

A Study on Concrete Deep Beams using Nonlinear Analysis

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Abstract

In this project work, an attempt is made to predict the shear strength for concrete deep beams at ultimate state, using ANSYS12.1 software. Two test beams will be accounted to predict their shear strength at ultimate state using ANSYS 12.1 software. The accuracy of the predicted values of shear strength based on ANSYS 12.1 software for the two test beams will be compared with their corresponding experimental results. In addition, the predicted values of shear strength for the two test beams using ANSYS 12.1 software will be compared with the results obtained by shear strength prediction models proposed by various researchers. The prediction of shear strength using ANSYS 12.1 is found to be reasonably in good agreement with the corresponding experimental results.

Keywords: Reinforced Concrete Deep Beams, Shear Strength

I. INTRODUCTION

Beams having larger depth are known as deep beams. Such beams are used as the wall of the water tanks, bunkers and also used as load distributing structural elements such as transfer girders, pile caps, foundation walls and in offshore structures. Deep beams are structural elements, in which significant amount of load is transferred to the supports by a compression strut joining the load and the reaction. The basic assumption of the plane section assumed to remain plane after bending is not valid for deep beams. It has a nonlinear stress distribution along the depth of the beam.

Because of their geometric proportions, the strength of reinforced concrete deep beams is usually controlled by shear, rather than by flexure if normal amount of longitudinal reinforcement is used. The shear action in the beam web leads to diagonal compression and tension in a direction perpendicular thereto. The deep beams do not fail immediately due to the formation of diagonal cracks. After diagonal cracking, the concrete between the diagonal cracks can serve as a concrete compression strut. The external shear is assumed to be transferred by the concrete compression strut. By detailing the end anchorage of longitudinal bars and bearing zones of deep beams, premature failures such as shear tension failure (due to insufficient anchorage of reinforcing bars) and bearing failure can be effectively avoided. The usual failure mode of deep beams is crushing of the concrete strut as shown in Fig.1.1.

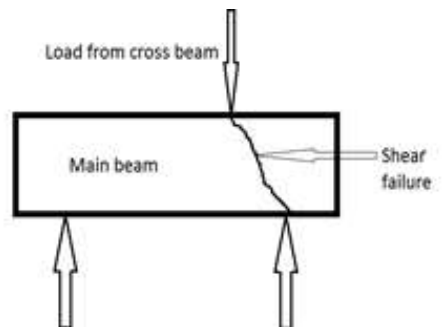


Fig. 1: Typical failure of deep beams

According to ACI-318 (2008), deep beams are defined as structural beams loaded on top face and supported on the opposite bottom face, so that compression struts develop between the load and the support. The concrete beams having clear span to depth ratio less than or equal to 4.0 or shear span to depth ratio (a/d) less than or equal to 2.0 are considered as deep beams (ACI-

318 2008).But IS 456(2000) stipulates that a beam is said to be deep, if effective span to overall depth of is less than 2.0. Due to the small value of span to depth ratio, the failure of deep beams is controlled by shear rather than flexure.

II. AIM AND OBJECTIVES

The aim and objectives of the project work is to predict the shear strength at ultimate state using ANSYS 12.1 software for the two concrete beams reinforced with steel bars subjected to two point loading and to compare the predicted results obtained by ANSYS 12.1 software with the corresponding theoretical shear strength values obtained from the strength prediction models proposed by various researchers The objectives in this research work are summarized as follows.

- To carry out analytical study using ANSYS12.1 software in order to predict the shear strength of two concrete beams reinforced with steel bars
- To compare the exipermental shear strength values and analytical shear strength values obtained using ANSYS 12.1 software for the concrete test beams.
- To compare the predicted shear strength values of two test beams obtained by ANSYS12.1 software with the corresponding results obtained by the models proposed by various researchers namely Zsutty1968, Mau and Hsu 1989, Siao 1994, Matamoros and wong 2003 and Russo, Venir and Pauletta 2005.

