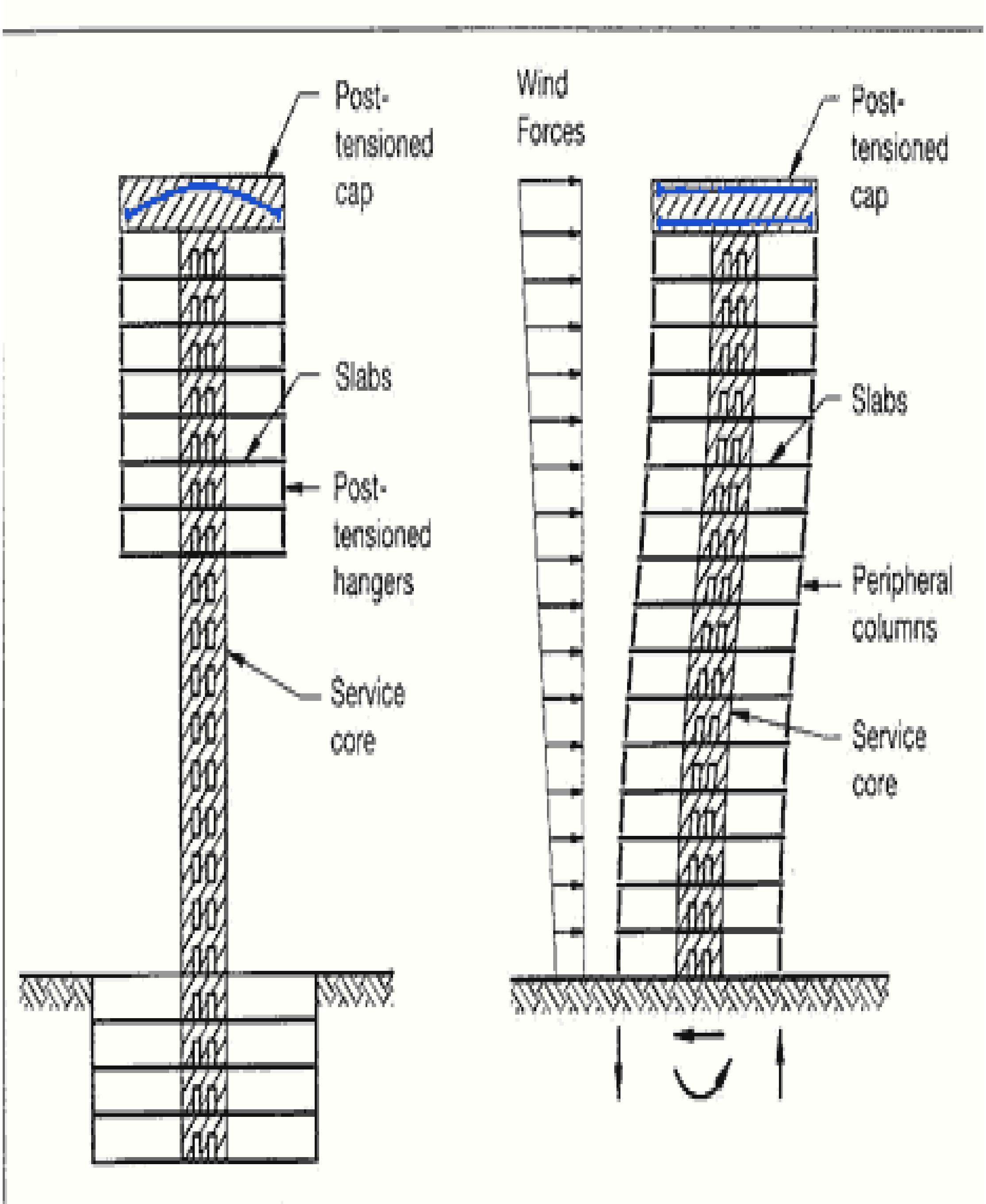
الاجهادات اللاحقة في الأبنية

Presterssing concrete (post-tensioning) In buildings

اعداد

المهندس زيدان ربيع مرداس



(a) To Support Hanging Floors (b) To Increase Lateral Stiffness

Introduction

Buildings can be classified in many different ways. They can be distinguished by:

- their use or occupancy.

-the construction materials.

-their owners (public / private).

-their height (low – rise / high – rise).

Here two representative building types , distinguished primarily by the predominant direction in which the construction progresses , are used to demonstrate some general objectives to be considered in the conceptual design.

The A.C.I. committee on prestressed concrete gives one of the most apt descriptions of post – tensional concrete .

Prestressed concrete is concrete in which there have been introduced internal forces of such size and distribution that forces resulting from given external loadings are counteracted to a desirable degree.

In 1989 the Structural Division of the South African Institution of Civil Engineers created a sub-committee to examine the design of prestressed concrete flat slabs. It was found that a certain amount of poor design was common, and the committee decided to produce a booklet of recommendations for good practice.
The matter was considered especially important because the South African Loading Code was changed with effect from 1990, and the required factor on D.L. is now 1.2, whereas it was previously 1.4. This has the effect of reducing reinforcement areas, and cracking and deflection require more attention. To make allowance for this, and among other

changes, the allowable concrete shear stress was reduced by 10 percent, to lessen the probability.
Flat slabs were originally invented in the USA at the beginning of this century, and there were a number of patented systems.

The early reinforced concrete flat slabs all had drops, and columns with capitals, and were considered to be the Structure of choice for warehouse construction and heavy loads. Because of the columns capitals and drops, shear was not really a problem.

Design was based on tests on stresses in reinforcement at working loads, and the early codes required a total moment in a span of WL2/11.

It was realized that statically a total moment of about WL2/8 was required for equilibrium, (If the column diameter is D, the statically required moment is (very closely) W(L-2D/3)2/8 where L-2D/3 is the effective span. The difference between WL2/11 and WL2/8 was attributed to a mystical '2 way action'. In fact it was due partly to tensile stresses in the concrete and partly to arching effects reducing the measured stress in the reinforcement.

The philosophy, and the empirical coefficients, persisted until the 1950's when the allowable stresses in reinforcement were increased, limit state design was introduced, and the statically required moment of WL2/8 was introduced into the codes.
This was because it was felt that it was not safe to rely on arching or tensile strength of the concrete.
In addition to the changed moment coefficients, the frame method of analysis was required in certain cases.

When Eugene Freyssinet developed and patented the technique of prestressing concrete in 1928 he little realized the applications to which his invention would be put in future years .

Spectacular growth in the use of prestressed concrete took place after the second world war with the material use to repair and reconstruct bridge in Europe.

Post Tensioned in Buildings

In post – tensioning we obtain several distinct advantages :

A -Designers have the opportunity to impart forces internally to the concrete structure to counteract and balance loads sustained by the structure thereby enabling design optimization.

B -Designers can utilize the advantage of the compressive strength of concrete while circumventing its inherent weakness in tension.

C -Post –tensioned concrete combines and optimises tody's very high strength concretes and steel to result in practical and efficient structural system .

The first post tensioned building were erected in the USA in the 1950 's using unbounded post – tensioning .

POST – TENSIONING in building can be loosely into two categories:

1 -THE first application is for specialized structural element such as raft foundation , transfer plates , transfer beams , tie beams and the like . for large multi-strand tendons used in these element , 15.2 mm diameter seven wire strands are preferred . the anchorages used are the freyssinet C range as shown in figure 1 below . this system can be used internally within the concrete section or externally .

