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REVIEW PAPER ON PRE-STRESSED CONCRETE

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Abstract— The pre-stressing concrete Used for preparing the section is a bit different from the reinforced cement concrete (RCC.) in concrete technology. The system used for pre-stressing is defined by two methods that are, pre-tensioning & post-tensioning methods. The pre-stressing by pre & post tensioning device mechanism, introduced for Anchoring the system in concrete structure element is used for structures. In modern type of Pre-stressing technique electricity having low value of voltage and high current is adopted in anchoring for a concrete member & A Coating of sulphur is applied on the steel bars working, as duct material before the casting of concrete member. When the electricity is supplied in the structure, the sulphur gets melted due to generation of heat in the steel structure and allowed them for pre-stressing. No provision is required for any duct. The steel alloy structure having high strength could be anchored by tightening the nuts at both ends. The Pre-stressing in concrete structure is found more effective then reinforced cement concrete (RCC) technology. So in this paper we will discuss about advanced technique of post tensioning by replacing duct with sulphur coating on tendon bars.

Keywords— Post-tensioning, Sulphur coating, Tendon bars, Anchoring.

I. INTRODUCTION

Pre-stressing is defined as a way to overcome concrete's limitations in tension. Usually, the concrete experiences compression on top flange and tension at the bottom flange. In pre-stressing the tendons are stretched along the axis and cement is poured, later when the tendons are released the compression is generated at the bottom which tries to overcome the compression due to loading at the top part of the beam. The upward forces along the length of the beam restrain the service loads applied to the member. The rare characteristics of pre-stressed concrete allow pre-established, engineering stresses to be placed in members to counteract stresses that occur when the unit is subjected to service loads.

Pre-stressing removes a number of design limitations conventional concrete faces on span and load and also permits the building of roofs, floors, bridges, and walls with longer unsupported spans. This helps architects and engineers to design and build shallower and lighter concrete structures without compromising with its strength. This also helps in the construction of longer spans, hence it reduces the requirement of intermediate columns and makes the construction of bridges more economical.

Pre-stressed concrete has experienced the greatest growth in the field of commercial buildings. For structures such as shopping centres, pre-stressed concrete is an ultimate choice because it provides the necessary span length for flexibility and alteration of the internal structure. Pre-stressed concrete also used in the construction of school auditoriums, gymnasiums, and cafeterias because of its ideal properties and its capability to provide long open spaces. Pre-stressed concrete is widely used in building parking garages.

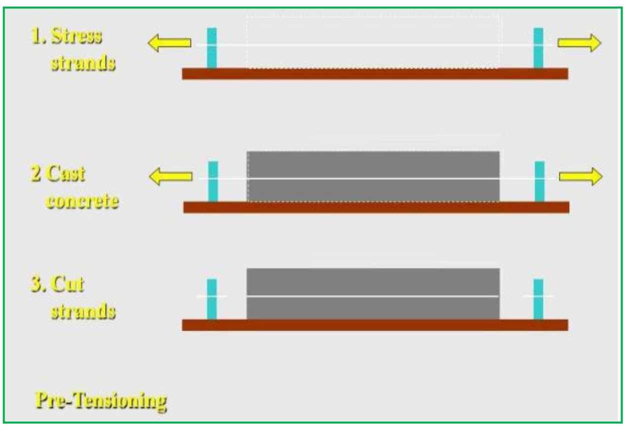


Fig. 1- Post-tensioning Pre-stress diagram

A). Types of Pre-Stressed Concrete Structures

Pre-stressed concrete structures are classified as;

i) Pre-tensioning: The steel Reinforcement is tensioned before placing of concrete.

ii) Post-tensioning: The tensioning of the tendons is done in duct, after the settlement of concrete.

