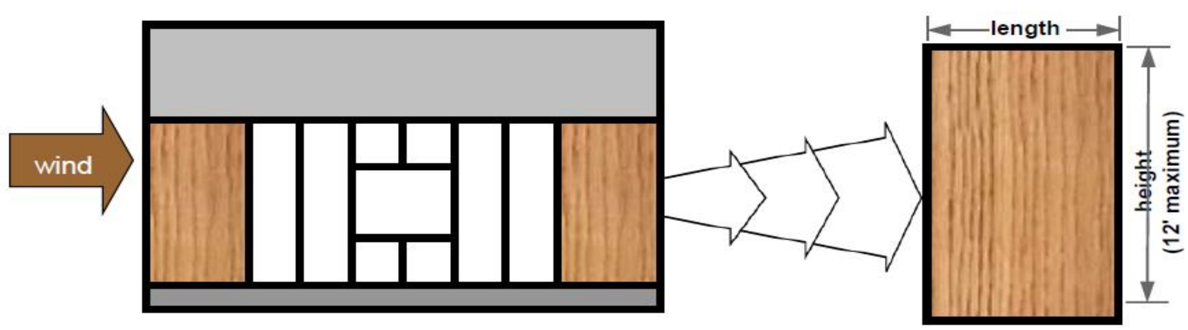
The structural system of a house is designed to transfer wind load from where it is applied all the way to the ground. Wind load is resisted by the walls parallel to the direction of the wind.



WIND LOAD FOR HOUSE

BRACED WALL PANEL:

The code prescribes a ―braced-wall-panel‖ as a sheathed, full-height section of wall that is placed in specified lengths and locations with a maximum height of 12 feet;



BRACED-WALL-LINES, a building code concept, help to ensure proper distribution of bracing on the walls of your house or addition. Braced-wall-lines are ―theoretical‖ straight lines that, as a designer, you draw through the house in the left-right and up-down plan direction. The amount and location of braced-wall-panels are derived from the characteristics of each braced-wall-line.

SPACING

In most cases, braced-wall-lines will be located along all the exterior sides of your house or addition. However, braced-wall-lines may need to run through the interior of your house as the spacing between parallel braced-wall-lines cannot exceed 60 feet.

BRACED-WALL-PANEL OFFSETS

To provide flexibility, the code allows braced-wall-panels up to 4 feet away from and parallel to the braced-wall-line to help it resist wind load. braced-wall lines to maximize the total amount of actual walls on or within 4 feet of it.

In FIGURE notice BWL-A is located so that all wall segments of the house are within 4 feet of the braced-wall-line's location, even though it does not fall on any one actual wall. This minimizes the number of braced-wall-lines and maximizes the number of wall segments which contain bracing that is able to contribute to the strength requirements of BWL-A.

BRACING RULES

Braced-wall-panels are required to be placed along each braced-wall-line such that you meet all four of the following rules.

LOCATION: A braced-wall-panel must be located at each end of a braced-wall-line or begin within 10 feet of the end.

SPACING: In each braced-wall-line, braced-wall-panels can be a maximum of 20 feet apart.

NUMBER: Braced-wall-lines are required to have at least two braced-wall-panels.

EXCEPTION: one panel 48-inch or longer is permitted in braced-wall-lines 16 feet or less in length.

AMOUNT:

The cumulative length of all braced-wall-panels must be greater than or equal to the minimum required length as calculated.

BRACING METHODS

The type, material and configuration of sheathing methods vary. There are two types of bracing: intermittent and continuous-sheathing.

- Intermittent braced-wall-panels are placed at required locations only. The non-sheathed area between them is infilled with other material such as insulating foam.
- In continuous-sheathing the entire face of the wall is sheathed, including areas above and below openings.

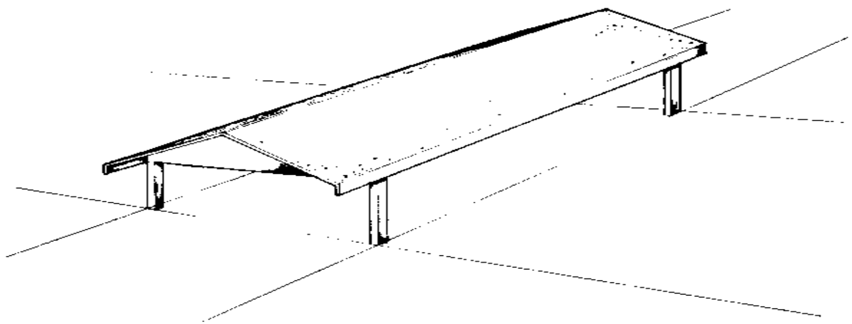
In our region, continuous-sheathing is the predominant sheathing type for the exterior, while intermittent is most common for the interior.

