APPLICATION OF POST TENSIONED CONCRETE IN PAKISAN AND ITS COMPARISON WITH CONVENTIONAL CONCRETE

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This is to certify that the

Final Year Project, titled

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DEDICATED TO OUR BELOVED PARENTS...!

ACKNOWLEDGEMENTS

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ABSTRACT

The research project is industry based and is objectified at an application of Post tensioning of concrete in Pakistan and its comparison with the conventional concrete systems. Our work of research is limited to Unbonded Monostrand Post-Tensioned concrete floor in multi-storey Buildings (more specifically the two story Parking structure). Post-tensioning is a pre-stressing type in which steel tendons and cables/wires are positioned in a special made ducts or sleeves before the concrete is placed in a formwork. After that concrete is placed and gained enough strength, the tendons are stressed to a known magnitude and anchored at the ends. The tendons are coated with grease and bituminous material within the ducts to prevent the bonding of concrete with steel. Anyway the ducts or sleeves are enough to prevent the bonding of concrete with steel. Post tensioning systems has a vital importance in civil engineering world because of having many advantages over normal concrete systems. Importance includes long spans which causes the reduction of other structural elements like columns and foundations, also increasing its aesthetic and architectural nature. Minimization of thickness of floor system also provides the facility of ceiling for horizontal services and also reduces the self-weights and foundation loads. Deflections can also be controlled by constructing longer spans with minimum depths. Speed, efficient and rapid construction is achieved in multi-story buildings due to less congestion of slab construction. Layout flexibility in structure can be achieved as the design can cover with irregular grids and patterns. Majorly parking lots, bridges, multi storey buildings and tennis courts are covered by this technique of pre-stressing.

The strength of concrete required to carry out the research was 5300 psi in 28 days and minimum strength of 2463 psi for 3 days. This was achieved in structural lab by the partial replacement of percentages of super plasticizer i.e. Glanium-51, in terms of ordinary Portland cement (OPC) while keeping the quantity of cement constant. The respective amounts of Glanium-51were 2%, 1% and 0.8% in terms of cement mass. Final selection was based on the slump and workability test as well as on the consideration of desired strength. Concrete was casted for the required number of samples and cured accordingly for required time period. Testing of each type of sample was done in three phases i.e. 3rd, 7th and 28th day. During each time of testing, we obtained more than desired results.

The research was kept on to cover the comparison of Post tensioned concrete with conventional concrete regarding the generated moments in structural members, top and bottom stresses, required story heights, columns to columns spacing, total area of steel and volume of concrete, structural loads on foundations, safety and feasibility, and cost comparison and economy. Firstly, a model of conventional concrete system for a parking structure was studied for roof systems. A model was drawn on ETAB for beams calculations and another model on CSI-SAFE for slabs. Calculations were also evaluated manually by hand and cross checked to satisfy the results. In the end total area of steel and concrete as well as the structural stresses in members were calculated manually. As far as the Post tensioning is concerned, another model of given plan was generated on AutoCAD and exported to CSI-SAFE. A strip of structure was selected and its calculations of stresses and forces losses were studied as per ASTM criteria. Given the

anchorage losses and friction losses according to the surroundings weather conditions and labor expertise, the force losses in tendons was manually evaluated and all the required data was compiled to compare it with the conventional concrete systems. Another software “Bentley RAM concept v8i” was also helpful for calculation of post tensioning concrete systems. In the end a clear comparison between conventional concrete systems and application of post tensioning of concrete was made and we got all those results for which our research was aimed at. There are large advantages of post tensioning of concrete systems in replacement of conventional concrete in terms of structural strength, stresses in members and as well as the cost and economy.

Post tensioned concrete has a large number of advantages compared to conventional RCC construction. Post-tensioning construction is advancing more and more with increasing innovations and environment friendly materials. It is of course mandatory to use high quality materials which should be able to withstand the pre-stress. However, one thing is for certain, Post tensioned concrete is going to serve the building community for many more years to come given the numerous advantages it bears.

As Engineers we have a responsibility our society to overview all methods of construction available. In some cases Post-tensioning will not be much suitable but it should be at least decently analyzed while considering other techniques.

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LIST OF ACRONYMS

SCCS	Self-Compacting Cementitious System
SCP	Self-Compacting Paste
SCM	Self-Compacting Mortar
SCC	Self-Compacting Concrete
SRM	Secondary Raw Materials
OPC	Ordinary Portland Cement
FA	Fly Ash
LSP	Limestone Powder
WD	Water Demand
w/c	Water to Cement Ratio
w/p	Water to Powder Ratio
SP	Super-plasticizer
SPD	Super-plasticizer Demand
IST	Initial Setting Time
FST	Final Setting Time
PSD	Particle Size Distribution
BET	Brunauer, Emmett and Teller
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
CH	Calcium Hydroxide
CSH	Calcium Silicate Hydrate
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials

CHAPTER 1- INTRODUCTION

1.1 General:

Post-tensioning is a type of pre-stressing for the production of structural elements. It is meant by developing the internal stresses into the concrete in order to resist the effects of externally applied loads during the service life of a structure. The process of production of internal forces is achieved by putting the steel of high strength into tension either before or after the concreting. If these forces in steel are developed in steel before concreting it is known as pre-tensioning and when these internal forces are achieved after concreting process, it is known as Post tensioning.

For a long time period, engineers have recognized the advantages of utilizing the pre-stressing method. Post tensioning is also done on-site just like pre-stressing. The material or equipment used for post-tensioning of cornet consists of high strength steel (pre-stressed) which is put in a duct or sleeves. For unbounded systems, grouting is avoided rather some organic material like grease is used between the concrete and steel to avoid the adhesive effects or bonding. While in bonded systems, grouting is done in a duct to cause a bondage link between a concrete and steel. Concreting is done typically and is allowed to reach to a known value of strength (almost of 3 days) and then steel is tensioned.

The most basic element of post tensioning technique is tendon. It is made up of one or more steel pieces usually in 7 wires form, with protecting coating and put inside of duct or sleeves. On both of the sides of a tendon, there are anchors for the transmission of loads. These tendons are essentially made of high strength steel and steel is manufactured as per ASTM standards. Typically one strand of tendons can bear a yield of about 24, 3000 psi while a conventional rebar piece can only bear strength of 60 ksi. Usually a typical size of a strand is .50 in and o.6 in diameters while the bar can range from 1 inch to 2.5 inches. Using a hydraulic jack, tension is being applied on both ends of steel with a known magnitude, due to this force steel elongates while the concrete is compressed. On a certain stage of applied force, when it is fully stressed by requirement, the steel is anchored in fixed conditions leaving it in tensioned state forever. The sleeve or duct, which comprises of steel, has one layer of corrosion protective material (mostly used grease). A duct, containing more than one steel piece is called multi-strand tendon while for one piece of steel strand, it is commonly known as mono-strand tendon

Whenever a concrete member is post tensioned, it is meant by improvising an idea that steel is under tension while concrete is under compression. These two forces are opposite in action as tension pulls the things apart while compression crushes it. Concrete is only weak in tension but it can largely take compression and steel on the other hand is good in tension and weak in compression. Thus implying the idea of post tensioning, before putting the member in service load, put concrete into compression and steel in tension, into their respective strong states to resist loads. Adding post tensioning effect in reinforcement collectively maximizes the tension zones as well as the compression in concrete. Installation of draped profiles of tendons instead of straight line also gives us additional benefits.

1.2 Problem Statement

In Pakistan, construction of floors is executed by conventional concrete construction. High rise building construction demand is increasing day by day. But due to some limitation of conventional concrete construction, alternative construction procedures are available one of which is Post-tensioning Construction. Thesis on Post-tensioning construction in Pakistan is very less, due to which enhancement in Post-tensioning construction field is less. If proper survey for post-tensioned concrete floors construction is done, it is possible to enlarge post-tensioning construction in Pakistan. It is very necessary to do the design and cost comparison between conventional concrete floors construction and Post-tensioned concrete floors, so that the investors should have an idea about its economic efficiency and structure benefit.

1.3 Objectives of Project

The main objective of project is to formulate a feasibility report for Un-bonded mono-strand Post-tensioned concrete floors in multi story buildings. Post-tensioning concrete floors will be compared with conventional concrete floors through Software and Lab design result. Contrast of Post-tensioned concrete construction with conventional concrete construction and cost comparison will be done. Moreover the whole crux of the objectives to be covered as per standards is:

- Design of a conventional concrete system
- Design of Post tensioning concrete system
- Achieving the required strength of concrete in lab
- Comparison of both the construction procedures and their feasibility
- Comparison of steel cost, concrete cost, moment and stresses generated, minimum story heights and columns to columns spacing and service life advantages

1.4 Advantages of Post-Tensioned Construction:

Using post-tensioned concrete floors has the following advantages.

- Procedure uses for grouting is eliminated in unbonded Post-tensioned construction.
- Long spans, which reduce the number of columns and foundations which accordingly increases space for architectural beauty.
- Minimum size floor thickness maximizes the ceiling zone available for horizontal services, minimizes the self-weight and foundation loads, and which keeps down the overall height of any building.
- Deflection of the slab can be controlled enabling longer spans to be constructed with a minimum depth of construction.
- Designing the whole slab to be in compression under normal working loads provides crack-free construction.
- Large area pours should be adopted on all concrete floors in order to reduce the number of pours and increase construction speed and efficiency.

- Rapid construction is readily achieved in multi-storey buildings as pre-stressing leads to less congested slab construction.
- Flexibility of structural layout can be achieved as the design methods can cover with irregular grids and tendons can easily be deflected horizontally to govern the building geometry or in some cases allow for openings in slabs.

1.5 Design Considerations:

Design methods for post-tensioned slabs are convenient and detailed design aid is available in Concrete Society Technical Reports. The design recommendation of prestressed concrete is given in BS 8110 and ASTM standards.

1.6 Material:

Material which are used in pre-stressing construction are

- High tensile Steel.
- High Strength Concrete.
- All the required equipments to carry out the construction for Post tensioning techniques i.e. Hydraulic jacks, tendons of high strength steel, coating material, ducts or sleeves, anchors, bearing plate basic, bearing plate special, anchor nut and intermediate, anchorage stressing and backup bars, bursting steel, multi strands and sheathing, strand tail, stressing pocket, encapsulated tendon, trumpet and concrete and grouting materials.

1.7 Post-Tensioning Devices:

Most basic requirements for installation:

- Casting bed
- Mould/Shuttering (aluminum shuttering)
- Ducts
- Anchoring devices
- Jacks
- Couplers (optional)
- Grouting equipment (Bonded Construction)

1.8 Methodology for Implementation of Project:

1.9 Construction Aspects:

1.9.1 Prefabrication of tendons:

In case of an un-bonded post tensioning system, first detailed drawings are made by which each tendon is cut accordingly and assembled with anchorages.

1.9.2 Sequence of installation:

In slab there are both normally reinforced steel and tendons which are needed to be fixed. Generally the sequence of installation is:

- Fix bottom mat reinforcement
- Fix tendon support bars to specified heights,
- Drape tendons across the support bars and secure
- Fix any top mat steel and column head reinforcement.

1.9.3 Construction joints:

Mainly there are three types of construction joint that can are used between areas of slab

- Construction Joint with no intermediate stressing.
- Construction joint with intermediate stressing
- Infill or Closure strip

When used they are typically positioned in the spaces of a quarter or third points of the span. The most commonly used joint is the infill. As this is an ideal procedure of resolving problems of restraint which also provides inboard access for stressing, removing the need for perimeter access from formwork or scaffolding.

1.9.4 Pour size/joints:

Large pour areas are possible in post-tensioned slabs, and the application of an early initial pre-stress, at a concrete strength of typically 12.5 N/mm2, can help to control restraint stresses. There are economical limits on the length of tendons used in a slab, and these can be used as a guide to the maximum pour size. Typically these are 35 m for tendons stressed from one end only and 70 m for tendons stressed from both ends.

1.9.5 Concreting:

Care must be taken when concreting to prevent operatives displacing tendons, but apart from this, both the placing and curing of the concrete is similar to that for a reinforced slab, although concreting is easier as there is no reinforcement congestion.

1.9.6 Stressing:

After concreting, about one-three days, when the concrete has gained a strength of typically 12.5 N/mm^2, initially stressing of tendons to about half (50%) of their final jacking force is done. With an unbonded system, stress from one end the remote end which is fixed by a dead-end anchorage. At stressing end the tendon passes through a bearing plate and anchor attached to the perimeter form by a mandrel holding in place a reusable plastic recess form. The tendon is stressed with a jack and the resulting force is confined into the tendon by means of a split wedge, which is located in the barrel of the anchor. After seven days, when the concrete has gained its design strength (typically 25 N/mm^2) the remaining stress is applied to tendons. The extension, which occurs in each tendon under load, is then recorded and compared against the calculated value. Provided that it falls within an acceptable limit, the tendon is then cut. With an unbonded system, a grease cap is placed over the recessed anchor and remaining void dry-packed.

1.9.7 Back Propping:

When designing the formwork systems for any multi-storey construction, the use of back-props should be considered for more than one floor to support the floor under construction.

1.9.8 Slab soffit marking:

Various methods present for marking the slab soffit to identify where tendons are fixed. One procedure is to increase the slab thickness over the width of the group of tendons - thus creating an identifying place - or paint markings can be done.

1.10 Utilization of Project Result:

After writing a feasibility report, we will have a clear idea about Post-tensioned concrete floors, its construction and implementation. After listing out of all necessary equipment and material, if necessary it can be imported from abroad.

Data for Post-tensioning construction to be collected from, NESPAK, DESCON, Habib Construction etc., In Pakistan Post-tensioning construction is done in bridges concrete Girder, there data will be helpful in compiling feasibility report. Post-tensioning cost and serviceability comparison with conventional construction to be done by using;

- Software
- Lab Modeling.

After this we will have an idea about how we can implement Post-tensioning in Pakistan. The formulated result and conclusion can be used in future.

