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Strength and Ductility of Tyre Rubber Concrete Columns

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ABSTRACT: This paper describes the results of short columns with different eccentricities. The response of columns was examined to probe the influence of rubber aggregate as a partial substitution of coarse aggregate in concrete.. The experimental outcomes were contrasted with the finite element model to evaluate the failure pattern of the test units. Columns with 5% rubber aggregate replacement ratio showed a similar load behaviour compared to conventional aggregate concrete. The ultimate load of columns made with 5% recycled rubber aggregate concrete could be complemented and used because of the similar response as that of columns made with conventional concrete .

Keywords: rubber concrete, recycled coarse aggregate, FEA

I. INTRODUCTION

India is a creating nation, it proposes multipurpose advancement ventures. Each spending proposition includes expansive development of streets, spans, dams, water system plans, general wellbeing designing plans, instructive structures and private structures and so forth all these development plans request ideal and effective utilization of development assets. The majority of the cutting edge overwhelming developments require gigantic amount of concrete brings about exhaustion of natural assets, for example, river sand and rock strata. This rising issue obliges contemporary material use to adjust the ecology. In this pith the bounteous accessibility of waste tyre rubber can be utilised as a powerful substitution for aggregate. Goulias et al. [1] test shows that rubber concrete samples displayed higher flexibility execution than ordinary concrete. Results indicated huge disfigurement without full deterioration of concrete. Chou et al. [2] shows the addition of rubber particles prompts the debasement of physical properties, especially, the compressive strength of the concrete. Chung et al. [3] presented that the compressive quality of rubber concrete was around 89 MPa and the Poisson's ratio ,was 5.5%.Eldin and Senouci [4] directed examinations to analyze the quality and durability of rubber concrete.

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The outcomes found that the example containing rubber when stacked in pressure shows increasingly slow failure.Fairburn and Larson [5] explored the utilization of concrete got from destroyed rubber from old tyres for restoring a pavement. It was found that the solid was more slip safe, exceptionally versatile, lighter in weight, and could be utilized for insulating and insulation.

Toutanji [6] discovered that the joining of the rubber chips in concrete made a decline in compressive quality of up to 75% and a basically a little lessening in flexural nature of up to 35%. The abatement in the two characteristics expanded with increment substitution of rubber aggregate. Concrete containing rubber aggregate demonstrated a ductile method of failure when contrasted from the control specimens.Gregory Grrick [7], demonstrated the examination of waste tyre altered concrete utilized 15% by volume of coarse aggregate when supplanted by waste tire as a two stage material as tyre fiber and chips scattered in solid blend. The outcome is that there is an expansion in sturdiness, plastic deformation, cracking and impact resistance. Be that as it may, the strength and stiffness of the rubber treated example were decreased. The control concrete broke down when peak load came while the TRAC had extensive deformation without deterioration because of the tyre particles. Schimizze [8] created two TRAC blends using fine rubber granulars in one blend and coarse rubber granulars in the other.Their results show a reduction in compressive nature of about 50% of the control blend. The elastic modulus of the blend containing coarse rubber granular was reduced to about 72% of that of the control blend, while the blend containing the fine rubber granular showed a diminishing in the elastic modulus to about 47% of that of the control blend. The decline in elastic modulus demonstrates higher flexibility, which may be viewed as a positive addition in rubber concrete .Topcu et al.[9] examined that, in spite of the fact that the strength had declined, the plastic limit showed improvement quite a lot. Khatib et al.[10] indicates that rubber content ought not surpass 20% of the total volume as it can serious decrease in strength. When the aggregate matrix contains non-traditional parts, for example, polymer added substances, fibers, iron slag, and other waste materials, unique arrangements would be required to structure and deliver these adjusted blends. Presently, no rules are there on the best way to incorporate tyre particles in concrete . Serge and Joekes[11] demonstrated that treatment with NaOH upgrades the bond of tyre rubber particles to cement paste, and mechanical properties, for example, flexural strength and fracture energy were improved with the utilization of tyre chips as addition rather than substitution for coarse aggregates. There was a decrease in compressive quality (33%) , which is less than previous literature.

