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Experimental Study of Improvement in Confinement of Reinforced Concrete Column by Using Expanded Metal Mesh

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Abstract: ***Traditional steel ties reinforcement cannot provide superior confinement for reinforced concrete (RC) columns due to the constraints on tie spacing and disturbance of concrete continuity. This project presents a practical confinement configuration consisting of single Expanded Metal Mesh (EMM) layer in additional to regular tie reinforcement. The EMM layer is warped above ties. The proposed transverse reinforcement with various volumetric ratios of ties, was investigated in twelve square short RC column specimens categorized in two groups according to their slenderness ratios. The specimens were cast in vertical position simulating the construction field and they were tested under concentric compression till failure.***

The results indicated that the columns, confined with proposed lateral reinforcement, revealed significant improvement in the strength and ductility. Also, high reduction in ties volumetric ratio with no loss in ultimate load could be achieved by installing the EMM layer.

Keywords: RC Column, Confinement, Lateral ties, Expanded Metal Mesh, ANSYS

I. INTRODUCTION

Reinforced concrete (RC) is widely used for construction all over the world. Columns transfer the loads from beams and slabs to foundation. Columns support high compressive force sin mega structures such as long-span structures and tall buildings. Moreover, columns may suffer damage due to overloading and natural disasters such as earthquakes and fires because of the limited strength and ductility of concrete. Failure of one or more columns may lead to the collapse of the structure.

Column confinement to improve their structural performance can be applied using externally applied transverse reinforcement configurations such as jackets, collars, straps or wraps which can offset significant material and labour costs as well as the disruption of the use and operation of the structure.

Traditional steel ties reinforcement cannot provide superior confinement for reinforced concrete (RC) columns due to the constraints on tie spacing and disturbance of concrete continuity. This project presents a practical confinement configuration consisting of single Expanded Metal Mesh (EMM) layer in additional to regular tie reinforcement. The EMM layer is warped above ties.

II. TESTING PROGRAM

Twelve Square short (150x150mm) reinforced concrete column with height of 1100mm& 700mm were tested under axial compression in concrete technology laboratory in civil engineering department of PVPIT Budhgaon. The columns were divided into two groups according to with and without wire mesh with various volumetric ratios of ties as lateral reinforcement. Out of this 12 column specimen:

3 no. of column specimen of without EMM layer of height 1100mm.

3 no. of column specimen of with EMM layer of height 1100mm

3 no. of column specimen of without EMM layer of height 700mm.

3 no. of column specimen of with EMM layer of height 700mm

The dimensions, reinforcement details and classification of the tested 12 column specimens are given in Table 1and shown in Figure 1 (a) & (b).

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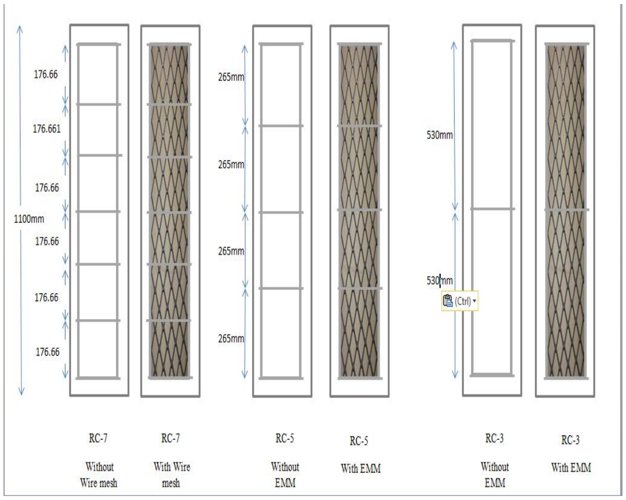

