

# **Experimental and Analytical Investigation of Structural Behaviour of Fe500 Grade of Steel as Per Limit State Method**

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**ABSTRACT:** The Structural Concrete at present used normally resist high compressive forces but is brittle and is weak in tension. In order to increase the tensile strength of concrete various grades of steel like Fe415 are used. The objective of the present investigation is to evaluate the structural behaviour of Fe500 as an alternate material for durable concrete as per codal provision by using limits state method. The structural behaviour of Fe500 is evaluated in terms of deflection, flexural strength, cracks and bond strength are designed by various grades of concrete Viz M30, M35 and M40.

Finite Element based model have becomes progressively popular and are considered to afford the closest approximation of actual behavior of the structure along with finite element models. For Getting the Accuracy of the results Beam models are created by using Finite element software ANSYS. The experimental and Theoretical calculation are carried out by as per IS 456-2000 codal provision.

The Final results of experimental and Theoretical calculation are compared with the Finite element analysis. The final results shows the Suitable grade of concrete for Fe500 grade of steel. The Structural behavior of Rcc beam are also analysed and discussed.

**KEYWORDS:** Fe500, Grades of concrete, Cracking moment, Structural behavior, Beam model, Bond strength, ANSYS

## **I. INTRODUCTION**

Engineers are Endure with increasing levels of ageing infrastructure which has, in turn, led them to implement new materials and techniques to efficiently combat this problem. For a variety of reasons such as ageing, fire, environmental degradation and overloading, reinforced concrete, steel may be found to be structurally inadequate. The New Materials is use Fe500 grade of steel in Rcc beam with various grade of concrete (M30, M35 & M40). The reinforcement steel bars used in RCC (Reinforced Cement Concrete) are designated as Fe500 depending on their Yield Strength.

Idealization of reinforcement in concrete, constitutive properties of concrete, mesh density, amalgamation of boundary conditions for supports and symmetric planes, modelling of loading and support regions, effect of shear reinforcement on flexural behavior, effect of convergence criteria, impact of percentage of reinforcement and other parameters which governs the analysis are considered for the present study. The FE analysis was carried out using IS 456: 2000 guidelines for material modelling of concrete and steel. The critical values of the test and FEA results, such as initial cracking, Bond strength, Deflection, cover depth were compared with calculated values as per IS 456: 2000 codal provisions. To calculate theoretically for flexural strength, ultimate load, ultimate moment resistance, crack width,

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shear crack, Deflection at mid-point, Deflection at cracking moment, Shear force, and Bond strength as per limit state method given in IS 456:2000. In this experimental approach the beams are casted manually and tested with hydraulic jack. Three numbers of specimens were casted. The inside of the mould was oiled to prevent adhesion of concrete. First aggregate and cement are well mixed and then water is added to have a uniform mixture of concrete. All the specimens are filled with concrete and are well compacted. The specimens are demoulded after one day and then placed in a curing tank for 28 days of curing. For 12 hours prior to the testing, the specimens are allowed to air dry in the laboratory. Two point load setup is arrangement in the laboratory. After air drying of casted beam to mark a grid at the size of 50mm.

The deflection of the structural beam is calculated by using deflectometer and cracking of the beam is investigated by visual eye and measured with Crack Width Gauge, first shear crack, diagonal crack, ultimate load and pull out is noted.

Finite Element Method (FEM) is a numerical method for solving a differential or integral equation. It has been applied to a number of physical problems, where the governing differential equations are available. The method essentially consists of assuming the piecewise continuous function for the solution and obtaining the parameters of the functions in a manner that reduces the error in the solution. In this article, a brief introduction to finite element method is provided. The method is illustrated with the help of the plane stress and plane strain formulation. The analysis of structural beam is analyzed by using finite element software ANSYS. Fig a shows the procedure for computational methods.

