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NEAR EAST UNIVERSITY

REINFORCED CONCRETE SKELETON TYPE BUILDINGS

A MASTER'S THESIS

IN

CONSTRUCTION, ARCHICTURE

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CONTENTS

INTRODUCTION

The subject of the study is Buildings of Reinforced concrete for the Middle East and Near East regions.

Purpose of the study is an examining of the architectural and planning capabilities as well as spatial capabilities of reinforced concrete skeleton structures used for different types of buildings.

The main reasons for choosing this subject matter are:

a) Abundance of raw materials in the countries of the Middle East.

b) Economic potential of the regional countries.

c) Technical and technological capabilities of the regional countries.

It is known that constant urban development requires an increasing number of lands lots for construction.

The urban growth at the expense of agricultural lands sets forward the issue of rational use of the land, which can be implemented by increasing the density of the population inhabiting those land lots. The increase of the population density can be realized only at the expense of "vertical" urban development versus "horizontal" development (meaning the increase of number of floors in buildings).

In other words the construction of multi-storey buildings and high-rise buildings is the only solution to the problem of economical use of land.

Various structural and engineering systems are used in the construction of multi-storey and high-rise buildings. Of those systems, skeleton type buildings are selected for the purposes of this thesis since they have certain advantages for construction in the conditions of the Middle East regions.

The thesis consist of introduction, five chapters, conclusion and bibliography list.

The chapter one includes the characteristics of reinforced concrete frame structures on the basis of structural and engineering systems. The brief historical over view of the development of reinforced concrete construction is provided and a comparison between steel and reinforced concrete frames for multi-storey buildings.

The second chapter includes the requirements and regulations design and construction for reinforced concrete skeleton type buildings, and he considers also the systems which used in high-rise buildings like shear-wall system, rigid-frame system and tubular system.

The chapter three, considers the structural elements of reinforced concrete frame structure, vertical subsystems and horizontal subsystems as foundation, columns, girders and beams, floors and roof, stairs and elevators, and exterior and interior walls.

The chapter four considers the technological types and methods of reinforced concrete, such as cast-in-situ and precast concrete.

The fifth chapter considers the capabilities of the existing column grids and skeleton structural systems from the viewpoint of architectural space creation inside and outside the building, attempts to offer new solutions of designing frames to better shape with architectural space in regard to architectural criteria.

In the conclusion the author summarizes the results of his findings and makes concluding remarks on the subject matter. The Bibliography list follows the conclusion.

CHAPTER 1

Primary Characteristics of Reinforced Concrete Skeleton Type Buildings

1.1 Frame Structural System and Diagrams

It is known that structural system of a building is the total sum of mutually connected structural members, facilitating, strength and stability.

The selection of materials for all structural systems is realized depending on the certain engineering system of a building.

It is also known that total structure of building consist of two main subsystems, vertical and horizontal, they are called as load bearing frame.

There are three main types of structural system as follow:

1. Frame structural system.

2. Wall structural system.

3. Shaft structural system.

The concept of "structural system" is generalized structural and static description of a building. This description doesn't depend on material and method of erection.

The building can be constructed from wood, steel, and reinforced concrete.

For frame structural system, it can be expressed in wood, steel and reinforced concrete constructions. The purpose of building and its number of stories define field and scales of certain structural systems applying in a building. Wall structural system is the basic system of the living houses, campuses, rest houses and so on.

Frame structural system is the basic system for majority of civil, industrial and also residential buildings. In order to get large space inside the building, which is free from walls and use this space for different functions, the frame structural system is used as a rule.

This thesis is concerned only with skeletal frames. These are the most architecturally and structurally demanding frames, because in both disciplines, designers feel that they have a free rein to exploit the structural system by creating large continuous spans while reducing structural depth and the extent of the bracing elements.

The skeleton structure can be used for low-rise, medium-rise and high-rise buildings it is distinguished from other types, because imposed gravity loads are carried to the foundations by beams and columns.

The advantages of frame structural system are as follows:

1. Minimum material consumption in comparison with wall structural system.
2. Light own weight.
3. High strength and supporting ability.
4. Possibility to erect building of any height.
5. Minimum cross-section area of vertical load bearing construction.

The main feature of frame structural system is column, and beam (fig.1). The column and beam all together creates frame.

Depending on position of frames in a building, the frame structural system falls into four general classifications by diagrams as follows:

1. Diagram with longitudinal placement of frames (fig.2a).
2. Diagram with transversal placement of frames (fig.2c).

3. Diagram with longitudinal and transversal frames (fig.2b).

4. Diagram of frame without beams (fig.2d)(Flat Plate System).

Structural members of frame structure may be made of reinforced concrete, metal and wood or glued laminated timber.

According to method of erection frame structural buildings, they may be differed by monolithic reinforced concrete, reinforced concrete composite frame, precast reinforced concrete frame, and lift slab construction.

The main structural members of reinforced concrete frame structural system are columns, beams, floors and roof, foundations and stairs.

By method of collection loads building, frames are differed by:

1. Rigid Joined Frame.

2. Cased Frame.

3. Braced Frame.

In rigid jointed frame, rigidity and stability of a building is provided by connection between floor slabs and beams. Vertical and horizontal loads are carried by skeletal frames of a building. In cased frame the horizontal loads are generally carried by vertical walls of rigidity and partially by frame.

Rigidity and stability of frame building is provided by team-work of frames, horizontal floor slabs and vertical wall rigidity.

In braced frame columns of frame system carry all vertical loads system, and horizontal by walls of rigidity.

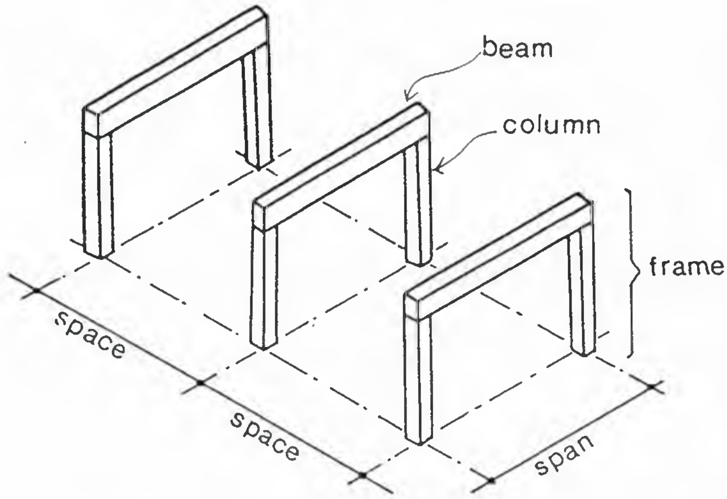


Fig.1 The Main members of frame

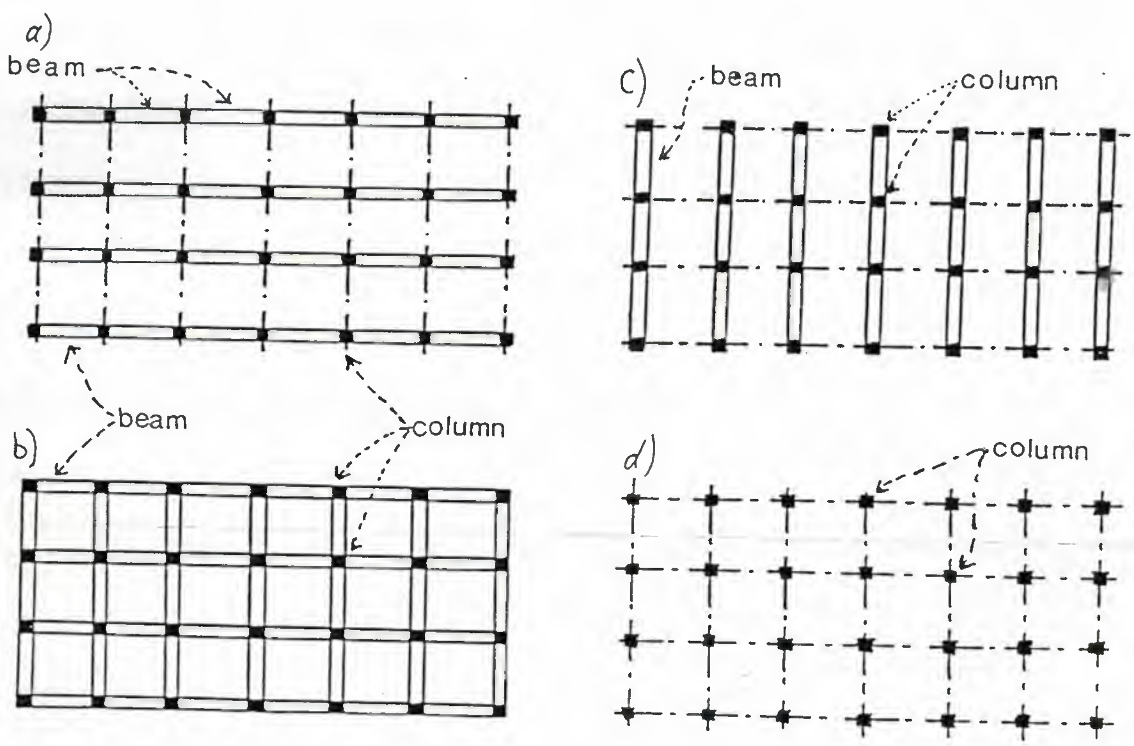


Fig.2 Structural diagrams of frame structural system

According to our studying based on advantages of frame structural system, it will be chosen from the other systems to be the main structural system during our thesis using reinforced concrete.

The main reasons for choosing reinforced concrete skeletal frame structure not explained before, but the advantages and the abilities of reinforced concrete skeleton structure will be explain in the following paragraphs.

1.2 Brief Historical Overview of the Development of Reinforced Concrete Skeleton Structural Buildings (1)

Much has been written about the numerous significant buildings of the Roman Empire constructed using concrete as the primary structural material. Many researchers believe that the first use of a truly cementitous binding agent occurred in southern Italy in about the second century B.C called pozzuolana. Large warehouses constructed in 193 B.C pozzuolana was used to bind stones together to make concrete.

In 1824 Joseph Aspdin, an English mason, patented an improved cement which called Portland cement, which is used until today.

During the nineteenth century concrete was used for many buildings in Europe, often of an industrial nature, as this new material did not have the social acceptability of stone or brick. The first real use of reinforcing in concrete was the construction of several small rowboats by Jean-Louis Lambert in the early 1850 is cited as the first successful example.

In 1854 a plasterer, William B. Wilkinson of Newcastle-upon-Tyne, erected a small Two-storey servant's cottage, reinforcing the concrete floors and roof with iron bars and wire rope. He built several such structures and is properly credited with constructing the first reinforced concrete building.

In 1867 Joseph MONIER, a French gardener took out a patent on some reinforced garden tubs and later patented some reinforced beams and posts used for guardrails for roads and railways.

The first widespread use of Portland cement concrete in buildings occurred under the direction of French builder, Francois Cognet. He built several large houses of concrete in England and France in the period 1850-1880, at first using iron rods in the floors.

The first landmark building in reinforced concrete was built by an American mechanical engineer, William E. Ward, in 1871-1875(fig.3). The house stands today in Port Chester, N.Y.

In 1879, G.A.Wayss, a German builder bought the patent rights of Monier's system and pioneered reinforced concrete construction in Germany and Austria, promoting the Wayss-Monier system.

At the late nineteenth century saw the parallel development of reinforced concrete frame construction by G.A.Wayss in Germany and Austria, by Ernest L. Ransom in the United States, and by Francois Hennebique in France.

The Ingalls building is a landmark structure in Cincinnati, was built in 1904 using a variation of the Ransom system, Designed by the firm of Elzner and Henderson, it was the first concrete sky scraper, reaching 16 stories (fig.4).

In 1870, Francois Hennebique started to build reinforced concrete houses, he was the responsible for the acceptability of reinforced concrete. Then it was August Perret who made it as acceptable as an architectural material, the work of Perret includes not only factor and apartment buildings, but also museums, churches and theaters.

His better known works or in or around Paris, such as the delicately facade apartment building (fig.5) completed in 1903.

In 1919, Mies Van Der Rohe had proposed the idea of a structural core for a high-rise building with cantilevered floor slabs, but it was not completed until 1947, that Wright brought the idea to fruition with his design for the John-Son Wax Tower.

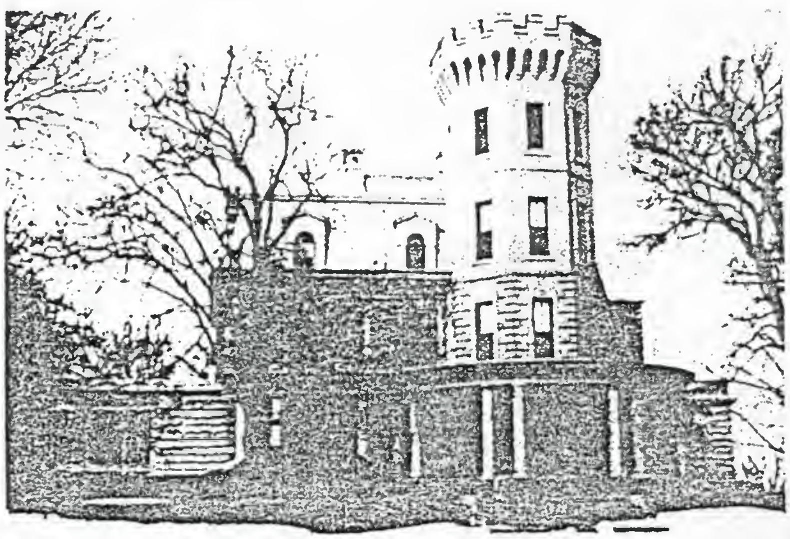


Fig.3.The William F. Word house (1)

High-rise construction in concrete progressed slowly forward from the Ingalls buildings in1904. During the period since World War II, buildings with reinforced concrete frame structure steadily increased in height, the tallest building in United States in 1962 were the Twin Towers of Marina City apartment buildings in Chicago, 60 storey high-rise (fig.6). The Chicago area with its plentiful supply of high quality fly flash has the greatest contraction of tall reinforced concrete skeleton structural buildings. In 1968, the 70 storey Lake Point Towers used 7500 psi concrete to reach around 200 meters. In 1990 two more towers in Chicago exceeded 250 meters.

Fig.4 The Ingells Building(2)
(Elzner and Henderson)

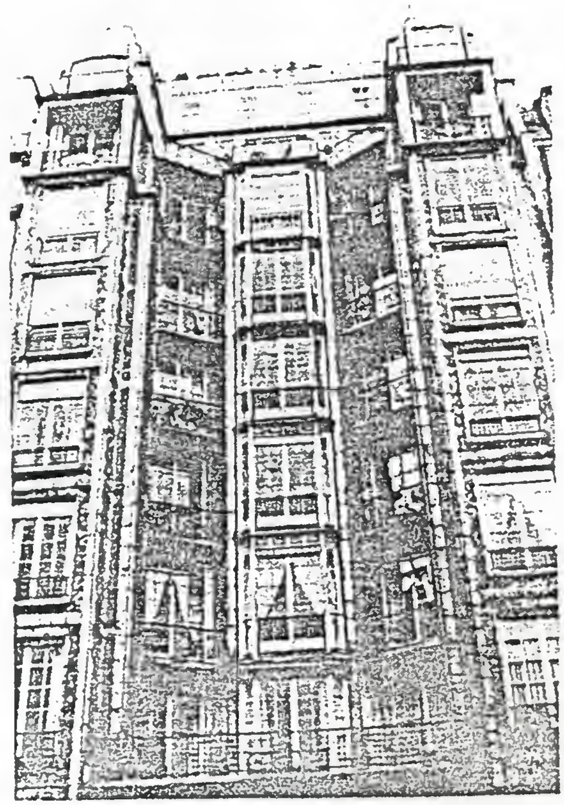


Fig.5 Apartment building (Perret)(3).

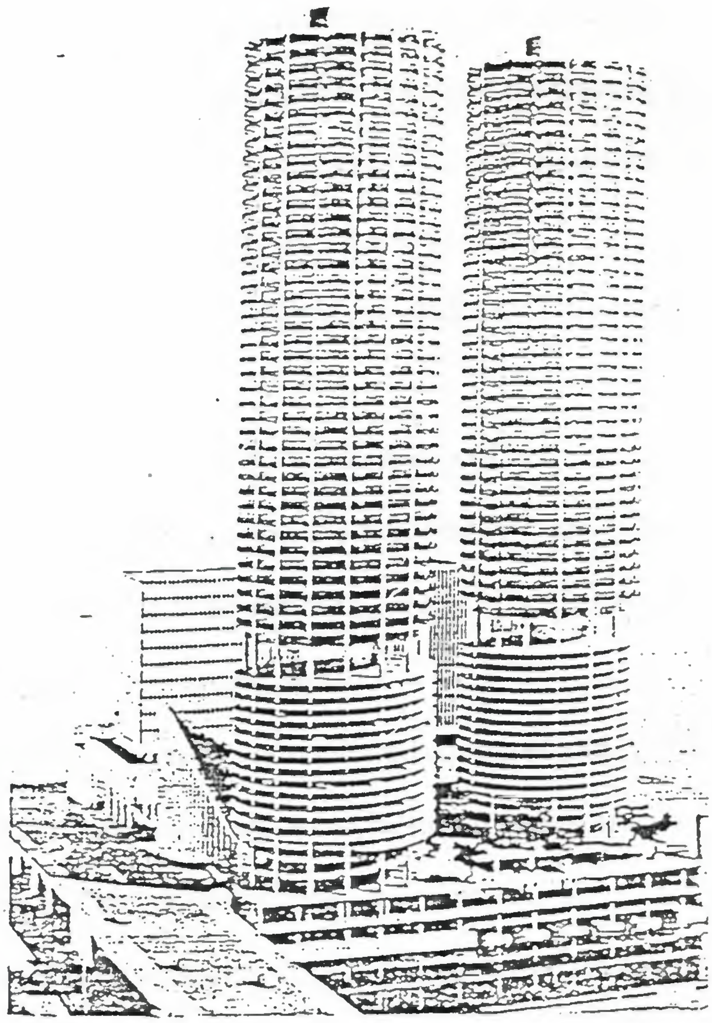


Fig.6 Model of Marina Towers in Chicago (4).

1.3 Advantages and Disadvantages of Reinforced Concrete

Advantages of reinforced concrete are as follow:

1. Reinforced concrete combines the advantages of steel and concrete, it is a happy marriage of these two materials. Steel can't prevent the cracking of concrete which is stressed in tension, however it prevents the widing of the cracks.
2. Reinforced concrete cheaper than the other materials.
3. Reinforced concrete structure has good fire resistance, high compressive strength and excellent for formability.
4. Reinforced concrete is a plastic material capable of being cast in any shape, in large area with slabs, and beams, continuous over relativity larger distance.
5. For the greatest economy to be achieved, the aim of reinforced concrete designer is to provide just enough concrete and steel.
6. The main purpose in the design of reinforced concrete building is to produce a structure which will remain serviceable for its full design life.

Disadvantages of Reinforced Concrete are as Follow:

1. The reinforced concrete is not so definite and regular that designer would not have any freedom for his won ideas and modification.
2. The freedom of dimensioning makes the design of reinforced concrete structure very difficult, because there are so many details have to be considered and correctly evaluated.

1.4. Comparison between Steel and Reinforced Concrete Frame Structure for Multi-Storey Buildings

The difference in cost, performance and maintenance between steel and reinforced concrete frame structure are small and neither has any marked advantage over the other. Each building needs separated consideration, individual analysis will determine the ultimate decision, guidance on the choice of frame structure can only be of a general character as follows(2):

1. Concrete is cheaper than steel and it is possible for a concrete frame to be up to 20 per cent cheaper than steel one. This is the main reason why reinforced concrete is the most popular framing material. Where wide spacing of stanchions is required these and the beams will be smaller if of reinforced concrete, where steel work has an in-situ concrete casing, the form work to the floor can be slung and props eliminated.

2. A building, which made with steel frame structure is more readily adaptable than one with a reinforced concrete frame structure. Certain premises like research in situates, sometime require structural alterations to be made, these are much more difficult in the case of reinforced concrete skeleton structure .

3. A steel frame structure is more quickly erected than cast in-place reinforced concrete, time being absorbed for the latter in placing the forms and waiting for the concrete to harden. Hence, the side cladding and roofing of the steel job can be finished sooner, which enables the internal work to be started and finished more quickly.

4. The reinforced concrete skeleton structure has inherent fire protection, for example, a 50 mm concrete cover to beam reinforcement gives a two hours rating. On the other

hand steel frame structure have to be protected and a steel beam can have a two hours resistance when covered which a 38 mm thick casing of mould asbestos.

The same resistance to fire is offered by encasing a steel beam with in-situ concrete, and although such concrete need not to be of the same high quality demanded for reinforced concrete work the casing enables higher stresses to be used in the design of the steel frame structure. The result is smaller steel sections being used, but it greatly increases the erection time and form work is needed.

5. The uses of concrete casings to permit greater stresses is probably only worth, while in the taller building. Alternative lighter casing ought to be used with greater frequency where analysis show that the adoption of concrete casting wouldn't permit a reasonable saving to be made in the size of sections.

Chapter 2

Requirements and Regulations for Design and Construction Of Reinforced Concrete Frame Structure

2.1. Requirements for Designing

The basic principles of designing vertical and horizontal subsystems are the same for low, medium and high-rise buildings. However, for high-rise building, vertical subsystem becomes a controlling problem for two main reasons:

1. Higher vertical loads will require increase of sections of columns, walls and shafts in order to resist them.
2. The overturning moment and the shear deflections produced by lateral forces significantly more than in low and medium rise buildings.

The vertical subsystems transmit lateral loads such as wind or seismic loads from storey to the foundation and these lateral loads increase rapidly with the increase of height of the building.

The vertical components carrying the gravity load, such as walls, columns and shafts, will need to be strengthen over the full height of the building, but the quantity of materials required for resisting lateral forces is even more significant. With reinforced concrete the quantity of materials increases as the increases of number of stories, but we have to note that the increase of the weight of materials added for gravity loads is much more sizable than steel structure material.

For reinforced concrete frame structure design there are basic principles for providing additional resistance to lateral forces and deflections in high-rise buildings as follows:

1. Increase the effective with of the moment resisting subsystems. It is very useful because the increasing of the width will cut down the over-turn force directly and it will reduce the power of the with increases (fig.7).

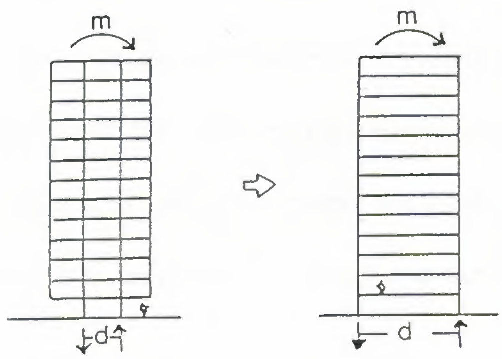


Fig.7 The effective width of the moment –resisting subsystem

2. Increase the material in the most effective resisting components, because the increase of these materials to the lower floors to the flanges of columns and girders will directly decrease the overall deflections and increase the moment resistance without contributing mass in the upper floors where the earthquake problem is aggravated.

3. Arrange to have the greater part of vertical loads by carried directly on the primary moment-resisting component, because this will help stabilize the building against tensile overturning forces.

4. Sufficient horizontal diagram action should be provide at each floor, this will help to bring the various resisting work together instead elements to of separately.

5. Great mega-frames by joining large vertical and horizontal components such as two

or more elevator shafts at multi-storey intervals with a heavy floor subsystems.

Fig.8 shows the design of a 65-storey building, using eight massive columns and three horizontal transfer floors to form against earthquake resistant cage, which is further stiffened by individual post-tensioned concrete waffle floors.

It is known that all high-rise buildings are essentially vertical cantilevers, which are supported at the ground. When the above principles are judiciously applied, structurally Shear walls, cores can obtain desirable schemes, rigid frame, tubular construction, and other vertical subsystems to achieve horizontal strength and rigidity. Some of these applications will be described in subsequent section of this chapter.

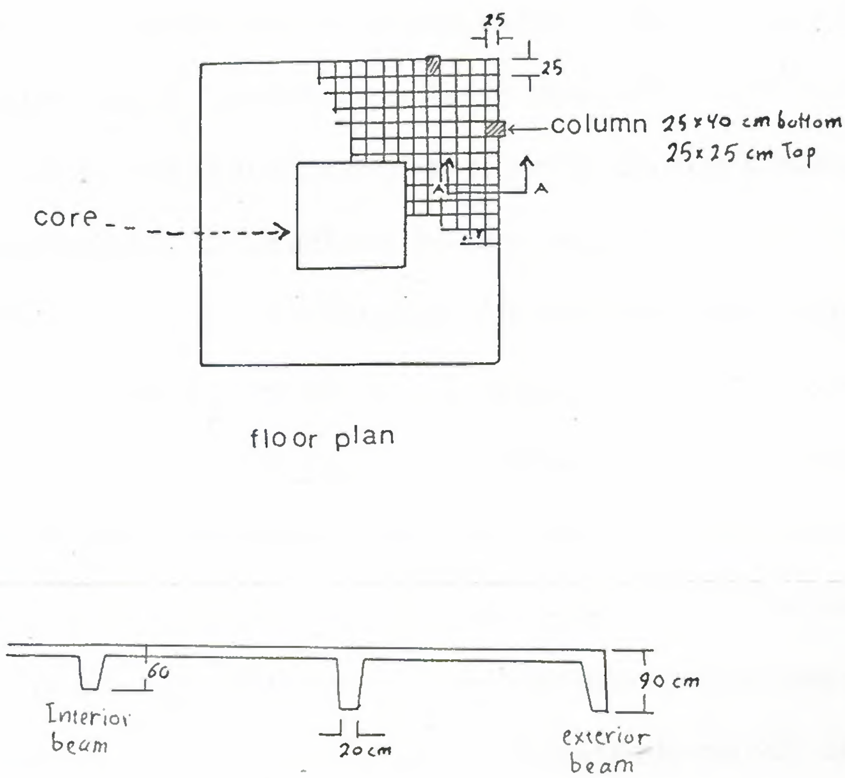


Fig.8 Plan and floor section
for 65-storey P.C office building

2.2. Shear-Wall Systems

In high-rise buildings, shear walls offer excellent resistance to lateral forces, when they are suitably located and connected to one another. High-rise buildings with long narrow horizontal sections or plans require special provisions to resist wind loads. For this reinforced concrete shear walls used, these walls are made integral with the structural members by tying them together with reinforcing bars. In fig.9 there are some forms of shear walls, these shear walls are not consider to carry any part of dead and live loads. The simplest patterns of shear walls are illustrated in fig.10, they may be possible in some buildings but not in the others. When it is not possible, shear walls may be located in walls enclosing cores, which include elevator shafts and stairwells, and in an other positions. The thickness of shear of shear walls is different from one to the other, it can be from 15 to30 cm, depending upon the prevailing conditions.

