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LOAD DEFLECTION BEHAVIOUR OF RC BEAMS: NONLINEAR ANALYSIS

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ABSTRACT

Nonlinear analysis of longitudinally reinforced RC beams with and without transverse reinforcement is attempted in this study. Simply supported beams of effective span 0.9 m, 1.2 m, 1.5 m & 1.8 m were analyzed, using ANSYS software. Load deflection behavior and ultimate load of the beams were obtained based on analytical results. Parametric study was attempted by varying shear span to effective depth ratio 2.4, 3.2, 4 & 4.8.

Key words: finite element analysis, material nonlinearity, parametric study, shear span, ANSYS.

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1. INTRODUCTION

Behavior of beams can be studied by experiment or by finite element analysis. Finite element method, saves time and resources. A linear analysis is conducted as an initial study, however a better proximity to experimental result can be expected only from a nonlinear analysis.

Barbosa et al. (1998) [1] has reported practical application of nonlinear models in the analysis of reinforced concrete structures. Based on their studies they have reported that satisfactory results can be obtained from relatively simple and limited models. They have analyzed simply supported reinforced concrete beams subjected to uniformly distributed loading.

Oldrich et al. (2018) [2] did a comparison on the effect of the application of experimental parameters to parameters computed according to the Model Code. Influence of tensile strength and modulus of elasticity which is not available commonly were analyzed experimentally.

Marta et al. (2017) [3] observed the failure process of longitudinally reinforced rectangular beams and T beams of M35 grade of reinforcement ratio 0.9%,1.3% and 1.8%. They have reported that, beams of shear span to depth ratio a/d> 2.5 failed suddenly in shear, soon after the appearance of the diagonal crack. Whereas for the beams with a /d ratio < 2.5 diagonal cracks were formed symmetric on both the sides at the support zones. They have concluded that the cross-section does not affect the resistance of reinforced concrete members without stirrups.

Michelini et al. (2017) [4] compares the different types of numerical methods that can be used for the analysis of reinforced concrete beams. They have developed two new simplified numerical methods.

Badiger et al. (2014) [5] modeled beams in ANSYS and tested by four-point bending. They provided cushions near loading points and supports and used M30 concrete and Fe415 steel. Linear and nonlinear properties of the materials were provided. Solid65, Link180 and Solid180 were used for modeling concrete, steel and cushions respectively. They have concluded that the load carrying capacity increases with increase in depth of beam and stress concentration increases if cushions were not provided.

Chowdhury et al. (2017) [6] analyzed plain concrete and steel fiber reinforced concrete, cylinder specimens using ANSYS 10.0 and validated with experimental results and failure patterns. They found that the FE models show slightly conservative results when compared to experimental investigation. The stress concentration in the FE models for both compression and split tensile were at the same place of formation of the crack. The position of stress concentration has been reported to be the same in SFRC specimen, but load carrying capacity is reported to be higher compared to plain concrete.

In the present study, nonlinear analysis of longitudinally reinforced RC beams with and without transverse reinforcement, was attempted using the commercially available finite element software ANSYS. Simply supported beams of effective span 0.9 m, 1.2 m, 1.5 m and 1.8 m were modelled in ANSYS.

2. MODELLING

Modelling was done in ANSYS 16.0 Mechanical APDL. Concrete was meshed using SOLID65 elements, as shown in Fig. 1, and reinforcement using LINK 180 elements as shown in Fig. 2. The mesh size was given as 25mm. Uniaxial behavior of concrete was captured by the numerical expression proposed by Desayi and Krishnan (1965) [8] incorporating the modification proposed by Gere and Timoshenko (1997) [9] which is shown in Table 1.

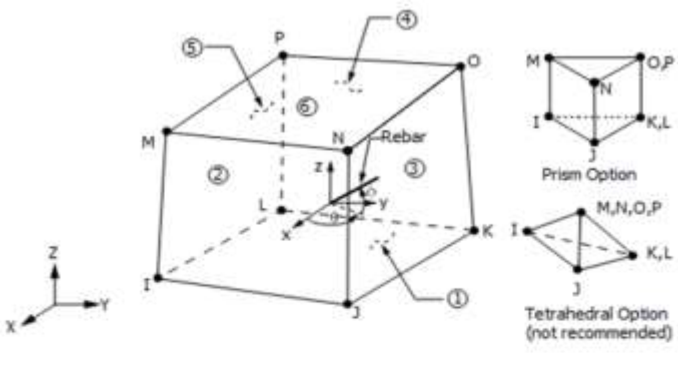

Figure 1 SOLID 65 (ANSYS Manual [7])