FIGURE 8: INTERMITTENT BRACING

FIGURE 9: CONTINUOUS-SHEATING

FOLDED PLATES:

Folded plates are assemblies of flat plates rigidly connected together along their edges in such a way so as to make the structural system capable of carrying loads without the need for additional supporting beams along mutual edges.



Historical Review :

 The first application of folded plates back to 1924, and attributed to Ehlers in Germany.

 In 1932, Gruber developed a rigorous analytical solution that take into consideration the compatibility of deformations and the relative ridge displacement, but for construction of "*n*" number of plates, Gruber's analysis requires the analysis of *7n-5* simultaneously equations. …. Big Trouble.

 In 1930, Vlasov developed considerably simpler procedure that still take into consideration the compatibility of deformations and the relative ridge displacement, but for "*n*" number of plates, Vlasov's analysis requires the analysis of *2n* simultaneously equations …. Also still hard.

 In 1947, an approximate and extremely simplified method was developed by Winter and Pei, in which the effect of ridge displacement was completely disregarded. but for "*n*" number of plates, analysis requires the analysis of *n-1* simultaneously equations.

 Attempts were then made by a number of investigators to introduce certain corrections to Winter and Pei solution, that take into account the ridge displacements. These attempts can be classified to : Analytical methods. Iterative Techniques.

Assumptions For the analysis of Folded Plates :

1- Material is homogenous, elastic, isotropic, Hook's Law is valid, thickness of plate is small when compared to plate dimensions.

2- Problem will be treated as one-dimension if plate is assumed to behave in beam action, but in two dimensions if based on the theory of elasticity.

3- Joints are assumed to be rigid enough.

Types of folded plates :

1- Prismatic : if they consist of rectangular plates.

2- Pyramidal : when non-rectangular plates are used.

3- Prismoidal, triangular or trapezoidal.

On the other hand, Folded plates can be classified as:

1- single.

2- Multiple.

3- Symmetrical.

4- Unsymmetrical.

5- Simple.

6- Continuous.

7- Folded plates with simple joints.

8- Folded plates with multiple joints.

9- Folded plates with opened cross sectional.

10- Folded plates with closed cross sectional.

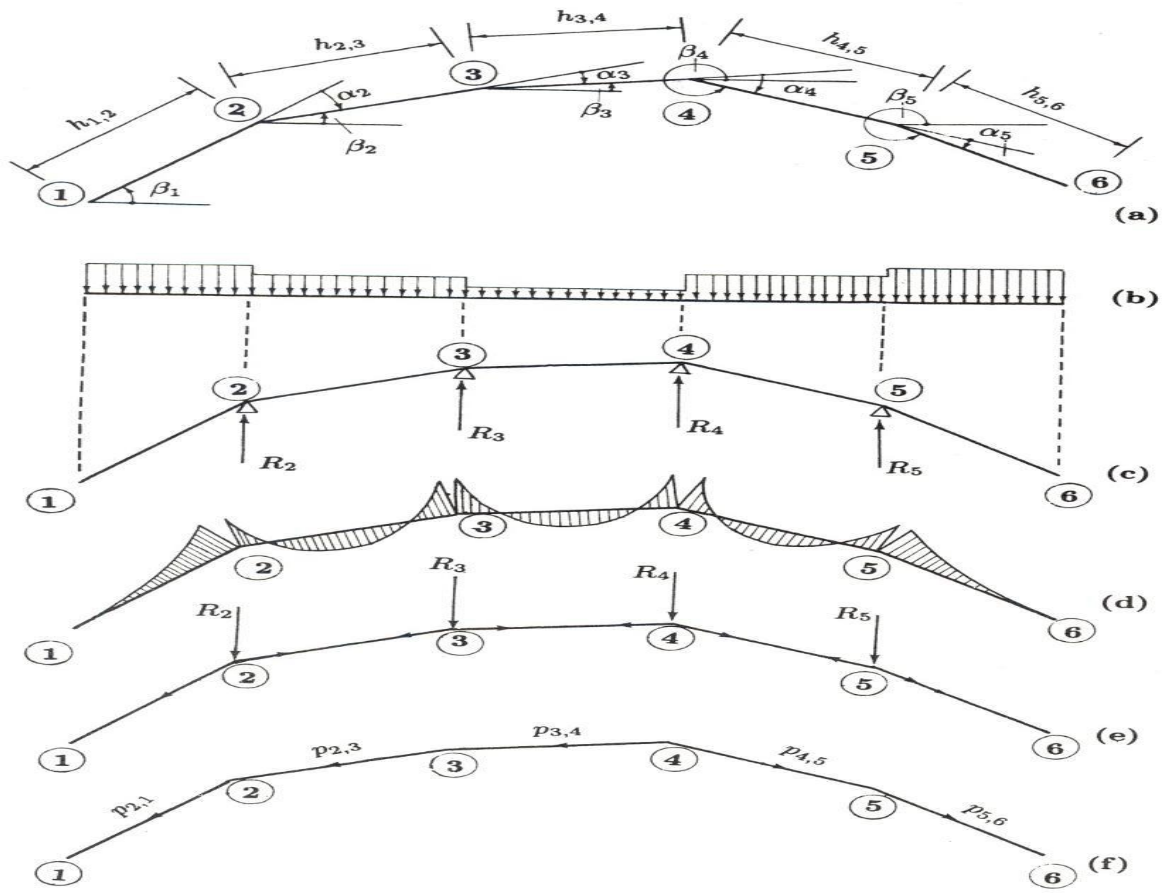
Actions of Folded plate due to loads :