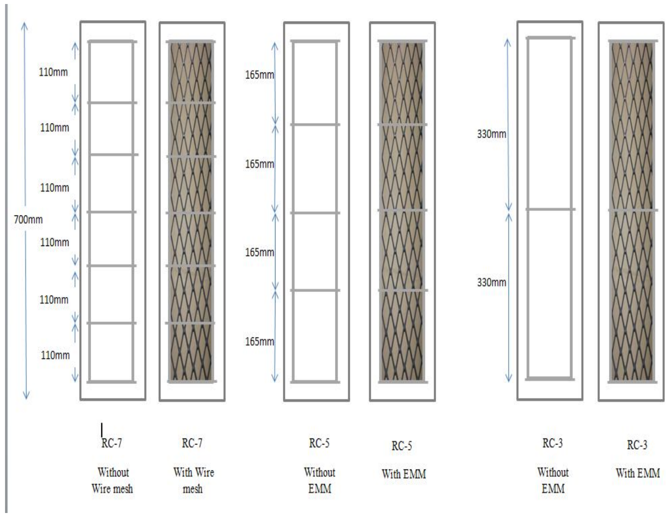

Figure 1 (a) details of with and without wire mesh Column specimens of height 1100 mm

Figure 1 (b) details of with and without wire column specimens of height 700 mm

Table 1: Details of tested column specimen with and without wire mesh

Group	Specimen ID	Height (mm)	Slenderness Ratio	Spacing between stirrups (mm)	Reinforcements			
					Vertical bars	Lateral Ties	Volumetric Ratio%	EMM Layer
1	RC-7	1100	7.33	176.66	4Ø10	7Ø6	0.8796	Without EMM
	RC-5			265		5Ø6	0.6283	Without EMM
	RC-3			530		3Ø6	0.1256	Without EMM
	RC-7	1100	7.33	176.66	4Ø10	7Ø6	0.8796	With EMM
	RC-5			265		5Ø6	0.6283	With EMM
	RC-3			530		3Ø6	0.1256	With EMM
2	RC-7	700	4.66	110	4Ø10	7Ø6	0.8796	Without EMM
	RC-5			165		5Ø6	0.6283	Without EMM
	RC-3			330		3Ø6	0.1256	Without EMM
	RC-7	700	4.66	110	4Ø10	7Ø6	0.8796	With EMM
	RC-5			165		5Ø6	0.6283	With EMM
	RC-3			330		3Ø6	0.1256	With EMM

A. *Material Properties*

The cement used in preparing the concrete mix is Portland cement of grade 53 MPa conforming is 8112:1989 43 grade ordinary Portland cement. Locally available gravel was sieved on the utilized EMM and then the past gravel was used as coarse aggregate in the concrete mix. The passed gravel is well graded with maximum size of 16 mm, specific gravity 2.7 and crushing value 19.20%. The fine aggregate is used in naturally available of medium sand with fineness modulus of 2.49, specific gravity of 2.55. Both coarse aggregate and fine aggregate conform the IS 383-1972 reaffirmed in 2002. The longitudinal reinforcement used in test specimen is grade of FE415 whereas the ties were formed from mild steel with grade of FE250. Longitudinal bar and lateral ties conform IS 1786-2008 and 432 (part 1)-1982 respectively. The mesh has diamond opening with size 18 x 36 mm and strand diameter of 1.25 mm. the specific gravity is 6.4.

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B. *Preparation of Column Specimen*

The column specimens were prepared according to the following procedure.

1) *Reinforcement:* Four vertical bars of 10mm where used for the vertical reinforcement. Length of each bar is 1.15m. Ties of 6mm diameter were added at both end of each column specimen to increases the confinement at column ends. One EMM layer was warped around the ties for each column specimen with regular lateral reinforcement. The EMM layer was secured by connecting it to the ties and longitudinal reinforcement using tying steel wire. Figure shows the some typical reinforcement cage of with and without EMM layer of RC Column specimen.

Figure 2: typical reinforcement cage of with and without EMM layer

2) *Special Timber Formwork Preparation:* Timber Plywood formwork with sizes of 15 x15 for height of 1100 mm as well as 700 mm were designed and manufactured to cast the concrete in vertical portion, similar to construct in field. Figure 3 shows the formwork. Concrete must pass from the core of column specimen through the diamond opening of EMM to form the cover without producing honeycomb and voids.

The formwork can easily assemble and separated to parts. Free isolated wooden pieces with size 15X 15 X 2.5 cm ware used to horizontally level the top and bottom edge of the column specimen. Oil (a release agent) was painted on the inner face of the formwork parts. Three sides (U shapes)were assembled in horizontal portion, the prepared reinforcement cage was carefully placed in the formwork, the fourth side was assembled, stiffener were added and the formwork was turned in vertical portion above horizontal timber base to be ready for casting concrete.

