

# A STUDY ON REVIEW OF LITERATURES OF ANCHORAGE ZONE STRESSES IN POST TENSIONED BEAMS

Suganthapriya K<sup>1</sup>, S Karthika<sup>2</sup>

<sup>1</sup>P.G Student, Civil Department, Dr Mahalingam College of engineering and Technology

<sup>2</sup>Assistant Professor, Civil Department, Dr Mahalingam College of engineering and Technology

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**Abstract** - The assessment of stress distribution in the anchorage zone of a pre stressed concrete post tensioned beam is of particular importance. Because, the state of stress exists in these beams is extremely complicated and three dimensional in nature. This paper deals with the study on literatures of stress distribution in anchorage zone. The author's suggestions were discussed and the possible methods with reference to the transverse tensile stresses were studied. It has been concluded from the study that there is necessity to study Anchorage zone stresses in three dimensions.

**Key Words:** Anchorage zone, Transverse tensile stress, three dimensional stresses, Literatures

## 1. INTRODUCTION

Many studies have been carried out in pre stressed concrete beams. Always a special consideration was given to the anchorage zone or end block in Post tensioned beams. The anchorage zone is the zone between the end of the beam and the section where only longitudinal stress exists. The major criterion for end block is due the state of stress distribution is complex and three-dimensional in nature. These anchorage zone stresses developed are continuous linear distribution which produces transverse tensile stresses and shear stresses. Hence there is a requirement of additional reinforcement for tensile stresses are required. Therefore a good study on this anchorage zone stress distribution is needed highly.

### 1.1 Background of Study

A number of investigators have studied the stress distribution in the anchorage zone using empirical equations and theoretical solutions based on the two or three dimensional elasticity or experimental techniques. The important investigations were done by Magnel, Guyon, Iyengar, Zelinski and Rowe, Yettram and Robbins et al. The main aim of stress analysis in the anchorage zone is to obtain the transverse tensile stress distribution in the end block from which the total transverse bursting tension could be computed.

## 2 REVIEW OF LITERATURES

### 2.1 STRESSES IN END BLOCK

**K.T.S Iyengar** investigated on the theoretical and numerical analysis of stress distribution in rectangular prism with length to depth ratio equal to 2.0 and depth to width

equal to 1.0 has been taken with a material which is homogenous, isotropic and linearly elastic and these were not totally valid for concrete. The value of Poisson's ratio of concrete varies from zero to 0.2. The ratio the loaded cross sectional area on the end block,  $k$  has been varied from 0.01 to 0.81. It was observed that the transverse tensile stress of large magnitude occur along the axis of loading.

The intensity of this stress is largest when  $k$ , the ratio of loaded area to the cross sectional area is smallest and as  $k$  increases the magnitude of this transverse tensile stress decreases. In a case a comparison has been made for using different values of  $\beta$ , the ratio of loaded depth to depth of the end blocks. In comparing the results of these solutions with the results of Zelinski and Rowe, Poisson's ratio of 0.167 was used.

It was concluded from the investigations were Along the axis of the end block the position of zero and maximum tensile transverse stress move away from the loaded end. The maximum bursting tensile stress occur on the axis of loading for both the concentric and eccentric loading or whether the cross section is square or rectangular for all values of  $k$ . Except the value of  $\beta$  is very small, the two dimensional solution gives the values of maximum transverse tensile stress. In case of an end block of square cross section with central loading of over a square area, the stresses  $\sigma_y$  and  $\sigma_z$  will be equal.

The bursting tension due to  $\sigma_y$  is larger than that due to  $\sigma_z$  and thus steel designed for  $\sigma_y$  if provided in the perpendicular direction is sufficient for the bursting tension due to  $\sigma_z$ . From the three dimensional solution it was observed that the presence of sapling zone near the loaded surface on the longitudinal forces of the end block. The importance of present study was that the stresses in the interior of the end block were larger than those on the surface.

**A.L Yettram** studied on the effect of the concentration ratio,  $a'/a$  upon the magnitude and distribution bursting stresses by using finite element idealization. The author had utilized double symmetry and an element mesh is used to represent one quarter of the prism. The distribution of the bursting stress  $\sigma_y$  over the critical plane  $y=0$  for values of  $a'/a$  equal to 0.2, 0.3, 0.5 and 0.7 respectively. These results confirm that bursting stress in the fully three dimensional problem, exhibit a significant variation in the third principal direction. Although surface

values of bursting stresses have shown to be greater than mean values throughout the range of concentration ratios.

For a small anchorage a high concentration of bursting stresses was developed in the centroidal axis and is separated from the bearing face only by a compression zone. As the concentration ratio increases, the inner stress region moves further from bearing face whereas the outer region moves nearer. In the case of anchorage across the full width of a wide beam, the centroidal and surface stresses are distinctly different; thus a 'plane stress' two dimensional analysis will not be accurate. The three dimensional finite element methods reveal variations in the stress distribution which are significant if the real behavior of anchorage zone in post tensioned members completely.

**K.T.S Iyyengar** reviewed on the two dimensional theories on anchorage zone stresses of Guyon, Morsch, Sievers and few others were examined. The stress distribution in the post tensioned prestressed concrete beams, the stress distribution is three dimensional in nature and complex. The distribution of the transverse tensile stress and other quantities computed by Guyon's method and the comparison of these results with the study almost agree closely. The maximum stress given by Guyon is slightly higher than the results of this study.