CHAPTER 2- LITERATURE REVIEW

2.1 Prestressed concrete:

Prestressed concrete is modified form of reinforced concrete. In reinforced concrete section, steel reinforcement is provided on tension face to compensate tensile stress. In prestressing, an external predetermined magnitude of axial force is applied to concrete member, which induces compressive stress in concrete section. Whenever the load is applied, the tensile stress(which is generated) has to overcome compressive pre-stress before the concrete is driven into tension.

Prestressing is very old principle, used throughout history. It is applied on different construction material of fabric, wood, masonary, metals and concrete. Casson(1971) and torr (1964) stated, Egyptian boats built approximately 3500 years ago, in which post and ropes built structure prevent negative curvature in hulls. In 1904, Freyssinet introduce idea of inducing permanent force in concrete to resist elastic force and this idea later developed name of “Prestressing”.

In prestressing concrete, the external prestressing force is applied generally by stretching steel rods, ropes or wire (strand), which goes into compression. The high strength steel rods, wires or strands are known as tendons. A typical strand consists of 7 wires wound into a rope, typically of diameter of 0.5 and 0.6 inch. These tendons compress the concrete and utilize the capacity of concrete compression strength.

Pre stressing of concrete has more merits than demerits. It includes applications mostly in high-rise buildings and the structures like nuclear reactors. While post tensioned slabs are majorly used in parking garages. As it has an ability to undergo stressed and de stressed phenomenon, it can be used effectively in repairing of building by holdingup floor until the process of temporary repair is completed. It also involves crack control and cost reduction benefits. Also reduction the number of joints increases the design life of any structure keeping in view the joints as the weaknesses of it. Its applications include bridges, concrete circular pipes, slabs, girders and parking lots.

2.2 Types of Prestressing:

2.2.1 Pre tensioning:

In prestensioning, tensioning of wires (strand) done before concrete casted. The wires (Strands) are in tension with external anchorage point. Tendons are pre tensioned with a known magnitude of stress and anchored at external points prior to concrete placing. After that concrete is placed and when the concrete has gained an enough strength the tendons are allowed to loosened and concrete is compressed and as a direct bond with the steel. Majorly hydraulics jacks are used to stress the tendons. Pretensioning is usually done with most stable anchorage ends between which a tendon can be easily stressed without any risk of breakage and disturbance. Thus mostly pre-tensioned concrete elements are prepared on site and are transpoted to construction site on request.

2.2.2 Post tensioning:

It is a prestressing type in which steel tendons and cables/wires are positioned in a special made ducts or sleeves before the concrete is placed in a formwork. After that concrete is placed and gained enough strength, the tendons are stressed to an known magnitude and anchored at the ends. The tendons are coated with grease and bituminous material within the ducts to prevent the bonding of concrete with steel. Anyway the ducts or sleeves are enough to prevent the bonding of concrete with steel.

Nearly when reinforced concrete had been produced, toward the end of the nineteenth Century, engineers perceived that its execution could be enhanced if the bars could be put in strain – and keep the concrete in pressure. In any case, it was not until much later that the utilization of post-tensioning for structures truly got to be across the board. BBR's long history of creative advancement started in 1948, when the association licensed the BBRV 'catch head wire' post-tensioning framework. In this manner, BBR built up a complete scope of prestressing and post-tensioning frameworks, ground grapples and stay link harbors, covering all basic building applications, and today, the BBR Network works in more than 50 nations around the world.

In 1940 , mcCALL's invested significantly in the development of plants and buildings which as a result formed first post tensioned system in 1948. It was a successful project though which for the first time brought the system of post tensioning. In 1980,Sir Norman foster designed the Renault distribution centre in swindon England using mcCALLOY's developed tension structure system. In November 2007, mcCALLOY celebrated its 60 years of contribution of post tensioning systems to civil engineering world.

Post tensioning systems has a vital importance in civil engineering world because of having many advantages over normal concrete systems. Importance includes long spans which causes the reduction of other structural elements like columns and foundations, also increasing its aesthetic and architectural nature. Minimization of thickness of floor system also provides the facility of ceiling for horizontal services and also reduces the self-weights and foundation loads. Constructing the longer spans with minimum depths can also control deflections. Speed, efficient and rapid construction is readily achieved in multi-story buildings due to less congestion of slab construction. Flexibility of layout in structure can be achieved as the design can cover with irregular grids and patterns. Majorly parking lots, bridges and multi story buildings and tennis courts.

2.2.3 Types of post tensioning:

2.2.3.1 Bonded systems:

In bonded systems of post tensioning, the pre-stressing tendons run through ducts and ducts are grouted with concrete after tendons are stressed. When the tendons have stretched sufficiently they are thus wedged or connected in position and maintain the tension after jacks are removed which in result transfers the pressure to concrete. The duct is then grouted to prevent the tendons from corrosion. This process is usually used in the construction of monolithic slabs in house construction where the soils are expensive. All stresses from seasonal expansion and contraction of the underlying soil are taken into the entire tensioned slab, which supports the building without significant flexure. Advantages include large reduction in conventional steel requirements as tendons cannot destress accidently, higher ultimate strengths due to the bond between concrete and strands and no longer-term issues of repairing. It is used in the construction of bridges both after concrete is cured after support by falsework and by assembly of prefabricated sections.

2.2.3.2 Unbonded system

In unbonded system the tendon is not grouted and remains free to move independently of the concrete. This has no effect on the serviceability design or performance of a structure under normal conditions.it does however change both the design theory and structural performance at the ultimate limit state which is preceded by large deflections but larger, associated cracks than with an equivalent bonded system. Thus in unbonded there are obvious visual indications that something is well before failure occurs.

Unbonded post tensioning system has advanages over bonded system because of its ability to adjust cables based on poor conditions. Moreover the procedure of grouting is eliminating. The ability to destress the tendons before attempting repair work. Unbonded systems provides greater lever arm and it reduces friction losses and simplifies prefabricating of tendons. Grouting is eliminated and can be constructed faster. It also provides protection against damage by mechanical handling and serves as a barrier that prevents moisture and chemicals from reaching the strand. The strand coating material reduces friction between the strand and the sheathing and provides additional corrosion protection. Anchorages are another critical element, particularly in unbonded systems. Major characteristics of unbonded system would be its economy, great flexibility in layout, force transmission by anchors,force limitations by anchor spacing ,retrofitting requires more care and it is replaceable. Faster installation and long term durability (corrosion protection by shealthing and anti-corrosive grease coating on cable). Encapsulated unobonded system for effective protection against corrosion. Slabs reinforced with unbonded p-t systems have better control over the tensile stresses and and deflections. Water cement ration for grouting to maintain on site is difficult. Post construction changes making cutouts and re adjustment in cable profiles is not possible once the grouting is done.

Unbonded post tensioning tendons are used in barrier cable and parking garages. Also due to its ability to be stressed and de stressed unbonded systems can be employed to repair a damaged building by holding up a damaged wallor floor until peranent repairs can be made. Others include crack control and lower construction costs, thinner slabs (especialy important in high rise buildings) .

Tendon:

An extended component utilized as a part of a solid individual from a structure to give prestress to the concrete. For the most part, steel wires, bars, links or stands of high ductile anxiety are utilized as tendons.

2)Anchorage(act like a dock):

A gadget which is for the most part used to empower the tendon to confer and keep up prestress in the concrete.Commonly utilized acchorages are freyssinet (broadly utilized as a part of India), Magnel Blaton,Gifford-Udall.

3)Fractional/partial prestressing:

The level of prestress connected to concrete in which ductile stresses to a certain point are allowed in cement under the effect of working loads.In this case,in expansion to tensioned steel,a extensive extent of untensioned reinforcement is by and large used to constrain the width of breaks or cracks created under administration or service loads.

4)Transfer:

This stage relating to the exchange of prestress to concrete. For post tensioned individuals,it happens after the fulfillment of the tensioning procedure.

5) Supplementary reinforcement:

It is the Reinforcement in prestressed individuals not tensioned as for the encompassing concrete before the utilization of loads. These are by and large utilized in partially stressed members

6) Transmission length:

It is the length of anchorage of bond of the prestressing wire from the end of a pre-tensioned part to the point of full steel stress.

7) Cracking load:

The heap of load on the auxiliary component relating to the primary break.

8) Creep in solid:

Progressive increment in the flexible misshapening of concrete under supported stress part.

9) Shrinkage of concrete:

This is the constriction of concrete when it kicks the bucket

10) Unwinding of steel:

Decrease of anxiety in steel on consistent strain

11)Proof stress:

The pliable stress in steel which delivers a remaining strain of 0.2 % of the first gage length on unloading.

12) Coefficient of creep: complete drag strain(creep strain)/elastic strain in concrete

13) Cap cable: A short bended tendon orchestrated at the inside supports of a beam. The grapples are the pressure (compression)zone.

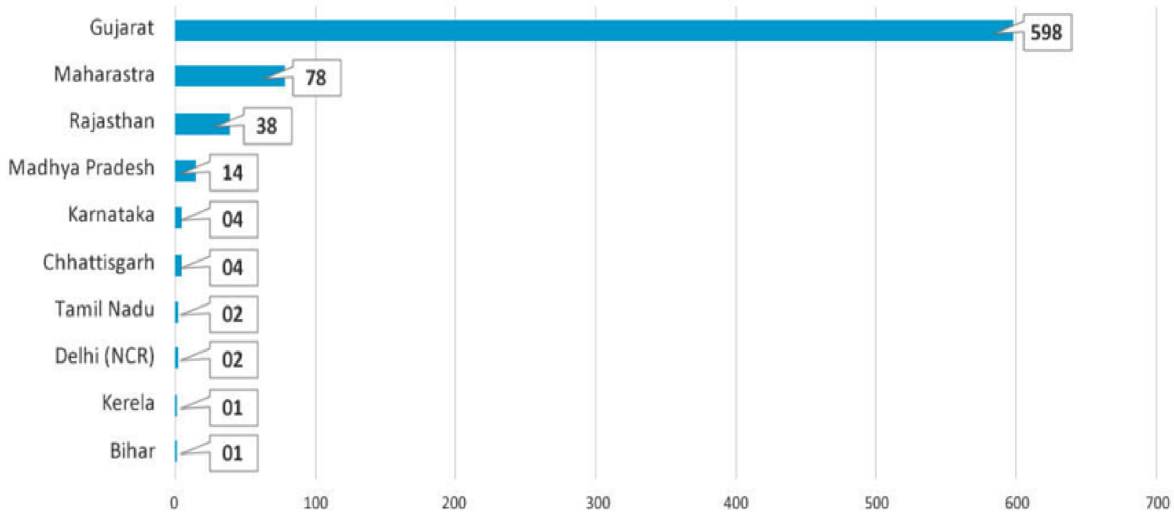
Applications:

Post-tensioning, or PT, has turned out to be progressively famous in the course of recent years or so as the innovation has been idealized. At one time there were issues with consumption of the links, particularly in deicing-salt-loaded stopping structures, however better materials and development techniques (in addition to great preparing and accreditation programs) have wiped out generally issues.

Previously following applications and projects in Pakistan have been carried out using the technologies related with post tensioning science:

ANIS APPAREL,KARACH,PRIME FLOUR MILLS KARACHI,PIA PLAZA LAHORE,NAZEER DYEING KORANGI,ISLAMABAD CLUB,D-COMFORTS KARACHI,70 RIVEIRA CLIFTON KARACHI,INTERNATIONAL TEXTILE LIMITED KORANGI KARACHI,REHBAR WATER COOLER KORANGI KARACHI,KARACHI PLAY HOUSE TEEN TALWAR CLIFTON KARACHI,SUKKUR PRIME HOUSE SUKKUR SINDH,SAINT MARY’S ACADEMY ISLAMABAD.

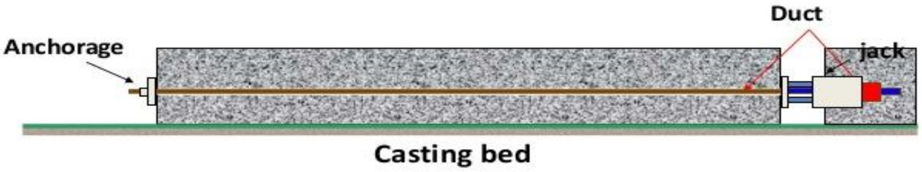
General applications include flat PT slabs, flat pt slabs with drop panels,slabs with pt beams,lightened pt slabs,pt slabs on side slabs,pt foundation rafts.PT transfer strucutures include PT transfer beams,PT transfer slabs, and special applications include wall prestressing,hangars, external reinforcement o



No of projects of post tensioned concrete buildings in INDIA

Devices in Post tensioning:

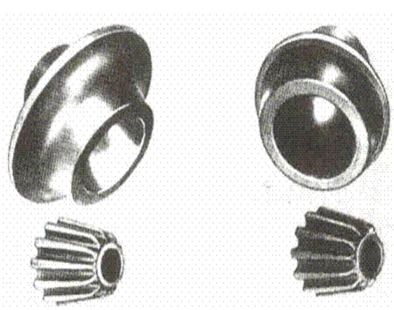
1) Casting beds, Mould/shutterings and ducts:



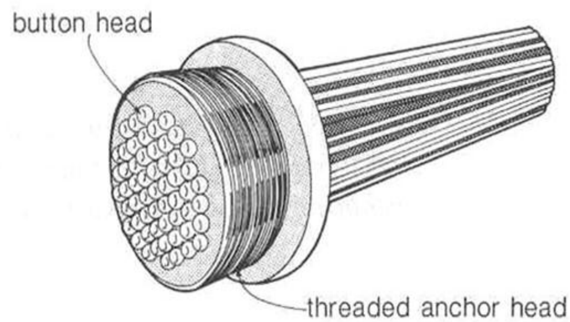
Anchorage devices:

In post-tensioned individuals the mooring gadgets exchange the prestress to the concrete. The gadgets depend on the accompanying standards of mooring the tendons.

