

# Deep Beam Analysis Using FEM Program and ANSYS for ISO-parametric elements

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**ABSTRACT:** The structural bending members can be broadly divided into two regions. The first region is the Bernoulli regions (B- regions) , where the strain distribution is linear. There are several analytical tools available for analyzing of a deep beam . It is recognized that the distribution of the strain across the section of deep beams is nonlinear and hence, these structural elements belong to the D-Regions. Traditionally, the D-Regions have been designed using empirical formulae or past experience. Recently, the Strut-and-Tie Model (STM) has been recognized as an effective tool for design of both B-and D- Regions but still method has not yet been widely implemented. There are various theories which consider the shear deformation effect, developed by the researchers for the analysis of deep beams. These theories have their own assumptions and limitations.

There are many software packages available for the analysis of deep beams but we generally use SAP, ANSYS software. In finite element method many isoparametric elements are available such as triangular element, elements of serendipity family. In ANSYS it is modeled using Solid82 for 2D analysis.

In this project, results of deflection, flexural stress and shear stress of cantilever prismatic deep beams obtained using FEM program for isoparametric elements, and ANSYS 2D analysis are compared. A parametric study of deep rectangular beams for point load has been carried out.

**KEYWORDS:** Deep beam, aspect ratio, convergence study, discretisation, flexural stress

## I. INTRODUCTION

Deep beams are defined as the members loaded on one face and supported on the opposite face so that compression struts can develop between the loads and the supports. In IS-456 (2000) clause 29, It is a fact that in the finite element analysis, as the number of elements increases the result comes closer to the true results. Continuous beams are considered as deep when the ratio  $L/D$  is less than 2.5. The effective span is defined as the center to center distance between the supports or 1.15 times the clear span whichever is less.

The use of reinforced concrete deep beam has become more prevalent in recent years. Deep beams often appear in form of transfer girders in high rise building as well as pile caps, foundation walls, water tanks, bins, folded plate roof structures, floor diaphragms, shear walls & brackets or corbels.

Plane section before bending remains plane after bending does not hold good for deep beams. The behavior of deep beam is significantly different from that of beams of more normal proportions, requiring special consideration in analysis, design and detailing of reinforcement. A deep beam is in fact a vertical plate subjected to loading in its own plane. The strain or stress distribution across the depth is no longer a straight line, and the variation is mainly dependent on the aspect ratio of the beam.

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## II. ANALYSIS OF BEEP BEAM

Analysis of deep rectangular beam subjected to point load. Comparative study of deep beams of various aspect ratios using FEM. Comparisons of the results obtained from FEM Program for isoparametric elements, and ANSYS 2D analysis

## III. DETAILS OF DEEP BEAM

A cantilever beam with rectangular cross section ( $b \times h$ ) is subjected to concentrated load  $P$  at free end i.e. at  $x = L$  at surface  $z = -h/2$  acting in the  $z$  direction. The origin of the beam is taken at fixed end i.e. at  $x = 0$ . The boundary conditions associated with cantilever beam are as given:

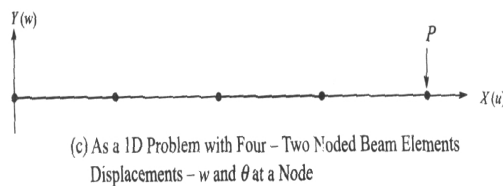
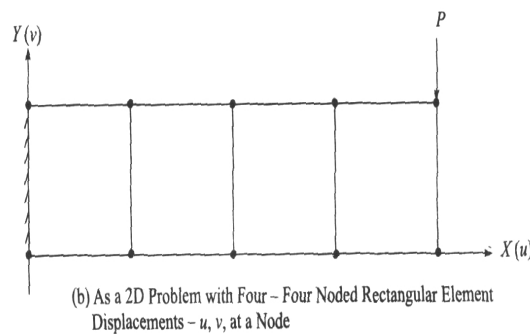
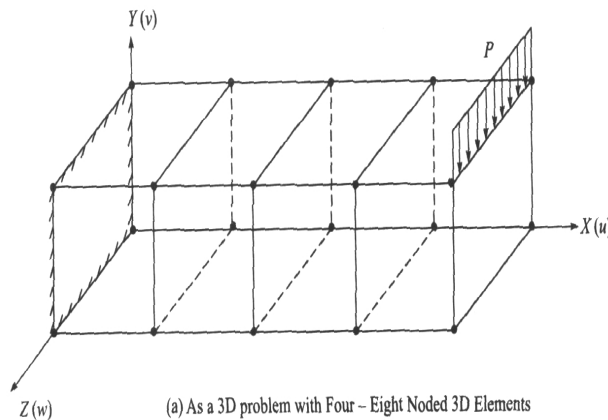


