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Study on the Compression behaviour of Self-Compacting Concrete Columns using Expanded Metal Mesh as Internal Confinement

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Abstract – *Traditional ties reinforcement cannot provide superior confinement for concrete column due to the overlapping hoops and bends made by ties. This paper provides an improvement in confinement due to the usage of Expanded Metal Mesh(EMM) in addition to the regular tie reinforcement. Total of 5 column specimens were cast and cured. Out of 5, 4 specimens were internally wrapped using Expanded Metal Mesh. Opening sizes of mesh are varied in each specimen having constant mesh thickness. Due to the congested reinforcement, Self-Compacting Concrete was used. The specimens were tested under uniaxial compression till failure. The results indicated that the internally confined column specimens shows significant improvement in the strength and ductility.*

Key Words: **Self-Compacting Concrete, Expanded Metal Mesh, Confinement, Ties.**

1. INTRODUCTION

The non-uniform distribution of reinforcement affects many engineering properties such as ductility, crack resistance, durability and in-plane strength. The shortage of confinement offered by ties paves a way for using materials such as Expanded Metal Mesh to confine the concrete core. EMM were used to reduce the reinforcement congestion caused due to the overlapping hoops and bends made by ties. This is formed by mild steel having diamond opening. This is advantageous due to its low cost, easy availability and flexibility during installation. Self-Compacting Concrete is widely used in areas of congested reinforcement. This helps to improve the reliability and uniformity of the concrete. SCC has the ability to flow under its own weight without vibration. EMM can be used as a substitute for conventional reinforcement. The structural behaviour of SCC columns with EMM as internal confinement is little known.

In this study, 5 circular short SCC column specimens were used. Out of them, 4 specimens were confined using EMM layer with various opening sizes of mesh having constant mesh thickness. The column specimens were tested under uniaxial compression. The ultimate load capacity, maximum deflection, ductility, stress- strain curves were investigated in this study. The analytical results from ANSYS Workbench were compared with the results obtained from laboratory experiments. The basic concern of this study was to provide a better lateral reinforcement using EMM with ties to enhance the confinement and the performance of SCC short columns.

2. EXPERIMENTAL PROGRAM

The experimental investigation were conducted as discussed below. SCC with a target strength of M40 grade was designed using Nan-su-et.al method. The specimens were cylindrical with a height of 700 mm and diameter of 130mm. These specimens were internally reinforced with the same quantity of steel reinforcement. The fresh concrete were tested for satisfying the basic requirements of SCC by using Slump Flow test, U-Box test, V-Funnel test and L-Box test. In the preliminary stage, 3 cubes and 3 cylinders were cast for M40 grade of concrete. The average compressive strength of SCC of M40 was found and verified. Total of 5 specimens were cast and cured. 4 specimens were internally wrapped using EMM around the reinforcement in one layer. After 28 days curing, these specimens were tested under UTM of 1000kN to find out the compressive strength of concrete.

Table -1: Details of column specimens

S. No	Specimens	Mesh Specifications		No. of EMM layer
		Mesh thickness(mm)	Mesh opening sizes(mm)	
1	C01	-	-	-
2	C02	1.5	15X30	1
3	C03	1.5	12X40	1
4	C04	1.5	16X40	1
5	C05	1.5	15X45	1

2.1. MATERIAL PROPERTIES

The cement used in preparing the concrete mix is Portland cement of grade 53 conforming to IS: 8112-1989 with a specific gravity of 3.09.

The used fine aggregate is natural siliceous sand having a specific gravity of 2.6 and fineness modulus of 2.7 conforming to Zone – II of IS: 383-1970.

Coarse aggregate used in study consists of crushed stone of size 10mm and below. The specific gravity is 2.66 and bulk density 1383 kg/m^3 conforming to IS: 383-1970.

High Yield Strength Deformed bars of 10mm and 8 mm were used as longitudinal reinforcement and lateral ties. Typical 4 EMM sheets of 1x3 m weighing 15kg per sheet were used. The mesh has diamond opening sizes with a constant thickness of 1.5mm.

Silica fume (30%) with a specific gravity of 2.2 were added to cement. The used super plasticizer is Conplast SP-430 with a dosage of 1.2%. Viscosity-modifying agent used here in a dosage of 0.3%

2.2 PREPARATION OF THE SPECIMENS

The short column specimens were prepared according to the following procedure.

