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A Review on External Prestressing In Concrete

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Abstract - *Prestressed concrete is the type of concrete in which internal stresses are introduced to counteract the tensile stresses that will imposed due to service load conditions. The hard-drawn wires, cables or bars of high strength alloy steel are used as tendons in prestress concrete to produce stresses in concrete. In Prestressed concrete structures, steel and concrete both are in active combination because these materials are already get stressed before the applications of external loads. The Pre-stressing in concrete structures is found more effective than RCC structures. In this case as the section is entirely compressive because moments from external loads and combined internal stresses will be within specific limits in concrete cross sections, the interaction between steel and concrete is not sufficient because the tendons are unbounded. So, plane sections are no longer valid as an assumption. External prestressing is one important part of prestress concrete structures. The external prestressing has been proven technically attractive, economic. The tendons are placed outside the member, than tensioned and anchored at their ends to improve the load carrying capacity of structural members. This paper presents the work done by different researchers on different parameters which are affected by externally prestressing. We were collected the information on external prestressing from different research papers (literature) then discussions were made on structural issues and construction of External prestressing systems.*

Key Words: Prestressed concrete, External Prestressing Technique (ETP), Strength, materials.

1. INTRODUCTION

External prestressing technology is broadly used for the construction of highway, railway and urban bridges in prestressed concrete structures. In construction and designing, the theory formulas are mainly used for determining the prestressing force. Durability factors like creep, shrinkage and temperature causes many changes in prestress force. In the past 2 decades, there has been an increasing need around the world to strengthen reinforced concrete bridges due to heavier traffic loads, progressive structural aging and corrosion of steel reinforcement. One of the preferred strengthening methods is external prestressing because of its speed and the possibility of monitoring, future retensioning and replacing the tendons [5]. External prestressing was firstly used for strengthening of bridges, but nowadays it is used for built new structures and strengthening purposes. External prestressing becomes very important and popular technique for prestressing of concrete structures, as it improves the load carrying capacity of structural members. External prestressing is used in concrete, steel and timber structures also. Steel and fibre reinforced polymer (FRP) can be used as materials for external prestressing. The external pre-stressing actively inducts load by tendons to impose stress to the concrete, and the behavior remains predominantly flexural. External prestressing provides one of the most efficient solutions to increase the rating capacity of existing bridges when the infrastructures are in need of renewal. It is often useful for rehabilitation, for strengthening or stabilizing a structure by providing confining forces. The applications of external prestressing rehabilitation techniques have shown to not only increase the life expectancy of the member or system, but to increase the flexural strength considerably, resulting in reduced deflection and cracks widths. [8] External Prestressing Techniques has been widely used in construction of new bridges as well as strengthening of existing bridges. Use of external prestressing has resulted in construction of several innovative bridges with large eccentricities and light weight concrete.

1.1 SYSTEM OF PRESTRESSING

Prestressing is a technique used for known values of stresses in a structural member before the applications of full or live load. Pre-stressed concrete is reinforced concrete in which the steel reinforcement has been tensioned against the concrete. These stresses are induced by tensioning the high tensile strands, wires or rods, and then anchored to the member being Prestressed, by mechanical means. A load applied to a prestressed concrete member with bonded tendons induces equal strains in the concrete and adjacent tendon. This compatibility of strains between the concrete and tendon is a basic design assumption in calculations for stress and strain in prestressed sections. Prestressing may be essential for the functionality or the stability of a structure;

it may simplify the connections and improves the performance by increasing stiffness or limiting cracking. Prestressed concrete having following applications [7]

1. In structural Member, where the span length is very high with low rises and low structural height, the application of Reinforced Cement Concrete shall be virtually impractical. In such a case, Prestressing is used to achieve a light weight, elegant looking and much economical structure with high durability. Prestressing, therefore, is widely used for long span beams and Bridges.
2. In building structure also, prestressing method is very effectively used to achieve lighter beams and slabs; thus reducing their dead load considerably as compared to R.C.C. Structures. Application of Prestressing in building construction also facilitates a larger span between the columns, thus reduces the number of columns. This also makes the structure more versatile for interior planning.
3. Prestressing is also very widely used in the construction of Mega Structures like Containment Wall of Nuclear Reactors, LNG Storage Tanks, Cement Silos, Chimneys, Dams and Rock Anchors etc.

