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Study on Behaviour of Reinforced concrete deep beam using finite element method

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ABSTRACT

The objective of the present work is to study the behaviour of the deep beam by using ABAQUS software. The behaviour of deep beam is understood by varying various parameters such as different percentage of tension reinforcement, different grades of concrete(M30 and M60), different depths of beam(400mm and 750mm). In this study a total eight simply supported reinforced concrete deep beams were modelled under four-point loading in ABAQUS software and the general behaviour of beams was investigated. The comparison between the ABAQUS results were made in terms of strength and deflection of deep beams. It was found that with increase in the percentage of steel, grade of concrete and depth of beam the flexural strength of beam increases significantly and with the increase in load, the finite element analysis gives good results in the deflection.

KEYWORDS: *Deep beam, Shear Strength, ABAQUS, Ultimate load, deflection.*

I. INTRODUCTION

Reinforced concrete deep beam has many useful applications in building structures such as transfer girder, wall footing, foundation pile cap, floor diaphragm and shear wall. The behaviour of deep beams is quite different from the shallow beams. While the behaviour of the latter beams is dominated by flexure and thus the bending stress is higher than the shear stress in these beams, while shear governs the behaviour of deep beams. For example, shear cracks usually appear in the web of a deep beam because of high inclined tensile stresses in this zone, which cause the beam to fail before reaching its moment capacity [1].The use of deep beam has increased rapidly in tall buildings for both residential and commercial purpose because of their convenience and commercial efficiency [2]. Even if there exist a huge number of researches, there is no agreed rational procedure to predict the deep beam strength. This is mostly due to the highly nonlinear behaviour related to the reinforced concrete beam failure. [3]

Deep beams normally fail in shear. Shear tension failure occurring due to the loss of the bond strength in flexural reinforcement caused by the horizontal cracks and shear compression failure occurring due to crushing of concrete at the point of application of the load. This shear failure is fragile in nature and results in sudden damage or collapse [4].Deep Beams possess two-dimensional action in compared with normal beams and the assumption where the plane section remains plane before and after bending is not applicable as the strain is not distributed linearly. The applied pressure will have more effect on the stress rather than strain, also shear deformation in normal beams can be neglected but in deep beams, the failure is mainly due to shear which cannot

be neglected. Due to larger depths, like in traditional method stress is not linear in elastic stage and the parabolic shape at ultimate stress is not achieved which is also a major reason for shear failure in deep beams[4].

II MODEL GEOMETRY

Arabzadeh et al. [4] has experimentally investigated sixteen simply supported deep beam specimens with rectangular cross section of 80x400 mm, their overall and effective spans were 1600 mm and 1200 mm, respectively.Fig.1 gives the additional details.