2.2.1 REINFORCEMENT

4 vertical bars of 10mm diameter were used for the longitudinal reinforcement and 7 nos. of 8mm diameter were used for ties spaced at 100mm. The clear cover was maintained at 20mm. 1 EMM layer was wrapped around the ties for each specimens. Each of the column specimen had distinguished mesh opening sizes as given in Table 1 and shown in Fig 1 and Fig 2.

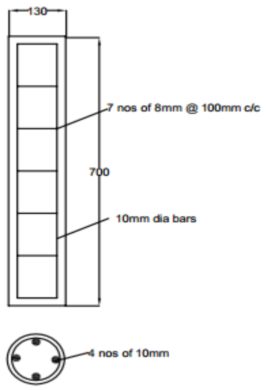

Fig 1: Reinforcement details

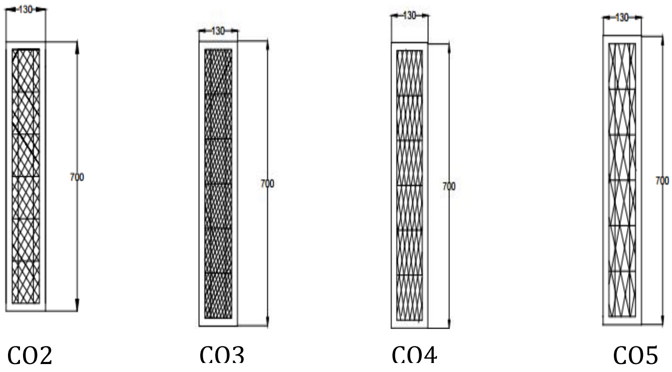

Fig 2: Specimen details

2.2.2 MIXING AND CASTING OF THE COLUMN SPECIMENS

The mix design for M40 grade of concrete was proposed using Nan-su-et.al method. The design mix obtained was 1: 2.17: 1.8: 0.36. The average compressive strength for cubes and cylinders was found to be 43 kN/mm^2 and 32kN/mm^2. The test methods used for the assessment of fresh properties of SCC are Slump flow, L-Box, V funnel U-Box test and the corresponding values are 710mm, 0.92, 7 sec and 25mm. All this values were compared with EFNARC and found to be within permissible limits. The mixing of the concrete was done. The column specimens were demoulded after 24 hours from the time of casting and cured in a water tank for 28 days. After curing, the specimens were kept for drying.

Fig 3: Reinforcement of specimen details

Fig 4: Casting of specimens

Fig 5: Column specimens after curing

2.2.3 INSTRUMENTATION AND SET UP

Fig 6 illustrates the instrumentation and set up. Tests were executed under Universal Testing Machine with a capacity of 1000kN which provided fixed end condition to bottom and free end condition to top. In order to avoid the movement of columns, the end plates were provided to have a uniform load distribution over the column.

Fig 6: Instrumentation and set up of the specimen

Fig 7: Failure of specimens

3 EXPERIMENTAL RESULTS AND DISCUSSION

Table 2 summarizes the ultimate load, peak stress and peak strain of column specimens.

Table 2: Test results of column specimens

S. No	Specimens	Mesh opening sizes(mm)	Ultimate load (kN)	Peak Stress(MPa)	Peak Strain
1	CO1	-	283.2	21.33	0.6
2	CO2	15X30	309.5	23.31	0.7
3	CO3	12X40	320.75	24.16	0.8
4	CO4	16X40	335.15	25.25	1.1
5	CO5	15X45	384.72	28.98	1.4

3.1 ULTIMATE LOAD

The experimental results showed that the ultimate load carrying capacity increases with increase in the mesh opening sizes. It is observed that the confined specimens experienced 9.28%, 13.25%, 18.34% and 35.84% higher load carrying capacities than the unconfined column. Fig 8 show the load carrying capacity of column specimens.

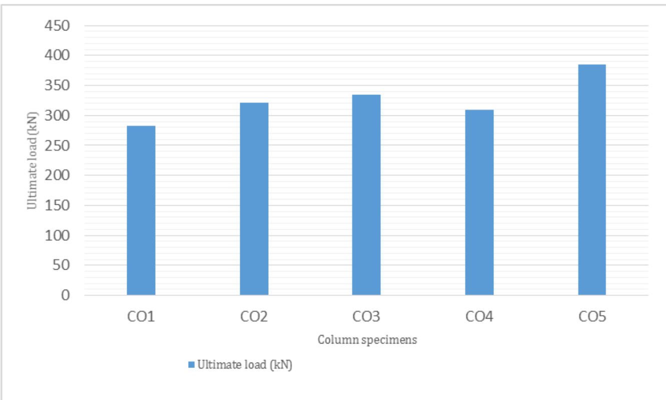

Fig 8: Load carrying capacity of column specimens.

