BONDED & UNBONDED POST-TENSIONING SYSTEM FOR THE BUILDING FLOOR SYSTEM

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ABSTRACT

The Principal design objectives for structural engineers are safety, functionality, economy and now a day's legality of design. When selecting a structural building system, it is important for the engineers and architects to understand the appropriate application of post-tensioned concrete and the effects that may result. If properly analyzed and assembled, concrete structures from high quality materials can provide a superior combination of durability, sound control and fire safety needed in today's building market. Considering above factors post tensioning floor systems has been considered for the present study. Prestressing of concrete is defined as the application of compressive stresses to concrete members. There are two types of prestressing named pre-tensioning and post-tensioning. Post tensioning has many reason which increases the use of the post-tensioning, such as increased span to depth ratio resulting in a reduction in construction materials and a subsequent reduction in overall cost, positive deflection control, design flexibility, minimum construction joints, improve durability and increase span length.

Keyword: *Prestressing,Concrete,Joints*

1. INTRODUCTION

The development of pre-stressed concrete can be studied in the perspective of traditional building materials. In the ancient period, stones and bricks were extensively used. These materials are strong in compression, but weak in tension. For tension, bamboos and coir ropes were used in bridges. Subsequently iron and steel bars were used to resist tension. These members tend to buckle under compression. Wood and structural steel members were effective both in tension and compression.
In reinforced concrete, concrete and steel are combined such that concrete resists compression and steel resists tension. This is a passive combination of the two materials. In pre-stressed concrete high strength concrete and high strength steel are combined such that the full section is effective in resisting tension and compression. This is an active combination of the two materials.

1.1 PRE-STRESSED CONCRETE

The pre-stressing and pre-casting of concrete are inter-related features of the modern building industry. Through the application of imaginative design and quality control, they have, since the 1930's, had an increasing impact on architectural and construction procedures. Pre-stressing of concrete is the application of a compressive force to concrete members and may be achieved by either pre-tensioning high tensile steel strands before the concrete has set, or by post-tensioning the strands after the concrete has set. Although these techniques are commonplace, misunderstanding of the principles, and the way they are applied, still exists. This paper is aimed at providing a clear outline of the basic factors differentiating each technique and has been prepared to encourage understanding amongst those seeking to broaden their knowledge of structural systems.

1.2 HISTORY OF PRESTRESSING

Before the development of pre-stressed concrete, two significant developments of reinforced concrete are the invention of Portland cement and introduction of steel in concrete. These are also mentioned as the part of the history. The key developments are mentioned next to the corresponding year. Pre-stressed concrete was started to be used in building frames, parking structures, stadiums, railway sleepers, transmission line poles and other types of structures and elements. In India, the applications of pre-stressed concrete diversified over the years. The first pre-stressed concrete bridge was built in 1948 under the Assam Rail Link Project. Among bridges, the Pamban Road Bridge at

Rameshwaram, Tamilnadu, remains a classic example of the use of pre-stressed concrete girders.

1.3 WHAT IS PRE-STRESSING?

Pre-stressed concrete is probably the latest discovery in man's continuing search for new construction materials and methods. Pre-stressing of concrete is defined as the application of compressive stresses to concrete members. Those zones of the member ultimately required to carry tensile stresses under working load conditions are given an initial compressive stress before the application of working loads so that the tensile stresses developed by these working loads are balanced by induced compressive strength. 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-tensioning applications include office and apartment buildings, parking structures, slabs-on ground, bridges, sports stadiums, rock and soil anchors, and water-tanks. In many cases, post-tensioning allows construction.

1.4 CLASSIFICATION OF PRESTRESSED CONCRETE

Pre-stressed concrete structures can be classified in a number of ways depending upon their features of design and construction.

1. Externally or Internally Pre-stressed
2. Linear or Circular Pre-stressing
3. Pre-tensioning and Post-tensioning.
4. End-Anchored and Non-End-Anchored Tendons.
5. Bonded or Unbonded Tendons.
6. Partial or Full Pre-stressing.