Figure 3: Special Timber Formwork

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3) *Mixing & Casting of RC Column Specimen:* Mixing of concrete should be done thoroughly to ensure that concrete of uniform quality is obtained. Electric mixing is done. A clean surface is needed for this purpose, such as a clean, even, paved surface or a wood platform having tight joints to prevent paste loss. Moisten the surface and level the platform, spread cement over the sand, and then spread the coarse aggregate over the cement. Turn the dry materials at least three times until the color of the mixture is uniform. Add water slowly while turn the mixture again at least three times, or until obtain the proper consistency. The fresh concrete was transferred by tray to formwork position and was poured vertically. Concrete was compacted by hand compaction method using tamping bars to provide good concrete without voids or honeycomb. Figure 4 shows the casting process.

Figure 4: Mixing and Casting of RC Column Specimen

4) *De-molding of Columns:* After 24 hours from casting the columns are de-mold carefully without disturbing of surface of specimen.
5) *Curing of Column:* After 24 hours this specimens are taken for curing of 28th days. We used water curing (immersion) method for curing of column specimen.

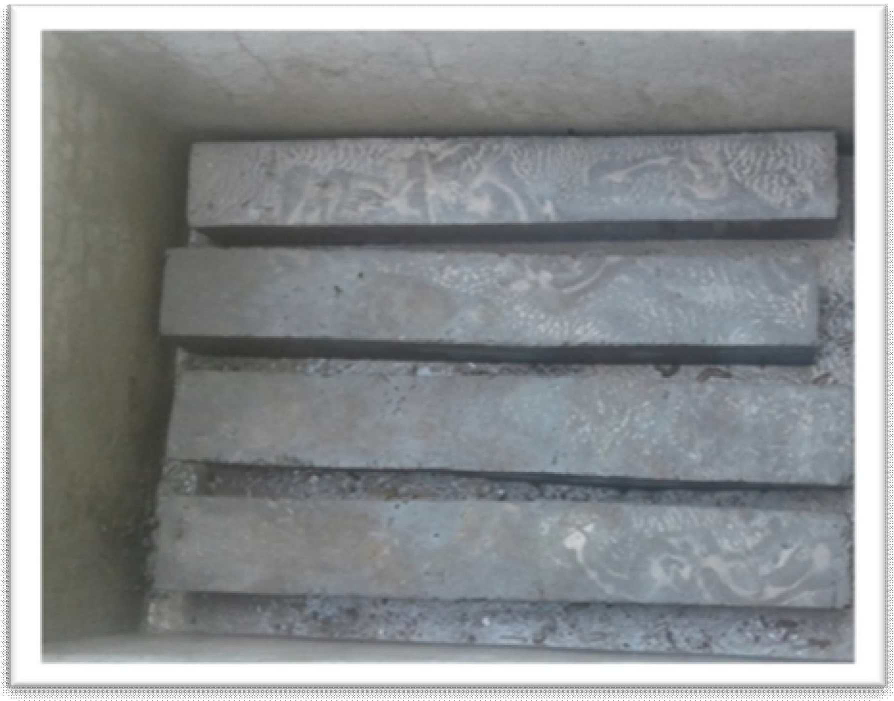

Figure 5 immersed curing of column specimen

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6) *Experimental Set-up:* Fig4.10 (a) & 4.10 (b) illustrates the instrumentation and test setup. Tests were executed using hydraulic loading Frame & UTM of 1000 KN capacity. The column specimen of height 1100 mm are tested in hydraulic loading frame &the column specimen of height 700 mm are tested in universal testing machine. The both the machine was calibrated before testing to ensure the accuracy of result. The column specimens were placed on the rigid steel floor of the machine with total height of 100 cm above the machine floor. Rigid steel plates were fitted under and above the ends of column specimen. Verticality of column specimen was carefully examined and adjusted to ensure perfect centric loading on the column. Steel jackets were clamped and bolted together with high strength bolts to provide enough confinement at loading and supporting ends. Three displacement transducers were mounted on a rigid wooden-stand which was manufactured and fixed into a RC base to be stable enough to monitor the deformation. One transducer was used at top of column specimen in vertical direction to measure the axial deflection whereas the other two were used at mid-height of specimen, in horizontal directions on two perpendicular faces of tested specimen, to measure lateral deflections. The load and displacements were monitored and logged using an automatic data acquisition system.

