JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES FACULTY

OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

Comparative Study on RCC and Post tensioning Slab Considering Cost and Time Effect In Case Of Addis Ababa

A Thesis submitted to School of Graduate Studies, Jimma University, Jimma Institute

Of Technology, Faculty of Civil and Environmental Engineering in Partial Fulfillment of the

Requirements for the Degree of Master of Science in Civil Engineering

(Construction Engineering and Management)

By yoseph Tsegaye

Jan 31- 2022

Jimma, Ethiopia

JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

Comparative study on RCC and post tensioning slab considering cost and time Effect in case of Addis Ababa

BY
YOSEPH TSEGAYE

Approved by Board of Examiners

.

1. Dr. Lucy Feleke	_______________	____/_____/_______
Advisor	Signature	Date
2. Engr. Kebene Adeba.	________________	____/______/_______
Co-Advisor	Signature	Date
3. Dr. Bayou Chane	_______________	18/03/2022_
External Examiner	Signature	Date
4. Engr Abebe Eshetu	_______________	___/_____/_______
Internal Examiner	Signature	Date
5. Engr. Fitih Tamrat	____________________	_____/_____/______
Chair Person	Signature	Date

DECLARATION

I declare that this research entitled **"**comparative study on Reinforced concrete and post tensioning slab in case of Addis Ababa**"** is my original work, and has not been submitted as a requirement for the award of any degree in Jimma University or elsewhere.

Yoseph Tsegaye Asart ______________ ________________

Name Signature Date

As research advisor, I hereby certify that I have read and evaluated this thesis paper prepared under my guidance, by Yoseph Tsegaye Asrat "Comparative study on reinforced concrete and post tensioning slab in case of Addis Ababa" and recommend and would be accepted as a fulfilling requirement for the degree of Master of Science in Construction Engineering and Management.

Advisor: Engr. Lucy Feleke (Ph.D.) ------------------- 11/03/2022 ----------------

NAME SIGNATURE DATE

Co-Advisor: Engr. KebeneAdeba ------------------- ---------------

NAME SIGNATURE DATE

ABSTRACT

At the present in construction industry the post tensioning method used widely due to its advantages compare to previous time. In developing countries like Ethiopia the benefit of post-tensioning slab are yet to be recognized. By using post tensioning method we can achieve the most economical and safe design for residential as well as commercial buildings. This paper deals with the study of comparison of reinforced and post tension slab with respect to cost estimate and project time consumption. The cost was analyzed by using unit rate analysis. For this application of cost estimation a commercial building is consider as a case study. The plan of the commercial building (G+6) and above is considered. The results indicate that PT slab has cost better than that of RC slab system. The main tools for the collection of data included questionnaires, interviews and site visit were used to identify the various efforts that have been made in the past to evaluate and examine the cost and time impact of post tensioning on selected building projects. Simple statistical analysis involving tables and percentages were used in analyze the results from the questionnaire. Secondary sources of data were obtained from relevant literature that covered research, publication on the subject matter. The results from analysis ranked from the first to third position by contractors, consultants and owners that the most significant factors causing post tensioning construction on building construction projects are:-cost factors, time factors and Operations factors respectively. The results of this study recommend to the government there is a need to establish post tensioning department, establish laws and policies that toward managing and application of post tensioning construction at all levels in a construction projects, The study recommended the clients who involved in the construction industries to take the post tensioning history of the post tensioning contractors and as a criterion in awarding contracts and Taking training on new technology which is afford the construction cost and good applicable on our country to participate and invest on it. The study recommended the consultants to give attention to new technology that is affordable and applicable.

Keywords: Cost, Post tensioning, pre stress, RCC, Quality and time.

ACKNOWLEDGMENT

I would like to thank the Almighty God for his abundant grace, mercies, guidance and protection has made during my academic pursuance worthwhile.

Second and foremost, I offer my sincerest gratitude to my Advisor. Engr Lucy Feleke (Ph.D.) and co-advisor, Eng. Kebene Adeba who have provided me with their heartfelt guidance till finalizing this research proposal.

In addition, I would also like to thank Wollayta Sodo University, for giving me such a precious chance to study Master of Science in Construction Engineering and Management at Jimma University.

Finally, I would like to thank my parents who encouraged and supported me in every aspect of situations even if in finalizing this research proposal.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

By T.Y. Lin, founder of T.Y. Lin International (1963), the popularity of post-tensioning application increased throughout the 1960s and 1970s. Lin proposed simplifying post-tensioning analysis by representing the tendons during the design process with the theoretical loads they would exert upon the concrete member. The paper then proposed designing the structure for the loads which were not eliminated by the pre stressing force with non-pre stressed reinforcement (Bondy 2001). Load-balancing is a widely accepted method of design used today in post-tensioning analysis. Post-tensioning systems provide many benefits. Use of post-tensioning in slabs reduces the amount of concrete required for a structure which offsets increased cost of labor and equipment, decreases the amount of formwork required, decreases the overall height of floors which allows more floors for a specified building height, decreases the weight of the building which is a benefit in seismic design, and increases the allowable span length, creating more open space in a structure (Gupta 2006). Over the last 20 years, many buildings with post-tensioned floor slabs have been successfully constructed in the USA, South East Asia, Australia and the rest of Europe, yet it took the construction boom of the late 1980s, with corresponding increases in both steelwork prices and delivery times. " Today, in unbounded post-tensioning, individual tendon strands are coated with corrosion-inhibiting grease and protected by plastic sheathing (Gupta 2006). Because this system is more economical and eliminates the construction issues involved with the button-headed tendon system, it became the post-tensioning system of choice. Rice of a modern anchorage system manufactured by General Technologies, Inc. (GTI). In addition to the fixed end anchors, intermediate anchorage systems have been developed to allow post-tensioning to be used in long slabs which would have otherwise been impossible due to material constraints. With the introduction of "load balancing"

The construction industry is a huge and vast sector in our continent. It involves either direct or indirect participation of a variety of personnel with varying skills and capabilities, wide range of materials, machineries as well as genuine capital. Nowadays, there are a number of massive infrastructural projects in various regional states of Ethiopia. The emergence and growth of construction industries play a great role with regards to satisfying a wide range of physical, economic, social needs as well as the fulfillment of various desired goals for the given country. In high rise building there is a number of struggle on cost, time and achieving the owner required building appearance like room area, floor to floor height and total building height also structural material cost specially, steel cost.

Post-tensioned slabs are use high strength tensioned steel strands to compress the thickness keeping the majority of the concrete in compression. This gives a very efficient structure which minimizes material usages and decreases the economic span range when compared to reinforced concrete. According to Park.E.H.Kimetal and Y. H. Luo, A. Durrani the most important advantages offered by post-tensioning systems are as follows smaller deflections compared to with steel and reinforced concrete structures. It has Good crack behavior and therefore permanent protection of the steel against corrosion, almost unchanged serviceability even after considerable overload, since temporary cracks close again after the overload has disappeared, if significant part of the load is resisted by post tensioning the non-pre stressed reinforcement can be simplified and standardized to a large degree. Furthermore, material handling is reduced since the total tonnage of steel (non-pre stressed + pre stressed) and concrete is less than for a reinforced concrete floor. In addition to the above mentioned general features of posttensioned construction systems, the following advantages of post-tensioned slabs over reinforced concrete slabs are listed as follows: More economical structures resulting from the use of pre stressing steels with a very high tensile strength instead of normal reinforcing steels, Larger spans and greater slenderness, which results in reduced dead load, which also has a beneficial effect upon the columns and foundations and reduces the overall height of buildings or enables additional floors to be incorporated in buildings of a given height.

1.2. Statement of the Problem

The high rise buildings now-a-days are provided with soft story's for parking purpose. When such building is located in the earthquake prone area, can be subjected to heavy lateral forces. Due to the presence of soft story in a building, the lateral load resisting capacity of building decreases, thereby the stiffness of building decreases. This leads to sudden failure of structure. And In high rise building there is a number of struggle on cost, time and achieving the owner required building appearance like room area, floor to floor height and total building height also structural material cost specially, steel cost. Nowadays in Ethiopia, most building construction projects are affected by project failure attributes. The other one is economics and construction speed is heavily linked in today's building construction environment. The speed of construction of a multi storied building is an important factor in order to achieve economic building construction. The key to the speed of construction of a post tensioned framed building can be attributed to expedient use and re use of form work. Post tensioning allows for early recovery of form work by early stressing of tendons. Reinforced concrete is the most widely used structural material of the 20th century. The conventional reinforced concrete slabs are limited by span and thickness on economic considerations. They require a specific thickness to maintain their strength. Post tensioned concrete slabs in buildings have many advantages over reinforced concrete slabs and other structural system for both single and multi-level structure. Post tensioned slabs should be considered as a possible economic alternative for most structures when span exceed 7 meter. According to Girum, 2017 Ethiopian building construction projects are affected by time delay, cost overrun, quality-related problems, low productivity and delay in material ordering and receiving, for this study will dig out optional alternative for the above problem.

1.3. Research Questions

1. What are the cost advantages of using post tensioning in building construction projects relative to conventional/RCC?
2. What is the reason of post tensioning is not applied in wide currently in Addis Ababa?
3. How to increase the post tensioning users by comparing with the RCC users?

1.4. Objectives of the study

1.4.1. General Objective

The general objective of this research is study on a comparison of post tensioning and conventional slab focus on cost and time effect in Addis Ababa city.

1.4.2. Specific objectives

1. To assessing the impact of post tensioning slab in cost and time as compare to conventional slab.
2. To identify effective ways of awareness creation to increase the users of post tensioning rather than RCC.
3. To assess current post tension practice in view of comparison.

1.5. Scope of the study

The scope of the study is a comparative study on RCC and post tensioning slab considering cost and time effect in case of Addis Ababa city.

1.6. Limitation of the study

The study limitation is on high rise building construction projects in Addis Ababa City and the other limitation is time and budget of the research. With the wide range of application and advantages of post tensioning method its use is increase day by day in Addis Ababa. Post tensioning method gives more economical and safe design but in shear and deflection criteria for slab more precautions should be used in construction. In Bs code there are two method of design of flat slab. Load balancing and equivalent frame method; equivalent frame method is more widely used. In load balancing method the 65% to 80% of the dead load is resist by the post tensioning tendon and rather than other load is resist by the reinforcement provided in the RCC slab.

1.7. Significance of the study

Nowadays, most construction projects are not managed within the proposed project time costs and quality. The need for improved cost time and quality of construction projects using PT is very important. That is why poor material selection and management not only results in delayed projects but also gives a poor image of the construction industry. Therefore, the main significance of this study is to address the issues of use of post tensioning in high rise building.

Post-tensioning is a method of reinforcing (strengthening) concrete or other materials with high-strength steel strands or bars, typically referred to as tendons. Post-tensioned construction is used more and more in industry today because of their advantages. Use of post tensioned flat slab is now a day becoming cost effective solution for improve seismic performance of construction industry. This study is focused on post tensioned. In this paper, an attempt has been made for assess comparative study on R.C.C and post tensioned flat slab considering cost and time effect also The purpose of this publication is to widen the understanding of post-tensioned floor construction and show the considerable benefits and opportunities it offers to both the developer and designer. These include:

- Rapid construction Economy
- Maximum design flexibility
- Minimum story heights
- Minimum number of columns
- Optimum clear spans, Joint-free, crack-free construction and Controlled deflections.

CHAPTER TWO

2. LITERATURE REVIEW

Definition

Post tensioning is a method of reinforcing concrete high strength steel tendons are positioned in ducts or sleeves before the concrete is placed. The tendons are stitched b/n strong bulk heads which with stand external forces and the concrete is poured around them.

2.1. History of Post-Tensioning

Eugene Freyssinet (1928 – 1939) began to use high-strength steel wires for pre stressed concrete in 1928. Between 1928 and 1939 developed the first practical system of posttensioning and designed conical shaped wedges for anchoring the wires (Gupta 2006). The early systems used multi-wire tendons grouted in large ducts, which were cast into the concrete section (Stevenson 1994). This practice is referred to as “bonded” posttensioning because the grout creates a bond between the concrete and the strand (Truby 2005). Most early applications of post-tensioning were in bridge design due to the fact that bonded systems require areas large enough to fit the ducts (Stevenson 1994). The first use of post-tensioning in the United States was the Walnut Lane Bridge in Philadelphia in 1949 which used bonded post-tensioning in its precast girders (Gupta 2006). Building practice in the United States started utilizing post-tensioning in the 1950s in the lift-slab industry. The lift-slab construction method involved pre-casting slabs in a stack on the ground, and then lifting the slabs into place using hydraulic jacks. This shows the slabs of a building being lifted into place as construction progresses. The slabs often stuck together after being cast and then broke as they were lifted into place. Large deflections also occurred in the slabs due to their long spans. To solve problems associated with this method of construction, the lift-slab industry started utilizing a system of post-tensioning called the “button-headed tendon system.”

In the 1960s, Edward Rice recognized the advantage of strand systems while working for the firm T.Y. Lin International. Post-tensioned strand systems eliminated the need for the exact length of the tendon. Rice invented and patented the first mono strand anchorage system for use in UN bonded post-tensioning system. Today, in unbounded post-tensioning, individual tendon strands are coated with corrosion-inhibiting grease and protected by plastic sheathing (Gupta 2006). Because this system is more economical and eliminates the construction issues involved with the button-headed tendon system, it became the post-tensioning system of choice. Rice of a modern anchorage system manufactured by General Technologies, Inc. (GTI). In addition to the fixed end anchors, intermediate anchorage systems have been developed to allow post-tensioning to be used in long slabs which would have otherwise been impossible due to material constraints. With the introduction of “load balancing” in 1963 by T.Y. Lin, founder of T.Y. Lin International, the popularity of post-tensioning application increased throughout the 1960s and 1970s. Lin proposed simplifying post-tensioning analysis by representing the tendons during the design process with the theoretical loads they would exert upon the concrete member. He then proposed designing the structure for the loads which were not eliminated by the pre stressing force with non-pre stressed reinforcement (Bondy 2001). Load-balancing is a widely accepted method of design used today in post-tensioning analysis. Post-tensioning systems provide many benefits. Use of post-tensioning in slabs reduces the amount of concrete required for a structure which offsets increased cost of labor and equipment, decreases the amount of formwork required, decreases the overall height of floors which allows more floors for a specified building height, decreases the weight of the building which is a benefit in seismic design, and increases the allowable span length, creating more open space in a structure (Gupta 2006).

2.2. Development of post tensioning

The invention of pre stressed concrete is often accredited to Eugene Freyssinet who developed the first practical post-tensioning system in 1939. The majority of the early applications were in the design of bridge structures. The systems were developed around the use of multi-wire tendons located in large ducts cast into the concrete section, and fixed at each end by anchorages. They were stressed by jacking from either one or both ends, and then the tendons were grouted within the duct. This is generally referred to as a bonded system as the grouting bonds the tendon along the length of the section. The bonding is similar to the way in which bars are bonded in reinforced concrete. After grouting is complete there is no longer any reliance on the anchorage to transfer the pre compression into the section.

2.3. Comparison between post tension slab and reinforced

According to Thayapraba M, "Cost Effectiveness of Post - Tensioned and Reinforced Concrete Flat Slab Systems," [May 2014] who's done an attempt is made to compare the cost effectiveness of Post-Tensioned flat slab systems with respect to reinforced concrete flat slab system. Both the systems were analyzed using SAP and MS Excel program was developed based on the design methodology. The results indicate that Post Tensioned flat slabs are cheaper than the RCC slab systems for different span which is (8x8)m, (9x9)m, (10x10)m, (11x11),m (12x12)m spans and G+8 building considered.

Boskey Vishal Bahoria and Dhananjay K. Parbat, "Analysis and Design of RCC and Post-tensioned Flat Slabs Considering Seismic Effect," [February 2013.] considering a plan of the office building (G+4) which is designed a four cases with different floor systems which is post tensioned (PT) flat slab, Reinforce concrete (RC) flat slab, PT slab with RCC beam and RCC slab with RCC beam. Along calculated quantities of reinforcing steel, concrete required for the slab, beam and column is calculated for the same and are presented in tabular form. Along with this total cost of the building per square meter is found and comparison of all the four cases with respect to cost which is given in table 2.1.

Table2:1Comparison of post tension and reinforced

Item	Concrete/M3	Rcc steel/Kg	Form work	Rate/M2	
PT flat slab	507.52	31659	2100	2800	
Rc flat slab	549.69	85550	2100	3600	
PT slab with R.c,c beam	641.33	42271	2100	3200	
R.c.c slab with R.C.C beam	626.31	86701	2100	3800	

- According to the author some observation made from table which is following: Post-tensioned flat slab is the most economical among all four floor systems from the economic point of view and the reinforced concrete slab with reinforced concrete beam is the costlier one for this span.

- Post-tensioned flat slab is more economical than the post-tensioned slab with reinforced concrete beams from both post-tensioned floor system building.
- The reinforcing steel is more in case of post tensioned slab with reinforced concrete beams because the slab transfers the load on the beam and more loads is taken by the beams itself.
- The amount of concrete required for a floor is more in-case of post-tensioned slab with reinforced concrete beams whiles it is least for the post-tensioned flat slab floor system.
- The reinforcing steel for the reinforced concrete flat slab is 41 Kg/m2 while for the reinforced concrete slab and beam it is 40 Kg/m2.
- If we consider the period of construction for a floor it is less in case of post- tensioned flat slab than the other three cases as the post-tensioning allows the earlier removal of the formwork. In case of post-tensioned slab with reinforced concrete beams the formwork of slab can be removed earlier but the formwork for the reinforced concrete beams cannot be removed earlier.
- The quantity of pre stressing steel is 4 Kg/m2 for post-tensioned flat slab and 3.2 Kg/m2 for posttensioned slab with reinforced concrete beams i.e. the pre stressing steel required for the posttensioned flat slab is greater.
- The reinforcing steel required for the posttensioned flat slab and post- tensioned slab with reinforced concrete beam is 15 Kg/m2 and 20.15 Kg/m2 respectively.

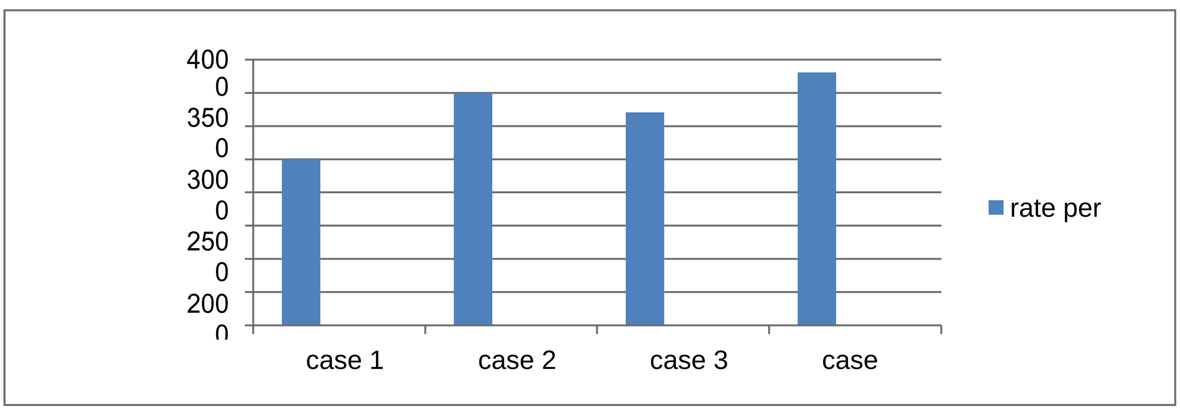


Figure 2-1 variation of rate for each floor system source (Thayapraba M, May 2014)

- If we consider the post-tensioned flat slab and reinforced concrete flat slab, the thickness of reinforced concrete flat slab is 12.5% greater and its cost is 27% greater than the posttensioned flat slab.
- The reinforcing steel is more in case of posttensioned slab with reinforced concrete beams because the slab transfers the load on the beam and more loads is taken by the beams itself.
- The floor to floor height available in case of post-tensioned flat and reinforced concrete flat slab is 2.65m while in case of post-tensioned slab with reinforced concrete beams and reinforced concrete slab and beams is 2.4m.

