ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 11(21), DOI: 10.17485/ijst/2018/v11i21/122490 June 2018*

Case Study on Double Tube Stub Columns

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Abstract

Objectives: Experimental study on Double tube Stub column is presented in this paper. **Methods/Analysis:** The behavior of the concrete infilled double tube stub columns was investigated. Three different strength of concrete namely 30 Mpa, 40 Mpa and 50 Mpa were used to fill the column specimens. To avoid buckling of the test specimen, diameter to thickness ratio was 33.3 and length to Diameter ratio was 3. This value was used for the entire test specimen. **Findings**: The failure modes of double tube column, load-deflection relation and load- strain relation were presented. **Application**: From the experimental study it is found that column strength increases due to the presence of additional inner mild steel tube for column having different outer tube materials namely Aluminium (Al), Stainless steel (SS) and Mild steel (MS). From the result it was observed that the presence of inner tube is more beneficial for columns with stainless steel and aluminium as outer tube if the strength of the concrete is less.

Keywords: Circular Column, Composite Column, Double Skin, Stress-strain

1. Introduction

The concept of double skin composite construction was originally devised for use in submerged tube tunnels. Steel tubular members have long been used in offshore and inland construction. A possible means of improving stability of tubulars is by void-filling. This technique has been used over the last 4 decades, where the hollow tube is fully filled[1]. Due to their high strength, ductility and good seismic resistance, Concrete in Filled Tubular (CFST) columns are widely used in high rise building construction[2]. Concrete in Filled Double Tubular (CFDST) members can be considered as a new type of CFT construction. CFDST columns consist of two concentric steel tubes. Concrete is filled between the steel tubes and also inside the core portion. The cross section of the steel tubes can be Square Hollow Sections (SHS) or it can be Circular Hollow Sections (CHS) [1–3]. Having lighter weight, excellent cyclic performance and high bending stiffness, the CFDST columns are more advantageous than concrete filled single tubular columns. CFDST columns will have higher fire resistance capacities than their CFT counterparts, due to the inner tubes of the former being protected effectively by the sandwiched concrete under fire condition. CFDSTs were firstly introduced as a new form of construction for vessels to resist external pressure[4]. More recently, they were mainly studied by several researchers as columns or beams, such as[1–3,5]. These studies highlighted the increasing demand and strong potential of using CFDST in offshore construction, highways and high-rise bridge piers. In the past, many studies have been performed on stub columns with stainless steel outer tube. A new type of double skin composite column: stainless steel concrete carbon steel was tested by many researchers[6-8] to study its behaviour. The effect of different types of aggregate on CFDST column was studied by [9,10]. To reduce

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the amount of steel used in CFDST column[11,12] studied the behaviour of CFDST column with stiffeners. In our present study a series of tests was performed to investigate the behavior of composite stub columns subjected to compression, for different combination of inner and outer tubular materials with fully filled and partially filled column sections.

2. Experimental Investigation

Tests were conducted on double tubular concrete infilled stub columns. The test program consisted of three series of tests with different outer tube materials. First series of test specimen (Fully filled) has two circular tubes; the outer column materials were Aluminium (Al), Stainless Steel (SS) and mild Steel (CS) and the Inner column is mild steel in all cases. Concrete is filled between circular hollow tubes and also in the core portion (Figure 1a). Second series of test specimen (partly filled) has two circular tubes, similar to first series but Concrete is filled only between circular hollow tubes (Figure 1b). Third series of specimen has single outer tube filled with concrete (CHS) column without inner steel tube (Figure 1c).

2.1 Specimen Preparation

Total of 27 specimens were casted. Three different series of test specimens, cross sectional view is shown in Figure 1. CHS indicate fully filled section without inner steel tube, FF indicate fully filled section with inner steel tube and PF indicate partially filled section with inner steel tube. All test specimens were labeled so that the type of outside tube material and concrete strength can be easily identified. For example, the label SS-FF-C50 meant outside stainless steel tube with inner carbon steel tube and C50 indicated the nominal concrete strength was 50 MPa. To avoid buckling of the column specimen, diameter to thickness ratio was 33.3 and length to Diameter ratio was 3. Table 1 summarizes the actual dimensions of test specimens and specimens were tested for concrete cube strengths of 30, 40 and 50 MPa. For each test specimen, tubes were tack welded on an end plate concentrically and sealed before concrete casting. All test specimens were subjected to 28 days curing.

