Buckling Behavior of Ecc Column Reinforced With Steel Bar

S.Abhilashdoss, G.Senthil Kumar, S.Manivel

Abstract*: *Engineered cementitious composite (ECC) is a type of high performance fiber reinforced concrete (FRC) with some good strain hardening behavior. This study deals with use of two different fibers, polyvinyl alcohol (PVA) and polypropylene (PP) fiber.PVA fiber is better than PP in terms of mechanical property. A total of 5 columns are prepared, one each of ECC with PVA fiber PVA(R/ECC), ECC with PP fiber PP(R/ECC), and one reinforced cement concrete (RC) column for comparisons. Rest of the two column deals with effective use of ECC in tension zone of the column PVA(R/ECC-RC) and PP(R/ECC-RC) i.e.in the top and the bottom (L/4) region, ECC is used and the centre (L/2) region is filled with RC. Same longitudinal reinforcement ratio was adopted for all the columns and columns were tested under eccentric compression. Due to eccentric compression RC column went through scaling and spalling process while this was not found in ECC columns due to fiber binding effect with cementitious material .Further more columns were analysed using finite element software ABAQUS to plot, Load versus Deformation curve, yielding pattern and stress distribution in the column .

Index Terms*: Column, ECC, finite element analysis(FEA), PVA fiber, PP fiber.

I. INTRODUCTION

Concrete being good in compression and weak in tension, it exhibits major concrete brittleness in the tension zone, so as an alternative to the concrete member ECC can be used having strain hardening more than 3%. ECC shows good behavior under compression, tension, ductility, but very minimal effort is being made in using ECC as a structural member. R/ECC is better than RC in terms of load carrying capacity, ductility, crack control ability and damage to tolerance[1]. Column is of mainly two types, short column fails by compression and long column fails by buckling. Slenderness ratio and load carrying capacity of column are both inversely proportional, i.e increase in slenderness ratio will result in decrease in the load carrying capacity of column. Use of high strength concrete was effective in case of short column and in long column increasing the reinforcement ratio led to more stable column

Compressive strength of ECC is almost similar to normal and high strength concrete ,but young's modulus value is less than RC due to absence of coarse aggregate[3].Use of ECC in the tension zone of the beam have been done by wen-jie ge[4] ,this study deals with filling ECC to the different thickness level in tension zone and finding the behavior of the beam. ECC being good in ductility ,effort has been made in using ECC at beam column joint giving rise to increase in load carrying capacity[5]. Concrete encased specimen exhibits brittle failure, sudden resistance drop after reaching its peak load such behavior disappeared when ECC was replaced by conventional concrete[6]. ECC is capable of resisting loads after the formation of minor cracks, this minor cracks have self healing ability if crack width is less than 60µm.There are many papers relating to ECC being used in a flexural member either has a part or has an entire member and in all the study ECC exhibits superior performance [7]–[11]

This study mainly focused on using ECC as a tension member. Fang yuan[1] have already used ECC as a compression member but in this study ECC is also being used in top and bottom [l/4] tension zone of the columns. For further verification purpose RC column was also prepared. In the end experimental results were compared with analytical results created using finite element analysis software ABAQUS.

II. EXPERIMENTAL INVESTIGATION

A. Material property

ECC involves use of cementitious materials in large content, but in preparation of cement large amount of carbon dioxide is emitted into earth so as an alternative to cement, fly ash has been replaced to a certain amount. Ordinary Portland cement grade 53 have been used .Fly ash is of class F and class C, for the purpose of ECC class F fly ash have excessively used . Class F fly ash is obtained from older and harder bituminous coal and lime content is very less in class F fly ash. Initially Manufactured sand was used as an alternative to River sand due to demand on river sand but optimum result was not obtained so River sand was used after sieving it through 2.36mm sieve. Potable water has been used for mixing purpose. Rest of the two materials are the key ingredients in ECC mixture proportion HRWR (high range water reducing admixtures) and fiber. Ceraplast300 is a HRWR used for reducing W/C ratio and to obtain ultimate strength in concrete.PVA and PP fibers are used in this mixture proportion. Bunchy monofilament type PVA of

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Table 1 : Ratio proportion

	Cement	Fly ash	Sand	Coarse aggregate	Water	HRWR%	Fiber%
ECC	1	1.2	0.8	-	0.55	1.2	2
RC	1	-	1.03	2.66	0.4	-	-

Table 2 : Mixture proportion in Kg/m^3

	Cement	Fly ash	Sand	Coarse aggregate	Water	HRWR%	Fiber%
ECC	590	705	470	-	325	7.08	Based on density
RC	450	-	466	1199	180	-	-

size 12mm and density 1.29g/cm^3 is used. PP fiber of size 6mm and density 0.92g/cm^3 is used.