- Figure-1

multi-strand anchorage

2- The second application is for building floor system ,the advantages and economics of which are discussed below . the preferred slab system for building works in Australia is the well proven bonded tendon which contains between 2 and 5 , 12.5 mm diameter seven wire prestressing strands with an ultimate tensile strength of 184 kn .housed in oval ducting .the strands are anchored in flat fan shaped anchorages and stressed mono-strand (that is one at a time) using light weight jacking equipment . figure 2 below shows the cast iron anchorage guide ,stressing block , reusable recess former and wedges. Minimum slab thickness for adequate edge distance, cover to anti-burst reinforcement and the like is 130 mm for 2 strands , 140 mm for 3 strands and 150 mm for 4 and 5 strands .

Figure -2-

Slab system anchorage components

Post –tensioning helps to meet each single one of design objectives .

The most famous ones are that Post –tensioning allows the floor farming to be more slender , solving the problem of the differing needs for long spans and small structural depth , and that it replaces a important amount of reinforcement , thus reducing steel quantities and allowing standardization and simplification of the reinforcement . further reasons why post – tensioning helps to improve the design are that usually the concrete quantities are reduced .

WHY DO WE USE BONDED TENDONS ?

Well there are a number of advantages higher flexural capacity good flexural crack distribution good corrosion protection and flexibility for later cutting of penetration and easier demolition however there are some disadvantage such as an additional operation for grouting and a more labor intensive installation .The main reason why bonded tendons are preferred relates to the overall cost of the structure and not just of the Post –tensioning . with unbounded tendons it is usual to have a layer of conventional reinforcement for crack control .

Using bonded tendons there is no such requirement and therefore the overall price of bonded Post –tensioning and associated reinforcement is less than for bonded tendons .

For unbounded tendons the Post –tensioning price may be less , but the overall cost of reinforcement materials is greater.

Post – tensiond concrete slab in building have many advantage over reinforced concrete slabs and other structural

system for both single and multi-level structures .some of the main advantages are described below :-

1-longer spans

Longer spans can be used reducing the number of columns . this results is larger ,coloum free floor areas which greatly increase the flexibility of use for the structure and can result in higher rental returns.

2-overall structural cost

The total cost of materials , labour and formwork required to construct a floor is reduced for spans greater than 7 meters ,thereby providing superior economy .

3-Reduced floor to floor height

For the same imposed load ,thinner slabs can be used .the reduced section depths allow minimum building height with resultant saving in façade costs .alternatively , for taller building it can allow more floors to be constructed within the original building envelope .

4-Defliction free slab

Undesirable deflections under service loads can be virtually eliminated .

5-waterproof slabs

Post – tensioned slabs can be designed to be crack free and therefore waterproof slabs are possible. Achievement of this objective depends upon careful design , detailing and construction .the choice of concrete mix and curing methods along with quality workmanship also play a key role .

6-Early formwork stripping

The earlier stripping of formwork and reduced back propping requirement enable faster construction is explained further in the next section on economics .

7- Materials handling

The reduced material quantities in concret and reinforcement greatly benefit on-site carnage requirement .the strength of Post – tensioning strand is approximately 4 times that of conventional reinforcement .therefore the total weight of reinforcing material is greatly reduce .

8-column and footing design

The reduced floor dead loads may be utilized in more economical design of the reinforced concrete columns and footing .in multi-storey building , reduced column sizes may increase floor net let table area .

STRUCTURAL SYSTEMS

The three most common floor system used for building structures such as offices , shopping centers and car parks are the flat plate , flat slab and banded slab . for high rise construction a fourth system is widely used which consists of band beams at relatively close spacing spanning from the building perimeter to the service core.

Although economy of each of these depend primarily on the span and applied load it is generally true to say that a band beam scheme is cheaper than a flat slab which in trun is cheaper than a flat plate .

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beam scheme is cheaper than a flat slab which in trun is cheaper than a flat plate .

To illustrate this an analysis was carried out on a structural for each of the three systems to show the percentage cost of each structural component . the schemes were based on a coloumn grid of 8.5 m and imposed load of 5 kpa.

A total relative cost figure , also shown is obtained by multiplying each structural element by its cost rate .this rate varies from country to country , but the style will remain unchanged .refer to table 1 below .

Floor system	Flat Plat	flat slab	banded slab
Concrete	25	24	24
Reinforcement	6	6	8
Post-tensioning	26	23	20
formwork	43	47	48
Total	100%	100%	100%
Relative total cost	1	0.97	0.96

Table 1. percentage floor cost .

Post-tensioning is not limited to simple flat slab and the rang of structural types which can be economically stressed is almost limitless. Some of the most common floor system are presented below along with recommended concrete size and span to depth ratios .

It should be noted that although often only of secondary consideration , the choice of the system can depend upon factors other than column spacing , imposed loads and economics headroom clearance for services .

1-Flat plate

USED **where spans are similar both direction**

Economic span range **7. To 9. M.**

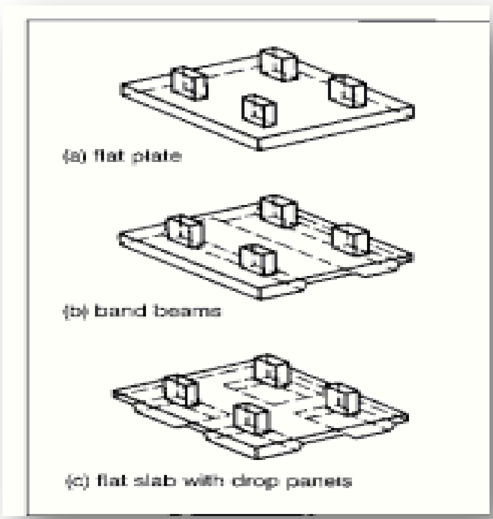
Imposed loads **up to 7.5 kpa .**

2-flat slab

USED **where spans are similar both direction**

Economic span range **up to 13.0 M.**

Imposed loads **up to 10.0 kpa .**



3-banded slab

USED — **span predominant in one direction**

Economic span range — **band beam :8.0 to 15.0m**

Slab : 6.0 to 10.0 m

Imposed loads — **up to 15.0 kpa .**

4- High rise banded slab

USED — **long span high rise construction**

Economic span range — **band beam :9.0 to 15.0m**

Imposed loads — **up to 7.5 kpa .**

__Preliminary sizing of post – tensioned floors__

The other effect responsible other decision criteria relate to the type of loading (small or large variable gravity loads) and whether or not the element is expected to develop plastic hinges during large intensity seismic response .generally the bonded system is to be chosen when the variable gravity loads are high in relation to the permanent loads since only a small portion of the total load can be balanced by draped tendons. The amount of additional reinforcement required to resist the bending moment produced by full loading or substantially greater when pattern loading would be unbounded tendons were used .bonded post tensioning is also to be favored for beams or columns of seismic load resisting frames required to waste energy in plastic hinges .

Post tensioned can be thinner for a given loading and deflection limitation than reinforced concrete floor .

This is primarily because of the load –balancing effect of the draped tendons as illustrated in the fig below, in the span deviation forces cause by the curved tendons act on the concrete to resist gravity . where the tendon curvature is inverted , i.e. Over the grid lines between the columns the difference forces act downward .inserting concentrated loads on the'' column strip '' tendons . i.e. The tendons running along the grid lines . these concentrated forces are balanced by the upward acting difference forces from the column strip tendons which in turn insert a downward acting force on the column .

Thus the system shown in fig. can be compared to a net strung between the columns .the difference forces act downward , inserting concentrated loads on the column strip tendons .ie.the tendons running along the grid line .

concentrated forces are balanced by the upward acting difference forces from the column strip tendons which in turn insert a downward , acting forces on the columns . thus the system shown in fig. below can be compared to net strung between the column . when this net is stretched from all four edges it inserts the load – balancing forces on the concrete . the amount of prestressing steel can be determined by the condition that the draped tendons provide sufficient distributed deviation force to load –balance a certain percentage of the floor self weight .this percentage depends on the ratio of total load to permanent load and is typically between 70 and 130%.for typical office or residential floors with live loads of 3 to 4 kn/m2 and 1 kn/m2 additionall permanent load one would normally balance 70 to 90% of the self weight while for floors with higher live loads more than 100% of the self weight would be load – balanced .