2. METHODS OF PRESTRESSING IN CONCRETE

Prestressing is again of two types pre-tensioning and post-tensioning and on the basis of placing of reinforcement inside or outside concrete are internal and external prestressing of concrete respectively.

2.2 .EXTERNAL PRESTRESSING

External prestressing refers to a post-tensioning method in which tendons are placed on the outside of a structural member. This technique is adopted in bridges and strengthening of buildings. It is an attractive method in strengthening operations because it adds little weight to the original structure and it allows the monitoring, re-stressing and replacement of tendons.

2.2.1.ADVANTAGES OF EXTERNAL PRESTRESSING

External prestressing is a very effective technique for both Existing and new structures. Many researchers proven that the external prestressing having following advantages:

1. Profiles of external tendons are easier to check during and after Installation hence, provide the ease of inspection.
2. Because of proper visualization, grouting is improved.
3. External tendons can be removed and replaced if any type problem found.
4. The external tendons are linked to the structure only at the deviation and anchorage zones, chances of friction losses are significantly reduced.
5. Due to independency of construction operations workmanship reduced.
6. It usually allows easy access to anchorages, adjustment and control of tendon forces
7. Members could be made thinner so that there is a reduction of dead load.

2.2.2 DISADVANTAGES OF EXTERNAL PRESTRESSING

The external prestressing having following disadvantages that should be kept in mind:-

1. External tendons are more easily accessible than internal ones and are more vulnerable to corrosion.
2. Free length should be limited because external tendons are subjected to vibrations.
3. At ultimate limit states, failure with little warning due to insufficient ductility is a major concern for externally prestressed structures.
4. Deviation and anchorage zones are vital additions to the cross section and these elements must be designed to support large longitudinal and transverse forces.
5. Values of eccentricities of external tendons are generally smaller as compared to internal tendons.

3 LITERATURE REVIEW

Arlyawardena N D and Ghali A (2002) investigated some of the parameters and design considerations for using external prestressing in prestressed concrete flexural members. They elaborates some issues such as bonded versus unbonded tendons, internal versus external tendons, the effects of friction and slippage at tendon deviators, the behavior of members with deviators at different locations, and various code issues. A bridge was designed as an example of a precast, prestressed girder implementing the proposed modification combining pretensioned and external post tensioned tendons are provided. They used a computer program for the design and analysis, then method was verified by comparing the numerical results with published experimental data. They concluded that externally post-tensioned tendons were advantageous than internally bonded tendons. It is recommended that in the design of externally post-tensioned tendons, one deviator be provided at midspan or two deviators at the third points. In external post-tensioning the tendons can be easily inspected in the event if corrosion occurs. It was propsed that web thickness of Nabska be reduced by 76mm.Thus reducing the self weight [2].

Ibrahim A M (2010) studied the parameters of Continuous Concrete Beam Prestressed with External Tendon. He was Evaluated the behavior of member at ultimate limit states. Three dimensional finite element method, ANSYS computer program (10.0) was used for a nonlinear analysis model. the external prestressing system with concrete strength, initial prestressing stress, effective depth of the external tendons, loading arrangement and tendon profile etc are the parameters which were used to compare with flexural behavior at ultimate capacity . The ultimate load capacity increased as the compressive strength of concrete increased. When the effective stress increased then the ultimate load increased for effective prestress. As in case of the tendon profile, the ultimate load increased with different Draped tendon profiles as compared to undraped profiles [5].

Ali J S *et al* (2013) introduced a method for the calculation of cable strain, which was based on the deformation compatibility of beam and friction at the deviators proposed to predict entire response of externally prestressed concrete beams up to elastic limit. They used numerical analysis for a rectangular beam with different profiles of prestressing cable.To determine the structural behavior at the deviator points in an externally pre-stressed beam, an algorithm was developed. The obtained results were verified by modeling of externally pre-stressed beam in ABAQUS. They used the finite element algorithm for deflection of the anchorage point due to applied load. Deformation compatibility of beam was used to find the strain variation in an external cable. They concluded that the predicted prestressing forces for various cable profiles are capable to bring back the deflected beam in its intial position and the stress increase in an external cable mainly depends on the