The shape of shear walls can be different, two or more shear walls can be connected to connected to form a rectangular shaft that will then resist lateral forces very efficiently. The walls of elevators, staircase, and shafts, are employed to resist both vertical and lateral forces. Since these shafts are normally rectangular or circular in cross section offer an efficient means for resisting moments and shear in all direction, but the problem in design to provide sufficient strength around openings. For reinforced concrete construction, special steel reinforcements are placed around openings.

In many highs rise buildings, a combination of walls and shafts can offer an excellent resistance to lateral forces, when they are suitably located and connected (3).

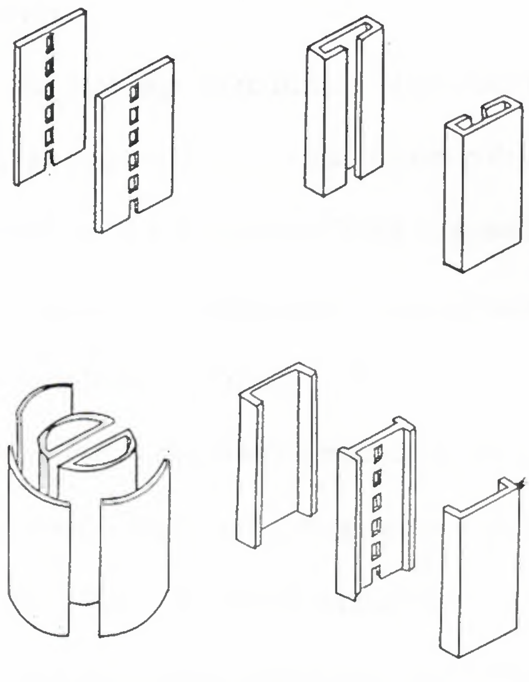
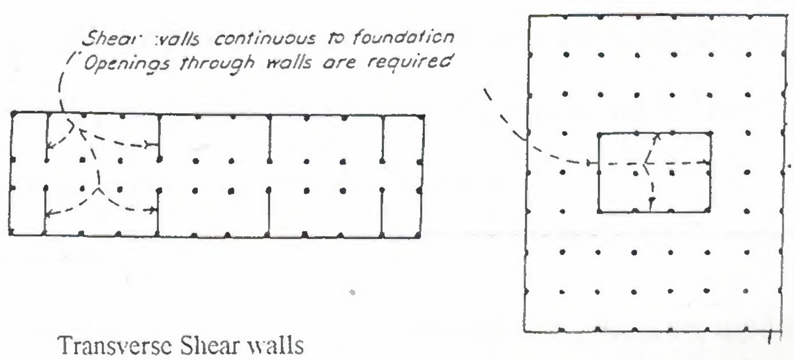


Fig.9 Forms of shear walls



Transverse Shear walls

Shear walls around
Central core

Fig.10 Shear walls

2.3. Rigid-Frame Systems

For designing high-rise buildings, to resist vertical and lateral loads, rigid frame system has been used as an important and standard means in designing. It is employed in high-rise buildings between 70 to100 stories. When compared with shear wall system, rigid frames have provide excellent opportunity for rectangular penetration of wall surface inside and outside the building(4).

Rigid frames will not have stiff as shear-wall construction, but it may produce excessive deflections for the more slender high-rise building design. But because of this flexibility they are considered as more ductile and less susceptible to a catastrophic earthquake failure when compared with shear-wall designs. But the problem of concrete rigid frames that it can not be able to withstand a catastrophic earthquake. But modern research and experience has indicated that concrete frame can be designed to be ductile, when sufficient straps and joinery reinforcement are designed in to the frame, and it called ductile concrete frames.

In high-rise building it is possible to combine rigid-frame construction with shear-wall systems, the building geometry may be such that rigid frames can be used in one direction while shear walls used in the other direction.

2.4. Tubular Systems

In high-rise buildings between 30 to 40 stories tubular system are used to resist lateral forces, it will give the building greater strength and rigidity compared with shear-wall or rigid-frame system(5).

The tube can be rectangular, circular, or some other fairly regular shape. The exterior walls may be penetrated with holes, which form round or rectangular windows (fig.11). when the girders are so deep and the columns so wide, the opening window will be small, so the frame tube will degenerate into a perforated wall tube.

The wall tubes with small windows are generally of concrete construction, the frame tube can be either of concrete or steel. For steel, the truss tube is used. The tube-in-tube concept offers an excellent approach (fig.12), the exterior tube with its larger width can resist overturn forces very efficiently, but the opening required may be reduce its capacity to resist shear, particularly in lower floors. On the other hand, the inner tube can better resist the storey shear, being more solid than the exterior tube, but it will not be as effective in resisting the over turning moment comparison with the outer tube.

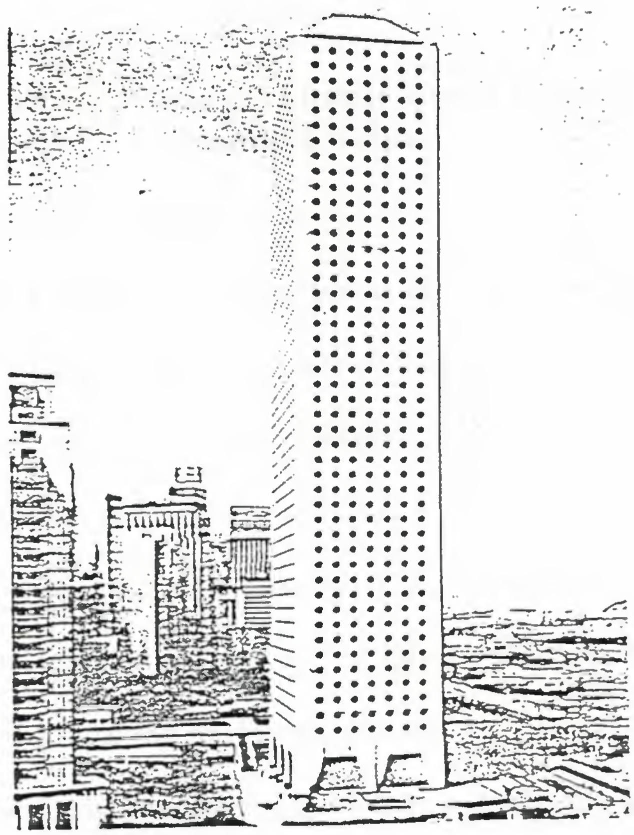


Fig. 11Tubular system, Connauht Building, Hong Kong (5).

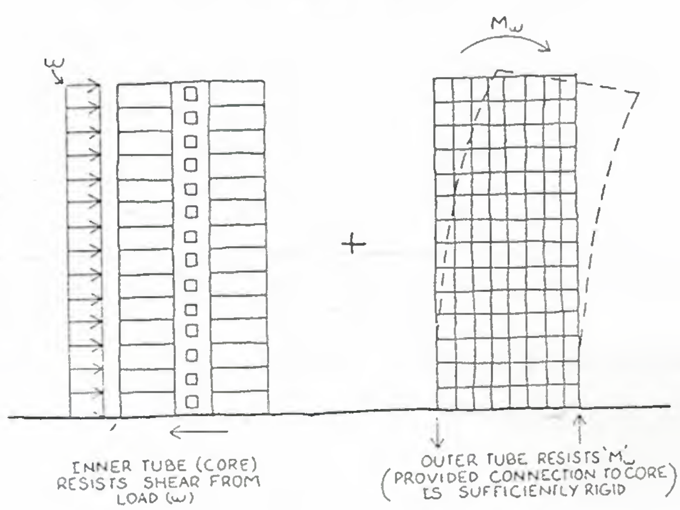


Fig. 12 The tube in tube

Chapter 3

Structural Elements of Reinforced Concrete Frame Structure

3.1. Reinforced Concrete Frame Structure

Frame structure is a frame work which supports all the loads and resists all the forces acting on the building and through which all loads are transferred to the soil on which the building rests (fig.13). Skeleton structure is suitable for low-rise and high-rise buildings, and for short and long span buildings.

Frame structure can be designed and constructed of wood, metal, reinforced concrete, and combination of these materials. From all mentioned types of skeleton structure, has chosen skeleton frame structure of reinforced concrete.

Frame structure is divided into two parts, substructure and superstructure. Substructure is an under part of structure, which includes foundation and or basement.

Superstructure is a part of structure, which is above the ground.

From static point of view, frame structure is divided into two subsystems, vertical and horizontal.

3.2. Foundations

Foundations are the underground part of a building, the function of any foundation is to safely sustain and transmit to the ground which it rests the combined dead, imposed and wind loads (6).

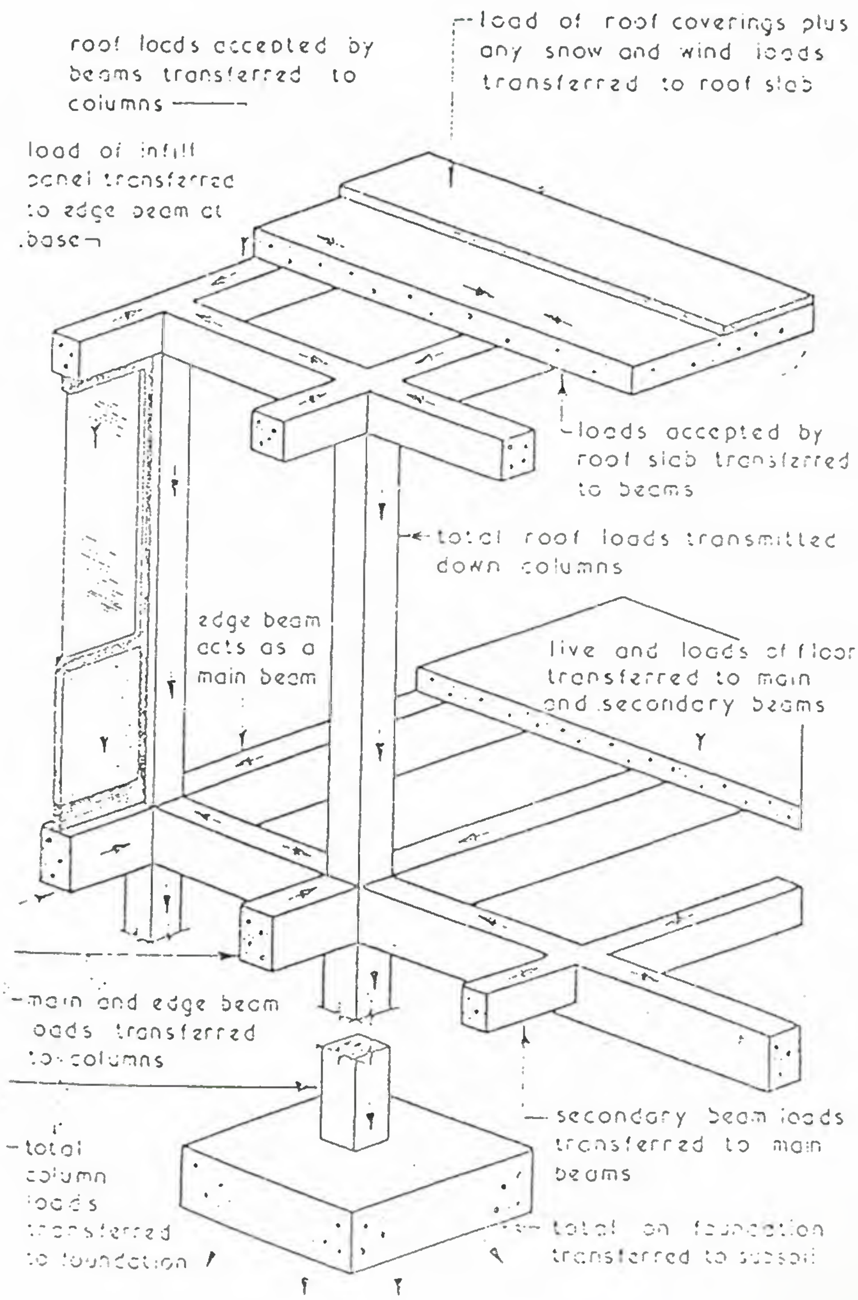


Fig.13 Members of frame structure (6)

Foundations are usually classified by their type such as:

1. Strip Foundations.

2. Pad Foundations.

3. Raft Foundations.

4. Pile Foundation.

The Choice of foundation type (fig.14) provided in according to:

1 Soil condition.

2. Type of structure.

3. Structural loading.

4. Height of the building.

5. Economic factors.

6. Seismic conditions.

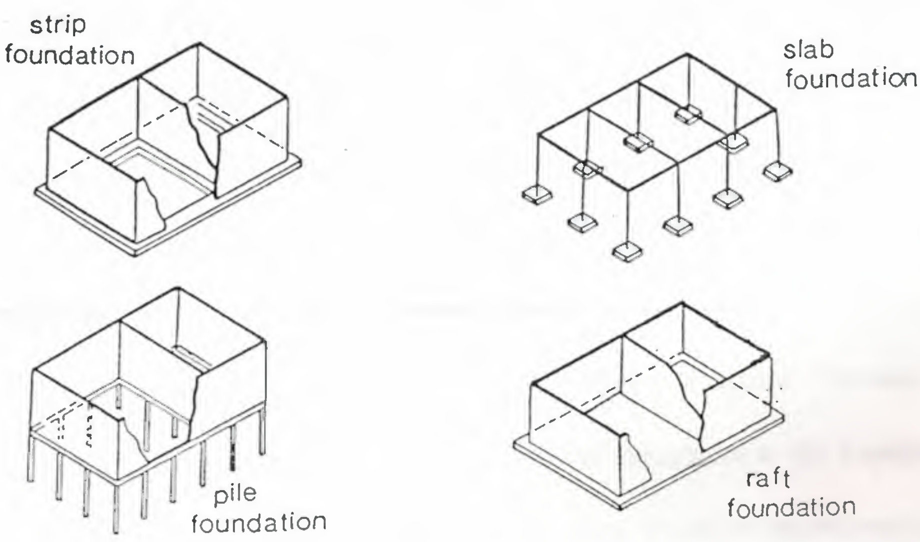


Fig.14 Foundation types

Strip Foundations: Strip foundations are suitable for most subsoil and light structural loading such as those encountered low and medium rise domestic dwellings, and are used for wall structural system. In this case the form of plan of foundations repeats the form of plan of main building walls.

Slab Foundations: Slab foundations are suitable for most subsoil except loose sands, loose gravels and filled areas. Slab foundations are commonly used for reinforced concrete skeleton structure for high rise buildings, the mats of slab foundations can distribute the loads to large areas.

Raft Foundations: In raft foundations whole the building area is covered, they are used where no firm bearing strata of soil exists.

It is used to spread the load of the superstructure over a large base to reduce the load per unit area being imposed on the ground.

Pile Foundations: Pile foundations can be defined as a series of columns constructed or inserted into the ground to transmit the load structure to the lower level of subsoil. They are used where unfavorable soil conditions on the site, they can transmit the loads to the lower strata where the pressure can be safely resisted, and they may be used to transfer loads to the soil below the level likely to be affected by moisture movement.

3.3. Columns

Columns are the vertical load bearing members of frame structure. The main function of columns are to transmit all loads from horizontal subsystem to the foundations (7). Cross section of column can be any reasonable shape, it can be square, rectangular, circular or octagonal and so on (fig.15).

Conditions may make it desirable to use column with other cross-section such as the section in fig.15h with inter locking spirals, and the section in g , j and k with ties arranged to support the longitudinal roads.

Principle columns must have a diameter at least 36cm. For circular columns, the thickness at least 24cm for rectangular columns. Auxiliary supports that are not continuous from story to story must have a diameter of thickness at least 18 cm.

Types Column: Columns constructed of concrete without reinforcing would be unreliable and would be cracked easily by bending stresses caused by differential statement, temperature, and unbalance loads on the surrounding floors.

Longitudinal bars are placed near to the outside surface of concrete columns to provide resistance to bending and using also ties spaced between 24 to36cm to prevent the buckle and spell of the surrounding concrete. The loads on columns are considered to be distributed between the concrete and vertical reinforcement.

Spirally Reinforced Columns: This type of columns is shown in fig.15 b, d, e, and f.

The cross-sectional area of the vertical reinforcement must not be less than 1 percent more than 8 percent of the overall cross-sectional area of the column.

The clear spacing between bars must be not less than 5 cm, the maximum clear spacing between spirals is 9 cm. The spiral reinforcement must be protected every where by covering the concrete which the thickness will not be less than 4cm.

Tied Columns: This type of columns is illustrated in fig.15a, c, d, e, f, and i.

The maximum allowable axial load on columns reinforced with longitudinal bars and separate lateral ties is 80 percent of such a load on a separate reinforced.

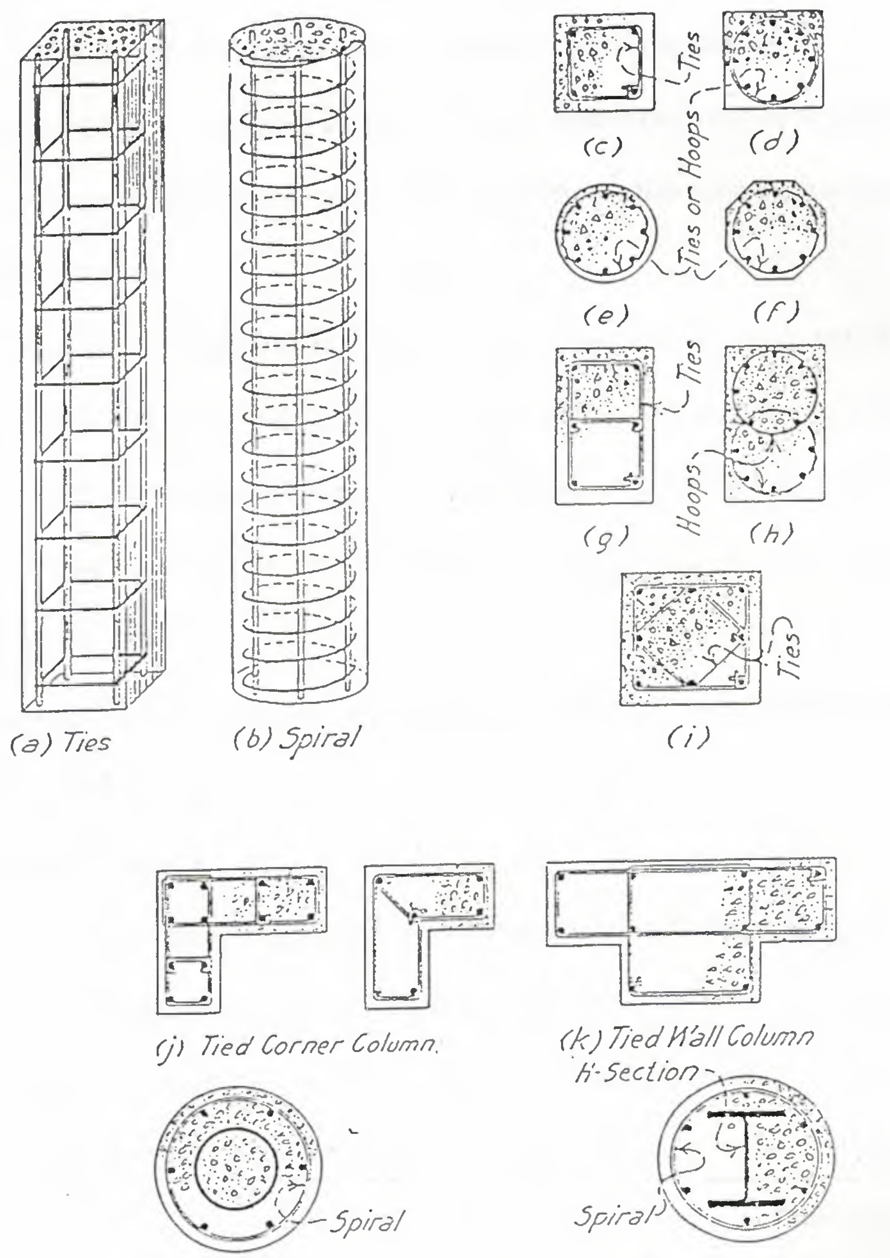


Fig.15 Types of columns (7)

The cross-section area of the vertical reinforcement must not be less than 1 percent nor more than 4 percent of the overall or cross-sectional are of the column.

The reinforcement must consist of at least four bars, lateral ties must be at least 9 mm in diameters, because more than four vertical bars, additional ties must be provided.

Composite Columns:

This type of column is illustrated in fig.15 L and m. The cross sectional area of metal of a composite column must not exceed 20 percent of the cross section area of the column. If a hollow core is used, it should be filled with concrete at least 9 cm, it must be maintained between the spiral and the metal core. But the clearance of H column may be reduce to 6cm.

Use dry technical language. It means, that the principle ideas of your sentences should be understandable at once

3.4. Beams and Girders

Beams are horizontal load-bearing members of horizontal subsystem. They are classified as main and secondary beams (8). Main beams transfer floor and secondary beam loads to the columns and secondary beams transmit floor loads to the main beams. Concrete being a material which has little tensile strength needs to be reinforced to resist the induced tensile stresses which can be in the form of ordinary tension or diagonal tension (shear).

The calculation of the area, diameter, type, position and number of bars required, is one of the functions of a structural engineer.

The simplest form of beam is rectangular in section (fig.16 a, b, c and d, another forms of beams are in use like T beam or L beam (fig.16 f, h).

Sometimes the size of a beam is limited, and it is necessary to design a beam of given strength to fit space which is smaller than would be required for an ordering rectangular or T beam. The tensile of strength may be secured by providing the require amount of tensile reinforcement and the compressive strength is secured by placing steel bars on the compression side of the beam, it is necessary to provide for shearing stresses also, which cause diagonal cracks. So for this reinforcement provided by tending a part of a tensile reinforcement or by providing vertical U-shaped members passing around the tensile steel (fig.16 e).

Girders: Girders are used when spans are greater than the economic limits. In the past, when the loads were heavy, it was the practice to increase the flange area by the addition of plates to the top and bottom flanges of a standard beam section forming a compound girder. It is used for heavier loads and for long spans Vierendeel girder can be used as an alternative to a floor height trussed girders, it has no diagonal members, the shear normally carried by these members being transferred to the bearing by the stiffness of the chords and vertical members.

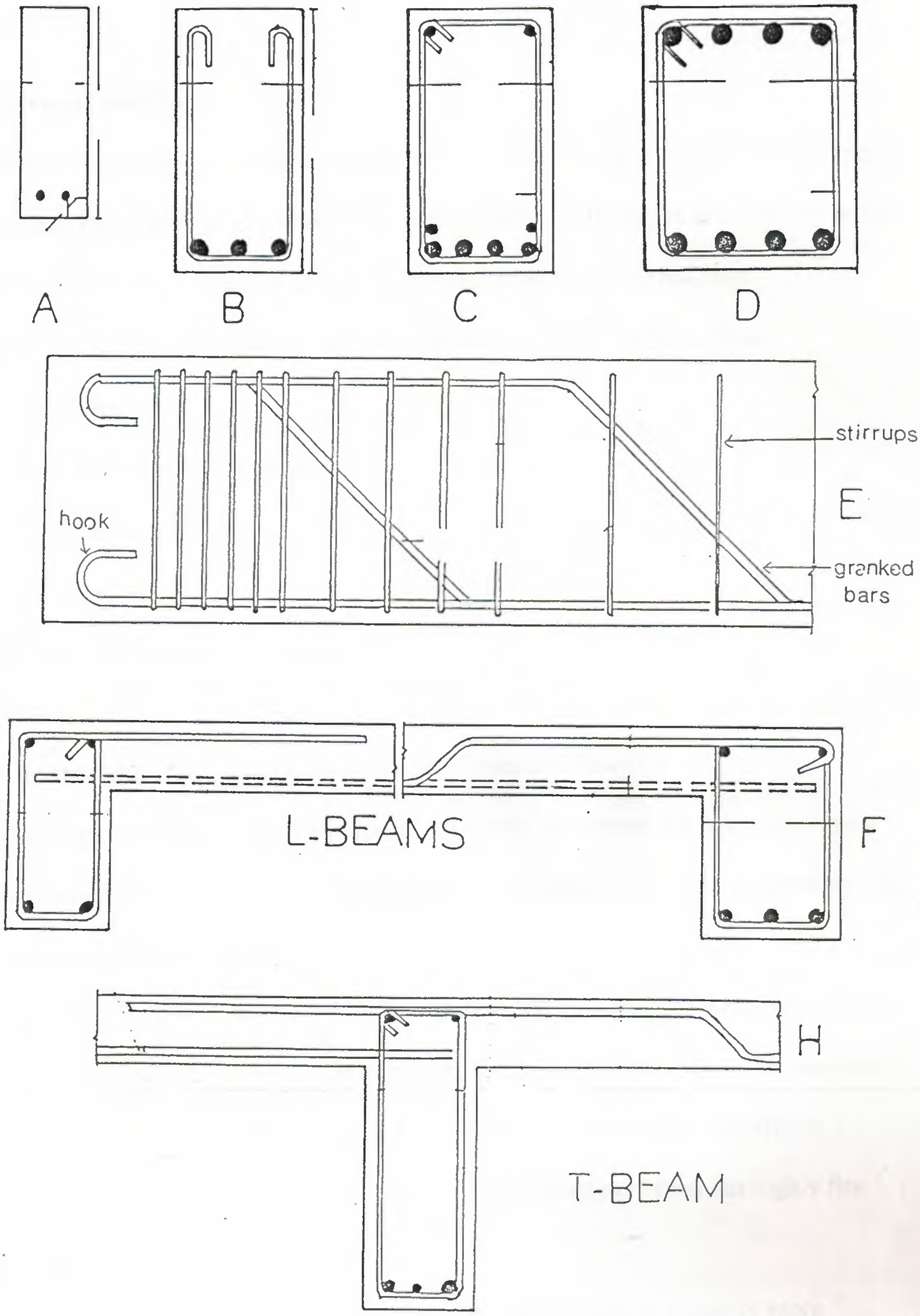


Fig.16 Types of beam

3.5. Floors and Roof

Floors are horizontal loads bearing members, which designed to carry the superimposed and dead loads. In large scale and multi-storey buildings, the floors are normally main structural elements closely related to the general structure of the building.