1) Wedge activity (The mooring gadget taking into account wedge activity comprises of a jetty piece and wedges. The strands are held by frictional hold of the wedges in the safe haven square. A few samples of frameworks taking into account the wedge-activity are Freyssinet, Gifford-Udall, Anderson and Magnel-Blaton anchorages)



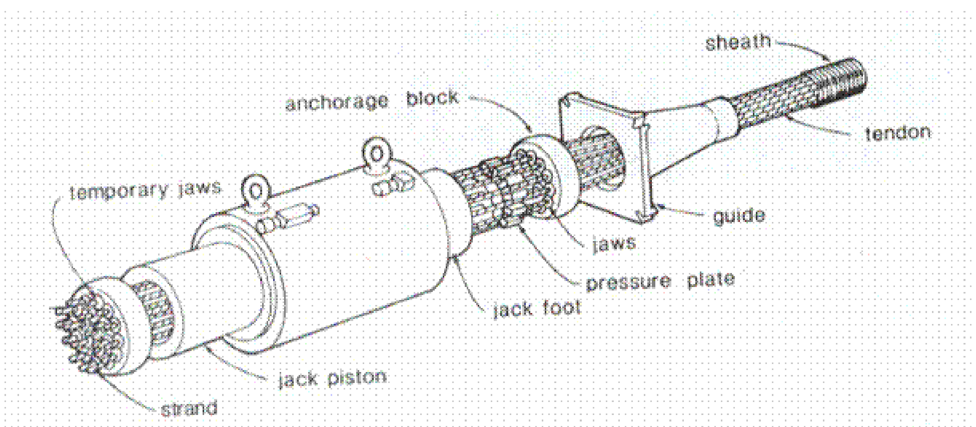
2) Direct bearing (The bolt or jolt heads or catch heads shaped toward the end of the wires specifically bear against a square. The B.B.R.V post-tensioning framework and the Prescon framework are taking into account this guideline. The accompanying figure demonstrates the securing by direct bearing.)



3) Looping the wires(The Baur-Leonhardt framework, Leoba framework furthermore the Dwidag single-bar dock framework, chip away at this guideline where the wires are circled around the concrete. The wires are circled to make a globule. The accompanying photograph demonstrates the dock by circling of the wires in a post-tensioned piece)

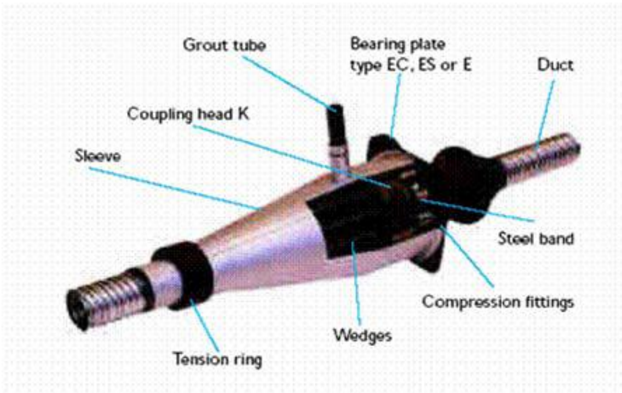
Jacks:

The accompanying figure demonstrates an expelled portrayal of the tying down gadgets.



Couplers:

The couplers are utilized to associate strands or bars. They are situated at the intersection of the individuals, for instance at or close segments in post-tensioned chunks, on wharfs in posttensioned span decks.

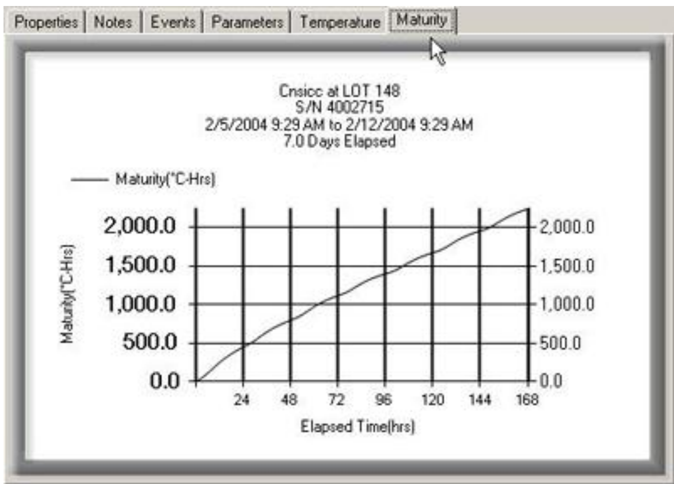


Grouting equipments(optional):

Grouting can be characterized as the filling of channel, with a material that gives an anticorrosive basic environment to the prestressing steel furthermore a solid bond between the tendon and the encompassing grout. The significant piece of grout involves water and bond, with a water-to-concrete proportion of around 0.5, together with some water-decreasing admixtures, extension operators and pozzolans. The accompanying figure demonstrates a grouting gear, where the fixings are blended and the grout is pumped.

Intelli-rock:

Before development starts, an arrangement of test chambers are thrown, a few with Loggers implanted, to plot the relationship between compressive quality and development (degrees Celsius x hours) for the predetermined blend outline. At standard interims – 1, 2, 4, 7, and 14 days – quality and development are measured. Results are charted on an alignment bend.



Materials and equipments:

Post-tensioned (PT) strands are made in agreement to the standard American Society for Testing and Materials (ASTM) A416. It is made out of seven treated carbon steel wires, six of which are orchestrated in a helical example around a somewhat bigger focus wire . PT strand is accessible in a few widths going from .250 in. to .600 in. For most post-tensioning applications, the standard size strand is either the .500 in. then again .600 in. width (ASTM). Breaking quality prerequisites and yield quality necessities are appeared in Table.

Strand Diameter (in.)	.500	.600
Min. Breaking Strength, T_U (kips)	41.3	58.6
Steel Area (in^2)	.153	.217
Strand Weight (lb/ft)	.520	.740
Min. Yield Strength, 1% Elongation, T_Y (kips)	37.17	52.74

ASTM A416 requirements

PT threaded bars (High-quality, high limit strung bars are icy moved steel and each are supplied with a course plate, hex nut, couplers and grout tops. PTE Strand's Threaded Bar Systems have numerous applications including: Geotechnical uses, for example, Soil and Rock Anchors, Tie-backs, and Tower Crane Foundations. Holding Walls and Tunnels. Connecting Steel components to concrete structures. Bars usually come in 75ksi and 150 ksi qualities with distances across from 1" to 3 ½".

Losses in PT:

The power which is utilized to extend the wire to the required length must be accessible all the time as prestressing power if the steel is to be kept from contracting. Constriction of steel wire happens because of a few causes, affecting decrease in the prestress. This lessening in the prestressing power is called losses in prestress. In a prestressed concrete pillar/column, the misfortune is because of the accompanying:

a) Elastic shortening

b) Shrinkage of concrete

c) Creep of concrete

d) Frictional misfortune(frictional loss)

e) Relaxation of steel

f) Anchorage take-up

There are separate reasons and magnitudes for each of the mentioned losses.

CHAPTER 3- MODELLING

3.1 Model architectural description

Our model under subject was "Parking structure" and we obtain the 2D drawing from Dr Bilal Ahmad, Executive director at SE groups. The story height is 10 ft each, totaling up to two stories and there was no basement in the structure. One elevator was provided in the centre of building. Total area is 28496 ft^2 and shear wall of 24" is provided for counter the seismic loads in case of earthquakes. 1st story will serve as a sole purpose for parking and spacing between columns is sufficient for the passage of cars with no hindrance.

3D view of building:

The 3d view of building was developed in AUTOCAD-2013 is shown in the figure

Furthermore the plans will be shown in the design and analysis

3.2 ANALYSIS AND DESIGN

3.2.1 ANALYSIS SOFTWARE:

ETAB is the evolutionary and innovative software package for design and analysis and is used at large scale in the world. ETAB can incorporate the each and every part of strucuture design procedure, majorly used for modelling, design and analysis and it can configure the concrete and steel panels,compsite bars and segments, shear walls and steel made joists etc. Etab is user firendly and also facilitates 3D viewing of model and can also display all elvations and plans at a desired level of user. This software has an ability to create the multi-stories with similar stories quickly,which makes ETAB prominent.

ETAB can work in real time and onscreen assignments of properties of material, supports to the structure and loading on structure. It shows direct results after designing and analysis of structure which majorly include bending moment diagrams,shear force diagrams,reactions of assigned loads and axial force magnitudes, and can also display design and analysis outputs in a report and tabular form. Working drawings and x-sections of single member of a structure as well as the solid building/structure can also be viewd in this software.

DESIGN GUIDELINES AND ASCE CODES:

- ASCE 7-05 (load distribution and minimum criteria for loading on structure and buildings)
- LRFD (load resistance and factor design method is followed for deisgning of a structure)
- ACI 318-11(Manual of american concrete institute)
- UBC-97(Uniform building code)
- ACI 314R-11 (Simplified design of RCC building)
- ACI 318-08 (ACI guidelines for post tensioning)
- ACI 423.7-07(Fabrication guidelines for unbonded single strand tendons and material criteria for)
- PTI M10.2-00(Unbonded single strand tendons guidelines)
- ACI 301-10 Section-9(requirements for PT concrete design)

ANALYSIS AND DESIGN IN STEPS:

- Grid formation
- Material and section properties of a structure
- Load calculation
- Assignment of loads as per ASI criteria
- Structural analysis
- Design

GRIDS FORMATION:

The very first step in carrying out the structural analysis and design is the formation of grids. For structural elements of a structure, separate as well as the same grid can be used;however we used separate grid for columns and slabs of a structure.

MATERIALS AND SECTION PROPERTIES:

Selection of material and properties of section is the step after defining grids in ETAB. Grade-60 steel and concrete of 150 lbs/ft^2 is used in our structure design. Shear wall is also consitutes of concrete of same unit weight. In our conventional design, beams,slabs,columns,shear wall and beams were all made of concrete of 4 ksi strength.

LOADS ALLOCATION:

Loads, which are considered in design process, are following:

- Live loads
- Dead loads
- Earthquake loads

- Superimposed loads
- Partition loads

Magnitudes of loads are according to ASI provisions

Dead loads:

It is defined by the self weight of a structure. Dead loads are permanent and they are subjected to a structure for the entire life time of a structure. Using dimensions of our structure from drawing and material properties(concrete density), dead loads are calculated.

Live loads:

These loads majorly depend on the purpose for which a structure is designed and the usage of building. Live loads can change in location and they vary over the structure and magnitudes of these loads do not remain constant. These are listed in ACI building codes provisions according to each different case of purpose of usage of building. Live loads for parking structure are different from commercial and residential buildings as per criteria of American concrete institute.

Earthquake loads:

Earthquake load is one of the major loads, which act on a structure. This is in the form of lateral force, which a structure faces during an earthquake, or when the building shakes. This force could larger be in magnitude especially in hilly areas that a structure undergoes a considerable lateral displacement. Magnitude of earthquake loads vary from one place to another

Superimposed loads:

Dead load other than the weight of building is known as superimposed load. It stays on a structure for life time or major time period of its life. These loads include finishing, ceiling and HVAC loads.

CALCULATION OF LOADS:

Loads are calculated according to the nature of structure and ACI provisions. Table 4.1 of ACI manual and ASCE 7-05 are utilized for loads calculations.

As far as other loads are concerned, they are also taken from the guidelines of ASCE. ASCE 7-05 and table C-3. Dead loads are calculated manually. Superimposed dead loads are encapsulated in model, which may include finishes, ceiling and HVAC.

Load combinations:

Structure should be designed with load combinations according to ACI requirement. Factored load include

- Dead + live load
- Three basic combinations may include dead+live+earthquake and some portions of snow,rain and roof live load

ETAB consider each combination as an individual applied load on structure and for analysis and design "AUTO" load combination option is available in ETAB

LOAD ASSIGNMENT/APPLICATION:

After the definition of each building component and material and section properties, we proceed to the application of loads where loads are applied in the form of UDL(uniform distributed loads)

STRUCTURAL ANALYSIS:

After the proper combination of loads and section properties,structure is analysed to check for shear force, axial forces and moments. One can also check the discontinuty, flaw or any other failure in the structure during analysis in model. Using "RUN ANALYSIS" command in software performs this.