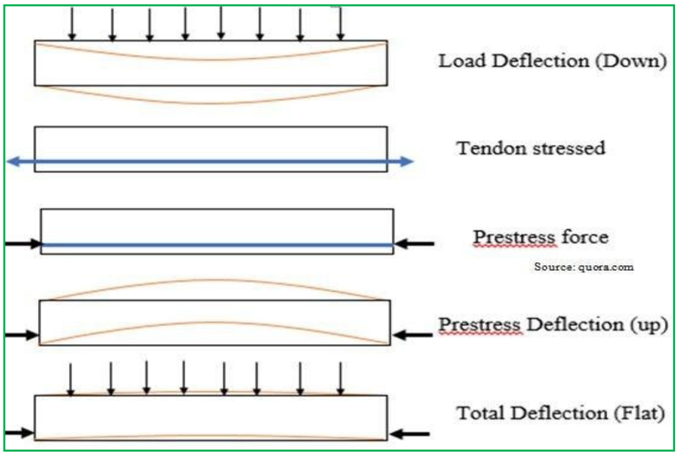


Fig. 2 Pre-stress concrete diagram

B). Difference between Reinforced Concrete and Pre-Stressed Concrete

S. No	Reinforced Cement Concrete(RCC)	Pre-Stress Concrete
1	Steel is able resist tension but concrete cannot.	Steel inducing pre-stress force. (If this can be by other means then steel is of no use.)
3	Less effective for higher span bridges.	More effective for higher span bridges
4	Stresses in steel must limited as, it controls cracking.	Stresses in steel must be unlimited to resist cracks.
5	Required IS Code is IS:456-2000	Required Code is IS: 1343-2012
6	In RCC reinforcement is not stressed before casting	In pre-tensioning reinforcement is stressed before casting & in post-tensioning reinforcement is placed in duct after casting also stressed.
7	In RCC stress in steel is variable with lever arm.	In Pre-stress concrete the stresses in steel is constant.
8	In RCC deflections are more due to eccentric force induced couple.	In Pre-stress concrete members, deflections are less.
9	RCC is less durable, as it is less dense.	Pre-stress concrete is more durable.
10	RCC has fatigue resistance less.	Pre-stress concrete fatigue resistance is more as compare to RCC.
11	RCC has large section for given load.	Pre-stress concrete has smaller section for a given load.
13	RCC Requires less strength concrete for casting for given load.	Pre-stress concrete Requires high strength concrete for casting for given load.
14	RCC gives less space for the required section	Pre-stress concrete gives more space for the required section.

C). Advantages of Pre-Stressed Concrete Over RCC

- We can utilize the concrete sections more effectively
- Weight of the member is less hence dead load is decreased.
- The cost of supporting structure will be reduced due to lesser weight of super structure, so it is effective for higher span bridges
- It Improves the shear resistance of concrete as compared to RCC
- The sections in pre-stressed concrete are smaller as compared to reinforced concrete sections hence they can be used for longer spans.
- Greater resistance towards impact and vibration.
- Pre-stressed concrete is preferred for water retaining structures like Dams.
- Deflections are less in pre-stressed structures and hence stiffer.

II. REVIEW OF LITERATURE

The development and design of anchoring mechanism is a function of pre-stressing perfection the compression and takes part in resisting moments. There is no corrosion and rusting of Steel and sections are comparatively much smaller. Self weight gets reduced as the anchors do not add to self weight of structural elements, this reduces the cost of foundations which have to bear less loads.

As per the **IS 1343 (1980)** anchoring devices may add to a smaller section of disadvantages along with high strength steel and concrete as well as skilled labor, yet there is an overall reduction in cost in using pre-stressed concrete as we know that decrease in member sections results in reduction of Design loads, Economical structure and foundations. The most common items in RCC and pre-stressing are materials –steel and concrete, but anchors require high strength tendons to produce compressive stresses in all sections.
FRP reinforcement can have some advantages over steel as they are lighter in weight, higher in tensile strength, more resistant to corrosion and electromagnetically transparent. Several methods for manufacturing are available for fabrication of FRP reinforcement for concrete. For grid and rod type reinforcement, pultrusion and braiding are the methods of manufacturing which are most commonly used because of greater economy, high quality and efficient fiber orientation. Round FRP or flat rods come in a variety of surface shapes, for E.g. Indented, Dimpled, or Coated with sand to provide better bonding with the concrete.