Sreenivasa Prasad (2016) stated that Post-tensioned slabs are a preferred method for industrial, commercial and residential floor slab construction. The increasingly extensive use of this method is due to its advantages and its nature of easy application to a wide variety of structure geometry and design solutions. The use of posttensioned floor slabs and reinforced concrete core walls has become increasingly popular in high-rise construction. In spite of the simplicity of its basic concepts and well known advantages, the application extent of post-tensioning solutions cannot be considered harmonized in the different areas and structural applications. In fact, for various reasons, it appears that the potential offered by pre stressing is far from being exploited, especially in building structures field. In many cases where post-tensioning would provide a superior solution, it happens after all that a more conventional non-pre stressed solution is often selected. Economics of the posttensioning slab system are discussed including relative material contents, speed of construction, and factors affecting the cost of post-tensioning. Finally, a discussion on the flexibility of post-tensioned building structures in terms of future uses, new floor penetrations and demolition is presented. The cost effectiveness of post-tensioned concrete structural systems has been done by Li Shengping and Dr. Robert Tiong, who considered different grid systems and loads to find the most cost effective system for a building in the article "Cost-Effective Reinforced Concrete Structural Systems" (Shengping and Tiong 2004). Shengping and Tiong examined the cost of material, labor, transportation, and necessary equipment. The paper focuses on construction in Singapore and provides an example of how to perform a cost analysis. The variables of material cost and labor cost will be adopted in the cost analysis for this project.

2.4. Function and future of post tensioning

Function of post tensioning is to place the concrete under compression is those regions where load causes tensile stress. Post tensioning applies a compressive stress on the material which offsets the tensile stress the concrete might face under loading.

Features of post tensioning

- High strength steel
- Load balancing
- Continuity
- Pre compression

Post tensioning slab is typically at least 2inch thinner than a Rebar deck and long term creep problems are significantly reduced by load balancing, also the slab can be stressed and the forms pulled in 3-4 days in order to this the technology can reduce the cost of form work like play wood, H-frame and props etc. by deducting demolishing time. And working time will be minimized. Also reduce shoring and re shoring times when using post tensioning.

2.5. Aspects of post tensioning construction

Many of the major specialist concrete frame contractors have experience with post-tensioned construction, and are aware of how it differs from using reinforced concrete and the benefits it offers. Those contractors less familiar may be wary as there is definitely a learning curve to be climbed in the early stages of a project. However, experience shows that once in their stride, all contractors can achieve exceptional floor cycles with post-tensioned construction

The sequence of construction of post-tensioned slabs is straightforward and typically includes the points given below. A number of aspects such as prefabrication of tendons, the reduction in quantities of steel to be fixed and large pour sizes help to speed the construction.

Dr. Uttamasha Gupta, ShrutiRatnaparkhe and Padma Gome, "Seismic Behaviour of Buildings Having Flat Slabs with Drops," **[**October 2012.**]** checked to improve the performance of building having flat slabs under seismic loading, provision of part shear walls is proposed in the present work. In the paper work is to compare the behavior of multi-story buildings having flat slabs with drops with that of having two way slabs with beams and to study the effect of part shear walls on the performance of these two types of buildings under seismic forces and provides a good source of information on the parameters lateral displacement and story drift. According to the author observed that in shorter plans use of flat slabs with drops results in increase in drift values and from analysis that use of flat slabs with drops in place of beam slabs causes increase in percentage reinforcement in columns and in shorter plans increment observed is not significantly affected by presence of shear walls. Results reveals that in case of column design reinforcement percentage is more with master slave approach as compared to realistic case that is consideration of slabs along with frames.

2.6. Benefits of post tensioning construction

The following are just a few of the many benefits to be gained from using post-tensioned floor construction. Long spans reduce the number of columns and foundations, providing increased flexibility for internal planning, and maximizing the available letting space of a floor.

Post-tensioning systems provide many benefits. Use of post-tensioning in slabs reduces the amount of concrete required for a structure which offsets increased cost of labor and equipment, decreases the amount of formwork required, decreases the overall 2.0 Background Optimization of Two-Way Post-Tensioned Concrete Floor Systems 9 height of floors which allows more floors for a specified building height, decreases the weight of the building which is a benefit in seismic design, and increases the allowable span length, creating more open space in a structure (Gupta 2006).

Minimum floor thickness maximizes the ceiling zone available for horizontal services, minimizes the self-weight and foundation loads, and keeps down the overall height of the building.

Minimum story height is achieved, as the need for deep down stands is reduced, and slab thicknesses are kept to a minimum. As a result, the story height of a concrete building can be less than that of a steel-framed building by as much as 300 mm per floor. This can give an extra story in a ten-story building. Alternatively, it minimizes the exterior surface area to be enclosed, as well as the vertical runs of mechanical and electrical systems. The reduced building volume will save on cladding costs and may reduce running costs of equipment. Deflection of the slab can be controlled enabling longer spans to be constructed with a minimum depth of construction.

Crack-free construction is provided by designing the whole slab to be in compression under normal working loads. Appropriate details may also be incorporated to reduce the effects of restraint, which may otherwise lead to cracking. This crack-free construction is often exploited in car parks with concrete surfaces exposed to an aggressive environment.

Large area pours should be adopted on all concrete floors in order to reduce the number of pours and increase construction speed and efficiency. With pre stressed floors, when the concrete has reached strength of typically 12.5 N/mm2, part of the pre stressing force can be applied to control shrinkage cracking and thus further aid larger area pours.

Rapid construction is readily achieved in multi-story buildings as pre stressing leads to less congested slab construction. Prefabrication of tendons reduces fixing time and early stressing enables forms to be stripped quickly and moved to the next floor.

Flexibility of layout can be achieved as the design methods can cope with irregular grids, and tendons can easily be deflected horizontally to suit the building’s geometry or to allow for openings in slabs. Future flexibility is provided as knockout zones can be identified for future service penetrations. Tried and tested methods are available to enable large openings for stairs, escalators and other features to be formed subsequently

Sonuvaret. al. (2004) in some other researches, the use of wing walls, attached to two sides of columns was investigated. The systems strengthened with wing walls exhibited ductile behavior Steel bracing for RC frames has also been used to reduce drift demands. Bracing can either be implemented inside the frame or applied from outside the system.

Albanesiet. al.(2006) Among the global strengthening methods, addition of RC infill is the most popular one. Many researchers have focused on this subject and found that installation of RC infill’s greatly improve lateral load capacity and stiffness of the structure Even in cases of application to damaged buildings, the infill method yields satisfactory results

Ohmura et. al.(2006) Post-tensioned steel bracing is also an efficient alternative for vulnerable framed buildings and it compensates structural irregularities. Experimental results for another alternative, knee bracing with shear links replaced with masonry infill's, lead to improvement in energy absorption capacity. Although, each of these methods satisfactorily increased the strength and stiffness, all of them with the exception of external steel bracing require construction work inside the building, which means disturbance of users and results in the buildings being out of service. Consequently, research efforts in this field have shifted their focus to new methods that could overcome this difficulty.

Kaplan et. al.(2009) The precast panel infill method, which causes less disturbance for the building occupants, has been investigated and found to be an efficient solution for strengthening of existing structures. Despite causing some architectural problems, some other researchers perpendicularly installed RC shear walls outside the building. This kind of shear walls was also applied to precast skeletal structures with an external diaphragm at the roof level.

T. Nagaeet.al. (2012) Analyzed a three-dimensional earthquake simulation test on a full-scale, four-story, pre stressed concrete building was conducted using the E-Defense shaking table facility. The seismic force resisting system of the test building comprised two post-tensioned (PT) frames in one direction and two unbounded PT precast walls in the other direction. The test building was subjected to several earthquake ground motions, ranging from serviceability level to near collapse. The behavior of the wall direction of the building under several ground motions is simulated using nonlinear response history analysis of practical structural engineering models, and the 2D simulation results are compared with the test results. Conducted analytical simulations are in good correlation with the test results for the important engineering parameters with some discrepancies. P.C. Louteret. al. (2014) studied that structural glass researchers have developed an innovative safety concept for glass beams. This safety concept shows some analogy with post-tensioned concrete; glass beams are posttensioned by unbounded steel tendons which are anchorage at the beam ends. In this way the load-bearing capacity is enhanced and safe failure behavior is obtained. Four methods to transfer the post-tensioning forces to the glass beam ends have been developed and tested in compression tests. Results show the level of pre-stress that can be applied is strongly dependent on the alignment of the edges of the beam ends. Eventually the validity of the post-tensioned glass beam concept has been examined by bending tests on scale models. Results show a gradual thus safe failure behavior and a significant residual strength of these glass beams.

D.Nobel et. al. (2015) Studied The effect of pre stress force magnitude on the dynamic properties of un cracked pre stressed concrete structures is something that has been widely debated among researchers to date. The effect of pre- and post-tensioning force magnitude on the natural bending frequencies of cracked pre stressed concrete structures is something that is more established, and widely agreed upon. This paper describes the results of dynamic impact testing on damaged posttensioned concrete beams.

2.7. Principles of pre stressing

Concrete has a low tensile strength but is strong in compression: by pre-compressing a concrete element, so that when flexing under applied loads it still remains in compression, a more efficient design of the structure can be achieved. The basic principles of pre stressed concrete are given in, Pre stressed concrete can most easily be defined as pre compressed concrete. This means that a compressive stress is put into a concrete member before it begins its working life, and is positioned to be in areas where tensile stresses would otherwise develop under working load. Why are we concerned with tensile stresses? For the simple reason that, although concrete is strong in compression, it is weak in tension. Consider a beam of plain concrete carrying a load. As the load increases, the beam deflects slightly and then falls abruptly. Under load, the stresses in the beam will be compressive in the top, but tensile in the bottom. We can expect the beam to crack at the bottom and break, even with a relatively small load, because of concrete's low tensile strength. There are two ways of countering this low tensile strength -by using reinforcement or by pre stressing. In reinforced concrete, reinforcement in the form of steel bars is placed in areas where tensile stresses will develop under load. The reinforcement absorbs all the tension and, by limiting the stress in this reinforcement, the cracking of the concrete is kept within acceptable limits. Pre stressed concrete, compressive stresses introduced into areas where tensile stresses develop under load will resist or annul these tensile stresses. So the concrete now behaves as if it had a high tensile strength of its own and, provided the tensile stresses do not exceed the pre compression stresses, cracking cannot occur in the bottom of the beam. The pre compression stresses can also be designed to overcome the diagonal tension stresses. The normal procedure is to design to eliminate cracking at working loads. However, bending is only one of the conditions involved: there is also shear. Vertical and horizontal shear forces are set up within a beam and these will cause diagonal tension and diagonal compression stresses of equal intensity. As concrete is weak in tension, cracks in a reinforced concrete beam will occur where these diagonal tension stresses are high, usually near the support. In pre stressed concrete, the pre compression stresses can also be designed to overcome these tension stresses.

Under an applied load, a pre stressed beam will bend, reducing the built-in compression stresses; when the load is removed, the pre stressing force causes the beam to return to its original condition, illustrating the resilience of pre stressed concrete. Furthermore, tests have shown that a virtually unlimited number of such reversals of the loading can be carried out without affecting the beam's ability to carry its working load or impairing its ultimate load capacity. In other words pre stressing endows the beam with a high degree of resistance to fatigue. It is indicated in Figure 2.2 that if, at working load, the tensile stresses due to load do not exceed the pre stress, the concrete will not crack in the tension zone but, if the working load is exceeded and the tensile stresses overcome the pre stress, cracks will appear. However, even after a beam has been loaded to beyond its working load, and well towards its ultimate capacity, removal of the load results in complete closing of the cracks and they do not reappear under working load. There are two methods of applying pre stress to a concrete member. These are:

1) By pre tensioning - where the concrete is placed around previously stressed tendons. As the concrete hardens, it grips the stressed tendons and when it has obtained sufficient strength the tendons are released, thus transferring the forces to the concrete. Considerable force is required to stress the tendons, so pre tensioning is principally used for precast concrete where the forces can be restrained by fixed abutments located at each end of the stressing bed, or carried by specially stiffened molds.

2) By post-tensioning - where the concrete is placed around sheaths or ducts containing unstressed tendons. Once the concrete has gained sufficient strength the tendons are stressed against the concrete and locked off by special anchor grips. In this system, which is the one employed for the floors described in this publication, all tendon forces are transmitted directly to

the concrete. Since no stresses are applied to the formwork, this enables conventional formwork to be used.

2.8. Post tension and seismic load stability

Saadatmaneshet. al. (1994) Confinement reinforcement is generally applied to compressive members as lateral reinforcement with the aim of increasing their strength and ductility. In addition, lateral confinement prevents slippage and buckling of the longitudinal reinforcement Frangou andPilakoutas(1995) Lateral reinforcement can be provided by using circular hoops, rectangular ties, jacketing by steel , FRP, Ferro cement, etc. Because the total cost of replacement of the vulnerable structures is so overwhelming, the development of innovative rehabilitation and strengthening techniques is required to extend the life expectancy of many existing buildings and bridges. A number of repair and strengthening techniques are currently in use for reinforced concrete structures. Unfortunately, the majority of them is very expensive, time consuming and require the interruption of use of the structure whilst works are carried out. Hence, there is a pressing need for the development of improved, low cost, less disruptive techniques, which will make necessary interventions in many structures economically viable. It should be borne in mind that the cost of retrofitting buildings is the primary factor which deters many private owners from executing essential works.

Dilgeret. al. (2000) recent earthquakes have revealed an urgent need to develop retrofit techniques for the existing buildings and bridges designed in accordance with old seismic codes so as to meet the requirements of current seismic design standards. Some of the common problems revealed by earthquakes such as Kobe (Japan 1995), Athens (Greece 1999) and Kocaeli (Turkey 1999) include inadequate confinement of concrete, leading to shear, anchorage and splice failures. It is well known and proven that lateral confinement improves the strength and ductility of concrete.

D.Y. Wang et. al. (2000) studied the working of one monolithic connection and 4 precast pre stressed un bonded post-tensioned concrete connections under reversed cyclic loading. Such parameters as PT initial posttensioning force, PT eccentric position and PT anchor length are discussed. Results of experiment indicate that these elements have desirable seismic characteristics, restoring characteristics and have an ability to undergo large nonlinear displacements with little damage. In this paper a detailed analysis as resilience, ductility, energy dissipation etc are carried out. The objective of this test is to develop guidelines for precast structure in regions of earthquake zone.

Sonuvaret. al.(2004) Nowadays, most of the strengthening strategies are based on global strengthening schemes as per which the structure is usually strengthened for limiting lateral displace-ments in order to compensate the low ductility In these schemes, global behavior of the system is transformed. Another approach is modification of deficient elements to increase ductility so that the deficient elements will not reach their limit state conditions when subjected to design loads However, the latter strategy is more expensive and harder to implement in cases of many deficient elements which is the reason that the global strengthening methods have been more popular than element strengthening

Sonuvaret. al.(2004) In some other researches, the use of wing walls, attached to two sides of columns was investigated. The systems strengthened with wing walls exhibited ductile behavior Steel bracing for RC frames has also been used to reduce drift demands. Bracing can either be implemented inside the frame or applied from outside the system.

Albanesiet. al.(2006) Among the global strengthening methods, addition of RC infill is the most popular one. Many researchers have focused on this subject and found that installation of RC infills greatly improve lateral load capacity and stiffness of the structure Even in cases of application to damaged buildings, the infill method yields satisfactory results

Ohmura et. al.(2006) Post-tensioned steel bracing is also an efficient alternative for vulnerable framed buildings and it compensates structural irregularities. Experimental results for another alternative, knee bracing with shear links replaced with masonry in fills, lead to improvement in energy absorption capacity. Although, each of these methods satisfactorily increased the strength and stiffness, all of them with the exception of external steel bracing require construction work inside the building, which means disturbance of users and results in the buildings being out of service. Consequently, research efforts in this field have shifted their focus to new methods that could overcome this difficulty.

Kaplan et. al.(2009) The precast panel infill method, which causes less disturbance for the building occu-pants, has been investigated and found to be an efficient solution for strengthening of existing structures. Despite causing some architectural problems, some other researchers perpendicularly installed RC shear walls outside the building. These kinds of shear walls were also applied to precast skeletal structures with an external diaphragm at the roof level.

T. Nagaeet. al. (2012**)** Analyzed a three-dimensional earthquake simulation test on a full-scale, four-story, pre stressed concrete building was conducted using the E-Defense shaking table facility. The seismic force resisting system of the test building comprised two post-tensioned (PT) frames in one direction and two un bonded PT precast walls in the other direction. The test building was subjected to several earthquake ground motions, ranging from serviceability level to near collapse. The behavior of the wall direction of the building under several ground motions is simulated using nonlinear response history analysis of practical structural engineering models, and the 2D simulation results are compared with the test results. Conducted analytical simulations are in good correlation with the test results for the important engineering parameters with some discrepancies.

P.C. Louteret. al. (2014) studied that structural glass researchers have developed an innovative safety concept for glass beams. This safety concept shows some analogy with post-tensioned concrete; glass beams are posttensioned by un bonded steel tendons which are anchorage at the beam ends. In this way the load-bearing capacity is enhanced and safe failure behavior is obtained. Four methods to transfer the post-tensioning forces to the glass beam ends have been developed and tested in compression tests. Results show the level of pre-stress that can be applied is strongly dependent on the alignment of the edges of the beam ends. Eventually the validity of the post-tensioned glass beam concept has been examined by bending tests on scale models. Results show a gradual thus safe failure behavior and a significant residual strength of these glass beams.

D. Nobel et. al. (2015) Studied The effect of pre stress force magnitude on the dynamic properties of not cracked pre stressed concrete structures is something that has been widely debated among researchers to date. The effect of pre- and post-tensioning force magnitude on the natural bending frequencies of cracked pre stressed concrete structures is something that is more established, and widely agreed upon. This paper describes the results of dynamic impact testing on damaged posttensioned concrete beams. The natural bending frequencies of the cracked beams were determined through experimental modal analysis. Dynamic impact response signals were obtained at different levels of post-tensioning force for the cracked beams. The Fast Fourier Transform was implemented and a peak picking algorithm was subsequently used to determine the natural bending frequencies of the beams. The relationship between pre stressing force and natural frequency for both the cracked and UN cracked beam sections was determined. The results for the cracked beams were compared to the results for the same un cracked beam sections. A marked difference in vibration behavior was observed for the cracked beams between the no fully pre stressed and the fully pre stressed case. Conclusions from the study are drawn and have profound implications in the fields of system identification and structural health monitoring in preened post-tensioned concrete structures.