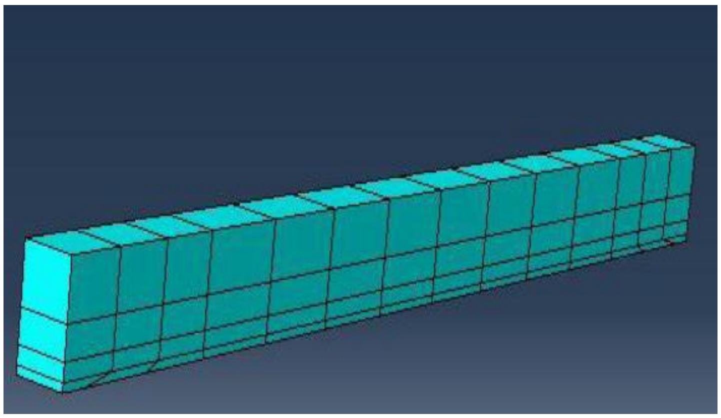
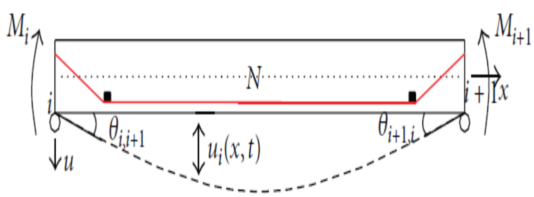


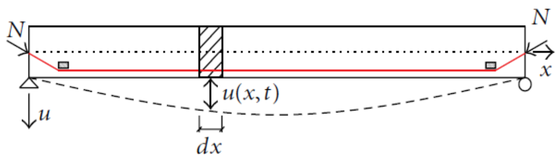
Fig.1, Finite element model of the beam with meshin in ABAQUS

overall deformation of beam. They suggested that the numerical analysis method can satisfactorily predict the behavior of externally prestressed concrete beams up to propotional limit [1].

Shi L *et al* (2013) studied Vibration Equations for various types of Externally Prestressed Concrete Beams (simply supported single span and multispan beams).They were also discussed about the Relations between Prestress Variation and Vibration Displacement.They proposed the method to identify the prestress force in externally prestressed concrete beams based on the frequency equation and the measured frequencies. They discussed the results using single-span and two-span externally prestressed concrete beam tests.



Analysis model of the *i*th span of the beam.



Analysis model of vibration system.

Firstly they used the single-span beam as an example; the influencing regularities of the error of the measured frequencies on the identified results were analyzed by numeric calculation. The multispan externally prestressed concrete beam was taken as the multiple single-span beams which must meet the bending moment and rotation angle boundary conditions. They were built the functional relationship between prestress variation and vibration displacement and they presented the formula of equivalent eccentricity H. In the long term bridge health monitoring, the measured frequencies can be obtained by practical signal processing. According to their identifications the prestress force of the bridge can be identified based on the identified method [9].

Suryawanshi Y R and Bhise M (2013) concluded that the externally prestressed precast bridges were more advantages but on the other hand Externally prestressed members have lower flexural strength as compared to that of bridges with internally bonded tendons because of smaller tendon eccentricity, which is limited by the bounds of concrete section of girder.FRP was used to increase flexure strength and shear strength of members. The innovated technologies can be used which are mainly consist of new structural systems, external prestressing with highly eccentric tendons and extradosed prestressing are excellent examples of a wider use of external prestressing technology to achieve a precast bridge with improved structural performance as well as cost-effective structural systems [10].

HakimKhalil A *et al* (2015) studied the behavior of reinforced concrete box beam under pure torsion which was strengthened experimentally with External Prestressing Technique (EPT) using horizontal and vertical direction. They were discussed about the Test specimens, strengthening schemes, Material properties, Test setup and instrumentations. For The experimental work they were made ten identical reinforced concrete single cell square box beams having cross section of 500mm x 500mm.Concrete with compressive strength of 35 N/mm^2 was used for casting of all specimens. A hydraulic actuator of 450 kN capacity was used to applied load. A load cell was attached to the loading actuator to record the applied load at 3 seconds. The load was applied through a diagonally placed steel spreader beam at the end of the two steel arms. These arms were fixed at the end parts of each tested beam. Horizontal movements of a vertical side of the beam were measured using LVDT. Electrical strain gauges were used to Strains of the EPT bars and internal reinforcements (stirrups and longitudinal bars). External Prestressing Technique (EPT) was used to strengthen the beams under pure torsion. The strengthening using EPT enhance the torsional capacity by 58% without affecting the final beam rotation. The strengthening using vertical EPT distributed along the beam section was found more effective as compared to other techniques. Ductility behavior of strengthening was improved using longitudinal EPT increase longitudinal bar strain by ratios ranged between 60-80%.They suggested that experimental results and modified equations were agreed with Egyptian code and ACI 318m-05.[3].