Taerwe ET. al. (1992) has claimed that concrete is conventionally reinforced with tendons and steel bars. It is known that the deterioration of concrete structures mostly occurs due to the effect of corrosion of the reinforcing steel. This results from exposure to environments which have high moisture and chlorides. Chloride from the sources like sea water or de-icing salt is used in the time of winter on bridges and parking garages.
Coating the steel reinforcement with a layer of epoxy is the most common method which is used for controlling the corrosion some of recent failures have left doubts about the reliability of epoxy coating protection. Galvanization of steel reinforcement is the another form of protective coating, is suspected of UN satisfactory protection in chloride containing concrete, of impairing steel to bonding of concrete and causing hydrogen embrittlement of pre-stressing tendons.

Nanny et al. (1996) claimed that ultimate load capacity is generally directed by the anchor rather than the tendon itself, claiming that anchor efficiency can be enhanced. It is explained that the three types of anchor systems (That is wedge, resin potted and spike) provides advantages and disadvantages. The degree of conspiracy in terms of installation procedure differs for wedge type anchor, dry lubrication and sand coating on the two alternate faces of the wedges are quite helpful. Protection of the tendon can be established with a sleeve. High temperatures do not affect the performance of the system tested. Wedge anchor systems are mostly suitable for pre-tensioning application.
If the Spike anchors are used with dry fiber ropes may work comparatively well. This system requires the longest time for setup causing from the combination of removal of the plastic sheath, combing and spreading of each of the fibers and regular placement of the spike with a uniform arrangement of fibers all around it.
Grit should be present on the wedge surface for wedge anchors to ensure correct gripping of the tendons. When carbon stress tendons is compared with Arapree tendons both of which uses plastic wedges, the carbon stress system with applied grit do not show the slippage of the untreated Arapree wedges.
For resin or Grout Potted anchors, failure may be due to pull-out of the tendon from the resin/Grout anchor without having rapture of the tendon however parabolic system may show shifting and erecting of the resin plugs. The plotted anchors are the easiest to setup for testing when pre-installed. The practical limitation includes pre-cutting the tendons to length and curing time for the resin or Grout.

Lin & Ned (2001) claimed that in pre- tensioning, anchoring mechanism is not essential working part of structural element. However at the stage of construction the manufacturing of pre-tensioning members, tendons are stretched by jacks and anchored at the ends. After settlement and hardening of concrete, the tendons are separated from anchors and imposing pre-stressing in the beam or structural elements. The system comprises of two bulk heads anchored against the ends of a stressing bed. The tendons are stretched between the two bulk heads. A pre-stressing bed is mainly used for casting usual units and possibly shorter units. It provides support to vertical reactions due to which pre-stressing of bent cables can be done. Hoyer system shall be studied. The anchoring devices for bearing pre-tensioning strands to the bulkheads left on the wedge and friction principle. One common device comprises of a split cone wedge, which is made from a tapered conical pin. The tapered conical pin existing is drilled axially and tapped, and then cut in half longitudinally to form pair of wedges. There is a conical hole in the anchoring block in which tapered conical pin holes are strands. These grips are used for single wires and for twisted wire strands too. Alternately the pin did not get drilled, but it is cut in half longitudinally and the surface which is flat got machined and serrated. The third option is to quickly release grips which are more complex and costly, are used commonly when wires are to be held in tension only for short periods. In other method, under study is to add mechanical end anchorages to the pre-tensioned wires. Dorland anchorage, having clips, can be held or gripped to the tendons under high pressure and the edges of the clips can be welded together at various points. In such mechanical anchorages, tendons of larger diameter can be permitted. In post-tensioning systems, mechanical pre-stressing, electrical pre-stressing by application of heat energy and chemically post-stressing by using expanding cement shall be the part of research.