DESIGN:

After analysis, the next part is the design of a structure by using check design commands. Members and sections which are overstressed can easily be checked and redefined untill they satisfy the criteria of given load distributions and design check. Strength reduction factors used in LRFD method are

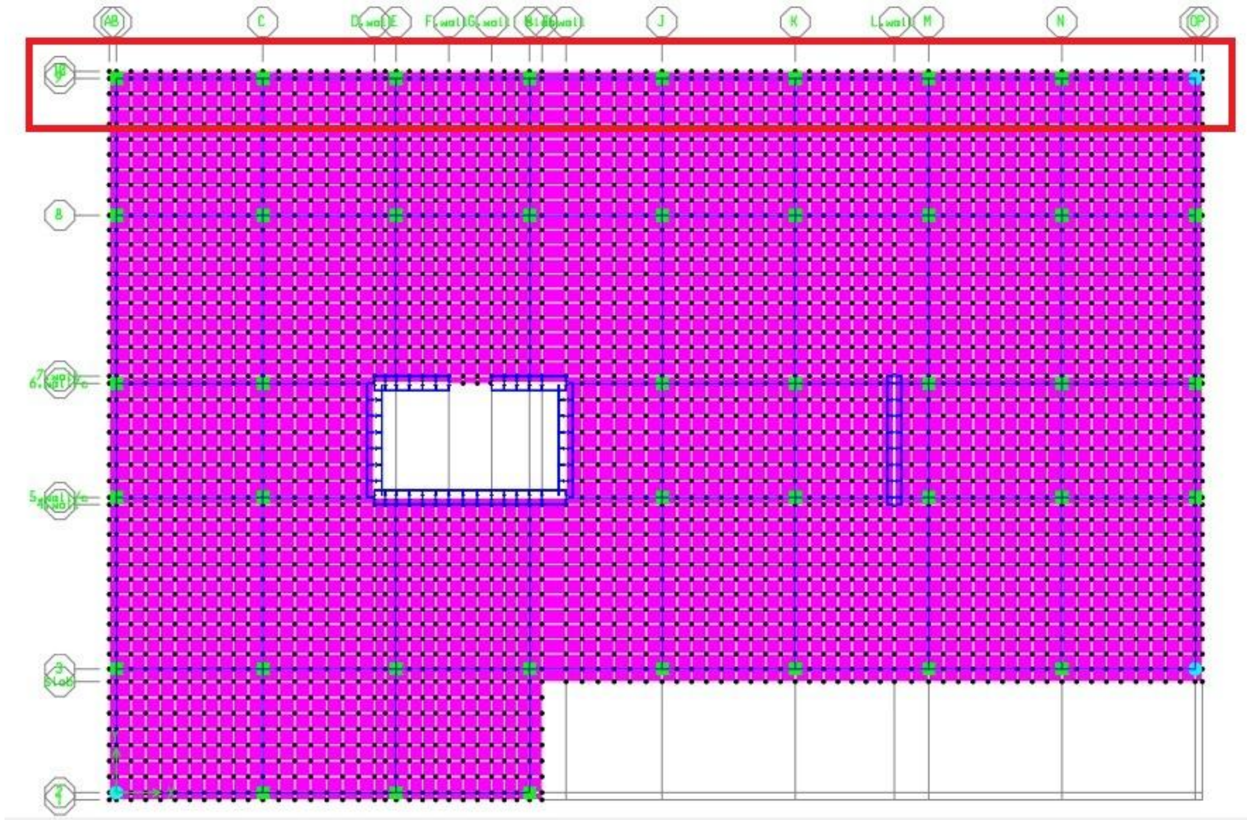
Tensioned control members	0.9
Compression controlled members	0.9
Tied reinforced members	0.65
Shear and torsion	0.75
Bearing on concrete	0.65
Post tensioning anchorage zone	0.85
struts	0.75

After the design of beams,columns,shear walls and other structural members, columns are exported to SAFE software which is specified in design of slabs and foundations. Slabs and foundations are designed with normal concrete(4 ksi).

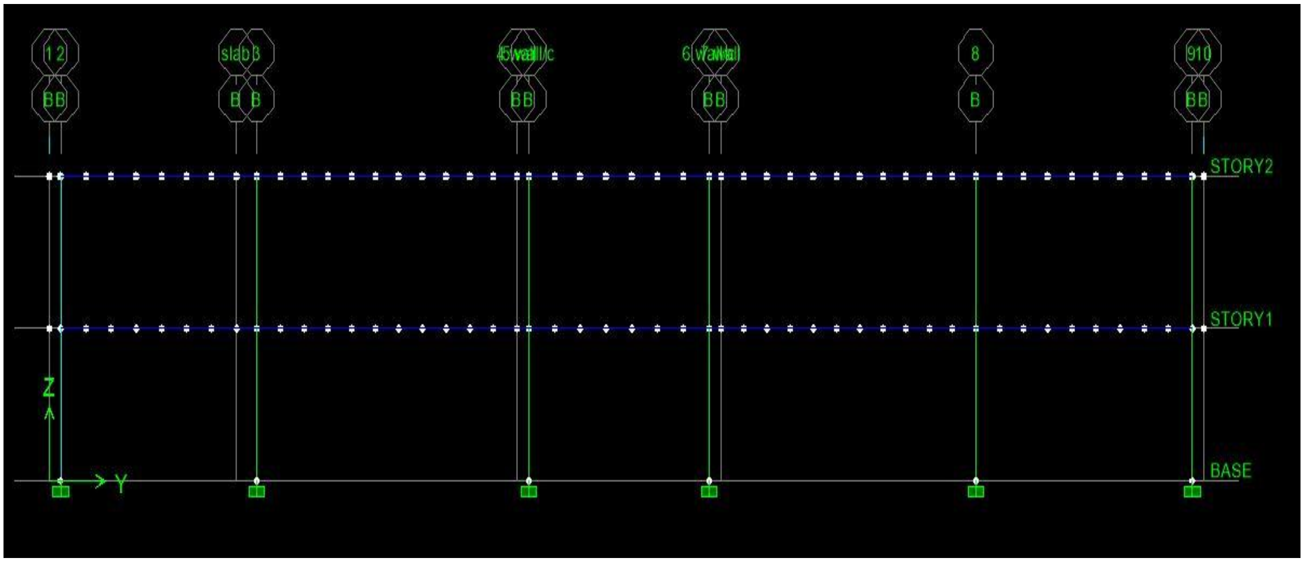
In addition to softwares, hand calculations for each member of beams and slabs are crosschecked to satisfy the results.

ANALYSIS AND DESIGN (COMPARISON):

The figure below is displayed portion of our structure,plan view of grid 9 as shown below :



Grid 9 has nine columns named as 9B, 9C, 9E, 9H, 9J, 9K, 9M, 9N and 9O. Beams are shown between these columns in blue colour and their design can be seen also. There are total 8 beams provided in this grid as shown.



Both elevation and plan of grid 9 are shown in the figures.

Beams comparison:

As we know, beams are designed on the most critical parameter of bending moments. Maximum bending moment in a beam is the basis of beam design. Bending moments of beams in GRID 9 are shown below:

Analysis of beam:

Beam bending moments in grid 9:

Beams bending moments in grid 9 (k-in)								
STORY	B1	B2	B3	B4	B5	B6	B7	B8
1	79.2	64.56	55.64	55.14	56.3	56.01	60.1	67.5
2	54.1	46.12	39.3	38.1	39.2	39.4	41.1	46.2

Design of beams:

Beams design								
STORY	B1	B2	B3	B4	B5	B6	B7	B8
STORY-1 Section(in^2)	18 x 24	18 x 24	18 x 24	18 x 24	18 x 24	18 x 24	18 x 24	18 x 24
Reinforcement area (in^2)	0.5	0.42	0.36	0.35	0.36	0.36	0.37	0.42
Shear reinforcement(in^2)	0.12	0.11	0.09	0.1	0.09	0.09	0.08	0.11
STORY-2 Section(in^2)	18 x 24	18 x 24	18 x 24	18 x 24	18 x 24	18 x 24	18 x 24	18 x 24

Reinforcement area(in^2)	0.5	0.59	0.51	0.51	0.52	0.51	0.55	0.62
Shear reinforcement(in^2)	0.12	0.15	0.12	0.12	0.12	0.12	0.13	0.18

Design and analysis of slabs:

After designing and analysis of beams and other structural components in ETAB, slabs are designed and analyzed by exporting the each story from ETAB to CSI SAFE including load cases, floor loads and all combinations of load. Only one of the strip of slab is selected and analyzed and designed accordingly in SAFE CSI. Analysis and design of slabs for strip # is shown below.

Strip	SpanID	Location	Top moment K-ft	Top steel In^2	Bottom Moment K-ft	Bottom Steel In^2
SA33	Span 1	Start	28.5325	0.4276	22.1293	0.602
SA33	Span 1	Middle	-1.1939	0.0562	37.3377	1.0767
SA33	Span 1	End	-51.704	1.5178	0.7317	0
SA33	Span 2	Start	-44.1779	1.2978	0.0149	0
SA33	Span 2	Middle	-1.0747	0	22.01	0.6319
SA33	Span 2	End	-36.0818	1.054	0.7436	0
SA33	Span 3	Start	-37.4412	1.0949	0.0152	0
SA33	Span 3	Middle	0	0	24.8458	0.7129
SA33	Span 3	End	-38.8518	1.199	0.769	0
SA33	Span 4	Start	-38.5435	1.1256	0.0158	0
SA33	Span 4	Middle	0	0	23.9683	0.685
SA33	Span 4	End	-38.0271	1.113	0.7364	0
SA33	Span 5	Start	-37.9141	1.112	0.015	0

SA33	Span 5	Middle	0	0	23.67	0.6807
SA33	Span 5	End	-38.4105	1.1195	0.7292	0
SA33	Span 6	Start	-38.8514	1.1426	0.0149	0
SA33	Span 6	Middle	0	0	24.6277	0.7102
SA33	Span 6	End	-38.2648	1.1145	0.7818	0
SA33	Span 7	Start	-37.4718	1.1012	0.016	0
SA33	Span 7	Middle	0	0	22.7692	0.654
SA33	Span 7	End	-41.1856	1.2039	0.603	0
SA33	Span 8	Start	-44.0667	1.2937	0.0123	0
SA33	Span 8	Middle	0	0	31.4733	0.9055
SA33	Span 8	End	-26.2904	0.773	4.0435	0.1219

POST-TENSIONING

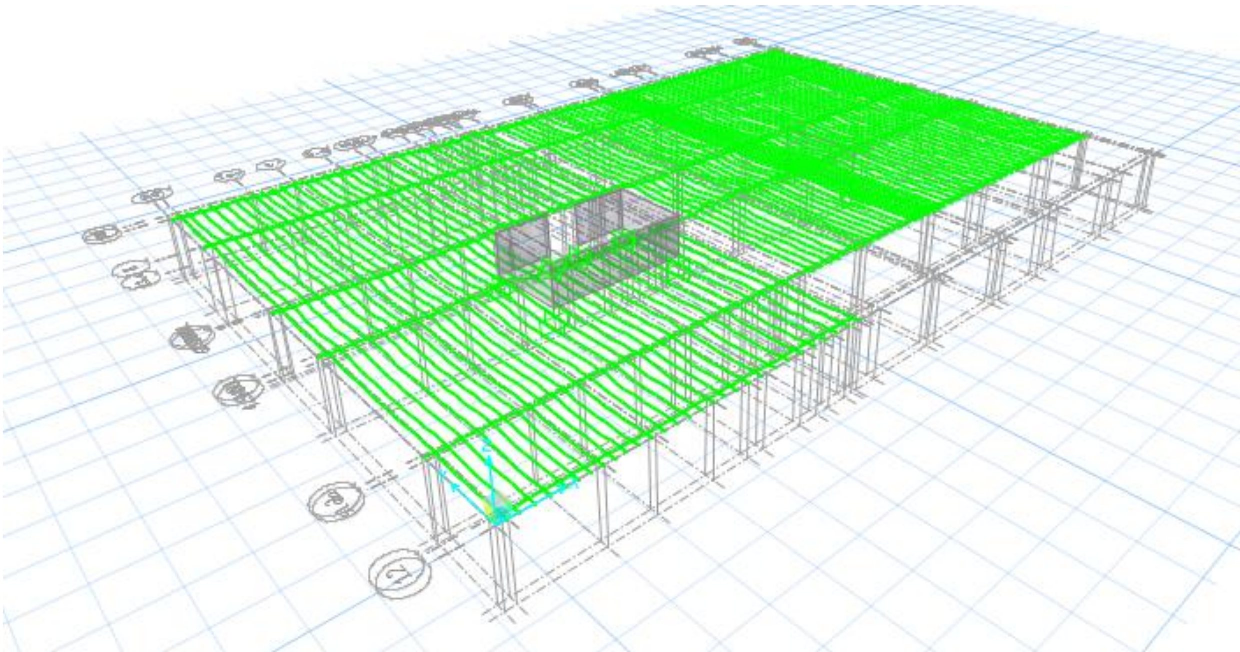
Architectural Description:

Analysis and design of two story Parking structure done and we obtain the 2D drawing from Assistant Professor, Dr. Bilal Ahmad. Structure story height is 9 ft each, totaling up to two stories. Elevator was provided in the center of building. Structure total covered area is 28496 ft^2 and shear wall of 24" is provided to counter the seismic loads in case of earthquakes. Spacing between columns is sufficient for the passage of cars with no hindrance.

Analysis Software:

CSI SAFE is one of the renowned software in the construction industry and is widely used for analysis and design of buildings. CSI SAFE incorporates each part of the building configuration process. It also provides built in templates to analyze and design the buildings. It is also capable of onscreen assignment of properties, loading and supports to the structure.

After analysis and designing of the structure, results can be shown directly on the model. Results include top and bottom fiber stresses, bending moment diagram, loads assigned and reactions generated. Moreover, CSI SAFE also generates reports and tables for all analysis and design output. Working drawings, detailing and cross sections can be displayed for either concrete or steel framed buildings.



Design Codes and Guidelines:

Codes and guidelines that are used in conventional modelling and design are applicable to Post-tensioning. Engineering Reference Manual Eighth Edition, issued in 2015, used as a base for design and calculation of Pre-stress short and long-term losses.

Steps followed for Analysis and Design:

- Grid formation
- Material and section properties of a structure
- Load calculation
- Assignment of loads as per ASI criteria
- Structural analysis
- Design

Grid formation:

First step for creation of building structure is formation of grid. We formed separate rectangular grid for column and slab. A rectangular grid formed for overhang slab around the Parking structure.

Material and section properties:

After formation of grid, the next step is assigning section and material properties in CSI SAFE. Concrete having a density of 150 pound per square feet and Grade 60 steel used as main material in the building. Monostranded tendon of ultimate strength 270 ksi used as banded and distributed tendon. Two types of column (Rectangular and circular) provided with sufficient space to incorporate vehicles. Slab of 7.5-inch thickness provided for first and second story with overhang of one and the half-inch thickness around the building.

- Tendons:
  Strand A416 of 0.6 inch size
  Ultimate strength of 270,000 psi
- At PT-transfer Concrete Strength:
  $f_{ci}=P_i/A_g + P_ie/S_b – M_G/ S_b$
  $f_{ci=}2463.088$ psi
  Concrete strength at transfer.

Load Calculation:

After assigning material and section properties next important step was to calculate loads for which we uses ACI provisions and ACI building codes. Post tension tendons jacking force calculated according to ACI-308 code. After calculation of PT-transfer force, Short and long term losses calculated according to engineering reference manual. CSI Safe on default incorporate self-weight of structure and Superimposed dead load calculated according to floor thickness and facilities provided in a structure. For Live load Table 4.1 of ACI manual used to calculate live load.