III. EXPERIMENTAL DETAILS

The experimental program reported in Dileep et al.(2012) has been considered. It comprised the testing to failure of 2 reinforced concrete deep beam specimens designed with various shear span- to-depth ratios and longitudinal reinforcement ratio. All beams were 1590 mm long, effective span is 990 mm, 500 mm deep and 170 mm wide. The beams were loaded at two point on the top face.

Table – 1
Preliminary details of Beams

Specimen no.	f_{ck}	$b(mm)$	$d(mm)$	$D(mm)$	a/d	Main bars ratio
0.3/0.5	50	170	416	500	0.5	0.3
0.3/1.0	50	170	416	500	1	0.3

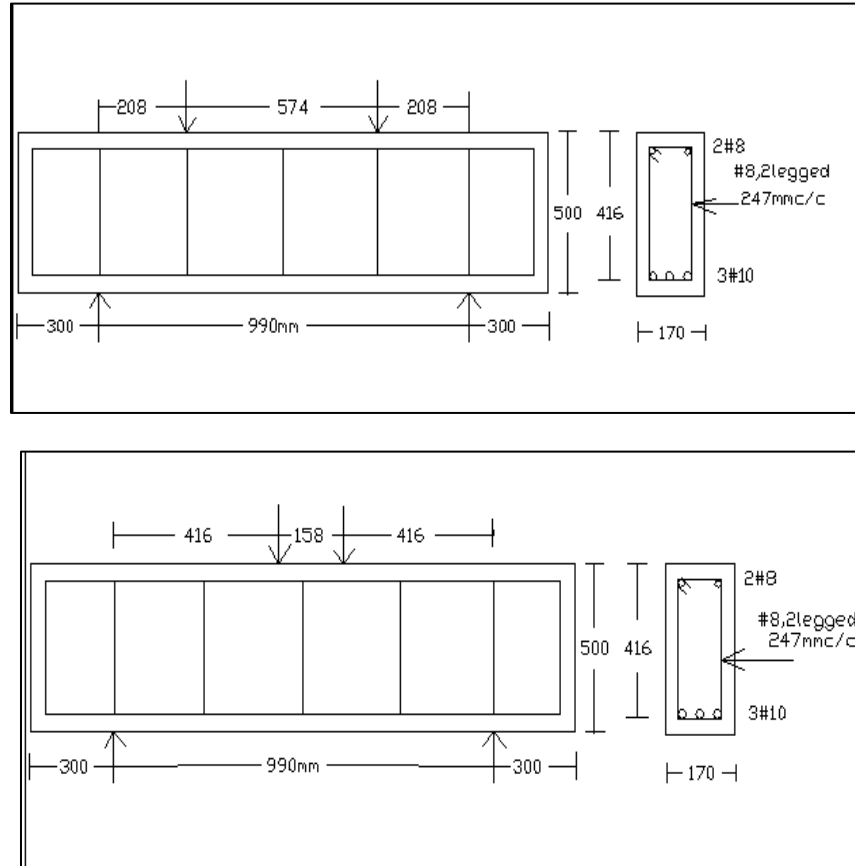


Fig. 2: Sketch showing the reinforcement details of beam specimen S 0.3/0.5& S 0.3/1.0

Table – 2
Results obtained by experimental work

Beam	f_{ck} (avg)	a/d	First cracking load	Failure load	Max Shear load	Mode of failure
0.3/0.5	44.0	0.5	275	500	250	Diagonal shear
0.3/1.0	42.7	1.0	240	400	200	Flexural failure