B. Mixture preparation

Mixing of ECC is a tedious process due to absence of coarse aggregate and inclusion of fiber. Initially dry mix containing cement, fly ash, sand is allowed to mix in drum mixer for 1 minute. Next step involves taking superplasticizer separately and adding it with the water firmly. This is done to ensure about the full usage of superplasticizer and to reduce the water content level, required water content is poured in the mixture at regular interval allowing some time for material to mix properly. In the final step fibers are added to the mixture machine, fiber due to bunchy nature will bond together and will form ball mortar in the mixture machine

Fig 1 : ECC in mixer machine

Table 3 : Compressive strength of cube in N\mm^2

	7day	14day	28day
ECC-PVA	30	41	50
ECC-PP	27	36	45

Table 4 : split tensile strength of cylinder in N\mm^2

	7day	14day	28day
ECC-PVA	2.78	3.72	4.32
ECC-PP	2.62	3.6	4.09

C. Specimen preparation and test setup

Total of 5 columns have been prepared to be test under eccentric compression. The columns dimensions are breadth (b)-120mm, depth(d)-120mm,and length(l)-1500mm. Column design and detailing is done using[12], [13]. Longitudinal reinforcement is of 4 numbers of 12mm dia bars and 8mm stirrups are used @100mm c\c. All columns were tested under eccentricity of 20mm. Construction of PVA(R/ECC-RCC) and PP(R/ECC-RCC) column initially began by separating each zone with steel plate, followed by filling subsequent layer. After completion of casting process steel plates are removed from the mould

Column were tested under column testing frame of 500KN capacity. Some parts of column test setup are verified using Yan [6] Columns are attached with steel caps on both the edges to minimize edge failure on application of eccentric loading. Roller support is used for eccentric loading, keeping the roller at the centre of the loading frame and columns are aligned accordingly for eccentric loading. Deflection are noted by using defelctometer and it is found at middle of the column and at the axial deformation.

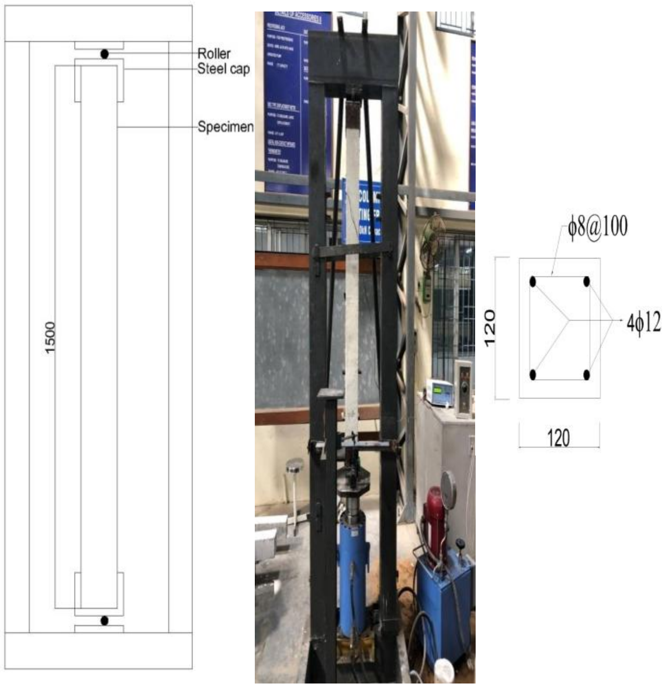


Fig 2 :Tested column details and test setup

III. ANALYTICAL STUDY

In recent research works experimental studies are cross verified using different finite element software. ABAQUS software is used for this analytical study. In general Behavior of material under application of load can be found by plotting load versus deformation curve. This study deals in finding yielding pattern, stress concentration, ultimate load of the column and Load versus Deformation curve

A. Material property

Property of each material is the important aspect because it is in direct proportion with analytical results so utmost care must be given while assigning the material property. Density of ECC is 1900Kg/m^3. Young's modulus value of ECC has been found by testing ECC cylinder in compression testing machine and finding out vertical and horizontal deflection. Stress and strain can be found with deflection values, with the help of all the above values young's modulus and poisson's ratio values of ECC is 29.98GPA and 0.15 respectively. Apart from above properties, concrete damage plasticity, yield stress and strain values were taken from S.B. singh.et.al., [14].

B. Analytical outcomes

After assigning material property next step involves assembling process. Instances are created separately and each instances are assembled using translate and rotation instances. ECC and reinforcement has a mixture of material, interaction should be done properly for the desired outcomes. Embedded constraints are used where reinforcement is the embedded region and concrete is the host region. Boundary condition (UR1=0,UR2=0,UR3=0) bottom end hinged and loads are applied at top end of the column. Boundary conditions for the slender columns are verified using[15] Loads were applied at eccentricity of 20mm from the centre. Global seeds were assigned to part instances created and corresponding instances were meshed. Mesh density and size were determined based on convergence study. Mesh size 10mm is used for column.