a) 1100 column specimen tested on Hydraulic loading frame

b) 700 mm column specimen tested on UTM

Figure 6: instrumentation test setup

7) *Experimental Results:* Table 2 & Table 3 summarize the experimental test results of ultimate load; the maximum axial deflection and the maximum lateral deflection for with and without Wire mesh of height 1100 mm and 700 mm column specimen respectively. Table 2 & 3 also shows the percentage increment in with EMM layer column specimen over without EMM layer column specimen.

Table 3: Experimental Test result for column specimen of height 700mm

Sr. no.	Specimen ID	Spacing between stirrups	EMM layer	Ultimate Load		Axial deformation		Lateral Deformation	
		mm		kN	±%	mm	± %	mm	±%
1	RC-7	110	No	767.12	-	5.85	-	1.01	-
2	RC-7	110	Yes	843.83	+9.09	12.8	118.80	1.51	49.50
3	RC-5	165	No	759.89	-	3.5	-	0.87	-
4	RC-5	165	Yes	828.09	+8.97	8.40	140.00	1.37	57.47
5	RC-3	330	No	709.79	-	3.38	-	0.64	-
6	RC-3	330	Yes	787.69	10.97	6.36	88.16	1.14	78.125

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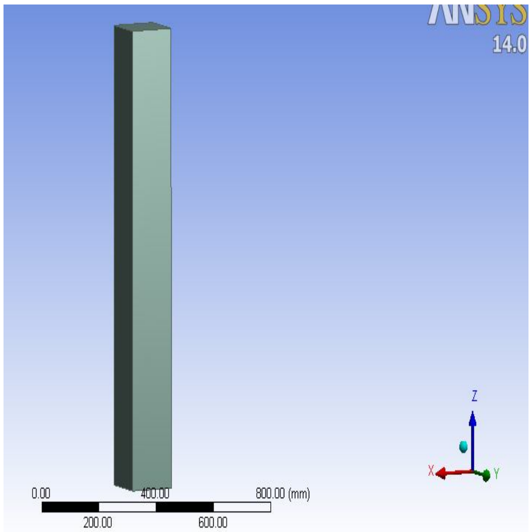
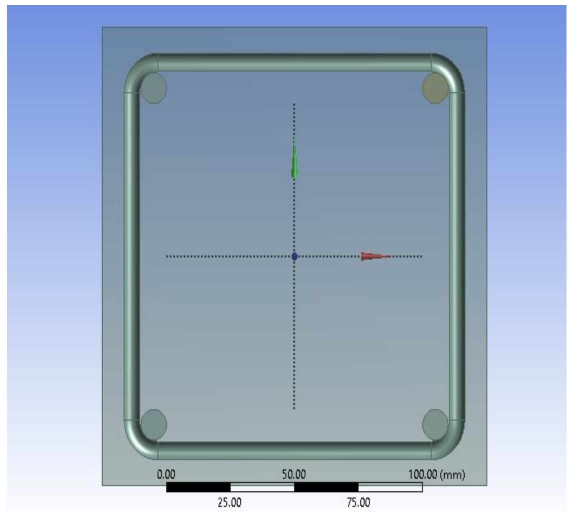
III. FINITE ELEMENT ANALYSIS USING ANSYS

Finite Element Analysis is a powerful tool that would be an alternative for the experimental tests. In this study all the twelve models of RC column with and without wire mesh are to be done in CATIA Software in STEP format and then they imported to ANSYS workbench software. Input data given for the various materials to the ANSYS software such as for longitudinal reinforcement bar and for lateral ties modulus of elasticity taken as $2x10^5$ Mpa, Poisson ratio 0.3 & density 7850 kg/m^3.for concrete modulus of elasticity taken as 31622.77 Mpa, Poisson ratio 0.3 & density 25000 kg/m^3 and similarly for Expanded metal mesh of elasticity taken as $0.235x10^3$Mpa, Poisson ratio 0.28 & density 7835 kg/m^3.The ends of the columns were restrained from displacing in X & Z directions. Boundary conditions were given as fixed at bottom and free at top. Figure shows the geometric models of with and without wire mesh RC column. Figure 7 shows the model of RC column specimen.