There are many types of floors, and the main factors influencing the choice floor type are:

- Nature of the building structure.
- Height of the building.
- Loading.
- Provision of service.
- Cost

There are many types of reinforced concrete floors as follow (9):

Solid Concrete Floor Slab: This type is commonly used when the slab is to act as a membrane supported on columns without beams or where high degree of lateral rigidity is required to be provided by the floor.

In buildings up to four stories in height in its simplest form it is more economic than hollow block construction. It gives maximum freedom in design on plan and section, it can be easily be made to cover irregular plan shapes and can easily be varied in thickness according to variations in loads or span. It is a heavy floor but highly fire resistance.

Flat Slab Floor: Slabs are defined as a concrete slab reinforces in two or more directions, generally without beams and girders to transfer the loads to the supporting members. To assist the transfer of the loads to the supporting columns, the upper portion of each column may be enlarged to form a column capital (fig.17a).

For maximum efficiency the column grid should be regular and have about 6 to 7.5m in approximately square bay, in order to provide adequate resistance to the compression stresses in the bottom of the slab over the point of supports.

The head of column can be square or circular depending up on the shape of column, in some circumstances it is necessary to thick the slab over this cap. The reinforcement is usually arranged in two directions parallel to side of panel, slabs reinforced in this manner are called two way flat slabs.

Flat slab construction is used for warehouses, and industrial buildings with heavy floor loads. It is not desirable for building whose floor area is to be subdivided by partition because of the interference of column capitals and drop panels.

Flat Plate Floors: For lighter floors such as those in office building, apartment houses, hotels, and dormitories, flat slabs designed without column capital or drop panels (fig.17b). This is called flat-plate construction and it is used extensively because it gives a flat uninterrupted ceiling, well situated to subdivision. It is used for lower storey height, than the other types of floors. The slab thickness required depends upon the column spacing, the loading and the allowable stresses and varies from about 18 to30 cm.

Slab band Floors: Slab band floors are consists of wide shallow beams, called bands, running continuously along each longitudinal row of column and supporting one-way slabs spanning the space between banding and cast monolithically with them (fig.17c).

Columns located in partitions may be rectangular in cross-section with a width of the band and the thickness sometimes as small as 24cm. The slab thickness depends upon the column spacing, the bandwidth, the loading, and various form about 15 to 24cm.

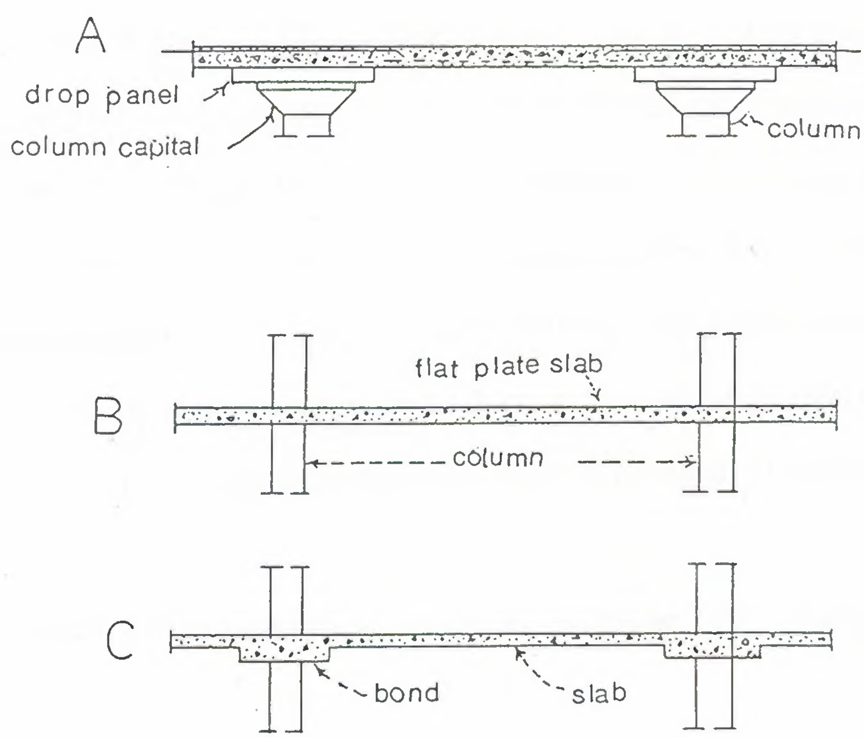


Fig.17 Types of floors

Ribbed Floors: In reinforced concrete beams and slabs the concrete between the natural axis and the tension force is not contributing to the flexural strength, but is effective in resisting a part of shearing stresses.

To reduce the weight of the slab, a large part of the concrete on the lower side of the slab is eliminated, leaving only the ribs or joists (fig.16a).

They can be either one way or two way ribbed floors (fig.17). These ribs are made enough wide to resist the shearing stresses and to carry the necessary tensile steel. The minimum width of joist is 12cm and the depth below of the slab is sometimes limited to three times the width. The clear spacing between the joist is limited to 90cm. It is advantages to support a slab on four sides and provide ribs in two directions as shown in fig.16d. Ribbed slabs are suitable for spans up to10m. Special types or style and steel cores are variable for two ways floor. A Steel core for two-way construction is shown in fig.16b, c. A form of a flat slab floor has been devised to make use of the ribbed slab in space of the flat slab, this is known as the grid flat slab (fig.16d).

Hollow Block Floors: This type of floor is lighter than the simple solid floor, like the solid concrete floor, in most floors it need a shuttering over its whole area. On this floor the blocks are laid end to end in parallel rows, about 75 to100mm a part according to the width required (fig.18).

Reinforcement is laid in these spaces and concrete poured between and over the blocks to form T-beams.

The hollow blocks are of clay, similar to those used for partitions, or of concrete, they are 30cm long and 25 or 30cm wide with depth from 7,5 to 20cm. The thickness of the structure topping is not less than 25mm, the thin slab and blocks only maybe punched with holes for the passage of services.

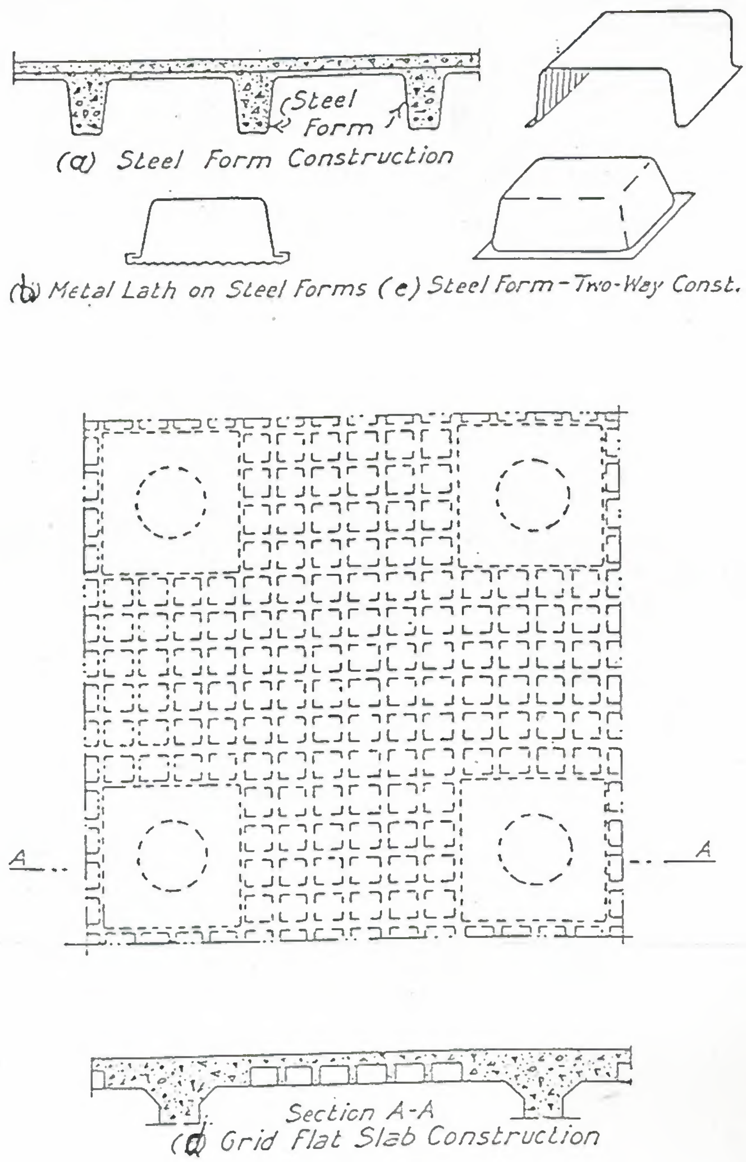
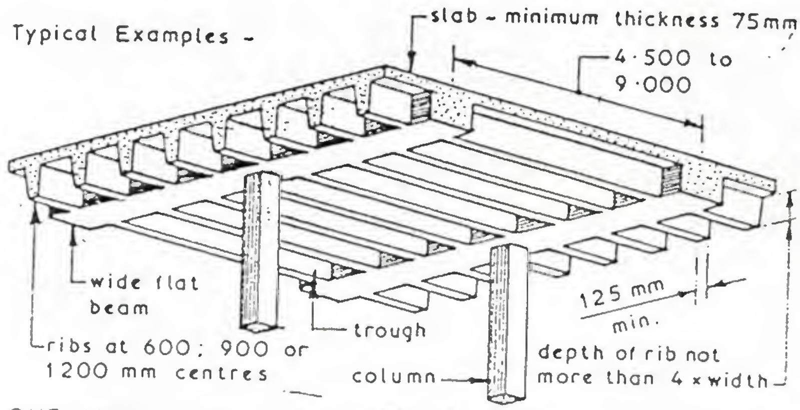
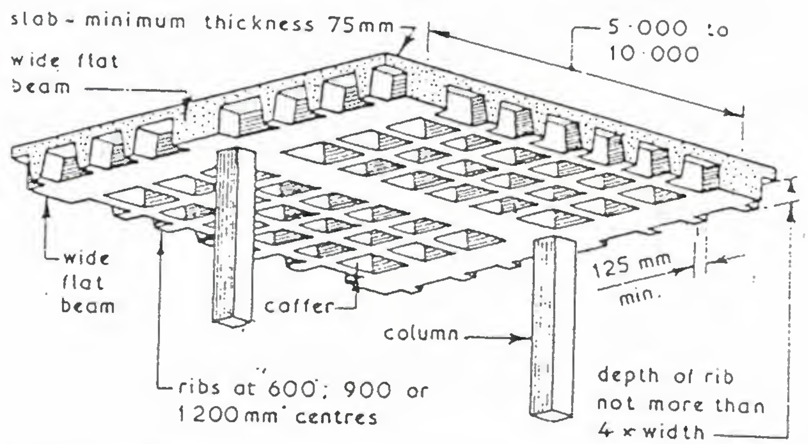


Fig. 16 Cores for ribbed slabs and grid-flat slab construction



ONE WAY SPANNING RIBBED OR TROUGHED FLOOR



TWO WAY SPANNING COFFERED OR WAFFLE FLOOR

Fig.17 One way and two way ribbed floors (8)

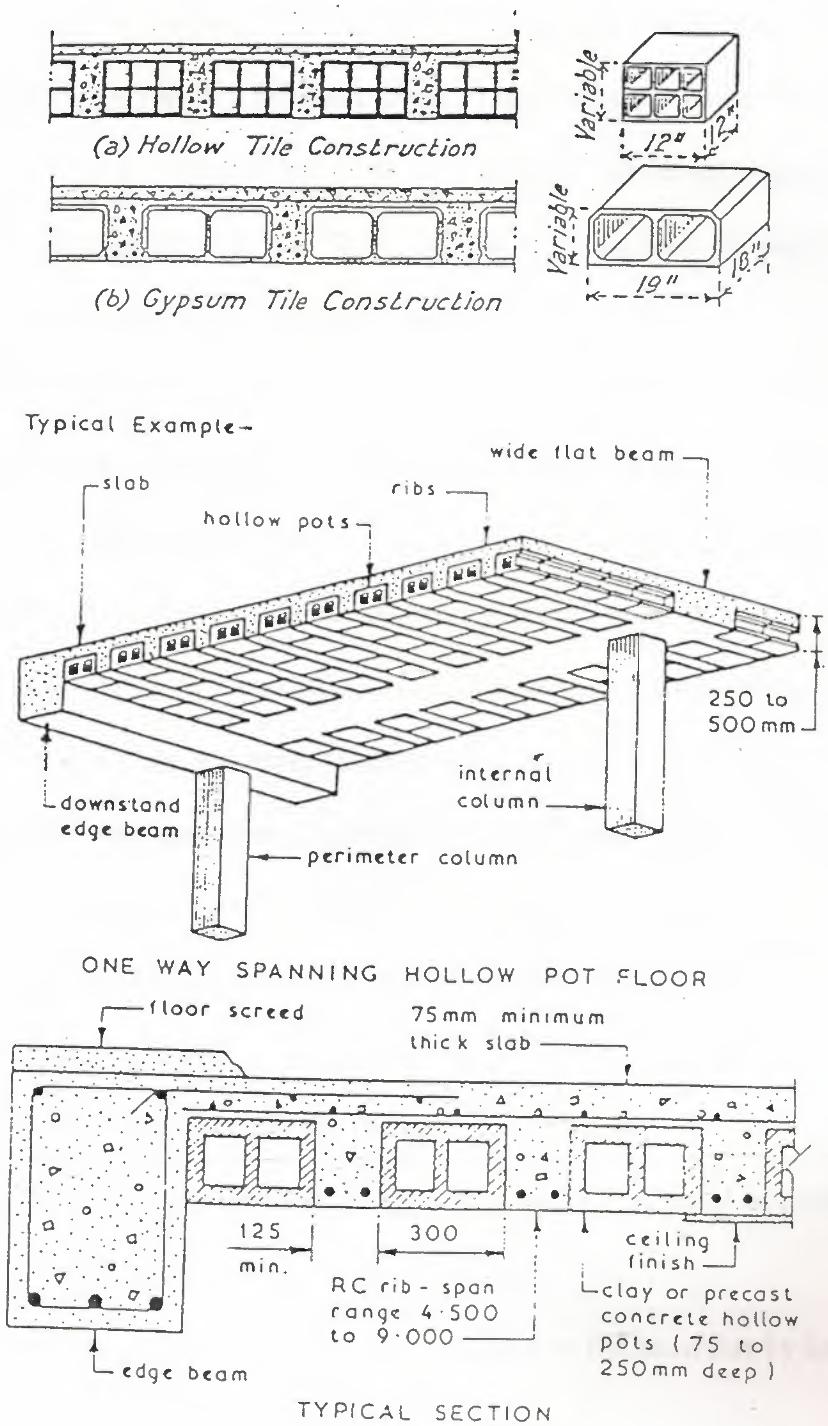


Fig.18 Hollow block floors (9)

3.6. Stairs

A stair is a number of steps leading from one level to another, the function of which is to provide means for movement different levels. This function in building two fold: firstly, that of normal everyday access from floor to floor, and secondly, that of scrape from upper floors in the event of fire. Stairs, must carry loads, from the weight of people using them, and furniture or equipment (10).

There are several ways to classify stairs according to the of from plan as follow:

Single Straight Flight Stairs: This from of stairs, although simple in design and construction, it is not popular because of the plan space it occupies. This has no landing and it is a useful form of stairs when the total rise is not too great, otherwise the absence of landings makes it tiring to ascend (fig.19). So it is not useful for floors, which have great heights, and it will be necessary to use landing in the length of the stair.

Inclined slab stair with half space landings: These stairs have the usual plan format for reinforced concrete stairs giving a more compact plan layout and better circulation than single flight stairs. The half space landing usually introduced at the mid-point of the rise giving equal flight span (fig.20).The point of intersection of the soffits to the flight with the landing soffits can be detailed in two ways:

1- Soffits can be arranged to the intersection or change of direction is in a straight line, it gives a better visual appearance from the underside.

2- Flight and landing soffit intersection are out of line on the underside by keeping the first and last risers in consecutive flights in line on plan.

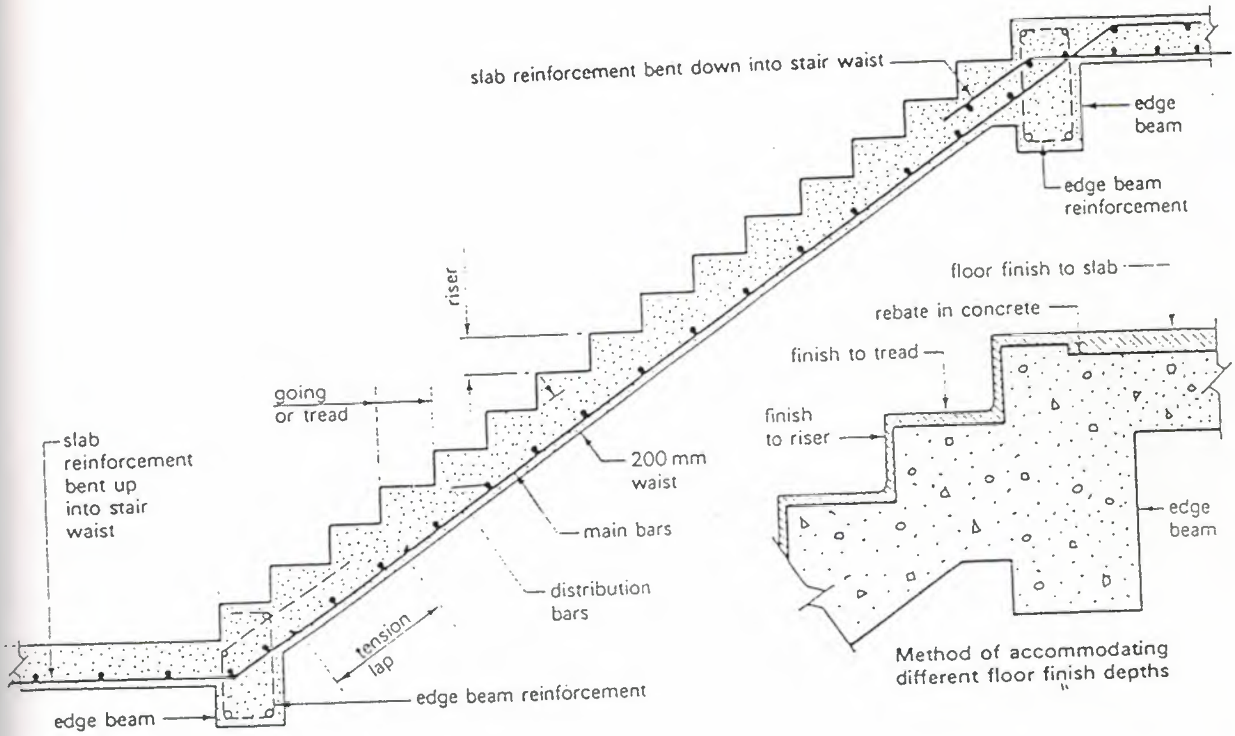


Fig.19 Single straight flight stairs (10)

Cranked Slab Stairs: In these stairs there are no trimmers and the top and bottom landings, together with the flight are designed as a single structural slab spanning between enclosing walls or frame. The thickness of these-stairs is not unduly great if the flight is not two long (fig.21).

Cantilever Stairs: Sometimes it called spine wall stairs and consists of a central vertical wall from which the flights and half space landing are cantilevered (fig.22). This from of stairs provides a useful solution to problems of sound insulation, because both flights and landings are cantilevers the reinforcement is placed in the top of the flight slab and in the upper surface of the landing to counteract the induced negative bending moment.

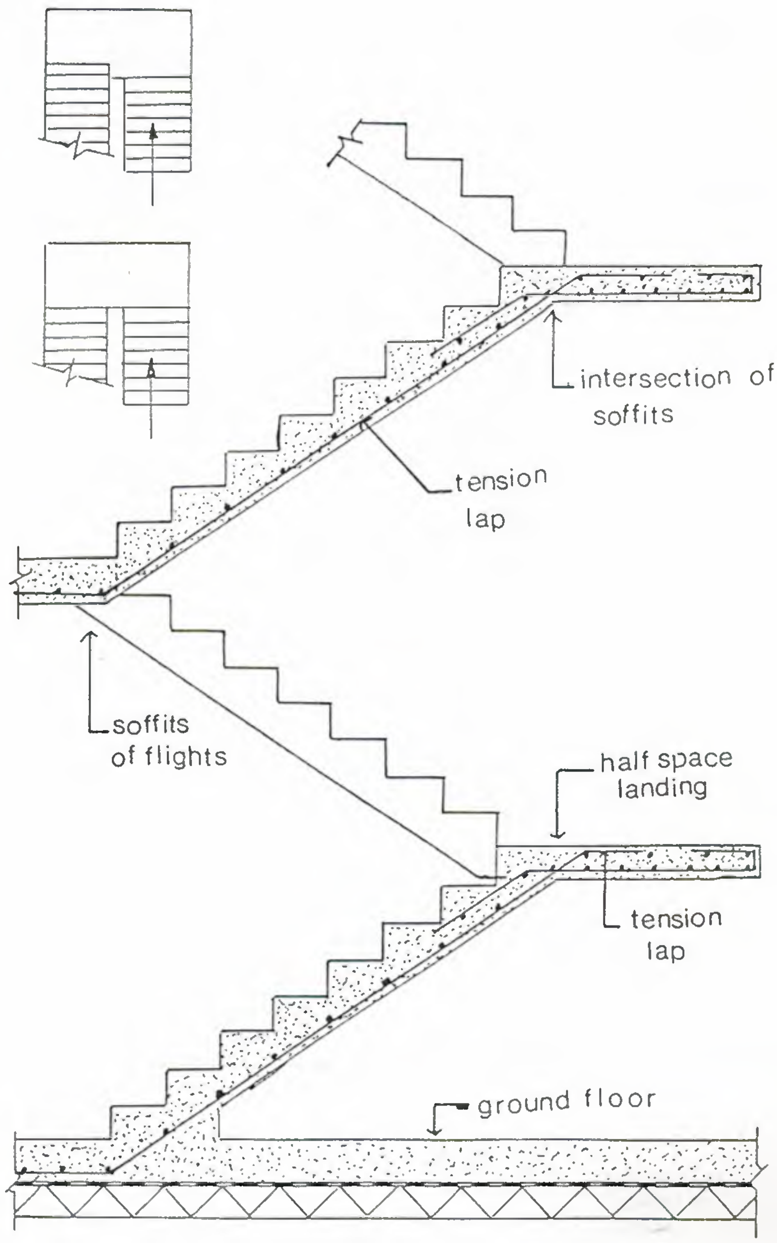
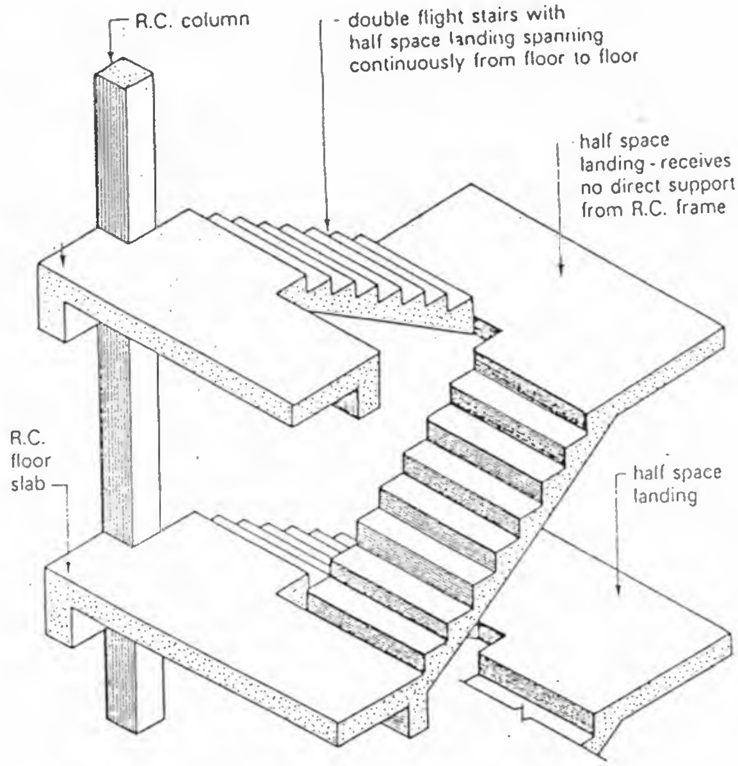