After the load being applied concrete starts to yield more at top and the bottom region very minimal yielding was seen in the centre part of the column.

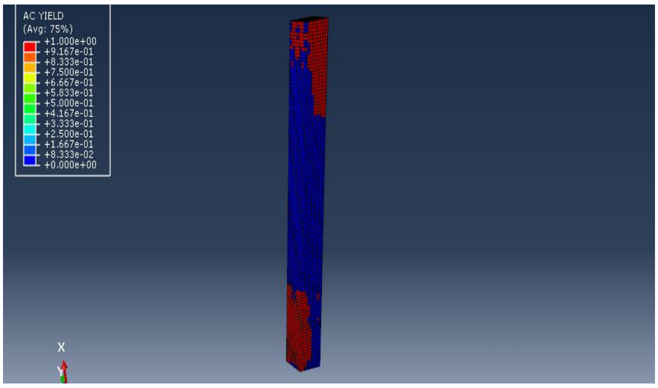


Fig. 3. Yielding pattern of PP(R/ECC-RCC) column

Stress pattern involves formation of More stress at the point of application of load. Tensile force were more in top region and compression force were more in the middle region of the column

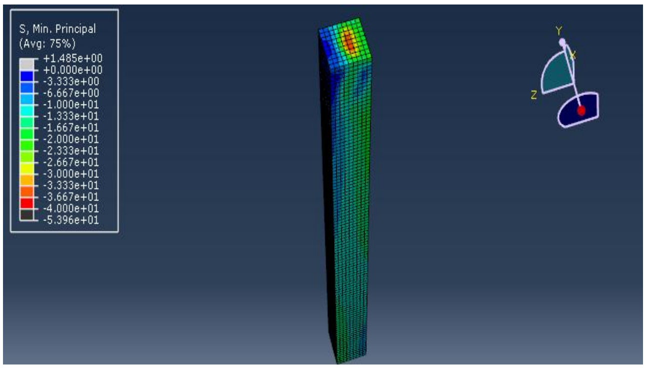


Fig. 4. Stress distribution in PVA(R/ECC-RC) column

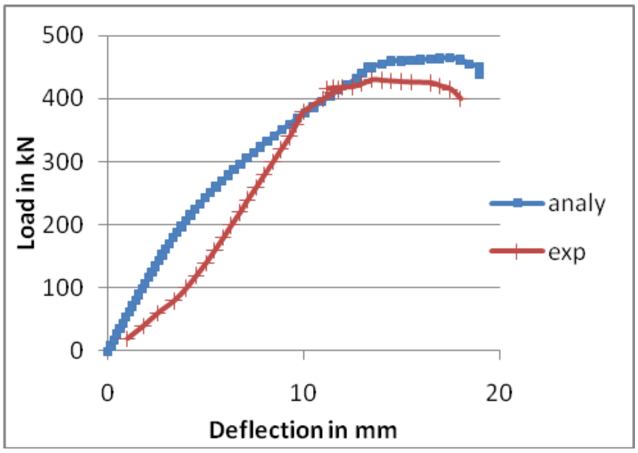
IV. RESULTS AND DISCUSSION

Failure modes of all columns tested under eccentric compression is shown in the fig 5. Due to eccentric compression column failure occurred in the top and bottom zones of the column. All columns failed by matrix crushing hence more crack patterns were seen in the tension zone of the column and very minor cracks in the compression zone

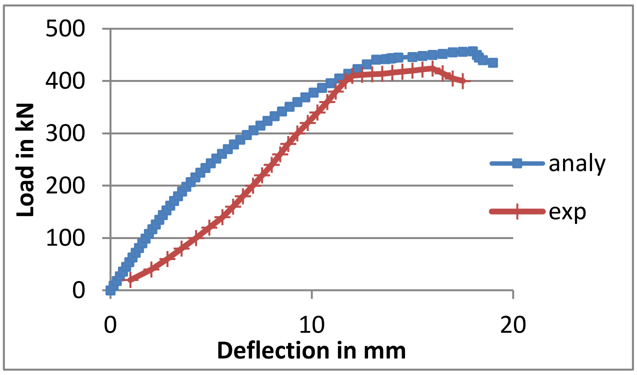
Fig.5. Crack pattern of column

Optimum 2% of fiber content was used, in case of fiber percentage more than two percent W/C ratio gets increased and workability issues arrived hence 2% of fiber quantity is adopted. Superplasticizer content should also fall within 1.2%, more than that would affect the fiber bridging effect hence bonding property might be affected. In general PVA, polypropylene, polyester, polyethylene fibers are used in ECC but in this study PVA and PP are adopted.