III. METHODOLOGY

Some systems shall be studied, analyzed and verified in strength and efficiency so that minimum pre-stress losses occur. The first anchoring system FREYSSINET had shown useful advantages and yet requires some improvement and / or additions and deletions. Other systems under analysis shall be Magnel Blaton, Gifford Udall (with anchoring-plate of two types, anchorage and tube anchorage), PSC Mono wire system & Lee McCall systems.
Electric pre-stressing can be experimented in which bars will be stretched by means of heating by using electrical energy. It shall be assumed as a transition from RCC pre-stressing. Chemically pre-stressing or self stressing shall be analyzed in which self stressing cement shall be used that shows increase in length chemically after setting and during hardening.
Finally perception of theoretical nature of pre-stressing anchoring technology which is a remarkable part can be studied on rational basis and critical study of the existing devices modification there of as well as seeking towards development of better and efficient mechanisms will be determined possibility. Role of welding shall be attempted and underlined practically for strong grips.

Electrical pre-stressing:- This is modern type of pre-stressing. In this method we use electric energy for working of Anchoring device system. This is introduced by Biller & Carlson. For post-tensioning we use sulphur coating to cause duct material while casting with concrete. When electricity is passed through the tendons it starts heating up and sulphur coating begins to melt. The tendons end as threaded & noted. By tightening those Anchoring of the section is obtained.

A). Devices Used for Tensioning

The principal upon which devices works are mentioned below-
- Mechanical devices
- Hydraulic devices
- Electrical devices
- Chemical device

B). Methods Used for Pre-Stressing

- Freyssinet method.
- Gifford-Udall method.
- Magnel Blaton method.
- Lee-McCall method.

C). Basic Assumptions to be Considered

- Concrete is a homogenous material.
- In the working stress condition concrete and steel behave elastically, under suspended load condition without having any small amount of creep.
- The plane section is assumed to be remained plane before and after bending.

D). Type of Losses in Pre-Stress

(1). Pre-tensioning
- Elastic deformation, Shrinkage and Creep of concrete.
- Relaxation of stress in steel.

(2). Post-tensioning
- No loss due to elastic deformation takes place in concrete, if the wires are tensioned simultaneously.
- Relaxation of stress in steel.
- Shrinkage & Creep of concrete
- Anchorage slips in steel.
- Friction between concrete and steel

IV. PRACTICAL APPROACH

We consider the Fe-410 steel bar – 8mm ф.
The property lies between cast iron and wrought iron. It have the properties of getting hardened and tempered, also has 0.1%-1.1% of carbon & granular structure.
Its specific Gravity.-7.85 & melting point between 1300^0 to 1400^0 C.
The ultimate compressive strength is 180-350 MPa. And ultimate tensile strength is 310-700 MPa.
It is found to be having the properties like toughness, malleability and ductility in nature.

The thickness of coating of sulphur material forming a duct, on steel bar shall be considering - 0.5 mm.
A mould is used to cast as a beam by concrete on coated steel bar. Mould is shown in figure below- dimensions 420x150x150 mm. cu.

M15 Grade concrete is used having ratio1:2:4 is prepared of required workability then it is poured to fill the mould to cast required beam. After 24 hours it is taken out from mould and curing is done for 7 days the casted beam required is two for our experiment of same dimensions. The prepared beam as shown in figure below-
Now the base plate is placed on both ends of beam. Electricity is passed so that coating starts melting & at bars nuts are tightened at both sides so that required anchoring object is solved.

Fig. 3 Beam with sulphur coated steel bar.

Fig. 4 Transverse test on RCC beam.