2.2 Material Properties

Standard cube tests were done to determine the concrete properties. The three nominal concrete strengths of M30, M40 and M50 were produced using commercially available materials with normal mixing and curing techniques. The detailed concrete mix design is shown in Table 2 and the mix proportion was calculated based on the guidelines given in Indian code of practice IS 10262. The 28 day mean cube compressive strengths for the three types of

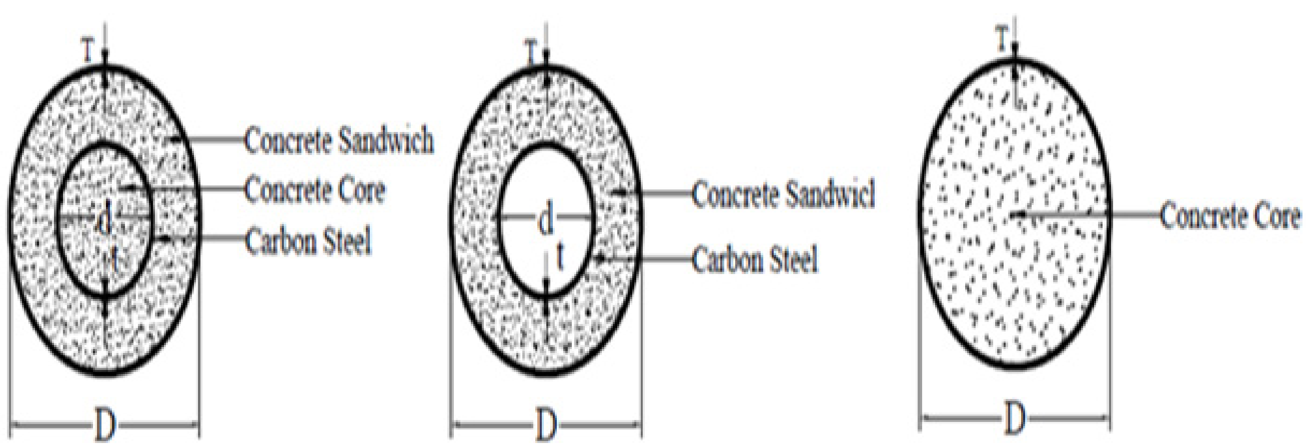

Figure 1. Cross section of types of specimens. a. Double skin fully filled (FF) b. Double skin partially filled (PF) c. Single skin fully filled (CHS)

