Effect of prestressing force, cable profile and eccentricity on post tensioned beam

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Abstract -*The main objective of this study was to develop three-dimensional finite element modeling (3D-FEM) of Post Tensioned Concrete Beam that can be used to investigate the effect of eccentricity, Prestressing force and Cable profile for concentrated point loading. The accuracy of the results obtained from static analysis using ANSYS is validated by comparing it with analytical study. The variables studied include the effect of Eccentricity, Prestressing force and Cable profile on the responses of the Post Tensioned Concrete Beam So we concluded that Eccentricity, Prestressing force and Cable profile should be taken into consideration while designing the Post Tensioned Concrete beam. Developed 3D-FE modelling is suitable for identifying the effect of different design features on the response of Post Tensioned Concrete Beam.*

Key Words: *3D-FE, static analysis, Eccentricity, cable profile****,*** *Software Indulge (ANSYS 14.0)*

SCOPE OF STUDY

The scope of this study is limited to investigate the effect of eccentricity, Prestressing force and Cable profile and to determine the structural static properties such as deflections and stress distributions. For that Rectangular prestressed concrete beam is taken for the analysis. The ANSYS 14.0 package program is used as a tool of this finite element analysis. The prestressed concrete beam is modelled as simply supported where one end is hinged and another end is roller support. Isotropic materials are used over the beam sections

1. INTRODUCTION

Concrete structural components exist in buildings and bridges in different forms. Understanding the response of these components during loading is crucial to the development of an overall efficient and safe structure. In Prestressed concrete members, stresses are induced during the construction in such a way that they can resist stresses caused by externally applied loads. Prestressed concrete is most suitable for long span structural elements like beams and girders, where larger bending moment results in greater depth of beam or girder. (Chouragade, M., 2013)

In most of the cases of prestress beam, Tendons are located with eccentricities towards the soffit of beams to counteract the sagging bending moments due to transverse loads Consequently, the concrete beam deflects towards (camber) on the application or transfer of prestress. Since the bending moment at every section is product of the prestressing force and eccentricity, the tendon profile itself will represent the shape of B.M.D. The method of computing deflection of beams with different cable profiles is outlined below (Krishna Raju N. 2011) There are a number of approaches for the study of the behaviour of concrete structures, viz., experimental, numerical, theoretical, etc. Finite Element Analysis (FEA) is a numerical one which provides a tool that can accurately simulate the behaviour of concrete structures. (Joshuva, N. R.,et al., 2014).

The use of computer software to model the elements has been proved to be convenient, faster and extremely cost-effective compared to experimental analyses. This study presents an analytical investigation of the effect of prestressing force, cable profile and eccentricity on post tensioned concrete beams in the finite element software package ANSYS 14.0

2. LITERATURE STUDY

Literature survey was carried out to comprehend the linear and nonlinear behaviour of post tensioned concrete beams and the applicability of the finite element software packages in simulating the behaviour of the beams.

Scordelis, A. C., (1984), discussed analytical models and an efficient numerical procedure for the material and geometric nonlinear analysis of reinforced and prestressed concrete rigid frames, slabs, panels, and three-dimensional solids. Time-dependent effects due to load history; temperature history; creep, shrinkage and aging of the concrete; and relaxation of the prestressing steel were included in the analysis. Fanning, P., (2001), presented dedicated numerical models for the nonlinear response of concrete under loading Appropriate numerical modeling strategies were recommended and comparisons with experimental load-deflection responses were discussed for ordinary reinforced beams and post-tensioned concrete beams. Kim, U., et al. (2010), suggested sophisticated 3-D finite element model for simulating the nonlinear flexural behavior of unbonded post-tensioned beams to compare analysis results with experimental results and investigated the effects of various prestressing forces on the flexural behavior of post-tensioned beams. The nonlinear flexural behavior of post-tensioned concrete beams, a 3-D finite element model was developed using ANSYS. In order to validate the developed finite element model, four post-tensioned beams were tested at the structures laboratory of California State University, Fullerton and the test results were compared with the analysis results. Kasat, A. S. & Varghese, V., (2012), discussed a study of prestressed concrete beams using finite element analysis to understand the response of prestressed concrete beams due to transverse loading:

3. RECTANGULAR PRESTRESSED BEAM

A Rectangular beam of cross-section 252 mm deep and 152.4 mm wide and span of 3.657 m is prestressed by means of 2 wires of 5.43 mm diameter located 63.5 mm from bottom of the beam. Assuming the prestress in the steel as 950 N/mm2. If a concentrated pt. load of 5 KN is imposed on the Beam, evaluate the maximum working stress in concrete. The density of concrete is 24 KN/m3.