1- Slab action : loads are transmitted to ridges by the bending of plates normal to their planes.

2- Beam action : Loads are transmitted through plates in their planes to diaphragms.

Slab Action:

A strip of unit length of folded plate is taken to act as one-way slab supported at ridges, the outer plates regarded as cantilevers. The ridges are assumed to behave as rigid support, producing the reactions R2, R3, and the moment diagram corresponding to slab action .



Beam action :

Applying the reactions R2, R3, …. And resolving the load at any ridge in the directions of two adjoining plates, one can get the forces p2,1, p2,3, p3,4, …. Acting in middle planes of plates (1,2), (2,3), (3,4), … respectively. These in plane loads transmitted by the plates behaving as beams to the supporting diaphragms.

DESIGN OF FOLDED PLATE

The design of folded plate roof structures follows the design of barrel shells, but is much simpler because the elements are all essentially beams. Support the folded plate at its longitudinal edges by frequent columns.

APPLICATIONS

- Trusses
- Domes
- Canopeis
- Roof
- Walls
- Frames
- Arches

ADVANTAGES

- Materials required – less
- Reduction in cost- compared to shell
- Longer span usage-economical
- Pre stressing can be used
- Aesthetically pleasing structures
- Covering larger areas
- Free of internal column and obstruction

DISADVANTAGES

- Form work & shuttering
- Design and analysis
- Usage of very skilled labours
- Transportation
- Erection
- Handling

SHELLS:

- Thin-shell structures are light weight constructions using shell elements . These elements are typically curved and are assembled to large structures. Typical applications are boat hulls and roof structures in building.
- A thin shell is defined as a shell with a thickness which is relatively small compared to its other dimensions and in which deformations are not large compared to thickness.
- A primary difference between a shell structure and a plate structure is that, in the unstressed state, the shell structure has curvature as opposed to plates structures which are flat.

Thickness of shells

The thickness of the slab elements are normally governed by the number of layers of reinforcing bars. For shells of double curvature, there are usually only two layers.

Preliminary Design for Types of Shells :

1. Barrel Shells
2. Folded Plates
3. Umbrella Shells
4. Four Gabled Hypars
5. Domes of Revolution
6. Translation Shells

1) BARREL SHELLS

A barrel shells acts as a beam in the long direction and as an arch in the curved area. The arch is supported by internal shears.

- The area of reinforcing is , the force divided by the allowable stress.

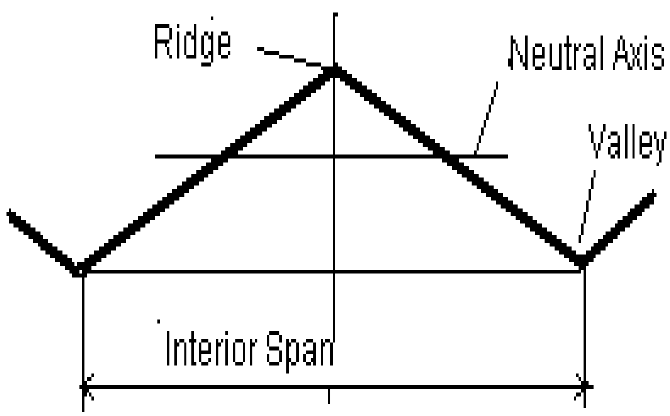
A = Force / Stress

- The force in the reinforcing is equal to the bending moment divided by the effective depth.
- The edge spans of the shell should be supported by intermediate columns.
- The stiffness of a barrel shell at the outside edges is simply not stiff or strong enough to carry the required loads. The shell reinforcing at the edge members acts more like a typical arch and should be reinforced with two layers of bars.