Sreenivasa Prasad (2016) stated that Post-tensioned slabs are a preferred method for industrial, commercial and residential floor slab construction. The increasingly extensive use of this method is due to its advantages and its nature of easy application to a wide variety of structure geometry and design solutions. The use of posttensioned floor slabs and reinforced concrete core walls has become increasingly popular in high-rise construction. In spite of the simplicity of its basic concepts and well known advantages, the application extent of post-tensioning solutions cannot be considered harmonized in the different areas and structural applications. In fact, for various reasons, it appears that the potential offered by pre stressing is far from being exploited, especially in building structures field. In many cases where post-tensioning would provide a superior solution, it happens after all that a more conventional non-pre stressed solution is often selected. Economics of the posttensioning slab system are discussed including relative material contents, speed of construction, and factors affecting the cost of post-tensioning. Finally, a discussion on the flexibility of post-tensioned building structures in terms of future uses, new floor penetrations and demolition is presented.

Rafal and Magdalena (2016) Analyzed that the Construction of buildings is often associated with creation of the large, free from supports spaces in the lower floors with dense structural system on the upper floors. To transmit the load from the upper floors to the foundation, transfer slabs and beams are constructed. They are heavily loaded, bended and sheared components, which require a significant height of cross-section. The use of pre stressing reduces cross-section height of reinforced concrete transfer elements. The Warsaw office and service building completed last year in the part situated above the W-Z route tunnel, contains 6 posttensioned transfer beams with 1.80×1.60m cross-section and variable span in the supports axes from 23.80 to 28.20m. Beams represent foundation for five story building. The paper presents basic principles of design; results of deformation of the structure during erection obtained from theoretical FEM model and measured as well as applied technology.

Nabil s. et. al. (2017) Studied the effect of post tensioned cables on strengthening steel frames and improving their load carrying capacity, giving more resistance against the external load (dead plus live or wind load). Different types of frames are analyzed: simple frame, double bay frame and double story frame. The analysis and the results are obtained using ANSYS finite element (FE) program. Different techniques were used to apply post tensioning to steel frame. Comparisons are made between these techniques to determine which technique is better in strengthening each type of frame. The results show that using post tensioned cables increases significantly the load capacity of the steel frame.

RafalSzydlowski and Barbara Labuzek (2017) analyzed that design of modern an architectural building structure requires the use of slender and free from numerous supports slabs. The most suitable solution for above requirements is the post-tensioned slabs with unbounded tendons. Slabs pre stressed by unbounded tendons are successfully used worldwide for several decades. During that time many recommendations dealing with the forming of geometry and pre stressing, dimensioning and erection technology were issued. During the recent years pre stressed slabs characterized by span and slenderness substantially exceeding recommended limitations were designed and erected with success in Poland. During the slabs erection and in two years of their using, the deflection of three oversized slabs was monitoring. In spite of designed the slabs significantly larger and slenderer than the recommended maximum value of span and span to depth ratio, the deflection of the slabs is definitely far from the limit value. The research shows the geometry, characteristic and deflection of erected slabs and conclusion. Description of a very large span slab (21.3m), that was designed regarded to the information obtained from the previous realization.

K Bednarz (2018) Analyzed the method for correct construction of large span, slim post-tensioned concrete slabs is conditioned by an appropriate cross-section selection. It is generally accepted that the thinnest slab can be constructed using the full cross-section as the largest compression stress storage. However, completely different cross-sections may help to overcome large spans. The paper presents the results of the computational analysis of several types of cross-sections (full, with internal relieving inserts and ribbed) in the application to a post-tensioned slab with a span of 15.0m. Based on the results presented, appropriate conclusions were drawn.

Rahul singhet. al. (2018) studied that In this fast-paced and competitive world, building sector is at the apex of the growth of any country. High-rise buildings are admired by every human being. Traditionally the construction of a building is done by RCC but in present world, construction of high rise buildings is done by Post Tensioning. In RCC, the economic expenditure is very high in commercial and institutional buildings because of more material required in construction and hence, Post Tensioned building proves to be more economic and durable. Post-Tensioned building saves quantity of steel and concrete as compared to RCC and increases clear span in rooms. Through this paper, the emphasis is to design a posttensioned building using ETABS and SAFE. ETABS stand for Extended Three-Dimensional Analysis of building systems. The main purpose of this software is to design multi-storied building in a systematic process which will be in accordance with Indian Standard design codes. Abbas abdulmajeedallawiet. al. (2018) studied The structural behavior of Segmental Precast Post-tensioned Reinforced Concrete (SPPRC) beams largely depends on the behavior of the joints that connect between the segments. In this research, series of static tests were carried out to investigate the behavior of full-scale SPPRC beams with different types of epoxy-glued joint configurations; multi-key joint, single key, and plain key joint.

CHAPTER THREE

3. RESEARCH METHDOLOGY

3.1. Study area

The study area of the research is carried out at Addis Ababa city which is the capital and largest city of Ethiopia and populated by peoples from different regional states of Ethiopia. The city of Addis Ababa is divided into eleven boroughs, called sub cities and absolutely located at N, E

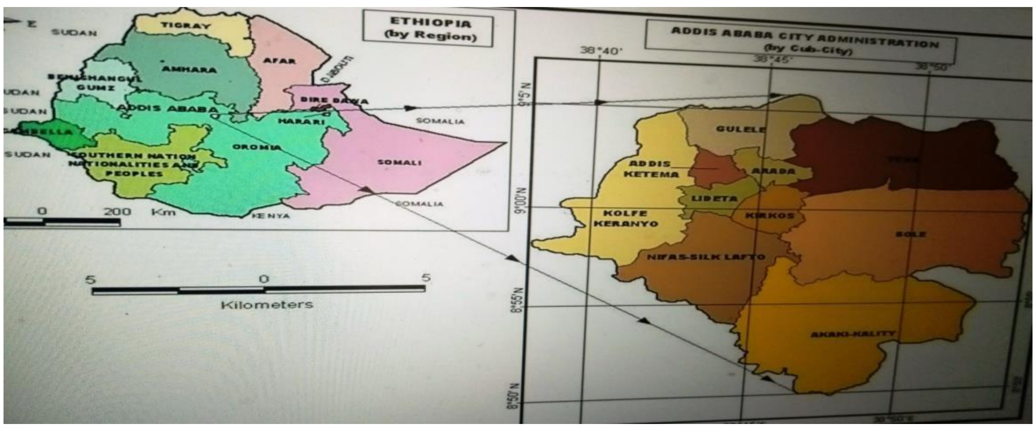


Figure 3-1 Map of the Research study area(source CSA 2007)

3.2. Research design

Research design is the overall plan for obtaining answers to the questions being studied and for handling some of the difficulties encountered during the research process. Research design is an action plan for getting from here to there where here may be defined as the initial set of questions to be answered, and there is some set of conclusion (answers) about these questions. Between here and there are a number of major steps, including the collection and analysis of relevant data (AlMoghany, 2006). The structured questionnaire is probably the most widely used data collection technique for conducting surveys to find out facts, opinions and views. Interviews can be classified according to the degree to which they are structured. In an unstructured or nondirective type of interview the interviewer asks questions as they come to mind. On the other hand, in the structured or directive interview the questions are specified in advance (Agyerum, 2012).

In a quantitative study, the steps involved in conducting an investigation are fairly standard (AlMoghany, 2006). In this study, interviews, structured questionnaire and site visits were used in the gathering of data. The interviews were adapted to collect detailed information about respondent's experiences and impressions about post tensioning and conventional slab. It was also used to collect preliminary information to help in structuring the questionnaires. The questionnaire survey was also adapted to get feedback on opinions of respondents‟ about post tensioning and RCC slab materials in Addis Ababa construction industry. This research is static in nature and therefore, survey research design is proposed to conduct the research. The data obtained from survey can be all kinds to describe some feature of the phenomena in which they exist. The research is using both explanatory and descriptive research approaches in order to get full information about the objectives of the research. For the study, qualitative and quantitative research approaches will be applied in order to address the research objectives and questions. And finally, a structured interview will be conducted with selected contractors, consultants and suppliers.

3.3. Target Population

The population of this research included construction companies, consultants and public owners sectors, the contractors companies had valid registration according to Ministry of Urban Development and Construction (MoWUD) and a randomly selected Consultants companies and Owners, which participated on public and private building projects. According to (MoWUD, 2013) the local construction firms are broadly classified based on trend of work as follows: General Contractors, GC; Building Contractors, BC; Road Contractors, RC; Specialized Contractors, SC. The first three categories are again divided into ten grades based on equipment, man power and turnover requirement. There are over 4034 contracting companies registered under G1 up to G10 in Ethiopia (MoWUD C. 2014). Therefore, the populations this research, includes General contractors classified as (GC1-GC3), G1Consultant Company and public owners that by reconnaissance survey in Addis Ababa and have a valid registration by MoWUD. Because those selected categories are have experience, efficiency and managerial and financial capability; Contractors of Category "SC" may register in one of the grades shown in Table 3.1

Table: - 3.1 Grades for Specialized Contractors [source (MoWUD, 2013)]

Category	Rank	Construction cost
Specialized Contractor	1	Above 100,000,00
Specialized Contractor	2	Up to Birr 45,000,00000
Specialized Contractor	3	Up to Birr 18,000,000
Specialized Contractor	4	Up to Birr 9,000,000

This table shows the minimum cost requires for specialized grade and rank and the data found from ministry of urban development and construction (MoWUD) and the data is used for 2013E.C

Table 3.2 Contractor grade [source (MoWUD, 2013)]

Category	Grade	Construction cost in birr		
		BC	RC	GC
(GC,BC,RC)	1	Above210,000,000	Above300,000,000	Above350,000,000
(GC,BC,RC)	2	Up to 210,000,000	Up to 300,000,000	Up to 350,000,000
(GC,BC,RC)	3	Up to 160,000,000	Up to 225,000,000	Up to 270,000,000
(GC,BC,RC)	4	Up to 110,000,000	Up to 154,000,000	Up to 185,000,000
(GC,BC,RC)	5	Up to 54,000,000	Up to 76,000,000	Up to 100,000,000
(GC,BC,RC)	6	Up to 27,000,000	Up to 38,000,000	Up to 45,000,000
(GC,BC,RC)	7	Up to 11,000,000	Up to 15,000,000	Up to 18,000,000
(GC,BC,RC)	8	Up to 5,400,000	Up to 7,500,000	Up to 9,000,000

(GC,BC,RC)	9	Up to 3,000,000	Up to 4,200,000	Up to 5,000,000
(GC,BC,RC)	10	Up to 1,000,000	Up to 1, 500,000	Up to 1,800,000

GC, General Contractors,

BC, Building Contractors

RC, Road Contractors

On the table the minimum requirement for the contractor grade those contractors are road, building and general contractor. This data is used for this study is to determine the parties that should be involved on it and the technology is limited or not widely found in Addis Abeba projects that's why needed this data for selective purpose.

3.3.1. Selected Sample construction parties

Based on the sampling method and criteria cited above, the researcher selected sixty-eight (68) construction parties which participated on private building projects in Addis Ababa. The study population for this study is selected from ongoing construction projects in Addis Ababa city and the main sources of the data is contractors, consultants, suppliers and other construction or civil engineering and PT professionals. The study is focus on the below listed sub city construction projects of varying scale with varying purpose and Characteristics. Hence, the study area to be considered for this study is those 6 sub city since a number of projects are more around there. Hence a number of construction projects are to be constructed here in the listed sub city and the construction activities and processes in the city are representing all over the city. Those cities are; - Kirkos, Nifas silk, Arada, Yeka, Bole and lideta.

3.4. Sampling procedure and Sample Size Determination

In this research, the population includes contracting companies of first, second, third category Contractors and G1Consultants companies that have a valid registration by Ministry of Urban Development and Construction (MoWUD) in Addis Ababa. Because those selected population, have a sufficient experience in construction, managerial capability and has more than one hundred twenty million Birr contracting amount capacity. There are 70 total numbers of GC1, GC2 and GC3 contractors and there are 80 G1 Consultant companies registered in Addis Ababa (MoWUD C., 2014). The sample population was distributed between contracting companies: 46

of GC1 contractors, 10 GC2 contractors, 14 GC3 contractors, 80 G1Consultant companies. To Sample public and private owners in building construction sites in Addis Ababa, Therefore, this research paper considers these owners as sample representative.

3.4.1. Sampling method

In this research purposive sampling technique is proposed for selecting contractors, consultants, suppliers and other civil engineering professionals. Purposive sampling allows the researcher to select respondents based on some criterion and importance for the objectives of the study. The following three sampling procedures are undertaken in this study in order to ensure the sample is provide a good representation of the population.

1. Identifying the population: the population is categorized based on their work activities for determining the use of PT and they are directly related with the system.
2. Stipulating the sampling frame: the sample frame are comprised; grade three and above construction contractors, consultants, suppliers and any other civil engineering professionals are included.
3. Determination of the sample size: the appropriate sample size is determined after obtaining relevant information from ministry of construction.

3.5. Study variables

Dependent variables; Dependent variable: Positive Impacts post tension slab in construction project.

Independent variables; Three independent variables are stipulated for this study.

i. Availability of post tension skilled labor.
ii. Demand of Post tensioning accessories.
iii. Cost and time of construction project

3.6. Data collection process

The research data were collected mainly through interviews and questionnaires. Field observations through site visits were also employed to gather data on the comparison of post tensioning and RCC slab. The questionnaire design was undertaken to determine the opinion of contractors, consultants and client regarding the advantageous type of slab in selected public and private building construction projects in Addis Ababa. The questionnaire are consists of three major sets of closed-ended and one open ended questions on the preferable slab type and overall related factor and acceptance of new technology the questionnaire further sought to obtain information on the level of knowledge of construction professionals on the concept of post tensioning of construction materials in the Ethiopian building industry. Interviews and site visit were also used to obtain specific information about advantage and dis advantage of post tensioning slab on building projects. The data collection process will be started after designing the research questionnaires. Then after, there will be a distribution of questionnaires and conduction of interviews with respondents. Figure 3.2 illustrates the general overview of the research data collection procedure

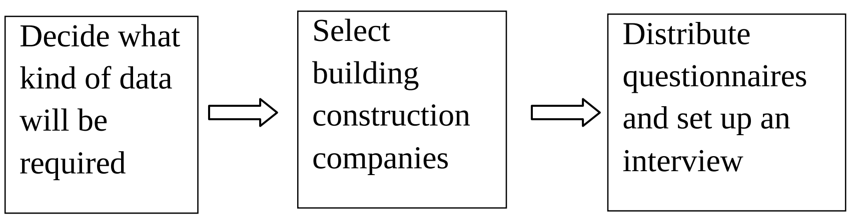


Figure 3.2 Data collection procedure

The questions were constructed using the Liker scale. The respondents were asked to rank on a scale of **1--5** factors that to select the best one on construction sites where E.S. = extremely significant [5], V.S. = very significant [4], M.S. = moderately significant [3], S.S. = low significant [2] and very low significant = [1]. In this research, methods of data collection include questionnaire with personal interview and site visits. The site visits involved observations where the researcher sought to find out how materials were stored and to assessing installment and check office documents of construction projects. The case studies spent time (6 months) on seven (7) building construction sites and observed the flow activities of materials cost and project duration. The Photographs were taken to document how these materials were erected on site and to list post tensioning accessories. The questionnaire survey consist 3 groups which address impact of post tensioning on construction project, these groups are cost impact, project completion time, and causes of not applicable in wide currently in Addis Ababa and create awareness on post tensioning slab by comparing with RCC (The questionnaire is included in appendixes).

3.7. Sources of data

The sources of data for this study both primary and secondary data are used. The primary data is collected from the distribution of the questionnaires and structured interview. The secondary Data is obtained from published materials like; books, articles, internet sources, dictionaries, reports and publications of various associations.

3.8. Data analysis and finding

The collected data obtained from primary and secondary sources is arranged systematically in order to analyze the data in various aspects of evaluation. This is involve editing, coding measuring, and tabulation of the collected data. Both qualitative and quantitative methods will be used in the computation of percentages and totals. The collected data will be analyzed and coded by using software's like Statistical Package for the Social Sciences (SPSS), Micro Soft Excel Finally, data presentation will be done by using tables, figures, charts, and graphs. The sample for this study is relatively small. As a result, the analysis had combined all groups of respondents (clients, consultants, contractors) in order to obtain significant results. Data was analyzed by calculating frequencies and Relative Importance Index (RII).

$$RII = 5n1 + \frac{4n2+3n3+2n4+1n5}{N}$$ -- {Equation 3.3}

Where: N = Total number of respondents

ni = the variable expressing the frequency of the ith response.

n1= Number of frequency 'extremely significant' response

n2= Number of frequency 'very significant' response

n3 = Number of frequency 'moderately significant' response

n4 = Number of frequency 'slightly significant' response,

n5 = Number of frequency 'not significant' response.

The levels of response are

E.S. = [100%], V.S. = [75%], M.S = [50], **S.S. = [25], N.S. = [0%]**

CHAPTER FOUR

4. RESULT AND DISCUSSION

Introduction

This chapter describes the results that have been obtained from processing of sixty-eight (68) questionnaires using Excel and statistical package for social sciences (SPSS). The results are prepared to present the information about the sample size, response rate and contracting companies‟ characteristics in Ethiopia especially; in Addis Ababa. It also includes the ranking of which slab type is preferable from post tensioning and RCC slab on construction projects based on their relative mean ranks.

4.1. General organization information

4.1.1. Classification of sample size

Chart 4.1 shows the characteristics of the sample size for the contracting companies. The sample consists of GC1-contactors (28.93 %), GC2-contactors (6.29 %), GC3-contactors (8.81 %), consultants (50.31 %) and client (5.66 %).

Table: - 4.1 case study information

Name	No of targeting sample	% of targeting sample	No of selected construction sample parties
Client	9	5.66	4
GC1 Contractor	46	28.93	20
GC1 Consultant	80	50.31	34
GC 2 Contractor	10	6.29	4
GC3 Contractor	14	8.81	6
Total	159	100	68

There are 159 targeting sample those parties selected from the data taken from MoWUD and from this the total client weight is 9 out of 159, GC1 contractor cover 46 out of 159, GC1 consultant take 80 out of 159, GC2 contractor is 10 out of 159 and the rest 14 is taken by GC3 contractor. But from this 68 selected construction sample parties are selected the selection is based on the project that applied the post tensioning technology from those 68 sample parties 4,20,34,4 and 6 weighted by client, GC1 contractor, GC1 consultant, GC2 contractor and GC3 contractor respectively.

4.1.2. Response rate

Out of the 68 questionnaires distributed on the contracting companies, 44 responses were returned with 64.71% return rate in this study. 16 (23.53%) unreturned, 8(11.76%) are invalid, see chart 4.2.