Figure 1: Discretization of a Cantilever Beam for analysis

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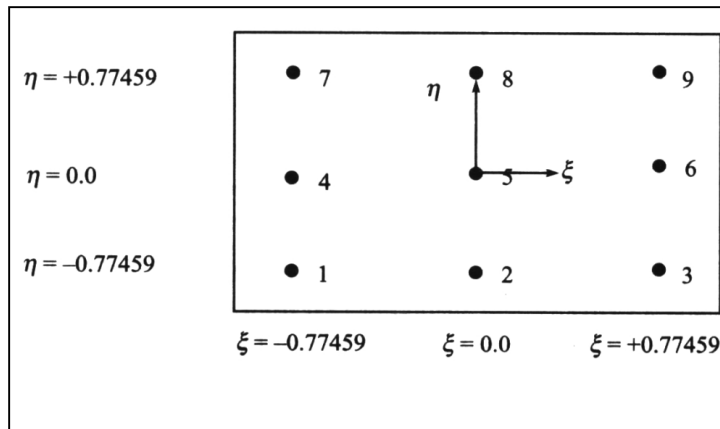
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## IV. ANALYTICAL RESULTS

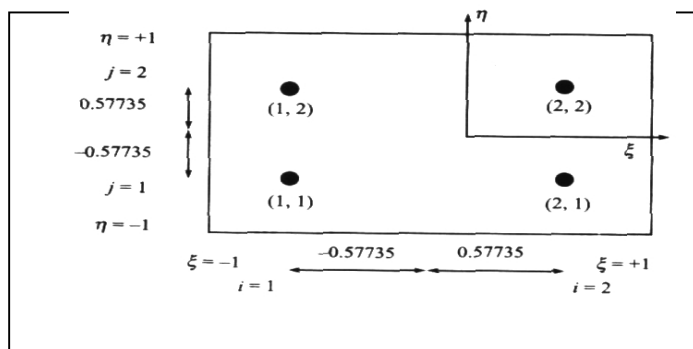
The common type of isoparametric elements used for 2D elastic analysis are linear, parabolic (quadratic) and cubic elements with 4,8 and 12 nodes respectively. Thus, we have

**Table 1: Abscissa and weight coefficient**

$n$	$\xi_i$	$W_i$
(1)	(2)	(3)
1	0.00000	2.00000
2	$\pm 0.57735$	1.00000
3	$\pm 0.77459$ 0.00000	0.55555 0.88888
4	$\pm 0.86113$ $\pm 0.33998$	0.34785 0.65214
5	$\pm 0.90617$ $\pm 0.53846$ 0.00000	0.23692 0.47862 0.56886



**Figure 2: Figure 4.4: Location of points in the  $\xi - \eta$  plane for the element**



**Figure 3: Location of integration points for linear elements**

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## ANSYS:

ANSYS software is a powerful and flexible general-purpose finite element analysis and computational fluid dynamics package used for civil engineering. Mechanical engineering, electrical engineering, physics and chemistry simulations. Simulation tools including ANSYS Mechanical APDL, ANSYS CFX and ANSYS FLUENT, can also solve mechanical problems, static/dynamic structural analysis, heat transfer and fluid problem as well as acoustic and electromagnetic problems.