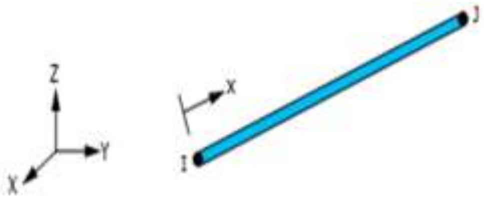

Figure 2 LINK 180 (ANSYS Manual [7])

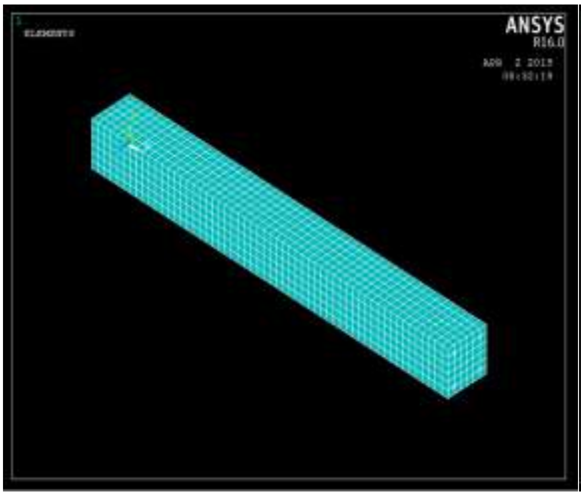

Figure 3: Model of the beam after meshing

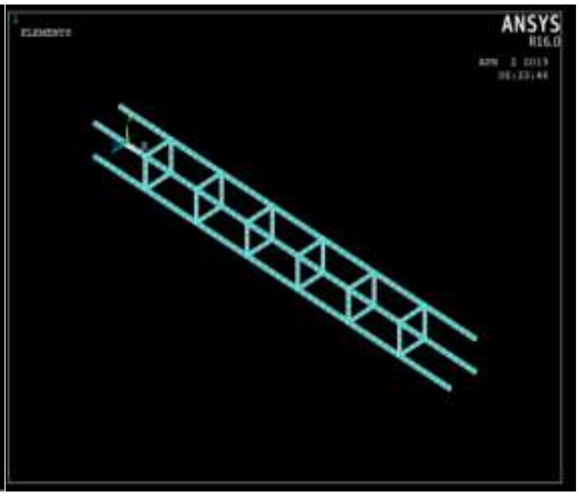

Figure 4: Model of the reinforcement cage

Table 1 Stress-Strain Values [9]

Points	M20	
	Stress	Strain
1	0.00083	4.02
2	0.000275	6.01
3	0.0005	10.37
4	0.0010	17.04
5	0.0012	18.51
6	0.0014	19.42
7	0.0016	19.89
8	0.0020	20
9	0.0035	20

Simply supported beams of length 1m, 1.4m, 1.7m and 2m were modelled with effective span 0.9m, 1.2m, 1.5m and 1.8m respectively. One set was modelled with stirrup and another set without stirrups Fig. 3 and Fig. 4 shows the model developed in ANSYS.

Two-point loading was applied on all the beams. The loading was given as stepwise loading so that the failure load could be identified. The step size was reduced after finding the approximate failure range, this reduction is done till the difference between each step is reduced to 1KN or lesser

The total load applied in the beam was divided into a series of smaller loads in an increasing manner. For updating the model stiffness the ANSYS program uses Newton Raphson Equilibrium iterations. The convergence criteria are based on the displacement and force for the reinforced concrete solid elements. The ANSYS program initially selects the convergence tolerance limits. This value was increased for the solution to converge. Load step size was decreased in each iteration, in order to get the load.

3. RESULTS AND DISCUSSIONS

Total of 8 beams were modeled which was a combination of 4 pairs with varying effective length (0.9m, 1.2m, 1.5m and 1.8m) with and without stirrups. Percentage reinforcement (0.69%) was kept the same for all the beams and area of cross-section 150mm x 150mm.

The shear span to effective depth ratio of the beam is varied from 2.4 to 3.2, 4 and 4.8 respectively. The failure load, deflection and the shear stress are also obtained for each of the beams having varying effective length and the beams with and without stirrups. The analytical results obtained is shown in Table 2.

Table 2 Output from ANSYS

Span		Failure Load (kN)	u_y (mm)	s_{xy} (MPa)
0.9m	Without stirrups	141.5	14.77	4.562
	With stirrups	154.65	14.55	6.349
1.2m	Without stirrups	75.8	12.76	5.267
	With stirrups	108.3	12.58	7.045
1.5m	Without stirrups	72.5	9.03	5.968
	With stirrups	96.3	8.88	7.65
1.8m	Without stirrups	70.5	6.42	6.325
	With stirrups	86.8	6.204	7.846