2) FOLDED PLATE

The design of folded plate roof structures follows the design of barrel shells, but is much simpler because the elements are all essentially beams.

Support the folded plate at its longitudinal edges by frequent columns.



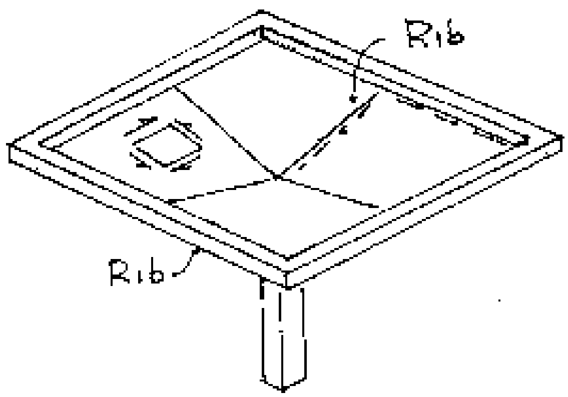
3) UMBERLLA SHELL

The principal elements are:

- The shell element with stresses predicted by the membrane equation.
- The interior rib created by the intersection of the shell elements.
- The exterior rib supporting the shell, particularly in the exterior corners .The central column and the connection to the shell. Loads are transferred directly to the supporting ribs through shear.

The membrane equation for a shell:

Shear = Tension = w X a X b / 2f,
where w = unit load, a and



b = the dimensions of the individual panel,

and f is the vertical height of the panel.

4) FOUR GABLED HYPARS

The shell acts as an arch in one direction and as a centenary in the other. The membrane theory would predict that the stresses would be the same but of different sign. The top ridge member is in compression and may require additional area above that of the shell. The slanting side ribs are also in compression and to some extent in bending, and should be designed for some of the weight of the rib.

5) **DOME OF REVOLUTION**

There will be some bending moment at the junction of the shell and the ring beam, so it is usual to gradually increase the thickness at this point and add moment reinforcing.

6) **TRANSLATION OF SHELLS**

The translation shell is simply a square dome as shown by the sketch. The shape is generated by a curve moving along another curve.

If the curves are circles, then every vertical section is the same. The dome is usually supported by arches. There are three principal design areas:

The central dome area which is designed like a spherical dome. The corners where there is considerable tension from the ring beam affect.

The arches which take their share of the total load. They are loaded in shear including the weight of the arches themselves.

SHORT SHELLS

Barrel vaults:

Length of the barrel is longer in comparison to the width.

Short shells:

A cylindrical shell having a large radius in comparison to the length

BASIC ELEMENTS OF SHORT SHELLS

The principle parts of a short shell structure are:

The abutment.

The arch structure.

The shell spanning between arches.

An edge beam may be provided at the springing level of the shell for additional support. This edge beam can be omitted in small structures if the shell is thickened.

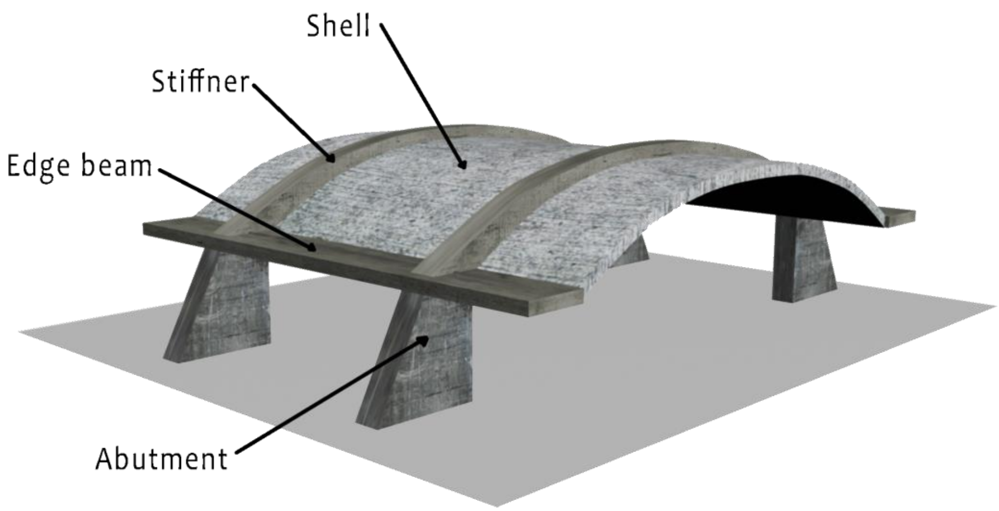
In structures making use of the short shell, the principle structural element is the stiffener, this may be:

A reinforced concrete arch

Steel arche

Truss

The arch is placed on top of the shell so that forms may be moved through the barrel. The curve of the shell is determined by the proper shape of the arch. It may be a circle for small structures or may conform to the thrust line of the arch for long span structures. The minimum shell thickness should be at the top in the center of the span. A thickness as low as 40 MM is used in some designs. At the arch, the shell thickness is increased slightly for local stresses. The thickness increases toward the springing line of the arch and if not supported by an edge



beam, the thickness here should be based on the thickness for a slab spanning the same distance. The edge beams act like the folded plate structures.

The short shell carries loads in two ways:

- As an arch carrying load to the lower elements.
- As as a curved beam to the arches.

The thickness of the shell can be quite thin due to these properties. The short shell serves only a minor role. The emphasis is on the arch shape. Many structures built with short shells, such a large hangars and auditoriums, could have been built with little more dead load by using a ribbed slab or other lightweight concrete framing system rather than the shell.The architecture of short shells, therefor, must be based on the exploitation of the shape of the arch rather than on the shell itself.

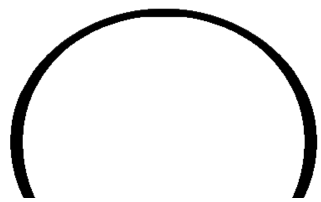
TYPE OF SHORT SHELLS:

1. PURE ARCH AND SHELL
2. CANTILEVER ABUTMENT
3. MASSIVE ABUTMENT
4. RIGID FRAME

1) PURE ARCH AND SHELL

- The classic simplicity of this structure may be used with startling effect. There are only two structural elements and these are clearly expressed so that their function is evident. Obviously, if the shells are obscured by the walls necessary to enclose this space, much of the effect is lost.
- However, window walls would be in keeping with the spirit of the design and can be made to follow the curve of the arch.If this structure is to be used as a canopy, the obvious curve of the arch is a ellipse because the arches can spring almost vertically from the ground and the slanting member will not be as great a hazard to people‘s heads.
- The curve requiring the least material would be the thrust line, or funicular curve, for the loads on the structure. This form would have

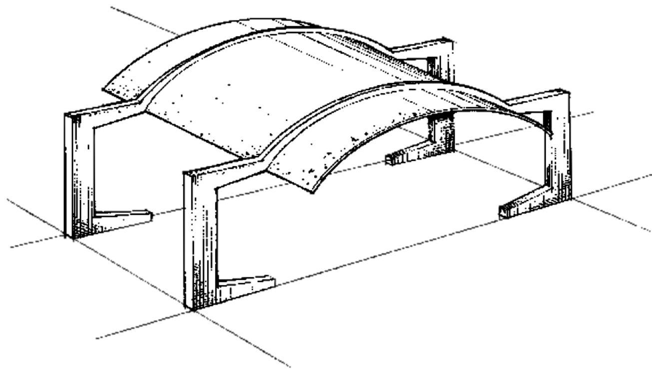
considerable curvature at the top but would be practically straight from the edge of the shell to the ground. The larger the arch span, the greater the saving of concrete and reinforcing by the use of a funicular curve.