Material Properties

1. Grade of Concrete – M35
2. Modulus of Elasticity - 5700√fck=5700√35 =33721.65N/ mm² (34000 N/ mm²)
3. Characteristic strength of concrete =35 N/mm²
4. Characteristic strength of High Tensile Wire 1862 N/ mm²
5. Modulus of Elasticity ES =2.1 $X10^5$N/mm²

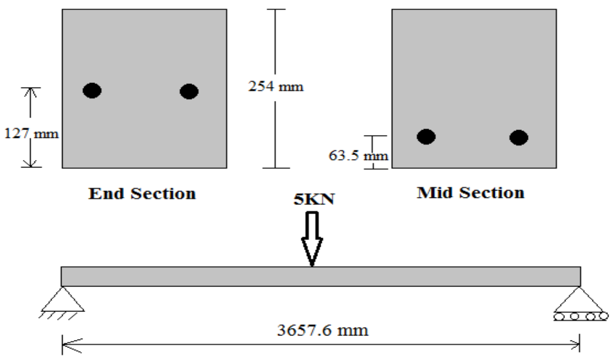


Figure 1.Detail sketch of beam

Analytical solution

Loading Calculations

i) Self-weight =0.254 X0.154X1 X 24= 0.91 N
ii) Concentrated load = WL =5KN at the center of the beam

Eccentricity for Prestressing Wire

At Centre 63.5mm

3.1 Prestressing force

$Pp=950X\frac{\pi}{4}\ x4^2$ =20000N each

Area of C/S

A=254X 152.4=38709.6 mm²

Moment of inertia =

$I=\frac{bd^3}{12}=\frac{152.4X254^3}{12}$ =208.11X $10^6 mm^4$

Section modulus

$Z=\frac{I}{Y}=\frac{208.11X10^6}{127}$ =163.86 x$10^3 mm^3$

3.2 Moments at center of Beam

a) Due to Self-Weight

$Ms=\frac{wl^2}{8}=\frac{0.91X3.657^2}{8}=1.52KNm$

b) Due to Live Load

$ML=\frac{wL}{4}=\frac{5X3.675}{4}=4.57KNm$

c) Due to Prestressing Wire

Mp = Pp X e
=40 X 0.0635
=2.52kNm

3.3Stresses in Beam

a) Direct Stress

$d=\frac{P}{A}=\frac{2X20X10^3}{38709.6}$

=1.03 N/mm²

b) Bending stress due to Prestress

$\sigma p=\frac{MP}{z}=\frac{2.52X10^6}{163.86X10^3}$

= 15.37 N/mm²

C) Bending stress due to Self-weight

$\sigma s=\frac{Ms}{z}=\frac{1.52\ X10^6}{163.86\ X\ 10^3}$

=9.27 N/mm^2

d) Bending Stress due to Live Load

$\sigma L=\frac{ML}{z}=\frac{4.57X10^6}{163.86X10^3}$

=27.88 N/mm²

3.4Resultant Stresses

i) At initial stage

a) σtop

$\sigma top=\sigma d-\sigma p+\sigma s$

=1.03 – 15.37 +9.27

=5.07 N/mm²(T)

b) $\sigma bottom$

$\sigma bottom=\sigma d+\sigma p-\sigma s$

=1.03 – 15.37 +9.27

=7.13 N/mm²(C)

ii) At final stage

a) σtop

$$= \sigma top = \sigma d - \sigma p + \sigma s + \sigma l$$

=1.03 – 15.37 +9.27+27.88

=22.81 N/mm^2(C)

b) $\sigma bottom$

$$= \sigma bottom = \sigma d + \sigma p - \sigma s - \sigma L$$

=1.03 + 15.37 – 9.27 – 27.88

= 20.75 N/mm^2(T)

3.5 Deflection in Beam

a) Due to self-weight

$$Ys = \frac{5}{384} X \frac{wl^4}{EI} = \frac{5}{384} X \frac{0.91X3657.6^4}{33721.6X208.11X10^6}$$

=0.30 mm(downward)

b) Due to point load

$$YL = \frac{wl^3}{48\,EI} = \frac{5000X3657.6^3}{48\,X33721.6X208.11X10^6}$$

= 0.72 mm(downward)

Total downward deflection =1.06mm

Table 1. Result of beam for central deflection and Top and Bottom Fibre Stresses

S.r no	Description	Result(analytical)
1	Central Deflection	1.06mm
2	Extreme Fibre Stresses (Final Stage)	
A	Top Fibre	22.81 N/mm²(C)
B	Bottom Fibre	20.75 N/mm²(T)