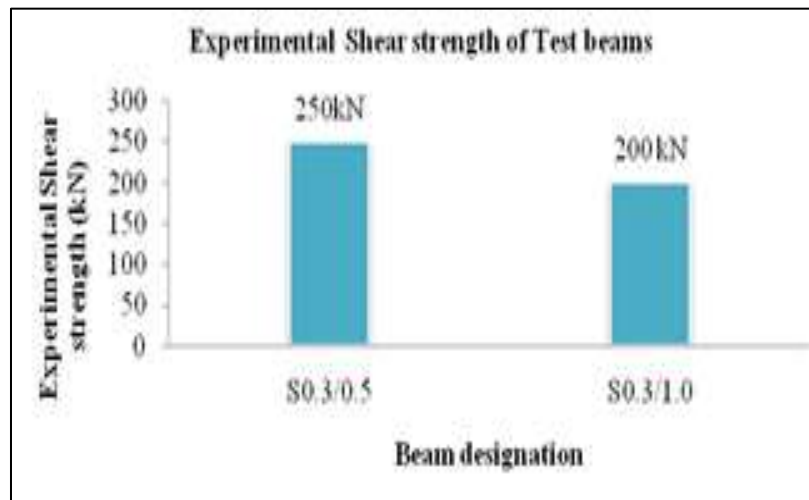


Fig. 3: Experimental shear strength of test beams

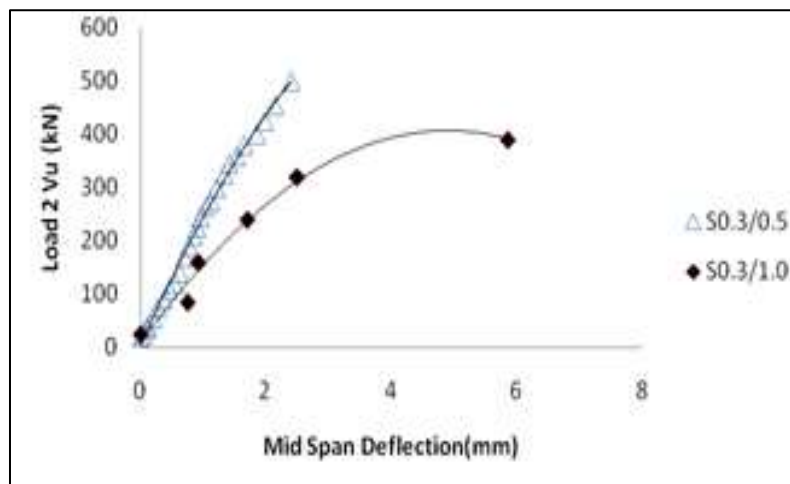


Fig. 4: Load versus mid span deflection graph

IV. ANSYS SOFTWARE MODEL

ANSYS is a finite element analysis (FEA) code widely used in the computer-aided engineering (CAE) field. ANSYS software allows engineers to construct computer models of structures, machine components or systems; apply operating loads and other design criteria; and study physical responses, such as stress levels, temperature distributions, pressure, etc. It permits an evaluation of a design without having to build and destroy multiple prototypes in testing.

Major steps involved in the analysis:

- 1) Preference (structural)
- 2) Pre-processor
- 3) Solution
- 4) General postprocessor