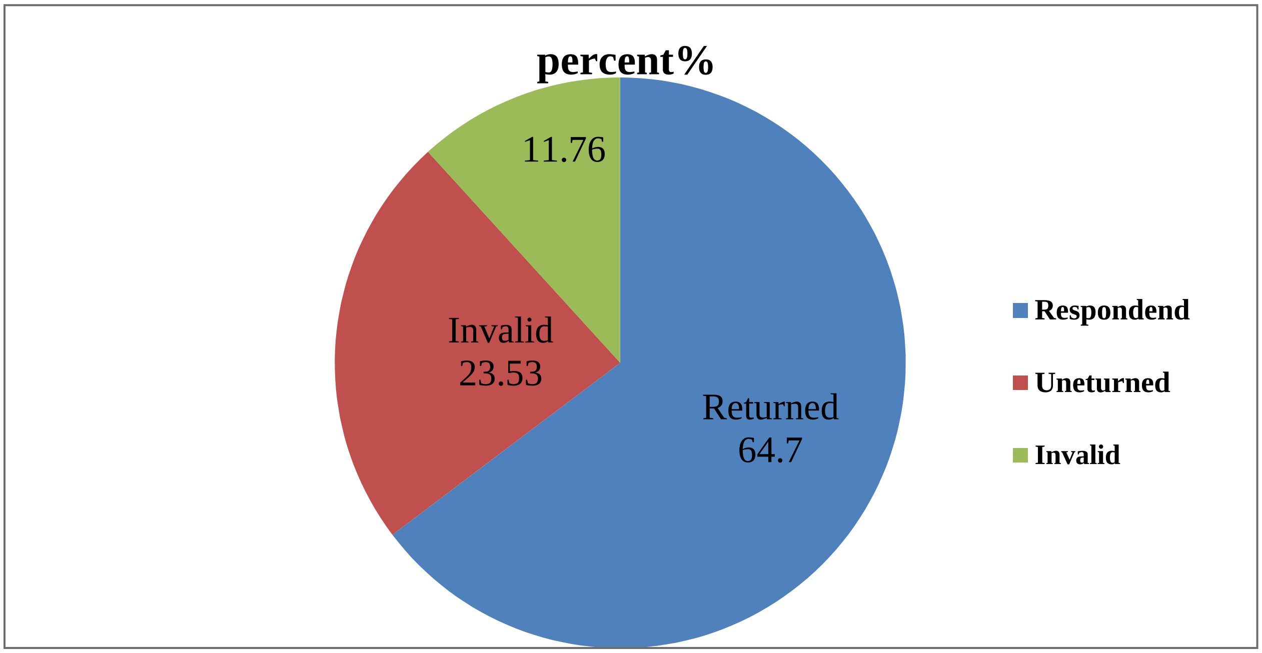


Figure4.1. Questionnaires general response rate

Table 4.2 represents the response rates among the groups of contracting companies, these rates are 75.00% GC1-contractors, 100.00% GC2-Contractors, 100.00% GC3-Contractors, 44.12% Consultants and 100.00% for Clients.

Table: - 4.2 Response rates among the groups of construction parties.

companies classification	No. of Selected company sample	Returned	Invalid
Gc1 contractor	20	15	5
Gc2 contractor	4	4	
Gc3 contractor	6	6	
Consultant	34	23	11
Client	4	4	
Total	68	52	16

From the table there are 68 selected company samples that applied the post tensioning technology from this 68 selected sample the total returned and used is 52 and the rest 16 is invalid which unreturned and uncompleted information.

4.1.3. Respondent's experience

Chart 4.3 shows the years of experience for the surveyed contracting companies in Addis Ababa. About 56.82% of contracting companies have 1-10 years of experience and 38.64 % of them have 11- 20 years of experience and while 4.55 % of them have more than 21years of experience.

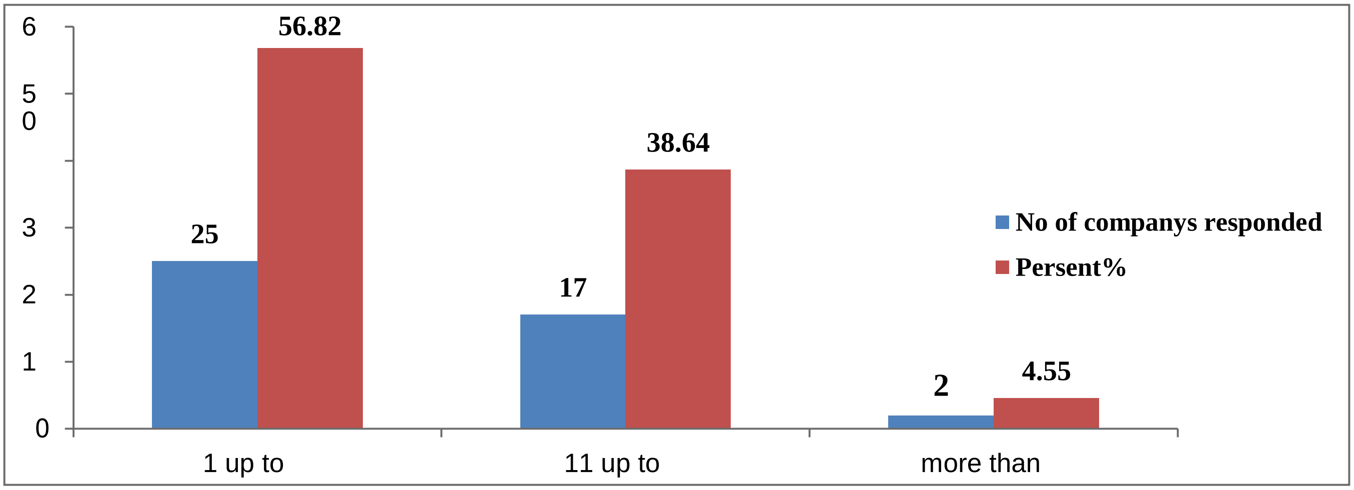


Figure4.2. Respondents experience on selected construction companies in Addis Ababa.

4.1.4. Executed projects and their value during the last five year

The value of the executed projects during the last five years is illustrated in chart 4.3 (29.55%) the executed projects up to 50 million ETB ,(38.64 %) of the executed projects up to 100 million ETB, (22.73%) executed projects up to 150 million ETB and while (9.09 %)of them with more than 150 million ETB.

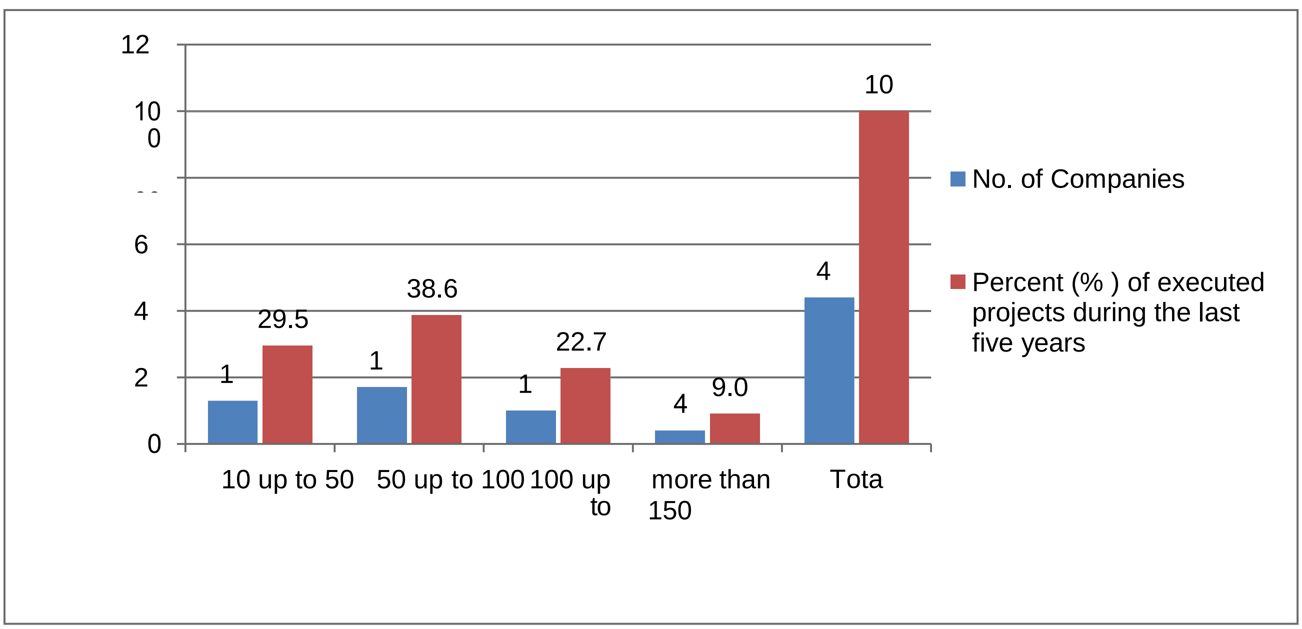


Figure4.3. value of the executed projects during the last five years construction companies in Addis Ababa

4.2. Comparisons of post tensioning and RCC Slab in construction project

There are many factors, which contribute to construction project completion cost and in the following table try to ask about the rank of factor that affects construction project cost as the starting point of the next comparison. Group 1.cost effect factors Respondents were asked to score which factors are considered to be major causes of cost arising from planning to project completion Table 4.3 shows that the Relative Importance Index of all the 13 causes of increase project cost evaluated for the respondents (contractors, client and consultants). This means that all the thirteen factors are considered as causes of cost factor.

4.2.1. Comparison of post tensioning and RCC based on cost

Table: - 4.3 Ranks of construction cost factors.

Factor	Contractor		consultant		client		Weighted average (all group)	
	RII	R	RII	R	RII	R	RII	R
Increase of project completion period	0.76	4	0.71	4	0.70	4	0.72	4
Inflation of construction material cost	0.74	5	0.68	5	0.68	5	0.70	5
Lack of knowledge about new construction techniques	0.70	6	0.66	6	0.62	6	0.66	6
Design changes and revisions	0.65	8	0.63	8	0.52	8	0.60	8
Lack of RCC Steel	0.78	3	0.75	3	0.76	3	0.76	3
Cost of labor/skilled unskilled	0.63	9	0.61	9	0.51	9	0.58	9
Quality of material	0.66	7	0.65	7	0.53	7	0.61	7
Not used of alternative construction material and method	0.80	1	0.86	1	0.79	1	0.81	1
Lack of awareness on new technologies	0.79	2	0.78	2	0.77	2	0.78	2

Time of form work demolition	0.54	12	0.56	12	0.42	12	0.50	12
Loading and un loading	0.49	13	0.52	13	0.40	13	0.47	13
Poor or wrong specification	0.61	10	0.60	10	0.50	10	0.57	10
Using excessive quantity	0.59	11	0.58	11	0.45	11	0.54	11

From the above table data gathered from the respondent there are different factor that affect project cost but from those factor Lack of awareness on new technologies, not used of alternative, Increase of project completion period and Lack of RCC Steel are the major factor of project cost. Which is the important index shows that 81% - 70%

There are different factor that affect construction cost but here cases use of alternative construction method and material, lack of awareness on affordable technology and becoming high coasty of common construction material are main factor influencing construction cost in order to this selecting the alternative construction material which is applicable and affordable that can change the conventional system as we know current Ethiopian constructions are dependent for conventional construction material like reinforced steel and cement but there are different alternative material that can replace it and more affordable also high quality that's why in this paper try to take a comparison between PT and RCC.

4.2.2. Cost impact of post tensioning

The respondents were asked to evaluate the cost impact of post tensioning in construction project Table 4.4 shows that the Relative Importance Index of all the 12 cost impact of post tensioning evaluated for the respondents (contractors, client and consultants).

Table: - 4.4 Ranks of causes for post tensioning cost effectiveness than RCC.

Factor	contractor		consultant		client		Average	
	RII	R	RII	R	RII	R	RII	R
Reduce RCC steel/mesh number	76	3	86	1	70	1	77	1
Decrease slab form work demolition period	70	4	64	3	55	3	63	3
Reduce slab thickness and column number compare to conventional	77	2	71	2	65	2	71	2
Availability of labor/skilled and unskilled	45	10	43	10	25	9	38	10
PT material and accessories availability	51	8	46	9	30	9	42	9
Cost of PT labor relative to bar bender	38	11	39	11	35	7	37	11
Cost of PT material	50	9	57	6	45	5	51	7
Low Complexity of PT installation related to bar/mesh	79	1	50	8	40	6	56	5
Easy to store PT Material	36	12	37	12	35	7	36	12
Cost of loading and unloading compare to RCC steel	52	7	54	7	40	6	49	8
Strength of PT material/ breaking capacity	68	5	61	4	50	4	60	4
Cost of design and consulting compare to conventional	62	6	58	5	35	7	52	6

This table shows that the comparison of post tensioning and conventional slab focusing on project cost from this post tensioning is advantageous in 12 different comparisons points and the main 5 point that selected by respondents are Reduce RCC steel/mesh number, Reduce slab thickness and column number compare to conventional, Decrease slab form work demolition period, Strength of PT material/un breaking capacity and Low Complexity of PT installation related to bar/mesh are the main factor that makes post tensioning is more advantageous in cost than conventional one.

From the above data and other literature post tension slab methods are preferable in case of reducing project completion cost by reducing the number of steel consumption this steel consumption is reduced by increasing the length of center to center distance between column to column the other one is post tension slabs are decrease slab thickness by reducing bar diameter in this case and other related method these all help to reduce project cost and the time required of form work demolition also one of cost deduction factor the maximum time required for PT is one week to remove totally. From this and other related case like labor cost, material cost and erection system post tension is more preferable based on project cost.

4.3. Impact post tensioning on project completion time

4.3.1. Operation (On site, Equipment) *factors*

The Relative Importance Index each of the sub-factors of the operation/on site group, which determining effect of post tensioning slab on project completion time comparing to RCC/conventional slab Table 4.5 in a descending order.

Table: - 4.5 Ranks of PT effect on project completion time due to operation/ on site factors.

Factor	contractor		consultant		client		Average(all group)	
	RII	R	RII	R	RII	R	RII	R
Easy Work complexity of PT compare to conventional	0.73	2	0.75	2	0.85	1	0.78	1
Fast Period of slab form work demolition of PT relative to conventional	0.64	6	0.54	6	0.50	6	0.56	6
Availability of post tensioning labor compare to RCC/conventional	0.51	9	0.43	9	0.30	9	0.41	9

Flexibility of PT material during installation than RCC steel	0.76	1	0.79	1	0.70	2	0.75	2
Easy to understand of working drawing design of PT than Rcc design	0.68	4	0.64	4	0.60	4	0.64	4
Low Number of cutting, bending and welding of PT strand compare to Rcc steel.	0.70	3	0.68	3	0.65	3	0.68	3
Reduce the quantity of installed Rcc steel/increase length of c/c b/n bar mesh	0.66	5	0.57	5	0.55	5	0.59	5
Easy to loading and unloading of Post tensioning material relative to Rcc steel	0.54	7	0.50	7	0.40	7	0.48	7
Breaking risk of post tensioning material	0.53	8	0.46	8	0.35	8	0.45	8
Poor workmanship of post tensioning	0.50	10	0.36	10	0.25	10	0.37	10

From the above table post tensioning are more selective by respondents than conventional slab in order to project completion time the factor that makes post tensioning are preferable than conventional are Easy Work complexity of PT compare to conventional, Flexibility of PT material during installation than RCC steel, Low Number of cutting, bending and welding of PT strand compare to RCC steel. And Easy to understand of working drawing design of PT than Rcc design this and other 13 factor that listed in the above table are causes that selected post tensioning by the respondents based on project completion time and the other thing is when the project completion time increase the project cost also increase so for this from the above data post tensioning slab consume small time to complete the project which is the maximum time required for floor is 3-7 days but in the case of conventional project it take up to 21 days even if some time after 21 days the back propping form work cannot demolished in the case of un stability and other exceptional case.

4.3.2. Common labor required for post tensioning and conventional slab

The Relative Importance Index each of the labor required for both systems is presented in Table 4.6

Table:-4.6 Ranks of labor required

Factor	contractor		consultant		client		Average(all group)	
	RII	R	RII	R	RII	R	RII	R
Post tension supervisor	0.76	3	0.86	1	0.70	1	0.77	1
Structural engineer	0.77	2	0.71	2	0.65	2	0.71	2
Site engineer	0.70	4	0.64	3	0.55	3	0.63	3
Daily labor	0.68	5	0.61	4	0.50	4	0.60	4
General Forman	0.79	1	0.50	8	0.40	6	0.56	5
Carpenter	0.62	6	0.58	5	0.35	7	0.52	6
Iron bending/welder	0.50	9	0.57	6	0.45	5	0.51	7
Mechanical	0.52	7	0.54	7	0.40	6	0.49	8

According to the respondents data shown In the above table major labor used in both conventional slab and post tensioning are the same except the post tensioning experts

4.3.3. Site supervision factors of post tensioning

The Relative Importance Index of each of the sub-factors of the site supervisor group, which is post tensioning slab construction, is presented in Table 4.7 in a descending order.

Table: - 4.7 Ranks of PT Supervision factor due to Site supervisor factors.

Factor	contractor		consultant		client		Weighted average(all group)	
	RII	R	RII	R	RII	R	RII	R
Change orders by owner	0.80	1	0.86	1	0.70	2	0.79	1
Poor qualification of consultant engineers staff assigned to the project	0.74	3	0.71	3	0.85	1	0.77	2
Lack of supervision and delay of inspections	0.61	4	0.75	2	0.65	3	0.67	3
Slow response from the consultant engineer to contractor inquiries	0.76	2	0.61	4	0.60	4	0.66	4
Poor coordination and communication between the consultant engineer, contactor and client	0.54	5	0.57	5	0.55	5	0.55	5

The Relative Importance Index of each of the sub-factors of the site supervisor group, which is post tensioning slab construction, is presented on the above table in a descending order. From this post tensioning supervision factors are listed in descending order from this change order by owners are the main factors which is ranked by 79% of relative importance index also other factor are listed in descending order.

