

A RELIABLE NUMERICAL APPROACH OF PRECAST PRESTRESSED PLANK

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Abstract - There are numerous methods available to improve the structural performance & structural enhancement of a Reinforced Elements, but compared to those methods the prestressing method plays a vital role in the construction technology. This article depicts about prestressing rectangular composite plank which was modeled using ANSYS software 17.2 with the theoretical data as per IS 1343-1980 standards. The three dimensional analysis were done for the composite plank element involves a dimension of (3000 mm x 1000 mm x 90mm) and the precast concrete member hoisting the five numbers of prestressing strands of 12.5 mm diameter with high tensile grade of 1770 MPa. The finite element modeling was done in eccentric mode with prestressing behavior, the models were analyzed based on the static structural material behavior for the plank element and also based on the mesh sensitivity. A comparative analysis of deflection behavior was done for both theoretical and numerical findings. This work deals with the simulation behavior is nearly close to the theoretical findings with a valid material standards of the model with a comparable accuracy.

Keywords: Prestressed beam, strands, Eccentrically Prestressing, ANSYS 17.2.

I. INTRODUCTION

Precast prestressed concrete is the most advanced form of the construction begins in the structural engineering and this type of construction is well reputable, unique in the developing nations. At present the prestressed concrete are used in underground construction sectors like tunnel and large spanning structures like bridge construction and for also small spanning construction like beams, slabs and many structural framing elements. The development of prestressed concrete can be studied in the perspective of the conventional building materials. Earlier, the stones and the bricks were extensively used and those materials are strong in compression and weak in tension. Where as in case of tension, they were used bamboo material and wire coir in the bridges and girder construction alternatively the iron and steel bars are used for resist the tension and the members are tends to buckle under compression. In reinforced concrete the concrete and the steel are combined such that the concrete resists the compression and the steel resists the tension and it is known as passive combination of the two materials. In case of the prestressed concrete the high strength concrete and the high strength steel were combined and the full section is effective resisting in compression, tension known as active combination^[2].

II. COMPOSITE PLANK

Slabs can be composite for the benefits of reduction in forms work, cost and time of construction and quality control. A precast plank can be prestressed and placed in the final location and the topping slab is overlaid on the precast plank. The grades of the concrete in the two portions can be different. The following Fig. 1 shows the cross section details of the composite one way plank.

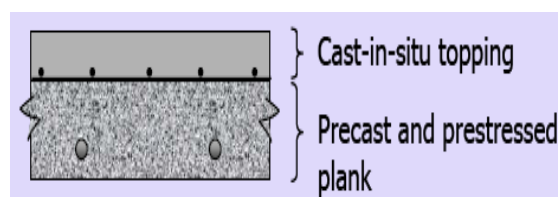


Fig.1 Cross section of the Composite plank

III. COMPOSITE ACTION

The full composite action of the precast slab can be achieved by concrete topping; good bond strength between the two portions is a key factor to have a monolithic system. The bond strength is achieved by adhesion between the overlay and substrate. In practice, some type of reinforcement crossing the interface is used to increase adhesion between the both surfaces. It is mandatory that the reinforcement be sufficiently anchored in both substrate concrete and the overlay.

IV. BONDING BEHAVIOR IN PRECAST & CAST-IN-SITU

The cement based bonded overlay technique is frequently used to repair a concrete slab surface or improve the mechanical capacity of the structure by increasing its thickness^[10]. This method consists of adding a thin layer of a cast-in-situ topping to the existing slab to enhance its structural performance.

V. OBJECTIVE

In this current scenario, the analysis and design of pretensioned concrete members betoken a specific insignificant absence and the practical guidelines for analytical simulation of precast prestressed concrete members. There is promising need and requirement in developing a validated methodological approach to analytically simulate the behavior of the prestressed pretensioning concrete structures during the various stage of construction and their service life. The main objective of this research is, to suggest the modeling approaches that can satisfy the requirement of the pretensioning process and to predict the deflection behavior of the beam in both theoretical findings and in the simulation behavior for the composite plank element.