4. MODELLING IN ANSYS

In this section, the post tensioned beam response is examined for Straight tendons, Trapezoidal tendons, Parabolic tendons (Central anchors), Parabolic tendons (Eccentric anchors) Sloping tendons (Eccentric anchors) analysis as shown in Figures below then following observations are noticed. In most of the cases of prestress beam, Tendons are located with eccentricities towards the soffit of beams to counteract the sagging bending moments due to transverse loads Consequently, the concrete beam deflects towards (camber) on the application or transfer of prestress. Since the bending moment at every section is product of the prestressing force and eccentricity, the tendon profile itself will represent the shape of B.M.D. The method of computing deflection of beams with different cable profiles is outlined below (Krishna Raju N. 2011) Following Cable Profile Were Modelled in ANSYS;

1. Straight tendons
2. Trapezoidal tendons (Drop harped shape)
3. Parabolic tendons (Central anchors and Eccentric anchors)
4. Sloping tendons (Eccentric anchors)

4.1 Straight tendons

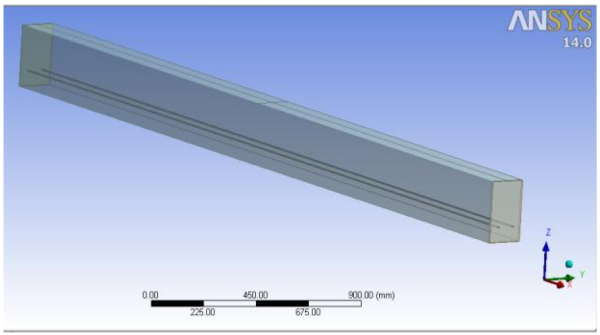


Figure- 2: Straight profile Tendon modelled in ANSYS

Figure 2. shows a beam with a straight tendon at a uniform eccentricity below the centroidal axis. If upward deflection is considered as negative=Prestressing Force (20000 N Per wire), L=length(3657.6mm)

Profile1 with eccentricity 63.5mm

Profile 2 with eccentricity 50mm and Profile 3 with eccentricity 40mm

$$a = \frac{(PeL)(\frac{L}{4})}{EI} = \frac{Pel^2}{8EI}$$ ……………… Equation (N Krishna Raju)

4.2Trapezoidal tendons (Drop harped shape)

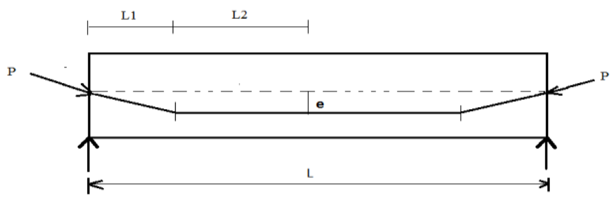


Figure- 3: Trapezoidal profile

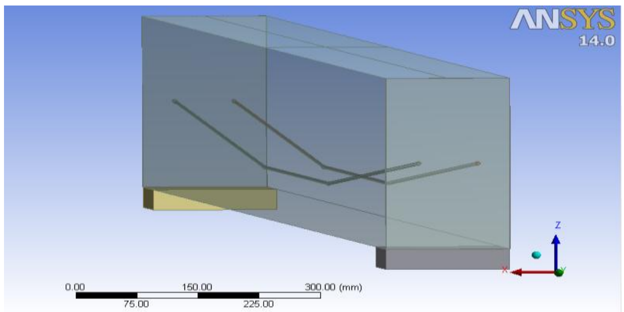


Figure- 4: Trapezoidal profile modelled in ANSYS

A draped tendon with trapezoidal profile is shown in figure 3 and 4 considering the B.M.D., the deflection at the Centre of the beam is obtained by taking the moment of area of B.M.D. over one-half of span. Thus

$= -\frac{Pe}{6EI}[2l_1^{\,2}+6l_1 l_2 + 3l_2^{\,2}]$ .. Equation (N Krishna Raju)