Fig. 20 Inclined slab concrete stair
with half space landings



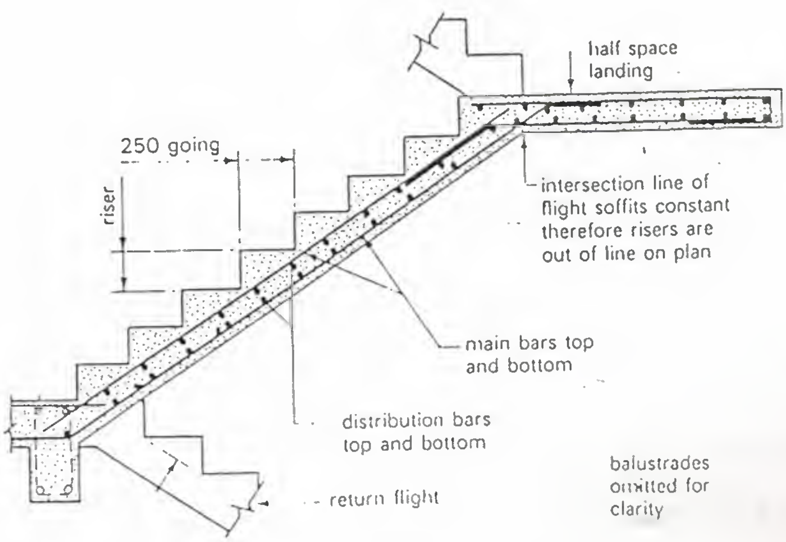


Fig. 21 Crank or continuous
slab concrete stairs (11)

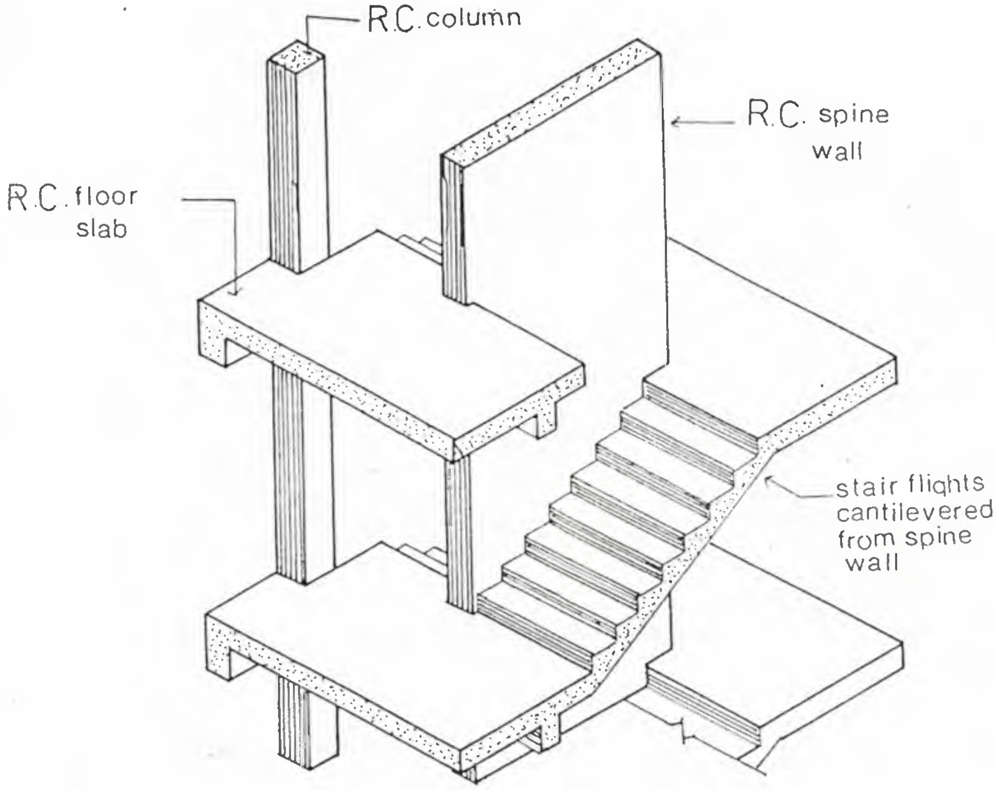


Fig. 22 Cantilever concrete stairs

Spiral Stairs: They are used mainly as accommodation stairs in the foyers of prestige building such as theaters and banks (fig.23). They can be expensive to construct seven times the cost of conventional stairs. The plan shape is generally based on a circle although it is possible to design an open spiral stair with an elliptical core.

A large proportion of steel is required to resist the bending shear and torsion stresses, and the shuttering is expensive. The slab usually varies in thickness form top to bottom, increasing towards the bottom, and vary in thickness a cross the width.

The reinforcement is placed at the top and bottom of the slab.

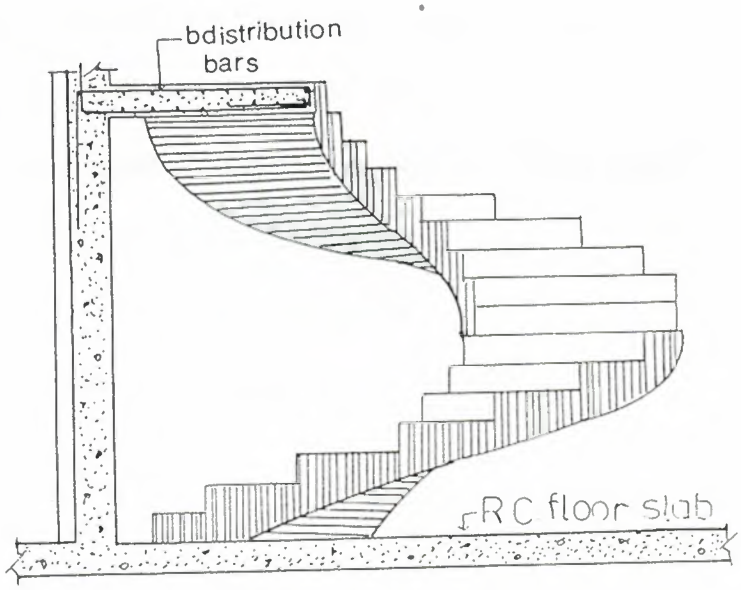


Fig 23 Spiral stairs

3.7 Exterior and interior walls

Walls are a vertical elements of a building which enclose the space within it space. They are divided into external and internal walls. They are also divided into two types, load bearing and non-load-bearing walls (11).

In frame structure the walls are non-load-bearing walls, they are used as an infill between the beams and columns, but they have basic requirements as follow:

1- Strength and stability

2- Provide the necessary resistance to penetration by natural elements

3- Provide the required degree of thermal insulation, sound insulation and fire resistance

4- Provide for movements due to moisture and thermal expansion of the panel and for contraction of the frame

For high rise buildings in form of frame structure, walls inside and outside are non-Load bearing, so they have to be light and not too thick. For these buildings, claddings and infill panel walls are used for external walls.

Cladding panels: Cladding is a form of masking or infilling a frame structure and it can be considered under the following headings:

1- Panel walls with or without attached facing.

2- Concrete and similar cladding panels.

3- Light infill panels.

4- Curtain walls.

Concrete Cladding Panels: These are usually made of precast concrete with a textured face in a storey height or undersell panel format. The storey height panel constructs from beam to beam, undersell panels span horizontally from column to column and are used where a high wall window ratio is required.

The weight of concrete cladding panels is usually reduced to a minimum by casting the body of the panel as thin as possible.

When designing or selecting a panel is depending upon the following factors:

1- Column or beam spaces.

2- Lifting capacities of plant available.

3- Exposure condition.

5- Any special planning requirements as to finish or texture.

Where a stone facing is required to frame structure, it may be advantageous to use a composite panels. These panels have the strength and reliability of precast concrete panel design and manufacture (fig. 24).

Thermal insulation can be achieved when using precast concrete panels by creating a cavity as shown in fig. 25.

Infill Panels: Infill panels are light weight and usually glazed to give good internal natural day lighting conditions. They are used between the framing members of a building to provide the cladding and division between the internal and external environment. A wide variety of materials or combinations of material can be employed for light weight infill panel such as timber, steel, aluminum and plastic, single and double glazing techniques can be used to achieve the desired sound or thermal insulation. They can be fixed between the structural horizontal and vertical members of the skeleton structure, or fixed to the face of either the columns or beams to give a grid, horizontal or vertical emphasis to the building (fig.26).

Brick infill panels can be constructed in a solid or cravity format which having an inner skin of block work to increase the thermal insulation properties of the panel.

The infill panels can be tied to columns by means of ties cast into the columns.

The head of every infill panel should have a compressible joint to allow for any differential movements between the frame and panel.

In fig.27 and fig.28 there are examples of timber and metal infill panel details.

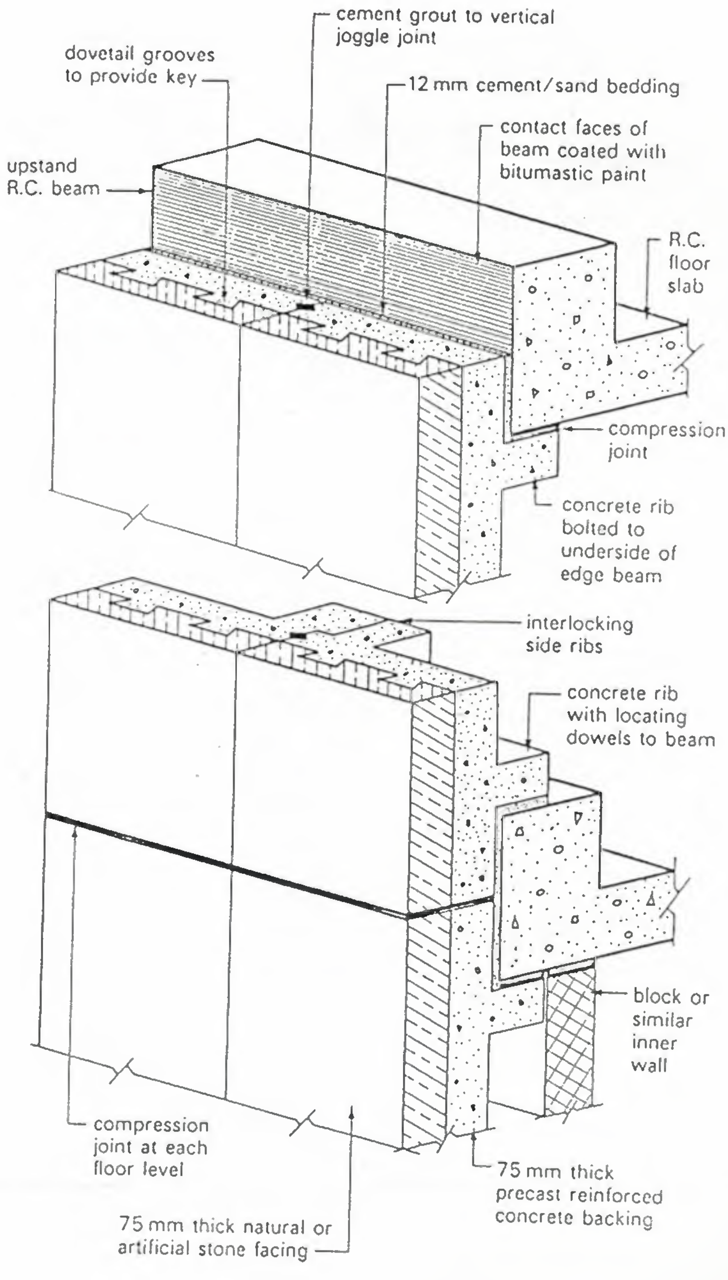


Fig. 24 Typical storey height composite panel (12)

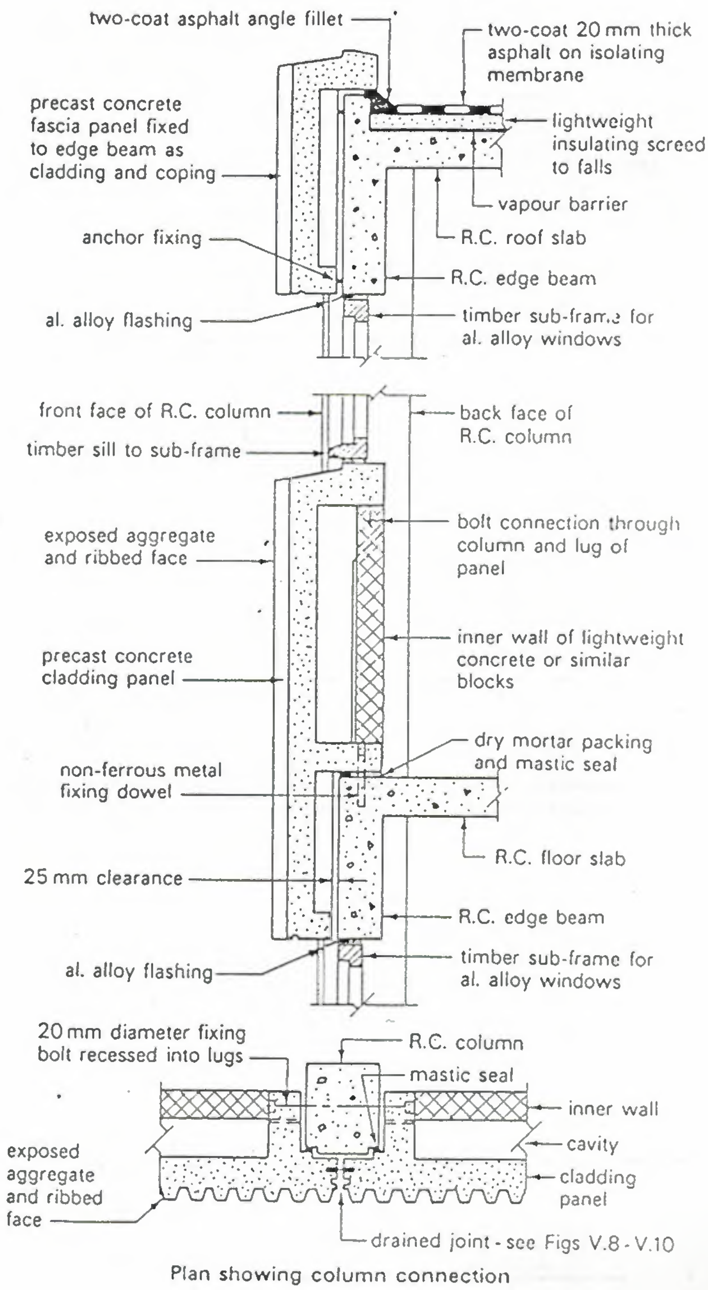


Fig. 25 typical undersill concrete cladding panel (13)

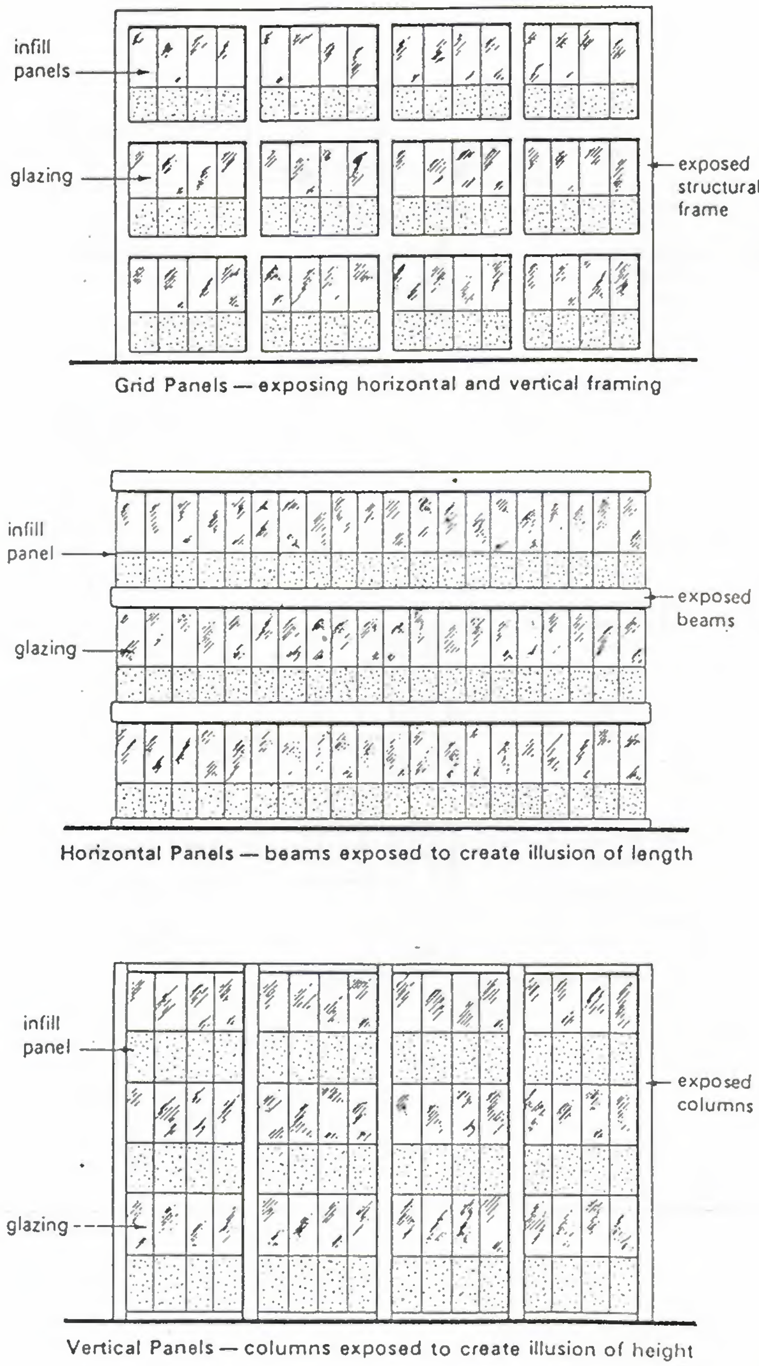


Fig.26 Infill panel

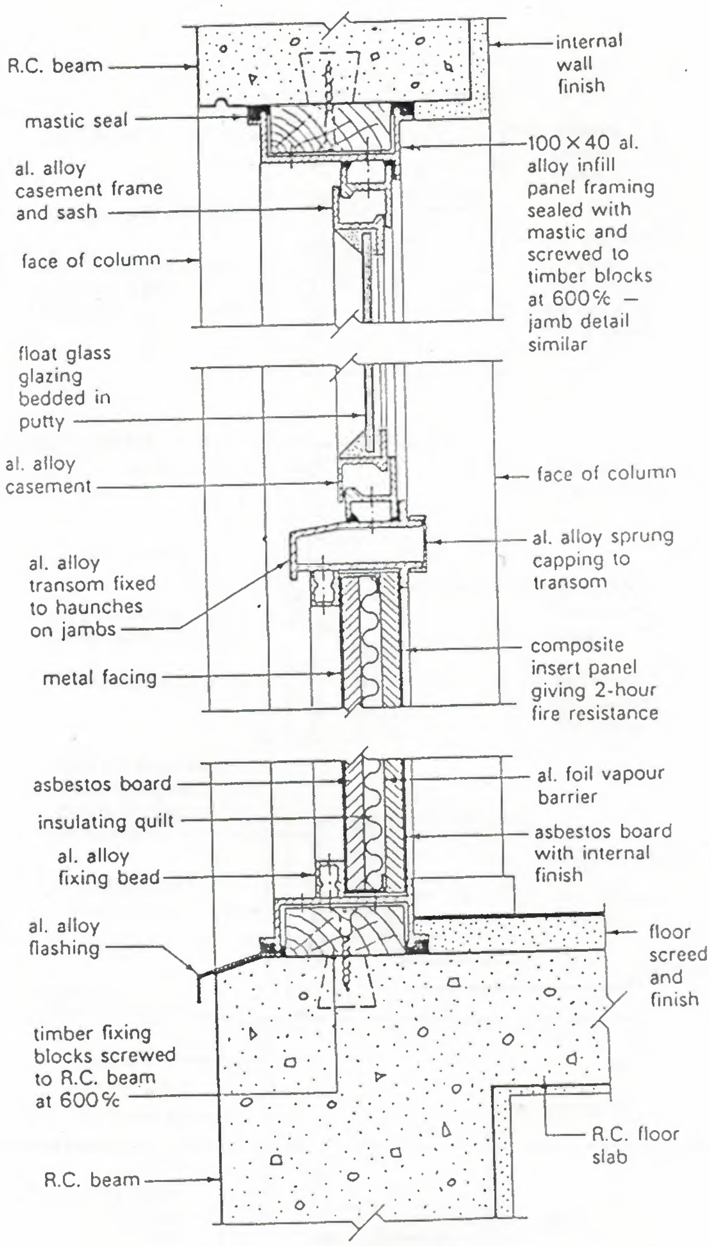


Fig.27 Typical metal infill panel details (14)

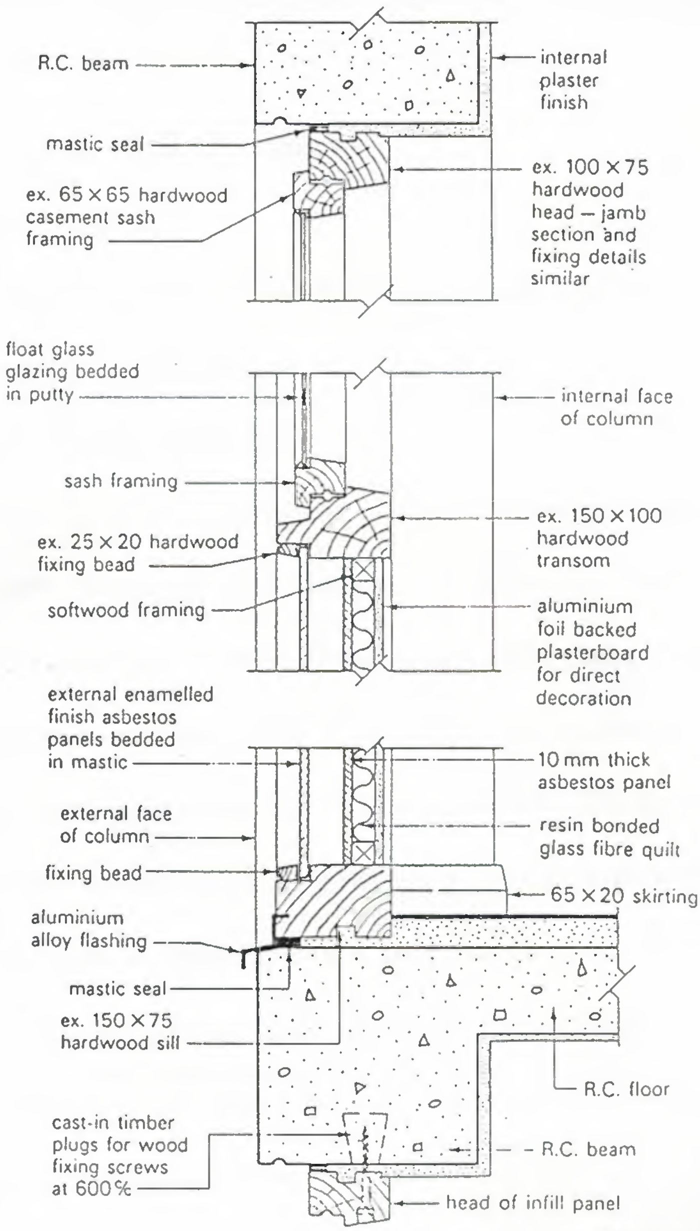


Fig. 28 Typical timber infill details (15)

Curtain Wall: Curtain wall is a form of lightweight non-load-bearing external cladding which form a complete envelope or sheath around the structural frame. The curtain wall must fulfil the same functional requirements as any other system of external walling.

Advantages of curtain walls are as follow:

1-Very light in weight.

2-Giving full economy in the size of a building structure, as it is relatively thin, it gives a greater floor area than heavier materials.

3- It has greater architectural freedom.

Curtain walls like the other cladding, carry only it's own weight between supports, but it must be capable of resisting wind forces and of transmitting them to the structure.

A wide variety of materials can be used for curtain walls, timber can be used for height up to two stories, but most commonly using for high-rise buildings, are galvanized steel, stainless steel, aluminum, bronze, and reinforced concrete. Reinforced concrete curtain walls are used when windows occupy a relatively small portion of the wall area.

Concrete curtain walls are made up of precast reinforced concrete slabs, whose size and shape can be selected to meet specific requirements. A common size of slab is 240 to 420 cm, the thickness range from10 to15cm, depending upon code requirements, degree of fire resistance, and heat insulation required.

The slabs are constructed of lightweight concrete not only to reduce their weight but also to improve their heat insulation properties.

Partitions: Partition is a kind of wall, which main function is to divide space inside the building into rooms. Partitions within skeleton structure are non-load-bearing walls. Partitions may be constructed of bricks or blocks and of various types of slabs of different materials.

Chapter 4

Technological Types and Methods of Reinforced Concrete

4.1. Technological Types of Reinforced Concrete.

Reinforced concrete because of its particular characteristic can be formed into walls, as well as into beams and columns to form skeleton structure, and floor slabs can be designed without projecting beams to carry them. At the beginning of its structural life reinforced concrete is fluid or plastic in character and this gives rise to two important factors concerning the nature of the structure of which it is used:

1. The ease with which a monolithic structure may be obtained, producing a rigid form of construction with the economies inherent in this form.

The ease with which almost any desired shape may be formed either for economic, structural or a esthetic reasons. There are two main types of reinforced concrete, cast-in-situ reinforced concrete and precast concrete.

4.1.1. Cast-in-Situ Reinforced Concrete

Up to comparatively recent time's multi-storey reinforced concrete frame structure have always been erected as Cast-in-situ reinforced which all the constituent concrete materials have been brought to the site mixed and placed in formwork erected in the position the concrete will finally occupy in the completed structure(12).

Cast-in-situ reinforced concrete often allows greater flexibility in design because of its monolithic nature and because it is not confined to standard sections. There is however, an economic limit set to this flexibility by the increase costs of the formwork as it will be explained later.