Tantala et al. [12] explored that the toughness of TRAC blend with 10% rubber (2 to 6 mm) was less than that of TRAC with 5% rubber on account of the abatement in compressive strength. Raghavan et al [13] detailed that mortar examples with rubber shreds had the capacity to take extra burden after the application of peak load. Eldin and Senouci [4] exhibited that the failure containing rubber particles was progressive instead of brittle. Biel and Lee [14] detailed that concrete samples with 30, 45, and 60% supplanting of sand with rubber particles failed as a continuous shear which brought about a diagonal crack, though failure of control samples was dangerous, making samples break into a few segments. Goulias and Ali [1] found that rigidity and dynamic modulus of elasticity diminished with larger quantity of rubber chips, demonstrating a less brittle material. Topcu and Avcular[15] recommended the utilization of rubber treated concrete in conditions where vibration damping is required . Similar perceptions were likewise made by Fattuhi and Clark [16]. Zhu [17] introduced the flexural sturdiness and impact resistance of steel fiber-strengthened light-weight concrete, and the outcomes demonstrate that the high compressive quality and density are attractive for good impact resistance of plain concrete and furthermore announced that the consolidation of steel filaments improved the impact resistance .Hernandez-olivares et al. [18] revealed that option of tyre rubber volume divisions up to 5% in a concrete framework did not yield a critical variation of the concrete mechanical properties. G.Senthi Kumaran et al. [19] showed that by including industrial waste products and admixtures as partial substitution of cement will help to make better quality of waste tyre rubber altered concrete. Nithiya.P and Portchejian G [20] claimed that compressive quality reduces with the level of substitution of crumb rubber increases. Split tensile strength diminishes at the limit of 25% when rubber replaces upto 10% in fine aggregate. Flexural quality of concrete increments when rubber scraps increments upto 10%. O Youssf et al. [21] proposed that his model can help structural planners who are thinking about utilizing CRC(crumb rubber concrete) as a promising option in contrast to customary concrete in seismic zones. R.Bharathi Murugan, Dr. C. Natarajan [22] proposed that 15% rubber substance is to be considered as the ideal replacement amount ,though the compressive quality of concrete is decreased, it has couple of alluring attributes, for example, low density, high flexural quality and high durability. Hanbing Liu et al. [23] demonstrated that by including pieces of rubber into concrete brought about a huge lessening of the mechanical properties, however expanded the durability .Senthil Vadivel et al.[24] is mainly concerned with strength ,ductility ,deflection and durability of Tyre Rubber Aggregate Concrete (TRAC).With beams ,pure bending tests were performed which showed that rubber reinforced concrete is providing better ductility character than that of conventional concrete.

The past examinations have demonstrated that with the incorporation of rubber aggregate in concrete as a full or partial substitution for natural aggregates lessens the compressive quality. Investigations likewise demonstrate that the mechanical quality of tyre rubber aggregate concrete (TRAC) is enormously influenced by the size, extent and surface of the rubber and the kind of cement utilized .This quality decrease can be normal essentially on the grounds that rubber aggregate is a lot gentler (flexibly deformable) than the encompassing cement paste. Also, the holding between the rubber and the cement is probably going to be frail, so delicate that rubber might be seen as voids in the solid blend. It has additionally been perceived that, the quality of concrete incredibly relies on the thickness, size and hardness of the aggregates. Further there is no particular writing found to analyse the ultimate load carrying capacity, ductility and deflection of Reinforced Cement Concrete Columns made of TRAC. In fact, the exploration centre around waste tyre as material itself is in early stage. Barely there is no writing accessible in the territory of structural application. In these conditions it is critical to find the important properties of tyre rubber aggregate concrete columns to improve its essential structural applications in construction development. The conceivable outcomes incorporate effect of load eccentricity , load curvature, strength , deflections , moment interaction diagram improved section ductility.

II. EXPERIMENTAL STUDY

A. Mix Design (as per IS 10262 – 2009)

In light of the trial mixes the final design mix was set up for M25 grade of concrete as appeared in table 1.1.

Table 1.1 Mix proportions

S.NO	MATERIALS	PROPORTIONS (kg/m^3)		
		SC(WITHOUT ADMIXTURE) kg/m^3	SC(WITH ADMIXTURE) kg/m^3	SGR0 kg/m^3
1	CEMENT	425.73	383.16	252.89
2	FINE AGGREGATE	804.84	841.66	812.87
3	COARSE AGGREGATE	996.36	1041.95	1006.3
4	GGBS	0	0	168.59
5	SILICA	0	0	19.16
6	GLENIUM	0	1.92	1.92
7	WATER	191.58	172.42	172.42
WATER/CEMENT RATIO		0.45	0.45	0.39
MIX RATIO		1 : 1.89 : 2.34	1 : 2.20 : 2.72	1 : 1.85 : 2.28