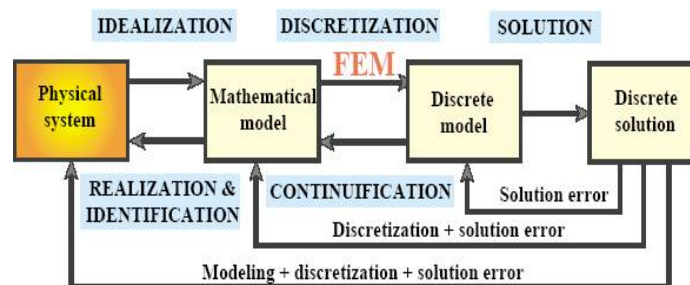


Fig a: Computational Methods

The flexural strength, ultimate load, ultimate moment resistance, crack width, shear crack, Deflection at mid-point, Deflection at cracking moment, and Shear force between steel and concrete are analyzed by ANSYS.

## II. RESULTS AND DISCUSSION

TABLE: 1 AREA OF REINFORCEMENT

Grade of Concrete, $f_{ck}$	M30		M35		M40	
Grade of steel, $f_y$	Fe500	Fe415	Fe500	Fe415	Fe500	Fe415
Area of Reinforcement used, $mm^2$	201.061	226.19	235.61	285.87	276.45	304.69

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TABLE: 2 CALCULATION OF THEORETICAL APPROACH FOR VARIOUS GRADE OF CONCRETE

Grade of concrete, fck	M30		M35		M40	
Grade of steel, fy	Fe500	Fe415	Fe500	Fe415	Fe500	Fe415
Breadth b, mm	150	150	150	150	150	150
Y <sub>t</sub> or x, mm	39.85	41.71	40.97	45.52	42.28	47.61
Breadth & overall depth, (a & h), mm	150	150	150	150	150	150
Effective depth d, mm	121	119	120	120	119	119
Y <sub>c</sub> =(d-Y <sub>t</sub> ), mm	81.15	77.29	79.03	74.48	76.72	71.39
Grade of concrete, fck	M30		M35		M40	
Grade of steel, fy	Fe500	Fe415	Fe500	Fe415	Fe500	Fe415
Moment of inertia I= bd <sup>3</sup> /12, mm <sup>4</sup>	42.18x10 <sup>6</sup>		42.18x10 <sup>6</sup>		42.18x10 <sup>6</sup>	
Depth at centroid axis y = 0.5D in mm	75		75		75	
d <sup>2</sup>	14641	14161	14400		14161	
Length of penetration P, mm	100		100		100	
K = L/3 mm	300		300		300	
Tensile strength, N/mm <sup>2</sup> f <sub>cr</sub> = 0.7*fck <sup>0.5</sup>	3.83		4.141		4.427	
Young's modulus Ec = 5000 *fck <sup>0.5</sup>	27.38x10 <sup>3</sup>		29.58x10 <sup>3</sup>		31.62x10 <sup>3</sup>	
Ultimate Load w KN	58	53	63	63	70	70
Moment M <sub>u</sub> , N.mm	8.62x10 <sup>6</sup>	7.95x10 <sup>6</sup>	9.51x10 <sup>6</sup>	9.51x10 <sup>6</sup>	10.5x10 <sup>6</sup>	10.5x10 <sup>6</sup>
M <sub>u</sub> limit in N.mm	8.76x10 <sup>6</sup>	8.64x10 <sup>6</sup>	9.61x10 <sup>6</sup>	10.43x10 <sup>6</sup>	11.11x10 <sup>6</sup>	11.5x10 <sup>6</sup>
Flexural strength at tension σ <sub>t</sub> N/mm <sup>2</sup>	8.217	7.825	9.235	10.84	10.52	12.03
Flexural strength at compression σ <sub>c</sub> , N/mm <sup>2</sup>	16.73	14.56	17.70	17.74	19.09	18.03
Maximum Deflection, mm	1.29	1.18	1.30	1.30	1.35	1.35
Cracking moment M <sub>cr</sub> , N.mm	2.15x10 <sup>6</sup>		2.32x10 <sup>6</sup>		2.49x10 <sup>6</sup>	
Cracking load, KN	14.33		15.46		16.6	
Deflection at cracking load, mm	0.320		0.320		0.323	
Shear force V <sub>u</sub> , KN	28.5		31.5		35	
Spacing of Stirrups, mm	300		300		300	
Bond stress [τ <sub>bd</sub> , N/mm <sup>2</sup> as per IS 1786:2008	2.4	1.5	2.72	1.7	3.04	1.9
Bond strength in KN(minimum)	10	5.65	11	6.40	12	7.16
Crack width W <sub>cr</sub> , mm as per IS 456:2000 Annex F	0.030	0.028	0.032	0.036	0.034	0.036