There are generally two types of plants for mixing concrete. One is known as central mixing, which mixed with small concreting plant that may be erected at the site, which the concrete materials would be transported to this plant dry, mixed with water and immediately used for construction. The second is transit mixer, which the concrete is mixed at a large premixing concrete plant, then it will be transported to the site. For the greatest economy to be achieved, the aim of reinforced concrete designer is to provide just enough concrete and steel. The arrangement of the bars should be as simple as possible with sufficient space left between the bars for each to be surrounded by concrete. The minimum distance between bars must be greater than the maximum size of aggregate used. The minimum number of different bar sizes should be used, and the use of the largest size consistent with good design will educe the number of bars to be bent and place. At all points of intersection the bars must be wired together to prevent displacement during concreting.

4.1.2 Precast Concrete

Precast concrete is applied to individual concrete members of various types, which are cast in separate forms before they are placed in a structure. It is one of the important developments in the construction industry, in which these structural members are not only designed for structural purposes and precast, but they designed and made for architectural purposes. The Technique of precasting concrete for structural purposes was originally applied to the manufactory of floor and roof slab. But the process has now developed to such an extant whole the building structures can be erected from factory produced precast concrete members as columns, beams, floor and roof slab, wall panels and cladding (13).

The advantages of precast concrete are as follow:

1. Quality of concrete can be controlled more carefully.

2. Finishing work on concrete surfaces can be done more easily and efficiently in a plant than in position on the site.

3. Greater erection speed is possible.

4. Erection is less restricted by weather conditions.

5. The cost of formwork is reduced, since it can be set up on the ground rather than being suspended or supported in position.

6. Because of superior reinforcing techniques, the load-carrying ability of a member may be increased while at the same time reducing its dead load by reducing the amount of concrete.

Precast structural members fall into two general types:

1. Normally reinforced precast concrete.

2. Prestressed precast concrete.

Normally Reinforced Precast concrete:

Normally reinforced precast concrete members are those in which at least a major part of the reinforcement is placed in much the same form as it might be in cast-in-place concrete members. Such units may be divided into two classes. One group includes the type of wall panel, which is cased on a flat surface on the job site and raised into position in what in known as tilt-up construction (14).

The other group includes units which because of their size or the fact that they may be few in numbers, cannot be economically prestressed or because of the way in which they will be loaded don't require prestressing.

Large or unique girders, beams and many columns fall into this category. Normally reinforced precast concrete members are designed according to accepted reinforced concrete practice, the main difference being that the reinforcing may be made up as a unit called cage and placed in position in the completed for.

In addition, the member will have the benefit of carefully designed and placed high-strength concrete and a number of units may subsequently be tied together by post tensioning. In the case of columns, the reinforcing may include provision for a bracket or corbel, which will support the end of a beam, or it may include provision for the insertion of the end of a structural steel member (fig.29).

Pre-stressed Precast Concrete

Prestressed concrete is the term applied to concrete members in which the concrete is subjected to compressive stresses before the external loads are applied, by inducing tensile stresses in the reinforcement to counteract tensile stresses in the concrete caused by external loads. To make pre-stressing advantageous, both the concrete and reinforcement must have much higher strength than are required for conventional reinforced concrete members (15).

In its application to building work prestressed concrete is mostly used for beam and slab members in precast construction. When applied to complete monolithic a structure prestressing presents complications in design and construction.

For wide spans freely supported beam are generally considered preferable to continuous beams in order to avoid similar complication. For spans below 6m, normal reinforced concrete construction is general cheaper than prestressed concrete. Between 6 and 9m prestressed work may or may not prove more economical according to the particular job having regard to such factors as the reductions in size and numbers of columns and foundations likely to result from the use of prestressed work. For spans greater than 9m prestressed work is usually show economic advantages over reinforced concrete especially when the imposed loading is light as in roof construction.

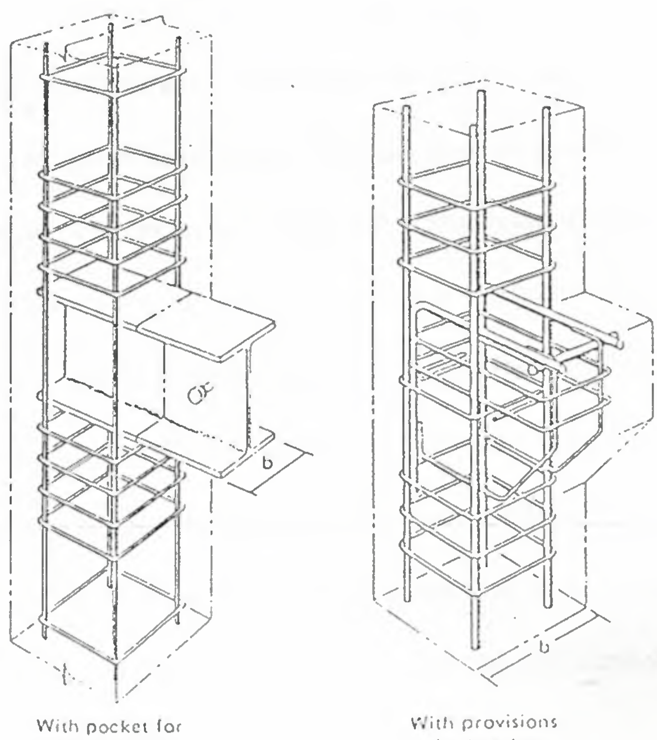


Fig. 29 Reinforced cages for precast concrete columns (16)

Prestressed precast concrete compared with cast-in-place, has advantages and disadvantages, among these advantages are the following:

1. Smaller dimensions of members for the same loading conditions, which may increase clearance or reduce storey heights.

2. Small deflection.

2. Smaller loads on supporting members because of the smaller dimensioned required.

Among the disadvantages are the following.

1. Higher unit cost of high-strength materials.

2. Cost of prestressing equipment.

3. Labor cost of prestressing.

4. Not advantages for short spans with low concrete stresses.

Prestressed concrete members are divided into two groups according to method of prestressing. These are pre-tensioned and the other is post-tensioned.

Pre-tensioned Precast concrete: In this system high-tensile steel wires are tensioned before the concrete is case round them. Then when the concrete has attained sufficient strength, the wires are released and in seeking to regain their original length but being bonded to the concrete, reduce in the concrete the required compressive force. The pre-tensioning technique is usually employed where mass production of a particular shape is feasible, frequently because standard shapes and sizes for such items have been established, this means that the same bed and form and the same stressing facilities may be reused many times (16).

Although pre-tensioning can be applied to individual members formed and stressed in their own mould, the most usual method is than known as the "long line" system. The wires pass through templates and the ends are gripped in anchor plates. Spaces are placed at various intervals along the mound according to the required length of the unite. The anchor plates then jacked a way the calculated distance to stretch the wires, then the concrete is poured, and after it has hardened sufficiently the wires are released and cut between each unit (fig.30).

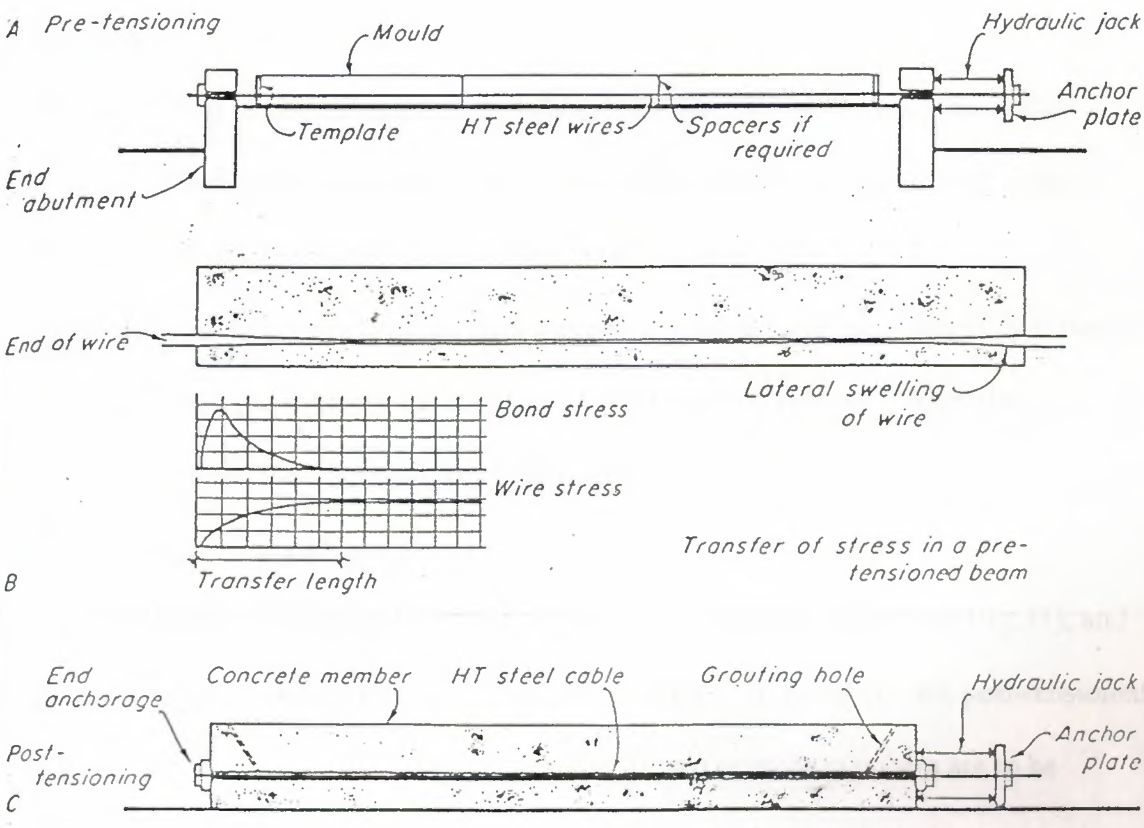


Fig.30 Methods of prestressing (17).

Members which are relatively small in cross-section or which can readily be mass-produced are normally pre-tensioned. They include double T, single T, hollow core, and flat slab, rectangular I shaped and inverted T beams and prestressed columns and bearing piles (fig.31).

Post-Tensioned Precast

Post-tensioning is a method used to apply prostrating to concrete after it has hardened. Its greatest use is with cast-in-place construction, such as concrete floors or bearing walls, but it is also used in precast members, either as a means of prestressing and individual member or as a means of providing continuity connection for two or more members (17).

Post-tensioning of precast concrete members involves placing and curing a precast member, which contains normal reinforcement, and in addition a number of channel through which post-stressing stands or bars may be passed (fig.32).

Suspending inflated tubes through the form and casting around them generally forms the channels. When the concrete has set, they are deflated and removed. After the concrete has reached a specified strength, the post-tensioning tendons are inserted in the channels and anchored at one end.

They are then stressed from the opposite end by a portable hydraulic jack (fig.33), and anchored by one of several automatic gripping devices. if members are post-tensioned individually, this is normally done at the plant. If two or more members are to be positioned together, the operation must be carried out after they have been erected.

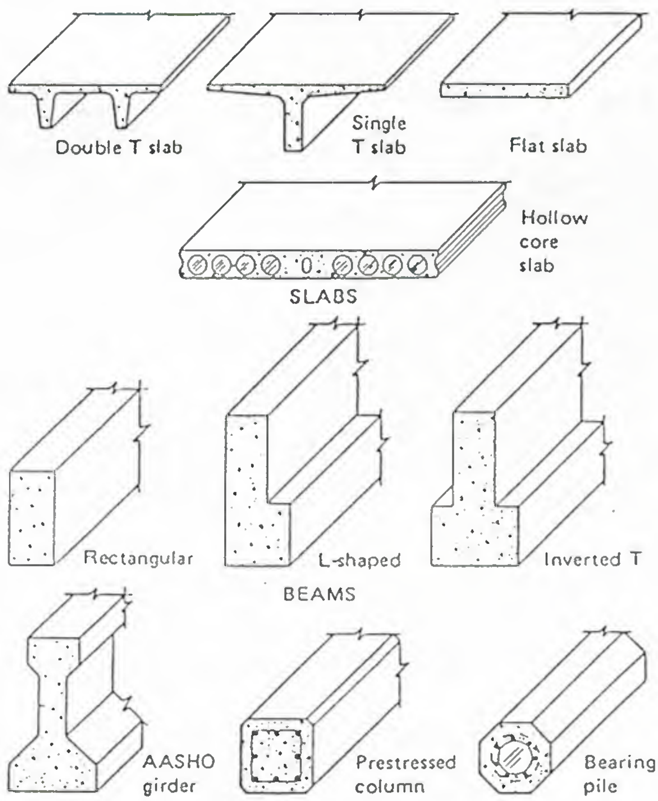


Fig.31 Prestressed structural shapes (18).

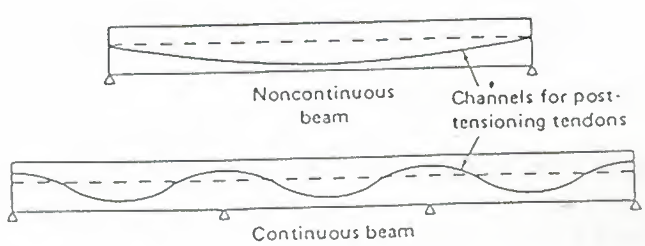


Fig.32 Channels for post tensioning tendons

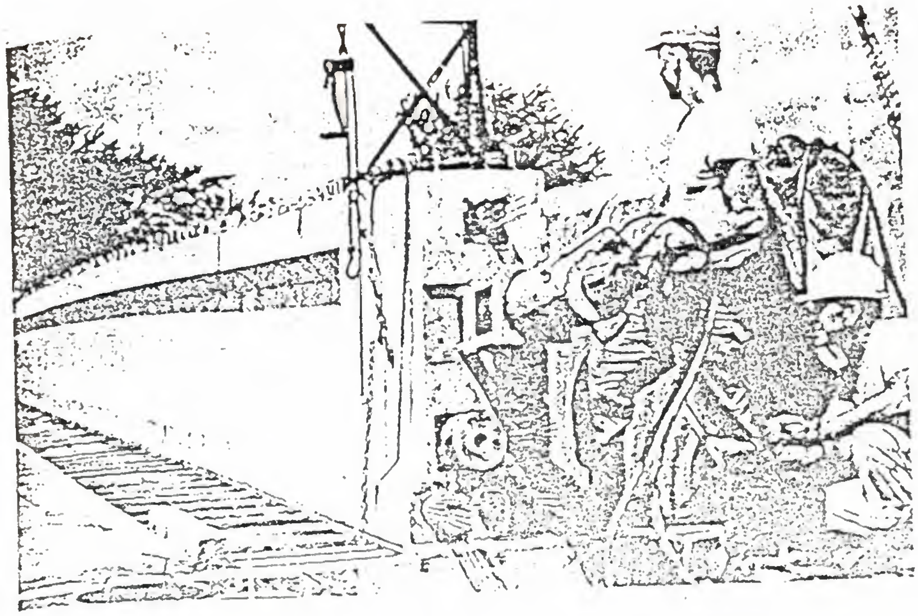


Fig.33 Post tensioning large single girder (19).

Connections: The design of the connections for precast concrete units plays an important part in the overall effectiveness of the system. Over the years, field experience laboratory test and structural analysis have resulted in the establishment of a number of basic connection systems as, welding, bolting, pinning or doweling, grouting and post-tensioning (fig.34). Nearly all connections are adaptations of one of these systems, and every precast concrete structural member. Members are also provided with bearing plates, where necessary to provide for the even distribution of load from one to the other. Figure 35 illustrates one typical connection for each of the basic connection situations, namely, column to foundation, beam to column, slab to beam and slab to wall (18).

Architectural Precast concrete: Precast concrete unites were originally intended to act as a building frame, performing the same functions as wood or steel framing members. But advance in design and in prostrating and manufacturing techniques have made it

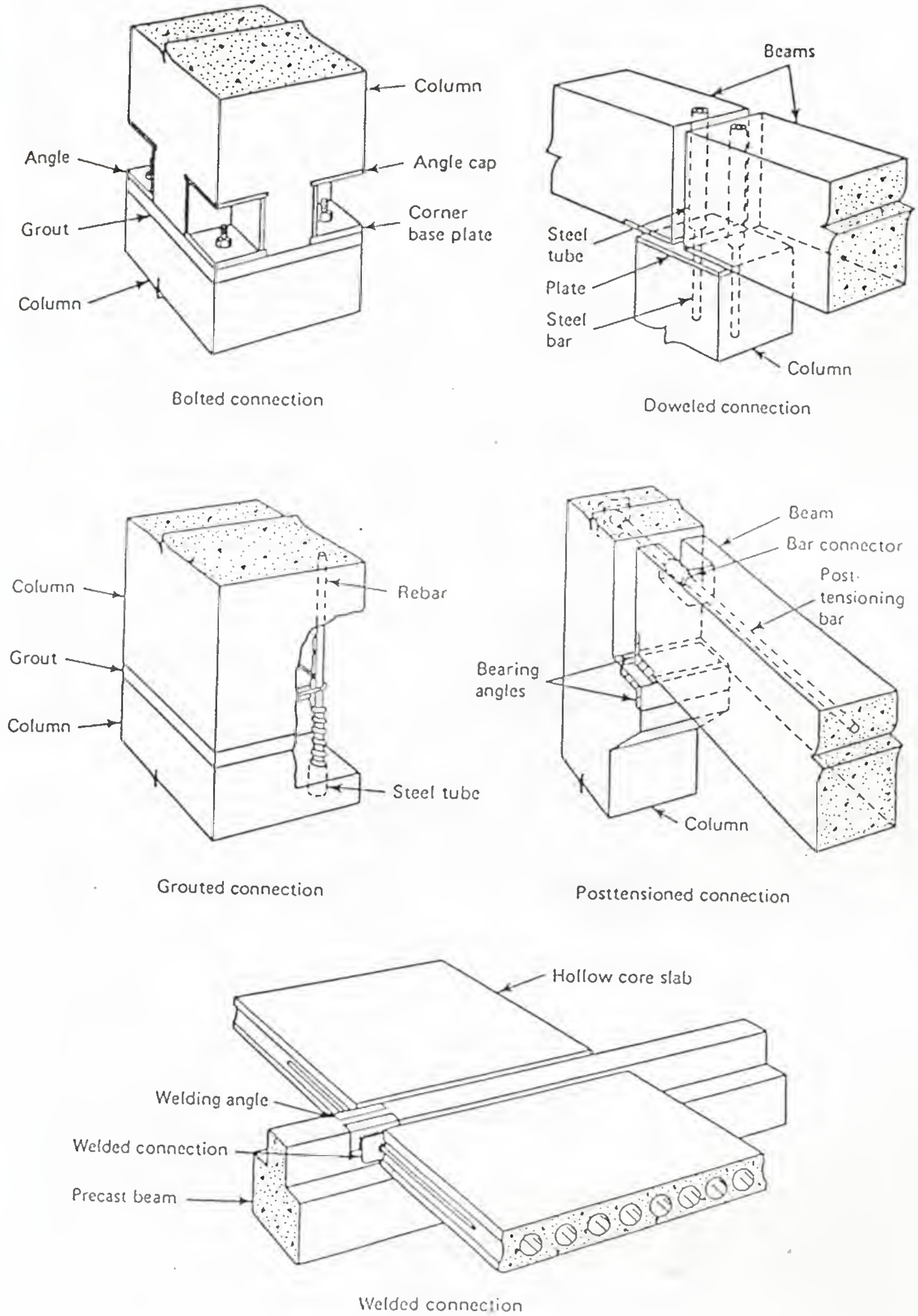


Fig.34 Basic connection systems for precast (20)

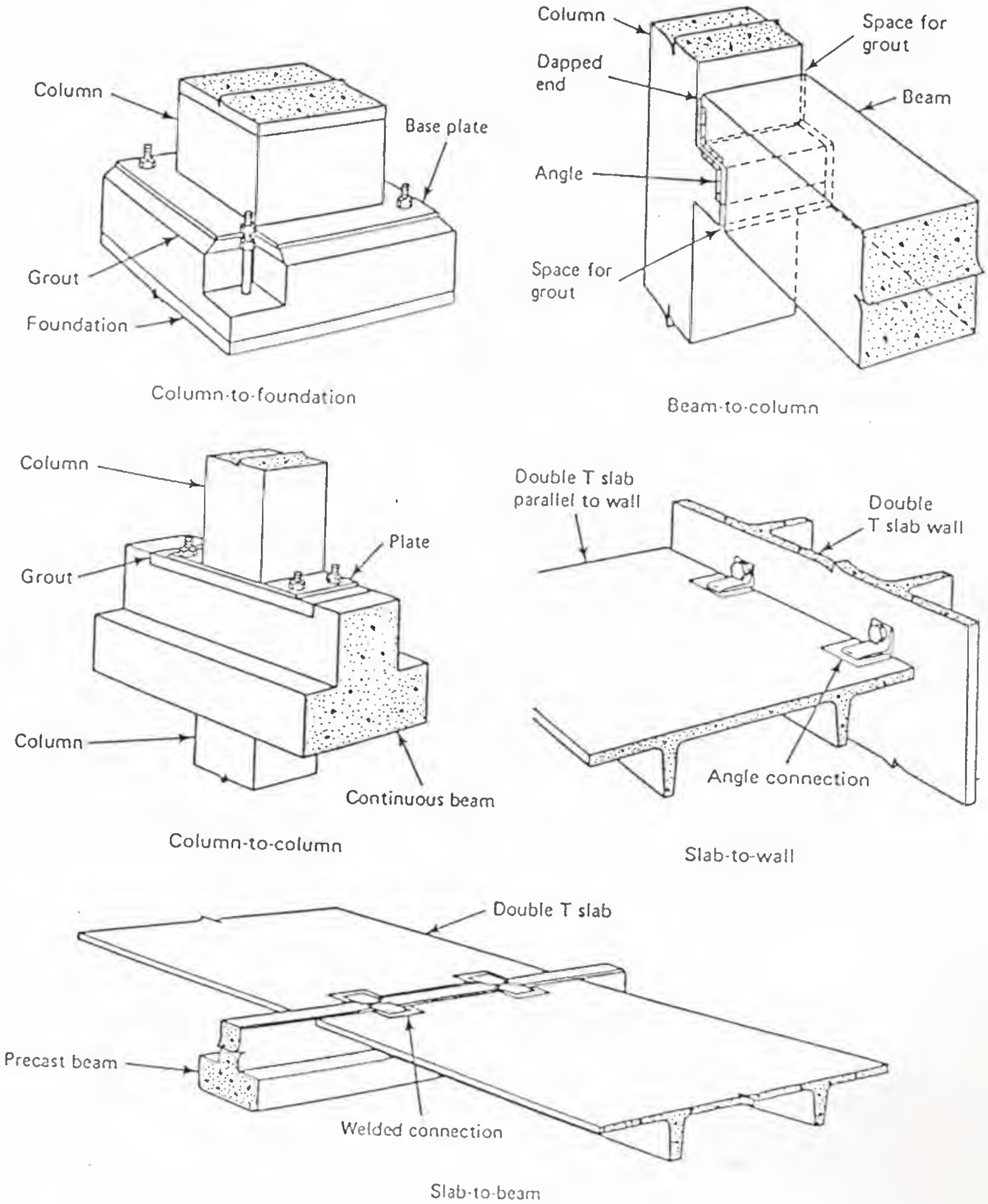


Fig.35 Typical structural precast connections (21)

possible and economical to produce precast units, which are not only the load-bearing components of a building but which, at the time provide the exterior finish for that building. There are two principal methods by which this type of unit can be produced. One is the tilt-up method, already described in which the finish desired on the face may be introduced into the slab when it is being cast. The other is the same central-plant type of operation used to produce structural precast, except that shapes are not necessary, in many cases special attention is paid to the color, texture, or profile of the exterior face (fig.36).

There are some distinct advantages to producing architectural precast building units in a central plant. They include the following:

1. Design freedom, the styles and designs of buildings may be widely diversified ranging from the use of one master mold to produce units for an entire building (fig.37) to unique structures, such as the one shown in fig.38.