4.4. Create awareness on the difference between RCC and posttension slab

4.4.1. Causes to not currently apply in wide

The Relative Importance Index each of the sub-factors of the post tensioning slab is not applicable now days, which determining causes Table 4.8 in a descending order

Table: - 4.8 Ranks of PT not applicable due to operation/ on site

Factor	contractor		consultant		client		Weight average	
	RII	R	RII	R	RII	R	RII	R
Lack of awareness	0.54	2	0.57	2	0.40	1	0.50	1
Lack of knowledge about post tensioning by governmental construction authority	0.58	1	0.50	4	0.35	2	0.48	2
Lack of confidence to accept by owner	0.52	3	0.54	3	0.30	3	0.45	3
Lack of confidence to accept by contractor	0.50	4	0.61	1	0.20	5	0.44	4
Thinking the price is high	0.45	5	0.46	5	0.35	2	0.42	5
Poor qualification of consultant and engineer staff	0.44	6	0.43	6	0.40	1	0.42	6
Lack of post tensioning designer	0.45	5	0.36	8	0.25	4	0.35	7
Lack of post tensioning consultancy office	0.39	8	0.39	7	0.25	4	0.34	8
Lack of skilled labor	0.40	7	0.32	9	0.20	5	0.31	9
Un available of lab test for PT material	0.35	10	0.36	8	0.20	5	0.30	10
Not flexible for change order by owner	0.39	8	0.29	10	0.15	7	0.28	11
Lack of material and accessories	0.38	9	0.27	11	0.15	7	0.26	12
Difficulty to install post tensioning slab	0.35	10	0.29	10	0.13	6	0.25	13
Difficulty to manage PT work	0.15	11	0.19	12	0.13	6	0.15	14

On this table the main factor that makes post tensioning not used widely in Ethiopia currently are listed from this lack of awareness about the general system of post tensioning and lack of experts and consultancy office by government and privates are the major causes to not applicable in Ethiopia according to the respondents

4.5. Advantage of post tensioning

The Relative Importance Index each of the sub-factors of the uniqueness of post tensioning, which determining advantage of post tensioning slab Table 4.9 in a descending order

Table: - 4.9 Ranks of PT uniqueness

Factor	contractor		consultant		Client		Weighted average (all group)	
	RII	R	RII	R	RII	R	RII	R
Low cost compare to conventional	0.69	3	0.89	1	0.75	1	0.78	1
Good structural strength	0.76	2	0.75	4	0.70	2	0.74	2
Flexible to construct any shape	0.80	1	0.86	2	0.50	3	0.72	3
Easy to work	0.62	4	0.79	3	0.45	4	0.62	4
Good and easy lab tested material	0.58	5	0.71	5	0.40	5	0.56	5
Perfect stability to various floor height and high tensile strength	0.56	6	0.68	6	0.35	6	0.53	6
Reduce c/c of column to column or number of column	0.52	7	0.64	7	0.30	8	0.49	7
Deduct number of mesh bar	0.50	8	0.57	9	0.35	7	0.47	8

Deduct slab thickness	0.46	10	0.61	8	0.25	9	0.44	9
Reduce diameter of bar	0.47	9	0.43	11	0.30	8	0.40	10
Reduce slab form work demolition date	0.38	12	0.39	12	0.40	5	0.39	11
Low wastage of material	0.40	11	0.46	10	0.25	9	0.37	12
Easy to logistic	0.37	13	0.38	13	0.27	10	0.34	13
Has perfect storing system	0.33	14	0.34	14	0.30	8	0.32	14

Based on the above data post tensioning are unique in Low cost compare to conventional, good and easy lab tested material, Flexible to construct any shape, Easy to work, Good structural strength and etc.

4.6. Factors affect post tensioning slab

The Relative Importance Index each of the sub-factors of the operation/on site group, which determining effect of post tensioning slab Table 4.10 in a descending order. On the below table the factors that affect post tensioning slab factors are provided and given the rank by the respondent and analyzed the information taken from the contractor, consultant and client and make the average rank of each factor depend on the gathered data.

Table: - 4.10 Ranks of PT effect due to operation/ on site factors

Factor	contractor	consultant	client	Weight average
Weather	0.82	1	0.86	1
Corrosion	0.73	2	0.68	2
Transport	0.67	3	0.64	3
Deflection	0.66	4	0.61	4
Structure complexity	0.56	5	0.54	5
Storing	0.52	6	0.50	6
Fire	0.50	7	0.49	7

According to the respondents post tensioning materials are low tendency to damage by weather and corrosion and related factor because of the strand and other accessories are un bonded and the bonded on is covered by duct. But from the above table try to determine the rank of factor that affect post tensioning material and from this weather are main factor during installation and fire and storing are low factor affect the strength and durability of post tensioning.

4.7. Limitation of RCC/conventional slab

The Relative Importance Index each of the sub-factors of limitation of Rcc, which determining dis advantage of Rcc slab on comparing to post tensioning slab Table 4.11 in a descending order. On the table the limitation factor of RCC factors are provided and given the rank by the respondent and finally makes the average weight of the data that gathered from client, contractor and consultant and set the final result on below.

Table 4.11 Ranks of RCC slab disadvantage

Limitation Factor	**contractor**		**consultant**		**client**		**Weight All group**	
	RII	R	RII	R	RII	R	RII	R
High consumption of RCC steel	0.83	2	0.96	1	0.80	2	0.86	1
Need more project completion time than post tensioning	0.87	1	0.82	2	0.85	1	0.85	2
High number of wastage	0.68	4	0.79	3	0.75	3	0.74	3
Limited structural design	0.65	5	0.71	5	0.65	4	0.67	4
Increase slab thickness	0.72	3	0.75	4	0.50	5	0.66	5
Low tensile strength	0.54	7	0.57	7	0.40	6	0.50	6
corrosion	0.58	6	0.50	9	0.35	7	0.48	7
Much number of cutting and bending required	0.52	8	0.54	8	0.30	8	0.45	8
Required more labor cost than PT	0.50	9	0.61	6	0.20	9	0.44	9

On the table the limitation factor of RCC factors are provided and given the rank by the respondent and finally makes the average weight of the data that gathered from client, contractor and consultant and set the final result on above.

4.8. Key cases of comparison between two slab post tensioning and conventional slab construction material on construction project.

The results showing that the key cases, which are preferable on construction project, are cost, quality, material availability, labor availability and cost, work complexity, consume time. Thus, the respondents agree that cost, quality, material availability, labor availability and cost, work complexity, consume time are more advantageous slab than the conventional one.

4.8.1. Cost comparison of post tensioning slab than conventional

In most construction project try to deduct project cost by drafting different strategic plan and work system but the main thing to deduct the project cost is work on alternative construction material and apply new technology. From the following table the post tensioning cost is lower than the conventional one and from the respondent response currently the cost and availability of reinforcement steel cost rise crazily. The advantage of PT cost set in a descending order.

Table: - 4.12 cost comparison

Cost of PT slab than RCC	contractor		consultant		client		Average all group	
	RII	R	RII	R	RII	R	RII	R
Cost of PT material/accessories compare to RCC	0.71	3	0.75	1	0.85	1	0.77	1
Cost of transport of PT than RCC	0.73	2	0.64	3	0.70	2	0.69	2
Cost of tools and equipment's of PT than RCC	0.74	1	0.61	4	0.60	3	0.65	3
Cost of labor of PT compared to RCC	0.65	4	0.68	2	0.55	4	0.63	4
Cost of loading and unloading of PT than RCC	0.60	5	0.57	5	0.50	5	0.56	5
Consumption of bar steel on PT slab of PT than RCC	0.58	6	0.46	6	0.45	6	0.50	6
Tendency to wastage of PT material compare to Rcc steel of PT than RCC	0.51	7	0.43	7	0.40	7	0.45	7

From this result conventional slabs are expensive than post tensioning slab in case of material cost, transport related case and execution of site work.

4.8.2. Case study on Actual comparison of post tensioning and conventional slab on Quantity and cost of four projects site.

This study covered selected Seven (7) public building construction projects in Addis Ababa which Constructed and supervised by different contractors and consultant and has project costs more than 300 million birr.

Table: - 4.13 case study information

NO	PROJECT NAME	PROJECT LOCATION	PROJECT DURATION	PROJECT COST[ETB]	CURRENT STATUS
1	Jesfan real estate mix used 4B+ G+18 building	kazanchis	2years	65 Million	Under construction
2	Velvet real estate B+G+2 residencies house	kotebe	2years	41 Million	Under construction
3	Joberg 3B+G+14	kazanchis	3years	60 Million	Under construction
4	Semu apartment and business center 4B+G+24	Bisrate gebreal	3years	112 Million	Under construction
5	Ccl mix used 3B+G+15	kality	2years	45 Million	Under construction
6	3B+G+6 hospital	Arada	2years	25 Million	Under construction
7	Tamrin lab, office and show room B+G+12	Bole	3years	39 Million	Under construction

In this part, the respondents were asked to identify the main differences of conventional and post tension slab focused on cost and time. Therefore, 30 contractors, 34 Consultant Company and 4

Clients are participating to response the questionnaires which is available and active on current both construction project method. From those seven projects three projects are selected for actual cost comparison case study. Method of selection is the project should be designed in both method which is in post tensioning and RCC and it helps to calculate both system cost value in once project.

4.8.2.1. Project one post tensioning and conventional slab

Assessment of actual comparison on the 2 building from the seven taken project this comparison is focused on quantity and cost of the project from existed design and taking the respondents response, from conducted of 7 projects 3 are constructed partial floor post tensioning and partials floor built by conventional slab from those are the first one is Joberg mix used building the building was first designed by conventional slab/RCC and the story was 4B+G+12 but the owner was want to design the story number increase with 4B+G+14 but in case of soil bearing capacity and structural engineer recommend that to continue according to the first design which is 4B+G+12 in case of the above condition and self-weight of the structure. And after the project become 4B+G+6 finish the post tension expert recommend that the structure can continue by adding the rejected two slab with the expected quality ,floor to floor height and foundation type then they made structural analysis and finally they decide to continue the rest floor to continue with post tensioning and added two floor also to the next floor rearranged the column number which is reduced number of column, reduce bottom and top mush bar number and reduce slab thickness. And when distributed the questionaries' the two slabs was completed by post tensioning and the other was on going. From this tried to determine the difference of the two slab type by checking the two structural drawing to prepare the quantity difference.

A. Form work cost

Table 4.14 form work cost rate

No	Material description	unit	Qty	Price/unit/m2	Total
1	H frame	M2	1	5	5
2	Props	No	1	3	3
3	RHS	M2	1	5	5
4	plywood	M2	1	12	12
	Total				**25.00**

Time Elapsed 15day

Rate per m2 25/day/m2

Area of formwork 1435m2

Total = 15day*25/day/m2*1435m2 = 538,125ETB

A. **Back propping**

No	Material description	unit	Qty	Price/unit/m2	Total
1	Props on semi basement/back props	no	**752**	**3**	**2256ETB**

Time Elapsed 22

Rate per Day 2256.00 birr/day

Total amount = 22* 2256.00 = 49632.00 ETB

Grand total = 49632+538125 = 587,757.00 ETB this is extra or overrun budget for formwork only.**Including the slab concrete and RCC bar only the cost difference per floor is**

Total = 587,757 + 6,580,478 ETB = 7,168,235ETB the rate is on appendix c

In addition to the above case the time schedule for conventional slab was 45 days for one floor and for the six floors consume one year to complete six floors by conventional slab but in case of post tensioning two floors completed per month including the vertical support, all form works removed after stressing. The maximum time required for stressing is one day only and to stressing time required after casting concrete is maximum 3 days but in conventional 15-21 days required to remove all slab form work and after 21 days also back props cant removed for safety. This all can reason of overrun cost and time of project. Material and labor cost comparison provided on appendix c.

Figure4.1 project one conventional slab after 45 days casting concrete

This figure shows that There is still back props are not removed after 45 days of concrete casting this is also reason for over run cost but in case of post tensioning maximum after seven days the back props are removed but the form work is removed after 3 days.

Figure4.2 joberg post tensioning slab all form work removed after 7 days.

As shown on the figure there is no any back props after 7 days of concrete casting but all form works are removed on the fourth date of after concrete casting except the back props

Figure4.3 Joberg post tensioning tendon installation.

The figure used to show how to install post tensioning tendon and c/c of bar mesh distance during post tensioning slab.

4.8.2.2. Project two residential house post tensioning and conventional slab

The other project used for comparison is velvet real estate project

1. Name of project____________velvet residential house
2. Location__________________kotebe/Addis abeba
3. Story number________________B+G+2
4. Single floor area________________35m*27m = 945m^2

   This project first deigned by conventional slab/Rcc but the owner of the project was not satisfied by the design in case of the following condition

A. Floor to floor height: this was too much short from the expectation of the owner the height was 3.5m and they need at least 5m and greater than floor to floor height. This is the first limitation on the conventional slab.

B. The other one is number of column according the client they not need much number of column on the middle room parts but according the structural engineer the c/c of column to column can't exceed 6m unless otherwise if there is no any special foundation and structural design.

In case of the above condition the design goes to prepare by post tensioning and after convert the design by post tensioning the following things are arranged

- Floor to floor height arranged by 5.2m
- Number of column minimized almost greater than 10 columns are rejected but there was additional two shear wall was added at the back of the room but the bar diameter minimized and slab mesh c/c was increased during conventional there was a number of 32mm diameter bar used for vertical support but all this arranged by 24mm diameter

There is a following advantage of post tensioning slab from collected response

- Post tensioning has high tensile strength than Rcc, the minimum tensile strength of post tensioning strand is 1770mpa

- As discussed before here is the same case of cost which is minimize bar diameter, number of bar reduce and number of column almost greater than 10 column are eliminated by replacing Rcc design by post tensioning design and after the conventional design replaced by post tensioning on cost there is greater than 2million birr difference between the two slab and the other thing is on post tensioning all client interest is accepted without limitation.

A. Form work extra price for ground floor of project one

Table 4.15 form work cost rate

NO	Material description	Unit	Qty	Price/unit/day	Total amount
1	H frame	M2	1	5	5
2	Props	No	1	3	3
3	RHS	M2	1	5	5
4	Plywood	m2	1	12	12
Total					**25.00birr/day/m2**

Time Elapsed minimum 15

Rate per m2 25 birr/m2

Area of form work 945m2

Total amount = 354,375birr

B. Back propping price

NO	Material description	Unit	Qty	Price/unit/day	Total amount
1	Props on semi basement/back props	no	775	3	2325.00ETB

Time Elapsed 21

Rate per Day 2325.00 birr/day

Total amount = 21* 2325.00 = 48825.00 ETB

Total = A+B

=48825+354375 = 403,200.00 ETB this is extra or overrun budget for formwork only**.**

Grand total difference = 403,200+1,036,724 ETB = 1,439,924 ETB difference per floor rate is on Appendix c

A B

Figure 4.4 (A) velvet resedencial building by post tensioning

Figure4.4 (B) velvet post tensioning installation

In this figure shows that velvet post tensioning slab installation which is one of the seven selected project. The way how to install the post tensioning duct and show how to tie together the post tensioning duct and the chair and also as showed on the above fig there are a difference elevation from chair to chair and this help to reduce the consumption of RCC steel but that is depend on the structural design the other thing is vent pipe installation that used to grout the cement paste on the duct hall after the stressing of the strand and its makes the the duct to be filled by cement paste and become solid

Figure4.5 velvet post tensioning slab with 5m cantilever

As shown on the above figure the slab can install with 5 meter cantilever by using post tensioning this tell us that by using post tensioning can erect any shape and structural design of any construction project. The cost comparison set on appendix c

4.9.Quality

Analyzing the quality of post tensioning slab comparing to conventional one are presented in Table4.16 in a descending order.

Table:- 4.16 Relative Importance Index and ranking PT quality compare to Rcc

Quality of PT material than RCC	contractor		consultant		client		Average(all group	
	RII	R	RII	R	RII	R	RII	R
Strength and durability of tendon than Rcc	0.77	1	0.79	3	0.85	1	0.80	1
Tensile strength of strand than steel	0.64	2	0.68	5	0.80	2	0.71	2
Load Bearing capacity of PT	0.62	3	0.86	2	0.55	4	0.68	3

tendon								
Resistance to corrosion	0.61	4	0.93	1	0.45	6	0.66	4
Resistance to fire	0.59	5	0.75	4	0.50	5	0.61	5
Adhesion with cement	0.57	6	0.61	6	0.60	3	0.59	6
Resistance to heat compare to steel	0.52	7	0.50	7	0.40	7	0.47	7

According to the above result post tensioning are qualitative than conventional slab, and it is highly tensile strength, durable, resistance to fire and corrosion and in the above listed case it is selective in quality

4.10. Design

The relative importance Index and rank of each factor of the design of post tensioning are presented in Table 4.17 in a descending order

Table: - 4.17 Relative Importance Index and ranking of post tensioning design compare to Rcc.

Design impact of PT compare to RCC	contractor		consultant		client		Average(all group)	
	RII	R	RII	R	RII	R	RII	R
Good stability	0.69	2	0.75	1	0.80	1	0.75	1
Capable to renewed the design of PT	0.73	1	0.68	2	0.70	2	0.70	2
Clear and easy to understand	0.60	3	0.64	3	0.65	3	0.63	3
Free from ambiguity than Rcc	0.52	4	0.57	5	0.60	4	0.56	4
Time required to design	0.54	5	0.61	5	0.50	5	0.55	5
Cost of PT design	0.50	6	0.50	6	0.45	6	0.48	6

The design of the construction project has own factor on the complexity of the work procedure and project completion time also affect the quality of the project which is the structural strength and durability, tensile strength and flexibility to take any architectural design all the above requirement is suitable on post tensioning slab according to the respondent and The relative importance Index and rank of each factor of the design of post tensioning are presented in Table 4.11 in a descending order. The major cause can be pointed out for design was free from ambiguity and clear to understand by anyone.

4.11. Material availability of post tensioning material than RCC steel

The relative importance Index and rank of each case on availability of post tensioning material are presented in Table 4.11 in a descending order. The major case of material availability and related are listed below with the respondent response.

Table:- 4.18 Material availability of post tensioning.

Material availability of post tensioning material than RCC steel	contractor		consultant		client		Average(all group	
	RII	R	RII	R	RII	R	RII	R
Sufficiently available	0.82	1	0.86	1	0.75	1	0.81	1
Locally available PT material	0.73	2	0.68	2	0.65	3	0.69	2
Imported PT material	0.67	3	0.64	3	0.70	2	0.67	3
If its imported the price of PT than RCC	0.66	4	0.61	4	0.60	4	0.62	4
Logistic cost of PT than RCC	0.56	5	0.54	5	0.55	5	0.55	5
Cost of PT material Tax of PT than RCC	0.52	6	0.50	6	0.45	6	0.49	6
Turkish steel price and logistic compare to PT material	0.51	7	0.43	7	0.30	7	0.41	7

Cost of Turkish steel tax	0.50	8	0.36	8	0.25	8	0.37	8

From this the availability of post tensioning materials are sufficient relative to Rc steel and currently in case of low demand there are extremely sufficient availability and supplier.

4.12, Labor availability and cost of PT than RCC

Table:- 4.19 labor availability of post tensioning

Labor availability and cost of PT than Rcc	contractor		consultant		client		Average(all group	
	RII	R	RII	R	RII	R	RII	R
Semi-skilled labor availability of PT than RCC	0.70	2	0.64	1	0.55	1	0.63	1
Un skilled labor availability of PT than RCC	0.68	3	0.61	2	0.50	2	0.60	2
Number of labor required for PT than Rcc of PT than RCC	0.79	1	0.50	4	0.40	3	0.56	3
Relation strength of skilled labor to the work	0.62	4	0.58	3	0.35	4	0.52	4

In labor case almost greater than 70% used labor in post tensioning and Rcc slab are the same from the collected data but in case of post tensioning slab daily labor is take the major work. Also the availability of labor by comparing PT and Rcc fill accordingly in ascending order.

4.13. Work complexity of PT compare to RCC due to minimize project time

Analyzing that the post tensioning is easy to work and install according to the respondents.

Table:- 4.20. Work complexity of post tensioning compare to Rcc

Work complexity of PT compare	contractor	consultant	client	Average(all group

to RCC	RII	R	RII	R	RII	R	RII	R
Easy to install	0.70	1	0.68	1	0.65	1	0.68	1
Minimum number of tying	0.68	2	0.64	2	0.60	2	0.64	2
Minimum number of bending work	0.66	3	0.57	3	0.55	3	0.59	3
Minimum number of stirrups work	0.64	4	0.54	4	0.50	4	0.56	4
Minimum number of chair work	0.54	5	0.50	5	0.40	5	0.48	5
Easy and clear to understand PT design	0.53	6	0.46	6	0.35	6	0.45	6
Simplest to load and unload	0.51	7	0.43	7	0.30	7	0.41	7
Clear procedure to execute PT work	0.50	8	0.36	8	0.25	8	0.37	8
Difficult to understand RCC structural design and to execute	0.46	9	0.25	9	0.20	9	0.30	9

Analyzing that the post tensioning is easy to work and install according to the respondents. The post tensioning installation is easier than RCC steel in case of no much wire and steel bendeng and cutting the other one easy to move and shaping to any shape cause the weight is less than bar steel and not rigid also there is a clear procedure during site work not structural complexity on it as RCC.