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## CEMENT

Ordinary Portland cement 53 grade (IS: 12269-1987) was used throughout this study. The properties of cement are listed in table 3

Table: 3 Properties of Portland cement

Property	Test result	IS 12269:1987
Initial setting time	35 min	30min
Final setting time	190min	600min
Specific gravity	3.15	-
Consistency	33%	-

## FINE AGGREGATE

The fine aggregate used in this study is passed through sand sieve 4.75 mm for mechanical studies. This sand attained a fineness modulus of 2.81 and a specific gravity of 2.4. The absorption of fine aggregate was experimentally measured at 1% respectively.

## COARSE AGGREGATE

Coarse aggregate used in this study consist of crushed stone of size 20mm and below. The specific gravity of coarse aggregates are 2.71. This sand attained a fineness modulus of 4.56. Water absorption of coarse aggregates are 1.81% respectively.

Table: 4 Mix Design as per IS 20262:2009

Grade of concrete	CEMENT	Fine aggregate	Coarse aggregate	Water /cement	Super plasticizer
M30	1	1.54	1.54	0.45	-
M35	1	1.38	2.557	0.48	-
M40	1	1.49	2.883	0.45	1%

Table: 5 Test of steel

S.no	Diameter of steel In mm	Area of steel in mm <sup>2</sup>	Yield stress In N/mm <sup>2</sup>	% of elongation
1	10	78.5	515.92	6.289
2	10	78.5	505.031	5
3	12	113	509.73	10.25
4	12	113	517.699	8.75

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Table: 6 Experimental approach for various Grade of concrete

Grade of concrete, f <sub>ck</sub>	M30		M35		M40	
Grade of steel, f <sub>y</sub>	Fe500	Fe415	Fe500	Fe415	Fe500	Fe415
Breadth b, mm	150	150	150	150	150	150
Effective depth d, mm	121	119	120	120	119	119
Ultimate Load w KN (Average of 3 samples)	58	55	64	62	72	69
Moment M <sub>u</sub> , N.mm	8.7x10 <sup>6</sup>	8.25x10 <sup>6</sup>	9.6x10 <sup>6</sup>	9.3x10 <sup>6</sup>	10.8x10 <sup>6</sup>	10.35x10 <sup>6</sup>
Flexural strength at compression σ <sub>c</sub> , N/mm <sup>2</sup>	12	12.49	13.33	12.91	15.25	14.61
Maximum Deflection, mm	1.89	2.3	1.68	2.0	1.60	1.9
Cracking load, KN	13	12	15	14	17	15
Cracking moment M <sub>cr</sub> , N.mm	1.95x10 <sup>6</sup>	1.8x10 <sup>6</sup>	2.25x10 <sup>6</sup>	2.1x10 <sup>6</sup>	2.25x10 <sup>6</sup>	2.25x10 <sup>6</sup>
Deflection at cracking load, mm	0.36	0.38	0.34	0.35	0.30	0.31
Crack width W <sub>cr</sub> , mm as per IS 456:2000 Annex F	0.032	0.030	0.035	0.038	0.035	0.040
Bond strength in KN	60	58	65	60	72	65