2. The high degree of quality control, of both the ingredients and the finishing techniques.

3. The shapes, sizes, and configuration units for one building may be as diversified or similar as the designer wishes.

4. The speed with which a building can be closed in reducing costs and allowing earlier access by the service trades.

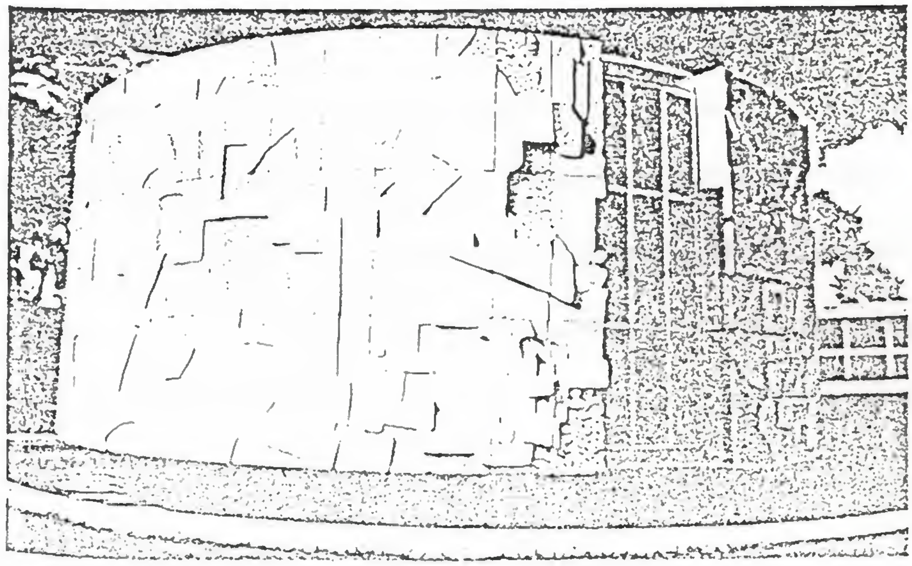


Fig.36 precast panels with high-profile face (22)

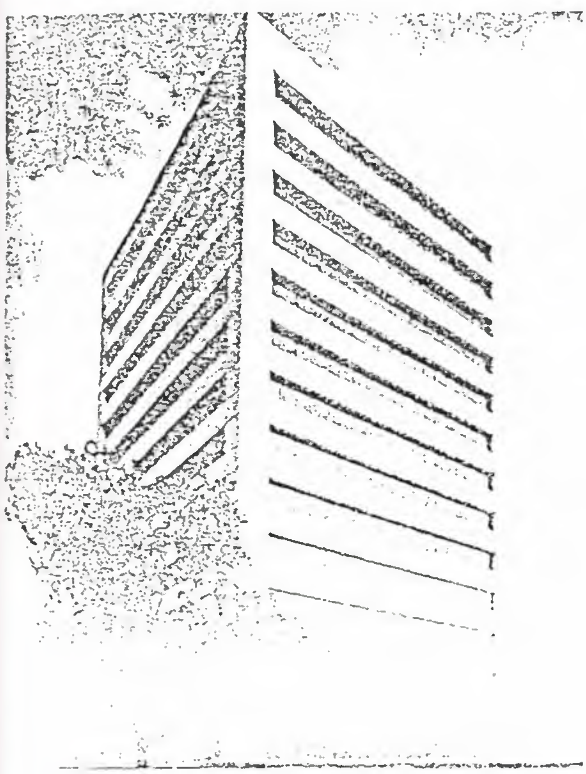


Fig.37 Architectural precast units made from one master mold (23)

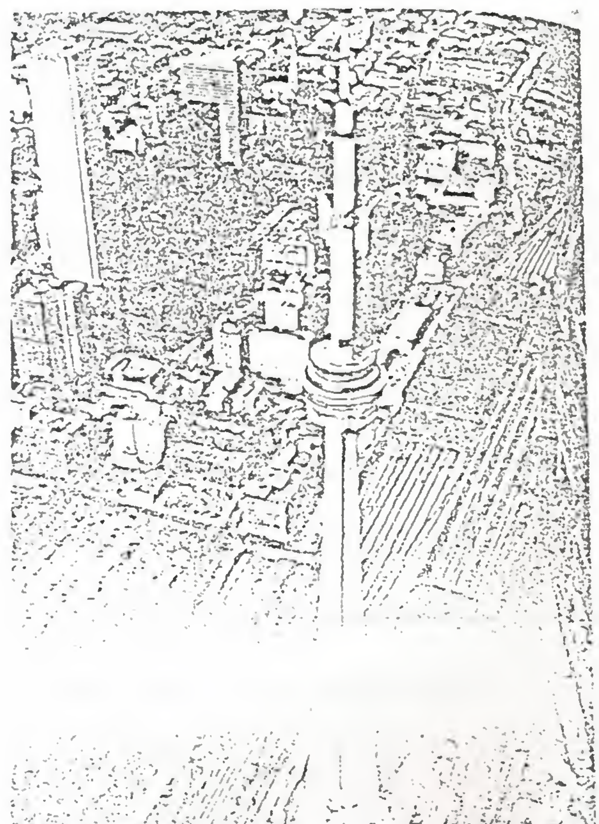


Fig.38 Telecommunication tour (24)

4.1.3. Composite Construction

Composite constructions consist of precast girders, beams, joists, or purlines on top of which a floor or roof slab is cast-in-place. Composite constructions offer many advantages in precast concrete design, particularly in enhancing the flexural and shear strength of precast concrete beams. To most minds composite construction means adding in-situ concrete on top of components to form a single unit acting as through it were one (19).

Composite action is used mainly to:

1. Increase flexural and shear strength of floor slabs.

2. Tie floor slabs to beams, by ensuring a secure bearing and increasing the flexural and shear strength of beams:

3. Provide the compressive and or shear transfer between adjacent precast units, between walls, shear walls and columns, and at column foundations.

4. Ensure floors diaphragm action, with or without structural screeds.

5. Anchor stability tie steel in to precast components.

The use of reinforced precast concrete units as permanent shuttering designed to act with in-situ concrete to form a composite structure as illustrated in fig.39, is a means of obtaining the continuity and rigidity inherent in in-situ-cast work without the use of formwork. It is also reduces the amount of precast work which factory overheads and transport costs tend to make more expensive than in-situ work.

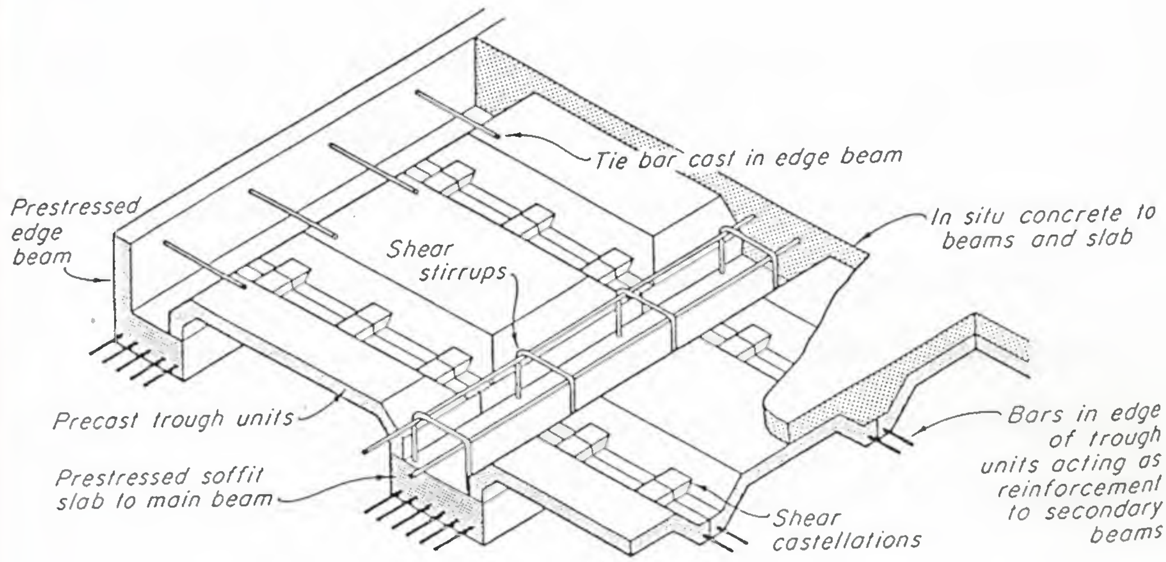


Fig.39 Composite construction (25)

Satisfactory bond between the precast units and the in-situ cast concrete is essential in order to transfer shear stress and although research has shown that a roughened surface on the precast unit is adequate.

This does assume good site supervision and workmanship in forming the junction between the two. When composite beams or slab are continuous the negative moments over the support must be resisted by reinforcement placed in the in-situ cast concrete.

Figure 39 shows a floor for heavy loads which incorporates a wide shallow beam in which the tensile zone is a precast prestressed slab, the compression zone being of in-situ cast concrete. The side shuttering of the beam is formed by the edges of the precast through units forming the lower part of the floor slab.

These trough units are very thin but their form, which provides the shuttering for main and secondary beams, makes them stiff enough to carry the live loads during the casting of the in-situ concrete. The combination of precast and in-situ cast concrete is particularly economical when allied to prestressing in the range of span of 6 to 9m spans, for which normal prestressed concrete is not generally economical.

Precast units and in-situ concrete may be combined in columns as well as in beams and slabs. By using a precast concrete casing with an in-situ cast core, time and labours can be saved by the elimination of normal shuttering and a good finish is obtained when the surface of the column is to be exposed. It also permits the construction of the next floor to proceed more quickly while still maintaining full monolithic junctions with the floors and beams above and below.

4.2. Technological Methods of Formwork

4.2.1. Formwork

Formwork is a temporary mound into which wet concrete and reinforcement is placed to form a particular desired shape with a predetermined strength.

Depending upon the complexity of the form, the cost of formwork to concrete can be as high as %75 of the total cost to produce the require member(20).

The formwork for any job must be considered at the design stage. There are general requirements governing the design and construction of formwork as follows:

1. It should be strong enough to bear the weight of the wet concrete and all incidental-working loads.
2. The joints should be tight enough to prevent the loss of fine material from the concrete.
3. If the concrete is to be fair-face the formwork in actual contact with the concrete should be so arranged and jointed to have a good appearance.

Formwork may be constructed from any suitable materials such as steel and timber. Timbers were once always used for this purpose. On in-situ work timber forms are usually unfit for further use after four or six times, they may then be cut up and parts can be used in the construction of other forms.

In precast work, particularly in factory production, up to twenty re-uses are possible with timber forms. Steel shutters are available, generally in standard units of suitable sizes, and are designed to eliminate timber. They can be quickly erected, and can be used a greater number of times than timber forms.

Timber Formwork: Timber should be sound and well seasoned and may be dressed on all four sides, on one side and one edge, or one side and two edges. Timber dressed on all four sides is uniform is size and therefore more easily adapted for different purposes. When a good finish is required, used and new boards should not be incorporated in the same panel. Plywood used instead of boards or as aligning to forms should be resin-bonded external grade.

The thickness of the timbers will depend on loads to be carried and on the available supply. Nailing used, they should be kept to a minimum and where used, the nail heads should not be quite driven home, as this make it easier to draw them with a claw hammer or nail bar.

Bolts and wedges are preferable to nailing, but are more costly.

Column Formwork: In the case of rectangular columns, the forms consist of four shutters or panels made up of boards nailed securely to a series of yokes to form the column casing (fig.40a).

The thickness of the boards varies between 25 to 50mm depending on the size of the column and the space of yokes, which are more closely at the bottom, where the outward pressure is greatest, than at the top.

Adjustable steel clamps as shown in fig. 40b are now widely used, as they reduce the amount of timber required, have along life and quickly fitted and dismantled. Circular column forms are built up from narrow vertical boards, called "staves" shaped to the correct curve and fixed to shape yokes of various forms. The latter are in two halves secured by bolts or steel clamps.

Beam Formwork: Beam sides are generally built up to 25mm boards, the bottom should be thicker, about 50mm, and where practicable should be made from a single width of board. The free side of an outer beam is braced at the top by struts off the ends of the head trees, which are extended to this purpose.

Junctions of beams and columns are formed as is it shown in fig.40a, e.

The ledger or runner is nailed to the battens of the beam sides to form. A bearing for the slab joists.

When plywood instead of solid timber is used, no external battens or cleats are required, except at the edges of the plywood, which must be provided with continuous support by patens and bearers.

Floor Shutters: This consists of decking of 25mm boards or 19mm plywood on which the concrete is placed, supported by timber joists as shown in fig.41. The actual thickness of the decking and the joists size will depend upon the loads, the form must

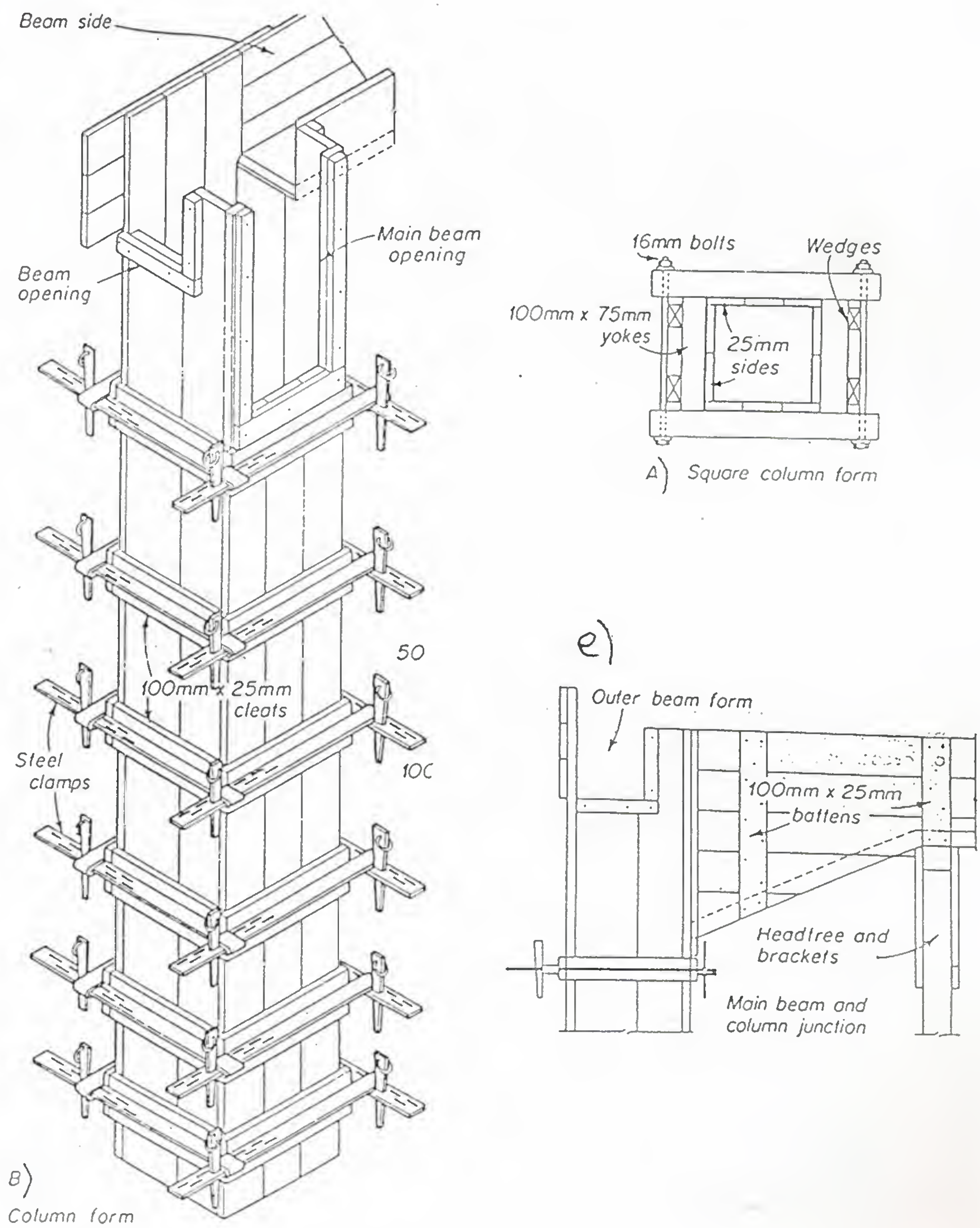


Fig.40 Column formwork (26)

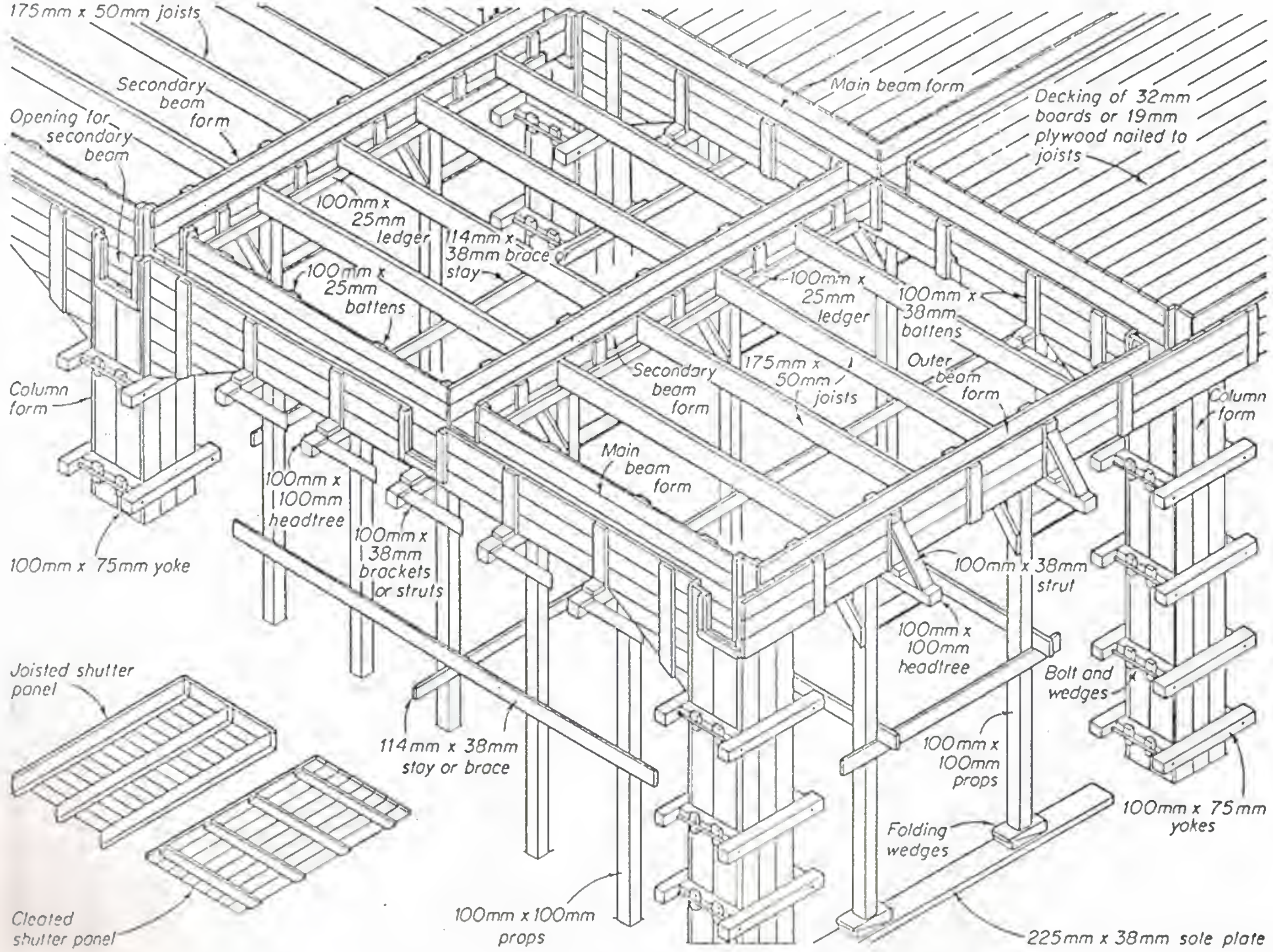


Fig.41 Formwork for Floors (27)

carry the spacing and the span of the joists and the maximum deflection of the shuttering, which may have been specified.

Adjustable steel props may be used which are simple to install and a voided the uses of wedges. Tubular steel scaffolding with fork heads may be used for the same purpose. The later is suitable where the height from the ground to the floor is great.

Rectangular grid floors and roofs presents a special problem because of the large number of intersecting beams or ribs to be formed, it is solved by the use of square box forms or pans of metal or glass-fibber reinforced plastic which are in the form of deep trays with projecting horizontal edges or lips. The pans are laid on temporary frame formwork with the edges touching to form soffits of the ribs. The depth of the pans varies according to the required depth of the ribs.

4.2.2. Proprietary Formwork:

This type of formwork is designed to eliminate timber and to be quickly erected and dismantled. The forms are made up of standard panel units, which can be used for columns, beams, and floors and wall construction as shown in fig.42 a, b, and d.

The units consist of an edge frame of light steel angle or extruded aluminum with cross members, where necessary faced Plywood or sheet steels.

This type of formwork can be reused great many times, but if roughly handled needs considerable maintenance in straightening and in welding up broken and cracked edges. With this type of formwork all-steel support system are used which include adjustable steel props (fig.42 b).

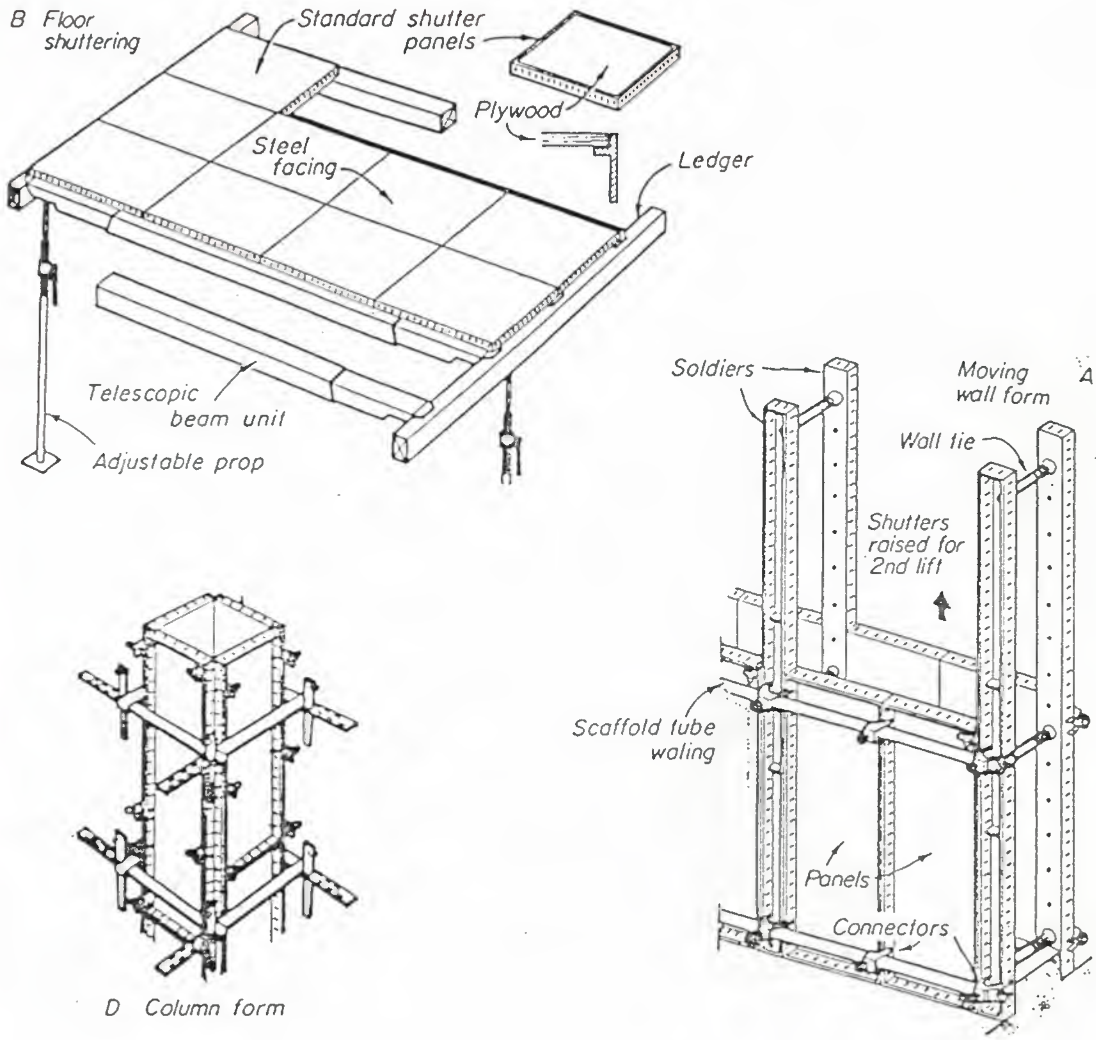


Fig.42 Proprietary formwork (28)

4.2.3 Slip forms or sliding shutters:

For the rapid construction of constant section walls, it is possible to use a continuously rising form, usually known as a slip form or sliding shutter. It has been used to construct such concrete structures such as, buildings, piers, towers, water reservoirs, shafts and chimneys. These are vertical structures, most of that have walls requiring slip forms with two surfaces to confine the concrete. The forms consist of the following parts such as sheathing, walls or ribs, yokes, working platform or deck, suspended scaffolding and lifting jacks (fig.43).

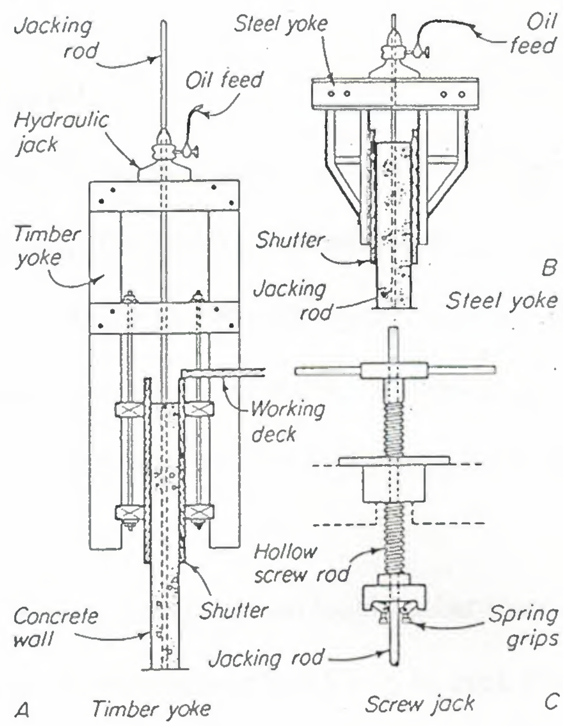


Fig.43 Sliding Shutters (29)

4.2.4 Flying Forms:

It is used to designate a system of form components that are assembled into construction units that may be located and used to form concrete into the desired shapes for a structure, the remove with no disassembly of the parts, moved into anew location and used again.

Each unit of a form system consists of structural components such as trusses or shores, steel or wood beams as stringers, joists and plywood decking.

The forms may be used to support concrete beams, girders, and slabs, shear walls and other parts of the structure. The flying forms may be used in constructing high-rise building (fig.44), and it will reduce substantially bellow the cost of forms provided by conventional methods.