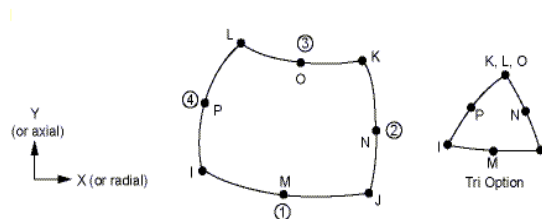


Figure4: PLANE82 Geometry

### PLANE82 Input Summary

#### Nodes

I, J, K, L, M, N, O, P

#### Degrees of Freedom

UX, UY

#### Real Constants

None, if KEYOPT (3) = 0, 1, or 2

THK - Thickness, if KEYOPT (3) = 3

#### Material Properties

EX, EY, EZ, PRXY, PRYZ, PRXZ (or NUXY, NUYZ, NUXZ),

ALPX, ALPY, ALPZ (or CTEX, CTEY, CTEZ or THSX, THSY, THSZ), DENS, GXY, DAMP

#### Surface Loads

##### Pressures --

face 1 (J-I), face 2 (K-J), face 3 (I-K), face 4 (I-L)

##### Body Loads

##### Temperatures --

T(I), T(J), T(K), T(L), T(M), T(N), T(O), T(P)

##### Fluences --

FL(I), FL(J), FL(K), FL(L), FL(M), FL(N), FL(O), FL(P)

### PLANE82 Output Data

The solution output associated with the element is in two forms:

- Nodal displacements included in the overall nodal solution
- Additional element output

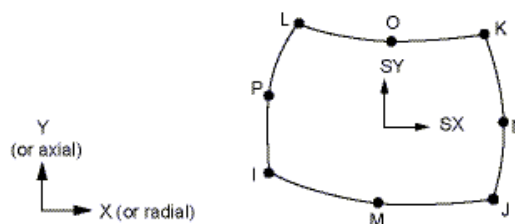


Figure5 :PLANE82 Stress output.

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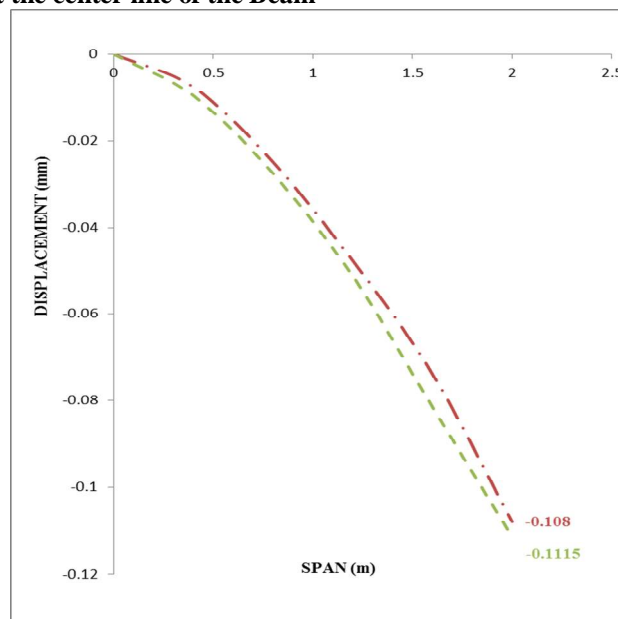
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**Table 2 : Results of displacement and stresses for various L/D ratios**

L/D	METHODS	DEFLECTION (mm)	$\sigma_x$ (N/mm <sup>2</sup> )	$\tau_{xz}$ (N/mm <sup>2</sup> )
(1)	(2)	(3)	(4)	(5)
1.0	PROGRAM –LINEAR ELEMENT (4NODES)	-0.108	1.388	0.322
	ANSYS	-0.1115	1.3164	0.344
	EBT	-0.06399	0.9598	0.249
1.25	PROGRAM –LINEAR ELEMENT (4NODES)	-0.1802	1.42	0.3134
	ANSYS	-0.17965	1.519	0.333
	EBT	-0.124997	1.199	0.269