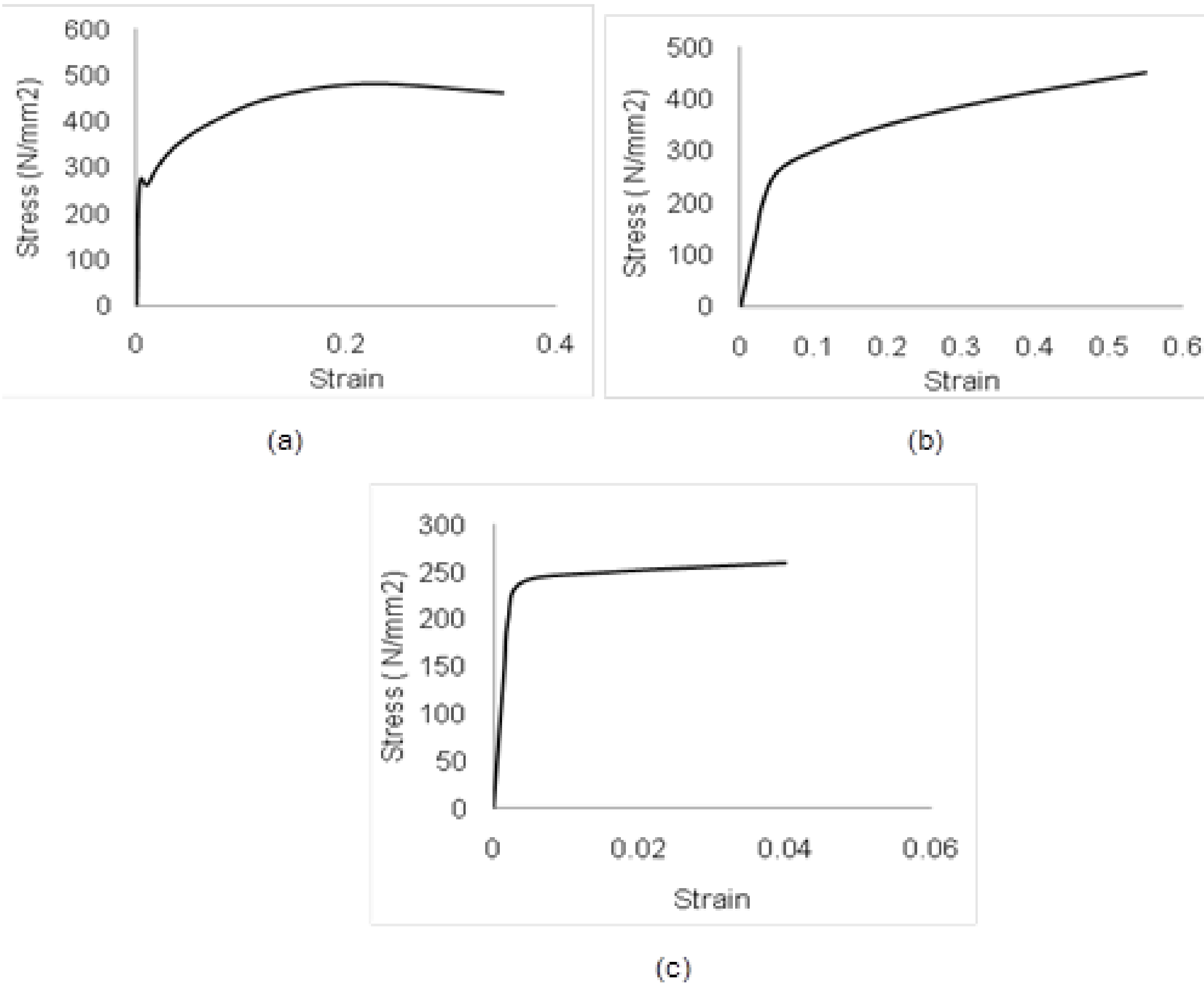

Figure 2. Typical stress-strain curves for outer tube material (a) carbon steel (b) stainless steel (c) aluminum.

concrete grades adopted in the test were 30 MPa, 40Mpa and 50 MPa respectively. The tensile coupons were taken from the curved faces of the CHS tubes in the longitudinal direction and tested in the tensile testing machine to determine the basic stress-strain characteristics. The tests were carried out in accordance with Indian standard IS 1608 specification. Figure 2 shows the stress vs strain curve for carbon steel, stainless steel and Aluminium. The properties of outer tube materials were given in the Table 3.

2.3 Instrumentation and Testing Procedure

All the Column specimens were subjected to axial compression load using a 2000 KN Universal Testing Machine (UTM). Four numbers of Strain Gauges were pasted at the middle height of the outer tube to measure the axial strain in the column specimen. To measure the axial displacement, two Linear Variable Displacement Transducers (LVDT) were used the LVDT were arranged in such a way, that it touches the end plates of the column specimen. The

Table 1. Details of test specimens and column strengths

Specimen Identification No.	L/D	D x T + d x t (mm)	Nominal Concrete strength (N/mm^2)	Column strength (kN)
MS - CHS - C30	3	100 x 3	30	750
MS - CHS - C40	3	100 x 3	40	770
MS - CHS - C50	3	100 x 3	50	1200
MS - FF - C30	3	100 x 3 + 50 x 3	30	800
MS - FF - C40	3	100 x 3 + 50 x 3	40	870
MS - FF - C50	3	100 x 3 + 50 x 3	50	1420
MS - PF - C30	3	100 x 3 + 50 x 3	30	700
MS - PF - C40	3	100 x 3 + 50 x 3	40	720
MS - PF - C50	3	100 x 3 + 50 x 3	50	1120
SS - CHS - C30	3	100 x 3	30	350
SS - CHS - C40	3	100 x 3	40	500
SS - CHS - C50	3	100 x 3	50	790
SS - FF - C30	3	100 x 3 + 50 x 3	30	550
SS - FF - C40	3	100 x 3 + 50 x 3	40	740
SS - FF - C50	3	100 x 3 + 50 x 3	50	970
SS - PF - C30	3	100 x 3 + 50 x 3	30	500
SS - PF - C40	3	100 x 3 + 50 x 3	40	530
SS - PF - C50	3	100 x 3 + 50 x 3	50	760
AL - CHS - C30	3	100 x 3	30	340
AL - CHS - C40	3	100 x 3	40	480
AL - CHS - C50	3	100 x 3	50	700
AL - FF - C30	3	100 x 3 + 50 x 3	30	520
AL - FF - C40	3	100 x 3 + 50 x 3	40	640
AL - FF - C50	3	100 x 3 + 50 x 3	50	780
AL - PF - C30	3	100 x 3 + 50 x 3	30	490
AL - PF - C40	3	100 x 3 + 50 x 3	40	500
AL - PF - C50	3	100 x 3 + 50 x 3	50	600