Where, L1 = 1346.2 mm L2 = 965.2mm

Profile1 with eccentricity 63.5mm

Profile 2 with eccentricity 50mm and Profile 2 with eccentricity 40mm

4.3 Sloping tendons (Eccentric anchors)

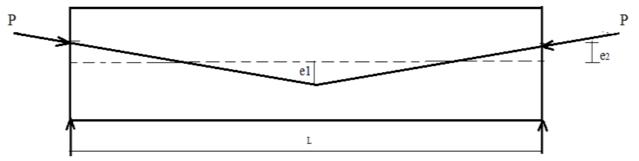


Figure- 5: Sloping tendons

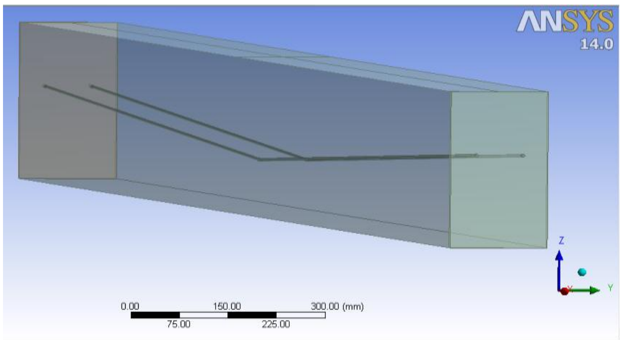


Figure- 6: Triangular Profile modelled in ANSYS

As shown in figure 5 and 6 there were 3 profiles modelled First Profile was modelled with eccentricity 63.5 mm at center. second profile modelled with e_1=50 at center and e_2 =13.5 mm at end and third profile modelled with e_1=50 at center and e_2 =13.5 mm at end.

$$\text{Deflection, } a = \left[-\frac{PL^2}{12EI}(e_1+e_2)\right] + \left[\frac{Pe_2L^2}{8EI}\right] = \frac{PL^2}{24EI}(-2e_1+e_2)$$

......Equation (N Krishna Raju)

4.4 Parabolic tendons (Central anchors and Eccentric anchors)

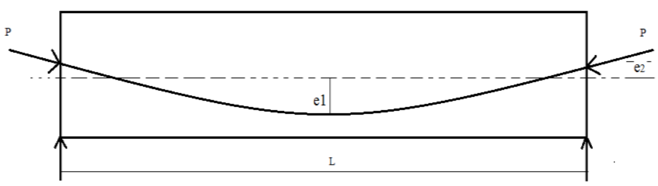


Figure- 7: Parabolic tendons with Eccentric anchors)

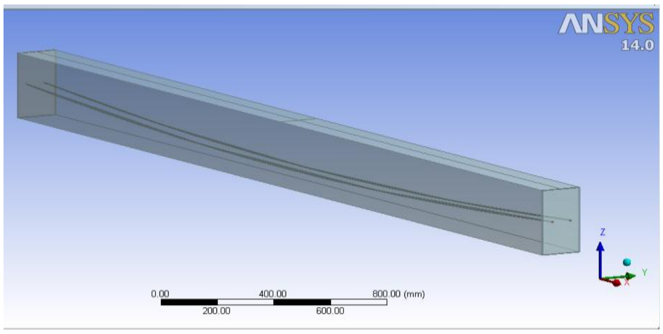


Figure- 8: Parabolic tendons modelled in ANSYS

Figure 7 and 8 shows a beam with parabolic tendon having an eccentricity e_1 at the Centre of span and e_2 at the support section. The resultant deflection at the Centre is obtained as the sum of the upward deflection of the beam with a parabolic tendon of eccentricity (e_1+e_2) at the Centre and zero at the support and the downward deflection of a beam subjected to a uniform sagging bending moment of intensity Pe_2throughout the length consequently the resultant deflection becomes

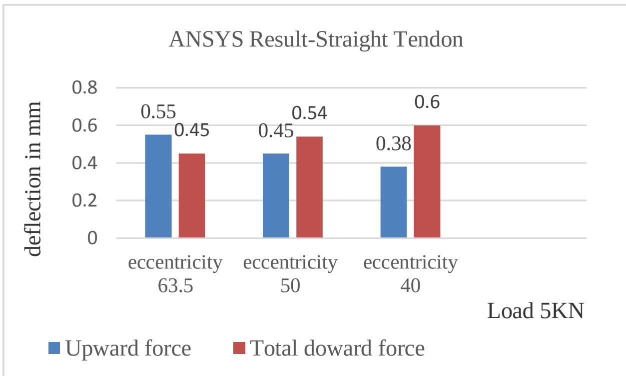
a $=\frac{PL^2}{48EI}(-5e_1 + e_2)$ .... Equation (N Krishna Raju)

Eccentricity for first profile 63.5mm with concentric anchors and for second and third profile same as in above profile mentioned in triangular profile

5.RESULT OBTAINED FROM SOFTWARE ANSYS

As mentioned in above chapter all profile was modelled with cable profile and eccentricity. And solution obtained from Ansys for each cable profile, eccentricity and prestressing force is compared below.

5.1Comparison of profile for various eccentricities



Graph 1. straight tendon for eccentricities