The other effect responsible for the improved deflection and cracking behavior of Post tensioned floor is the in-plane compression stress field in the concrete stemming from the anchorages of the prestressing tendons .provided that there

are no significant restraints these compression stresses neutralize apart of the flexural tensile stresses caused by the portion of the loading not balanced by deviation forces from the tendon drape .typically the post – tensioning in floor provides an average in- plane compression stress of 1.0 to 2.5 n/mm2 .Now let us look typical span –to- depth ratios of Post tensioned floors. For light loading say up to about 30.5kn/m2 and provided that punching shear is not critical .a post-tensioned flat plate can be designed with a thickness of about 1/40 of larger span dimension for interior panels compared to about 1/30 for a flat plate in reinforced concrete .

If drop panels are provided over the columns the span – depth ratio can be increased to about 45 and 35 for interior panels of post - tensioned and reinforced concrete slabs respectively .for higher superimposed loading the span / depth ratio decreases particularly if the super – imposed load is predominantly variable in place and time .

Then the amount of post tensioning cannot simply be increased to load – balance the super – imposed load so that in order to meet the deflection limitation greater floor thickness is required .

Details improving the constructability of post – tensioned floors .

One of the most effective ways to safeguard against construction delays and to avoid unacceptable crack widths is to specify appropriate connection details and prestressing arrangements .

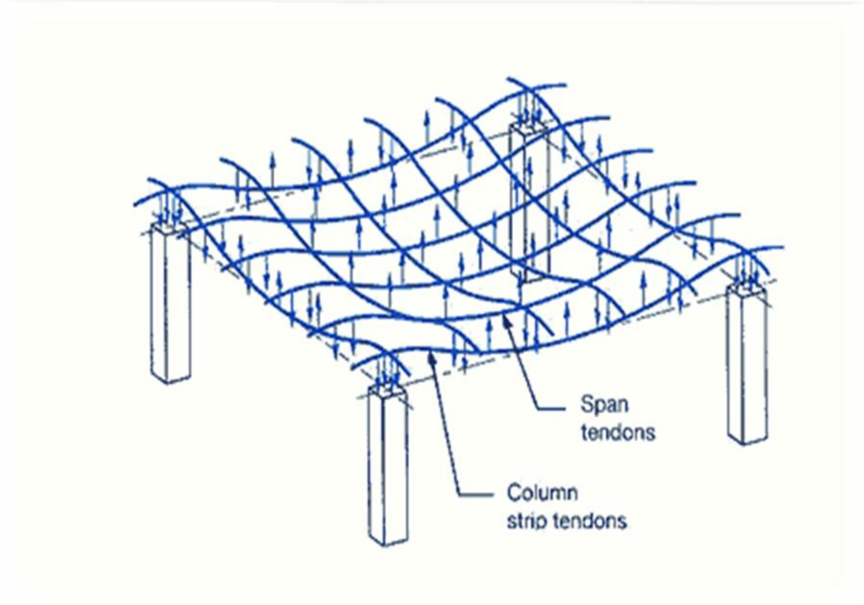
One of the first decisions in the conceptual design of a building is whether and where expansion joints are be provided in the floor system if there is not important restraint by stiff vertical members very large post – tensioned floors can be constructed without any expansion joints since the compression stress compensates shrinkage and temperature induced tensile stresses to a large . fig below

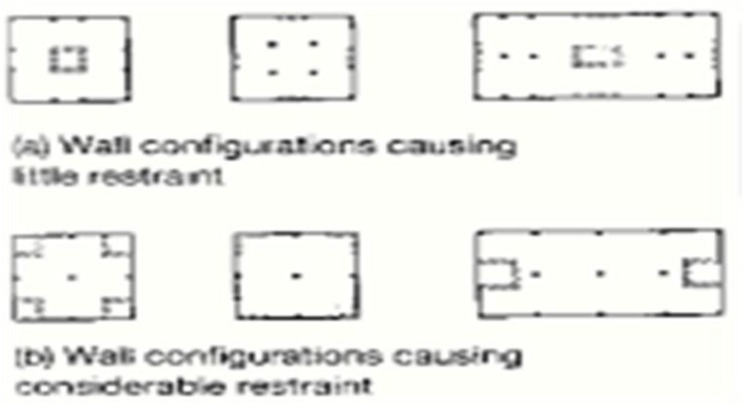
Illustrates how the arrangement of the supporting walls stiff columns and service cores positively or negatively influences the design in this respect.

Wherever possible, arrangments according to fig. blow.

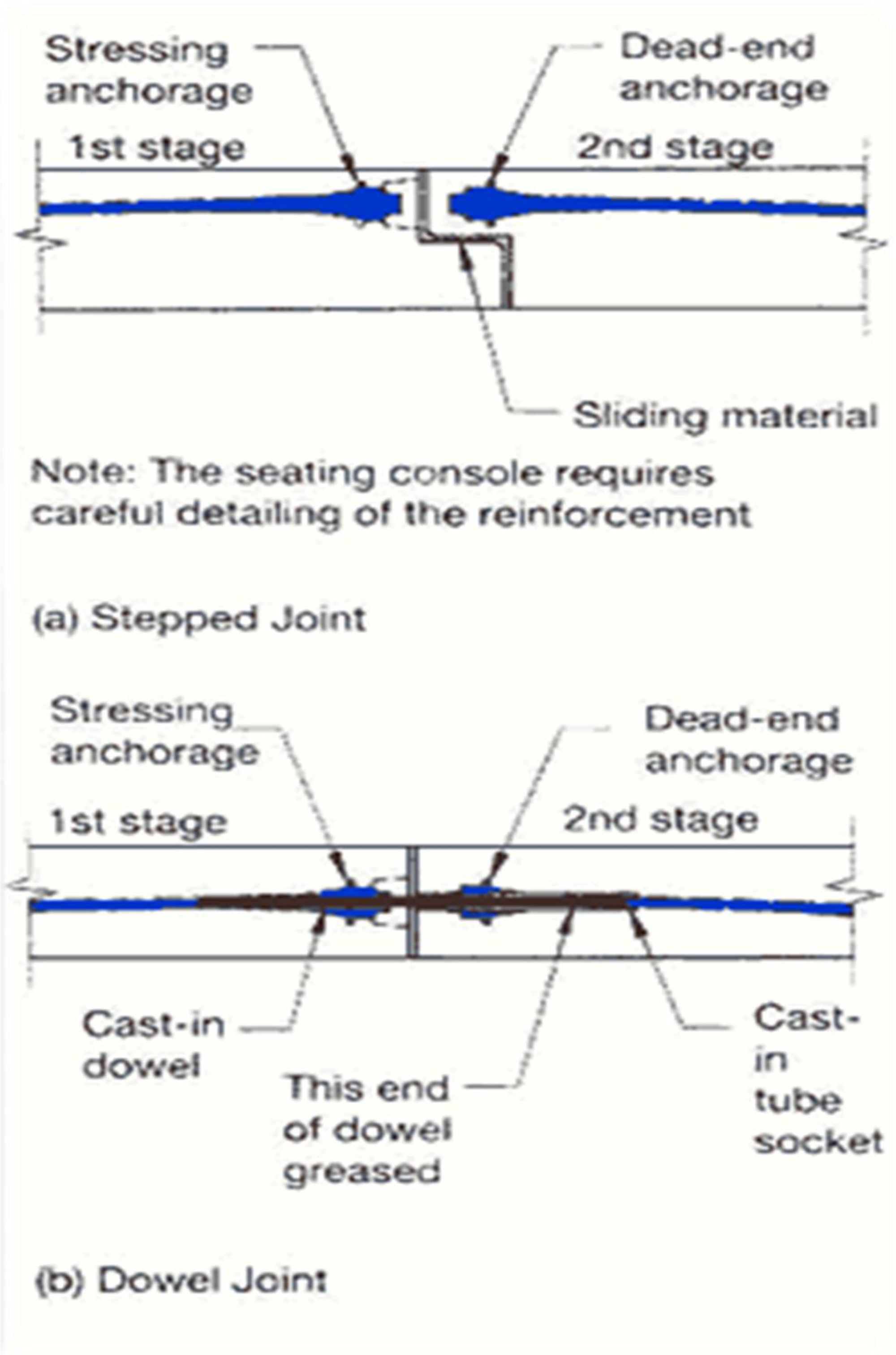
Should be used expansion joints or other often costly measure