funicular curve

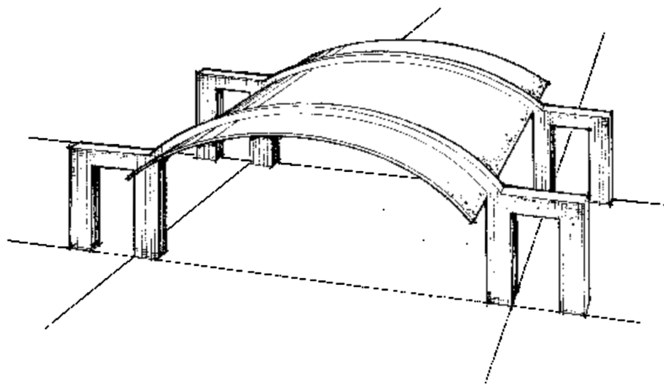
CANTILIVER ABUTMENTS

- The span of the arch may be reduced and the depth and thickness may be made smaller if the support of the arch is placed at the end of a beam cantilever from the wall of the building.
- This design provides space under the cantilevers for seating by using area that would otherwise be required for the arch rib. The design of this structure requires a balance between the height of the arch and the span so the thrust line will be located in the optimum position.
- This structure is most suitable for a large monumental auditorium structure rather than a building where economy is the principle consideration.
- The large volume of concrete and reinforcing steel in the abutment would not be required if the abutment could follow the thrust line.



MASSIVE ABUTMENTS

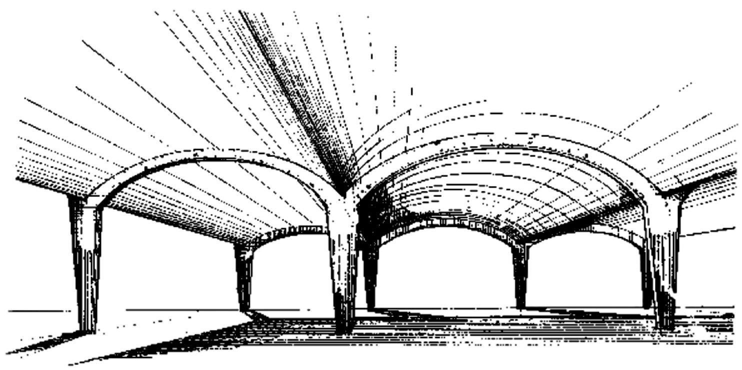
- The abutments to the arch in this structure have been made in the form of an inverted U rigid frame.
- If the abutments are made heavy and rigid, then the arch may be lighter so it may be more economical to use the large mass of concrete at the lower elevation to save concrete in the arches.
- In a monumental structure, such as an auditorium, the side spaces can be used as archways for access to the seating area.
- Instead of the U frame, which is subjected to very heavy bending moments, a triangular frame may be used with the apex at the springing of the arch.
- The structural members of this abutment can be quite thin because they follow the thrust line of the forces better than does the U frame. An architectural problem of the short shell structure is the proper design of the end walls.
- On a long span structure there will be large blank areas that require careful architectural treatment to make the structure pleasing.



RIGID FRAMES

- Short shells may be used with concrete rigid frames as the principle structural element.
- The rigid frame without a horizontal tie at the low point of the shell is suitable only for short spans because of the massive proportions required for the knees. It is not necessary to have the spans of all the rigid frames equal, and the bending moments in the frames may be reduced if shorter side spans are used. The ribs are shown in this sketch and are placed below the shell.
- To save the cost in the forming, it may be better to place the ribs above the shell so they may be moved with very little decentering.
- Skylights may be used in a short shell and they may be continuous transversely if they are placed in every other span so the shell on each side of the skylight cantilevers out from the adjacent span.

- Rigid frames are usually built with tie rods connecting the base of the columns, especially if soil conditions will not permit lateral loads on the soil material.



EXPANSION JOINTS:

An expansion joint is an assembly designed to safely absorb the heat-induced expansion and contraction of various construction materials, 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.

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 completely review the structural system layout, and other items which may affect the performance of the expansion joint. Particular attention shall be given to the following items

The system should be reviewed to determine the location and type of expansion joint which is most suitable for the application. Both the EJMA Standards and most reliable expansion joint manufacturers' catalogs provide numerous examples to assist the user in this effort. The availability of supporting structures for anchoring and guiding of the system, and the direction and magnitude of thermal movements to be absorbed must be considered when selecting the type and location of the expansion joint.

Expansion joints are designed to provide stress relief in piping systems that are loaded by thermal movements and mechanical vibration. To deal with the various forces on the joint they require fibre reinforcement which guarantees both flexibility and strength. Conventional expansion joints are reinforced using prefabricated fibre plies. The use of these fabric plies makes it impossible to control the orientation of the fibres on complex shapes such as the bellow of an expansion joint. In both cases the inability to use the fibres in an optimal way leads to the following disadvantages:

High material cost

- More fibres needed than necessary
- More rubber needed than necessary
- Additional parts such as metal reinforcement rings necessary with multiple bellows

Lower Performance

- High rubber wall thickness and fibre pack make product less flexible
- Undesired radial and axial expansion under pressure