Table 2. Concrete mix design

Grade of Concrete	Cement	Sand	Gravel	Fly Ash	Super plasticizer	w/c
M30	1	3	3.5	-	-	0.65
M40	1	1.87	3.37	-	-	0.42
M50	1	1.69	1.86	1.64	3.6	0.45

Table 3. Material properties obtained from tensile coupon tests

Tube material	Yield strength (N/mm^2)	Ultimate strength (N/mm^2)	Elastic modulus (KN/mm^2)
Carbon Steel	275	480	206
Stainless Steel	260	450	190
Aluminium	240	260	65

axial shortening was obtained by taking the average of two readings from LVDTs for each column specimen. In order to ensure that the loads were applied uniformly to the test specimen, both the ends of the column were covered with plaster of Paris and provided with end plates. Before the start of every experiment, working of the strain gauges were ensured by applying small loads and after necessary adjustments initial readings were taken. The load increment was maintained constant as 5 KN and the load was applied until failure of the specimen occurred. At every load increment, the strain readings and axial shortening measurements were recorded using a data acquisition system. A typical concrete filled CHS composite stub column test is shown in Figure 3.

Figure 3. Column specimens under testing.

3. Test Result

The failure modes of double tube column, load-deflection relation and load- strain relation were observed for the test specimens.

3.1 Load Deflection Relation

The typical structural behavior of the tested columns is represented in Figure 4. The graphs show the correla-