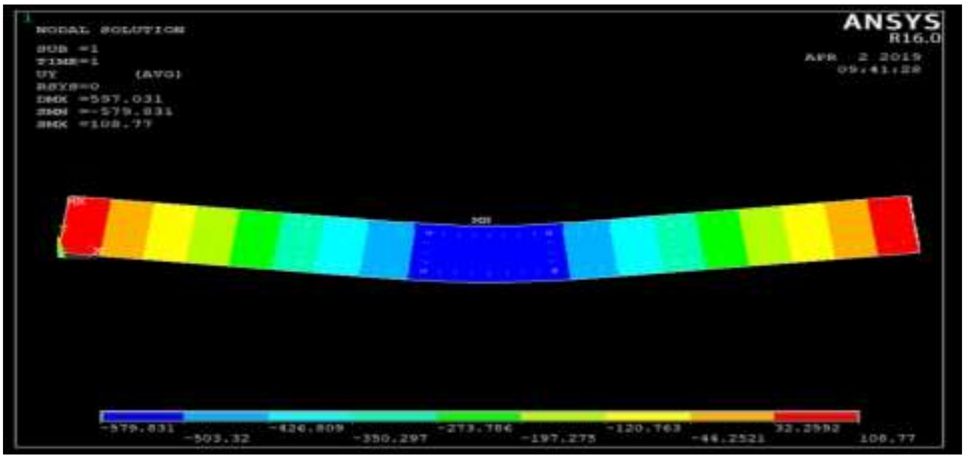

Figure 5 Plot for vertical deflection in beam of span 0.9m

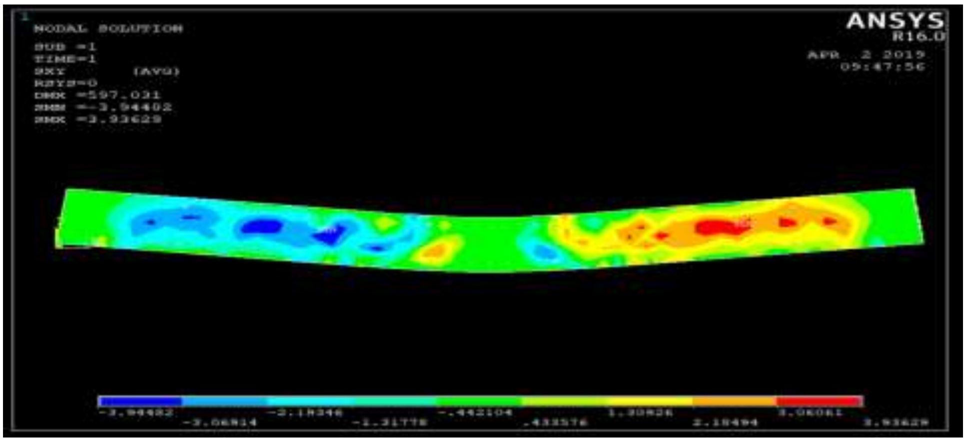

Figure 6 Plot for shear stress in beam of span 0.9m

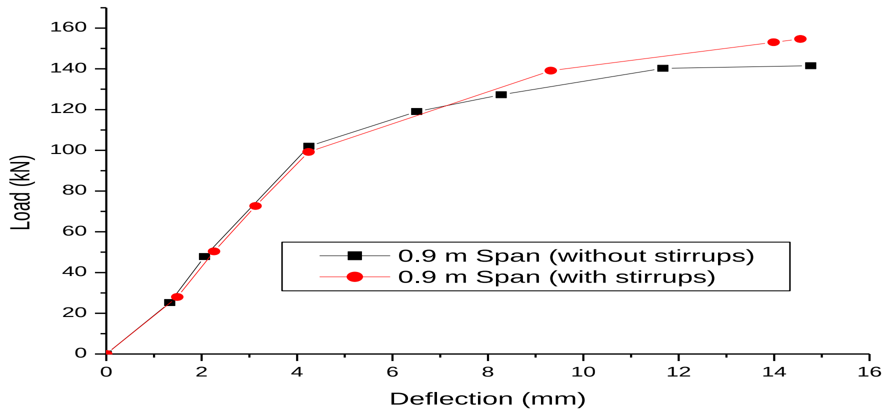

Figure 7 Load deflection in beam of span 0.9 m

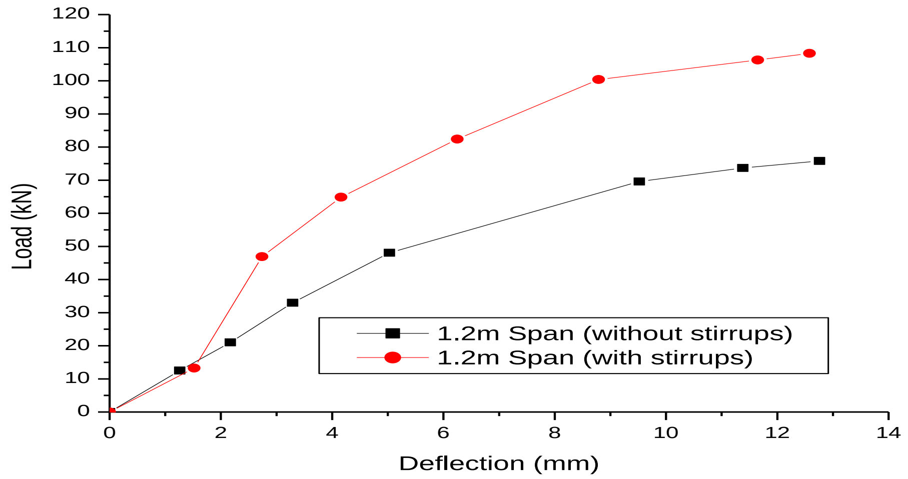

Figure 8 Load deflection in beam of span 1.2 m

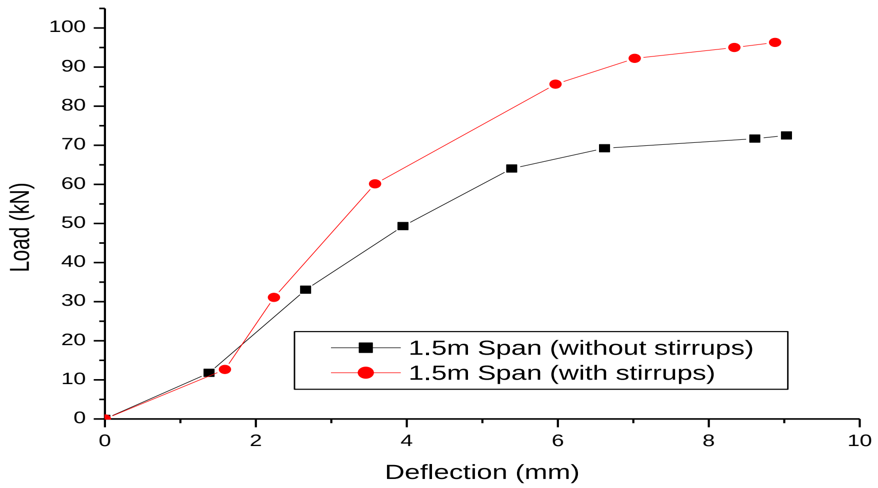

Figure 9 Load deflection in beam of span 1.5 m

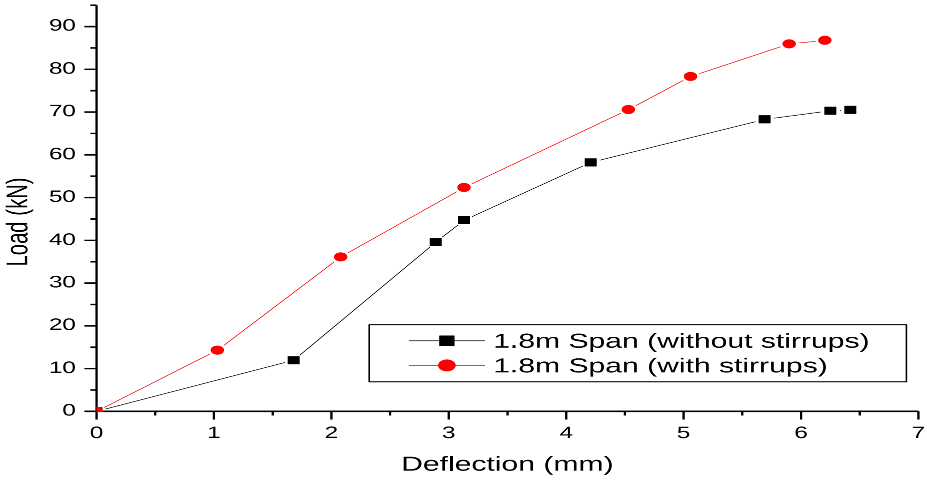

Figure 10 Load deflection in beam of span 1.8 m

4. CONCLUSION

- For beams without stirrups, the failure load decreased by 47%, 49% and 50% when the effective span was increased from 0.9m to 1.2m, 1.5m, and 1.8m respectively and for beams with stirrups the failure load decreased 30%, 38% and 44% respectively.
- For beams without stirrups, the deflection in the y-direction decreased by 15%, 39% and 57% when the effective span was increased from 0.9m to 1.2m, 1.5m, and 1.8m respectively and for beams with stirrups deflection in the y-direction decreased by 14%, 39% and 57% respectively.
- For beams without stirrups, the shear stress increased by 15%, 31% and 39% when the effective span was increased from 0.9m to 1.2m, 1.5m, and 1.8m respectively and for beams with stirrups the shear stress increased by 11 %, 20% and 24% respectively.

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