## MODELLING

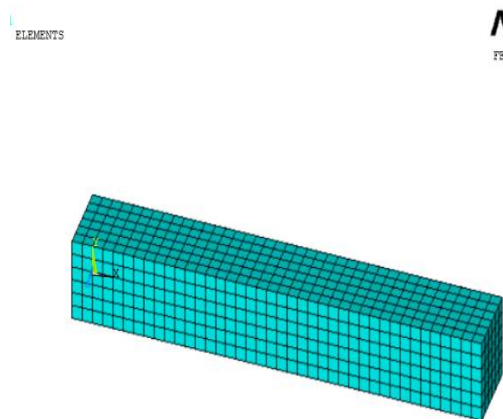


Fig a: Concrete modelling in ANSYS 12

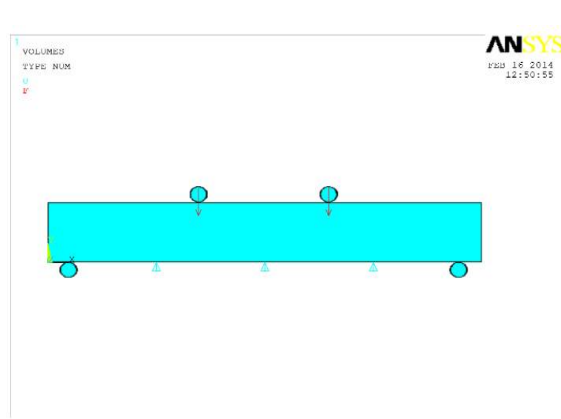


Fig b: Load system of RCC beam in ANSYS 12

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## ANSYS RESULTS For M30 Grade of Concrete