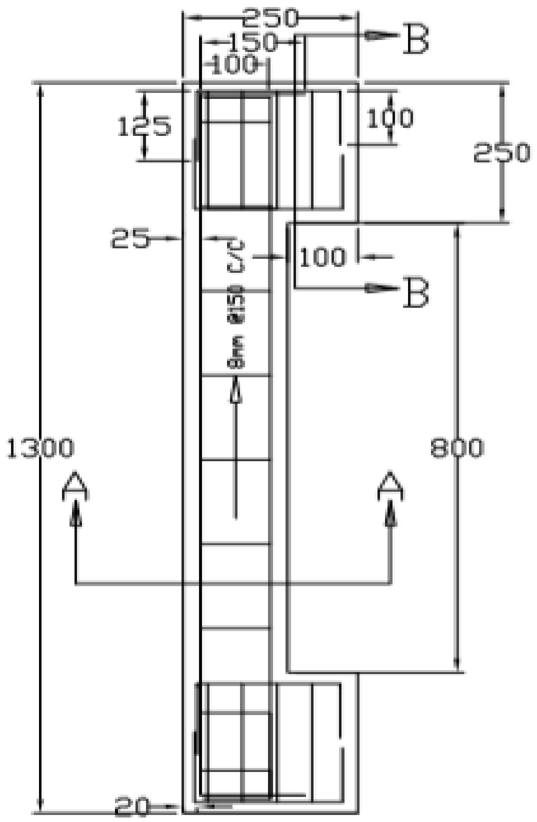
The general behaviour of reinforced concrete columns with and without rubber under axial and eccentric loads is discussed in detail in this research. The columns reinforced with steel bars were designed as per IS 456:2000 based on the assumed dimensions to fit the laboratory and testing facility. 18 column specimens comprising of 9 (SC) controlled columns, 9 (SGR5) columns with addition of extra silica by 5% weight of cement and with 40% replacement by weight of cement with GGBS and 5 % by volume of coarse aggregate is being substituted by tyre derived rubber aggregate (tda) with the addition of glenium admixture were casted and tested in ultimate load with different eccentricities of 0 (axial) , 25 and 50 mm after 56days of curing.

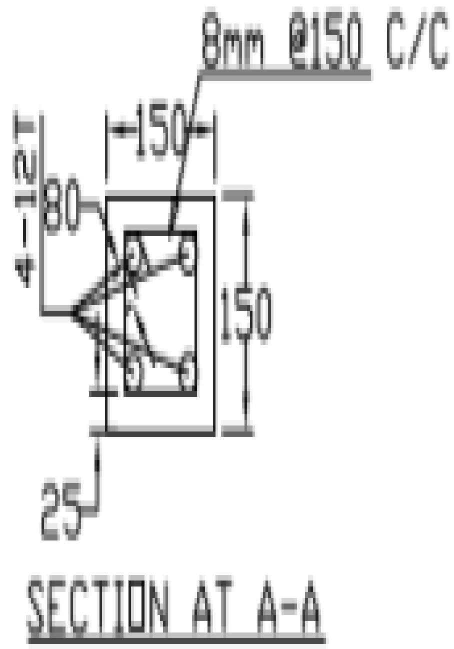
The geometry and reinforcement details of column specimens are shown in figure 1.1. The clear cover of the columns was 25mm. Every one of the specimens were loaded by a pressure driven testing machine. The compressive burden was connected at a pace of 6–8 kN/min and the failure of specimens accomplished inside 5–10 min. Two TML strain gauges were fixed at the mid range of the tension bar and compression bar and afterward secured utilizing covering tape to maintain a strategic distance from inadvertent harm during pouring of concrete.

Six strain gauges were likewise joined to the concrete surface at both front and back surfaces in the central region of the column and at the two beam column junctions to measure the strain at different depths. Linear Voltage Displacement Transducers (LVDT) was used for measuring deflections at mid span. Strain gauges and LVDTs as shown in figure 1.2, were associated with a data logger from which the readings were caught by a PC at each load interim until cracks of the segment happened. Every one of the members were set vertically and essentially simply supported along the depth direction of the columns by unidirectional knife-edge hinge supports, as appeared in Plate 1.1. Three specimens were cast and tested in every arrangement. The specimens were tested at 56th day from the date of casting. The designation of specimen is given according to the nature of material and the eccentricity of load applied and is shown in table 1.2.