VI. SUMMARY IN PHENOMENA OF PRETENSIONING

Pretensioning is a method of prestressing in which the high tensile steel is stretched between two bulkheads in a prestressing bed or within a self- straining frame called stress bench. The moulds are placed in the position between the bulkheads or within the self- straining frame. The high tensile steel is threaded through the moulds at the required levels with or without eccentricity to the elements to be cast. The steel is then stretched and anchored on the bulkheads or on the booms of the self- straining frames^[5] and the concrete is poured & it is allowed to set. When the concrete is well set and has attained required strength, the high tensile steel is released from the bulkheads or the self-straining frames. The steel, not being able to get back to its position due to bond between steel and the concrete during setting and it transfers the force on concrete through bonding. No additional anchorages are provided and the force is transferred by bond between the steel and the concrete. At the transmission length, the force is not felt throughout the cross section, and it is felt fully in cross section only after the transmission length. Transfer length, which is the distance required for the strands to transfer their full effective stress (F_{pe}) to the concrete, depends typically on multiple parameters such as compressive strength of the concrete, surface condition of the strands prior to the pretensioning, number and spacing of strands, level of confinement, and the number of wires per strands^[11].

VII. ASSUMPTIONS MADE FOR THIS ANALYTICAL STUDY

- a. Plane sections remains to be plane after bending
- b. Perfect bonding is exist between the bonded steel and the surrounding concrete
- c. The stress, strain relation of the concrete in tension is assumed as linearly cracking up to zero stress^[3]

VIII. FE MODELLING OF THE PRECAST CONCRETE STRUCTURES

The analytical model of the prestressing beam element is presented in this research are created using a commercial finite element package, ANSYS17.2 and their functions and features are also utilized in this software only.

Two different methods have been used so far for the analysis of reinforced concrete slabs by the FE method, the modified stiffness approach and the layer approach. The former is based on an average moment-curvature relationship which reflects the various stages of material behavior, while the latter subdivides the finite element into imaginary concrete and steel layers with idealized stress-strain relations for concrete and reinforcing steel.

A layered finite element procedure for slab elements divided into layers to account for the progressive cracking through the slab thickness^[11]. They used layered rectangular slab elements which could be cracked progressively layer by layer, and assumed that cracks propagate only parallel and perpendicular to orthogonal reinforcement^[12].

The smeared crack model and examined the effect of the slope of the descending branch of the concrete stress-strain relation on the behavior of reinforced concrete (RC) slabs^[13]. They were among the first to point out that analytical results of the response of reinforced concrete structures are greatly influenced by the size of the finite element mesh and by the amount of tension stiffening of concrete. Today the smeared crack approach of modeling the cracking behavior of concrete is almost exclusively used by investigators in the nonlinear analysis of RC structures. Since its implementation in a finite element analysis program is simpler than that of the discrete crack model.

IX. FE MODELLING OF THE STEEL REINFORCEMENT

In discrete model the reinforcement model are used as bar or beam element that are connected to the concrete mesh nodes. Therefore the concrete and the reinforcement mesh share the same nodes and concrete occupied the same regions occupied by the reinforcement. A downside to this model is that the concrete mesh is restricted by the location of the reinforcement and the volume of the steel reinforcement is not deducted from the concrete volume.

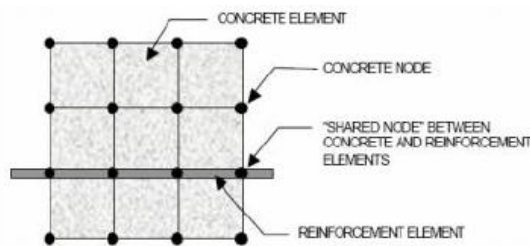


Fig. 2 Discrete Model

The embedded model overcomes the concrete mesh restrictions because the stiffness of the reinforcing steel is evaluated separately from the concrete elements. The model is developed in a way that keeps reinforcing steel displacement compatible with surrounding concrete elements. When reinforcement is complex, the model is very advantageous. However this model increases the number of nodes and degrees of freedom in the model, therefore increasing the runtime and the computational cost.

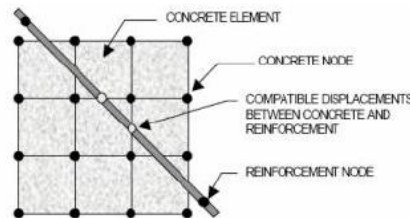


Fig. 3 Embedded Model

The smeared model assumes that the reinforcement is uniformly spread throughout the concrete element in a defined region of the FE mesh. This approach is used for large scale models where the reinforcement doesn't significantly contribute to the overall response of the structure^[14].