4.14. Steel reinforcement

The mean and rank of each factor of the steel reinforcement waste are presented in table 4.13 in a descending order. And a different factor that causes the waste of RCC steel bar is rise on the question and given the result for each factor and analyzed the weight of the average from the data took from contractor, consultant and client. Then provided on the table each factor on descending order

Table: - 4.21Relative importance Index and ranking of steel reinforcement wastage on building construction sites.

Factors	Contractors		consultants		clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Structure design was poor in terms of standardization and detailing	0.71	3	0.75	1	0.85	1	0.77	1
Unnecessary replacement of some bars by others of large diameter	0.73	2	0.64	3	0.70	2	0.69	2
Short unusable pieces are produced when bars are cut	0.74	1	0.61	4	0.60	3	0.65	3
Non-optimized cutting of bars	0.65	4	0.68	2	0.55	4	0.63	4
Damage during storage and rusting due to Wrong handling and poor storage	0.60	5	0.57	5	0.50	5	0.56	5
Using longer bars than what are required	0.58	6	0.46	6	0.45	6	0.50	6
Poor handling because its cumbersome to handle due to weight and shape	0.51	7	0.43	7	0.40	7	0.45	7

Dominating the use of steel reinforcement in construction sites is relatively difficult because it is cumbersome to handle due to its weight and shape (Carlos T. Formoso, 2002), but this reason has one of the lowest waste indices among all factors, which cause the waste of steel reinforcement. Most companies in Ethiopia use a table to calculate the weights of required bars.

However, most construction companies do not have a table to calculate the weight of surplus bars and short unusable pieces. The mean and rank of each factor of the steel reinforcement waste are presented in Table 4.13 in a descending order.

4.14. Assessment of key post tensioning slab construction materials/accessories used on building construction sites

In this part, respondents were asked to assess post tensioning slab materials used in construction projects. The results exposed that the key materials/accessories, which are used most on construction sites, are strand, anchorage, duct, wedge and barrels/anchor block are most commonly used as post tensioning materials on building construction sites.

4.15.1. Strand

The strand used in post tensioning system is manufactured from seven cold drawn wires and is termed a 7 wire pre stressing strand; it has a straight central wire called a core or king wire around which six wires are spun in one layer. The outer wire is tightly spun around the central wire with a lay length between 14 and 18 times the nominal strand diameter. The diameter of the central wire is at least there percent greater than the diameter of the outer helical wires. Strands are supplied to site typically in 3 – 4 tone coils

Table: - 4.22 strand specification

Steel designation	Nominal dia (mm)	Tensile strength Mpa	Steel area (mm2)	Breaking load Fm (KN
Y1770S7	12.5	1770	93	165
Y1860S7	12.5	1860	93	173
Y1860S7G	12.7	1860	112	208
Y1770S7	12.9	1770	100	177

Y1860S7	12.9	1860	100	186
Y1860S7	13.0	1860	102	190
Y1770S7	15.2	1770	139	246
Y1860S7	15.2	1860	139	259
Y1820S7G	15.2	1820	165	300
Y1770S7	15.3	1770	140	248
Y1860S7	15.3	1860	140	260
Y1770S7	15.7	1770	150	266
Y1860S7	1507	1860	150	279

Figure4.6 strand coiled

As shown in Figure4.7 that how to coiled and store post tensioning strand as shown one coil strand measure 3ton or 3000 kg and it's easy to transport and cutting also its easily rounded.

Figure4.7 cutting strand

4.15.2. Anchorage

Anchorage is a flat system used mainly in slabs and transversally in bridge dicks. It can also be used in transfer beam containment structure and other civil applications and for both 13mm and 15mm strands. The system connects bare strands which run through a steel or plastic flat oval duct. The strands are stressed individually using a mono strand jack.

A mono strand system mainly used in slabs it can also use in containments structure and remedial applications. The anchorages can be used for both 13mm and 15mm nominal diameter strands. The system connects to unbounded strand, therefore eliminating the need for duct. In some cases it's used as a mono strand bonded system or as a dead-end system on multi strand applications.

The strands are stressed individually using a mono strand jack on completion of the stressing, the strand is cropped and the strand end and wedge are sealed with a grease filled plastic cap.

Table:- 4.23 Anchor specification

13mm tendons			**15mm tendons**		
Anchorage	**No of strand**	**Dia of strand**	**Anchorage**	**No of strand**	**Dia of strand**
XM S2	2	12.5/12.9/13.0	XM S2	2	15.2/15.3/15.7
XM S3	3	12.5/12.9/13.0	XM S3	3	15.2/15.3/15.7
XM S4	4	12.5/12.9/13.0	XM S4	4	15.2/15.3/15.7
XM S5	5	12.5/12.9/13.0	XM S5	5	15.2/15.3/15.7
XM-20	6	12.5/12.9/13.0	XM-20	6	15.2/15.3/15.7
XM-30	9	12.5/12.9/13.0	XM-30	9	15.2/15.3/15.7
XM- 35	12	12.5/12.9/13.0	XM- 35	12	15.2/15.3/15.7
XM- 40	18	12.5/12.9/13.0	XM- 40	18	15.2/15.3/15.7

From the respondent response in Ethiopia work only by XM S2- XM S5 because thus are suitable for high rise building slab work the rest is used for bridge and related so on site available S2, S3 anchorage are figure out as following.

Figure4.8 Anchorage

On the above figure shows that different type of anchorage those are S2 and S3 strand anchorage which is 65*22 and 55*22 surface area of anchorage respectively and its used for S3 is suitable to pass 3 strands and S2 used to pass 2 strand and the strand diameter is 12.7mm

4.15.3. Duct

In order to insert the strands within the structure a void must be formed in the concrete. The most effective and economical way to do this is to cast metal corrugated duct in to the concrete at the desired position and profile. After the strands have been stressed, the remaining void in the duct is grouted. This provides corrosion protection and bonds the strands to the duct. The corrugations within the duct provide an excellent bond between the grouted strands and the concrete structure.

4.15.3.1. Metal duct

Metal corrugated duct sheaths are made from rolled sheet with a minimum thickness of 0.3mm. The usual guide for the required diameter of duct is 2.5 times the nominal area of the strands encased inside the duct. These should be checked against the local requirements and regulations.

Table 4.24 duct specification

Anchorage	No of strand	Duct		Coupler	
		Dia Inside mm	Dia outside mm	Dia inside mm	Dia outside mm
XM S2	2/2	55	60	60	65
XM S3	3/2	55	60	60	65
XM S4	4/3	55	60	60	65
XM S5	5/4	65	70	70	75
XM- 20	6/4	65	70	70	75
XM - 30	9/7	70	75	75	80

From the data those listed duct specification is on work in all projects in all duct size and cross sectional are including the coupler or connector.

4.15.3.2. Plastic duct

This duct supplies round and flat plastic duct where enhanced corrosion protection or improved fatigue resistance is required manufactured from high density polyethylene(HDPE) or polypropylene, the duct provides excellent secondary corrosion protection in aggressive environments. Although supplied typically in 6 meter lengths for ease of transportation, it can be manufactured to specific lengths or coils according to project requirements its connected using specific clam shell couplers, with or without integrated grout vents, for ease of installation and to provide secure joints.

Table: - 4.25 duct

Anchorage	No of strands 13mm/15mm	Dia duct Inside mm	Dia duct Outside mm	Duct thickness
XM S2	2/2	48	59	2.0
XM S3	3/2	48	59	2.0
XM S4	4/3	48	59	2.5
XM S5	5/4	48	59	2.5
XM- 20	6/4	76	91	2.5
XM- 30	9/7	76	91	3
XM- 35	12/9	76	91	3.5

In here case all project which is the seven projects 2 are used the duct size of

1. Duct size 55*20*0.25
2. Duct size 55*20*0.35
3. Duct size 65*20*0.35
4. Duct size 72*20*0.35 for plastic

The first two type duct used for the strand or anchorage of XM S2 and for the diameter of strand is 15.24 and on the site of the velvet real estate project use this duct type for the strand number of s2 and s3. The rest duct type which is number 3 and 4 used for the anchorage of S4 and S5 respectively.

Figure4.9 Duct of 55 and 65mm diameter

This are duct used to cover the strand and filled by cement paste to protect the strand from corrosion and makes that to stress the strand without any difficulty and there are different type of ducts depends on their surface area and thickness but in the above case cached only two type which is 65*22*.35 and 55*22*.35mm and suitable for S3 and S2 respectively.

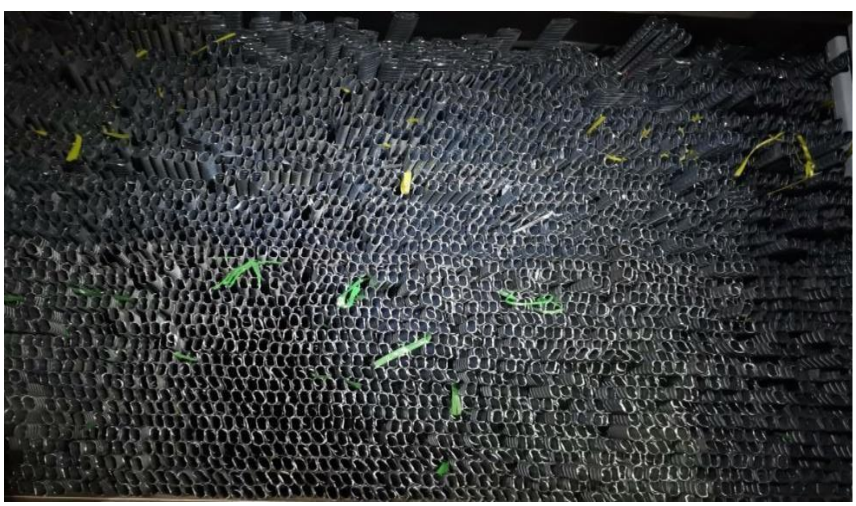


Figure4.10 During storing and transporting

This shows how to store post tensioning duct in store and how to set during transportation

Figure4.11 duct and duct installation

4.15.4. Wedges

After the transfer of load from the jack to the anchorage the strand and wedges draw a little further in to the anchor head. This further movement is known as wedge set or draw and the material used to connect the anchor head/barrels with the anchorage called wedge its diameter is depend on the strand diameter which is directly proportional with strand. The wedge set leads to a loss of tension in the strand which must be taken in to account in the loss and elongation calculations the value for wedge set to be used in the calculation for all active anchorage stressed with jacks with hydraulic lock – off is

Wedge set = 6mm + 2mm

Figure4.12 wedge and barrel

Figure4.13 how to install wedge

Figure4.13 shows how to install wedges and what looks like after installation also its shows that The wedge set leads to a loss of tension in the strand which must be taken in to account in the loss and elongation calculations the value for wedge set to be used in the calculation for all active anchorage stressed with jacks with hydraulic lock – off.

4.15.5. Anchor block/ Barrels

A special anchor used for single strand tendons, consisting of a cylindrical metal device housing the wedges, normally used with a bearing plate to transfer the pre stressing force to the concrete. Also used with miscellaneous steel members in barrier cable application

Figure4.14 barrels

4.15.6. Coupler/connecter

Couplers use a special double ended joint to connect the second stage of the tendon to the first. The special double ended joints are extremely slim and use internal wedge to grip the strand unique safety pegs are used to ensure that the wedges grip the strand securely when fitting. The movable couplers are staggered to allow for a very compact section the assembly is contained within a steel or high density polyethylene shroud. The double ended joints can also be used to join mono strand systems or multi strand systems by coupling each strand individually.

Figure4.15 connector/coupler 70mm diameter

The diameter of the connector is depend on the diameter of the original duct and its used to connect the two strand duct/tendon if not needed can install without using the connector and for short tendon is not provide the connector but if the design of tendon is greater than 12m should use the connector.

4.15. Recommended way of post tensioning slab installation and steps

4.16.1. Pre site work

The strand is cut by using the designed cutting list as shown in appendix B before moving into the site. When cutting the rolled strand it inserted in to the rolled RHS by rounding and cut by circulating the rolled strand using the fixed RHS.

Figure4.16 strand cutting

This shows how to cut the strand as showed on the figure the strand insert on RHS angle by rotating then the strand will cut by rounding

After cutting onion will be provided for the dead end of the strand using onion jack then rolled all the strand according to the tendon number which is if the tendon has three strand in one tendon line thus three strand cut equally and the dead end and live end are the same so thus are rolled in one and tie together also on the rolled strand stamp the ID number of tendon then on site it will be set on the line which have the same ID number.

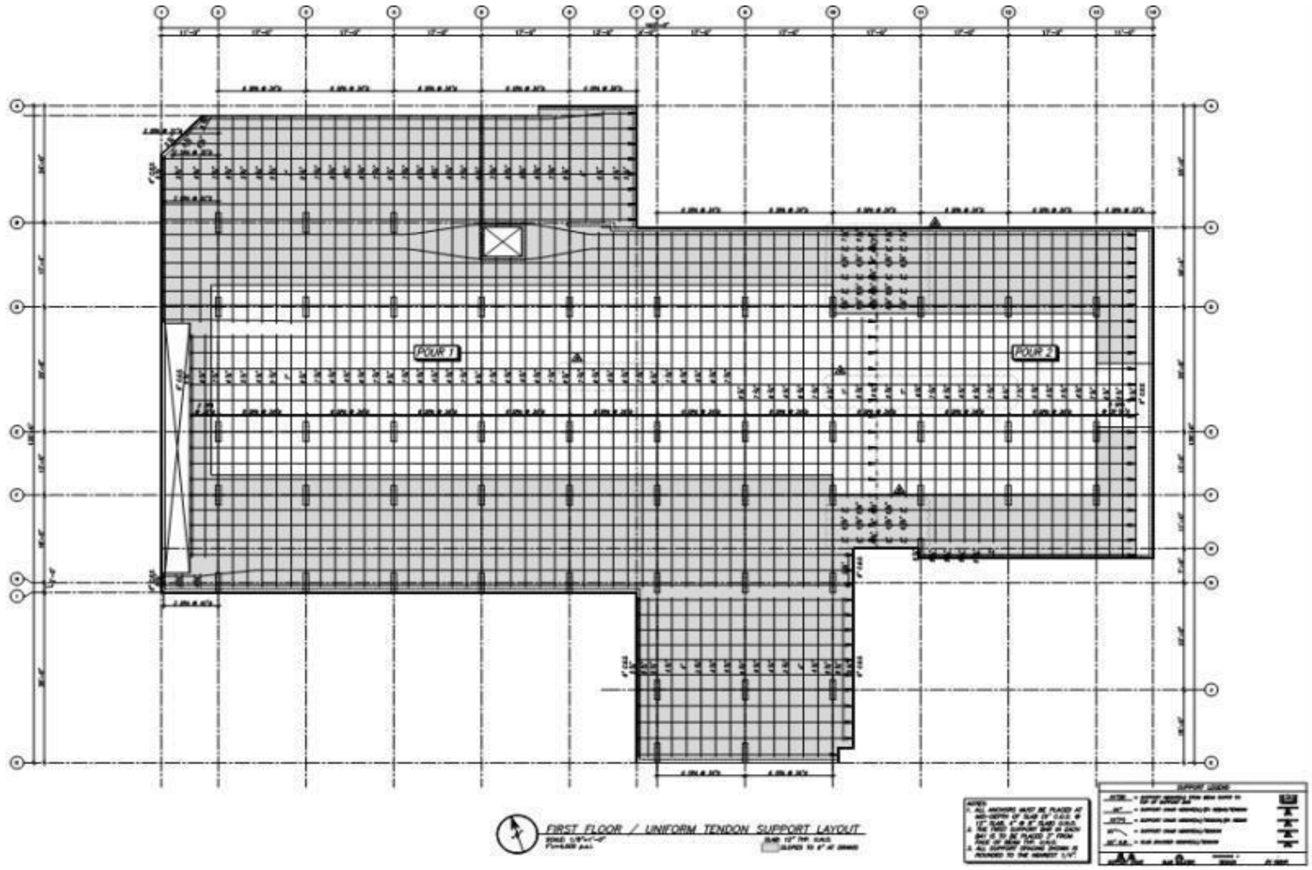


Figure4.17 post tensioning slab design drawing

4.16.2. Site work

According to the respondent there are 10 main steps during the execution of post tensioning slab.

1. Bottom mesh: this process is start after the all formwork erection are completed first false forces or all vertical and horizontal formwork is erected then after this according to the design of the bottom mesh center to center distance marked and the bar will be set on the mark place and tying all X and Y direction bar on each joints.

Figure4.18 form work

2. Post tensioning tendon line mark: after the bottom mesh is set the post tension tendon line will be marked on the plywood by using any color full paint/spray it helps if after casting the concrete and needed any change can be work by following the marked paint during marking the design center to center length should be measure accurately.

Figure4.19 mesh work

3. After marking the tendon line the next step is moving the pre prepared strand on the site and set the strands on the marked tendon line according to the stamped ID number Mach and when the strand set the strand ID should place on the panel and dead end and live end should be specify.

4. Setting the chair: mean different height bar chair used to set the duct indifferent slope so this chair set according to the design and the duct tie on it the maximum chair height is according to the respondent is 20cm and most time it sets in 5m distance and less than depend on the design analysis. And after the chair set the anchorage and the duct tie together according to the duct size and strand number the then anchor and duct filled with any filled material it can be gypsum or mortar the after the inside of the slab panel and anchorage tied together by black wire.

Figure4.20 chair setup

Shows how to set tendon chair and the c/c distance between each chair

5. Duct installation: the duct be set on the strand line and if there is need of connector the duct will be connected and when the duct install on the dead end will be onion and on live end will be covered by tape, the other thing is the strand will be pass on the duct and on the dead end will leave 1m strand on the live end will be minimum 40cm will be left for stressing.

Figure4.21 duct installation

6. Pan box: this work is if there is unsuitable area or insufficient place to stress on the edge of the slab/outside of the slab should be provide pan box by measuring 1.2m in to the inside of the slab and set the pan box to stress after concrete casting. The second case is if the tendon is designed the length not reaches up to the edge of the slap and its stop on the middle of the slab pan box will be erected to stressing the tendon after casting. And the strand live ended length which used for stressing is 1m and after the setup of pan box it should be covered the top of the pan box with plywood before concrete casting to protect from fill of concrete and after casting will be removed for stressing. Pan box/basket dead end anchorage can be used in place of standard dead end anchorages. The pre stressing forces is transfer to the concrete by bond a rebar net is required to act as a spacer for the individual strands. Basket dead ends are constructed on site using an extrusion rig.

