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Experimental Investigation on Stainless Steel Tubular Slender Column Filled with Concrete

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ABSTRACT: Stainless Steel being an excellent corrosion resistance with decorative qualities having an ease of maintenance, its use in the constructions is accelerating throughout the world. Concrete along with Stainless Steel can behave excellent in its load carrying capacity due its advantages. For its excellence, Composite action between the Stainless steel and concrete plays an important role. The Bond capacity is interrelated with slip at the Stainless steel concrete interface. An exponential distribution of bond stress is expected prior to slip, and a more uniform distribution occurs after slip. The Bond Capacity of the Stainless steel concrete composite is to be compared with that of the conventional Steel concrete composite. To check the composite action between Stainless steel and Concrete, three Cylindrical Stainless steel specimens (304 grade) of 390 mm high, 150 mm Diameter of 3mm thick were taken. For comparison three similar Cylindrical Steel specimens (105 grade) of 390 mm high, 150 mm Diameter of 4mm thick were taken. To carry out the Pushout Test a gap of 90 mm was left at the bottom of the specimens and M25 grade concrete (1:1.338:2.485) designed as per IS10262-2009 was filled up to the top surface. The Bond Strength between the concrete and the Stainless steel is found by Pushout Test. The average of the results is compared with that of the Conventional Steel concrete specimens tested similarly and the result is expected.

KEYWORDS: Stainless steel, tubular column, slender column, concrete filled column, Bond capacity

I. INTRODUCTION

Composite tubular columns were developed because they provided permanent and integral formwork for a compression member and were instrumental in reducing construction times and consequently cost. They reduce the requirement of lateral reinforcement and costly tying, as well as providing connection to Steel universal beams of a Steel-framed structure. Ben Younga et al present an experimental investigation of concrete-filled cold-formed high strength Stainless Steel tube columns. The high strength Stainless Steel tubes had a yield stress and tensile strength up to 536 and 961 MPa, respectively. The behaviour of the columns was investigated using different concrete cylinder strengths varied from 40 to 80 MPa. specimens were subjected to uniform axial compression. Based on the test results, design recommendations were proposed [1]. M.A. Dabaon et al presents an experimental investigation on concrete- filled normal-strength Stainless Steel stiffened tubular stub columns using the austenitic Stainless Steel grade EN 1.4301 (304). The specimens were fabricated by welding four lipped angles or two lipped channels at the lips. The concrete-filled stiffened Stainless Steel tubular columns were subjected to uniform axial compression over the concrete core and the Stainless Steel tube to force the entire section to undergo the same deformations by blocking action and the failure was achieved by the local buckling of the Stainless tube and the crushing of concrete[2].

For the slender columns, there is no obvious difference between CFSST columns and conventional carbon Steel CFST columns in terms of test observations and failure modes. More ductile behaviour was achieved as normal strength concrete was used. This trend is less obvious with an increase of slenderness ratio, owing to the fact that slender columns generally underwent elastic buckling [3]. B. Uy et al conducted test on the specimens and concluded that, Composite action between Steel tube and concrete core still exists for slender CFSST columns, but this action decreases with increasing slenderness ratio. Slenderness reduction factors should be applied in designing slender CFSST columns [4]. Shrinkage can be very detrimental to bond stress capacity, and the importance of shrinkage depends upon the characteristics of the concrete, the diameter of the tube, and the surface condition at the inside of the tube. After slip, the bond stress was approximately uniform over the slipped region. The bond capacity is interrelated with slip at the Steel concrete interface. An exponential distribution of bond stress is expected prior to slip, and a more uniform distribution occurs after slip [5].

Push out test is emerging as an important experimental tool for characterizing the interfacial behaviour of the Steel tube and concrete in concrete filled Steel tube columns. Based on the results, it is indicate that bond strength of MCFTS specimens is greater than that of CFTS specimens [6,7]. In the short columns with the load applied to the concrete section, the concrete core exhibited greater compressive stresses than predicted, due to the confinement of the Steel tube. The effect was most pronounced for the stub column with bond strength between the concrete core and the Steel tube, when the load is applied only to the concrete section [8,9].

Pull out tests to assess influence of different parameters in the developed bond capacity. The influence of reinforcement material (CS or SS) on the developed bond capacity is more relevant for smooth samples than for ribbed ones [11]. The chemical adhesion mechanism governing smooth samples bond behaviour explains the difference. Micro roughness has a secondary influence on the bond behaviour of smooth samples [12]. Other parameters, as reinforcement material or geometry, are more deterministic. Regarding flat ribbed samples, where bond mechanisms are governed by the mechanical interaction between the concrete and the ribs of the reinforcement, roughness of the rebar (characterized by the relative rib area) determines the bond capacity of the specimen [13]. The use of SS instead of CS is not influencing the bond behaviour of samples. For comparable cross section areas, round rebars develop higher bond strength values than flat elements [14]. However, higher forces are reached with strips as larger contact areas are involved.