4.2.5 Treatment of Formwork:

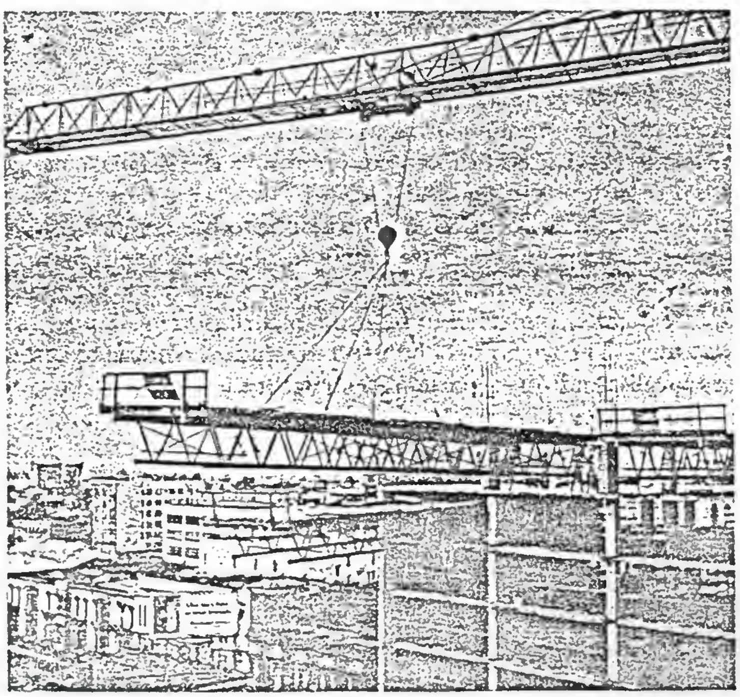
The nature and treatment of the working faces of the formwork, that is the faces in contact with the concrete, will effect the finished surface of the concrete.

All working faces should always be treated with mound oil to prevent the concrete adhering to them thus reduce the damage when the formwork is stripped. To produce a good smooth face, the framework may be lined with plywood, hardboard or plastic sheeting.

Where a patterned surface is required, patterned tough rubber sheet or expanded plastic is used as a lining or glass reinforced plastic forms may be used. Permanent shuttering of precast concrete may be used to provide the final finished face. Concrete pipes may be used for circular columns and concrete slabs for walls.

Wood wool slabs used for thermal insulation to a wall may be used as an inside permanent shutter.

Forms moved out to be flown to higher position (*FORM-EZE*
).



Landing a flying form in a new position (*FORM-EZE Systems*.

Fig.44 Flying forms (30)

Chapter 5

Column Grids and Architectural Space

5.1. Particularities of Architecture of Framed Buildings

It is known that architecture can't exist apart from structure. Structural elements put together to create structural frame of building built up structural space as basic space to be transformed into architectural space. There are strong restrictions in meaning of scale of structural space. These restrictions are based on the capacity of a system to span definite distance or to cover definite area without intermediate supports. In other words vertical and horizontal subsystems of a building being interdependent install strictly definite space inside building to be used as functional and architectural space.

Planes in architecture define three-dimensional volumes of mass and space. The properties of each plane, size, shape, color and texture, as well as their spatial relationship to one another ultimately determine the visual attributes of the form they define and the quality of the space they enclose.

In frame structure all of its members being put together to create space, floor is a horizontal element that sustains the force of gravity as we move around and place objects for our use on it. The texture density of the flooring material influences both the acoustical quality of space and how we feel as we walk across its surface, includes required area for furniture or equipment and circulation of people and mechanical means of functional process. Exterior walls isolate a portion of space to create a controlled interior environment. Their construction provides both privacy and protection from the climatic elements for the interior spaces of a building, while openings within or between their boundaries reestablish a connection with the exterior environment.

Interior walls govern the size and shape of the internal spaces or rooms within a building. Their visual properties, their relationship to one another, and the size and distribution of openings within their boundaries determine both the qualities of the spaces they define and the degree to which adjoining spaces relate to one another.

In frame structure columns are not used only to support beams and slabs. They are also used by means of column grids to afforded new possibilities for the definition and enclosure apace inside and outside the building.

The usage of column grids in frame structure have many advantages as follow:

1. Loads on the structure are transmitted evenly to the foundatin, thus minimising relative settlement and standarising the sizes of foundation slabs.

2. It results in regularity beam depth and column size and in the position of columns and beams relative to walls.

3. In reinforced concrete work the regular slab and beam spans minimise the variations in rod sizes.

4. It permits greater re-use of formwork, both in precast and in-situ concrete construction.

5.2. Column Grid and Space

Plain grid is pattern of lines and joints that articulates division of surface by constituent parts or elements. The organizing power of grid results from the regularity and continuity of its pattern that pervades the elements it organizes. Its pattern establishes a stable set or field of reference points and lines in a space with which the spaces of a grid organization although dissimilar in size, form or function can share a common relationship.

A grid is established in architecture most often by a frame structural system of columns and beams. Within the field of this grid, spaces can occur as isolated events or as repetitions of the grid module. Regardless of their disposition within the field, these spaces if seen as positive form, will create a second set of negative spaces.

Space grid is three-dimensional system of lines and joints, which articulates division of space by constituent parts or elements. Space is form enveloped by surfaces, of course it has shape inside and outside because these surfaces are boundaries between space outside and inside of overall space.

Space is a visual physical medium-bearer of the masses and itself. It is dimensional matter because it can be evaluated on the base of visual perception in accordance with scale. It creates in our consciousness feeling of presence in and orientation.

The eye evaluates metrical properties of space and forms our understanding of space, and the ability to orient ourselves in this space without assistance. Visual space is a part of overall space enveloped with and limited by surfaces of masses involved in its body. Architectural space is a space between surfaces of masses. Surfaces of masses are forming architectural forms and architectural spaces.

In frame structural system columns supports beams and slabs, and during this studying, it will be shown how these column grids and beams form an architectural spaces.

Column grids consists of repetitive modular units of space, it can be subtracted from, added to or layered, and still maintain its identity as a grid with the ability to organize spaces. These formal manipulations can be used to adopt a grid form to its site, to define an entrance or outdoor space, or to allow for its growth and expansion.

A regularly spaced series of columns or similar vertical elements form a colonnade. This archetypal element in the vocabulary of architectural design effectively defines an edge of a special volume while permitting visual and spatial continuity to exist between space and its surroundings. A row of columns can also engage a wall and become a plastered that supports the wall, articulates its surface, and tempers the scale, rhythm, and proportioning of its bays (fig. 45).

A gird of columns within a large room or hall not only serves to support the floor or roof plane above. The orderly row of columns also punctuates the spatial volume, mark off modular zones within the spatial field, and establishes a measurable rhythm and scale, which make the spatial dimensions comprehensible.

In 1926, Le Corbusier stated what he believed to be the "five points of the new architecture". His observation were to a great extent the result of the development of reinforced concrete construction that began in the late nineteenth century (21).

This type of construction in particular the use of concrete columns to support the floor and roof slabs afforded new possibilities for the definition and enclosure of spaces within a building.

Concrete slabs could cantilever beyond their column support and enable the "free facade" of the building to be "light membranes" of screen walls and windows.

In fig. 46 there are two contrasting examples of the use of a column grid are illustrated:

1- A column grid establishes a fix, neutral field of space in which interior spaces are freely formed and distributed.

2- A grid of columns or posts corresponds closely to the layout of the interior spaces there is a close fit between structure and space.

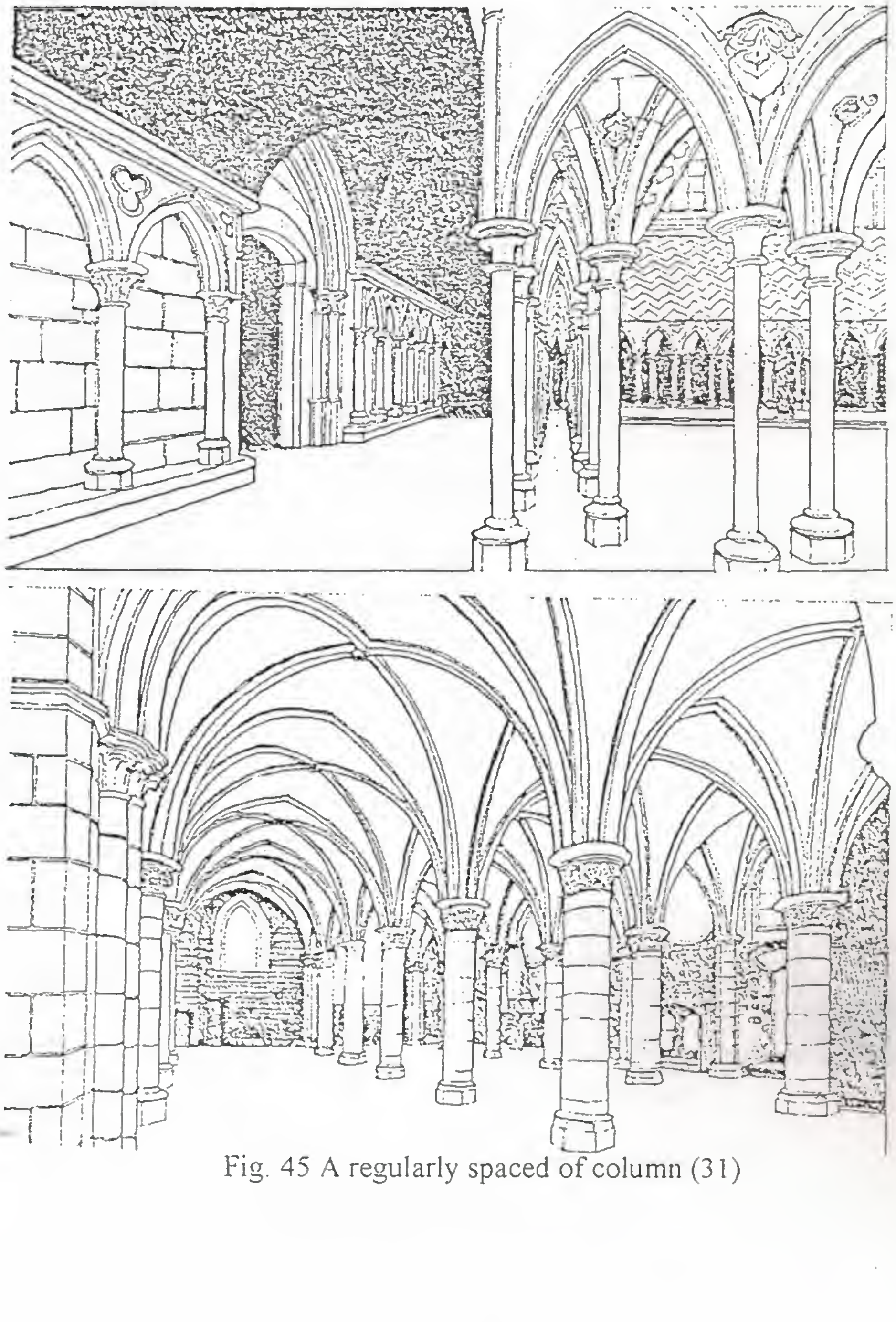


Fig. 45 A regularly spaced of column (31)

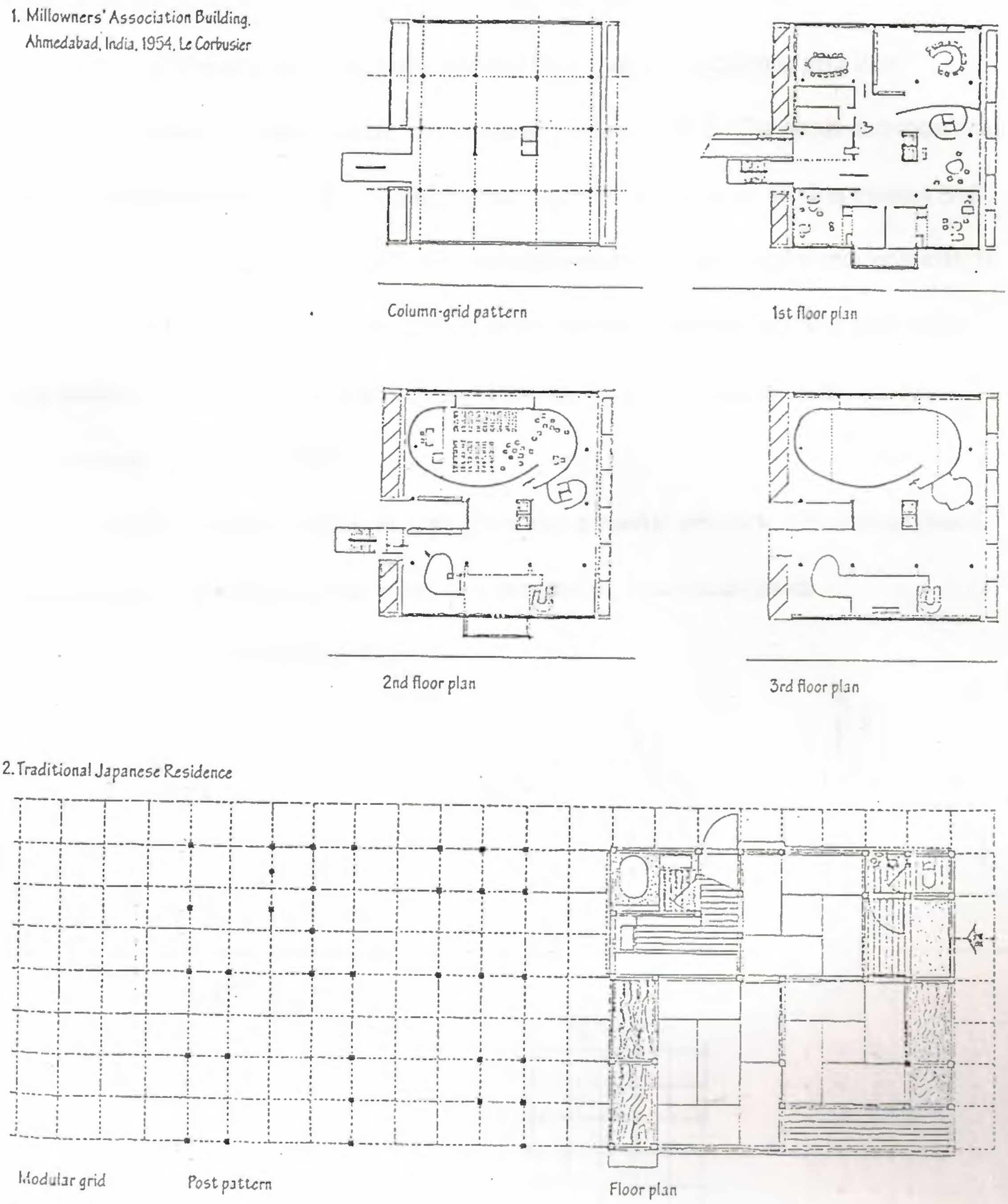


Fig.46 Examples of using column grid (32)

5.3. Geometrical Shapes of Column Grid

The quality of the architecture will be determined by the skill of the designer in the using of column grid to create a space inside and outside the building.

For columns grid plans there are many geometrical shapes of columns grid like:

Orthogonal Grid: It means square and rectangle columns grid. The most common grid is based on the geometry of the square, because of the equality of its dimensions and its bilateral symmetry, a square grid is essentially nonhierarchical and nondirectional. It can be used to break the scale of a surface down into measurable units and give it an even texture. It can beused to warp several surfaces of a form and unify them with its repetitive and passive geometry.

In frame structure, square columns grid generates a spatial network of reference points and lines with its modular frame work, any number of forms and spaces can be visually organized (fig. 47).

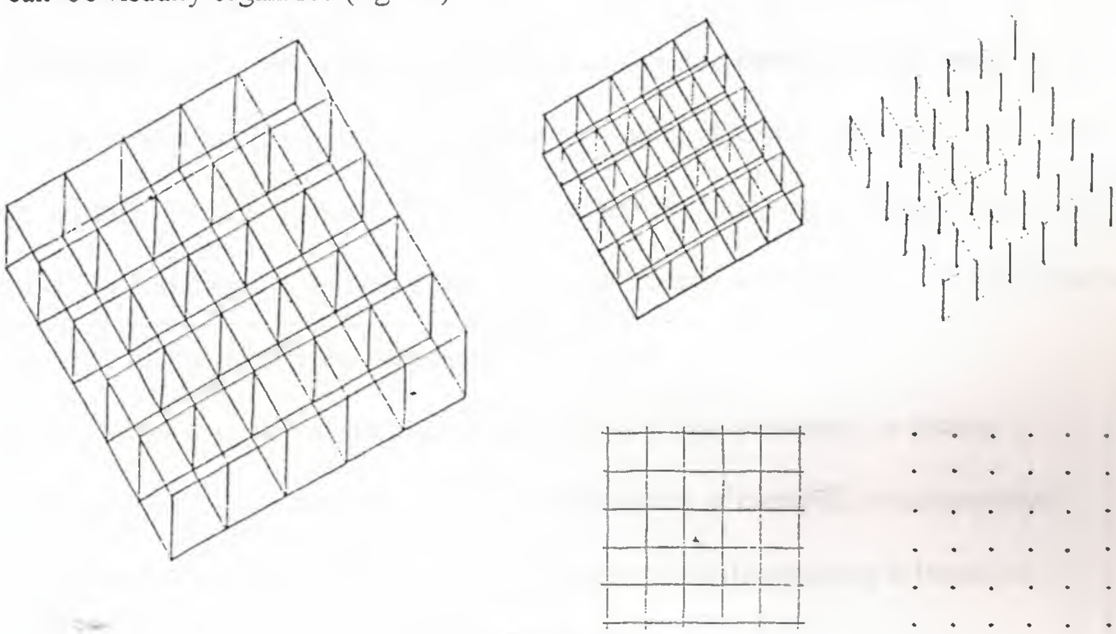


Fig. 47 Orthogonal grid

Triangular Grid: The triangular grid signifies stability, when resting on oneof its sides, the triangle is an extremely stable figure. When tipped to stand on one of its vertices, however it can be balanced in a precarious state of equilibrium or be unstable and tend to fall over onto one of its sides (fig.48 a, b, c).

Polygonal Grid: A clustered organization can also consist of polygonal column grid, that are generally equivalent in size, shape, and function.

These forms are visually ordered into a coherent, nonhierarchical organization not only by their close proximity to one another, but also by the similarity of their visual properties (fig.48 d, e).

Circle Grid: The circle is a centralized, introverted figure that is normally stable and self-centering in its environment. A circular form can be freestanding into its context to express its ideal shape and still incorporate a more functional, rectilinear geometry with its boundaries (fig. 48 f).

Combination of orthogonal, polygonal-triangular and circle columns grid:

During architectural compositions of these different grid forms, real differences exist among their forms and spaces. These differences reflect the degree of importance of these forms and spaces, as well as the functional, formal, and symbolic roles they play in the organization of different shapes of columns grid.

A form or space can be made visually dominant and thus important by clearly differentiating its size and shape from that of the other of elements in composition.

A discernible contrast in shape is critical, whether the differentiation is based on a change in geometry a regularity.

The shape also selected for the hierarchically significant element be compatible with its functional use.

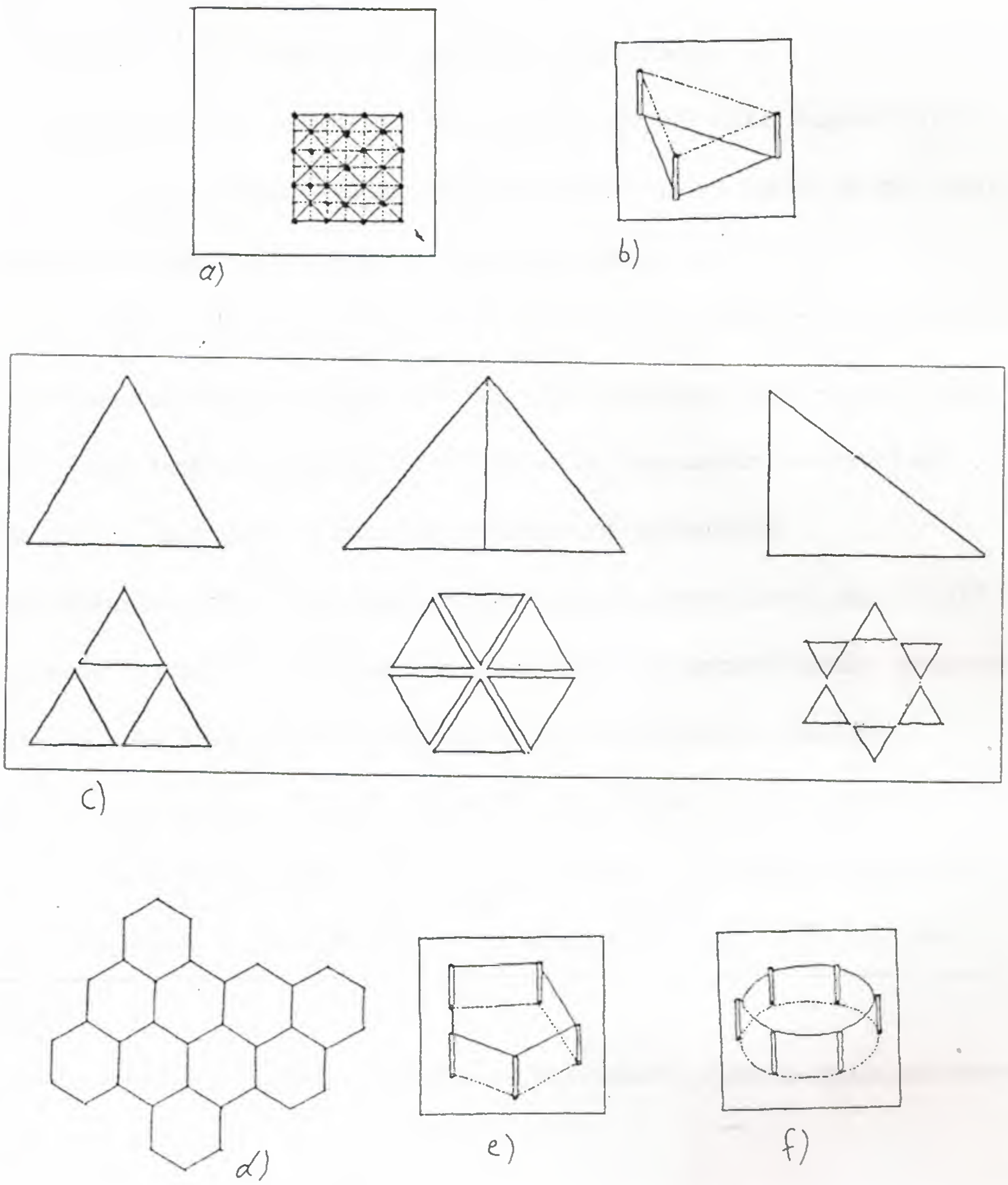


Fig. 48 Triangular, Polygonal and Circular grid

The composite shapes are choosing according to:

- Their closeness or proximity to one another.

- The visual characteristics they share in common.

All of these forms of columns grid can used for any building.

The combination of these forms can be regular and irregular forms. Regular forms refer to those parts are related to one another in a consistent and orderly manner. They are generally stable in nature and symmetrical about one or more axes.

Irregular forms are those whose parts are dissimilar in nature and related toone another in an inconsistent manner. They are generally asymmetrical and more dynamic than regular forms, they can be regular forms from which irregular elements have been subtracted or result from an irregular composition of regular forms.

Additive forms resulting from the accretion of discrete elements,can be characterized by their ability to grow and merge with other forms. For us to perceive additive grouping as unified compositions of form, the combining elements must be related to one another in a coherent manner which will be consider in the following section.

There are many different forms of column grids which are differing in geometry or orientation maybe incorporated into a single organization for any of the following reasons:

- To accommodate or accentuate the differing requirements of interior space and exterior form.

- To express the functional or symbolic importance of a former space with in its context.

- To inflect a space toward acetified feature of a building site.

- To carve a well-defined volume of space from a building form.

- To express and articulate the various constructional or mechanical systems that exist within a building form.

- To reinforce a local condition of a symmetry in a building form.

- To respond to contrasting geometries of the to pography, vegetation, boundaries or existing structures of a site.

- To acknowledge an already existing path of movement through abuilding site.

These combination of different forms of column grid can used for any kind of buildings, such as civil, industrial, and residential buildings without facing and problem in designingand construction.

The quality of architecture solution will be determined by the skill of the designer in the using of column grids to create space inside and outside the building,according to the different forms which combined together as it is shown in the following forms.

•This form combined of hexagon, octagonal and square forms which are different in sizes and orientation (fig.49).

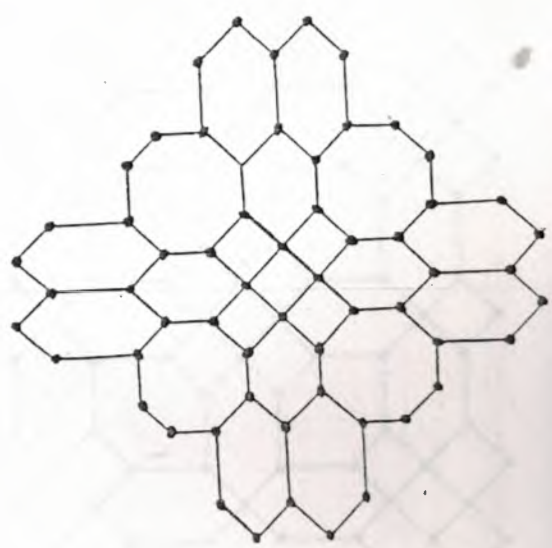


Fig.49 Composite forms

• This form consiste of octagonal, hexagon, square and rectangular forms which are diferent in sizes according to the function of the building (fig.50 a).

• Another form is shown in the opposite side which consists of different size of square, hexagon and central rectangular form (fig.50 b).

• In the opposite form another different forms combined together (fig.50 c).