Table 1.2 Designation of column specimens

SPECIMEN CODE	NO OF SAMPLES	ECCENTRICITY e (mm)	MIX DESIGN CONDITION
C0	3	0	SC
C25	3	25	
C50	3	50	
R0	3	0	SGR5
R25	3	25	
R50	3	50	





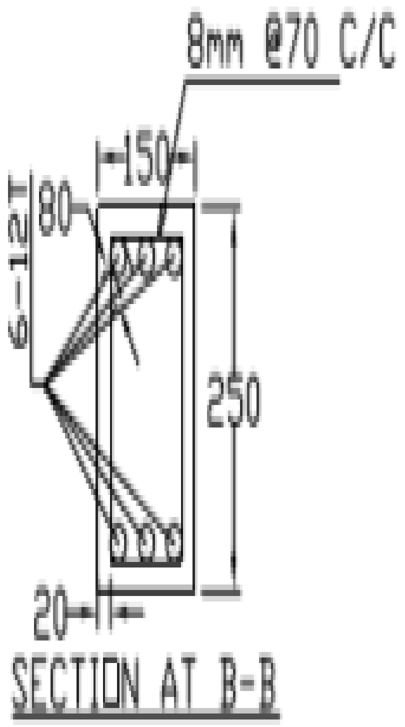
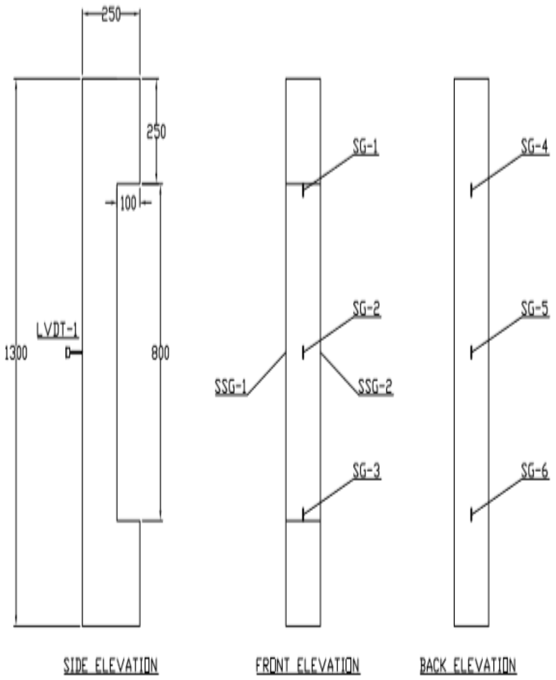


Figure 1.1: Geometry and reinforcement details of column specimens (9 Nos-SC & 9 Nos SGR5)



NOTES:-

SG-x	STRAIN GUAGE
SSG-x	STEEL STRAIN GUAGE
LVDT-x	LINEAR VARIABLE DIFFERENTIAL TRANSFORMER

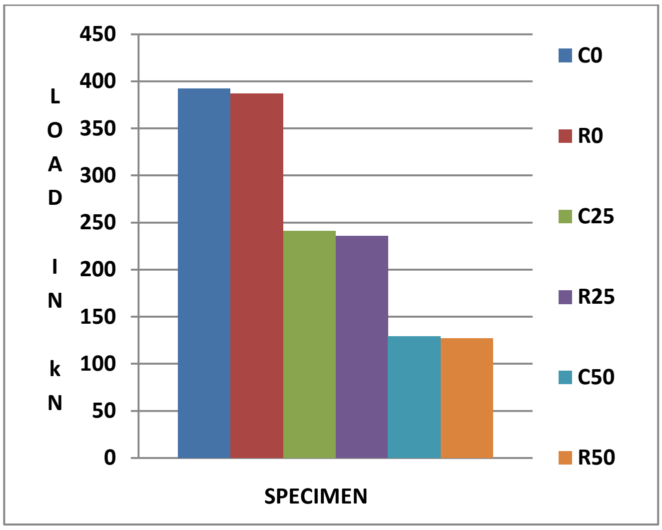
Figure 1.2 Position of LVDT's and Position of Strain gauge

Plate 1.1 Experimental set up for column specimens

III. RESULTS AND DISCUSSION

A. EFFECT OF LOAD ECCENTRICITY

As eccentricity of the applied loads is increased it is seen that load limit decreases and the mid height deformation increases. In terms of load the rubber concrete behaves more or less equivalent to that of concrete without rubber aggregates and in terms of deflection the rubber concrete shows more deflection than the conventional one though the ultimate load is almost the same which is shown in figure 1.3.