Calculation of Post-tension forces:

- PT-transfer:
  $P_i=A_{ps} \text{ x } f_{si}$
  $f_{si}=0.7 \text{ x } f_{pu}$
  $f_{si}=0.7(270{,}000)$
  $f_{si}=189{,}000$ psi
  $A_{ps}=\pi d^2/4$
  $A_{ps}=0.2827 \text{ in}^2$
  $P_i= A_{ps} \text{ x } f_{si}$
  $P_i=53{,}438$ lb per tendon
- PT-final:
  First all losses incorporate in post-tensioning calculated by provision given in Engineering Reference Manual Eighth Edition. Consequently, PT-final in a tendon calculated by subtracting all losses in tendon from PT-transfer force.

  PT losses Calculation:

  i. Friction Loss:
     $R=a^2/2g$

$L_{px}=a + g^2/3a$
$\alpha= L_{px}/R$
$KL_{px}+\mu\alpha=x$
Where,
K and μ friction coefficient from ACI Code-308
$x<0.3$
$P_{px}=P_i/(1+x)$

ii. Anchor Seating Loss:
$L_c^2=CA_{ps}E_p/m$
$m= (P_{pj}-P_{px})/L_{px}$
$P_c=P_{pj}-mL_c$
$P_{pj(anch)}=P_{pj}-2mL_c$

iii. Elastic Shortening of Concrete:
$P_{\Delta el}=n_iA_{ps}f_{pp}$
$n=E_p/E_{ci}$
$E_{ci}=57(f_{ci})^{0.5}$
$f=P_p(1/A_g + e^2/I_g)$

iv. Long-term Creep of Concrete:
$P_{\Delta creep} =1.6nA_{ps} f_{pd}$
$n=E_p/E_c$
$f=P_p(1/A_g + e^2/I_g)– eM_g/I_g – eM_d/I_g$

v. Long-term Shrinkage of Concrete:
$P_{\Delta sh} =K_{sh} A_{ps} \varepsilon_{sh} E_p (1 – 0.6A_g/P_{cp})(100-H)$

vi. Long-term relexation of stress in prestressed tendons
$P_{\Delta re} = (A_{ps} * K_{re} –J(P_{\Delta creep} + P_{\Delta sh} + P_{\Delta el}))C$

Calculation of all above losses were done according to formulas given above. In the end after summation of all losses it were subtracted from PT-transfer force to calculate the PT-final force which will remains in tendon.

Losses	Values
▪ Friction Loss	2.5 K
▪ Anchor Seating Loss	4.2 K
▪ Elastic Shortening of Concrete	6.4 K
▪ Long-term creep of concrete	4.2 K
▪ Long-term Shrinkage of Concrete	2.09 K
▪ Long-term relexation of stress in prestressed tendons	4.22 K
Total	23.61 K

Load Type	Value	Unit
Dead load= Self weight + Superimposed Dead load		
40 mm Ceramic Tiles	15.2	psf
15 mm Screed	8.666	psf
24 mm Cement fiber Board	7.999	psf
False Ceiling	18.14	psf
Total Dead Load	50	psf

Combining factored Loads using Load resistance & Factored Design:

- 1.2DL+1.6LL
- 1.4DL
- 1DL+1PT-transfer
- 1DL+1LL+1PT-final
- 1DL +0.5LL + 1PT-final

Analysis of Structure:

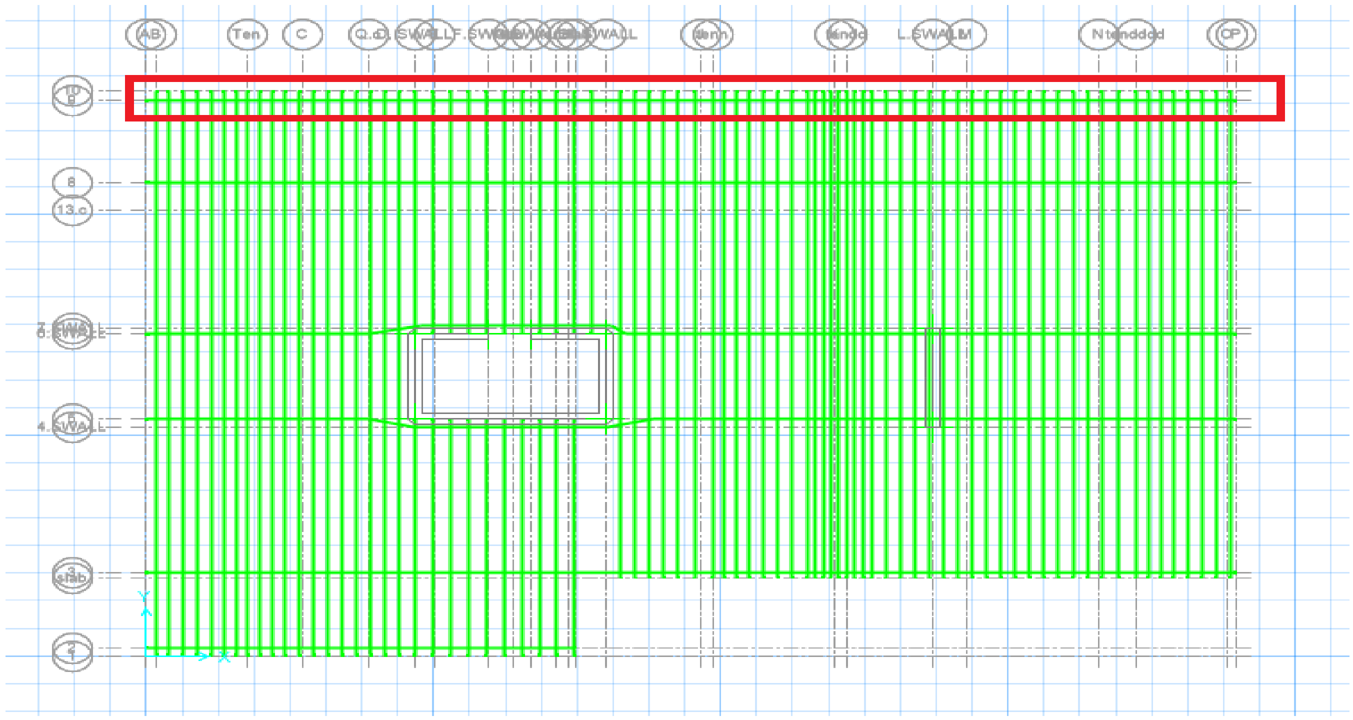
After following all of the above-mentioned step, analysis was run on CSI Safe. Desired result of bending moment, top and bottom stresses shown by moving cursor on slab. One can also check the discontinuity, flaw or any other failure in the structure during analysis in model.

Design:

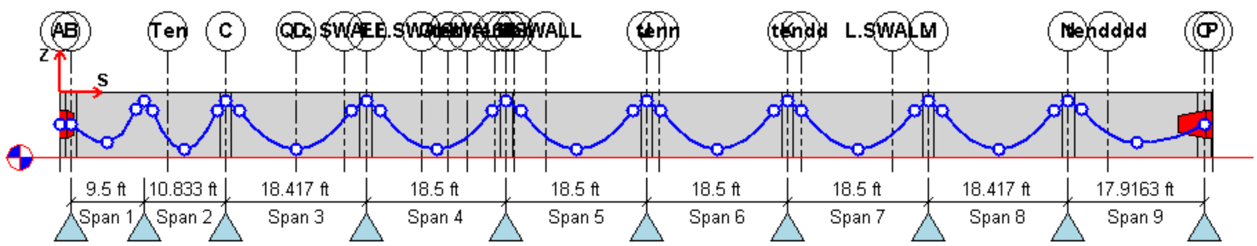
After designing and analysis of beams and other structural components in ETAB, slabs are designed and analyzed by exporting the each story from ETAB to CSI SAFE including load cases, floor loads and all combinations of load. Only one of the strip of slab is selected and analyzed and designed accordingly in SAFE CSI. Analysis and design of slabs for strip # is shown below.

After analysis, the next part is the design of a structure by using check design commands. Members and sections which are overstressed can easily be checked and redefined untill they satisfy the criteria of given load distributions and design check.

The figure below shows the selected Grid 9 for structure:



Generated vertical tendon profile of selected grid 9 is shown below,



Slab Moment Data:

Strip	Load Combination	Top moment (k-ft)	Bottom moment (k-ft)	Shear force Kip
CSA1	1DL+1LL+1PT-final	0.0000	0.0000	0.000
CSA1	1DL+1LL+1PT-final	-7.7014	8.5484	3.102
CSA1	1DL+1LL+1PT-final	-9.0322	8.7240	4.130
CSA1	1DL+1LL+1PT-final	-67.1982	8.7240	4.130
CSA1	1DL+1LL+1PT-final	-18.8373	18.4673	19.794
CSA1	1DL+1LL+1PT-final	0.0000	47.8951	0.885

CSA1	1DL+1LL+1PT-final	0.0000	47.8951	0.885
CSA1	1DL+1LL+1PT-final	-1.1591	34.8142	11.677
CSA1	1DL+1LL+1PT-final	-72.5883	0.0031	15.919
CSA1	1DL+1LL+1PT-final	-24.0638	0.1362	4.846
CSA1	1DL+1LL+1PT-final	0.0000	25.0650	4.152
CSA1	1DL+1LL+1PT-final	-10.9385	9.7608	11.164
CSA1	1DL+1LL+1PT-final	-13.6115	0.0713	2.648
CSA1	1DL+1LL+1PT-final	0.0000	30.8915	0.813
CSA1	1DL+1LL+1PT-final	-10.3693	11.0787	13.883
CSA1	1DL+1LL+1PT-final	-15.3387	0.0825	2.583
CSA1	1DL+1LL+1PT-final	0.0000	27.9984	5.796
CSA1	1DL+1LL+1PT-final	-10.3277	7.4035	10.667
CSA1	1DL+1LL+1PT-final	-14.7251	0.0894	3.335
CSA1	1DL+1LL+1PT-final	0.0000	29.9226	0.106
CSA1	1DL+1LL+1PT-final	-7.1258	4.2813	9.132
CSA1	1DL+1LL+1PT-final	-15.6897	0.0623	3.652
CSA1	1DL+1LL+1PT-final	0.0000	28.0498	1.267
CSA1	1DL+1LL+1PT-final	-8.0349	11.3664	14.182
CSA1	1DL+1LL+1PT-final	-13.0425	0.0653	2.248
CSA1	1DL+1LL+1PT-final	0.0000	29.8736	0.290
CSA1	1DL+1LL+1PT-final	-7.6938	4.1120	9.347
CSA1	1DL+1LL+1PT-final	-15.7218	0.0514	3.779
CSA1	1DL+1LL+1PT-final	-0.6832	30.3328	9.765
CSA1	1DL+1LL+1PT-final	-4.5251	14.5560	9.791

Slab Stresses Data:

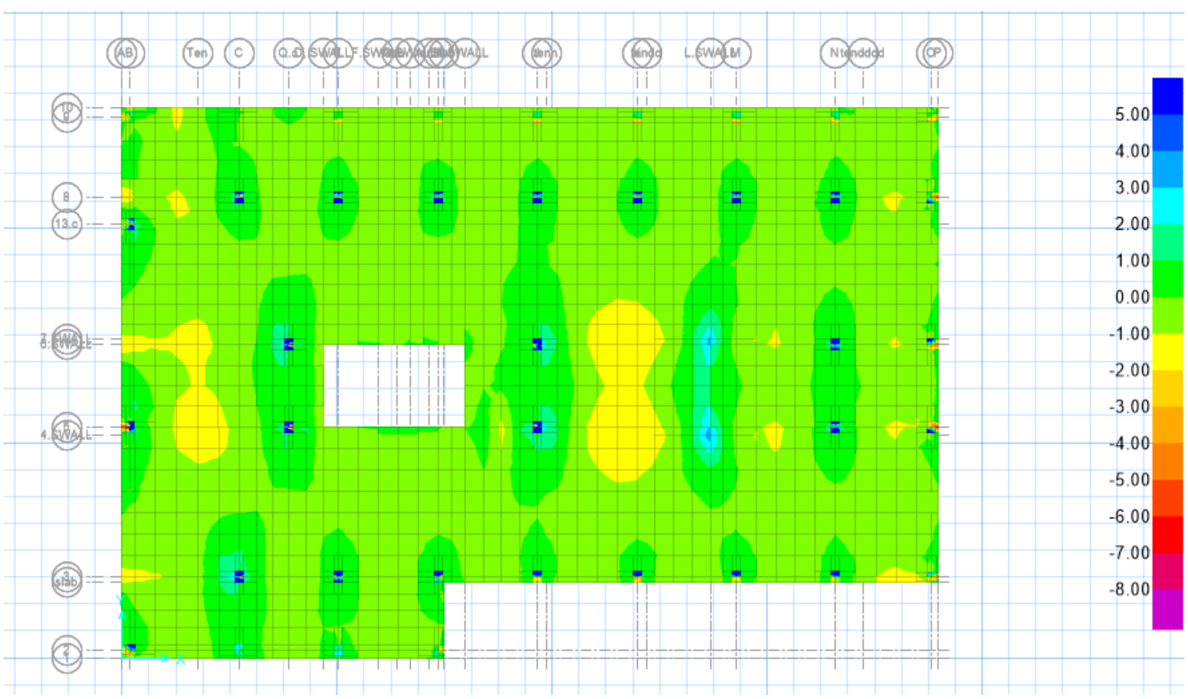
Strip	Top Stresses (kip/in^2)	Bottom Stresses (kip/in^2)