II. MATERIALS

For comparison of the composite action between the composite material and that of concrete, it requires a composite (Stainless Steel and Conventional Steel) and concrete as a infill. In this investigation Stainless Steel of grade 304 was used as one of the composite material and the other being Conventional Steel which had a grade of 108. Concrete was to be used as an infill and its mix ratio was designed as per IS10262-2009.

STEEL

The conventional Steel of 108 grade is used in this work. The Chemical compositions of the Stainless Steel (304 grade) obtained from the Manufacturer Certificate are listed in the table 1

Table 1 Composition of Stainless Steel

S.No	Composition	% in Stainless Steel
1	Car bon	0.08 (max)
2	Man ganese	2.00 (max)
3	Pho sphorus	0.045 (max)
4	Sulp hur	0.030 (max)
5	Silic on	0.75 (max)
6	Chr omium	18.00-20.00
7	Nic kel	8.00-12.00
8	Nitr ogen	0.10 (max)
9	Iron	Balance

From the Literature 4 the following properties are taken for the Stainless

- Initial elastic modulus 182GPa
- 0.2% proof stress $\sigma_{0.2}$: 390.3 Mpa

CONCRETE

To obtain the average Characteristic Compressive strength of 25MPa, mix ratio was designed as per IS10262-2009 and the mix ratio was arrived at (1:1.338:2.485) with a w/c of 0.35. To prepare this concrete Ordinary Portland Cement

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(KCP Cements) of 53 Grade was used along with Coarse Aggregate of 12mm and 20 mm (40% & 60%), Fine Aggregate (Sand) and potable water.

III. METHODOLOGY

The Bond Action between the composite material (Stainless steel and Steel) and concrete is usually found out by conducting Pull-out or Push out test. Since the Stainless Steel is used as an outer core (concrete infilled composite). Pushout test is more apt for this type of specimen to find out the Bond Stress. Hence Pushout Test was carried out to find the Bond Action of a Stainless Steel Concrete Composite and comparison was made with that of the Conventional Steel Concrete Composite. Three standard cubes of 150mm x 150mm x 150mm were cast using the concrete arrived as per the mix design (1:1.338:2.485) with a w/c of 0.35. The Specimens were named as C1, C2, and C3. This is to confirm if the mix proportion arrived gives a concrete of average Characteristic Strength of 25kN/m².Three Cylindrical Stainless Steel specimens (304 grade) of 390 mm high, 150 mm Diameter of 3mm thick were taken. The specimens were named as SS1. SS2, SS3. Three similar Cylindrical Steel specimens (105 grade) of 390 mm high, 150 mm Diameter of 4mm thick were taken. The specimens were named as S1, S2, S3. The specimens bought directly from retailers contained rust and dust on their inner surface and also the top and bottom surface were not plain and contained ups and downs so they were first rubbed with an emery sheet on their inner side to remove the rust and dust present, so that after concreting only the metal surface of the Stainless Steel was in contact with that of the concrete. Also the top and the bottom surfaces were filed, so that the specimen surfaces became flat and the specimen can stand upright when placed on a flat surface. A gap of 90 mm was left at the bottom of the specimens and M25 grade concrete (1:1.338:2.485) was filled upto the top surface as in fig 1. The gap was left so as to carry out the Pushout test on the specimens. The specimens are cured for 28 days by placing them under water in the curing tank.

Fig 1 Testing of the Stainless Steel concrete specimen

The specimens after cured for 28 days was wiped with a cloth to make the surfaces dry and then weight of the specimens were noted. Then the specimens were placed one by one, upright with the air gap of 90 mm at the base so that it was resting on the Stainless Steel alone as in the fig 4.2. The specimens were placed at the testing position of the Universal Testing Machine (UTM), such that the load is applied only to the concrete portion of the specimen. This was done by means of a metal circular disc placed in between the concrete and the loading portion of the UTM. The fig 1 shows the testing position of the Stainless Steel specimen. Specific range of the compression (Maximum range of 750 KN) was selected and the specimen was loaded in fine increments till they fail. Similar procedure was done to find the Bond Action for Steel Specimens. The specimen details along with their dimensions, weight and Surface area of concrete in contact with the inner surface Composite are listed in the table 3.3.