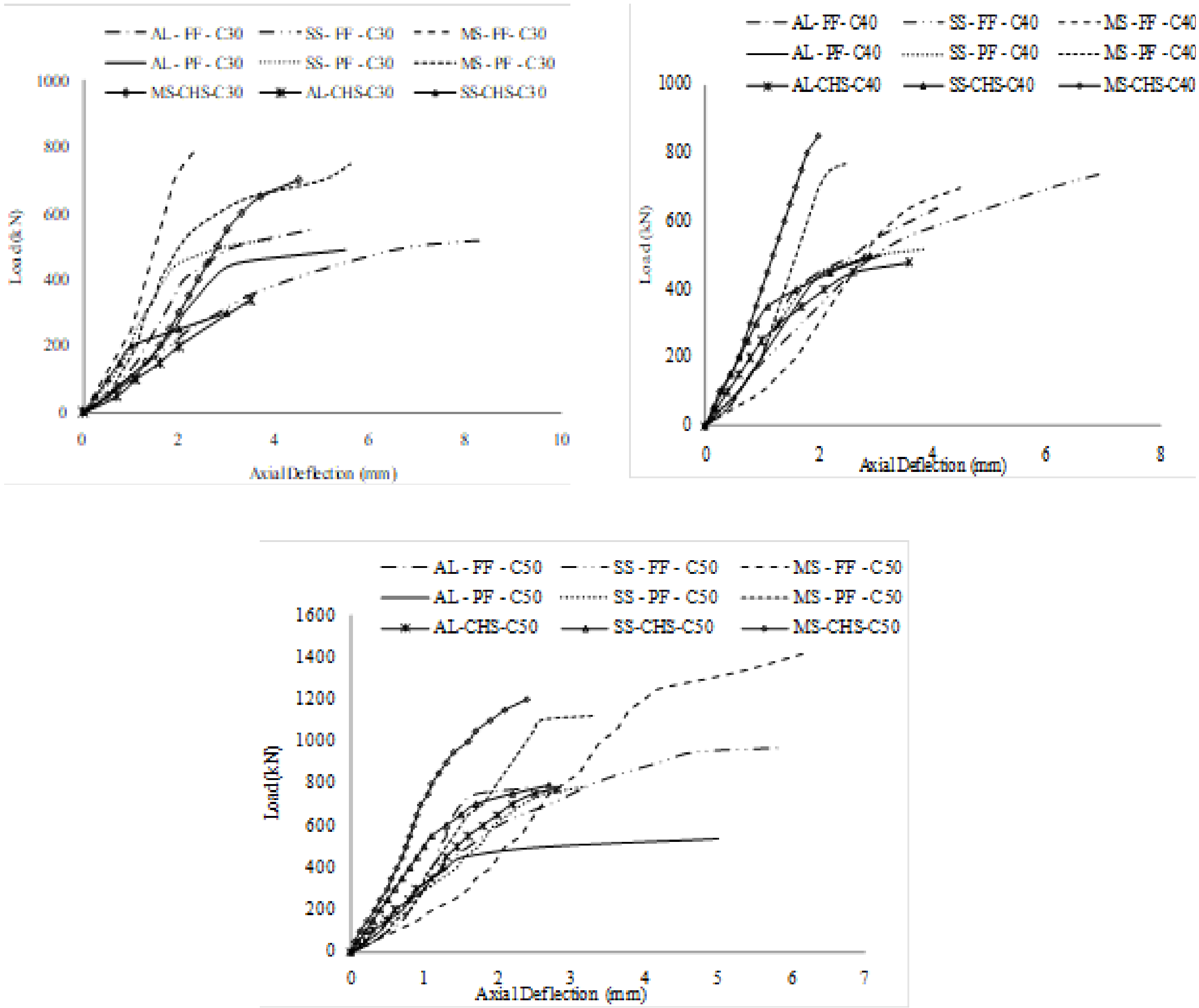

Figure 4. Load-deflection response of the column specimens.

tion between the load and axial shortening measured for all series of specimens. The figure shows quite clearly that axial shortening was small during the initial part of the loading and increased rapidly near the ultimate load. Furthermore, the Figure 4 also shows the stiffness of the composite columns is improved due to the addition of inner carbon steel tube made with different outer tube materials as evidenced from the larger slopes of the load-axial shortening curves for all grades of concrete. It is seen that aluminum and stainless steel specimens partially filled with M30 and M40 grade of concrete exhibits relatively less axial shortening than corresponding single skin fully filled specimens at any given load. It may also be observed that aluminum specimens have shown better ductile behavior for all grades of concrete even though the column strength is less when compared with stainless steel and carbon steel column specimens.

3.2 Load vs Strain Relation

From the strain the reading, graphs were plotted between load and strain for all the series of test specimen (Figure 5). The common feature of these curves is that the variation