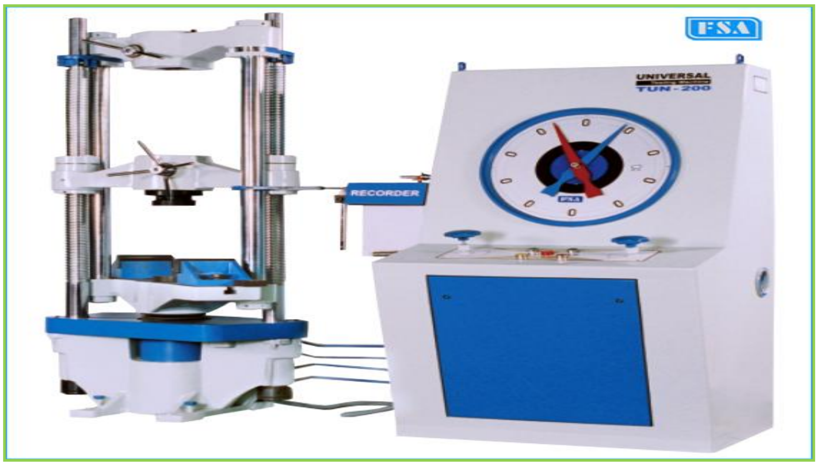


Fig.5 Universal Testing Machine with Plotter & Hydraulic Load Dial

V. RESULTS

The Peak load of Pre-stress beam = 32.50 KN.
The Peak load of RCC beam = 31.45 KN.

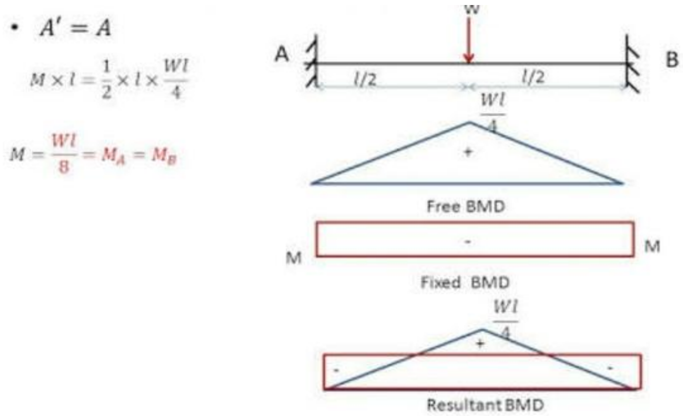
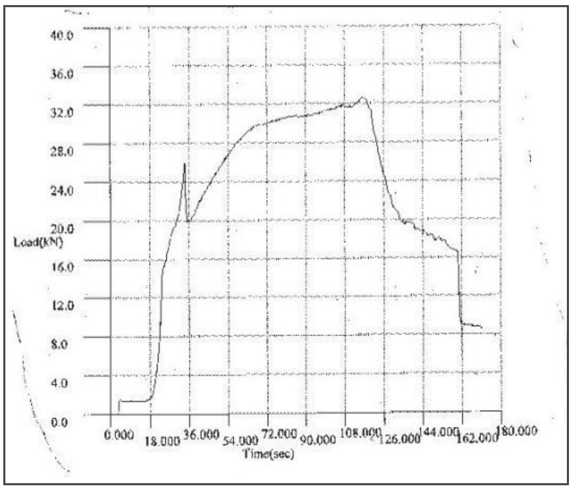