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| Volume 1, Issue 1, November 2018 |

Table 2 Material properties of the specimen

S.No	Name of the specimen	Height H (mm)	Diameter D (mm)	Thickness T(mm)	Weight (Kg)	Surface Area(A) (mm^2)
1	SS1	390	150	3	20.600	141371.67
2	SS2	390	150	3	22.200	141371.67
3	SS3	390	150	3	21.600	141371.67
4	S1	390	150	4	21.600	141371.67
5	S2	390	150	4	22.400	141371.67
6	S3	390	150	4	22.200	141371.67

SS1, SS1, SS1 - Stainless steel specimens
S1, S2, S3 - Steel specimens
Surface Area (A) = D(H-90)
= TT X 150 X (390-90)
= 141371.67 mm^2

IV. RESULT AND DISCUSSIONS

The Compressive strength of the cube specimens, tested in the Compression Testing Machine (CTM) are listed in the table 3. From the experiment carried out on the test specimens, Ultimate Load and Slip at varies points of loads and the Slip the Ultimate Load was obtained. The Bond stress for each of the Stainless specimens was found from the Ultimate load and the Surface area (concrete touching the inner surface of composite) of specimen from the formula given below and the values are listed in the table 4.

Table 3 Summary of Test Results for Concrete specimens

S.No	Name of the Specimen	Ultimate Load(kN)	Surface Area(A)	Compressive Strength (kN/mm^2)	Average Compressive Strength (kN/mm^2)
1	C1	659	22500	29.289	29.21
2	C2	624	22500	27.733	
3	C3	689	22500	30.622	

Bond Stress = ultimate load / surface area of concrete (A)

Table 4 Test Results for Stainless Steel Specimens

S.No	Name of the Specimen	Surface Area(A)	Ultimate Load(kN)	Bond stress (N/mm^2)	Slip at the ultimate load (mm)
1	SS1	141371.67	101.700	0.720	7.050
2	SS2	141371.67	101.750	0.719	7.190
3	SS3	141371.67	100.550	0.711	6.975

In a similar way the Bond Stress was calculated for each of the Steel specimens and the values are listed in the table 5

Table 5 Test Results for Steel Specimens

S.No	Name of the Specimen	Surface Area(A)	Ultimate Load(kN)	Bond stress (N/mm²)	Slip at the ultimate load (mm)
1	SS1	141371.67	195.300	1.382	3.980
2	SS2	141371.67	196.250	1.388	3.860
3	SS3	141371.67	197.150	1.395	3.785

Table 6 Average of Ultimate load, Bond stress, Slip at ultimate load

S.No	Name of the Specimen	Average Ultimate Load(kN)	Average Bond stress (N/mm²)	Average of Slip at the ultimate load (mm)
1	Stainless Steel	101.333	0.717	7.072
2	Steel	196.233	1.388	3.875

Fig. 2 Comparison of load

From the loads and their respective slips obtained from the experiments, load to slip graph was plotted for the Stainless Steel specimens taking slip(mm) along X axis and Load(kN) along Y axis. In similar way load slip graph was plotted for the Steel specimens. For discussion of the results, the Load Slip graph for the SS2 and S2 were taken and are shown in Fig 2 respectively. The slip at ultimate load for each of the specimen is given in the table 6. From the Load Slip Graphs shown in the Fig 2 for the Stainless Steel specimen (SS2) the Steel Specimen (S2) respectively, we can discuss that the Load Slip ratio is greater for the Steel when compared to that of the Stainless Steel. The Slip is greater for the Stainless Steel when compared to that of Steel for any particular load. For specimen SS2 from the Fig 2, we can find that there is almost a slip of 6mm for a constant load of nearly 19 KN and the Ultimate Load of 101.700 KN was reached at a slip of 7.190 mm. The Bond Stress for this Particular Specimen was found to be 0.720N/mm², which was calculated using the formula mentioned earlier.

V. CONCLUSION

From the Results obtained, le the Ultimate Load, Slip at Ultimate load. Bond Stress and Load slip Graphs we can summarize that we can conclude the following points

a) The average Ultimate Load capacity of Stainless Steel is 51.64% of that of the Steel

b) The slip at Ultimate load is nearly 82.5% more than that of the slip at ultimate load for Steel.

c) The average Bond Stress for the Stainless Steel is 51.65% of that of the average value of Steel.

Hence it is concluded that, though the Stainless Steel has its Bond Stress nearly half of that of the Steel it can be considered an effective composite material due to its main advantage of corrosion resistance.

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