CSA1	0.2787	0.2442
CSA1	0.2867	0.2460
CSA1	0.2798	0.1879
CSA1	0.1654	0.1674
CSA1	0.9109	0.3466
CSA1	0.4441	0.0000
CSA1	0.0000	0.0000
CSA1	0.1488	0.5266
CSA1	0.1273	0.2802
CSA1	0.2544	0.2255
CSA1	0.1783	0.0729
CSA1	0.0141	0.0988
CSA1	0.0122	0.3077
CSA1	0.1700	0.329
CSA1	0.4858	0.1469
CSA1	0.021	0.0000
CSA1	0.2901	0.0680
CSA1	0.1961	0.0782
CSA1	0.0570	0.1623
CSA1	0.0593	0.3803
CSA1	0.1892	0.3753
CSA1	0.5130	0.1863
CSA1	0.3350	0.000
CSA1	0.3381	0.0457
CSA1	0.2164	0.0864
CSA1	0.0906	0.1571
CSA1	0.0930	0.3694
CSA1	0.2419	0.3810
CSA1	0.5985	0.1927
CSA1	0.3967	0.0000
CSA1	0.3525	0.0542
CSA1	0.2076	0.1005
CSA1	0.0832	0.2667
CSA1	0.0987	0.4408
CSA1	0.2387	0.4179
CSA1	0.6092	0.1976
CSA1	0.4129	0.0000
CSA1	0.3480	0.0648
CSA1	0.2028	0.1071
CSA1	0.0826	0.2393
CSA1	0.1102	0.4237
CSA1	0.2721	0.3914

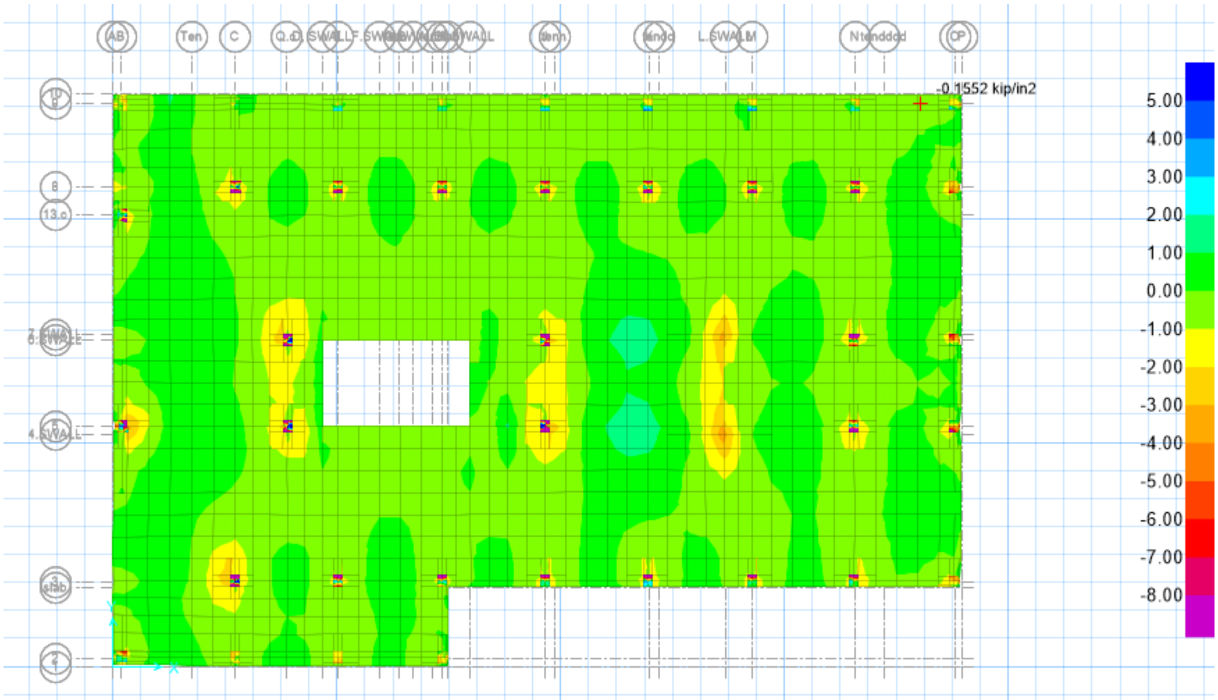
CSA1	0.6741	0.1702
CSA1	0.4467	0.0000
CSA1	0.3506	0.0028
CSA1	0.1716	0.1313
CSA1	0.0742	0.2837
CSA1	0.0984	0.4470
CSA1	0.2644	0.4219
CSA1	0.6457	0.1985
CSA1	0.4499	0.0000
CSA1	0.3126	0.0672
CSA1	0.1630	0.2036
CSA1	0.2358	0.3436
CSA1	0.3488	0.3604
CSA1	0.4190	0.2491
CSA1	0.4233	0.1388
CSA1	0.3203	0.1095
CSA1	0.0887	0.0295

Graphical Results:

Top stresses:



Bottom Stresses:



EXPERIMENTAL WORK

Introduction:

Laboratory work applicable to this project has been covered in this chapter. Chapter divided into following sections:

- Experimental Program
- Equipment
- Materials
- Mixing and Sampling
- Testing

Experimental Program:

General:

The study of high strength concrete needs the determination of properties that may effect and influence the concrete parameters; followed by studying the outcomes of changing these parameters. The final response was taken by keeping the external variables and factors within a certain limit of variation and recording the values obtained for each step like mixing and curing afterwards, which gives us the a set of reliable results of involved external factors which are mainly slump (workability) and mixing water temperature. However the first step is the acquisition of the required materials:

Materials:

Cement:

- Manufacturer: Best way
- Factory: Hattar
- Type: OPC TYPE 1 (ASTM C-150)
- Mean particle size: 10.165 µm
- Density: 1440kg/m3
- Blaine fineness 3100-3200 cm^2/g
- Sieve residue > 45 µm of 9-11 % by mass

5 bags were purchased in order to carry out the experimentation from primary distributor so that the research work may not be disturbed by variation in different batches in initial approach

as well as during casting of concrete. Cement bags were stored in damp free air tight environment and required conditions.

Water:

Water from structure engineering lab NICE, was contained in a container in order to achieve the maximum uniformity in temperature conditions and water properties in concrete. The characteristics of obtained water were studies in IESE lab

Super plasticizer (Glanium-51):
Glenium-51 is a superior cement superplasticiser in view of polycarboxylic ether. Glenium-51 has been produced for applications in the ready mixed and pre-cast RCC commercial enterprises where the most elevated toughness, durability and execution is required. Particularly its fantastic scattering/dispersion properties make it the perfect admixture for precast and ready mixed RCC where low water proportions are required. This admixture is used for following aspects:

- To obtain high early strength of concrete
- Desired workability without the risk of segregation and bleeding actions
- Less vibrations
- For places in congested reinforcement
- It can reduce the labor
- Betterment of surface finishes
- Standards: EN-934-2 table 3.1 & 3.2

Other aspects and information of Glanium-51:

- No chloride and can easily comply with ASTM C494 types A&F
- Actions against carbonation
- Increased early and ultimate strengths
- More flexure strength for beams and durability
- High adhesion properties and elastic modulus
- Reduce shrinkage and creep and it also lower permeability effects

SG	PH	ALKALI %	CHLORIDE %	CHLORINE %
1.095	7.20	Less than or equal to 4	Less than or equal to 0.1	Less than or equal to 0.1

Dosage:

Dosage of glanium-51 highly depends on the mix design of concrete. However the recommendation about its dosage is between:

- 0.2-1.0 % per 100 kg of cement (measure “by volume”)
- 0.219-1.095 kg per 100 kg of binder (cement) (measure “by mass”)

- Other dosages may be recommended in a certain condition where it is specified by designer

Packaging, storage and shelf life:

- Glanium-51 is mostly available in market in the form of 205 liters drums or in bulk. Packaging is also available in 1000 liters containers
- Glanium-51 must be protected from extreme weather conditions. Temperature should not drop below $5c^0$ and exposure of direct sunlight should be avoided. Failure of achieving the specified controlled conditions may cause premature non-uniformity and deterioration.
- Life is about 12 months if stored under recommended conditions and if seal of container is not opened.

Mix proportions:

The experimental program was done to cross check the mix design issued by BASF Islamabad Pakistan. Mix design was improved by changing the quantity of Super Plasticizer. The very first step is to modify water to cement ratio and quantities of super plasticizer to attain desired value of slump and concrete strength. Initially the process is improvised with the constant replacement of percentages of Glanium-51 ratios (with respect to the cement ratio which is held constant) in order to get the synergy effects of maximum enhancement of fresh and hardened state properties of mix also in addition to improved filler effects, reduction of pores, density and desired strength. The formulations initially considered are the fixed mix-ratio (1:1.4:2) with minimum slump criteria of 2". An additional admixture "Rheobuild" was also recommended by distributor but later it was considered of no use as far as the desired strength was required. While the other variables are replaced in three hit and trials steps are as follows:

STEP-1	
Mixing ratio	Fixed
Glanium-51	2% by cement mass
Rheobuild	1.5%
W/C ratio	0.325

STEP-2	
Mixing ratio	Fixed
Glanium-51	1% by cement mass
Rheobuild	1%
W/C ratio	0.34

STEP-3 (Final &Selected)	
Mixing ration	Fixed
Glanium-51	0.8%
Rheobuild	0 %
W/C ratio	0.36

Step -3 quantities were finalized on the basis of slump (2”) and workability. The next part is mixing regime of ingredients for casting of concrete of desirable strength.

9"

- Glennium- 2%
- Rheobuild - 1.5%
- W/C - 0.325

5"

- Glennium- 1%
- Rheobuild- 1%
- W/C - 0.34

2"

- Glennium - 0.8%
- Rheobuild - 0%
- W/C - 0.36

Mixing regime:

Followed by 1 minute of dry mixing, mixing is done in a pan mixer to mix all the material and constituents of concrete. After that, water and super plasticizer is added slowly and gradually in a pan mixer and the mixing is continued for another 3 minutes. The mixing regime was taken from standards of casting and previous thesis work of final year students.

Sampling:

After standardized mixing in pan mixer, a sample of fresh state concrete was taken immediately as per ASTM C-172 and slump test was done within the 5 minutes of mixing. After achieving of required slump of 2”, fresh state concrete was taken immediately to the place where sampling is carried out via wheel barrow which was wetted before pouring of concrete in it. Conditions were controlled in a way that there was no direct sunlight exposure and wind. Afterwards moulds were fully prepared by cleaning and oiling from inside and tightening. The part of sampling was ensured in a limited time of 15 minutes only. In our experiment, samples are as follows:

Type of samples	Number of samples	Size of samples
Cubes	9	4” x 4” x 4”
Cylinders	9	6” x 12”
Beams	3	6” x 6” x 2.5’

Curing:

Curing was achieved after removing all samples from moulds after 24 hours and transferring them into the curing tanks. Samples are subjected to curing until they are tested as per criteria of ASTM C-192.

Testing:

It comprises of two parts:

- Fresh state testing
- Hardened state testing

Fresh state testing:

Slump test:

This test is carried out according to the ASTM C-143 standards. Slump cone and base plate was wetted and was placed on a level surface. Concrete was added in cone in three layers whereas the tamping was also carried out in three layers (each layer with 25 blows with tamping rod). Slump readings were noted with the help of ruler.

Hardened state tests:

Compressive strength test:

For carrying out the compressive strength of concrete, cubes and cylinders are subjected to UTM (Universal Testing Machine). For each test, cubes are cylinders were removed from curing taken 24 hours prior to testing time and samples are stored in cool temperature. Weights and dimensions of samples were noted before testing. Samples were kept in UTM accordingly and loading rate of UTM was kept at 0.2MPa. In the end, maximum load and maximum strength was noted down for each sample.

"Beams" were also tested in "flexure testing machine" by three point flexure test. Flexure is defined by the stress in a material before it yields. It provides the values of modulus of elasticity, flexural stress and, flexural strain and stress-strain relation. Three point test has benefits of ease in specimen preparation and testing. Conditioning of sample influences the test outcomes. The specimen is set on two supporting sticks a required separation apart and a third stacking pin is brought down from above at a steady rate until test ends at failure of the sample. Testing is done as per ASTM D-790. Flexural strength of a beam member was calculated simply by these formulas:

Stress =MC/I

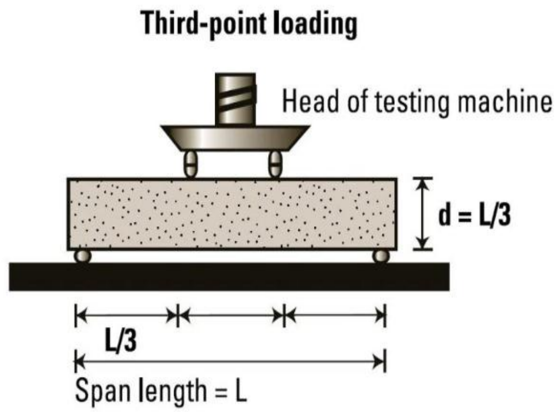
M=PL/4

P= Maximum load

L= length between two pin supports

I=Moment of inertia

C=Distance from neutral axis



Experimental results and conclusions:

Samples were basically the cubes, cylinders and beams. Results and data for respective day and type of samples are shown as below:

Data of samples		
Type of samples	Number of samples	Size of samples
Cubes	9	4” x 4” x 4”
Cylinders	9	6” x 12”
Beams	3	6” x 6” x 2.5’

Results and strengths of cubes and cylinders at respective days are shown as below:

DAY-3rd				
CUBES				
Cubes #	Wet weight (kg)	Dry weight (kg)	Maximum load (kN)	Compressive strength(N/mm^2)
Cube -1	2.61	2.55	297	16.6
Cube- 2	2.52	2.47	292	16.1
Cube -3	2.56	2.50	301	17.6
CYLINDERS				
Cylinder #	Wet weight (kg)	Dry weight (kg)	Maximum load (kN)	Compressive strength(N/mm^2)
Cylinder-1	13.4	13.22	261.2	15.1
Cylinder-2	13.33	13.05	264.3	15.4
Cylinder-3	13.45	13.28	263.1	15.2

DAY-7th

CUBES				
Cubes #	Wet weight (kg)	Dry weight (kg)	Maximum load (kN)	Compressive strength(N/mm^2)
Cube -1	2.54	2.516	363.8	36.4
Cube- 2	2.49	2.47	313.5	31.4
Cube -3	2.53	2.51	334	32.4
CYLINDERS				
Cylinder #	Wet weight (kg)	Dry weight (kg)	Maximum load (kN)	Compressive strength(N/mm^2)
Cylinder-1	13.26	13.21	513.1	29
Cylinder-2	13.23	13.19	522.4	30.3
Cylinder-3	13.8	13.76	510.7	30.01