To provide for good in –service behavior of the floor are then avoided .in cases where for architectural reasons, walls and service cores have to be arranged as in fig. blow ,prestressing does not guarantee a crack free floor . this is because the prestressing force in partly or completely lost due to the shear and flexural stiffness of the walls. Any shortening due to shrinkage or cooling will then cause tensile stresses that are relieved as soon as a sufficient number of cracks have formed to provide compatibility between the floor and the flexing member.

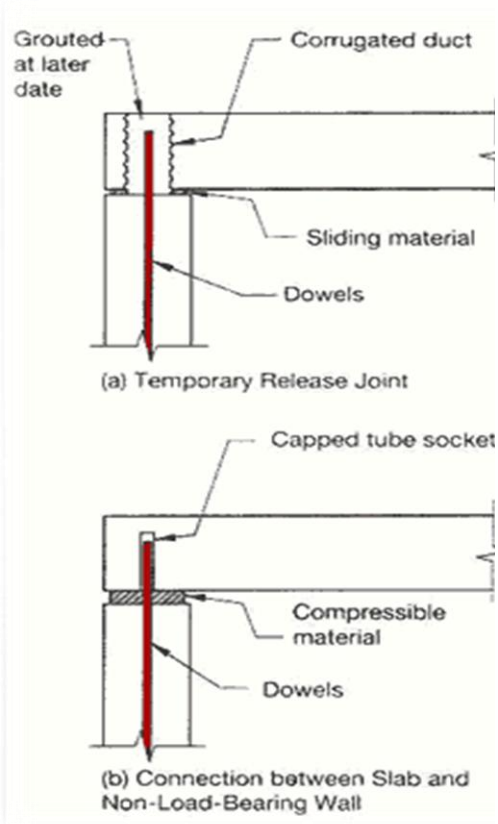


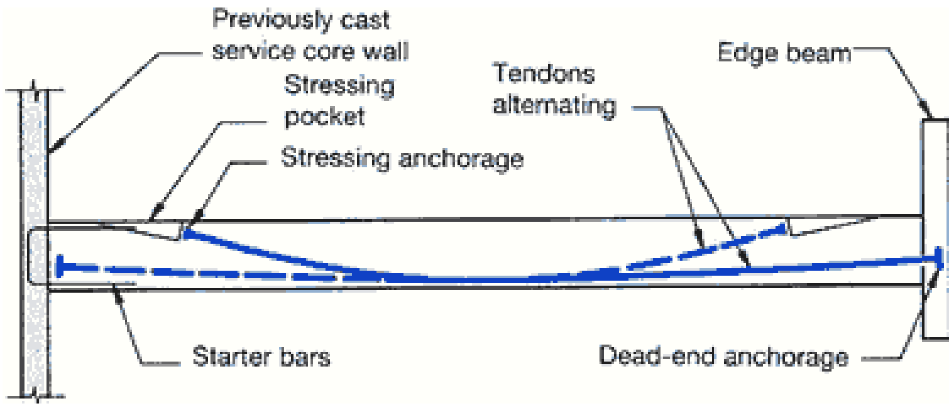


Influence of wall configuration on slab restraint

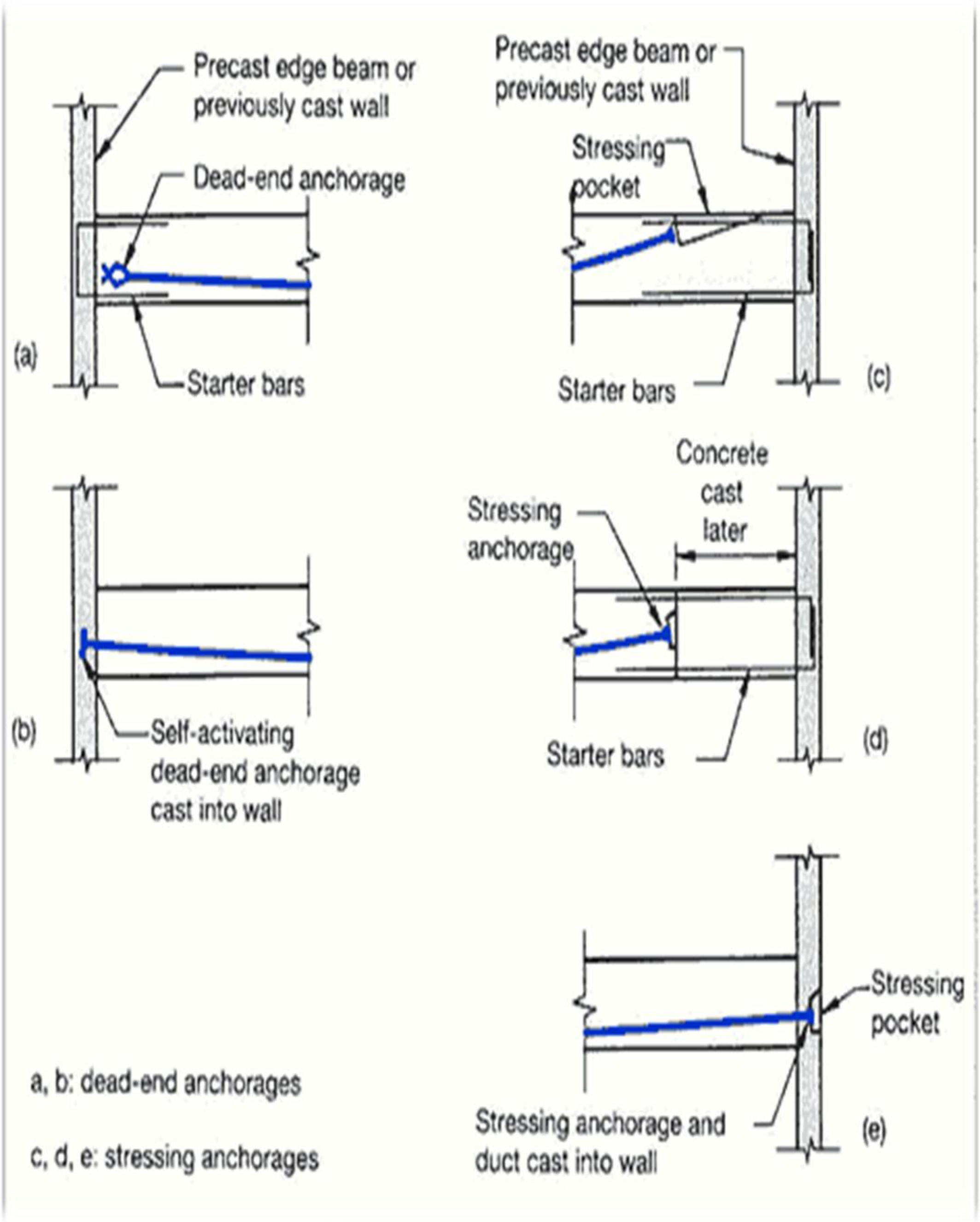


Expansion joint details

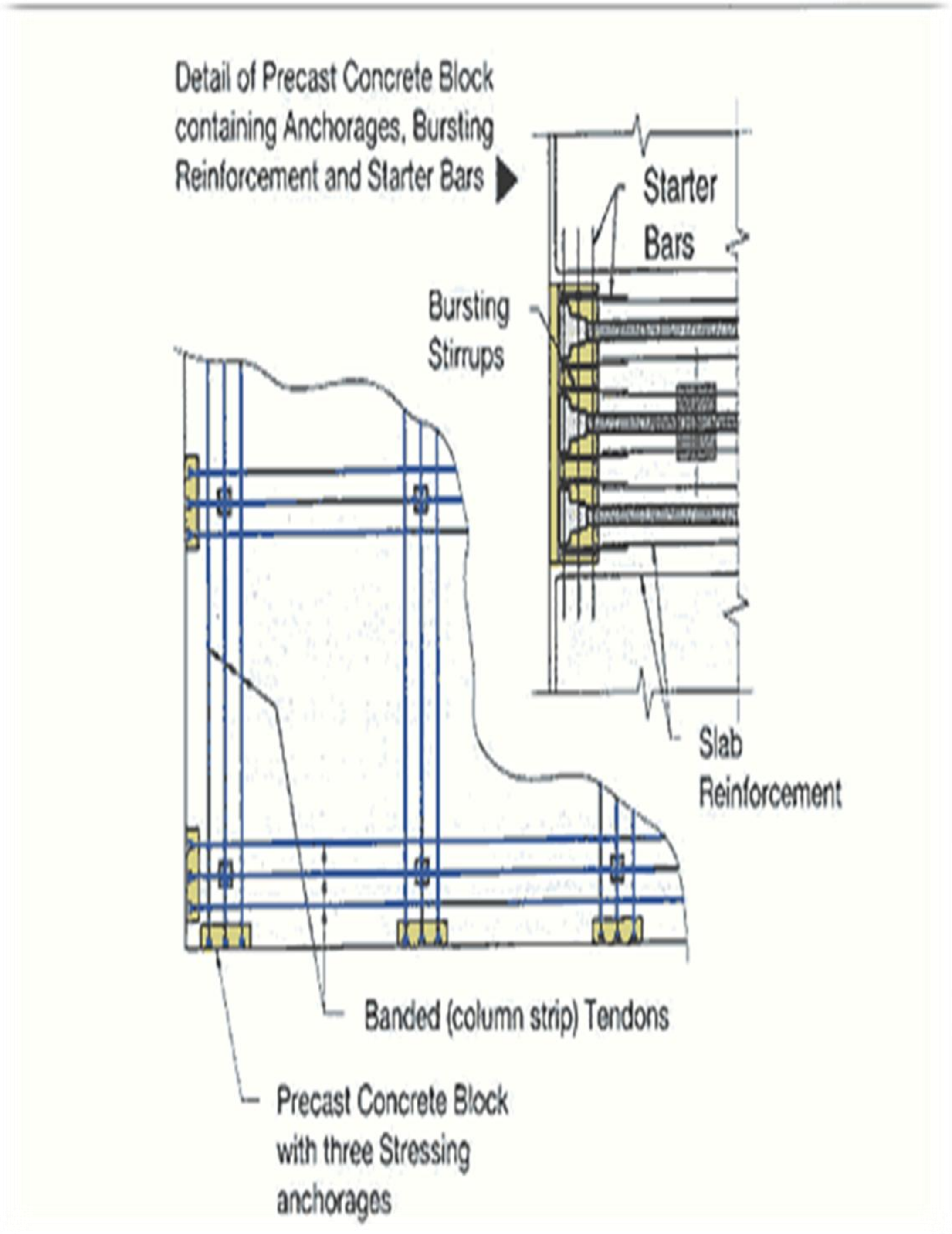




Alternating tendon arrangement with stressing pocket

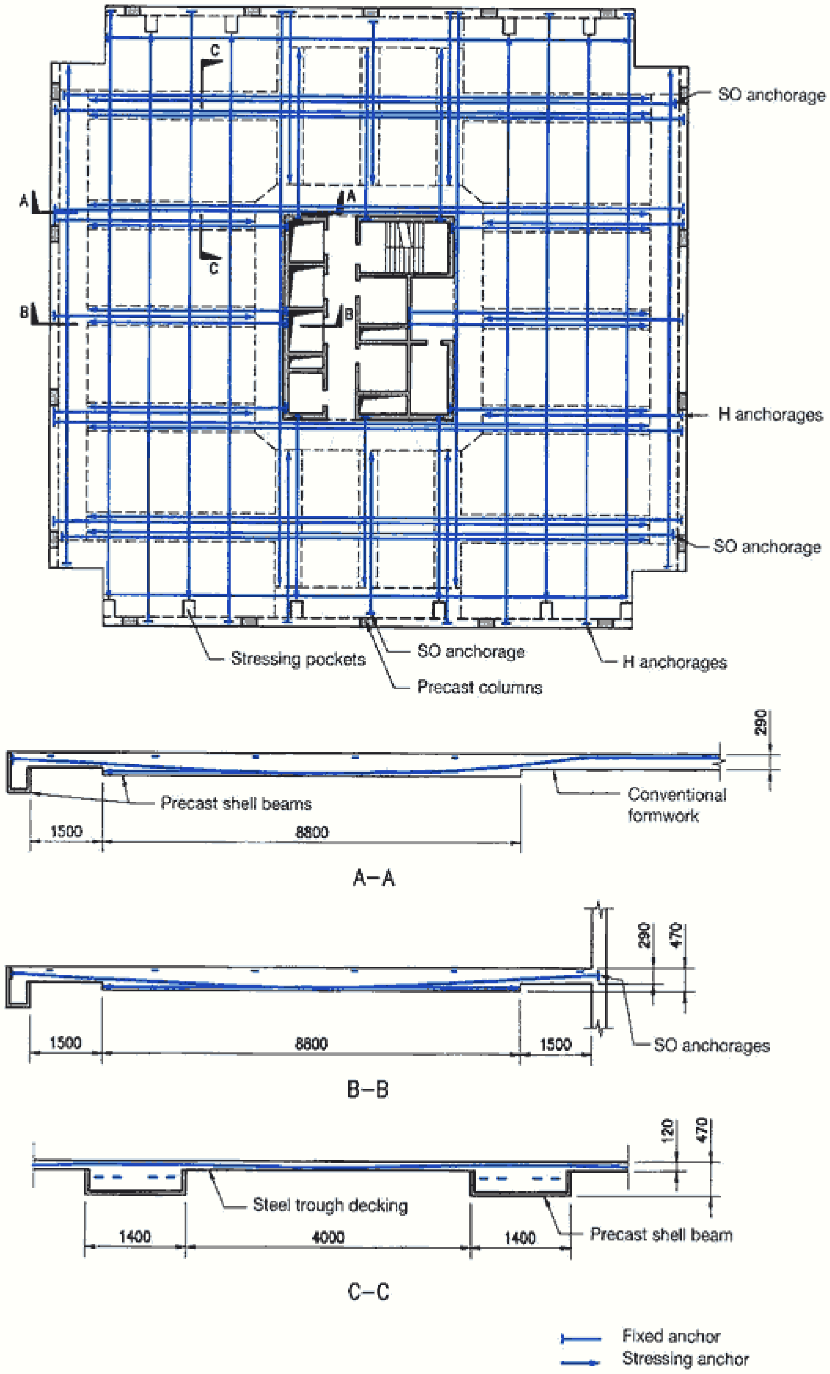


Detail of connections between post-tensioned slab and previously cast walls or edge beams