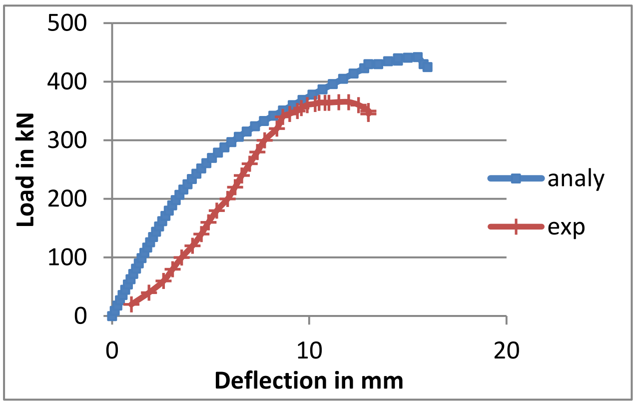
Fig 6 represents Load (KN) versus axial deformation (mm) for the columns. On application of load column deflects steadily till it reaches ultimate load. Following figures represents Load versus deformation curve for all tested columns both analytically and also experimentally



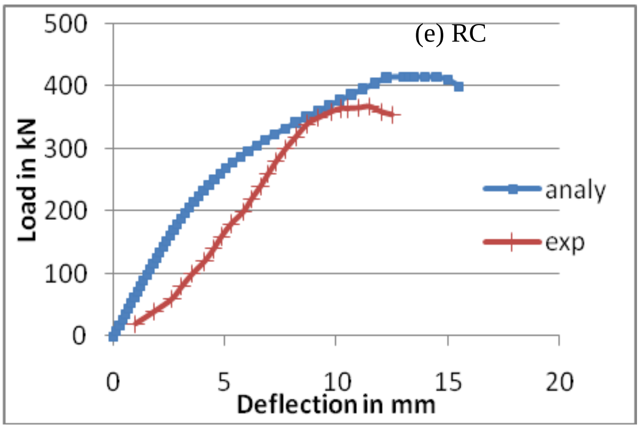
(a) PVA(R/ECC-RC)



(b) PP(R/ECC-RC)



(c) PVA(R/ECC)



(d) PP (R/ECC)

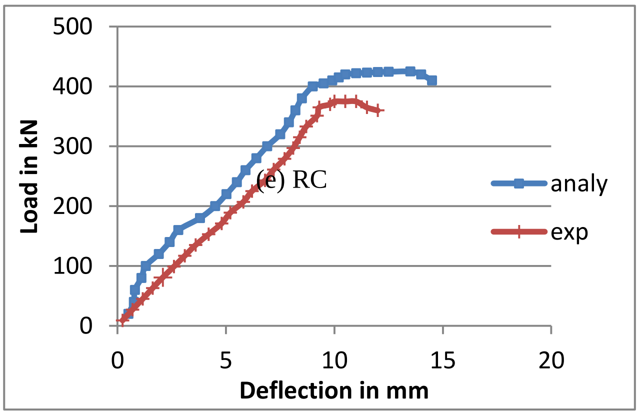


Fig 6 : Load versus Deformation curve

Use of PVA fiber in the ECC yields more compressive strength in the case of cubes and also in column because PVA fiber has good Modulus of elasticity, excellent tensile strength, molecular bonding property better than rest of the fibers. Table 5 illustrates ultimate load carrying capacity of each column (kN) both experimentally and analytically

Table 5 : Ultimate load of column in kN

	EXPERIMENTAL	ANALYTICAL
PVA(R/ECC-RC)	420	460
PP(R/ECC-RC)	400	450
PVA(R/ECC)	360	430
PP(R/ECC)	350	420
RC	345	410

V. CONCLUSION

Steel reinforced ECC and RC columns mechanical property has been briefly discussed in this study. Total of 5 columns have been prepared for eccentric compression. Experimental outcomes are verified with analytical results created using ABAQUS software. Following points are concluded from this study.

- PVA fiber is better than PP fiber in terms of load carrying capacity, split tensile strength, bonding property and modulus of elasticity
- Optimum mixture proportion should be adopted, fiber content not more than 2%and SP content not more than 1.2% should be used. Use of manufactured sand in ECC is also not appropriate .
- ECC due to excellent strain hardening behaviour is capable of withstanding load after formation of minor cracks, but this phenomenon was not observed in RC after crack formation, crack width gets increased and column load carrying capacity subsequently gets decreased.
- By using ECC in slender column, load carrying capacity gets increased without increasing longitudinal reinforcement ratio.
- Results suggest use of ECC in top and bottom tension zone gives better result than RCC and full ECC column.
- Due to fiber bonding effect with cementitious materials scaling and spalling of concrete can be avoided

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