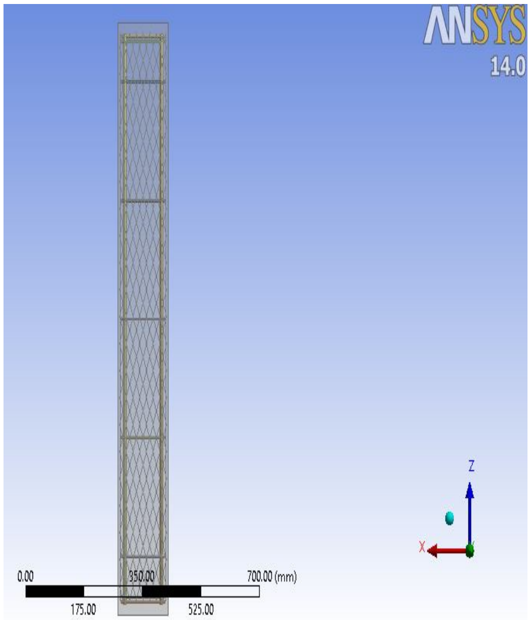
(a)RC Column Solid model



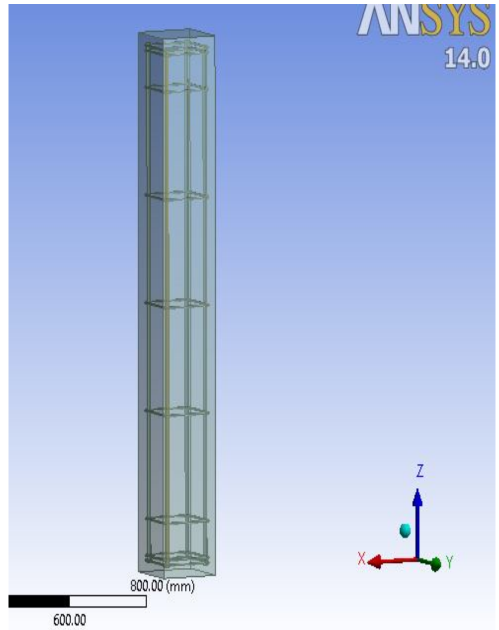
(b) cross section of RC Column

Table 2: Experimental Test result for column specimen of height 1100mm

Sr. no.	Specimen ID	Spacing between stirrups	EMM layer	Ultimate Load		Axial deformation		Lateral Deformation	
		mm		kN	±%	mm	± %	mm	±%
1	RC-7	176.66	No	631.10	-	5.85	-	1.01	-
2	RC-7	176.66	Yes	700.52	10.99	12.8	118.80	1.51	49.50
3	RC-5	265	No	554.9	-	3.5	-	0.87	-
4	RC-5	265	Yes	615.939	11.00	8.40	140.00	1.37	57.47
5	RC-3	530	No	516.04	-	3.38	-	0.64	-
6	RC-3	530	Yes	567.64	9.99	6.36	88.16	1.14	78.125



(c) RC Column With Mesh



(d) RC Column Without mesh

Figure 7: Model of RC columns Specimen

A. ANSYS results

After analyzing the all the models of RC column on ANSYS software ultimate load, axial deformation and lateral deformations are obtained for all specimens and they showed almost similar behavior when compared with the experimental work. ANSYS does not provide the exact results as given by experimental results and also the term used in experimental results are not the same in ANSYS. So here we use 'Axial deformation' in experimental work means 'Total deformation' in ANSYS. Similarly, Lateral deformation in experimental work means Directional deformation in X &Y direction in ANSYS. And Ultimate load is calculated by multiplying equivalent stress by Cross sectional area. Table 4 shows the ANSYS results of 1100 mm height column specimen of with and without wire mesh. & similarly Table 5 shows the ANSYS results of 700mm height column specimen of with and without EMM layer.