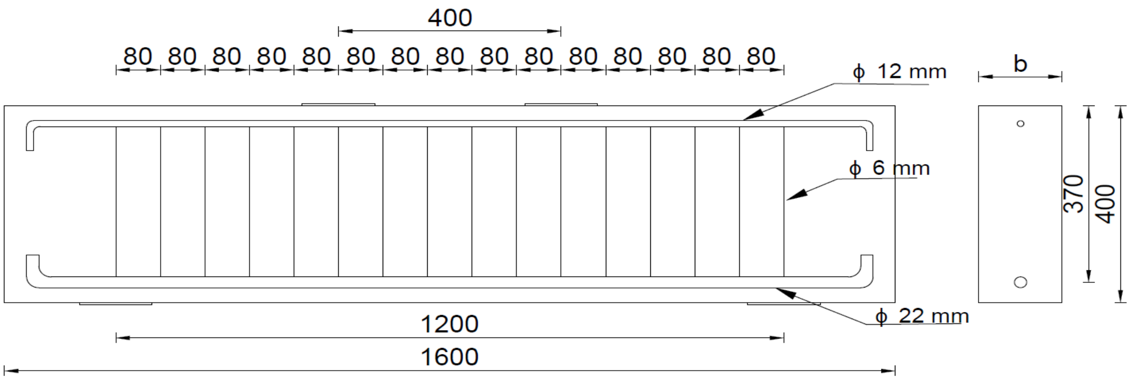

Fig 1. Dimension of Specimens

In the current study, one of the deep beam specimens was selected having concrete compressive strength 60MPaand was analyzed in ABAQUS, the results were validated with the experimental results and then different parameter of the deep beam such as depth of the deep beam, grade of concrete and percentage of longitudinal tension reinforcement were changed and different FEA models were created in ABAQUS software. Results of these model were compared and deep beam behaviour was examined. Table1 gives information of different models used for finite element analysis.

Table 1. Geometrical properties of deep beams models

Beam No.	Width (mm)	Depth (mm)	F_c' MPa	Bottom Reinforcement	Top Reinforcement	Vertical Stirrups
B1	80	400	60	1-22D	1-12D	16-6D
B2	80	400	60	1-25D	1-12D	16-6D
B3	80	400	30	1-22D	1-12D	16-6D
B4	80	400	30	-25D	1-12D	16-6D
B5	80	750	60	1-22D	1-12D	16-6D
B6	80	750	60	1-25D	1-12D	16-6D
B7	80	750	30	1-22D	1-12D	16-6D
B8	80	750	30	1-25D	1-12D	16-6D

Table 2. Mechanical properties of steel reinforcements

S. No	Bar diameter (mm)	Area(mm^2)	fy (MPa)	fu (MPa)	E(MPa)
1	6	28.27	397	469	201000
2	12	113.1	433	491	208000
3	22	380.1	585	585	206000
4	25	490.9	577	577	214000

III FINITE ELEMENT ANALYSIS

The Finite Element Analysis is an approximate technique, it gives a specific and realistic solutions to determine the nonlinearbehaviour of reinforced concrete deep beams. So, ABAQUS [5] software was used to predict thebehaviour of deep beams under 4-point bending configuration.The modelling technique was verifiedby validating the model prediction with the experimental work from previous study. Then the experimental and analytical results were compared for validation. Later, the parameters affecting the shear strength of deep beam such as depth of the beam, grade of concrete and longitudinal reinforcement were changed and the beam was analysed in FEM software (ABAQUS). The results of these models were compared and the behaviour of deep beam was predicted.With the increase in load, the finite element analysis givesgood results in the deflection. It also gives same crackpatterns and load displacement response. The main intention in comparing the experimental and finite element analysis is to know how far the FEA can analyse the behaviour of deep beam.

Table 3 gives the values of Poisson's ratio, dilation angle, eccentricity, viscosity used for the analysis of deep beam using Abaqus.

Table 3. Modal parameters for deep beams in ABAQUS

S. No	Modal parameter	Value
1	Poisson's ratio	0.18
2	Dilation angle (ψ)	35
3	Eccentricity (e)	0.1
4	σbo/σco	1.16
5	Second stress invariant (K)	0.667
6	viscosity	0.005

K = ratio of second stress invariant on tensile meridian to compressive meridian; σbo/σco = ratio of initial equibiaxial compressive yield stress to initial uniaxial compressive yield stress.

IV RESULTS AND DISCUSSIONS

To verify the deep beam, a comparison is done with the load and deflection behaviour. Figure 2 gives the comparison of load vs deflection of the experimentally tested deep beam specimen and the analytically modelled deep beam. A close correlation between the FE model predicted results and experimental results have been found.