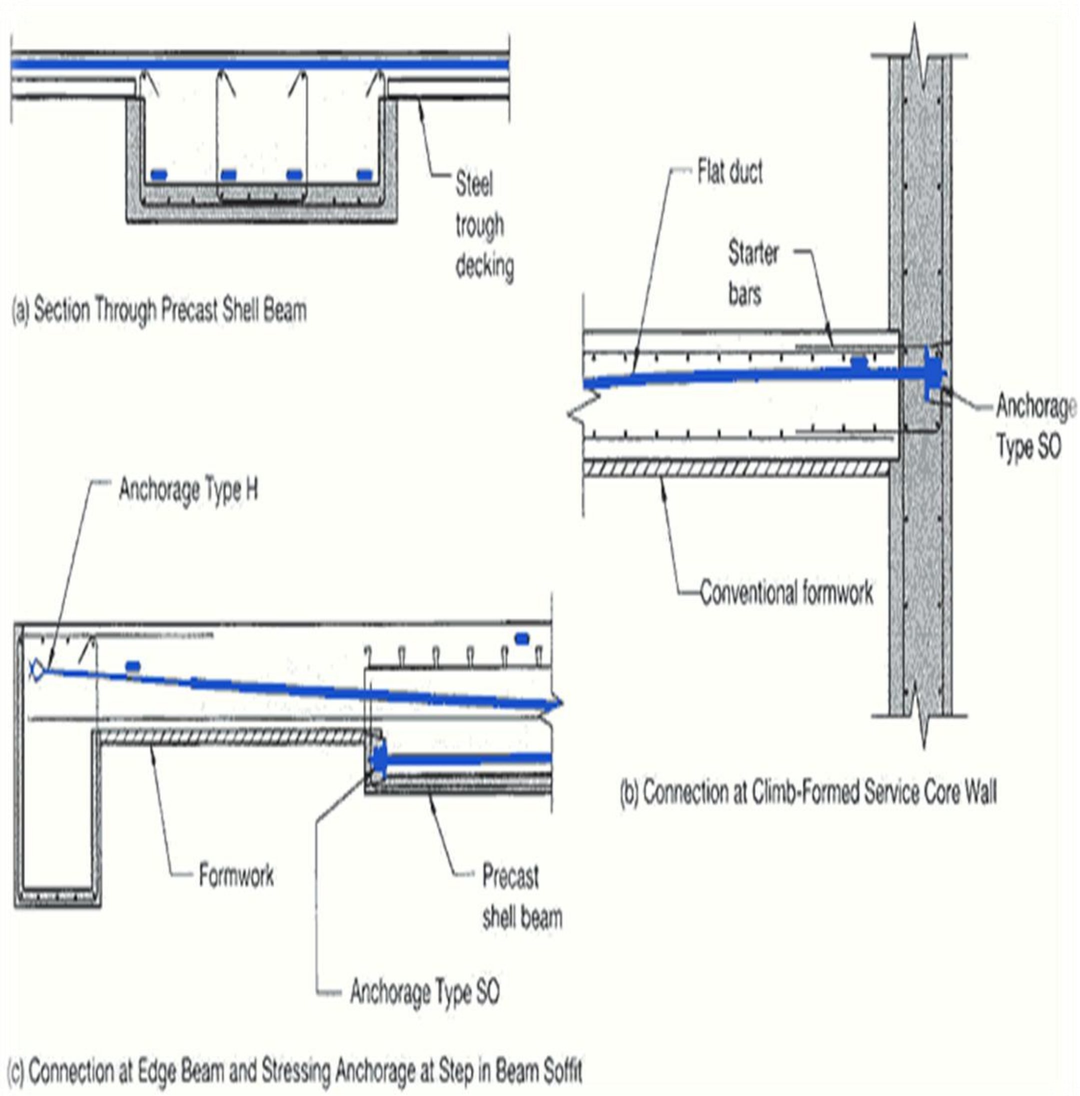


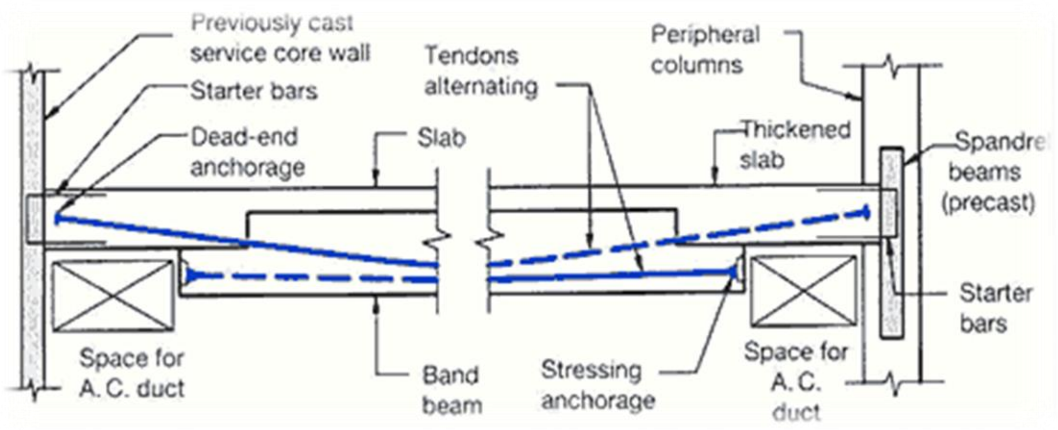
Precast anchorage block

Floor Plan of Selected Floor Framing System Showing Arrangement of Prestressing Tendons and Typical Section

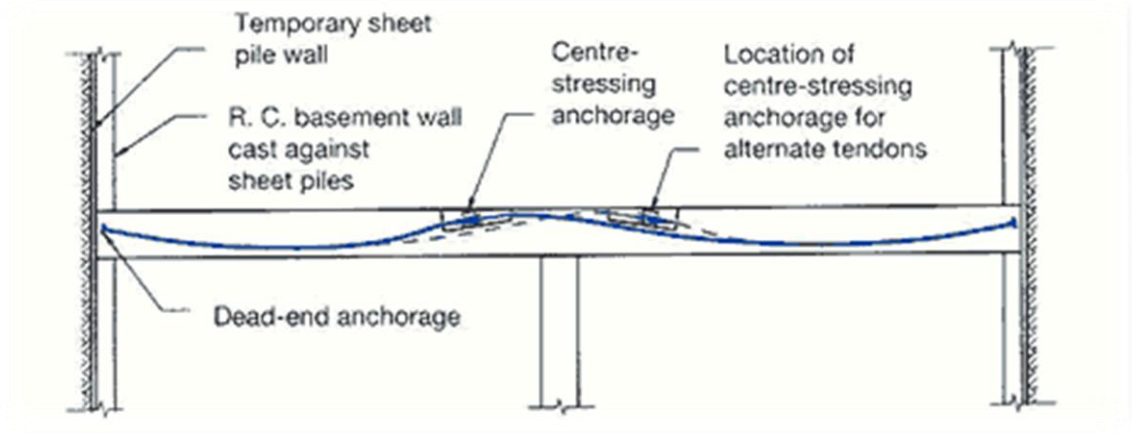


SO anchorage
H anchorages
SO anchorage
Stressing pockets
SO anchorage
Precast columns
H anchorages
A
A
B
B
C
C
290
Precast shell beams
Conventional formwork
1500
8800
A–A
290
470
1500
8800
1500
SO anchorages
B–B
120
470
Steel trough decking
Precast shell beam
1400
4000
1400
C–C
Fixed anchor
Stressing anchor