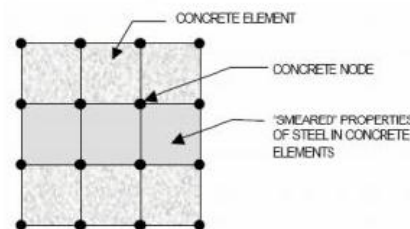


Fig. 4 Smeared Model

TABLE.1
 MATERIAL PROPERTIES FOR BOTH THEORETICAL AND NUMERICAL FORMULATION

Concrete (M40)	Grade	M40
	Characteristic Strength of Concrete (f_{ck})	40 N/mm ²
	Elastic Modulus of the Concrete (E_c)	31622.78 N/mm ²
	Unit weight of Concrete (γ_c)	24 kN/m ³
Prestressing Strands	Poisson ratio (μ)	0.15
	Diameter of the strand (ϕ)	12.5 mm
	Elastic modulus (E_s)	2×10^5 N/mm ²
	Ultimate Characteristic Strength in wire (f_{pu})	1770 N/mm ²
Reinforced Steel	Poisson ratio (μ)	0.3
	For Longitudinal Bars (ϕ)	10 mm
	For transverse bar (ϕ)	8 mm
	Yield Strength of Steel (f_y)	415 N/mm ²
Concrete (M20)	Poisson Ratio (μ)	0.3
	Grade	M20
	Characteristic Strength of Concrete (f_{ck})	20 N/mm ²
	Elastic Modulus of the Concrete (E_c)	22361 N/mm ²
	Unit weight of Concrete (γ_c)	24 kN/m ³
	Poisson ratio (μ)	0.15

In this design consideration, five numbers of prestressing strands are located 25 mm from the bottom fiber of the section centroid in a parallel direction. The empirical formulation were done by the stress concept design methodology in pretensioning concept as per IS standards 1343-1980 and also for the deflection findings and the cross section details of the prestress composite plank as shown in the figure. The prestressing force for the section has maintained in each wire as 18253 N and the live load and dead load is 2 kN/m & 2.16 kN/m until the deformation of the plank structure.

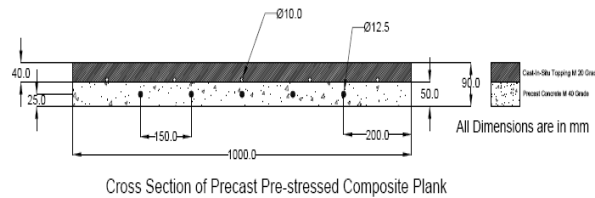


Fig. 5 Cross section of the Prestress Composite Plank

X. MODELLING OF SLAB ELEMENT

The prestressing slab elements are modelled in the space claim design tool in the ANSYS software package. By comparing the design module tool, it has quite advantage for easy element modelling. The slab and reinforcement element are modelled in the solid element and the extrusion technique was made in the space claim drawing tool [7]. The solid elements are modelled in the eight noded brick element and the reinforcement is modelled in the Link 8 element in the ANSYS default properties.

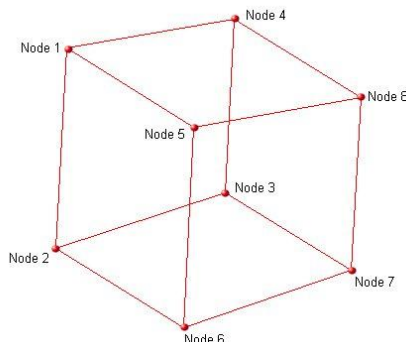


Fig.6 Solid 65

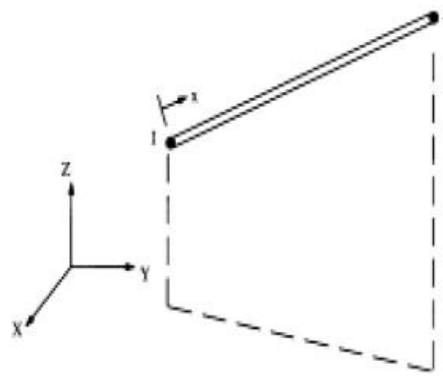


Fig.7 Link 8 Element

The material properties are selected as per design standards with IS Codes and some industrial guide specifications are included in empirical calculations. In finite element modeling, the slab elements are related directly to the matrix analysis of structures. Additionally the term displacement method or stiffness method is used in the field of study known as theory of structures.