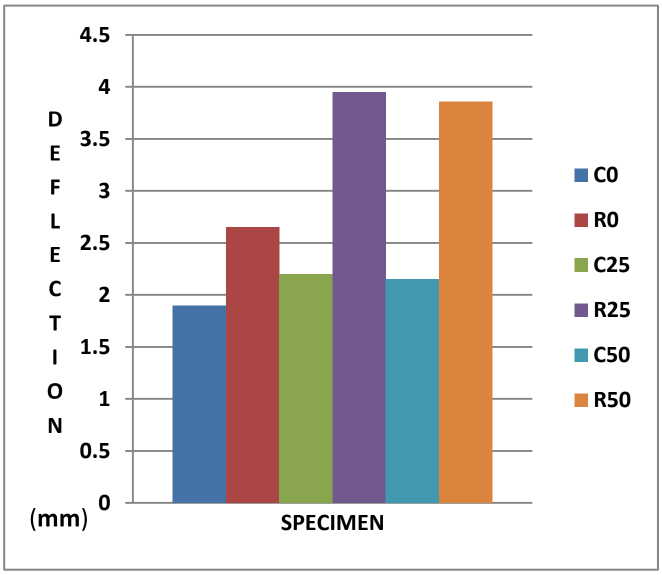


Figure 1.3 Ultimate Load & Mid Span Deflection of Columns

B. Load Moment Interaction Diagram and Load Curvature Diagram

Prediction of load and moment capacities from figure 1.4 , using interaction diagrams based on IS Code, is achieving relatively similar values as that of the code with a sensible safety factor to be utilized in structuring columns under eccentric loading. The rubber columns have more moment capacity and hence ductility than that of concrete columns. From the figure 1.5 , the curvature of the rubber columns improve greatly than those of the control columns. So the brittleness of rubber concrete is becoming less than that of conventional concrete.