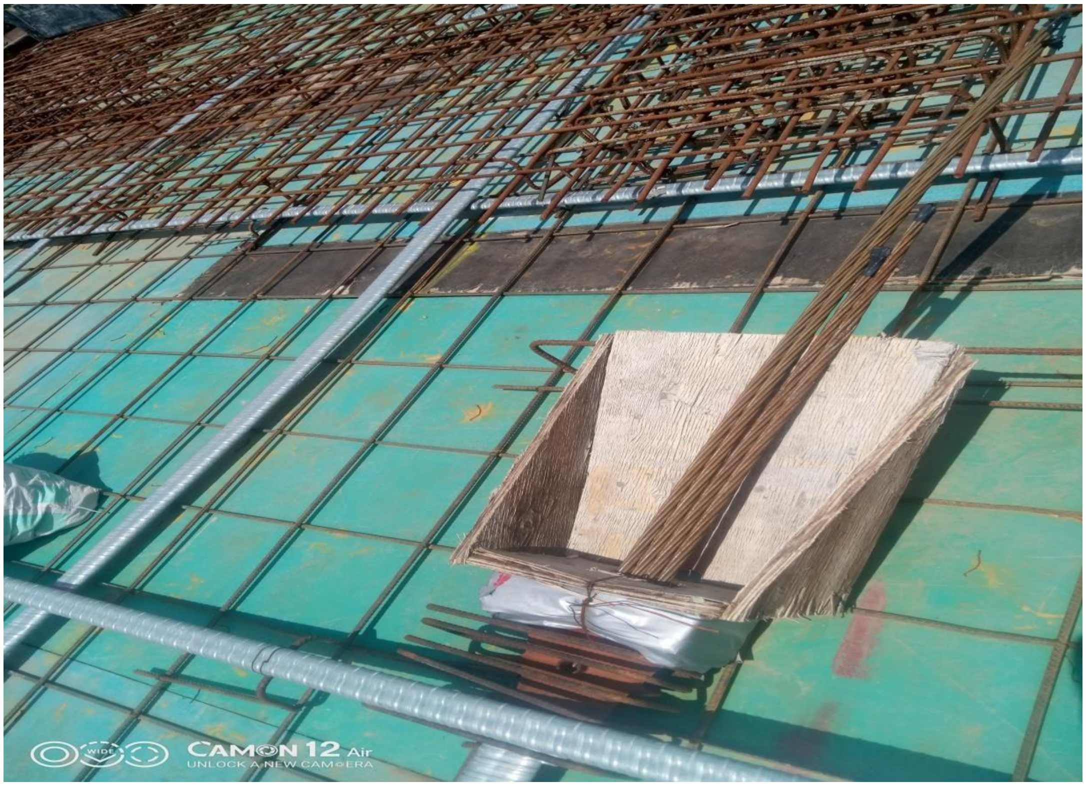


Figure4.22 pan box

7. Inserting strand on the duct: after all strand and duct are set on the marked line and measurement the strand will be inserted in to the duct according to the design dead end and live end and passing the strand 40cm out of the slab edge for stressing and all connector be tie by tape.
8. Inspection: the process of checking the stetted tendon according to the design and every up and down tendon be checked by the supervisor also pan box dead end and live end direction checked and finally casted the concrete, during casting the tendon parallel checked if there is any over loaded matter and for test a concrete sample taken from the mix.
9. Stressing: after three days from casting the concrete will come the result and can start the stressing process during the stressing there are two stressing
   - ✓ Pan box stressing which is the inner side of the slab tendon which casted on the pan box
   - ✓ Outside tendon stressing

When stressing the strand cleaned properly to be capable to passé the barrel and wedge, then can insert the barrels in to each strand if used barrel and for each strand there is individual barrel if there is three strand need three barrels but in case of anchor block all three strand tie together in one which is one anchor block which has three hole on it. Also if we have S5 we can cast with anchor block which have five whole can order according to the strand number. After casting or inserting the barrels next insert the wedge on the barrels to tie barrels and anchorage, Then after marked on the strand after the wedge to measure the elongation/the difference between the original strand length and the stressed one. Then finally stressed by using the stressing jack, the stressing pressure and the expected elongation are attached with the design and work accordingly.

Figure4.23 step to stress

4.16.3. Live ended anchorage

Most time Mono strand mainly used in slabs. It can also be used in containment structures and remedial applications. The anchorage can be used for both 13mm and 15mm nominal diameter strands. The system connects to unbounded strands, therefore eliminating the need for duct. In some cases it's used as a mono strand bonded system or as a dead end system on multi strand application. The strands are stressed individually using a mono strand jack. On completion of the stressing the strand is cropped and the strand end wedges are sealed with grease filled plastic cap.

Figure4.24 live end anchorage

4.16.4. Dead ended anchorage

Dead end anchorages are used where pre stressing force is required immediately behind the anchorages in inaccessible locations. The anchorages are made by threading plates onto the strands and swaging compression fittings to hold the plates in place. A shorter length of strand is required to develop full pre stressing force.

Figure4.25 dead end anchor

4.16.5. Stressing option

- Place the anchor head plate onto the strands, ensuring that the center mark is at the top. Fit the wedge into the anchor head, then fit the bearing ring and lock-off plate.
- Thread the jack onto the strands. A suitable lifting device should support the wedge of the jack.
- Push the jack up to the anchorage. For jacks without auto- release innards, insert the jack wedges into the pulling plate inside the rear of the jack.
- All stressing operations are controlled from the pump unit to ensure the operators safety. Carry out stressing, lock-off and retraction. The lock-off pushes the lock-off plate forward, which seats the anchorage wedges firmly into the anchor head.

4.16.6. Stressing sequence

- ✓ After removal of form work the anchor head and wedges are threaded on to the strand

- ✓ Using the correct jack and nose combination with calibrated pump/guage, the jack is threaded on to the strands and pushed up to the anchor head
- ✓ All stressing operations are controlled from the pump unit to ensure the operators safety. The jack lock-off system is applied which firmly seats the wedge in to the anchor head.
- ✓ The jack is then retracted and the wedge released so the jack can be removed when the full loads is reached or the operation can be repeated until the required load is achieved.

The other thing is during measuring the elongation it should be achieved at least 85% of the actual or designed elongation/elongation tolerance is ±15% according to ASTM which is its acceptable if it's come above and below 85% of the designed elongation if not achieved should be re stressed after 24hour. Between calculated and measured elongations. The following is a list of tolerance that are specified or recommended by the ACI 318 code, euro code (EC2) and post tensioning institute (PTI) special topic committee technical notes.

1. ACI 318-14 allows for a tolerance of ±7% (section 26.10.2)
2. BS EN 13670 (section 7.5.3) states:
   Single tendon in a group: ±15%
   Group of tendon average ±5%

If during the stressing of post tensioning tendons to the specified force, the actual elongation of the group of all tendons at a particular cross section of the structure is not within ±5% of the calculated elongation; action should be taken in accordance with the execution specification. But from experience of the expert the happening of it is 0% and it didn't happen on their project yet.

During stressing the pressure of stressing is read from the gauge after get the required pressure then remove the jack noise and take a measurement from the marked to the edge of the wedge or measure the elongation difference, by this method all tendons are done and the data will recorded and reported to the designer for approval after approval the outside strand cut and fill the outside edge of the slab by using mortar.

Figure4.26 cutting strand and mortar fill part/stressing whole

4. Grouting

It’s filling of ducts with cement paste using vent pipe which installed before. The durability of any post tensioning is affected by the quality of the grouting operation. The grout, as well as providing a bond between the concrete and the tendon provides long term corrosion protection for the steel strand. If the grouting is not carefully controlled and under taken by experienced professionals, it will compromise the structure and affect its life span. Grouting is under taken through the anchor using special threated fittings and valves to ensure a clean and effective grouting operation. Intermediate vents are created a long the tendon using grout saddles.

Figure4.27 grouting vent pipe after and before concrete casting

During grouting the form removals are work done parallels and can remove immediately after the stressing completion and approval cause grouting is not related with the removal of the form work so can perform together/before.

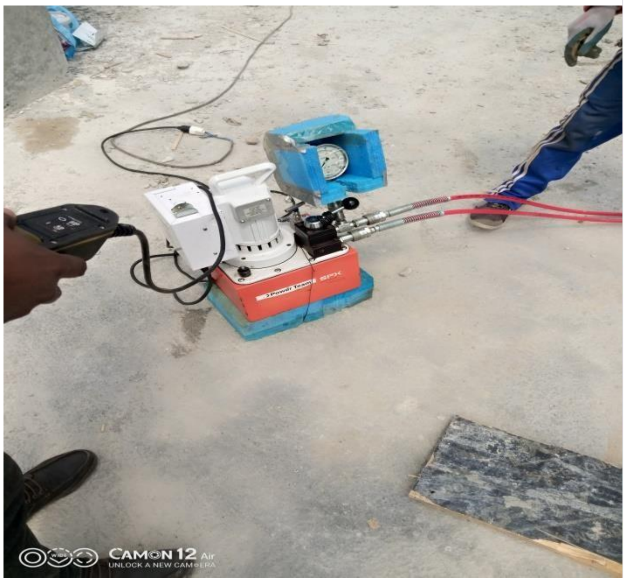
4.16. Equipment used for post tensioning

4.17.1. Onion jack: used to make onion on the strand

Figure4.28 onion jack

The above figure shows the equipment that used to preparing onion shape on the strand or in other word used to make dead end on the strand using those equipment one tie the strand and the other push the strand and after getting the required shape the hanged machine released.

4.17.2. Stressing jack: used to stressing the tendon



As shown the stressing machine/stressing jack how to stress the strand and how to read on the gage as shown the gage is on zero during start the stressing then after stressing its reads the gage 620mpa and as shown on the bottom figure after the applying of the required pressure the jack mouse become out with the hanged strand.

Figure4.29 stressing jack

4.17.3. Grouting machine: for the grouting of cement paste on the tendon duct

Figure4.30 grouting machine

CHAPTER FIVE

CONCULSION AND RECOMMENDATION

5.1. Conclusions

This study is focused on impact of post tensioning on cost, time and quality of construction materials on selected building projects in Addis Ababa and it also try to create awareness on post tensioning and presented a comprehensive analysis of these causes. The questionnaire of this study considered greater than 50 impacts which used to compare two slab type in construction, and those factors were distributed into three groups namely, cost, time, Operation, Site practices and Site supervision. Therefore, the results from analysis ranked from the first to third position by contractors, consultants and owners that the most significant impact of post tensioning on building construction projects are:-project cost, project completion time and project quality, Design and documentation factors and Operations factors.

Project cost

The findings showing that in the first ranks the post tensioning slab project cost is better than the conventional one on building construction site by contractors, consultants and owners due to Reduce number of RCC steel, Reduce slab form work demolition period, Deduct slab thickness compare to conventional, Availability of labor, Post tensioning and accessories availability, Reduce cost of labor relative to conventional, Cost of post tensioning material, Easy to installation , easy to storing post tensioning material, Low cost of loading and unloading relative to RCC steel, Low range of risk and cost of safety, Cost of design related to structural design.`

Posttensioning method is the economical method of having slabs with large span. For slabs having span more than 8 meters post-tensioning technology is effective as well as cost saving method. The length of the tendon affects total cost of the post-tensioned slab to a greater extent. Some others affect the total cost of slab to higher and lower extent. Hence, it is always helpful to known the total cost from the Post-tensioning expert agency, which also have been contracted for post-tensioning work. Generally, for posttensioned slabs the system is used to reduce the cost of the slab. Still some considerations like total height between two consecutive floors, floor usage type, architectural requirements, etc. are taken into considerations deciding the type of the slab

And total floor height between two consecutive floors. In construction of High-rise buildings, the type of Slab system is decided, while considering the feasibility of design of formwork and the time required for completion of next slab cycle. According to the result obtained for the 7th project, the structure may reduce the cost of construction because of lesser thickness of slab and as slab thickness is reduced the number of columns and beams required is less which results in less quantity of concrete and steel. Hence post tensioning method is the economical method of having slab with large span. For slabs having span more than 8 meter post tensioning technology is effective as well as cost saving method.

Project completion time

The findings showing that in the second ranks post tensioning slab project completion time comparing to conventional one is need less project period to complete the project on site by contractors, consultants and owners due to no Work complexity of post tensioning, fast period of form work demolition, Availability of skilled labor, easy and fast of post tensioning erection relative to Rcc steel bar. Flexibility of post tensioning material during installation, easiest of post tensioning working drawing design to understand, low number of cutting and welding of post tensioning strand, Reduce c/c of slab mesh, Not Difficulty of post tensioning material mobilization from ground to up story, Low breaking risk of post tensioning material. And when compare to the used labor in both case are the same except the skilled labor so the type of labor used is not that much affect the project completion time and project cost as comparison factor. And related to this from the response data Site supervision factors on Rcc The findings showing that in the first ranks the site supervision factor as causes of materials wastage on building construction site by contractors, consultants and owners due to Change orders by owner, Poor qualification of consultant engineer's staff assigned to the project, Lack of supervision and delay of inspections, slow response from the consultant engineer to contractor inquiries, Poor coordination and communication between the consultant engineer, contactor and client and reverse condition on post tensioning also the design and flexibility is better than the conventional one.

Create awareness on the difference between two slab

The findings showing that in the third ranks the result of post tensioning not applicable in wide currently in Addis Ababa on building construction site by contractors, consultants and owners due to Lack of awareness, Lack of knowledge about post tensioning by governmental construction authority, Lack of confidence to accept by owner, Lack of confidence to accept by contractor, Thinking the price is high, Poor qualification of consultant and engineer staff, Lack of post tensioning designer, Lack of post tensioning consultancy office, Lack of skilled labor , Un available of lab test for PT material, thinking that Not flexible for change order by owner, considering Lack of material and accessories, looking as Difficulty to install post tensioning slab Difficulty to manage PT work. The other thing is creating awareness about post tensioning slab and finding out the uniqueness of it such as listed on the bottom in ascending order, Low cost compare to conventional , Good structural strength, Flexible to construct any shape, Easy to work , Good and easy lab tested material, Perfect stability to various floor height and high tensile strength , Reduce c/c of column to column or number of column, Deduct number of mesh bar, Deduct slab thickness , Reduce diameter of bar, Reduce slab form work demolition date , Low wastage of material, Easy to logistic and Has perfect storing system**.** And on the listed case is Rcc steel bar is limited than post tensioning slab in the following case given by contractor, client, and consultant**.** Those are: - High consumption of RCC steel, Need more project completion time than post tensioning, high number of wastage, Limited structural design, Increase slab thickness, Low tensile strength, corrosion, much number of cutting and bending required, required more labor cost than PT.

5.2. Recommendation

5.2.1. Government

1. Should establish post tensioning department.
2. Should establish laws and policies that toward Managing and application of post tensioning construction at all levels in a construction projects.
3. Should establish new practices to apply post tensioning technology in construction projects.
4. Should develop the effective strategy to increase a new affordable/applicable technology and work on educational institution to develop the industry.
5. Should provide the concerned parties with guidelines for post tensioning of construction industry.
6. Should give training for construction parties about the technology including governmental construction authority.

5.2.2. Owners

1. Should invest on new technology and be confidential on the expert.
2. Should take the post tensioning history of the post tensioning contractors and as a criterion in awarding contracts.
3. Should Taking training on new technology to participate and invest on it.
4. Should be interested to install new construction material fabric.

5.2.3 Consultant

1. Should give attention to new technology which is comparing the quality and cost including the environmental effect and try to minimize conventional but not effective system.
2. Should update the offices by taking post tensioning design and related courses in the world.
3. Should able review the specifications, design, detailing drawing or other errors of post tensioning at the construction stage.
4. Should assigned qualified consultant engineer's staff to the project.
5. Should give daily inspections to contractor.
6. Should invite post tensioning experts to take training on it.

7. Should Work on it to create awareness to the investors and different stake holders.

5.2.4. Contractors

1. Should assign qualified staff and workforce in post tensioning construction projects.
2. Should Preparing post tension cutting list and tendon installation documents to the next project experience.
3. Should give the chance to the new labor on site.
4. Should provide technological training to site staff to raise their technological awareness and improve working procedures.
5. Should proper site management techniques, and preparation of accurate specification for materials.

Recommendation for further studies

1. It is needed to develop a study concerning cost minimization alternatives base on material selection and application of new construction technology and improving an efficient practice in Ethiopian Construction Industry.
2. It is required study Practices of post tensioning Construction materials Management in Ethiopian Construction Industry.
3. It is necessary to repeat this research every three years to observe the new trends of contractors, consultant.
4. It required the research of new technology of increase quality and cost minimization mechanism for applying to construction companies in Ethiopia, especially in Addis Ababa.
5. It requires the research on the structural limitation of conventional slab/Rcc and find out technological replacement material.

REFERENCES

[1] Abbas abdulmajeedallawiet. al. (2018**)** studied The structural behavior of Segmental Precast Post-tensioned Reinforced Concrete (SPPRC) beams

[2] Anshuman. S, D. Bhunia, B. Ramjiyani, "Solution of Shear Wall Location in Multi-Storey Building;" International Journal Of Civil And Structural Engineering ISSN 0976 – 4399, Volume 2, No 2, 2011; pp. 493-506

[3] A. S. Agrawal, S.D.Charkha, "Effect Of Change In Shear Wall Location On Storey Drift Of Multistorey Building Subjected To Lateral Loads"; International Journal of Engineering Research and Applications (IJERA); ISSN: 2248- 9622; Vol. 2, Issue 3, May-Jun 2012, pp.1786-17932012

[4] Boskey Vishal Bahoria and Dhananjay K. Parbat, "Analysis and Design of RCC and Post-tensioned Flat Slabs Considering Seismic Effect," (IACSIT) International Journal of Engineering and Technology, Vol. 5, No. 1, February 2013.

[5] Dr. Uttamasha Gupta, ShrutiRatnaparkhe and Padma Gome, "Seismic Behaviour of Buildings Having Flat Slabs with Drops," International Journal of Emerging Technology and Advanced Engineering ISSN 2250-2459, Volume 2, Issue 10, October 2012.

[6] E. H. K. Park, "RC Flat Plate under Combined inPlane& Out-Of-Plane Loads," Journal of Structural Engineering, vol. 125, no. 10, October, 1999.

[7]. Eugene Freyssinet began to use high-strength steel wires for pre stressed concrete in 1928. Between 1928 and 1939 he developed the first practical system of posttensioning and designed conical shaped wedges for anchoring the wires (Gupta 2006).

(Stevenson 1994)

[8] Er. R. Kumar, Er. S. Singh Sidhu, Er. ShwetaSidhu, Er. H. Singh Gill, "Seismic Behavior Of Shear Wall Framed Building;" International Journal of Engineering Technology, Management and Applied Sciences; ISSN 2349-4476; Volume 2 Issue 1, July 2014, pp.28-38.

[9] Kasliwal S. K., Prof. M. R. Wakchaure, Anantwad S, "Effects Of Numbers And Positions Of Shear Walls On Seismic BehaviourOfMultistorey Structure;" International Journal Of Advanced And Innovative Research; ISSN: 2278-7844, september 2012; pp.189-193

[10] P. P. Chandurkar, Dr. P. S. Pajgade, “Seismic Analysis of RCC Building with and Without Shear Wall,” International Journal of Modern Engineering Research (IJMER); ISSN: 2249-6645; Vol. 3, Issue. 3, May - June 2013 pp.1805-1810

[11] Rahul singhet. al. (2018**)** studied that In this fast-paced and competitive world, building sector is at the apex of the growth of any country

[12] R. J. Prajapati& V. R. Patel, “Effect Of Different Position Of Shear Wall On Deflection In High Rise Building,” International Journal of Advances in Engineering & Technology, ISSN: 22311963, Vol. 6, Issue 4,2013 pp. 1848- 1854

[13] Thayapraba M, “Cost Effectiveness of Post - Tensioned and Reinforced Concrete Flat Slab Systems,” International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-3, Issue-12, May 2014.