Table 5: ANSYS result for column specimen of height 700 mm

Sr. no.	Specimen ID	Spacing between stirrups	EMM layer	Ultimate Load		Axial deformation		Lateral Deformation	
		mm		kN	±%	mm	± %	mm	±%
1	RC-7	110	No	767.12	-	5.85	-	1.01	-
2	RC-7	110	Yes	843.83	+9.09	12.8	118.80	1.51	49.50
3	RC-5	165	No	759.89	-	3.5	-	0.87	-
4	RC-5	165	Yes	828.09	+8.97	8.40	140.00	1.37	57.47
5	RC-3	330	No	709.79	-	3.38	-	0.64	-
6	RC-3	330	Yes	787.69	10.97	6.36	88.16	1.14	78.125

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IV. VALIDATION OF RESULTS & DISCUSSION

A. Ultimate load

Results indicated that one EMM layer, as an additional lateral reinforcement for column specimens with various volumetric ties ratio increased the ultimate load of with wire mesh.

In experimental study results indicated that, for the height of 1100mm percentage of increment in ultimate load of RC column specimen are 10.99%, 11.00% & 9.99% for the column of RC-7, RC-5 & RC-3 respectively. For the column of 700 mm percentage of increment in ultimate load of RC Column specimen 10.86%, 8.97% & 10.97% respectively. Figure 2 & 3 shows the experimental results of ultimate load of 1100 mm and 700 mm height of column specimen.

In ANSYS Software results not shown exact same as experimental results but results are nearly same to the experimental work. In ANSYS software results indicated that, for the height of 1100mm percentage of increment in ultimate load of RC column specimen are 8.85%, 19.09% & 16.35% for the column of RC-7, RC-5 & RC-3 respectively and as well as for the column of 700 mm percentage of increment in ultimate load of RC Column specimen 10.08%,8.47% &11.00% respectively. Figure 4 & 5 shows the ANSYS software results of ultimate load of 1100 mm and 700 mm height of column specimen. Figure 8 & 9 shows the comparison of experimental and ANSYS results. For both groups, higher increments in ultimate load can be achieved by using meshes with better mechanical properties and installing additional EMM layers.

Table 4: ANSYS result for column specimen of height1100 mm

Sr. no.	Specimen ID	Spacing between stirrups	EMM layer	Ultimate Load		Axial deformation		Lateral Deformation	
		mm		kN	±%	mm	± %	mm	±%
1	RC-7	176.66	No	652.52	-	4.31	-	1.06	-
2	RC-7	176.66	Yes	717.77	9.99	12.05	179.58	1.57	48.11
3	RC-5	265	No	554.625	-	4.01	-	0.789	-
4	RC-5	265	Yes	619.87	11.76	11.23	180.04	1.38	74.90
5	RC-3	530	No	522.00	-	2.59	-	0.59	-
6	RC-3	530	Yes	574.2	10.00	7.19	177.60	1.12	89.83

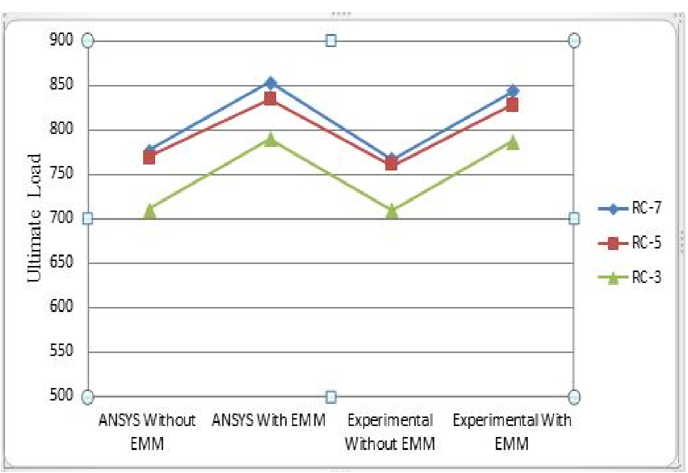

Figure 8: Comparison between ANSYS and Experimental results of Ultimate load of 1100mm height