**Graph showing deflection at the center line of the Beam**



..... Program 4 nodes

..... Ansys

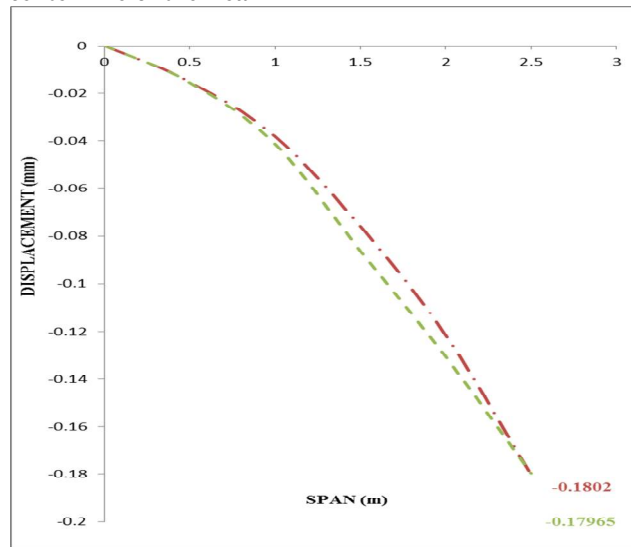
**Figure6 : Deflection curve for L/D=1**

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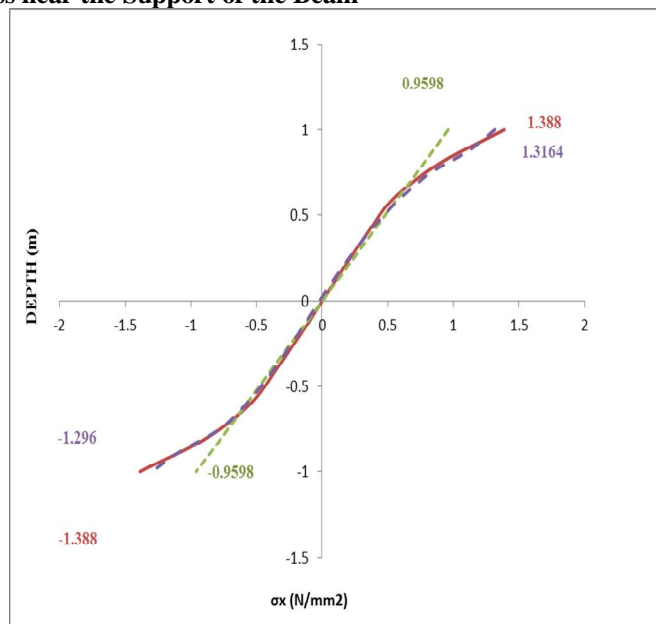
Graph showing deflection at the center line of the Beam



..... Program 4 node  
-.-.-.-.- Ansys

Figure7: Deflection curve for L/D=1.25

Variation of Flexural Stress near the Support of the Beam



..... Program 4 nodes  
-.-.-.-.- EBT

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## Variation of Flexural Stress near the Support of the Beam

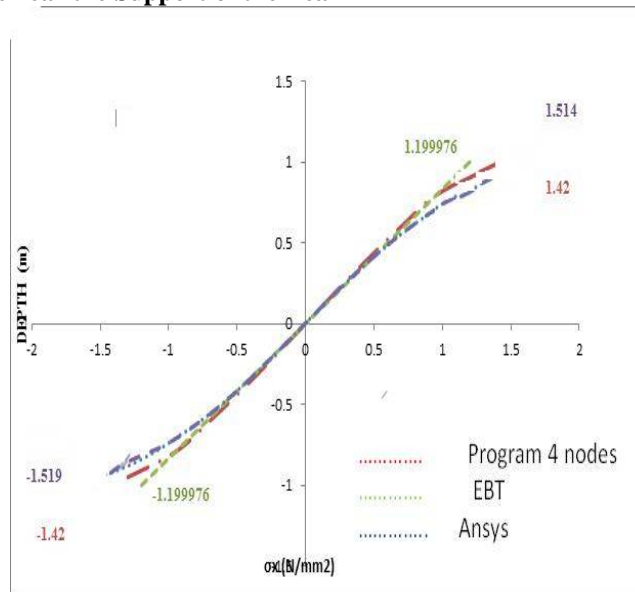
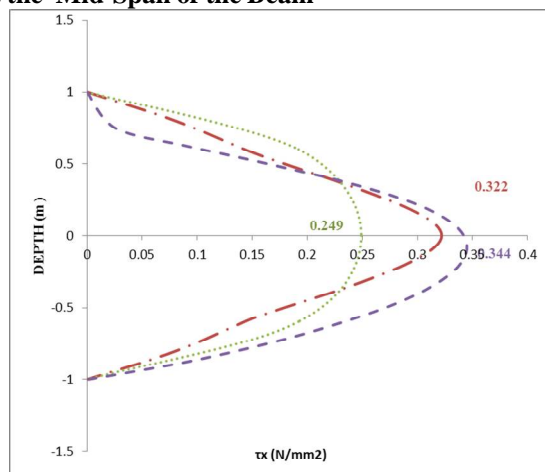