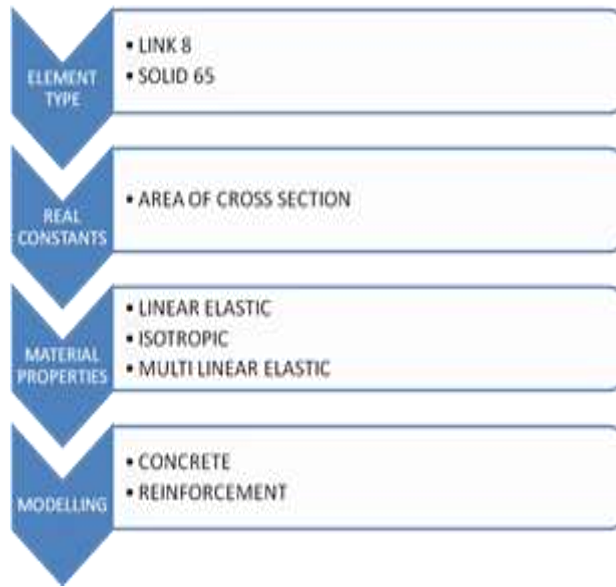


Fig. 5: Steps involved in preprocessor

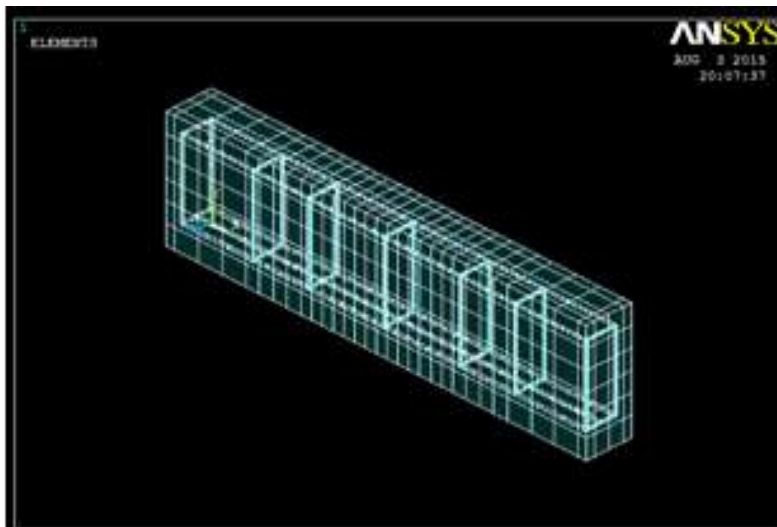


Fig. 6: Isoropic view of beam 0.3/0.5

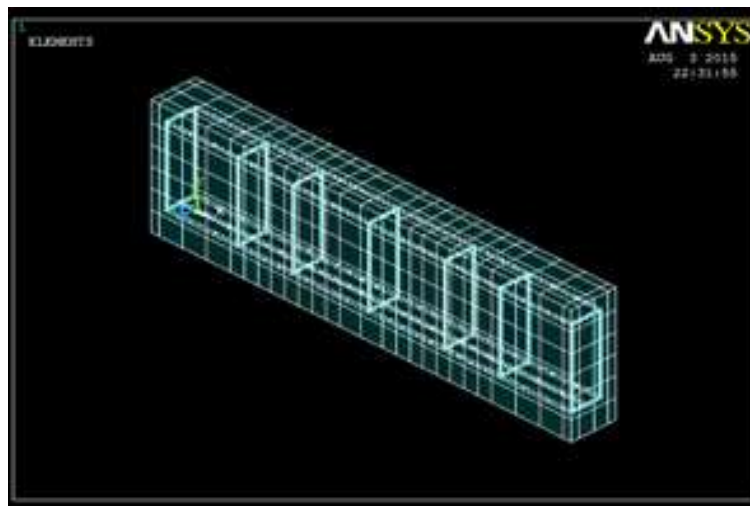


Fig. 7: Isoropic view of beam 0.3/1.0



Fig. 8: Steps involved in solution

A. Loads and Supports

Displacement boundary conditions are needed to constrain the model to get a unique solution. To ensure that the model acts the same way as the experimental beam. The support was modelled in such a way that a roller was created. A single line of nodes on the plate were given constraint in the UY, and UZ directions, applied as constant values of 0. By doing this, the beam will be allowed to rotate at the support. The force, P, applied at the beam is applied across the entire cross section of the beam on particular point as in the experimental setup. The force applied at each node on the beam is one tenth of the actual force applied.

B. Results and Discussions

Table – 3
Details of analysis

	BEAM 0.3/0.5	BEAM 0.3/1.0
Depth (mm)	500	500
Shear Span To Depth Ratio	0.5	1.0
Flexural Steel Provided (mm ²)	3-10mm ϕ	3-10mm ϕ
Load At Failure	549.67 kN	438.62 kN
Maximum Shear Load	274.835 kN	219.31 kN
Mid Span Deflection	1.38 mm	2.2636 mm