DAY-28th				
CUBES				
Cubes #	Wet weight (kg)	Dry weight (kg)	Maximum load (kN)	Compressive strength(N/mm^2)
Cube -1	2.614	2.587	531.7	53.2
Cube- 2	2.573	2.545	481.1	48.1
Cube -3	2.598	2.578	444	44.4
CYLINDERS				
Cylinder #	Wet weight (kg)	Dry weight (kg)	Maximum load (kN)	Compressive strength(N/mm^2)
Cylinder-1	13.3	13.08	613.9	34.7
Cylinder-2	13.22	13.01	603.7	33.2
Cylinder-3	12.89	12.01	607.3	33.9

Results and strengths of beams at respective days are shown as below:

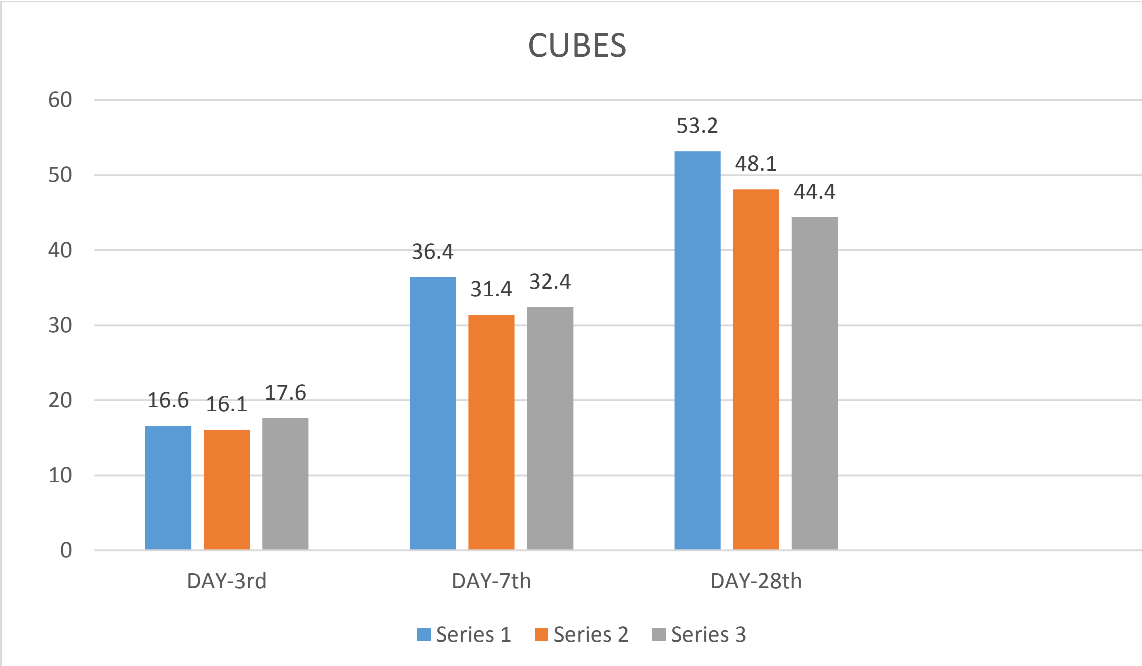
BEAMS			
3 days			
Beam #	Load (KN)	Moment (K-inch)	Flexural Strength (Ksi)
Beam-1	7.22	42.6377	1.242
Beam-2	7.14	42.165627	1.228
Beam-3	7.44	43.93692	1.2799
7 days			
Beam-1	14.3	84.44865	2.46
Beam-2	14.6	86.2203	2.51177
Beam-3	14.54	85.86597	2.50145
28 days			
Beam-1	24.6	145.2753	4.2322
Beam-2	25.3	149.40915	4.3526
Beam-3	25.4	150.1	4.373

Graphical Representation:

Graphical representation of compressive strength of cubes and cylinder and flexural strength of beams are shown below,

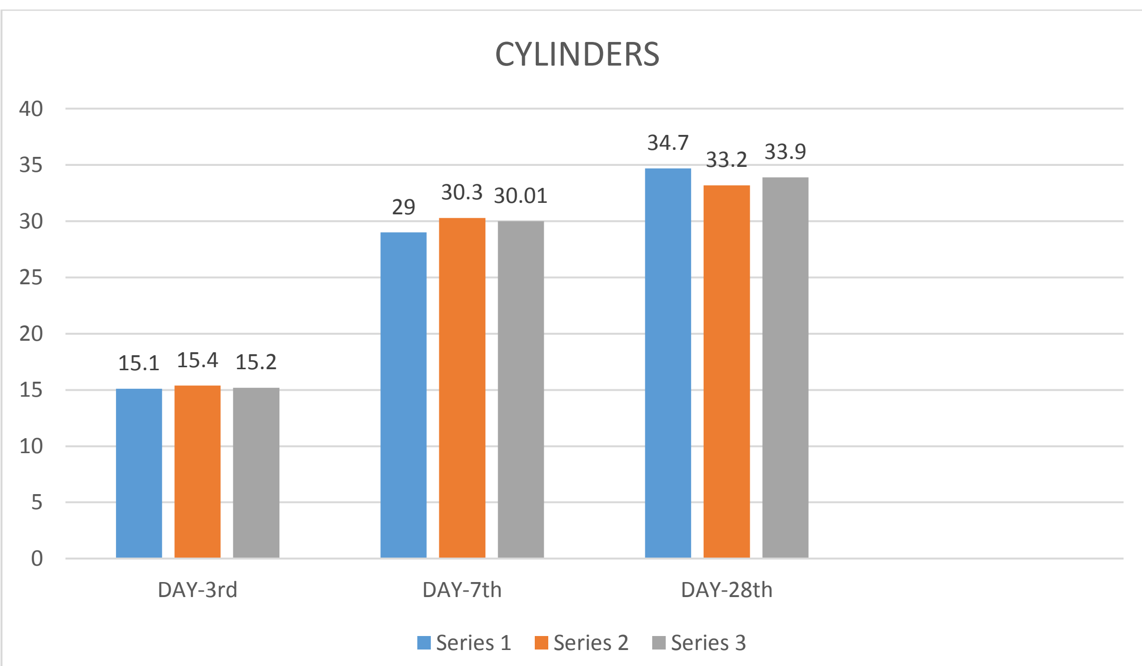
Cubes Compressive strength:

Compressive strength of cubes are shown on Y-axis and on X-axis testing days of 3, 7 and 28.



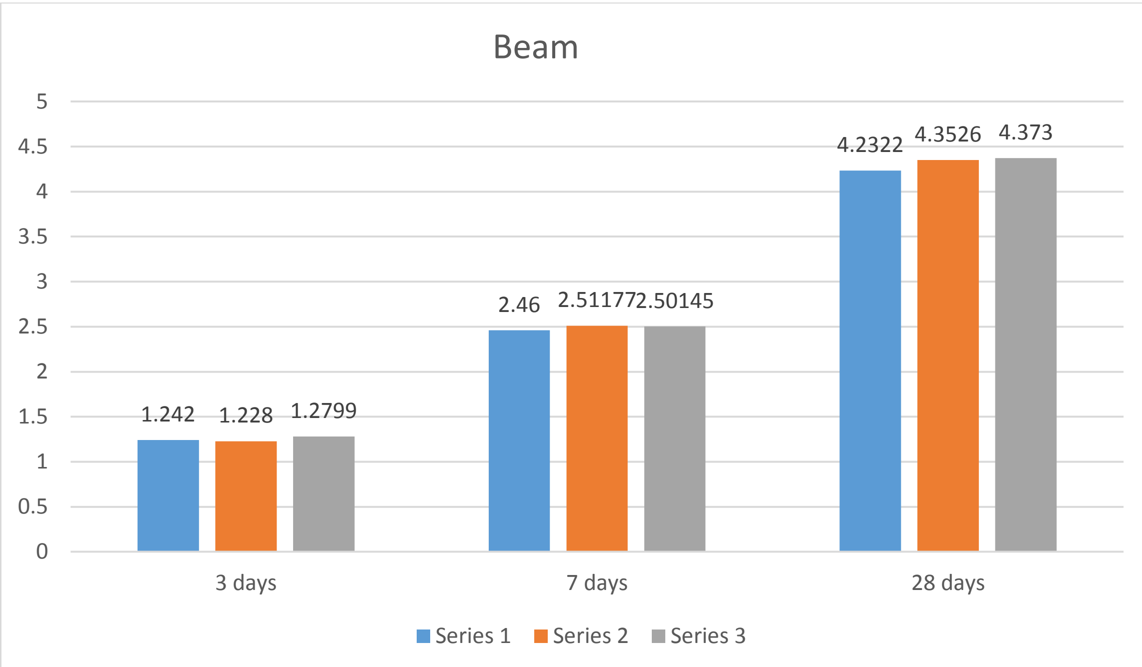
Cylinder Compressive strength:

Compressive strength of cubes are shown on Y-axis and on X-axis testing days of 3, 7 and 28.



Beams flexural Strength:

Beam flexural strength of 3, 7 and 28 days are shown on Y-axis,



COMPARISON ANALYSIS

After the complete and detailed calculations and analysis of both the conventional concrete system and Post-tensioned concrete systems and its applications, the results we obtained are very reasonable and self explanatory.

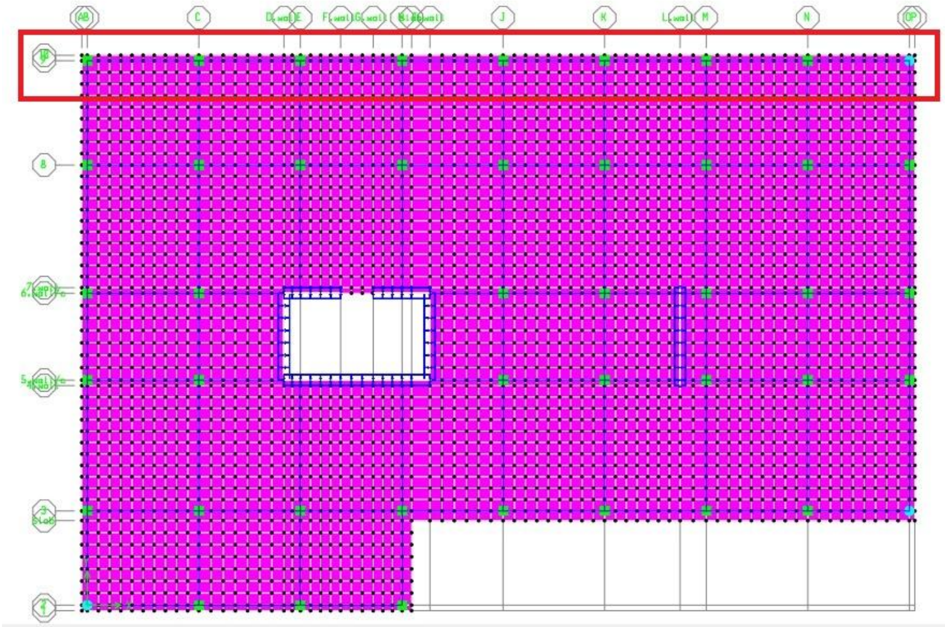
By using the Post tensioning concrete system, it doesn't only reduce the loads on the structures but the overall cost of a building reduces to a considerable amount. We deduced the following outstanding benefits regarding the structural advantages and cost economy:

- Structures designed by Post tensioned concrete technology are more efficient and strong and have larger limits to bear loads as compared to the conventional concrete design
- Less concrete and steel reinforcement is needed for the structural capacity than in case of normal design.
- Slab stiffness is enhanced sufficiently that a slab can resist bending actions by differential soil settlements
- Post tensioning also helps in minimizing the crack formation thus controlling the entry of insects and water agents
- Deflections are considerably controlled in post tensioning when a slab is put under the actions of service loads.
- Installation of post tensioning is easy as compared to normal design. We require less concrete to place and slab can be placed more quickly often than an equivalent rebar or normal reinforced slab
- Post tensioning has an outstanding performance and service records and hence recognized as more reliable
- Reductions in the quantities of concrete, excavation, steel and reduced labor costs. Beams are of smaller dimensions and thickness of slabs is small which in turn saves a lot in carrying out the general construction including the excavation and general preparation of site
- Using post tensioning concrete technology , we can save 20% of concrete and steel by 60-70% considering ideally
- Reduction in the size and dimensions of the structural members causes the reduction in dead loads which in turn reduces significantly the amount of steel and concrete in columns, roof systems and foundations
- Lower maintenance is required and also results in reduction of overall costs of structure. Reduction in building height can also save the general appliances costs like HVAC, energy savings and fixing etc

General cost benefits in any case of post tensioned construction is shown below:

Concrete	2-10%
Formwork for construction	10-20%
Steel required	50-80%
Overall cost saving	10-20%

Now we will compare and show the results of our projects for different structural member i.e. slabs (limited to our scope). The selected strip for comparison between two system of design is shown below:



Slabs comparison:

In case post tensioning, stresses and moments generated in slabs were more conservative as compared to conventionally designed slabs. It doesn't only reduce the loads on the structure but also effectively reduces the costs of a system. Slabs used in conventional design were 9˝ and in P.T the depth of slab was 7.5˝, clearly reducing the quantity of concrete and steel. Stresses and moments in both the systems are compared below as shown:

Post-tensioning:

Strip	Span-ID	Location	Top stresses Kip/in^2	Bottom Stresses Kip/in^2	Moment K-ft
SA33	Span 1	Start	-0.4965	-0.4968	-6.234
SA33	Span 1	Middle	-0.463	-0.1056	8.661
SA33	Span 1	End	-0.441	-0.388	-9.132
SA33	Span 2	Start	-0.2946	0.122	9.606
SA33	Span 2	Middle	0.0621	-0.2987	-5.707
SA33	Span 2	End	-0.3108	0.0158	8.0288
SA33	Span 3	Start	-0.0885	0.014	9.9091
SA33	Span 3	Middle	-0.2801	-0.2963	-5.1264
SA33	Span 3	End	-0.2933	-0.1015	6.9524
SA33	Span 4	Start	-0.1059	0.0201	9.5478
SA33	Span 4	Middle	-0.4101	-0.3245	-4.2819
SA33	Span 4	End	-0.3498	-0.0132	12.2062
SA33	Span 5	Start	-0.1636	-0.0947	8.6195
SA33	Span 5	Middle	-0.4441	-0.3235	-6.1583
SA33	Span 5	End	-0.3359	0.0291	14.0761
SA33	Span 6	Start	-0.1269	-0.1106	7.7906
SA33	Span 6	Middle	-0.4499	-0.3403	-5.5121
SA33	Span 6	End	-0.3114	0.0129	17.317
SA33	Span 7	Start	-0.1489	-0.1474	5.5918
SA33	Span 7	Middle	-0.4656	-0.331	-6.8834
SA33	Span 7	End	-0.4783	0.0507	16.0481
SA33	Span 8	Start	-0.5833	-0.511	-9.861
SA33	Span 8	Middle	-0.416	-0.2057	9.2661
SA33	Span 8	End	-0.326	-0.5038	7.3937

Conventional concrete

Strip	Span-ID	Location	Top stresses Kip/in^2	Bottom Stresses Kip/in^2	Moment K-ft
SA33	Span 1	Start	0.3913	-0.2385	-22.4686
SA33	Span 1	Middle	-0.4821	0.507	34.7355
SA33	Span 1	End	0.5721	-0.5841	-46.3732
SA33	Span 2	Start	0.5104	-0.5261	-41.3134
SA33	Span 2	Middle	-0.299	0.2991	20.8524
SA33	Span 2	End	0.3931	-0.3946	-33.0905
SA33	Span 3	Start	0.5355	-0.5369	-32.3848
SA33	Span 3	Middle	-0.367	0.3366	23.132
SA33	Span 3	End	0.4277	-0.4288	-35.662
SA33	Span 4	Start	0.4243	-0.4259	-33.6226
SA33	Span 4	Middle	-0.3263	0.3263	23.0739
SA33	Span 4	End	0.415	-0.4165	-33.5195
SA33	Span 5	Start	0.414	-0.4166	-30.7511
SA33	Span 5	Middle	-0.3244	0.3243	22.6884
SA33	Span 5	End	0.4231	-0.4247	-33.5939
SA33	Span 6	Start	0.4264	-0.4279	-34.1926
SA33	Span 6	Middle	-0.388	0.3387	23.304
SA33	Span 6	End	0.4177	-0.4193	-32.9136
SA33	Span 7	Start	0.4109	-0.4125	-34.2917
SA33	Span 7	Middle	-0.3102	0.3101	22.2921
SA33	Span 7	End	0.4698	-0.4669	-35.382
SA33	Span 8	Start	0.5012	-0.4991	-38.0313
SA33	Span 8	Middle	-0.4211	0.4193	28.07
SA33	Span 8	End	0.1168	-0.174	-17.67

Cost comparison:

Due to the more competent design in case of Post tensioning, the structures are generally thinner and more efficient. For example, the slab thickness in RCC flat slab system may be of 250mm think while the P.T slab with 200mm thickness is sufficient to serve with an equal effect and efficiency, fulfilling the economy of cost along with the structural advantages.

As Post tensioning design reduces the steel requirements and keeping in view that steel laying is a labor intensive part, it reduces the labor costs as well as steel costs. Large spacing between columns, reductions of dead loads due to more thinner slabs, reduction of steel reinforcement in the form of tendons, less work force requirements and earlier construction than conventional system, reduction in the overall weight of building versus conventional concrete with the same number of floors and functions, more advantageous under seismic activity, less concrete and maintenance and repairing works make Post tensioned concrete much more economical and beneficial in every aspect of construction than conventional RCC concrete. Our results for both the conventional concrete and P.T concrete system for amounts of steel and concrete and their total costs are shown as below:

Note: The rates of quantities are according to NHA composite schedule rates and Punjab finance department i.e.

Price of concrete (4ksi) =8732.04 Rs/m^3

Price of steel (60ksi) =86, 376.68 Rs/ton

Conventional RCC concrete:

- 1^{st} story (thickness) = 9″
- 2^{nd} story (thickness) = 10”
- Steel grade=60 ksi
- Concrete =4 ksi

Total Quantities(Steel and Concrete)		
Story #	Steel (ton)	Concrete (ft^3)
Story-1	47.949	22351.95
Story-2	27.26	15155.3
Net total	75.209	37507.25

Total price (Rs)		
	Steel	Concrete
Story-1 & Story-2 (Total)	6496303.726	9274361.649
Total Price	15770665.38	

Post-tensioning concrete:

- 1^{st} story (thickness) = 7.5″
- 2^{nd} story (thickness) = 7.5”
- Steel grade=60 ksi
- Concrete =5300 psi
- Price of concrete = 9182.08 / m^3 (According to NHA composite schedule rates)

Tendons (1^{st} and 2^{nd} story)	
Tendon length	15356′
Unit weight	0.74 lbs/ft
Weight total	5.68 tons
Price per ton	188303.30 Rs
Price	1072727.486 Rs

Minimum reinforcement	
Weight	38.6082 ton
Price	3334851.672 Rs

Concrete	
Volume	35983.25 ft^3
Price	9356072.96 Rs

Total price (Rs)		
	Steel	Concrete
Total Price	13763652.12 Rs	

Conventional RCC vs. P.T:

Price contrast	
RCC conventional	RS. 15770665.38
P.T	RS. 13763652.12
Difference	RS. 2007013.255

As per above mentioned cost analysis between Conventional RCC and Post tensioned concrete, difference between costs comes out as RS. 2007013.255 Which is a very significant and cost saving keeping in view that the total cost of the project was about RS. 15770665.38as per Conventional RCC design.

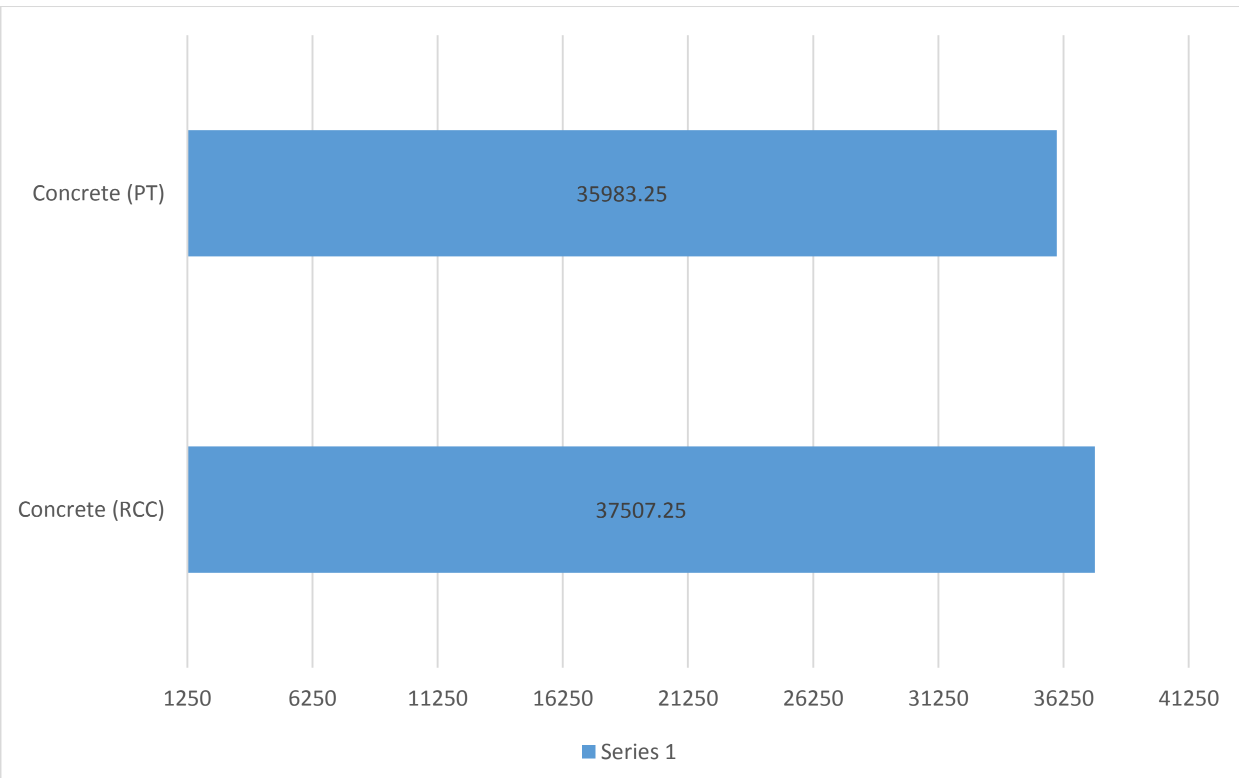
General cost benefits in any case of post tensioned construction is shown below:

Concrete	2-10%
Formwork for construction	10-20%
Steel required	50-80%
Overall cost saving	10-20%

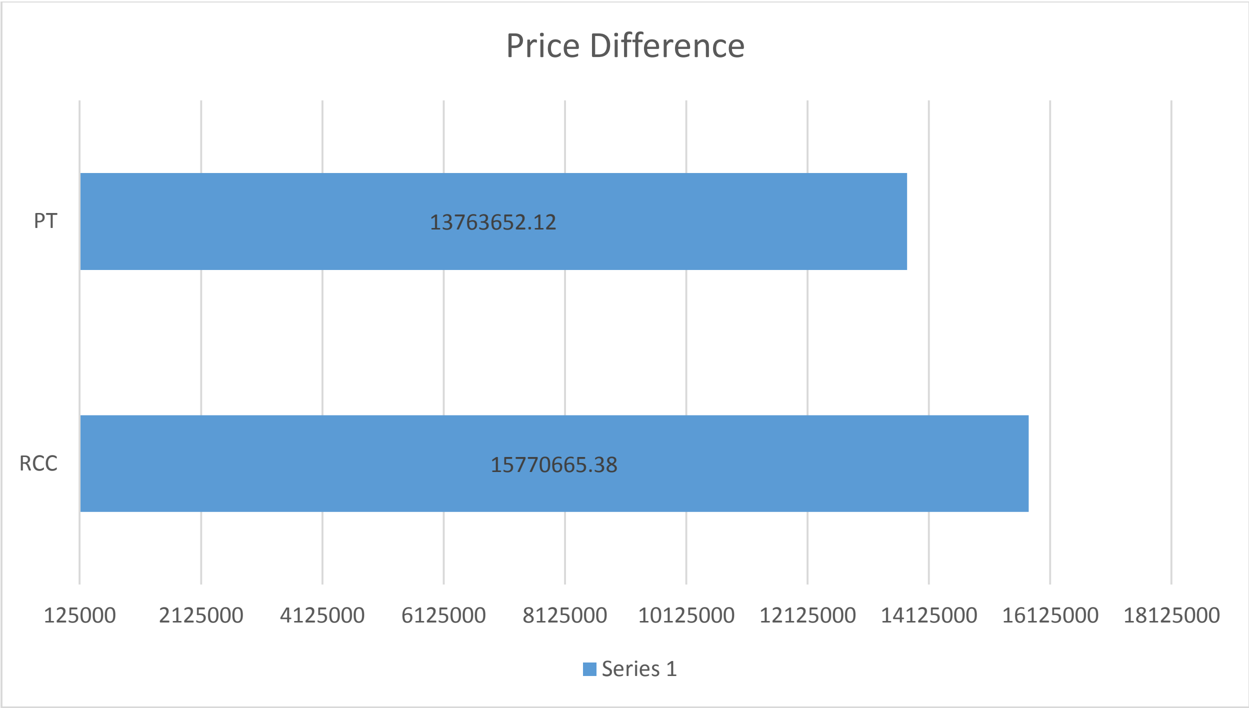
In our case the overall cost saving is 10.58 % which is considerable and within the limits as above mentioned.

Graphical Representation:

Difference of concrete volume between conventional and post-tensioned concrete are shown below,



Price difference between conventional and post-tensioned concrete are shown below,


Price Difference
PT
13763652.12
RCC
15770665.38
125000
2125000
4125000
6125000
8125000
10125000
12125000
14125000
16125000
18125000
Series 1

CONCLUSION

After having the complete analysis, design and comparison of two story parking structure with two systems of construction i.e. P.T and RCC conventional concrete, it can easily be stated that Post tensioning is much cheaper than normal designed concrete. By using post tensioned concrete, loads on the buildings reduces to such an extent that it almost saves costs about 2-10% of concrete, 10-20% of formwork, 50-80% of steel and 10-20% of overall costs of the structure. Above all, it also gives us the more efficient structural feasibility and strength other than cost economy. Reduction of stresses in top and bottom slabs, moments and loads on columns are also achieved in Post tensioned concrete design.

Advantages are not only limited to cost and structural feasibility, but it also includes future consideration of labor costs, overhead costs and working activities. For unbounded post tensioning, grouting is eliminated and a longer span with architectural beautification is also achieved. Deflection of slabs is controlled and crack control is minimized while keeping the rapid construction as compared to conventional RCC building.

In these days, trend is being shifted from conventional and old methods of construction and design methodology to new and next level of environmental friendly and more user-friendly structures. Therefore the current trend in building construction is towards larger spans to provide more uninterrupted space of floors, which can even cause high returns of rental. Post tensioning concrete design is a good way to achieve these objectives of larger spans considering the costs and benefits also.

Tendon length is a very significant factor affecting the economy in slab construction. The main schemes which may be available for Post tensioning in buildings are flat plat system, flat slab system, flat slab and the banded slab, contributing significantly towards the economy and costs of construction. Thus it is highly advisable for a designer and an owner to consider at least the option of Post tensioning concrete before construction.