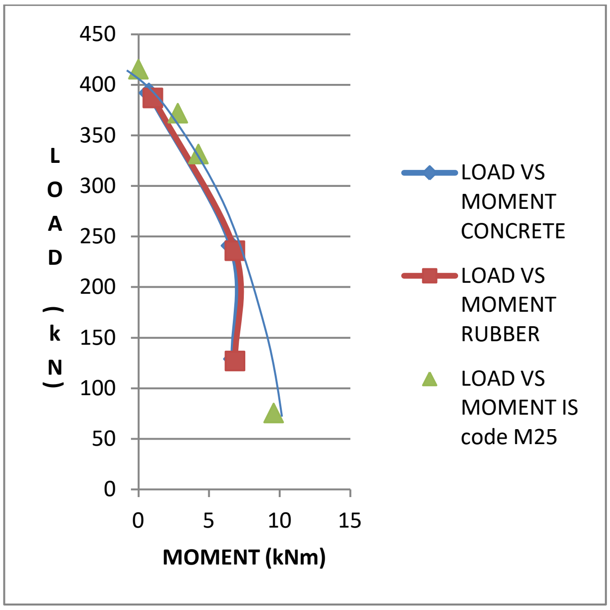


Figure 1.4 Load Moment Diagram

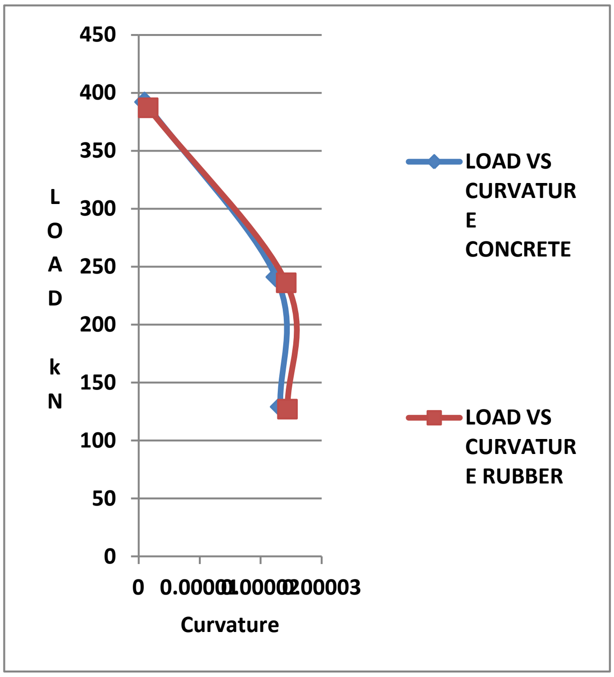


Figure 1.5 Load Curvature Diagram

C.Section Ductility

Section ductility is defined as the curvature at ultimate (ϕu) divided by the curvature at the first yield (ϕy). Here section ductility has been determined for the conventional concrete (SC) and for the rubber concrete (SGR5) from the data given in table 1.3 and from the moment vs curvature plot as given in figure 1.6 & figure 1.7.

Table 1 .3 Moment vs Curvature for Section Ductility of Conventional Concrete and Rubber Concrete

REMARKS	f (1/mm) (rubber)	M (kNm) (rubber)	f (1/mm) (concrete)	M (kNm) (concrete)
Start of loading	0	0	0	0
Just before cracking	3.46E-06	3.25	3.02E-06	3.1
Just after cracking	1.13E-05	3.25	1.06E-05	3.1
Concrete reaches 0.7 f_c	0.000024	6.89	2.33E-05	6.81
Nominal Strength	6.09E-05	8.44	6.21E-05	8.49

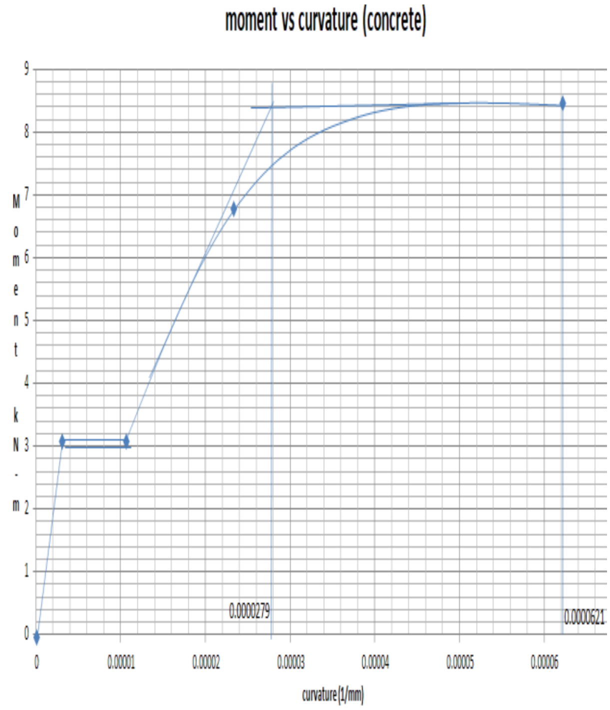


Figure 1.6 Moment vs Curvature for Section of Conventional Column

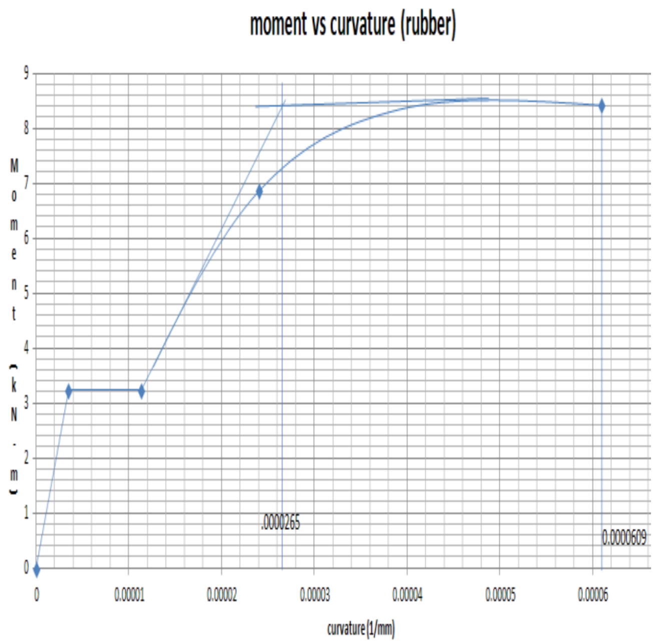
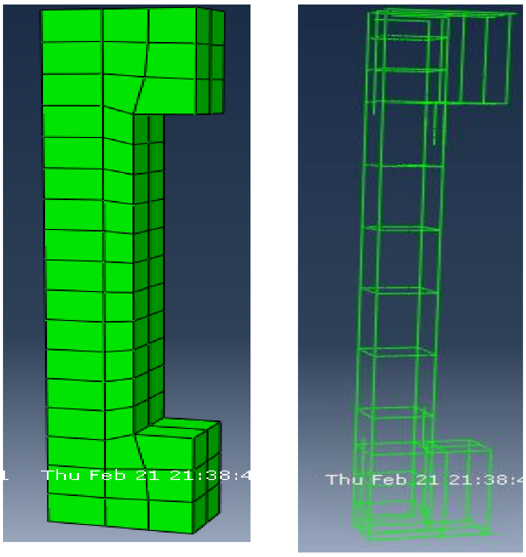