Figure 8: Flexural Stress curve for  $L/D=1.25$

## Variation of Shear Stress at the Mid-Span of the Beam



..... Program 4 nodes  
..... EBT  
..... Ansys

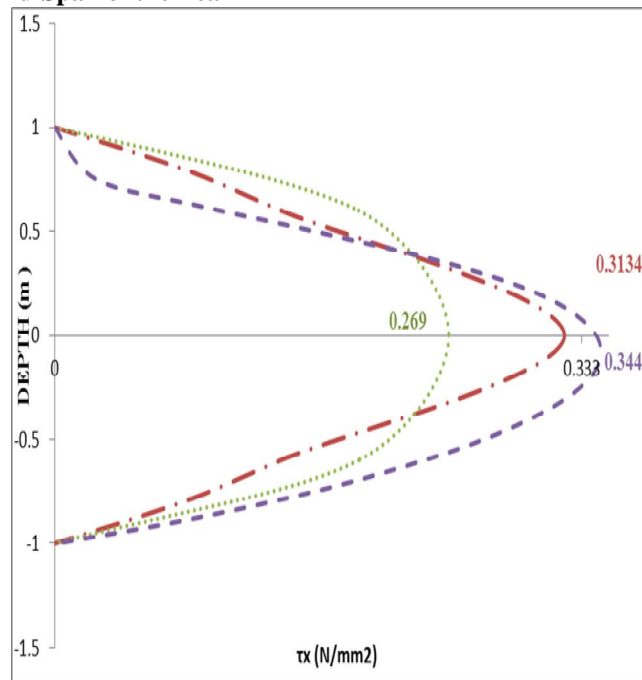
Figure 9: Shear Stress for curve for  $L/D=1$

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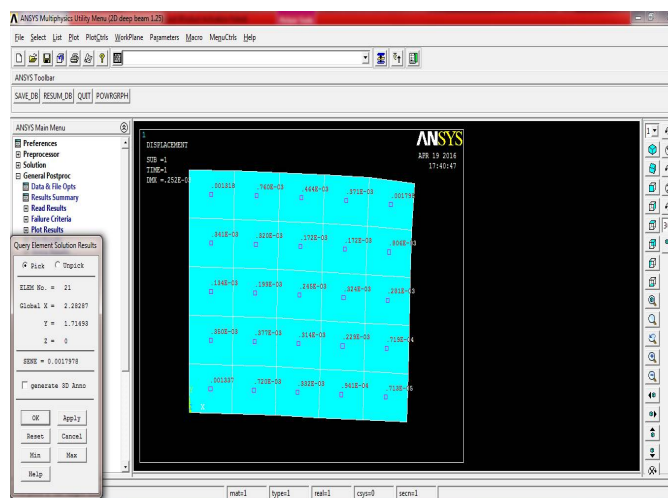
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## Variation of Shear Stress at the Mid-Span of the Beam



..... Program 4 nodes  
..... EBT  
..... Ansys

Figure 10: Shear Stress for curve for L/D=1.25



ANSYS SCREENSHOT SHOWING FINAL SOLUTION



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## III. CONCLUSION

Deflection values given by EBT are much less than the values given by FEM program and ANSYS in case of rectangular deep beam. From the results given by FEM program, ANSYS it is found that the flexural stress distribution in deep beam is not linear as in case of slender beams, but EBT gives the flexural stress distribution as linear for deep beam. EBT gives the maximum shear stress at the centre line of the beam, but in deep beams the maximum shear stress is below the centre line of the beam. It is observed that the neutral axis moves downward. It is observed that though there is a variation in the results of deflection obtained from FEM Program and ANSYS, the agreement is very close.

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