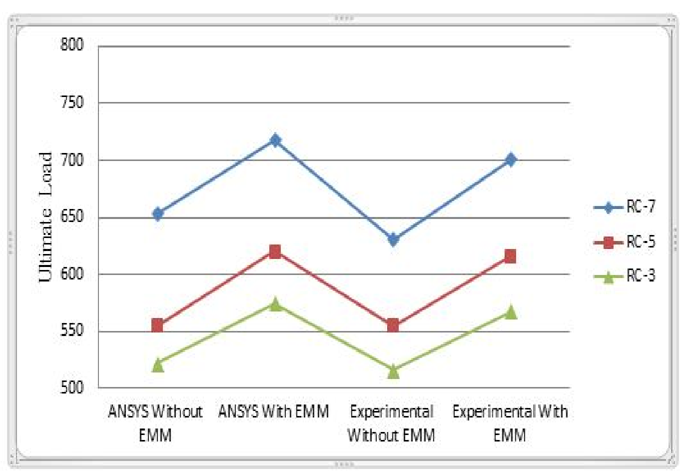

Figure 9: Comparison between ANSYS and Experimental results of Ultimate load of 1100mm height

B. Axial deformation

At failure, all with mesh column specimens exhibited higher axial deflection than reference without wire specimens. Therefore, the additional lateral reinforcement of EMM layer resulted in higher axial deformation.

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In experimental study results indicated that, for the height of 1100mm percentage of increment in Axial deformation of RC column specimen are 118.80%, 197.14% & 185.27% for the column of RC-7, RC-5 & RC-3 respectively and similarly for the column of 700 mm percentage of increment in axial deformation of RC Column specimen 62.87%, 60.97% & 59.81% respectively. Figure 2 & 3 shows the experimental results of axial deformation of 1100 mm and 700 mm height of column specimen.

In ANSYS software results indicated that, for the height of 1100mm percentage of increment in ultimate load of RC column specimen are 63.32%, 69.230% & 72.94% for the column of RC-7, RC-5 & RC-3 respectively and as well as for the column of 700 mm percentage of increment in axial deformation of RC Column specimen 56.30%,72.63% & 46.97% respectively. Figure 4 &5 shows the ANSYS software results of axial deformation of 1100 mm and 700 mm height of column specimen. Figure 10 & 11 shows the comparison of experimental and ANSYS results.

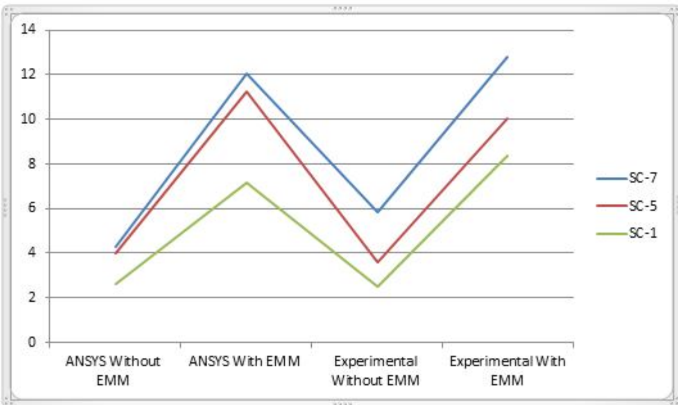

Figure 10: Comparison between ANSYS and Experimental results of axial deformation of 1100mm height

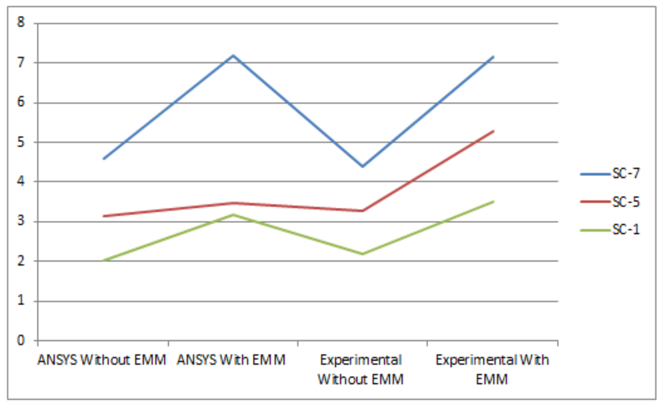

Figure 11: Comparison between ANSYS and Experimental results of axial deformation of 700mm height