It was concluded that a theoretical solution of the two - dimensional elasticity problem of anchorage zone stresses in post tensioned beams has been presented under all the four types of cases, viz., normal and tangential, symmetrical and asymmetrical. Numerical results for the case of a symmetrical normal loading were also been carried out by the author. The assumption made by many researchers that the stress distribution becomes purely a longitudinal one at a distance equal to the depth of the beam can be justified.

## 2.2 ANCHOR ZONE STRESSES:

**S.P Christodoulides** investigated on stress distribution in the end anchorages of post tensioned concrete beams using photoelastically. This work was designed as a preliminary investigation to the solution of the complete three dimensional problems and there were some deviations from the practical form of post tensioned concrete units which were considered permissible. The distribution of principal stresses was recorded, as it is considered that failure will be governed by the maximum principle tension.

It was concluded from the study that the maximum shear stress and the absolute maximum principal stress occur immediately under and on the center line of the loading steel cubes, i.e, anchorages. The position and the magnitude of the principal tensile stresses obtained explain the anchorage failures. In these beams the mild steel reinforcement provided at the end anchorages would be considered inadequate if compared with the values of tensile stresses given by the author. It must however be

remembered that the actual distribution of stress in end block of post tensioned beams is a three dimensional one. The experimental investigation of the problem indicates the importance of the point and also the cable ducts cast in the concrete will affect the distribution of the stresses.

## 2.3 FINITE ELEMENT ANALYSIS OF ANCHORAGE ZONE

**P.K. Gupta et al.**, investigated in the development of stresses in anchorage zone in prestressed post-tensioned concrete beam using the finite element analysis. A finite element computer code on the platform of a supercomputer PARAM 10000 was developed and employed for this study. A parallel algorithm for matrix inversion method was developed and implemented in the presented finite element code. Concentric and eccentric prestressing forces were applied for prestressing of the beams. Effect of Poisson's ratio over the bursting tensile force developed in the anchorage zone was studied and an equation to compute the magnitude of bursting tensile force by incorporating the effect of Poisson's ratio was proposed.

Two cases were considered for the study. In order to get the in-depth stress distribution, various simulation studies were carried out and several distribution curves were produced for concentric prestressing forces at different values of  $k$  ranging from 0.1 to 0.9 and varying from 0 to 0.3. It was observed that the magnitude of maximum transverse tensile stress ( $\sigma_t$  (max)) in the anchorage zone starts decreasing with the increase in the value of  $k$ . It was also observed that as the value of  $k$  increases, the locations of zero and maximum transverse tensile stress points start moving away from the loaded face and close to the center of beam.

To study the effect of eccentric prestressing forces, a particular set was considered which has  $k = 0.1$  and  $v = 0.15$ . It can be observed that as the eccentricity of prestressing force increases the magnitude of  $\sigma_t$  (max) inside the anchorage zone also increases but its location shifts towards the loading face.

It was concluded that Study shows that Poisson's ratio affects the magnitude of bursting tensile force in prestressed post-tensioned concrete beam. An expression for computing the magnitude of bursting tensile force was developed incorporating the effect of Poisson's ratio. The results of developed equation was compared with the available literature and discussed. It was found that the equation given in Indian Standard Code IS: 1343-1980 computes maximum magnitude of  $F_{bst}$ . Effect of eccentricity over the transverse tensile stress developed in spalling zone was found to be that stresses of very high magnitude were developed for the higher magnitude of the eccentricity. Hence it was advised that spalling zone should be carefully analyzed for prestressed post-tensioned beams subjected to eccentric prestressing forces. Significant saving in computational time was achieved by employing parallel computing technique in Finite Element Analysis. It was also founded that the obtained Speedup is very much near to the ideal Speedup.

**MeenakshiChouragade** conducted an analytical study on three dimensional stress analysis of anchorage zone in prestressed post-tensioned concrete beam using finite element analysis using ANSYS. A case study was performed in which the loaded area ratio ( $k$ ) was varied for beam subjected to concentric loading & eccentric loading and various stress distribution were obtained.

The problem of anchorage zone was idealized as three-dimensional problem by adopting a cubical block. This block was discretized using 35705 tetrahedral elements with 57228 nodes for performing finite element analysis. Default material properties of concrete available in ANSYS were used in the present analysis. To get accurate results, the mesh was kept advance fine with relevance center. Circular shape anchorage plate was considered during the analysis. The diameter of this plate was adjusted such that value of  $k$  varies from 0.1 to 0.7 for concentric loading, then the analysis of anchorage zone is carried out for different values of  $k$ . Displacement support was provided at the back face of loaded face such that displacement along the axis of loading is restricted. The author used cylindrical co-ordinate system instead of Cartesian co-ordinate system so that stresses in radial and circumferential direction have been obtained.

From the study the author concluded that there is a reduction of stresses with introduction of eccentric loads this directly affects the bursting tensile forces. Exactly reverse situation can be seen in case of spalling zone. Hence it was recommended to analyse spalling zone as well as anchorage zone for prestressed post-tensioned concrete beams subjected to eccentric loading.

### 3. CONCLUSIONS

The various literature surveys revealed the importance of analysis of stress distribution in End block or Anchorage zone of Prestressed concrete beams. The study pointed need for experimental and numerical investigation of three dimensional stress distributions in Anchorage zone. Some papers showed the numerical study using Finite Element software.

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