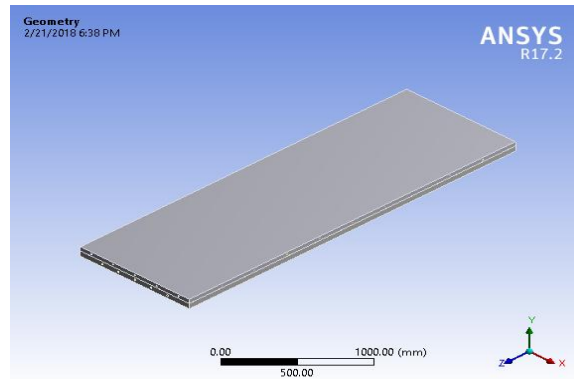


Fig.8 Geometry Model of the Prestressed Composite Element

The Fig. 8 shows that the geometry model done in the ANSYS workbench software with suitable material properties as per standards.

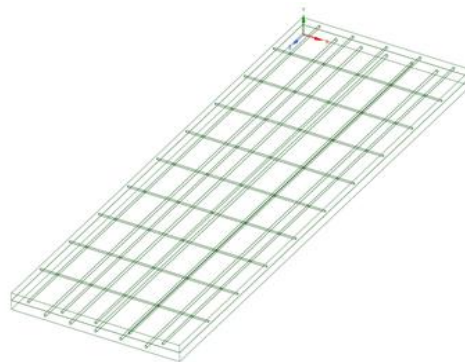


Fig.9 Reinforcement Model

The Fig.9 shows that the reinforced bar, prestressing strands are modeled, the wireframe view of the Prestress plank element in the ANSYS workbench software with a suitable spacing and the spanning. The reinforcement and the strands are modelled in LINK 8 elements are modelled face element in the design tool bar.

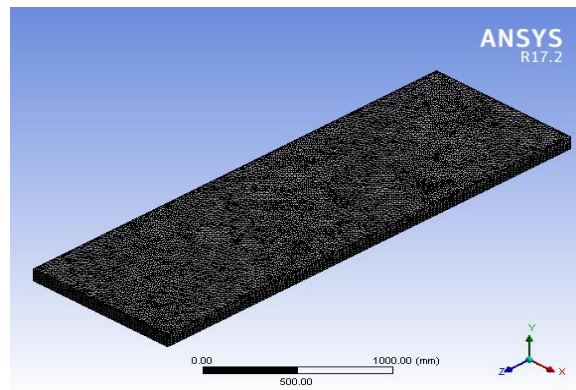


Fig.10 Fine Meshing

In mesh generation, mathematics plays a vital role in providing values to various geometric quantities such as distance, angle, volume, mappings, shape measures and metric tensors in quantifying element shape and size, etc [9]. However, mesh generation is more concerned with the number of nodes, where to place them and how they should be connected to form elements – topological operations in terms of nodal combinations for which there is no direct relationship with geometrical computations, though some estimations can be derived from the required element size and shape quality as additional constraints in mesh generation. For this plank element the mesh can adopted shown in Fig.10 in more fineness with element size of 12 mm in the analysis and it leads to give the accuracy behavior of the element.

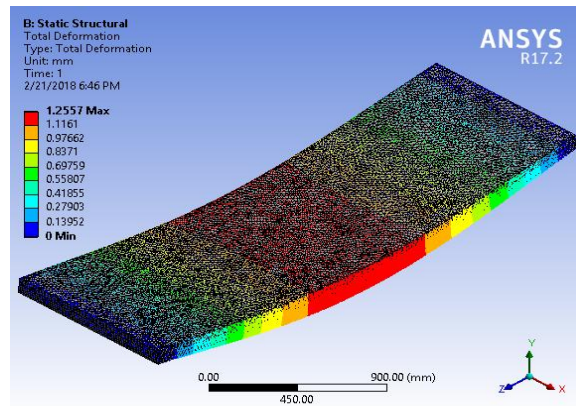


Fig.11 Total Deformation

The Fig.11 represented the deflection behavior of the prestressing composite plank in minimum to maximum ranges with the iteration 2 analysis in post processing view after the structure subjected prestressing force, self-weight and live load.

TABLE. 2
 DEFLECTION CHECK IN BOTH EMPIRICAL AND ANALYTICAL

Parameters	Theoretical Deflection	Analytical Deflection
Deflection due to Prestressing Force + Self weight + Live Load	1.580 mm	1.255mm

XI. CONCLUSIONS

The following conclusions are stated based on the evaluation of the analysis for the calibration model and the prestressing composite plank element.

1. The failure mechanism of the prestressed composite plank is modeled quite well using Finite Element Modeling.
2. The numerical deflection accuracy quite near to the calibration model of the prestressed composite plank.
3. The behavior of the structure and the results accuracy were depends upon the mesh sensitivity in fine mode of the mesh elements.
4. Flexural failure of the prestressed composite plank is modeled well using finite element software.

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