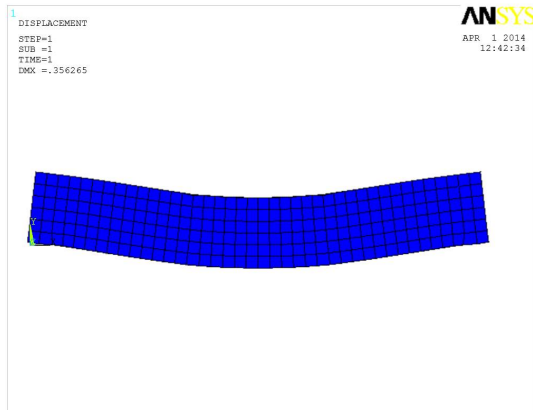


Fig a: Deflection for Fe415 Grade of steel

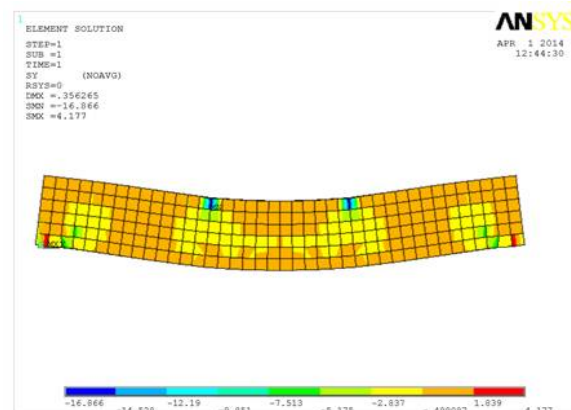


Fig b: Stress variation for Fe415 Grade of steel

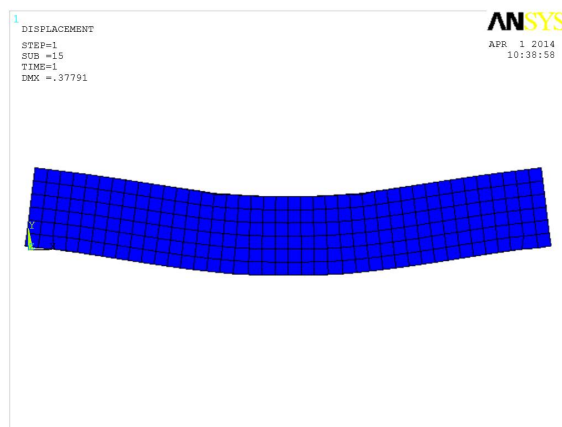


Fig c: Deflection for Fe500 Grade of steel

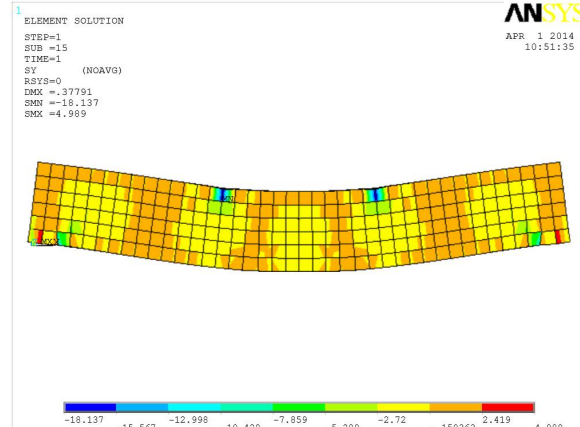


Fig d: Stress variation for Fe500 Grade of steel

## For M35 Grade of Concrete

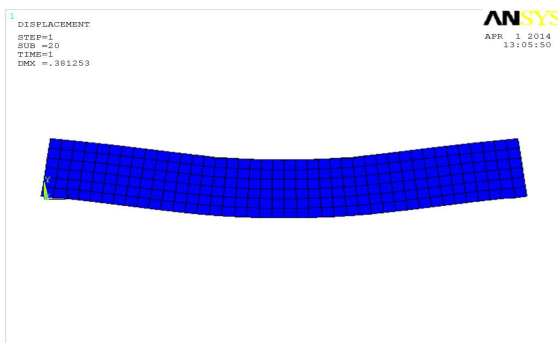


Fig a: Deflection for Fe415 Grade of steel

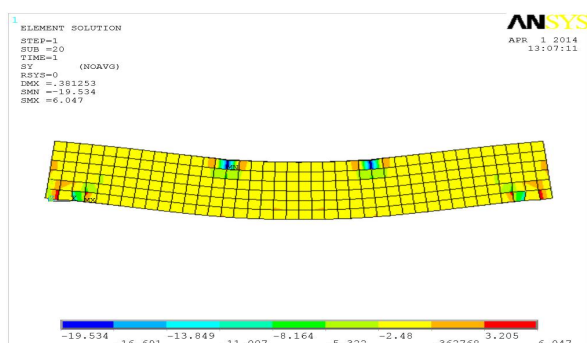


Fig b: Stress variation for Fe415 Grade of steel

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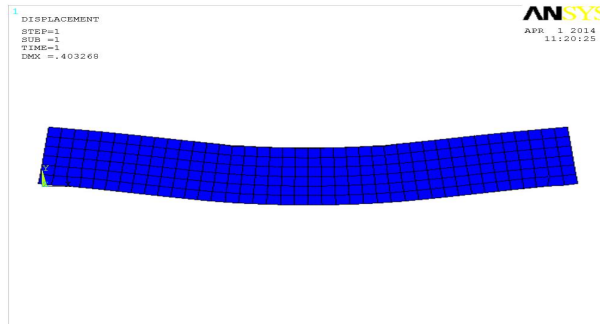