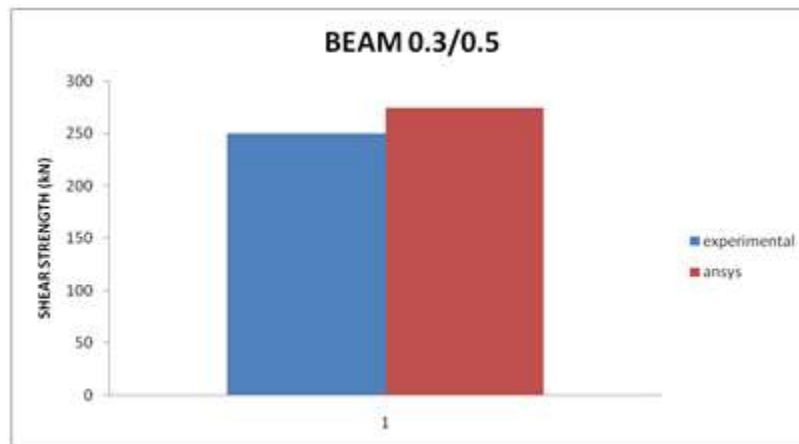


Fig. 9: Comparison of experimental shear strength and predicted shear strength using ANSYS for beam specimen S0.3/0.5

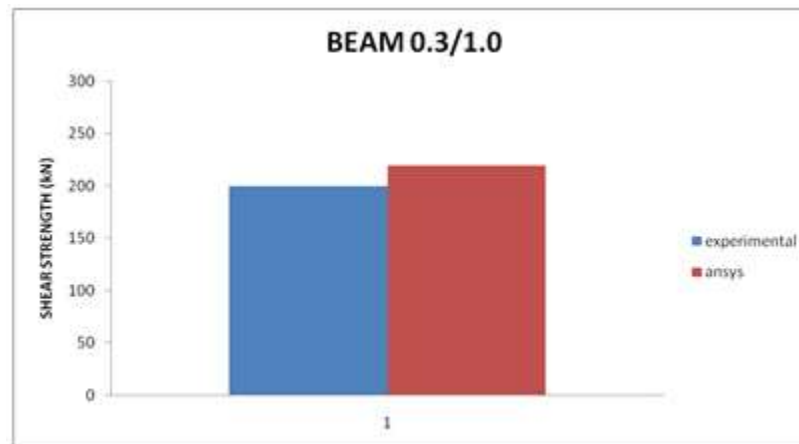


Fig. 10: Comparison of experimental shear strength and predicted shear strength using ANSYS for beam specimen S0.3/1.0

Fig: 9 and 10 shows comparison of experimental shear strength and predicted shear strength using ANSYS 12.1 software. For beam specimen S0.3/0.5 the shear strength is found to be 9.93% higher in magnitude when compared with the corresponding experimental results. For beam specimen S0.3/1.0 the shear strength is found to be 9.65% higher in magnitude when compared with the corresponding experimental results. The shear strength of the predictions of the proposed model are consistent for shear span to depth ratios 0.5 and 1.0.