Steel
trough
decking
(a) Section Through Precast Shell Beam
Flat duct
Starter
bars
Anchorage
Type SO
Conventional formwork
(b) Connection at Climb-Formed Service Core Wall
Anchorage Type H
Formwork
Precast
shell beam
Anchorage Type SO
(c) Connection at Edge Beam and Stressing Anchorage at Step in Beam Soffit



Notched band beam to provide space for ducts



Centre – stressing anchorages



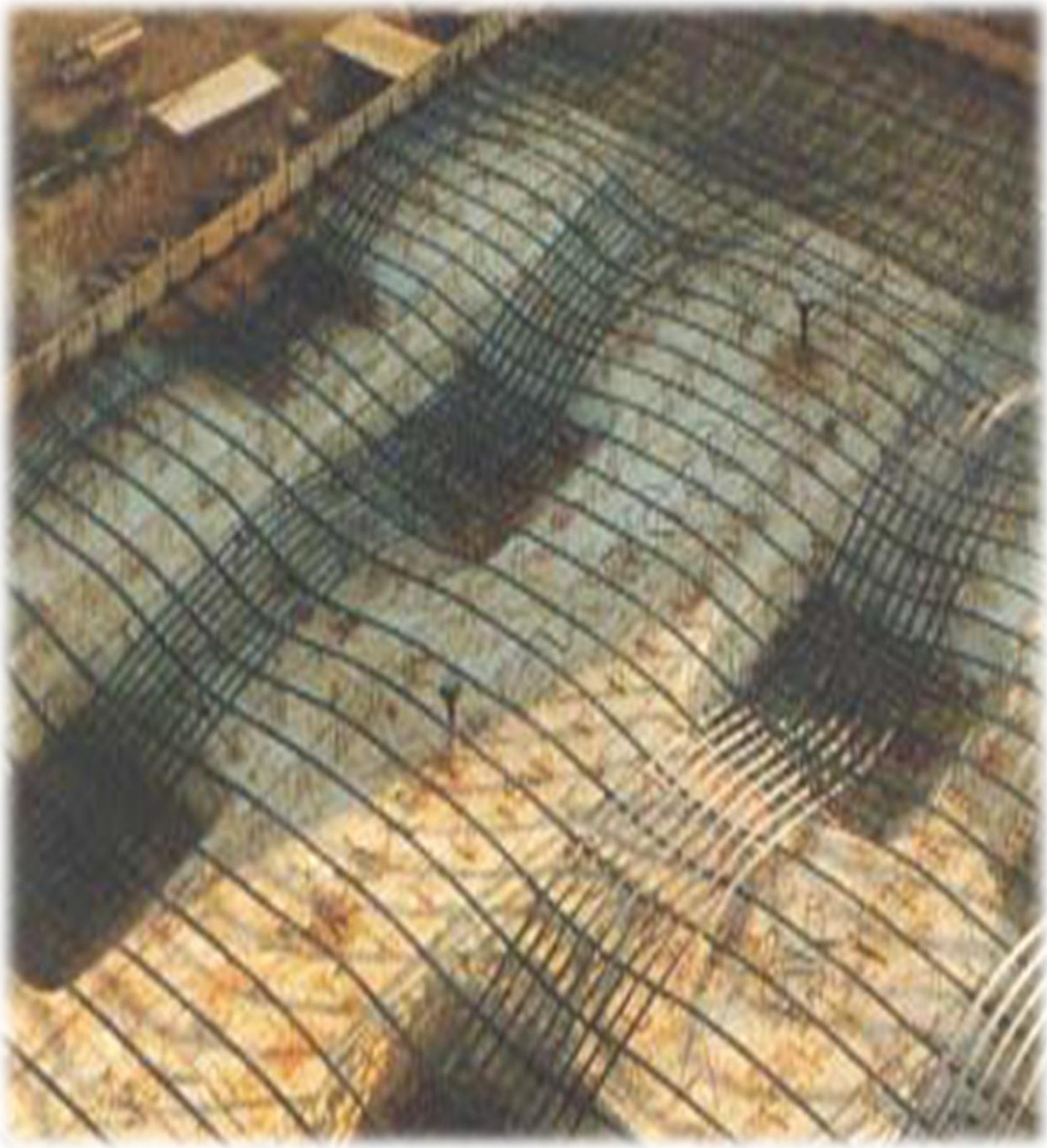
CONCLUSION

In conclusion it is worthy to reinforce a few key points .

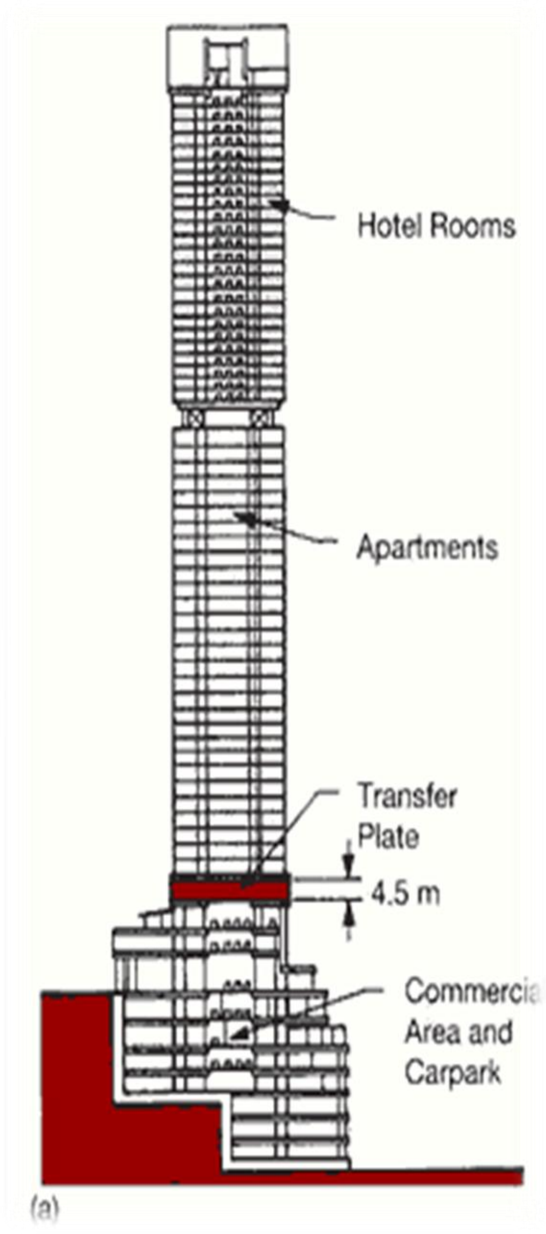
There is a definite trend towards large spans in buildings due to the fact that there is now more emphasis on providing large uninterrupted floor space which can result in higher rental returns .

Post-tensioning is an economical way of a achieving these larger spans .for spans 7.5 m meters and over , Post-tensioning will certainly be economic and as the Spans increase ,so do the saving .

The main structural scheme available are the flat plate ,flat slab and banded slab .with the latter generally leading to the most cost –efficient structure . however ,other factors such as floor to floor heights ,services ,etc. ,must be taken into account in the selection of the floor structure .for high rise construction and highly repetitive floor plates ,the use of more specialized structural schemes suitable with highlighting on systems formwork .