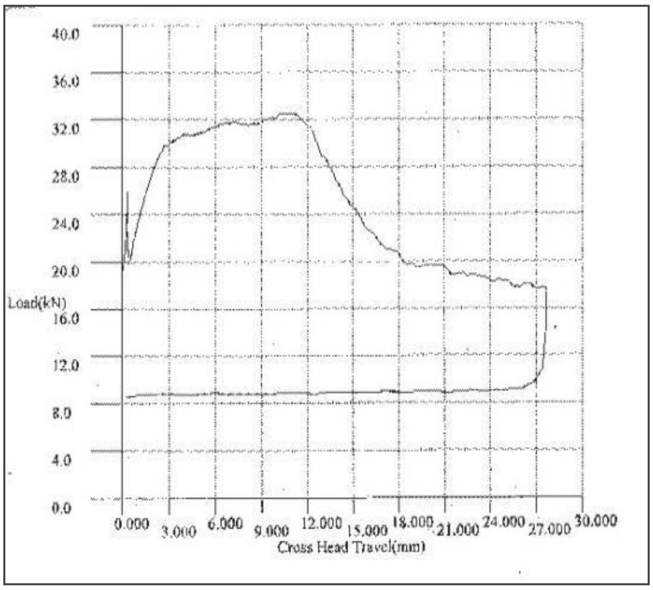
Fig.6 Beam with base plate and nut is shown in figure

Heat energy with temp 170^0 C is generated which causes sulphur to be melted and bars to expand at this time the nuts should be tightened by using mechanical tools. Some types losses will be occur in beam after anchoring has been done hence it needs 24 hours for further test. Now considering beam as simply supported beam and using UTM (Universal Testing Machine) as for determination of bending moment.
This process is used for both the conditions that are flat and transverse so that graphs may be plotted for both the conditions. Under UTM the distance between supports is constant. Width, Thickness and Crosshead Travel is firstly determined then Peak Load, Cross Head Travel at Peak and Transverse strength is calculated. Plotter attached with UTM machine plot complete graph from beginning to specimen break point.

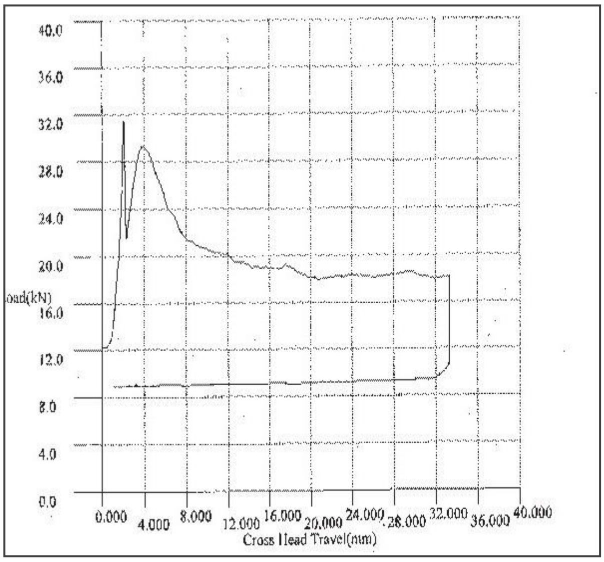
(1). Transverse Test Report
Machine Model: TUE-C-1000.
Machine Serial No. : 2009/50
File name: A4, CIVIL, UTM.
Material Type: RCC Beam 1 (Pre-stress)
Distance between
Supports: 420.00 mm
Width: 150.00 mm
Thickness: 250.00 mm
Max. Cross head
Travel: 250.00 mm
Peak Load: 32.50 KN.
Cross head Travel
At Peak: 11.20 mm
Transverse strength: 06.07 N/mm^2