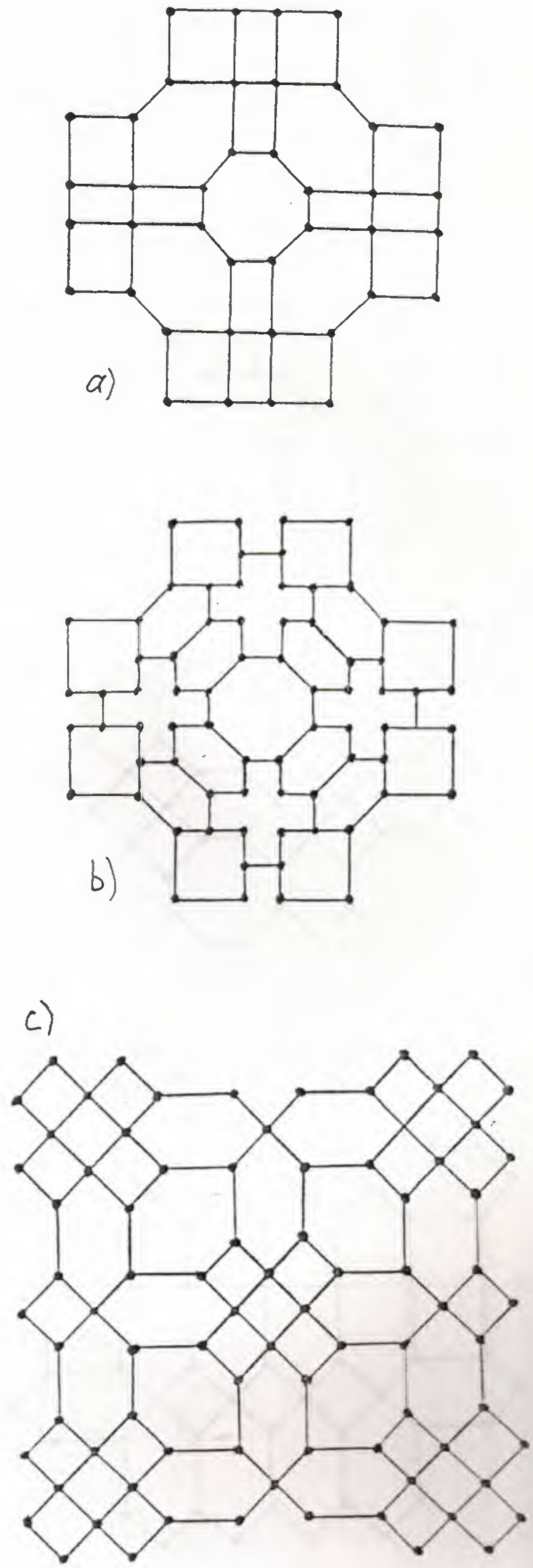


Fig.50 Composite forms

In fig.51a, it consists of two different forms, square and hexagon which is different in sizes and orientation

In fig.51b, it consists of three different forms, square, hexagon and polygonal

In fig.51c, it consists of three forms, hexagon, rectangular, and square form.

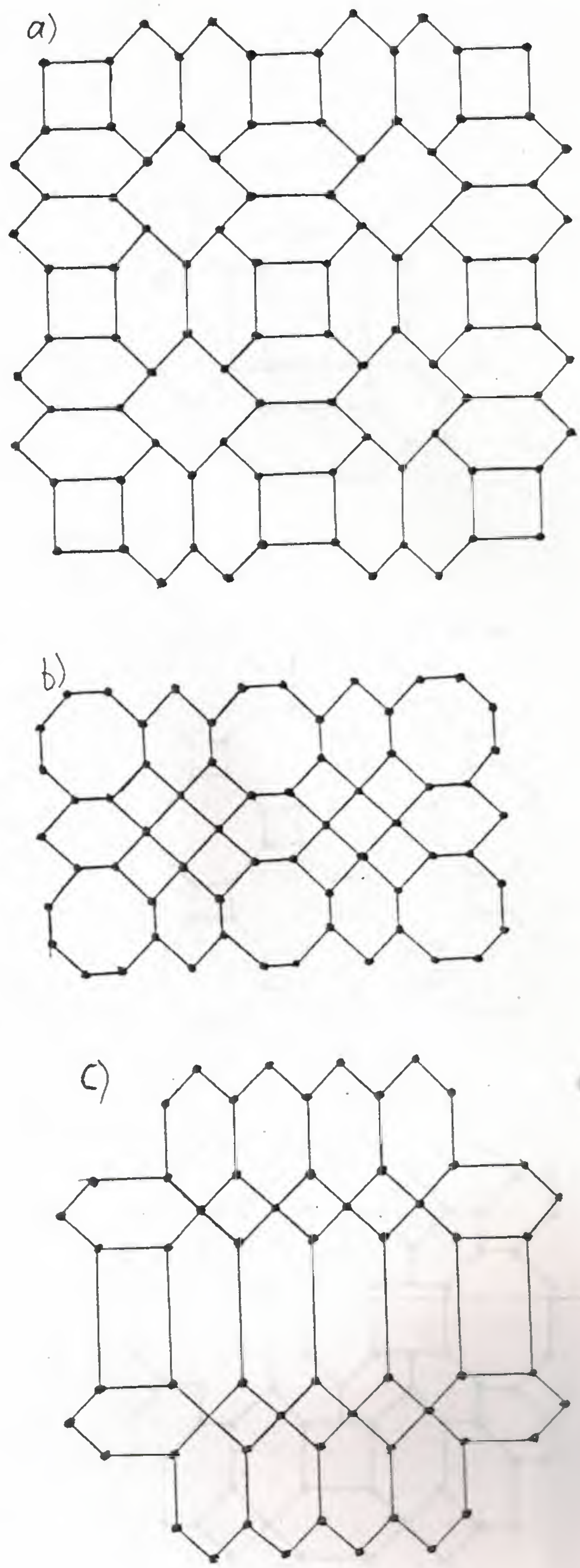
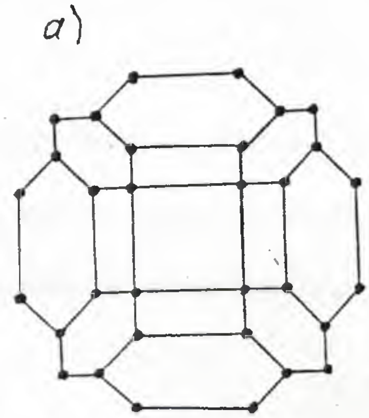


Fig.51 Composite forms

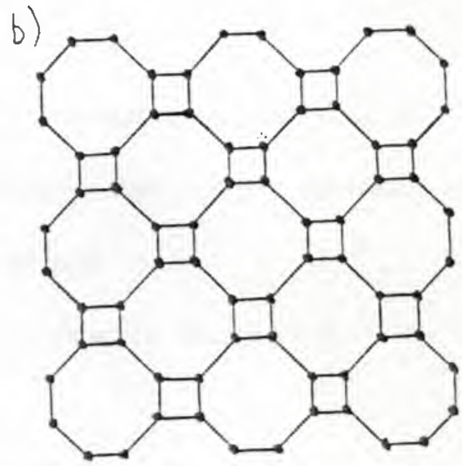
In fig.52a, it consists of three forms,

hexagon, rectangular, and square form.



In fig.52b, it consists of two forms,

octagonal , and square form.



In fig.52c, it consists of three forms,

hexagon, octagonal, and square form,

which is different in sizes & orientation

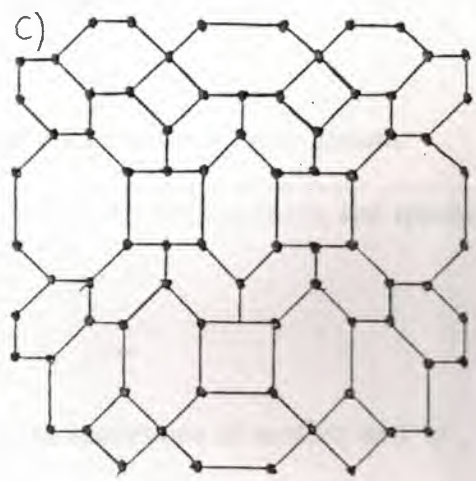


Fig.52 Composite forms

5.4. Organization of Column Grid

In frame structural system according to columns grid forms, the following section lay out the basic ways which we can arrange and organize the spaces of a building (22). In typical building program,three are usually requirements for various kind of spaces. There may be requirements for spaces that:

- have specific functions or require specific forms.
- have similar functions and can be grouped into a functional cluster or repeated linear sequence.
- require exterior exposure for light, ventilation, out look, oraccess to outdoor spaces.

The manner in which these spaces are arranged can clarify their relative importance and functional or symbolic role in organization of column grid.

The decision as to what type or organization to use in a specific situation will depend on:

- demands of the building program, such as a functional proximities, dimensional requirements, hierarchical classification of spaces, and requirements for access light or view.
- exterior conditions of the site that might limited the organization form or growth.

Each type or columns grid organization discusses the formal characteristics, and spatial relationships, each type will be studied in terms of.

- The kinds of space are accommodated and where.
- What kinds of relationships are established among the spaces one of another, and to the exterior environment.

- Where can the organization be entered and what configuration does the path of circulation have.

Linear organization of column grid

Alinear organization consists essentially of a series of spaces,these spaces can either be directly related to one another.Alinear organization usually consists of repetitive spaces which are alike in size, and function (fig.53).

It may also consist of a single linear space that organizes alongits length a series of spaces that differ in size, form or function. In both cases, each space along the sequence has an exterior exposure.

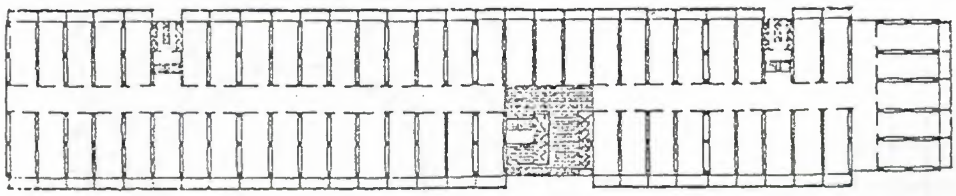
Because of their characteristic length. Linear organization express a direction and signify movement, extension, and growth. To limit growth linear organization can be terminated by a dominant space or form, by an elaborate or articulate entrance, or by merging with another building form or the topography of its site.

The form of a linear organization is inherently flexible and can respond readily to various conditions of its site. It can adopt to changes in topography, maneuver around body of water or a stand of trees or turn to orient spaces to capture sunlight and views. It can be straight, segmented or curvilinear.

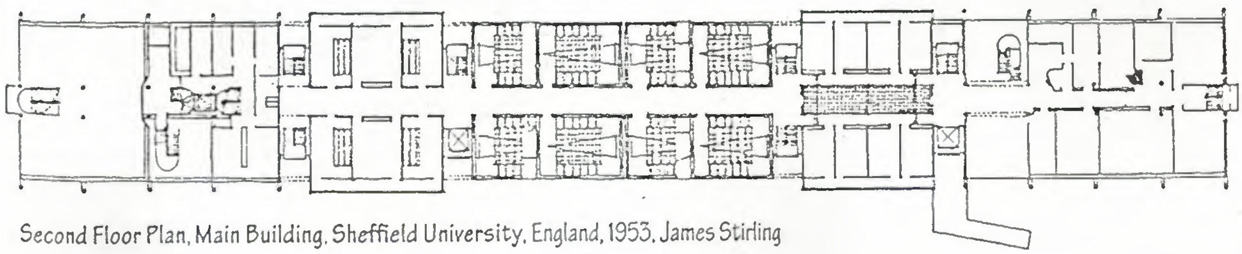
The form of linear organization can relate to other forms in its context by:

- Linking and organizing them along its length.
- Surrounding and enclosing them within a field of space.

Curved and segmented forms of linear organizations enclose a field of exterior space on their concave sides and orient their spaces toward the centre of the field.



Typical Apartment Floor, Unité d'Habitation, Marseilles, 1946–52, Le Corbusier



Second Floor Plan, Main Building, Sheffield University, England, 1953, James Stirling

Fig.53 Linear organization of column grid (33)

Centralized organizations of column grid

A centralized organization is a stable concentrated composition that consists of a number of secondary spaces grouped around a large dominant, central spaces (fig.54), the secondary spacesof the organization may be equivalent to one another in function, form, and size, and create an overall configuration that is geometrically regular and symmetrical about two or more axes.

The secondary spaces may differ from one another in form or size in order to respond to individual requirements function, express their relative importance, or acknowledge their surrounding.

This differentiation among the secondary spaces also allows the form of a centralized organization to respond to the environmental conditions of its site.

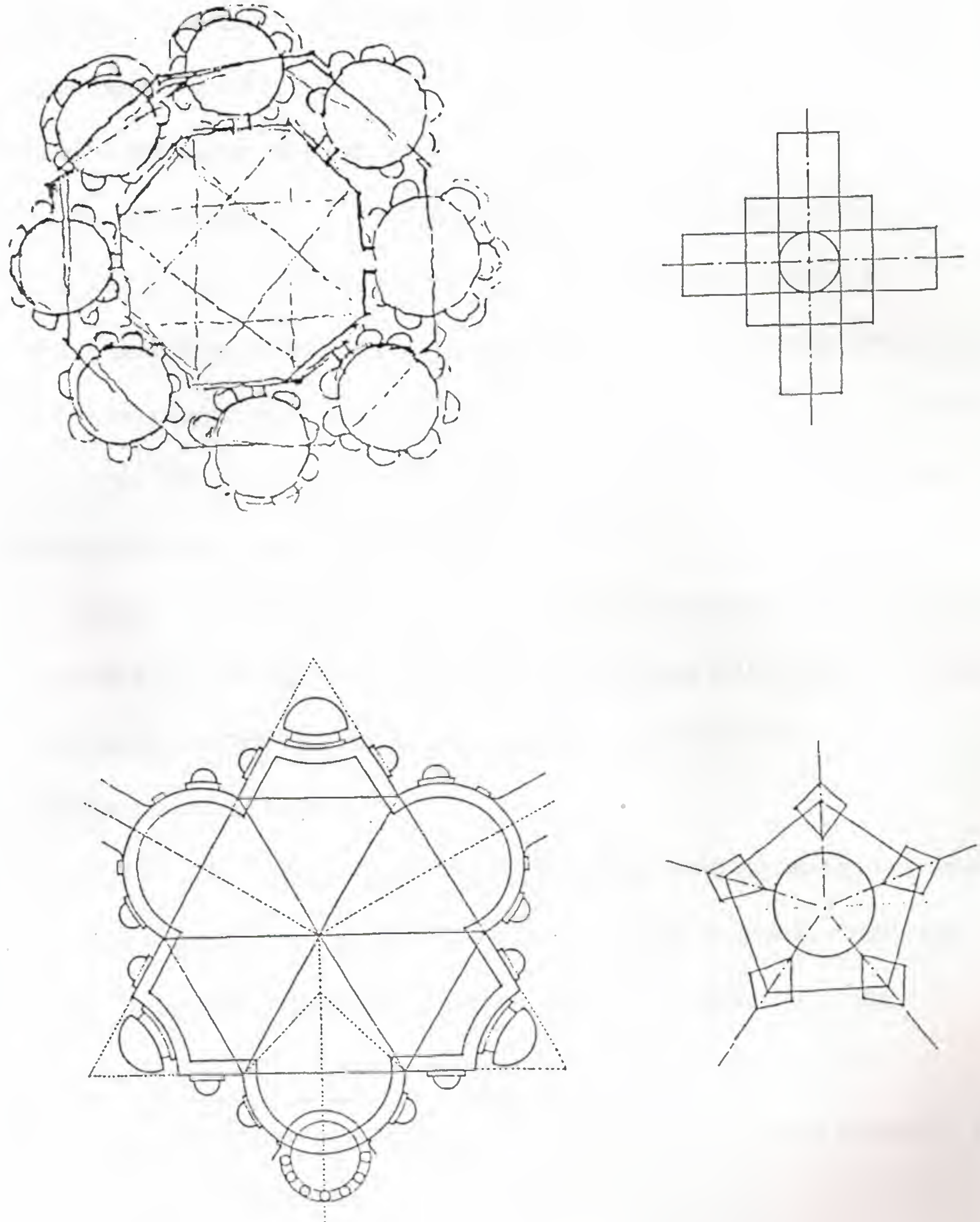


Fig.54 Centralized organization (34)

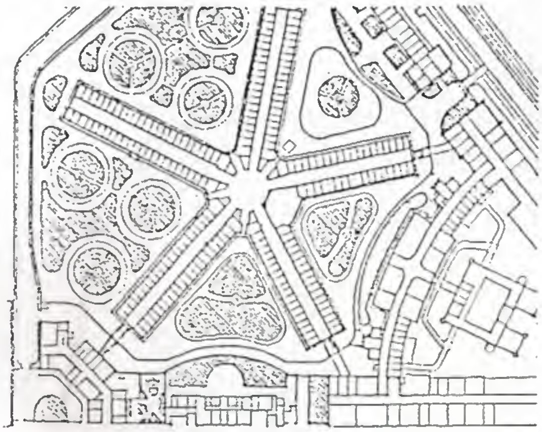
The pattern of circulation and movement within a centralized organization may be radial, loop, or spiral in form.

Radial organization of column grid

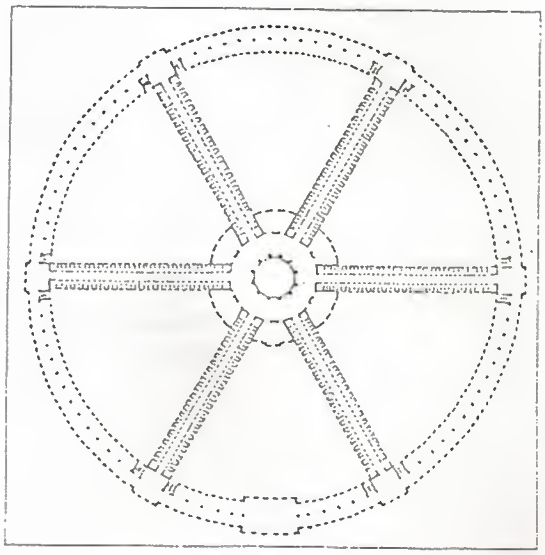
A radial organization of space combines elements of both of both centralized and linear organizations. It consists of dominantcentral space from which a number of linear organizations extend in a radial manner. Where as a centralized organization is an introverted scheme that focuses inward on its central space, a radial organizati on is an extroverted plan that reaches out to its context. With its linear arms, it can extend attach itself to specific elements or features of its site (fig.55,56).

As with centralized organizations, the central space of a radial organization is generally regular in form. The linear arms, for which the central space is the hub, may be similar to one another in form and length and maintain the regularity of the organizations overall form.

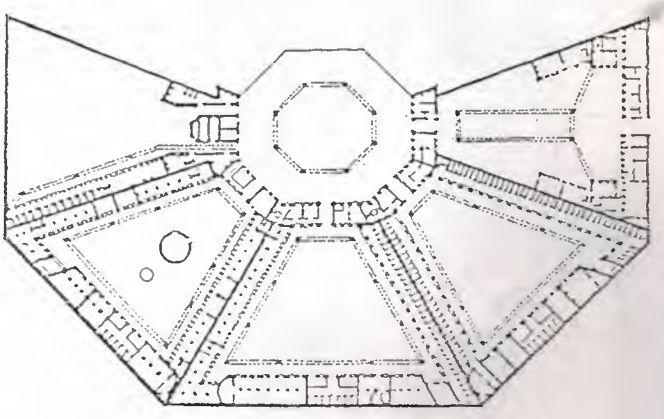
The radiating arms may also differ form of columns grid from one another in order to respond to individual requirements of function and context. A specific variation of a radial organization is the pinwheel pattern where in the linear arms of the organization extend from the sides of a square or rectangular central space. This arrangements results in a dynamic pattern that visually suggests a rotational movement about the central space.



Moabit Prison, Berlin, 1869–79, Herrman



Hôtel Dieu (Hospital), 1774, Antoine Petit



Maison de Force (Prison), Ackerghem near Ghent, Belgium, 1772–75, Malfaison and Kluchman

Fig.55 Radial organizations plans (35)

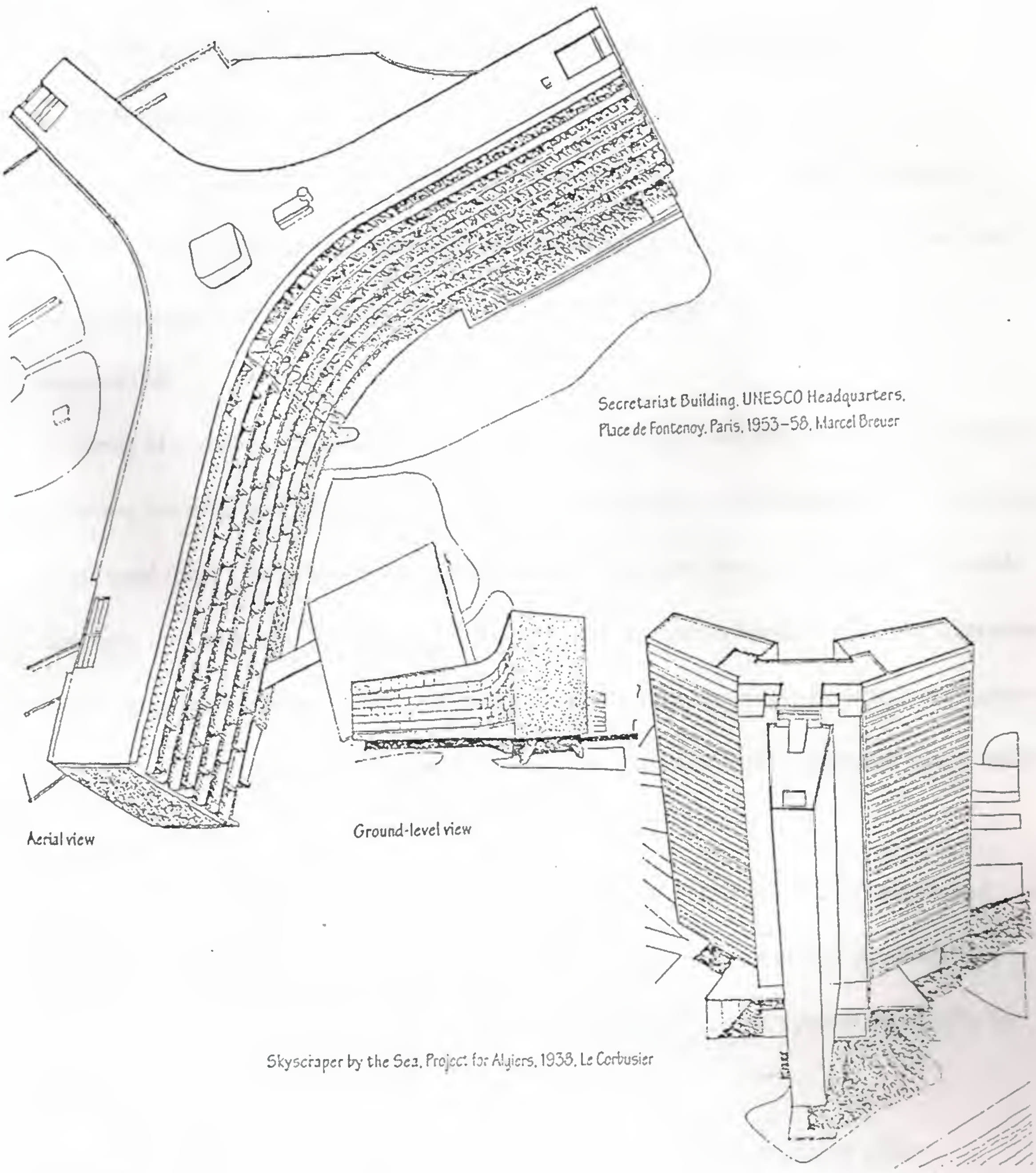


Fig.56 Radial organizations (36)

CONCLUSION

On the basis of aspects that considered in the thesis, there is possible to draw conclusions, which could be categorized according to their importance. Some of them are a very commonly and another particular that could be applied to the local conditions of the Middle East.

Reinforced concrete skeleton type buildings in the base of which frame structural system and its combinations lies together with other structural system have a number of advantages such as, functional, structural planning, architectural technological and economical .

In terms of function the reinforced concrete skeleton type building offer the freedom of function introduction based on the minimum volume of structural elements of a building in its total (bulk). In other words the space restrictions for the introduction of the main function into bulk of a building are done up to the minimum because of linear character of the main constituent structural elements of a building-columns, the linear character of structural elements and small size of close section allows to use maximum space inside buildings.

From structural point of view where the main problem is providing of strength and stability of a building influences of the forces, the reinforced concrete skeleton type buildings have certain advantages over wall and shaft structural system especially for buildings over 5 stories.

On the other word, in combination with mentioned above systems they offer possibilities for most effective structural solutions in terms of strength and stability, for example frame-and-shear wall systems, frame and shaft system etc.

From the planning point of, view the reinforced concrete skeleton type buildings allow solution of planning with the minimum restriction due to the minimum column-sectional area to total area of a building ratio. On the other hand the development of planning in reinforced concrete skeleton type building takes place into two orthogonal direction instead of linear one in wall structural and shaft structural systems.

Architectural solutions of reinforced concrete skeleton type buildings have no restrictions in the development of the architectural space in horizontal and vertical planes (directions).

They allow construction of buildings of any number of stories and of any length.

Structural division of the outer envelope of a building in horizontal and vertical directions is based upon the nature of frame structural system. Introduction of transparent enclosure of a building together with different types of effective paneling and cladding allows variety of arch solutions, which cannot be easily realized, in, for example, wall structural system.

There fore architectural- compositional capacity of reinforced concrete skeleton type buildings are based on linear character of their structure elements.

The development of modern construction allows the use of precast concrete members and industrial methods of based on different types of modern shattering systems.

Economical advantages and particularities of reinforced concrete skeleton type buildings are rised with the rise of a building in height. More effective construction in comparison with wall structural system.

Those economical advantages of reinforced concrete skeleton type buildings are based on the following particularities:

a) Minimizing of dimensional characteristics of structural elements columns and beams.

b) minimization of material and energy consumption on the base of their sizes. minimization of the total mass (dead load) of a building on the base of their sizes minimization.

c) Simplification of engineering systems layout based on planning mobility of frame system.

All noted above advantages stimulate the application and providing of reinforced concrete skeleton type buildings in the Middle East countries where restriction of raw material and labor force abundance create extremely good and reasonable base for their application.

Development of new types of column grid presented in chapter 5 together with studies of their structural, functional and architectural capacities will allow developing architectural solution of buildings constructed and designed in frame structural systems.

NOTES

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NOTES OF FIGURES

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