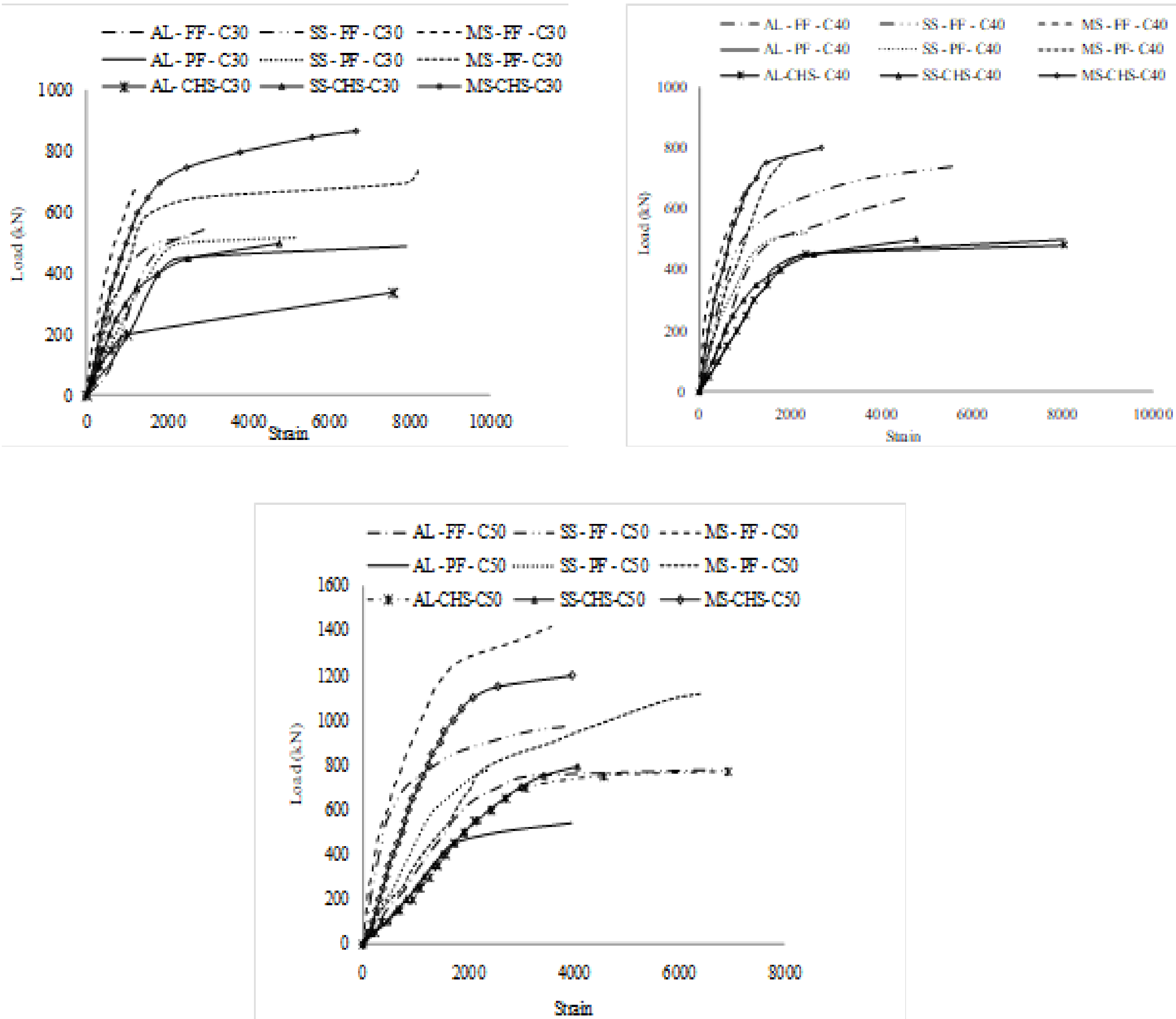

Figure 5. Load – strain response of the column specimens.

is non-linear and is characterized by an ascending branch up-to failure. It is seen that all double skin specimens fully filled with concrete have relatively less strain gradient as seen from the higher slope in the load-strain curve for all three grades of concrete. The reason is mainly to due to the additional confinement, provided by the inner steel tube. It also seen that maximum compressive strain value ranging between 0.006 and 0.008 has been reached in the aluminum specimens as seen from the graphs.

3.3 Failure Modes

All column specimens were loaded to failure and Figure 6 shows the column specimens after failure. Typical failure modes of the outer tubes were local outward buckling and occurred near mid-height for some of the column specimen. For few specimens elephant foot buckling was observed which results from end effects. Similar failure pattern was observed by[1] in his experimental study.

Figure 6. Column specimens after failure.

4. Conclusion

A test program on concrete filled composite CHS stub columns has been presented in this paper. The axial compression behaviour of double tubular column was done by subjecting the column to compression load. The test specimens include columns for different outer tube materials with and without inner steel tube. Various concrete strengths of 30, 40 and 50 MPa were investigated for fully filled column sections and partially filled column sections. The failure modes of double tube column, load-deflection relation and load- strain relation were presented.

1. The column strength increases for double skin fully filled specimens made with carbon steel, stainless steel and aluminum outer tube materials because of additional confinement of concrete core present inside the inner mild steel tube. Therefore it would be more effective to provide additional inner steel tube for stainless steel and aluminum specimens if the concrete of relatively less strength is used.

2. The column strength increases with increase of concrete strength for both fully filled and partially filled column sections made with different outer tube materials. Maximum column strength is obtained for MS-FF-C50 specimen (Mild Steel outer tube and inner tube filled fully with M50 grade concrete). The ultimate strength for the column specimen is 1420 KN (Table 1).

3. The yield strength of the steel tube and concrete strength determines the ultimate strength of partly filled column specimen. The increased value of column strength is attained in aluminum and stainless steel specimens for relatively less concrete strength when compared with corresponding fully filled specimens without inner steel tube.

It is observed from the load- axial shortening and load-strain curves, all types of column specimens shows same ductile behavior and the inner steel tube provides additional confinement which increases the stiffness further for the double skin fully filled column specimens.

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