Figure 1.7 Moment vs Curvature for Section of Rubber Column

From the above table 1.3 and figures 1.6 & 1.7 we calculated section ductility of rubber concrete as 2.3 and section ductility of conventional concrete as 2.23. So there is an improvement of 2.70 % in section ductility and hence the rubber concrete may be considered as more ductile than that of conventional concrete.

D. Analysis of Reinforced Concrete Columns using Finite Element Technique

Finite Element Analysis (FEA) has been done by ABAQUS FEM to reenact the conduct of Reinforced Concrete (RC) columns with and without rubber under axial and eccentric loads. The modeled columns resembled the real column considered for experimental investigation as shown in plate 1.2.Stress strain values obtained experimentally for all specimens were given to vary the material property of controlled columns and columns with rubber. Displacement boundary conditions were allocated like the exploratory set up in order to compel the model to get a one of a kind arrangement. The support was modeled as a hinged support on top and bottom of column. The analysis type chosen was static. Using these models, ultimate load, load deflection, load strain of concrete columns and reinforcements under axial load and eccentric loads were tallied with the experimental results as shown in table 1.4.



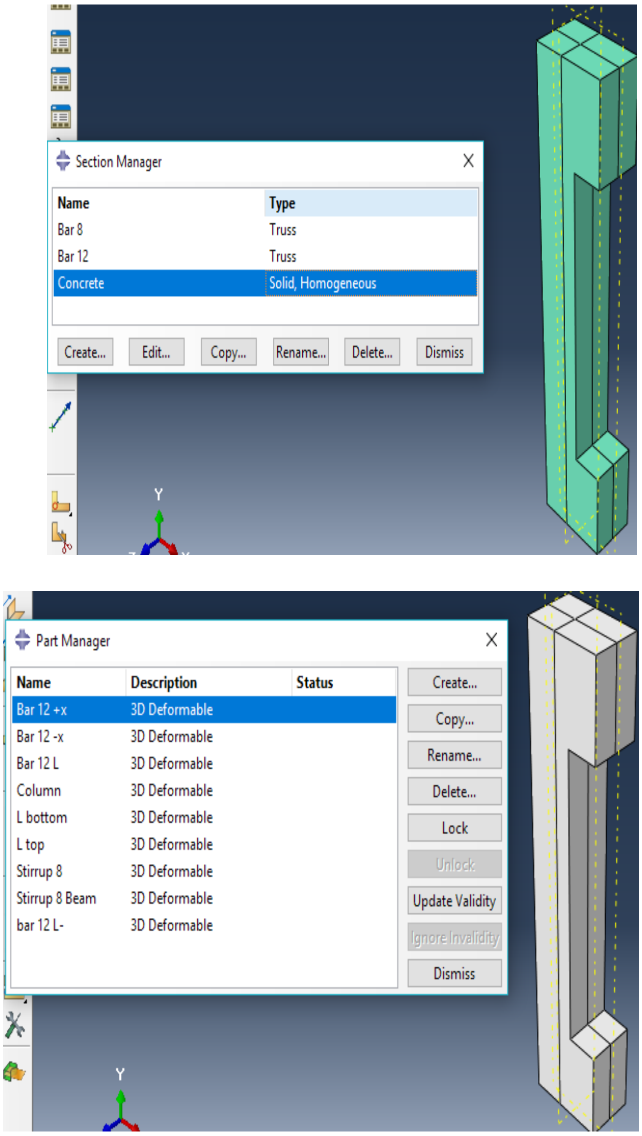


Plate 1.2 Column specimens modelled using ABAQUS with reinforcements

Table 1 .4 Expeimental vs Analytical results

PARAMETERS	SPECIMENS					
	SC			SGR5		
	C0	C25	C50	R0	R25	R50
ULTIMATE LOAD (KN, EXPERIMENTAL)	392	241	129	387	236	127
ULTIMATE LOAD (KN, THEORETICAL)	375	260	133	350	249	131
% DEVIATION (THEORITICAL FROM EXPERIMENTAL)	-4.33	7.88	3.1	-9.56	5.5	3.15
MAXIMUM DEFLECTION (MM, EXPERIMENTAL)	1.9	2.22	2.15	2.65	3.95	3.86