3.2 STRESS-STRAIN CURVE

The response of confined specimens were presented graphically in the form of stress-strain curves in fig 9. The stress-strain curve depends on the ratio of confinement reinforcement provided. It showed that the ultimate stress and strain for confined specimens was higher than the unconfined columns.

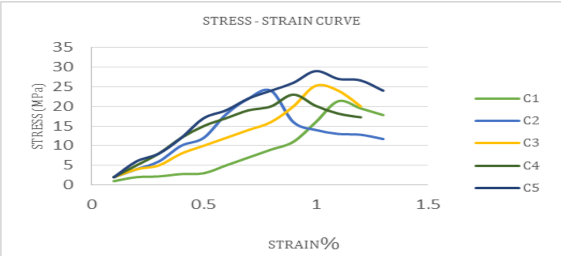

Fig 9: Stress- strain curves of column specimens

3.3 DUCTILITY

The ductility shows the ability of structural members to deform excessively at large loads without any failure. Fig 10 showed that confined columns have improved ductility over the unconfined columns. This improvement is due to the confinement provided by EMM layer. Table 3 summarizes the ultimate load, deflection at maximum load, deflection at first yield and ductility of column specimens.

Table 3: Ductility of column specimens

S. No	Specimens	Deflection at max load(mm)	Deflection at first yield(mm)	Ductility
1	CO1	8.5	7.8	1.08
2	CO2	5.7	6.5	1.14
3	CO3	8.8	8.6	1.02
4	CO4	7.9	7	1.1
5	CO5	14.7	7.2	2.04

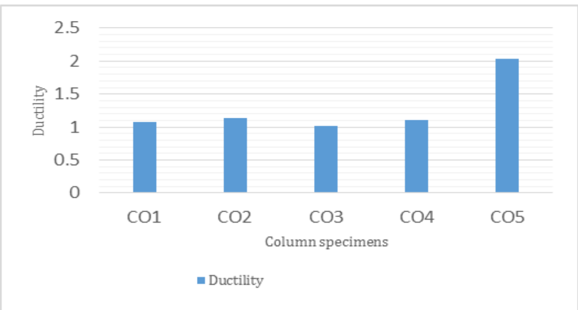

Fig 10: Ductility of column specimens

4 ANALYTICAL RESULTS

Finite Element Analysis is a powerful tool that would be an alternative for the experimental tests. The dimension of the confined column specimens were investigated analytically using Finite Element Software ANSYS Workbench. The chosen elements followed the exact geometric dimensions of tested specimens. The steel elastic modulus was taken as 2E5 MPa and poisson's ration as 0.3. The surface to surface frictional contact was given as 0.2. 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. Fig 11 shows the geometric and meshed model of the column specimen. Fig 12-21 shows the stress distribution and displacement plot for the column specimens. The crushing is more severe at bottom than at the top. The displacement of unconfined column is 1.7mm , while the displacement of confined column for CO 2, CO 3, CO 4, CO 5 are 1.816mm, 1.988mm, 2.024mm and 2.239mm respectively. Stress strain curves are obtained for all specimens and they showed almost similar behaviour when compared with the experimental work.