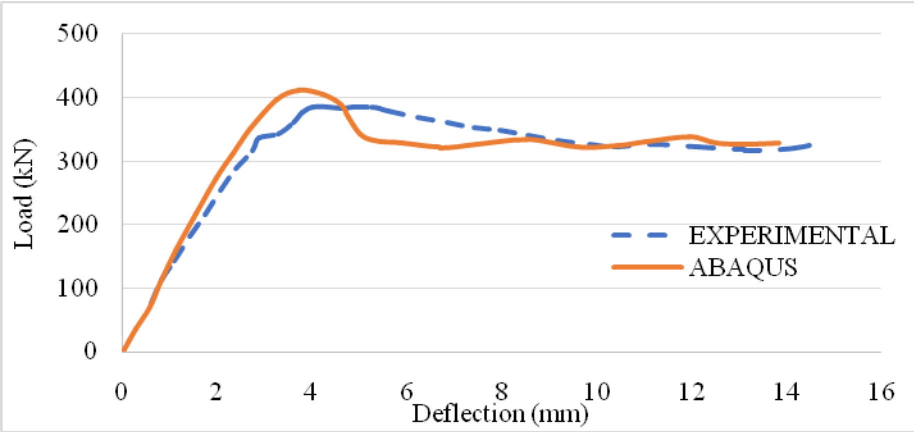

Fig 2. Load vs Deflection plot for analytical and experimental results

Table 4 gives the comparison of ultimate load and ultimate deflection between analytical and experimental results. It can be seen that FE model gave high prediction of ultimate loads for deep beams and experimental results gave high prediction of deflection values in comparison to FE model. FE model shows good efficiency in simulating the deep beams in terms of load and less prediction in terms of deflection.

Table 4. Comparison of ultimate load and ultimate deflection between analytical and experimental results

Beam No.	Ultimate load			Ultimate deflection		
	Pu Exp (kN)	Pu Abaqus (kN)	Pu Exp /Pu Abaqus (%)	δ Exp (kN)	δ Abaqus (kN)	Pu Exp /Pu Abaqus (%)
B1	385.57	410.17	94	4.37	3.72	117.47

Figure 3 shows the tension crack pattern due to tensile stress of the FE model (DAMAGET). The tension cracks started from the position of support and reached to the point of application of load at an average angle of 38 degree.