[14] V. R. Harne, “Comparative Study of Strength of RC Shear Wall at Different Location on Multi-storied Residential Building;” International Journal of Civil Engineering Research; ISSN 2278-3652 Volume 5, Number 4 (2014), pp. 391-400

[15] Y. H. Luo and A. Durrani, “Equivalent Beam Model for Flat-Slab Buildings: Interior Connections,” ACI Structural Journal, vol. 92, no.1, pp. 115-124, 1995.

APPENDIX –A

Questionnaire Survey for Thesis paper on comparative study on Rcc and post tensioning slab considering cost and time effect in case of Addis Ababa.

JIMMA UNIVERSITY

JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES FACULTY

OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

Questionnaire Survey for Thesis paper on comparative study on Rcc and post tensioning slab considering cost and time effect in case of Addis Ababa.

Dear respondents:

The purpose of this questionnaire and formats is to obtain information and data for the specified research conducted as partial fulfillment of the requirements for a master's degree in civil engineering (Construction Engineering and Management) at Jimma Institute of Technology.

Title:

Comparative study on RCC and post tensioning slab considering cost and time effect in case of Addis abeba.

Confidentiality

The data collected and the information to be answered in this questionnaire will be used for academic research purpose only. All specific companies and interviewee information will be kept confidential at all times. Only a generalized analysis of the information contained within this completed questionnaire will be utilized in the research process.

Instruction

Please answer, rate, and thick () the questionnaire by choosing the appropriate choices. The questionnaire and data collection contains two parts. Part one contains the company and respondent's general information, part two deals with research question. I realize that there are numerous demands on your time. However, your involvement is a vital requisite for this study. I appreciate your anticipated cooperation in answering this questionnaire.

Thank you for your earnest cooperation in advance.

Yours faithfully

Yoseph Tsegaye Asrat

(Mobile): 0936291531

E-mail: yomeo66@gmail.com

Postgraduate student in Construction Engineering & Management at Jimma University, JIT, Civil Engineering & Envi. Department

Supervised by

Dr Lucy Feleke and Engineer Kebene Adeba

Part one: General information

A. Company information

1. Name of the company:(optional) ____
2. Project location:____
3. Categorize your firm in construction business
   Governmental ☐ private ☐

   If other, please specify _______________________________________
4. Ownership of the project
   Private ☐ joint venture ☐ partnership ☐
5. Number of story: ____
6. Please specify what most represent your organization
   Clint ☐ consultant ☐ contractor ☐

   If other please specify ____
7. Grade of contractor/consultant _____________________________________
8. Number of project executed in the last five years
   1-10 ☐ 11-20 ☐ more than 20 ☐
9. Number of post tensioning project executed in the last five years
   1-10 ☐ 11-20 ☐ more than 20 ☐

B. Personal information

10. Gender: male ☐ female ☐

11. Your age: ________________________

12. Level of education: Certificate ☐ Diploma ☐

Bachelor degree ☐ Master's degree ☐ Phd ☐

13. What is your position in the project
    Project manager ☐ post tension supervisor ☐ bar bender ☐
    Site engineer ☐ Forman ☐ structural designer ☐
    If other please specify ____

14. Your experience in construction project
    Less than 5 yrs ☐ 5-10 yrs ☐ 11-15 yrs ☐
    Greater than 15 yrs ☐

Part two: cost impact of post tensioning

Below there are factors influencing project cost. As per your experience on the field and your observation, please express your opinion on the following factor. To measure the degree of factor affect construction cost uses a scale of 1-5, and please tick in the appropriate box. (5 = very high, 4 = high, 3 = medium, 2 = low, 1 = very low).

S.N	**Factor affect construction cost**	1	2	3	4	5
1	Project completion time					
2	Lack of R.C.C steel					
3	Inflation of construction material					
4	Cost of labor / skilled and daily					
5	Quality of material					
6	Fear of use alternative construction material					
7	Lack of cement					
8	Lack of awareness on new construction material					
9	Period of form work demolition					
10	Used of the same construction material in various project					

To measure the degree of cost impact of post tensioning use a scale of 1-5, and please tick in the appropriate box. (5 = very high, 4 = high, 3 = medium, 2 = low, 1 = very low).

	Group 1 cost impact of post tensioning compare to Rcc	V.H.S	H.S	M.S	L.S	V.L.S
S.N	**Cost impact of post tensioning**	1	2	3	4	5
1	Reduce number of RCC steel					
2	Reduce slab form work demolition period					

3	Deduct slab thickness compare to conventional					
4	Availability of labor					
5	Post tensioning and accessories availability					
6	Reduce cost of labor relative to conventional					
7	Cost of post tensioning material					
8	Easy to installation					
9	easy to storing post tensioning material					
10	Low cost of loading and unloading relative to RCC steel					
11	Low range of risk and cost of safety					
12	Affordable Cost of design related to structural design					

Group2. Impact post tensioning on project completion time	contractor		consultant		client		Average(all group)	
Group2A. Operation (On site, Equipment) factors	RII	R	RII	R	RII	R	RII	R
Easy Work complexity of PT compare to conventional								
Fast Period of slab form work demolition of PT relative to conventional								
Availability of post tensioning labor compare to RCC/conventional								
Flexibility of PT material during installation								

than RCC steel								
Easy to understand of working drawing design of PT than Rcc design								
Low Number of cutting, bending and welding of PT strand compare to Rcc steel.								
Reduce the quantity of installed Rcc steel/increase length of c/c b/n bar mesh								
Easy to loading and unloading of Post tensioning material relative to Rcc steel								
Breaking risk of post tensioning material								
Poor workmanship of post tensioning								

Group2C. Site supervision factors of post tensioning	contractor		consultant		client		Weighted average(all group)	
	RII	R	RII	R	RII	R	RII	R
Change orders by owner								
Poor qualification of consultant engineers staff assigned to the project								
Lack of supervision and delay of inspections								

Slow response from the consultant engineer to contractor inquiries								
Poor coordination and communication between the consultant engineer, contactor and client								

Group2B. Common labor required for post tensioning and conventional slab								
	contractor		consultant		client		Average(all group)	
Factor	RII	R	RII	R	RII	R	RII	R
Post tension supervisor								
Structural engineer								
Site engineer								
Daily labor								
General Forman								
Carpenter								
Iron bending/welder								
Mechanical								

Group3. Causes not applicable in wide and create awareness on the difference between two slab types

Group3A. Causes to not currently apply in wide	contractor		consultant		client		Weight average	
	RII	R	RII	R	RII	R	RII	R
Lack of awareness								
Lack of knowledge about post tensioning by governmental construction authority								
Lack of confidence to accept by owner								
Lack of confidence to accept by contractor								
Thinking the price is high								
Poor qualification of consultant and engineer staff								
Lack of post tensioning designer								
Lack of post tensioning consultancy office								
Lack of skilled labor								
Un available of lab test for PT material								
Not flexible for change order by owner								
Lack of material and accessories								
Difficulty to install post tensioning slab								
Difficulty to manage PT work								

3B. Uniqueness of post tensioning

Factor	contractor		consultant		client		Weighted average (all group)	
	RII	R	RII	R	RII	R	RII	R
Low cost compare to conventional								
Good structural strength								
Flexible to construct any shape								
Easy to work								
Good and easy lab tested material								
Perfect stability to various floor height and high tensile strength								
Reduce c/c of column to column or number of column								
Deduct number of mesh bar								
Deduct slab thickness								
Reduce diameter of bar								
Reduce slab form work demolition date								
Low wastage of material								

Easy to logistic								
Has perfect storing system								

Group3C. Factors affect post tensioning slab	contractor		consultant		client		Weight average	
	RII	R	RII	R	RII	R	RII	R
Weather								
Corrosion								
Transport								
Deflection								
Structure complexity								
Storing								
Fire								

Group3D. limitation of RCC/conventional slab	**contractor**		**consultant**		**client**		**Weighted average All group**	
	RII	R	RII	R	RII	R	RII	R
High consumption of RCC steel								
Need more project completion time								

than post tensioning								
High number of wastage								
Limited structural design								
Increase slab thickness								
Low tensile strength								
corrosion								
Much number of cutting and bending required								
Required more labor cost than PT								

4.7. Key cases of comparison between two slab post tensioning and conventional slab construction material on construction project to create detail awareness about the post tensioning.

Cost of PT slab than Rcc	contractor		consultant		client		Average all group	
	RII	R	RII	R	RII	R	RII	R
Cost of PT material/accessories								
Cost of transport								
Cost of tools and equipment								
Cost of labor								

Cost of loading and unloading								
Consumption of bar steel on PT slab								
Tendency to wastage of PT material compare to Rcc steel								

4.7.2. Quality

Quality of PT material than Rcc	contractor		consultant		client		Average(all group	
	RII	R	RII	R	RII	R	RII	R
Strength and durability of tendon than Rcc								
Tensile strength of strand than steel								
Load Bearing capacity of PT tendon								
Resistance to corrosion								
Resistance to fire								
Adhesion with cement								
Resistance to heat compare to steel								

4.7.3. Design

Design impact of PT compare to Rcc	contractor		consultant		client		Average(all group)	
	RII	R	RII	R	RII	R	RII	R
Good stability								
Capable to renewed the design of PT								
Clear and easy to understand								
Free from ambiguity than Rcc								
Time required to design								
Cost of PT design								

4.7.4. Material availability of post tensioning material than Rcc steel

Material availability of post tensioning material than Rcc steel	contractor		consultant		client		Average(all group	
	RII	R	RII	R	RII	R	RII	R
Sufficiently available								
Locally available PT material								
Imported PT material								

If its imported the price								
Logistic cost								
Cost of PT material Tax								
Turkish steel price and logistic compare to PT material								
Cost of Turkish steel tax								

4.7.5. Labor availability and cost of PT than Rcc

Labor availability and cost of PT than RCC	contractor		consultant		client		Average(all group	
	RII	R	RII	R	RII	R	RII	R
Semi-skilled labor availability								
Un skilled labor availability								
Number of labor required for PT than Rcc								
Relation strength of skilled labor to the work								

4.7.6. Work complexity of PT compare to RCC due to minimize project time

Work complexity of PT compare to RCC	contractor		consultant		client		Average(all group	
	RII	R	RII	R	RII	R	RII	R
Easy to install								
Minimum number of tying								
Minimum number of bending work								
Minimum number of stirrups work								
Minimum number of chair work								
Easy and clear to understand PT design								
Simplest to load and unload								
Clear procedure to execute PT work								
Difficult to understand Rcc structural design and to execute								

4.7.7. Steel reinforcement

Factors	Contractors		consultants		clients		Weighted average (all groups)	
	RII	R	RII	R	RII	R	RII	R
Structure design was poor in terms of standardization and detailing								
Unnecessary replacement of some bars by others of large diameter								
Short unusable pieces are produced when bars are cut								
Non-optimized cutting of bars								
Damage during storage and rusting due to Wrong handling and poor storage								
Using longer bars than what are required								
Poor handling because its cumbersome to handle due to weight and shape								

Part 2: Open Questioners

1. What are the major disadvantages of post tension slab?

____
____
____
____
____

2. How to erect post tensioning slab in detail and share us the equipment required?

____
____
____
____
____
____

3. ____
____

4. Which slab system is preferable in order to material wastage? Why?

____
____
____
____

5. How is the capacity of post tensioning consultancy office and availability in number?

____
____
____
____

6. ____
____
____
____

7. In overall condition which slab type is acceptable from post tension and Rcc/conventional slab? Why different reason from the above rise reason?

____

____

____

____

____

____

____

____

APPENDIX –B

A suggested form for estimating quantity of strand from list of cutting on building Construction projects

TO Project Manager From

JFS Project ESPT Pre stressed concrete contracting

Addis – Ethiopia Business Bay- The binary Tower- Office 1012

#	Label	Tendon/ Duct Length	Strands No	Strand Length	Stressing ends	DLV	Extension	Strand Cut Length	Total Tendon length	weight	Barrels nos		
1	tendon 830	13.75	2	27.375	1		0.4	14.156	28.313		2		
2	Tendon 831	13.688	4	54.47	1		0.4	14.088	28.175		2		
3	tendon 832	13.618	2	18.256	1		0.4	14.018	56.07				4
4	Tendon854	9.128	2	18.238	1		0.4	9.528	19.056		2		
5	Tendon855	9.119	2	18.133	1		0.4	9.519	19.038		2		
6	Tendon856	9.066	2	18.171	1		0.4	9.466	18.933		2		
7	Tendon857	9.085	2	27.43	1		0.4	9.485	18.971		2		
8	Tendon860	13.715	2	28.938	1		0.4	14.115	28.23		2		
9	Tendon878	14.469	2	31.7	1		0.4	14.869	29.738		2		
10	Tendon879	15.85	2	76.349	1		0.4	16.25	32.5		2		
11	Tendon881	38.174	2	76.039	2	DLV	1	39.174	78.349		2		
12	Tendon882	38.019	2	74.77	2	DLV	1	39.019	78.039		2		
13	Tendon891	37.385	2	74.619	2	DLV	1	38.385	76.77		2		
14	Tendon892	37.309	2	43.116	2	DLV	1	38.309	76.619		2		
15	Tendon893	21.558	2	43.236	1		0.4	21.958	43.916		2		
16	Tendon894	21.618	2	31.16	1		0.4	22.018	44.036		2		
17	Tendon895	15.58	2	26.044	1		0.4	15.98	31.96		2		

18	**Tendon897**	**13.022**	**2**	**54.538**	**1**		**0.4**	**13.422**	**26.844**		**2**		
19	**Tendon899**	**18.179**	**3**	**45.7**	**1**		**0.4**	**18.579**	**55.738**			**3**	
20	**Tendon902**	**15.24**	**3**	**54.52**	**1**		**0.4**	**15.64**	**46.92**			**3**	
21	**Tendon905**	**18.173**	**3**	**51.994**	**1**		**0.4**	**18.573**	**55.72**			**3**	
22	**Tendon906**	**18.095**	**3**	**18.137**	**1**		**0.4**	**17.731**	**53.194**			**3**	
23	**Tendon916**	**9.068**	**2**	**18.095**	**1**		**0.4**	**9.468**	**18.937**		**2**		
24	**Tendon917**	**9.048**	**2**	**13.139**	**1**		**0.4**	**9.448**	**18.895**		**2**		
25	**Tendon920**	**6.569**	**2**	**13.23**	**1**		**0.4**	**6.969**	**13.939**		**2**		
26	**Tendon921**	**6.615**	**2**	**96.06**	**1**		**0.4**	**7.015**	**14.03**		**2**		

APPENDIX –C

Compression of cost between conventional and post tensioning slab

Project one

For conventional slab unit rate and the cost is sum of material, labor and equipment cost

- For conventional slab

Material	Unit	Qty	Unit price	Amount
concrete	M3	886.6	3400	3,014,440
Rc steel	kg	81,736.81	80	6,538,944.8
TOTAL		**9,553,384.8ETB**		

- For conventional column

Material	Unit	Qty	Unit price	Amount
concrete	M3	251.422	3400	854,834.8
Rc steel	kg	13,656.5	80	1,092,520
TOTAL		**1,947,354.8 ETB**		
GRAND TOTAL= Slab total + column total		**11,500,739.6 ETB**		

Project one

For post tension slab unit rate and the cost is sum of material, labor and equipment cost

- For post tension slab

Material	Unit	Qty	Unit price	Amount
concrete	M3	511.5	3400	1,739,100
Rc steel	kg	17,959.06	80	1,436,720
strand	kg	1,200	38.88	46,656
duct	M3	2,122	22.5	47,745
anchorage	pcs	58	270	15,660
TOTAL				**3,285,881ETB**

- For post tension column

Material	Unit	Qty	Unit price	Amount
concrete	M3	217.5	3400	739,500
Rc steel	kg	11,186	80	894,880
TOTAL		**1,634,380ETB**		
GRAND TOTAL= Slab total + column total		**4,920,261ETB**		

- **Difference between two slab type = conventional – post tension**

  = **11,500,739.6 ETB - 4,920,261ETB**

  = 6,580,478 ETB

Total difference from project = 24*6,580,478 ETB

= 157,931,472ETB

Project two

For conventional slab unit rate and the cost is sum of material, labor and equipment cost

- For conventional slab

Material	Unit	Qty	Unit price	Amount
concrete	M3	227.5	3400	773,500
Rc steel	kg	25,775.73	80	2,062,058.4
TOTAL			**2,835,558.4 ETB**	

- For conventional column

Material	Unit	Qty	Unit price	Amount
concrete	M3	111.4	3400	378,760
Rc steel	kg	10,336.95	80	826,956

TOTAL	**1,205,716ETB**
GRAND TOTAL= Slab total + column total	**4,041,274.4ETB**

Project Two

For post tension slab unit rate and the cost is sum of material, labor and equipment cost

- For post tension slab

Material	Unit	Qty	Unit price	Amount
concrete	M3	170.6	3400	580,040
Rc steel	kg	20,469.13	80	1,637,530.4
strand	kg	740	38.88	28,771.2
duct	M3	1550	22.5	34,875
anchorage	pcs	45	270	12,150
TOTAL				**2,293,366.6ETB**

- For post tension column

Material	Unit	Qty	Unit price	Amount
concrete	M3	70	3400	238,000
Rc steel	kg	5914.8	80	473,184

TOTAL	**711,184ETB**
GRAND TOTAL= Slab total + column total	**3,004,550.6ETB**

- **Difference between two slab type = conventional – post tension**

= 4,041,274.4ETB - 3,004,550.6ETB

= 1,036,724 ETB

Total difference from project = 4*1,036,724

= 4,146,896

Project Three

For conventional slab unit rate and the cost is sum of material, labor and equipment cost

- For conventional slab

Material	Unit	Qty	Unit price	Amount
concrete	M3	227.5	3400	773,500
Rc steel	kg	21,604	80	1,728,320
TOTAL			**2,501,820ETB**	

- For conventional column

Material	Unit	Qty	Unit price	Amount
concrete	M3	41.6	3400	139,400
Rc steel	kg	5392.6	80	431,408
TOTAL			**570,808ETB**	
GRAND TOTAL= Slab total + column total			**3,072,628ETB**	

Project Three

For post tension slab unit rate and the cost is sum of material, labor and equipment cost

- For post tension slab

Material	Unit	Qty	Unit price	Amount
concrete	M3	131.5	3400	447,100
Rc steel	kg	4035	80	322,800
strand	kg	1100	38.88	42,768
duct	M3	1800	22.5	40,500
anchorage	pcs	36	270	9,720
TOTAL				**862,888ETB**

- For post tension column

Material	Unit	Qty	Unit price	Amount
concrete	M3	14.976	3400	50,918.4
Rc steel	kg	10707	80	136,533.33
TOTAL			**187,451.7ETB**	
GRAND TOTAL= Slab total + column total			**1,050,339.7ETB**	

- **Difference between two slab type = conventional grand total – post tension grand total**

  = 3,072,628ETB - 1,050,339.7ETB

  = 2,022,288.3 ETB

Total difference from project = 15*2,022,288.3 ETB

= 30,334,324.5 ETB