Hussein M *et al* (2015) they conducted an experimental program to evaluate the structural performance of an innovated hybrid strengthening technique for low strength RC cantilever slabs. They were casted nine RC slabs having dimensions (120 x 500 x 2650) mm and that were divided into three groups I, II, and III. The slabs of group I were selected for the purpose of evaluation of the efficiency of external prestressing in strengthening both low and ordinary strength reinforced concrete cantilever slabs. Group II were designed to investigate the efficiency of strengthening low strength reinforced concrete cantilever slabs using an innovated hybrid strengthening technique. The strengthening technique was designed to reach about 60% target gain. The group III of slabs was chosen to evaluate the efficiency of using the proposed strengthening technique to repair cracked slabs. Group III consisted of three reinforced concrete cantilever slabs that were preloaded by 35%, 65% and 85% of the ultimate load of control slab, prior to the application of the proposed strengthening technique. The technique was composed of external prestressed stainless steel bars on the tensile surface and ECC strengthening layer overlay on the compressive surface and efficiency of the proposed technique was also studied.Based on results they concluded that the slab failed by concrete crushing in the compression zone when tested externally prestressed strengthened. they proposed hybrid strengthening technique has a great potential application towards flexural strengthening of low strength concrete cantilever slabs, in terms of increasing the slab ultimate load capacity and also sits stiffness in case of the suggested hybrid strengthening technique,they proposed equation for prediction of the ultimate stress in the pre-stressing steel having good agreement with the experimental results[4].

Mathur *et al* (2015) concluded that the pre- stress concrete structure, found to be More effective then the Reinforced concrete structure .They studied the anchoring devices in pre and post Tensioned concrete structural elements.Prestressed structures are found more strength & durability as compare to RCC structure. Rich concrete grade was used with high strength alloy steel hence, density and load caring capacity may enlarge. Other benefits of pre-stressing property of light weight along with high strength may be adopted by including FRP to reduce cracks as resistance to cracks is obtained, also gives more space, impact, fatigue, vibration etc. In prestressing concrete about 10 to 20 percent losses may be due to creep and shrinkage in concrete. They suggested that the greater numbers of expensive equipmenst are required in using this process thus prestressed members are found effective then unstressed RCC structures. At the end they recommend for adopting pre-stressing in all possible concrete structures instead of RCC works [6].

Tianlai Yu *et al* (2016) investigated Bending in Concrete Experimentally and Theoretically from the

Beams Strengthened using External Prestressing with carbon fibre-reinforced plastic (CFRP)Tendons. They were analysed failure mode, strain features,loading ductility of the strengthened concrete beams.They determined a bending bearing capacity formula for concrete beams strengthened with external prestressing CFRP tendons.In static load testing of the simply supported beams, they were studied the flexural properties of the strengthened concrete beam. External Prestressing CFRP tendons can improve the stiffness and flexural properties of concrete beams. The ductility decreases with the concrete strength and increases in the internal non-prestressing steel reinforcement ratio. The turning angle of the CFRP tendons has little influence on the ductility. The equations of bending bearing capacity of the external prestressing strengthened beams were deduced in the plastic hinge region. Without any secondary effect, the equations for the bending bearing capacity of beams strengthened by external prestressing CFRP tendons, as introduced in this study, can provide good reference values. For small beam spans, it is feasible to ignore the secondary effect; the proposed formulas can satisfy the required levels of precision in actual engineering projects [11].

4 CONCLUSIONS

From the review of literature it is concluded that the external prestressing improves the quality of the structures and makes the design simpler. Use external prestressing has resulted in construction of several innovative bridges with large eccentricities and light weight concrete. The External prestressing technique widely used for the construction of new bridges and for the strengthening of existing bridges. External prestressing improves the load carrying capacity of the structure, as the tendons are placed outside member. It is one of the simple methods for anchoring the beams at cheaper rate. It makes the structures stable. It is very important to carry the studies for different parameters of External Prestressing Technique. Strengthening using EPT improve ductility behavior of structures.

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