MAXIMUM DEFLECTION (MM, THEORETICAL)	**2.011**	**2.456**	**2.048**	**2.011**	**2.532**	**2.164**
% DEVIATION (THEORITICAL FROM EXPERIMENTAL)	**0.584**	**10.63**	**-4.74**	**-24.11**	**-35.89**	**-43.93**
MAXIMUM COMPRESSIVE STRAIN IN CONCRETE (EXPERIMENTAL)	**0.00122**	**0.001567**	**0.000636**	**0.00116**	**0.00116**	**0.00059**
MAXIMUM COMPRESSIVE STRAIN IN CONCRETE (THEORETICAL)	**0.00122**	**0.00129**	**0.00062**	**0.00123**	**0.00133**	**0.00066**
% DEVIATION (THEORITICAL FROM EXPERIMENTAL)	**0**	**-17.67**	**-2.52**	**6.03**	**14.65**	**11.86**
MAXIMUM COMPRESSIVE STRAIN IN STEEL (EXPERIMENTAL)	**0.00095**	**0.00099**	**0.0006**	**0.0011**	**0.000963**	**0.000752**
MAXIMUM COMPRESSIVE STRAIN IN STEEL (THEORETICAL)	**0.00113**	**0.00098**	**0.00071**	**0.00113**	**0.00101**	**0.00075**
% DEVIATION (THEORITICAL FROM EXPERIMENTAL)	**18.94**	**-1.01**	**18.33**	**2.73**	**4.88**	**-0.27**
MAXIMUM TENSILE STRAIN IN CONCRETE (EXPERIMENTAL)	**NA**	**0.000146**	**0.000198**	**NA**	**0.000127**	**0.0002045**
MAXIMUM TENSILE STRAIN IN CONCRETE (THEORETICAL)	**NA**	**0.000135**	**0.000184**	**NA**	**0.000136**	**0.000193**
% DEVIATION (THEORITICAL FROM EXPERIMENTAL)	**NA**	**-7.53**	**-7.07**	**NA**	**7.08**	**-5.623**
MAXIMUM TENSILE STRAIN IN STEEL (EXPERIMENTAL)	**NA**	**0.00025**	**0.000425**	**NA**	**0.000269**	**0.0003269**
MAXIMUM TENSILE STRAIN IN STEEL (THEORETICAL)	**NA**	**0.000274**	**0.00031**	**NA**	**0.000277**	**0.000327**
% DEVIATION (THEORITICAL FROM EXPERIMENTAL)	**NA**	**9.6**	**-27**	**NA**	**2.97**	**0.031**

From table 1.4, it is found that the results obtained from finite element examination additionally demonstrated great concurrence with the exploratory outcomes.

IV. CONCLUSION

The following conclusions of the test results can be produced using the different trials directed on the structural behaviour of rubber concrete -

1. Increasing load eccentricity prompts decline in column load limit , yet increment in mid height displacement at failure.
2. Systematic reenactments give awesome forecast of trial load limit , deflections , strains , and so forth with certain special cases.
3. Forecast of load moment capacities, utilizing interaction diagrams dependent on IS CODE strategy is achieving relatively more or less same values as that of experimental ones. 4.TDA as a lightweight aggregate in concrete would improve the section ductility of concrete by 2.7%.
5.It was found that TDA in the range of 5% can be used as an effective substitution for coarse aggregates.
6.From column failure pattern, it is observed that failure of all columns are brittle in nature and when the columns are failing due to compression the compressive strains in concrete is around 0.0015 and when the columns are failing due to tensile stress ,the tensile strain in concrete is around 0.0002.
7. The developed FEM by ABAQUS was capable of predicting the ultimate load, deflections , stresses and strains of concrete and steel which were almost at per with the experimental results. The experimental results showed close correlations when compared with those obtained from FEM analysis. So ABAQUS was a well handy tool for modelling the columns.

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