V. COMPARATIVE STUDY

Table – 4
Models for the prediction of shear strength of concrete deep beams

Sl. No.	Citation	Proposed model by various researchers
1	Zsutty (1968)	$V_n = V_c + V_s$ $V_c = \left(2.5 \frac{d}{a}\right) 2.2 \left(f_c' \rho \frac{d}{a}\right)^{\frac{1}{3}} bd$ $V_s = \rho_v f_y bd$
2	Mau and Hsu (1989)	$V_n = bd \frac{1}{2} f_c' \left[\frac{K(\omega_h + 0.03)}{\sqrt{K^2(\omega_h + 0.03)^2 + 4(\omega_h + 0.03)(\omega_v + 0.03)}} + \omega_v \right] \leq 0.3 f_c'$ <p>where,</p> $\omega_h = \rho_h f_y / f_c' \leq 0.26; \quad \omega_v = \rho_v f_y / f_c' \leq 0.12$ $K = 2 \frac{d_v}{h} \quad \text{for } 0 < a/h = 0.5; \quad d_v = d - d'$ $K = \frac{d_v}{h} \left[\frac{h}{a} \left(\frac{4}{3} - \frac{2}{3} \frac{a}{h} \right) \right] \quad \text{for } 0.5 < a/h = 2.0$ $K = 0 \text{ for } a/h > 2.0$
3	Siao (1994)	$V_n = bd \times 1.8 f_t$ <p>where f_t is the greater of the following two expressions</p> $f_t = 0.58 \sqrt{f_c'} \left[1 + n(p_h \sin^2 \alpha + p_v \cos^2 \alpha) \right] \quad (\text{MPa})$ $f_t = f_y (p_h \sin^2 \alpha + p_v \cos^2 \alpha)$
4	Matamoros and Wong (2003)	$V_n = \frac{0.3}{a/d} f_c' b w_{st} + \rho_{wv} b \frac{a}{3} f_{yv} + 3 \left(1 - \frac{a}{d}\right) \rho_{wh} b \frac{d}{3} f_{yh}$ $\tan \theta \approx 1/(a/d)$ $w_{st} = l_b \sin \theta + h_a \cos \theta$ $\frac{0.3}{a/d} \leq 0.85 \sin \theta \quad \text{and } (1 - a/d) > 0$
5	Russo, Venir and Pauletta (2005)	$V_n = bd \times 0.545 \left(k \chi f_c' \cos \theta + 0.25 \rho_h f_{yh} \cot \theta + 0.35 \frac{a}{d} \rho_v f_{yv} \right)$ $k = \sqrt{(n \rho_f)^2 + 2n \rho_f} - n \rho_f$ $\theta = 2 \arctan \left[\frac{\sqrt{\left(\frac{a}{d} - \frac{w_l}{2d}\right)^2 + \left(1 - \frac{k^2}{4}\right)} - 1}{\frac{a}{d} - \frac{w_l}{2d} - \frac{k}{2}} \right]$ $\chi = \left[0.74 \left(\frac{f_c'}{105}\right)^3 - 1.28 \left(\frac{f_c'}{105}\right)^2 + 0.22 \left(\frac{f_c'}{105}\right) + 0.87 \right]$

Table – 5
Summary of Shear Strength by various Researchers

Sl.no.	CITATION	BEAM 0.3/0.5	BEAM 0./1.0
1	Experimental	250	200
2	ANSYS	274.835	219.31
3	Zsutty (1968)	415.4	305.7
4	Mau and Hsu (1989)	752.3	377.6
5	Siao (1994)	62.9	157.2
6	Matamoros and Wong (2003)	20.5	250
7	Russo, Venir and Pauletta (2005)	18.8	24.6