1.5 USES AND ADVANTAGES OF PRE-STRESSING:

Post-tensioning has found widespread use and effectiveness in a variety of structure types, including:

- Slabs-on-Ground: residential slab-on-ground foundations, light industrial foundations, heavy industrial foundations, mat foundations, sport courts, and pavements.
- Buildings: office buildings, condominiums/residential buildings, hotels, mixed-use, theaters, shopping centers/malls, schools, casinos, libraries, manufacturing plants, research/academic institutions, and governmental.
- Parking Structures: commercial, airport, underground parking structures, and mixed-use.
- Storage Structures: water storage tanks (floors, walls, roof), clarifiers, digesters, and silos.
- Grandstands and Stadiums
- Staged Construction: transfer plates, transfer podiums, transfer slabs, and transfer girders.
- Tension Members: tension rings and tie-beams.

2. LITERATURE REVIEW

Amorn pimanmas et al. The post-tensioned flat slab construction is widely used for constructing medium to high rise buildings in Thailand. Normally, the design of post-tensioned flat slab considers the effect of gravity load only while the shear wall is designed to resist wind forces. The distinctive features of post-tensioned flat slab reinforcement detail are 1) no transverse reinforcement in the slab column connection, 2) temperature and shrinkage bonded steels in the bottom of slab and 3) no tendons passing through the column. Under lateral forces, the slab-column connection is expected to transmit large moment, shear and torsion between slab and column. This may lead to the punching shear failure. This paper presents the result of reversed cyclic test of 3/5 scaled post-tensioned interior flat slab-column connection. The author have collected the architectural and structural data of five post-tensioned flat slab buildings constructed in Thailand and defined structural indices to characterize the structural behavior of the slab column connection. The test specimen was designed to have the structural indices as close as possible to the mean values of the actual buildings. The test results indicated complex transfer of forces around the connection. These forces include longitudinal and transverse moments, torsion and shear. The specimen can displace up to 2% story drift. The failure is caused by sudden punching shear occurring after most of top bars have yielded.

rajeh z. ai-zaid et.al. A simple and rational analytical model that allows the determination of the history of strain and stress distribution in un-cracked bonded post-tensioned RC concrete sections is proposed. Expressions for the direct computation of the time dependent strain are extended to consider a two-stage sustained loading and the state of shoring or un-shoring during the period of initial hardening. The analysis is performed at arbitrary points in time satisfying the conditions of force and moment equilibrium as well as the strain compatibility between all layers of steel and the surrounding concrete. The effects of the change in modulus of elasticity of concrete and the change in geometric properties due to grouting of tendon ducts are taken into account. A numerical example of a pre-cast post-tensioned beam is given to demonstrate the method.

ehab ellobod and colin g. et.al. This paper presents new fire tests conducted on bonded and unbonded post tensioned concrete slabs. A total of 16 tests were carried-out, of which four were conducted at ambient temperature to evaluate the capacity of the slabs in the cold condition. The remaining 12 tests were conducted under fire conditions, with the slabs subjected to the standard fire curve under a static load equal to 50% of the capacity of the unbonded slabs in the cold condition. The slabs were one-way simply-supported and reinforced with 15.7mm nominal diameter seven-wire mono-strand tendons. The effects of different aggregate types, boundary conditions and duct material (steel and plastic) in the bonded slabs have been investigated in the tests. The temperature distribution throughout the slab, the strains in the tendons, the deflection behavior and the longitudinal expansion were recorded during the tests. A nonlinear finite element model for the analysis of the slabs at elevated temperatures was also developed. The mechanical and thermal material nonlinearities of the concrete, pre-stressing tendon and anchorages were accurately modeled..

alan h. mattock, jun yamazaki and basil t. kattula et al. Tests were made of seven span beams of 28 ft span and of three beams continuous over two spans of 28 ft each. The primary variables were the presence or absence of bond; the amount of bonded unpre-stressed reinforcement; and the use of seven wire strand as bonded unpre-stressed reinforcement. The unbounded post tensioned beams with minimum recommended unpre-stressed bonded tensioned beams with minimum recommended unpre-stressed bonded reinforcement had serviceability characteristic, strength and ductility equal to or better than those of comparable bonded post tensioned beams. An expression is proposed for the ultimate stress in unbounded tendons. Seven wire strands can be used effectively as unpre-stressed bonded reinforcement.

bijan aalami et al. In this paper the author compares the bonded and unbounded system of post tensioning. First he gives the basic characteristics of the system such as the formation of bonded with concrete, anchorages for the system, construction procedure. Second he compares both the system regarding the differences in their design procedures. Unbounded system gives more eccentricity with greater ease as compared to bonded system which gives a greater lever arm and hence balances more moment. However ultimate strength of bonded section, as compared with minimum non pre-stressed reinforcement. This has been demonstrated with the help of a design example where in a beam of 19 mt. span is designed for both the systems taking in to consideration the code provision if ACI & UBC.