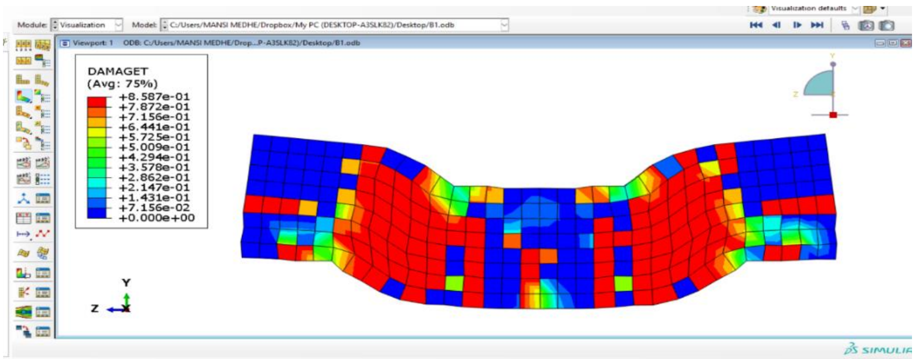

Fig 3. Crack pattern for FE damaged tension model

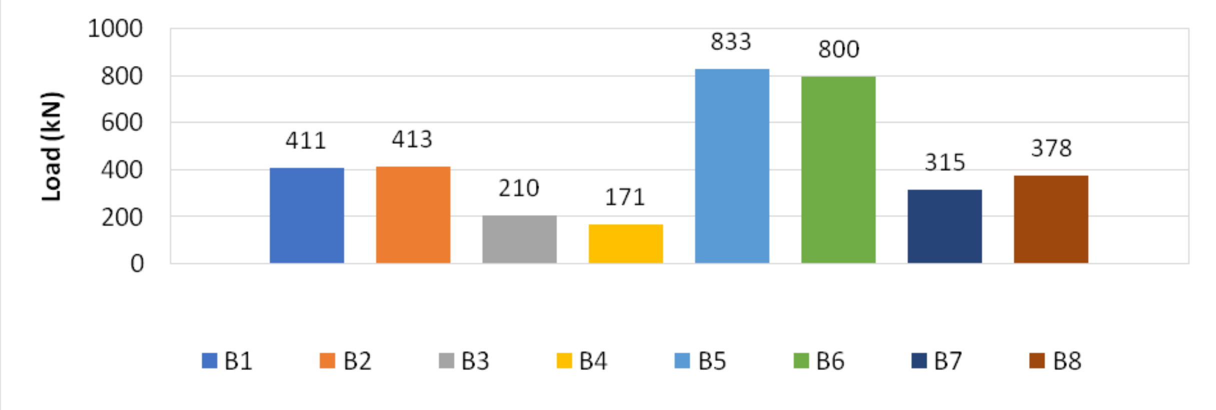

Fig 4. Comparison of ultimate loads for all the deep beams

From fig 4 it can be seen that the beam with larger depth show high values for ultimate load while the beams with smaller depth shows lower values. Also, the beams having high compressive strength (60MPa) have high ultimate load than those having low compressive strength (30MPa).

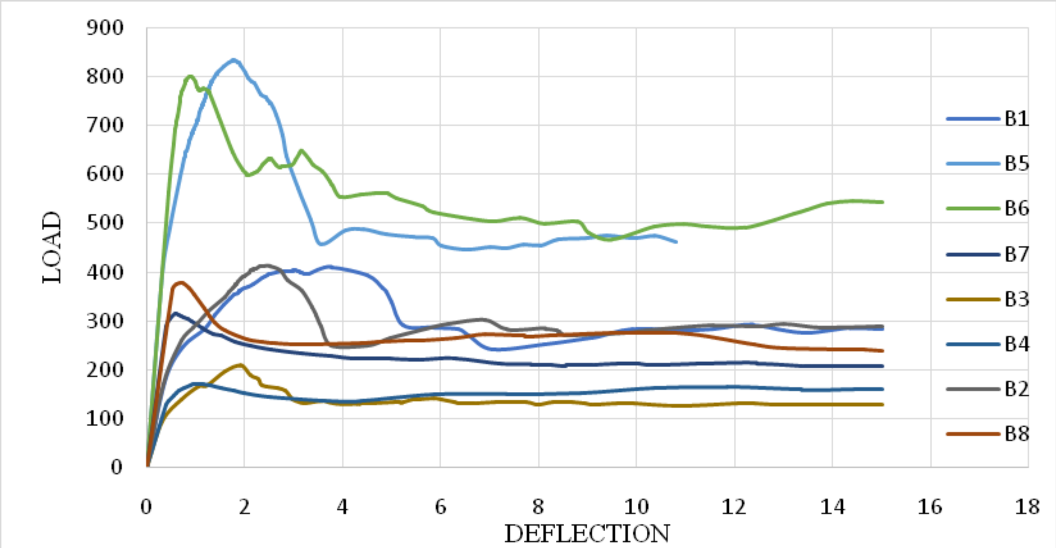

Fig 5. Load vs Deflection plot for different deep beams

From fig 5 it is observed that the beam having higher percentage of tensile reinforcement fails at lower strain value and it shows more brittle behaviors.

V CONCLUSION

One reinforced concrete deep beam was analyzed numerically and compared with the experimental results. After validating the results some parameters such as compressive strength of concrete, depth of the beam and percentage of tension reinforcement of the same model were changed and eight different models were formed and analyzed in ABAQUS software. Comparative study between their results were made and the following conclusions were derived.

a) A variation of 17% has been found between experimental and FE model results in terms of deflection where as 6% variation was observed in terms of ultimate load.

b) All the beams showed linear response up to failure.

c) Large size beams (750 mm) failed at lower strain and their failure is relatively brittle than that of the beam of depth 400mm.

d) Ductility of deep beam decreases with increasing the percentage of tensile reinforcement.

e) Ultimate load increases with increasing the compressive strength and longitudinal steel bar ratio and decreases with increasing the shear span to depth ratio.

f) Shear strength increases with increasing the depth of the beam.

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