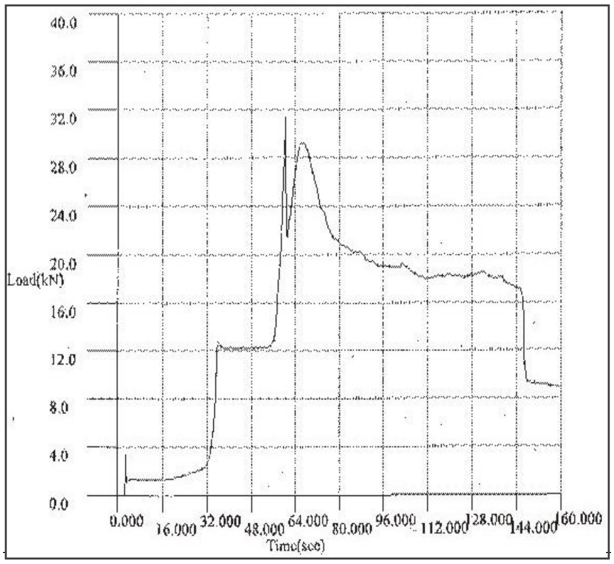
(2). Transverse Test Report
Machine Model: TUE-C-1000.
Machine Serial No. : 2009/50
File name: A4, CIVIL, UTM.
Material Type: RCC Beam 2 (Pre-stress)
Distance between
Support: 420.00 mm
Width: 150.00 mm
Thickness: 250.00 mm
Max. Cross head
Travel: 250.00 mm
Peak Load: 32.50 KN.
Cross head Travel
At Peak: 11.20 mm
Transverse strength: 06.07 N/mm^2



(3). Transverse Test Report
Machine Model: TUE-C-1000.
Machine Serial No. : 2009/50
File name: A4, CIVIL, UTM.
Material Type: RCC Beam 3
Distance between
Support: 420.00 mm
Width: 150.00 mm
Thickness: 250.00 mm
Max. Cross head
Travel: 250.00 mm
Peak Load: 31.45 KN.
Cross head Travel
At Peak: 2.20 mm
Transverse strength: 05.87 N/mm$^{2.}$



(4). Transverse Test Report
Machine Model: TUE-C-1000.
Machine Serial No. : 2009/50
File name: A4, CIVIL, UTM.
Material Type: RCC Beam 4
Distance between
Support: 420.00 mm
Width: 150.00 mm
Thickness: 250.00 mm
Max. Cross head
Travel: 250.00 mm
Peak Load: 31.45 KN.
Cross head Travel
At Peak: 2.20 mm
Transverse strength: 05.87 N/mm^2



VI. SOME SUGGESTIONS MADE BY

- **C.R. Steiner of USA (1908)** Suggested that the tightening of reinforcement rod after some shrinkage and creep of concrete had taken place.
- **According to the Committee of ACI** "Pre-stressed concrete is the one in which the internal stresses are introduced of such magnitude and distribution that the stresses resulting from giving external loadings are counteracted to a desired degree. P. Jackson of USA (1886) obtained patents for pre-tensioning steel tie rods in artificial stones and concrete arch to serve as floor slabs.

- **K. Doring of Germany (1888)** recommended that pre-tensioning of wires in reinforced concrete floor structures.
- **R. E. DILL of Nebraska (1925)** used high strength steel bars.

VII. CONCLUSION & RECOMMENDATIONS

We came to conclusion to promote the use of sulphur coating on tendon bars by replacing tendon duct in actual practice by using post tensioning by electrical pre-stressing for all kind of structural work today. As it is found more effective and economical, may be at long run but a small section could resist more loads in a structure. It has been found that, post tensioning by suphur coating on tendon bars have more strength & durability as compare to RCC structure. Rich concrete grade is used with high strength steel alloy, hence, density and load bearing capacity may enlarge. Other advantages includes property of light weight along with high strength may be taken over by including FRP to reduce cracks as resistance to cracks is established, it also gives more space, impact, fatigue, vibration etc. The cracks in RCC may be removed having large section but, load bearing capacity is improved with less sized section in pre-stressing. As it can be made with high strength and light weight sections by using pre-stressing in FRP (Fiber Reinforced Polymers) the crack is also gets reduced.

In pre-stressing concrete about 10 to 20 percent losses may arises due to, creep and shrinkage in concrete. As we know that a large quantity of expensive equipment are required when using this process, but still it is found more effective then unstressed RCC structures. It is sincere suggestion for adopting the use of sulphur coating on tendon bars by replacing tendon duct in pre-stressing concrete in all possible concrete structures instead of using reinforced cement concrete (RCC) works.

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