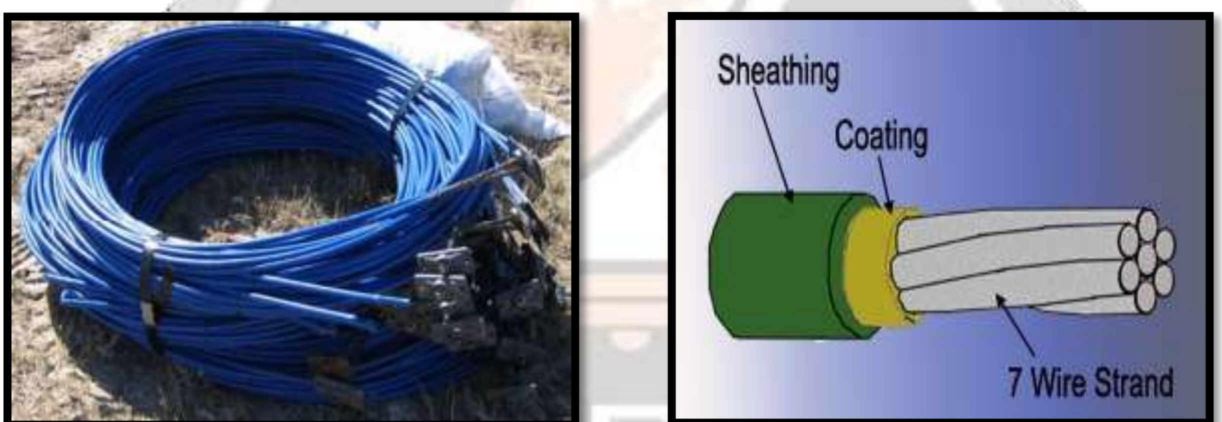
3.CONCEPT OF PRE-STRESSING

This concept treats concrete as an elastic material and is probably still the most common view point among engineers. Concrete which is weak in tension and strong in compression is compressed so that brittle concrete would be able to withstand tensile stresses. From this concept no tensile stresses are born. From this standpoint concrete is visualized as being subject to two systems of forces: internal pre-stress and external load, with the tensile stresses due to the external load counteracted by the compressive stresses due to pre-stress. Similarly, the cracking of concrete due to load is prevented or delayed by the pre-compression produced by the tendons. Consider a simple rectangular beam pre-stressed by a tendon through its centroidal axis and loaded by external loads.

3.1 BONDED AND UNBONDED :

Unbonded tendons typically consist of single (mono) strands or threaded bars that remain unbonded to the surrounding concrete throughout their service life - giving them freedom to move locally relative to the structural member. The strands in unbonded mono-strand systems are coated with specially formulated grease with an outer layer of seamless plastic extruded in one continuous operation to provide protection against corrosion. Depending on the application and the level of protection that is needed, the anchorages of unbonded mono-strand systems may also be encapsulated. Light and flexible, unbonded mono-strand can be easily and rapidly installed - providing an economical.

TYPICAL CROSS SECTION OF STRAND



3.2 LOSSES OF POST-TENSIONING:

Loss due to elastic deformation of concrete

The loss of pre-stress due to elastic deformation of concrete depends on the modular ratio and average stress in concrete in concrete at the level of steel.

f_c = pre-stress in concrete at the level of steel
E_s = modulus of elasticity of steel.
E_c = modulus of elasticity of concrete $\alpha_e = E_s/E_C$ = modular ratio
Strain in concrete at the level of steel = (f_c/E_c)
Stress in steel corresponding to this strain = $(f_c/E_c)E_s$
Loss of stress in steel = $\alpha_c.f_c$

3.3 FAILURES

- The problem presents significant challenges to the structural engineer for the following reasons. The problem is relatively new.
- Methods of analysis used for new design are not always applicable, especially in cases of severe breakage.
- Codes and consensus guidelines for such analyses have not been extensively developed.