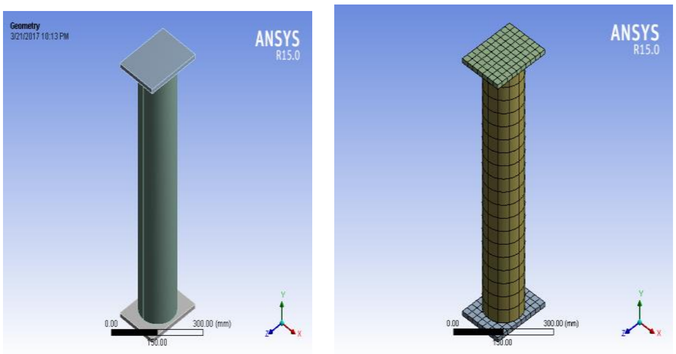

Fig 11: Geometric and meshed model of specimen

4.1 Specimen CO 1

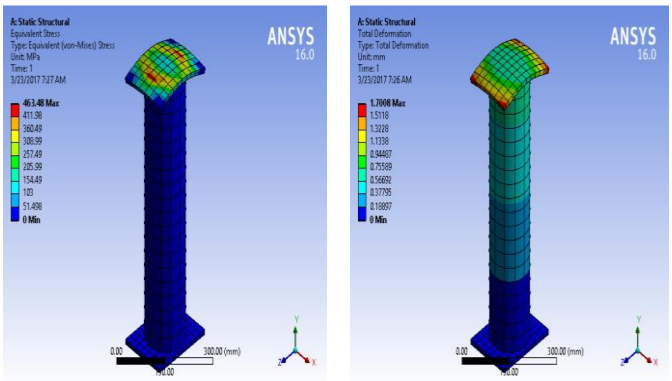

Fig 12: Stress and Displacement distribution plot for CO 1

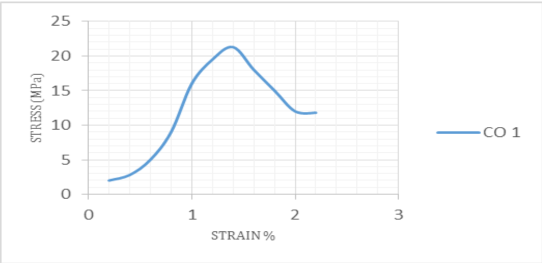

Fig 13: Stress strain curve for CO 1

4.2 Specimen CO 2

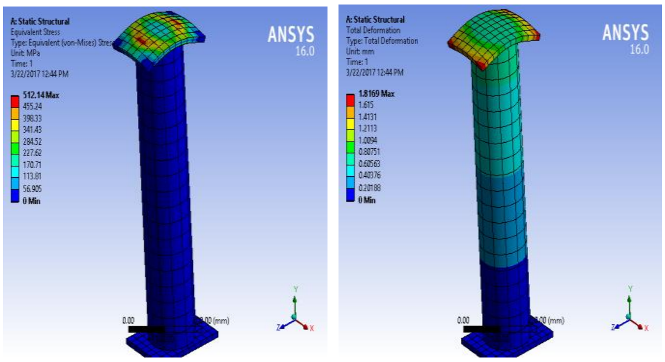

Fig 14: Stress and Displacement distribution plot for CO 2

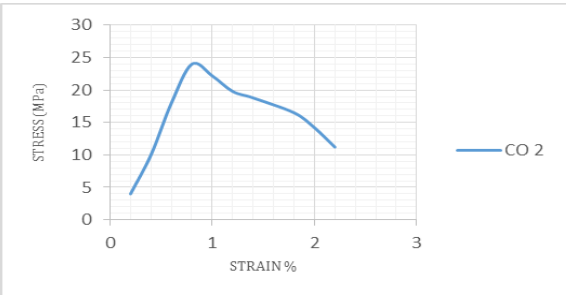

Fig 15: Stress strain curve for CO 2

4.3 Specimen CO 3

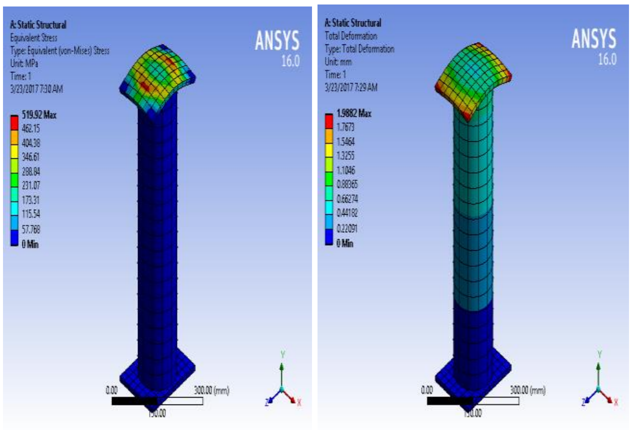

Fig 16: Stress and Displacement distribution plot for CO 3

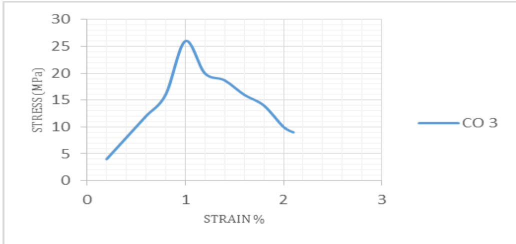

Fig 17: Stress strain curve for CO 3

4.4 Specimen CO 4

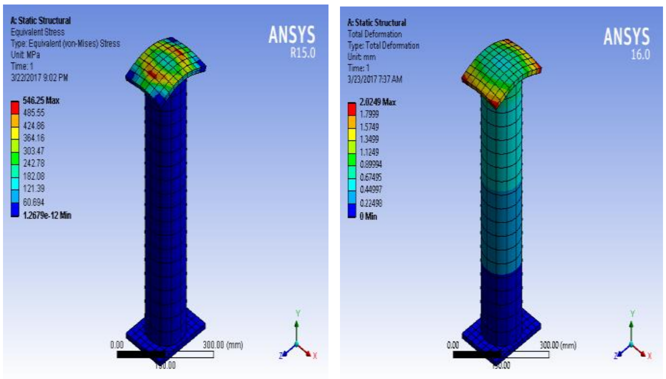

Fig 18: Stress and Displacement distribution plot for CO 4

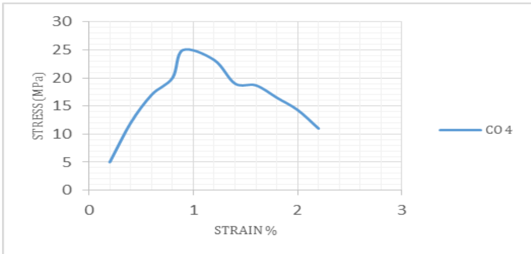

Fig 19: Stress strain curve for CO 4

4.5 Specimen CO 5

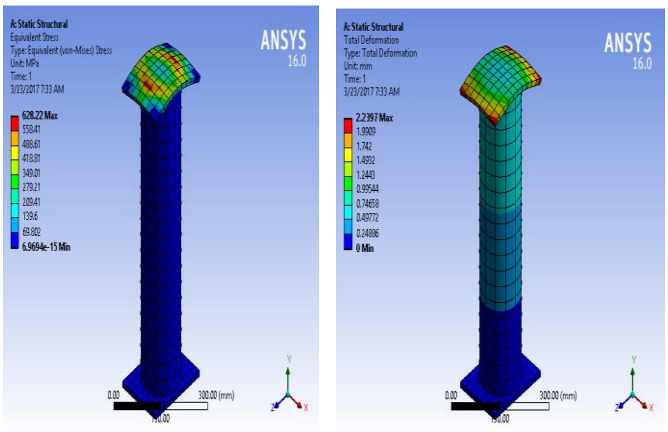

Fig 20: Stress and Displacement distribution plot for CO 5

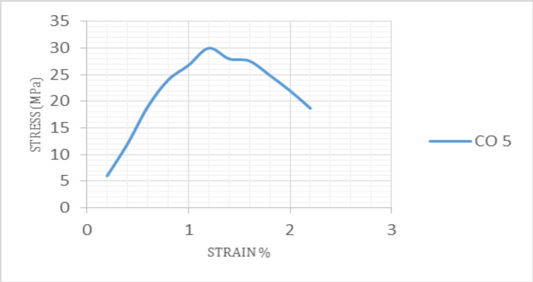

Fig 21: Stress strain curve for CO 5

5 CONCLUSIONS

The following conclusions are drawn based on the experimental and analytical studies:

1) EMM when used as an additional reinforcement in column, enhanced the compression behaviour of the column by distributing the forces along the section.
2) The load carrying capacity of confined columns are 9.28%,13.25%,18.34% and 35.84% higher than the unconfined column.
3) The column specimens confined with ties and EMM shows improved ductile behaviour when compared to the control specimens.
4) The displacement ductility for CO 1, CO 2, CO 3, CO 4 and CO 5 columns were 1.7mm,1.816mm, 1.988mm, 2.024mm and 2.239mm respectively. The ductility of specimens increases with increase in the mesh opening sizes.
5) Analytical simulations with ANSYS Workbench gives 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.
6) Stress strain curves obtained for all specimens showed almost similar behaviour when compared with the experimental work.

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