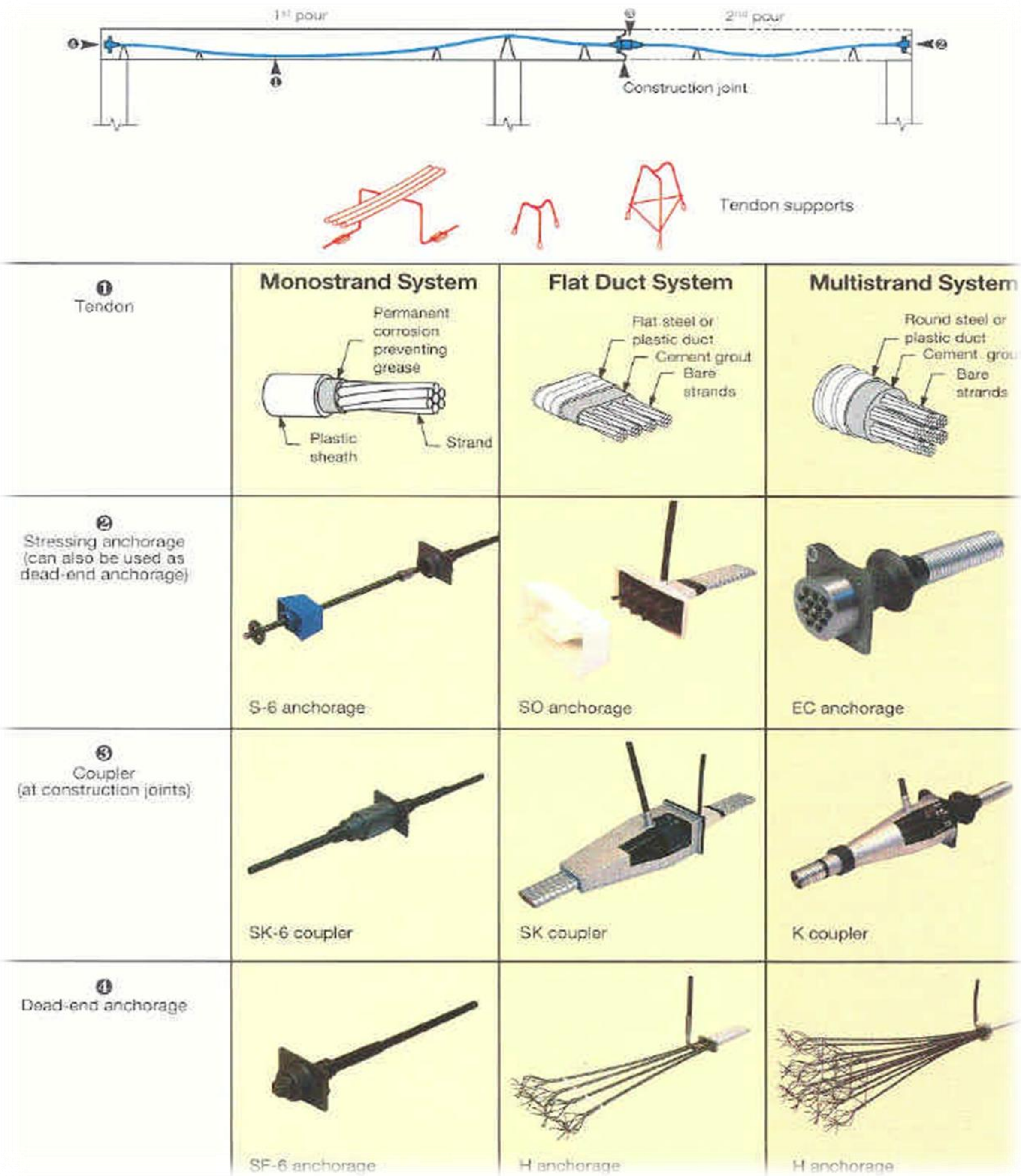


A Post-Tensioned Raft Foundation under Construction
Ground Anchors and Tension Piles



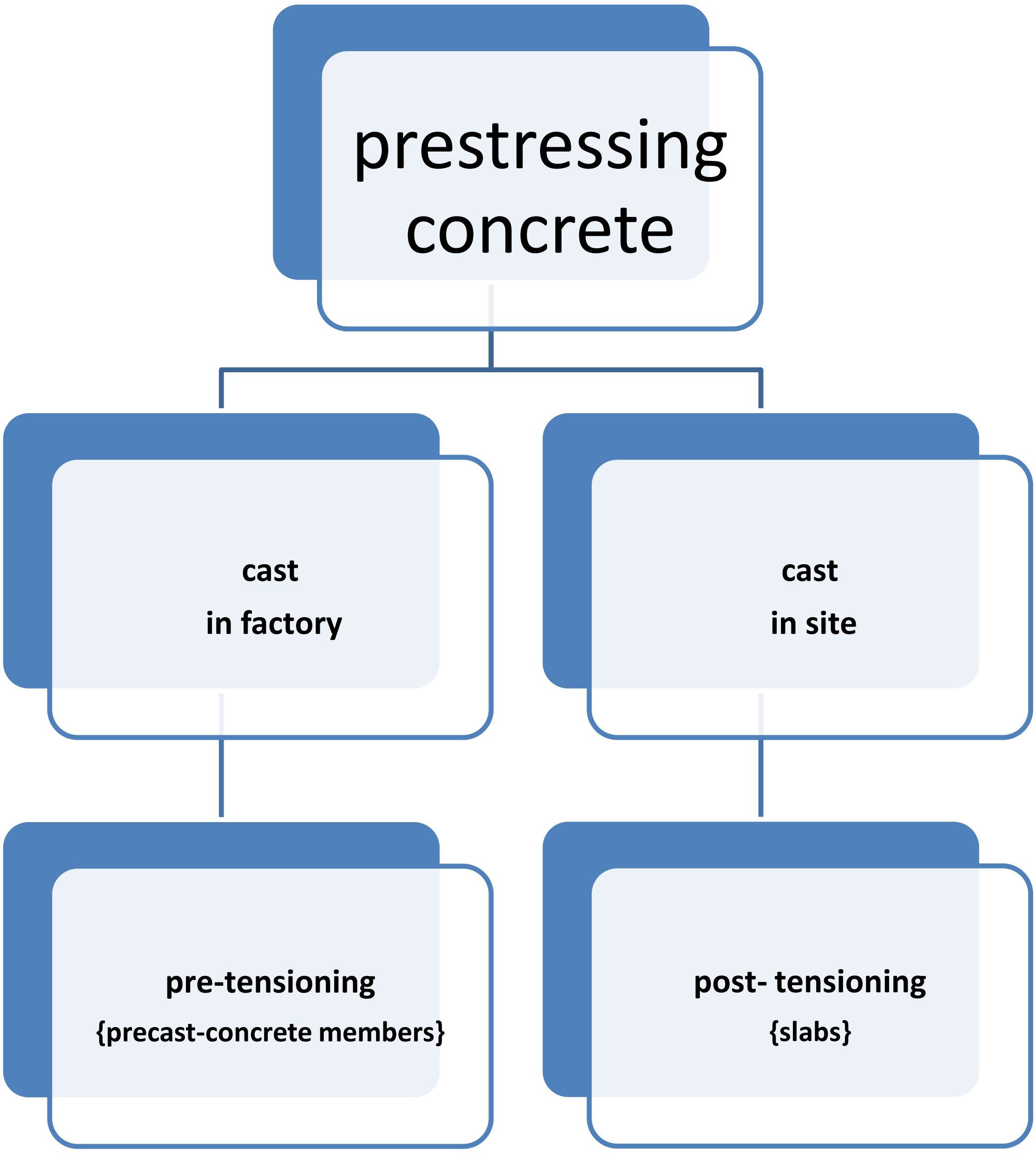
Section showing location of transfer plate

Hydraulic jack used to stress PT bars



Types of anchorages use in

building Structures


prestressing
concrete
cast
in factory
cast
in site
pre-tensioning
{precast-concrete members}
post- tensioning
{slabs}