4. MATERIALS
4.1 CONCRETE

Stronger concrete is usually required for pre-stressed than for reinforced work. Present practice in this country calls for 28 day cylinder strength of 28 to 55 Mpa of pre-stress concrete. While corresponding value for reinforced concrete is around 24 Mpa. The usual cube specified for pre-stressed concrete in Europe is about 450 Kg/cm2 based on 10-, 15- or 20- cm cues at 28 days. Higher strength is necessary in pre-stressed concrete for several reasons. First in order to minimize their cost, commercial anchorage for pre-stressing steel are always designed on the basis of high-strength concrete. Experience has shown that 28 to 34 Mpa strength will generally work out to be the most economical mix for pre-stressed concrete. To attain strength in excess of 34 Mpa, it is necessary to use a water-cement ratio of not much more then 0.45 by weight.

4.2 PT STRANDS

Strands for pre-stressing generally conform to ASTM specification A-416 for “unbonded seven wire Stress relieved for Pre-stressed Concrete". Two grades are available 1724 Mpa and 1862 Mpa. Where grade indicates minimum guaranteed breaking stress. These seven wire strands all have a center wire slightly larger than the outer six wires which enclose it tightly in helix with a uniform pitch between 12 and 16 times the nominal diameter of the strand. For calculations, a modulus of elasticity of 190000 Mpa grade strand. The specified minimum elongation of the strand is 4% in a gage length of 609.6 mm at initial rapture, although typical values are usually in the range 6%. When these strands are galvanized, they are about 15% weaker in strength and slightly lower in Es depending on the amount of zinc coating used
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4.3 MULTI-STRESSING JACKS

The MK4 stressing jacks represent the fourth generation in multi-stressing equipment. They incorporate innovative developments including compact design, high precision and ease of handling. The MK4 stressing jacks are essentially centre hole rams of the double acting type with fixed cylinder and moving piston and are designed to work at a pressure of 700 bar. The jack’s internal unit can be rotated thereby facilitating easy alignment with the tendon. The jacks can be operated in either the standard horizontal position or vertically and features an automatic hydraulic "lock off' device to positively seat the wedges and, thereby, minimize load losses at transfer. All jacks are calibrated before delivery to site to establish individual force/pressure characteristics.