C. Lateral deformation

Lateral deflection is an important issue for long columns. However, all tested specimens represent short RC columns. Table 5.2 indicate that column specimens experience lateral deflection more than the without wire mesh column specimen. This increment has been achieved with the aid of additional confinement offered by the EMM layer. Higher reduction in ties volumetric ratio results in smaller increment in lateral deflection. In experimental study results indicated that, for the height of 1100mm percentage of increment in Axial deformation of RC column specimen are 49.50%, 57.47% & 78.125% for the column of RC-7, RC-5 & RC-3 respectively and similarly for the column of 700 mm percentage of increment in ultimate load of RC Column specimen 32.11%, 21.68% & 37.87% respectively. Figure 2& 3 shows the experimental results of ultimate load of 1100 mm and 700 mm height of column specimen.

In ANSYS software results indicated that, for the height of 1100mm percentage of increment in ultimate load of RC column specimen are 37.27%, 41.94% & 35.00% for the column of RC-7, RC-5 & RC-3 respectively and as well as for the column of 700 mm percentage of increment in ultimate load of RC Column specimen 20.10%,28.80% &54.81% respectively. Figure 4 & 5 shows the ANSYS software results of ultimate load of 1100 mm and 700 mm height of column specimen. Figure 12 & 13 shows the comparison of experimental and ANSYS results.

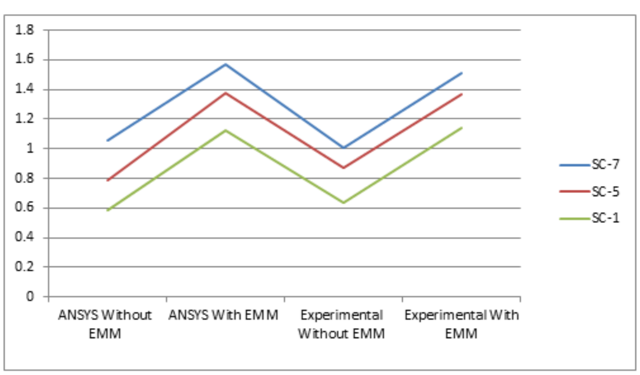

Figure 12: Comparison between ANSYS and Experimental results of Lateral deformation of 1100mm height

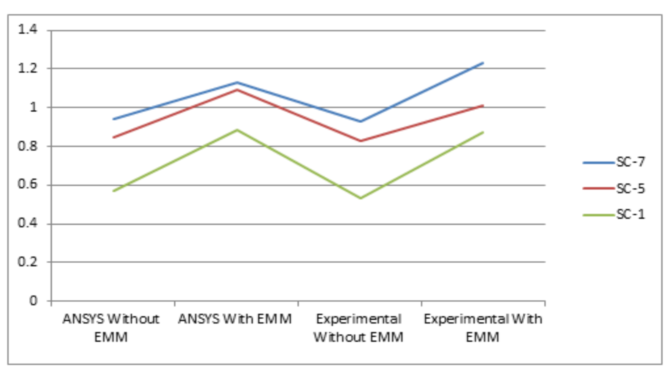

Figure 13: Comparison between ANSYS and Experimental results of Lateral deformation of 700mm height

V. CONCLUSION

This projects presents investigation for using single EMM layer combined, in practical configuration, with various volumetric ratios of ties as lateral reinforcement for square short RC columns. Based on the results of conducted tests, the following conclusions can be drawn:

A. EMM when used as an additional reinforcement in column, enhanced the compression behavior of the column by distributing the forces along the section

B. RC column specimens confined with ties and EMM layer exhibits more plastic deformation and more ductile behavior, compared to without wire mesh column specimen.

C. When wire mesh is used in RC column, it gives the higher results of ultimate load, axial deformation and lateral deformation as compared to without wire mesh RC column.

D. Higher ultimate load capacity, better ductile behavior and greater reduction in the ties volumetric ratio can be achieved by warping additional EMM layers and using EMM with better mechanical properties.

E. Analytical simulations with ANSYS Workbench give very good prediction of experimental stress distribution and displacement plots. For columns, crushing failure occurred at the ends. The crushing is more severe at bottom than at top.

F. Intensive experimental program is required to check there liability of proposed lateral reinforcement using different types of meshes for short and long RC columns under various loading types and environmental effects.

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