Fig c: Deflection for Fe500 Grade of steel

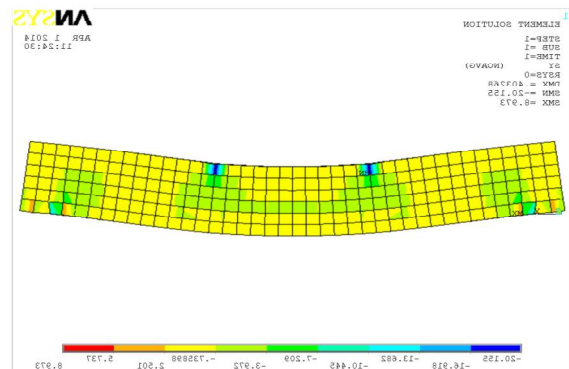


Fig d: Stress variation for Fe500 Grade of steel

## For M40 Grade of Concrete

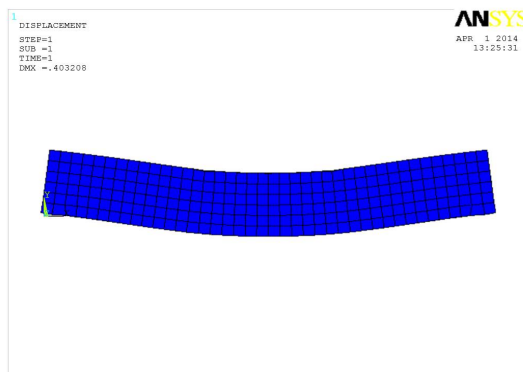


Fig a: Deflection for Fe415 Grade of steel

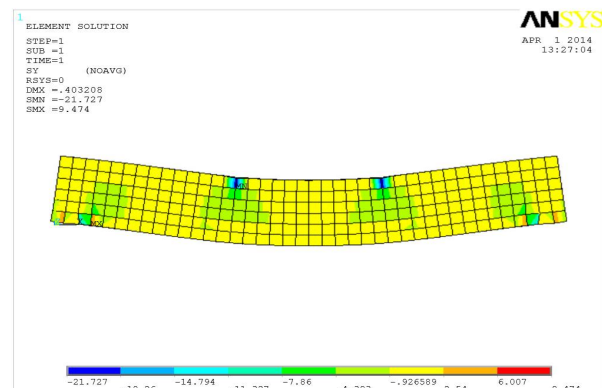


Fig b: Stress variation for Fe415 Grade of steel

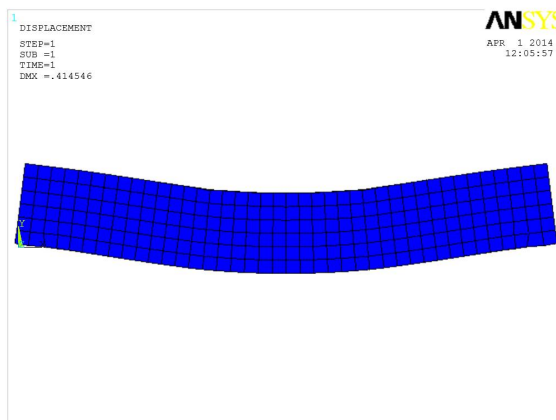


Fig c: Deflection for Fe500 Grade of steel

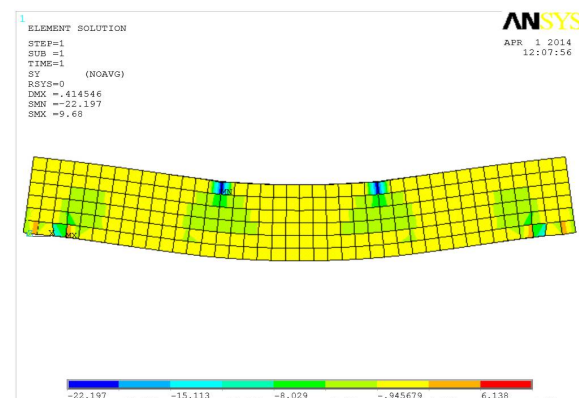


Fig d: Stress variation for Fe500 Grade of steel

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The figure a, b, c, d shows the stress ,deflection variation for different grade of concrete with different grade of steel. the values of stress,deflection are similar as per Experimental result.s

### III. CONCLUSION

The theoretical calculation, Experimental Results, Analytical results for various grade of steel and various grade of concrete are calculated,

- The Fe500 grade of steel used in concrete for various mix(M30,M35,M40) got similar results like cracking moment, Deflection, Flexural strength, obtained in Fe415 Grade of steel used in concrete for various mix(M30,M35,M40).
- The reinforcement area for Fe500 steel is less compare to Fe415 grade of steel. The bond strength is higher than Fe415 grade of steel.
- The ultimate load resistance is similar to Fe415 Grade of steel.
- The Fe500 grade of steel Economical compare to Fe415 grade of steel. To save 16-20% of cost compare to Fe415.

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