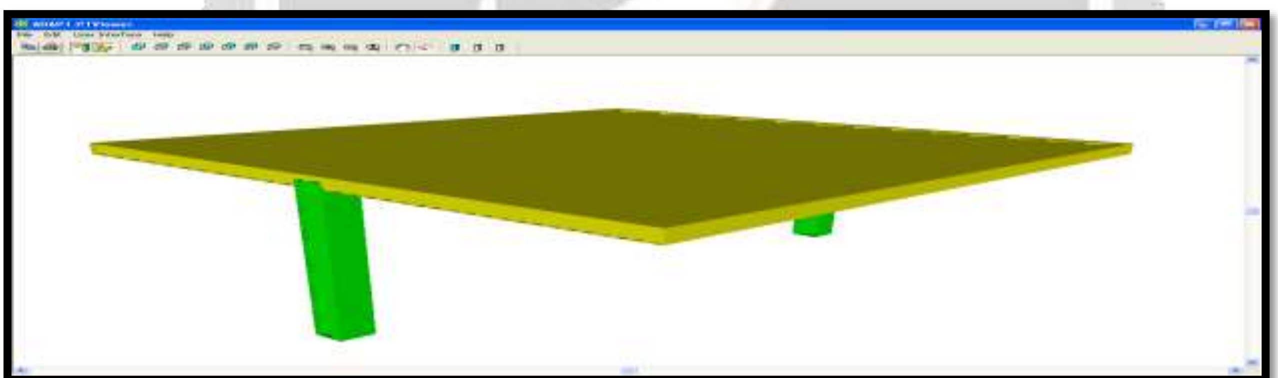
Multi-stressing jack

5.1 ANALYSIS AND DESIGN OF FLOOR SYSTEM

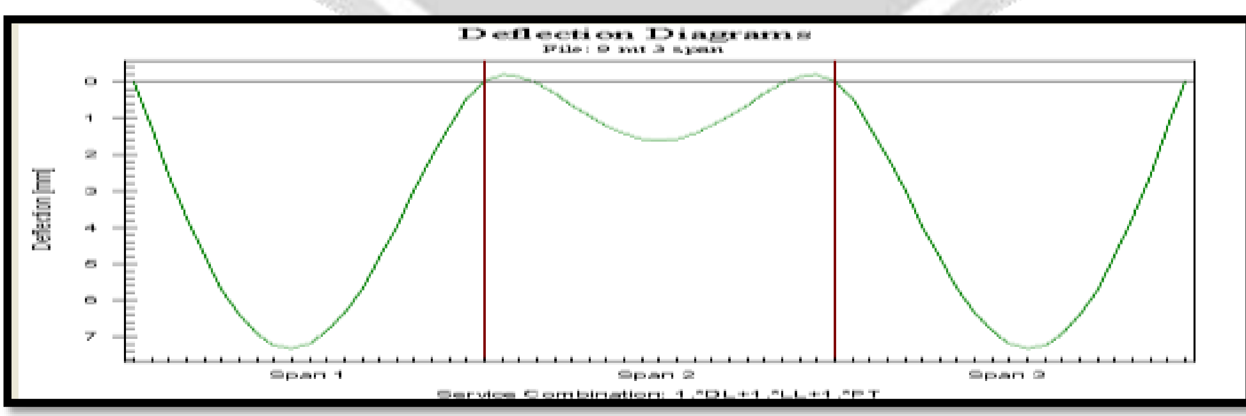
Two way systems: In two way slab construction, the bonded system compares more favorably to a bonded system similarly designed because generally shallow depth of slabs, the loss of drape due to duct size becomes more significant. This places the bonded construction at a disadvantage. Here geometry considered for the study is a square interior panel of varying length. The length consider range from 5 mt x 5 mt pannel to 9 mt x 9 mt of single and multiple span.For every square panel three type of spans are considered- one span,two span and three span. Two cases are considered where in flat slabs without and with drop pannels have been design. The equivalent frame method of analysis is employed for analysis of flat slab along with code provision of ACI-318. Based on such a floor system the two types of post-tensioning system, bonded and un-bonded, are compared.

5.2 ANALYSIS OF FLAT SLAB:

Analytical and design tool
For the comparative study ADAPT post tensioning software [ADAPT-TS, 1993] was used. ADAPT-TS is commercially available software for analysis and design of bonded and unbounded floor systems. The variable force option the actual number of strands selected is used in the analysis. Below shown figure demonstrate geometry of interior slab panel without drop cap. Loss of immediate and long-term stress along the tendon is integrated into the analysis. The loss in pre-stressing force due to friction is higher in short and heavily profiled bonded tendons due to higher friction between the strands its housing. For seating loss and elastic shortening, the losses are the same.



ADAPT PT summary report



ADAPT PT Deflection diagram

6. CONCLUSIONS

The PT reinforcement requirement for bonded system is comparatively more than the unbonded system. This can be attributed to the losses in friction. The friction coefficient for bonded tendons is more than unbonded tendons, resulting in the loss of effective stress in the tendons which ultimately results in the loss of effective pre stress force in the section. Hence the number of tendons required for bonded PT system as compared to unbonded PT system is more for same pre-stress force.

The Non PT reinforcement requirement for bonded PT system than unbonded PT system comes out to be more, comparatively. But this is attributed to the fact that for bonded system minimum amount of Non PT reinforcement as stipulated by code is 0.12% of the section. Therefore, the bars considered are through and no curtailment is done. But for unbonded PT system the Non PT reinforcement, as given by the software, is a curtailed one, wherein the bars are either top or bottom reinforcement. Hence the quantity of Non PT reinforcement for bonded PT system comes out to be more than unbonded PT system.

7. FUTURE SCOPE

This study is emphasized on two way post-tensioned unbonded floor systems. So one may extend this work as follows:

Study of the irregular building with same configurations.
Study the effect of variable grade of concrete and variable span.
Lateral load response of unbonded PT members
Influence of tendon distribution in a slab designed as a two way system
Fatigue strength comparison of bonded & unbonded PT members
Ductility of bonded & unbonded PT members
Comparative study of PT members using equivalent frame method & finite element method

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