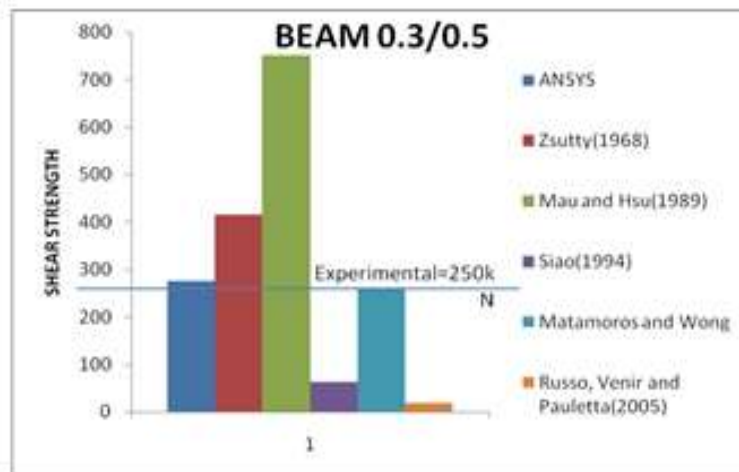


Fig. 11: Predicted shear strength of beam 0.3/0.5

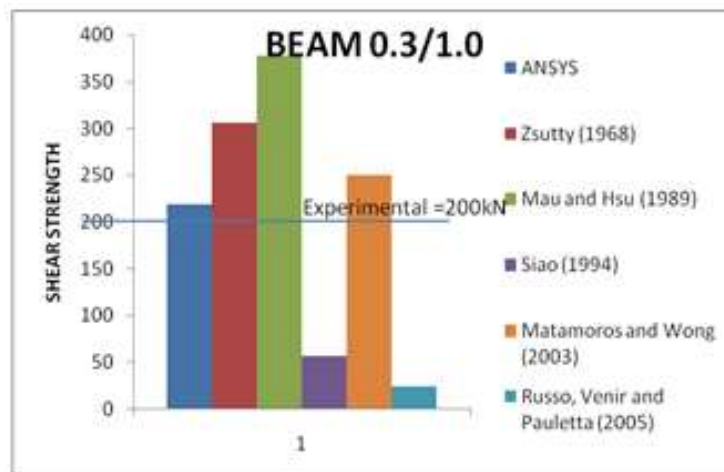


Fig. 12: Predicted shear strength of beam 0.3/0.5

Fig. 11 and 12 are showing the predicted shear strength values proposed by various researchers on beam 0.3/0.5 and 0.3/1.0 respectively. The shear strength of beam predicted using the model proposed by

- Zsutty (1968) was found to be 66.16% higher in magnitude when compared with the corresponding experimental result for beam 0.3/0.5 and 9.655% higher in magnitude when compared with the corresponding experimental result for beam 0.3/1.0
- Mau and Hsu (1989) was found to be 200.92% higher in magnitude when compared with the corresponding experimental result for beam 0.3/0.5 and 88.8% higher in magnitude when compared with the corresponding experimental result for beam 0.3/1.0
- Siao(1994) was found to be 34.84% lower in magnitude when compared with the corresponding experimental result for beam 0.3/0.5 and 21.4% lower in magnitude when compared with the corresponding experimental result for beam 0.3/1.0
- Matamoros and Wong (2003) was found to be 4.2% higher in magnitude when compared with the corresponding experimental result for beam 0.3/0.5 and 25% higher in magnitude when compared with the corresponding experimental result for beam 0.3/1.0.

- Russo, Venir and Pauletta(2005) was found to be 92.48% lower in magnitude when compared with the corresponding experimental result for beam 0.3/0.5 and 87.7% higher in magnitude when compared with the corresponding experimental result for beam 0.3/1.0

From these 5 equations proposed by various researchers, Matamoros and Wong (2003) gives the better result for shear strength. Mau and Hsu (1989) gives the over estimated value for shear strength and by Russo, Venir and Pauletta (2005) gives the under estimated value for shear strength. The variation in results is mainly because of the effect of parameters used in each equation.

VI. CONCLUSION

The shear strength at ultimate state was predicted using ANSYS 12.1 software for the two concrete beams reinforced with steel bars subjected to two point loading and compare the predicted results obtained by ANSYS 12.1 software with the corresponding theoretical shear strength values obtained by the models proposed by various other researchers

- Carried out analytical study using ANSYS 12.1 software for the prediction of the shear strength of two concrete beams reinforced with steel bars.
- Compared the experimental shear strength values and analytical shear strength values obtained using ANSYS 12.1 software for the concrete test beams.
- Compared the predicted shear strength values of two test beams obtained by ANSYS software with corresponding results obtained by the models proposed by various researchers namely Zsutty1968, Mau and Hsu 1989, Siao 1994, Matamoros and wong 2003 and Russo, Venir and Pauletta 2005
- Model proposed by Matamoros and Wong (2003) gives the better result for shear strength. Mau and Hsu (1989) gives the over estimated value for shear strength and by Russo, Venir and Pauletta (2005) gives the under estimated value for shear strength of concrete deep beams.
- A detailed experimental study is to be conducted for identifying the appropriate ranges for which model proposed by ANSYS 12.1 and IS 456 are recommended.
- The scope of the study extended to study the behaviour of concrete deep beams with openings reinforced with steel bars.

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