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Confinement of Concrete by Stainless Steel Tubular Sections –A Review

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Abstract*: Concrete infilled steel tubular section (CFST) is a composite column used for modern construction. CFST column system is the most successful system, and the confinement of concrete by steel tubular sections enhances in core's strength. In recent scenario, stainless steel has been popular and widely used in many modern structural applications owing to their anti-corrosion resistance, durability, good in appearance and easy in maintenance. Stainless steel is quite expensive. To reduce the cost significantly stainless steel tube filled with concrete that is, concrete filled steel tubular (CFSST) is used and it is referred as composite material system. This composite material system has a wide application in column made up of concrete, to provide a better performance in terms of strength, stiffness, ductility and seismic resistance. Compare to all other composite material system. This paper discuss about the different types of stainless steel tubular sections, shapes used for stub column under axial loading, strength enhancement and the different modes of failures both experimentally & analytically of stub column.

***Index Terms:* stainless steel, stub column, shapes, coupon test, axial load, compressive strength**

I. INTRODUCTION

Steel have been used as structural application and as replacement of concrete structures for many years. Steel members Steel individuals have the upsides of high elasticity i.e., tensile strength and malleability. Steel sections may be subjected to one of four generic types of buckling, namely local, global, and distortional and shear. Stainless steel sections are used in many structural applications because of their anti-corrosion resistance, good in appearance and easy in maintenance [1-3]. Compare to carbon steel the mechanical properties of stainless steel are quite different, but expensive is comparatively high. For carbon and low-amalgam steels, as far as possible is thought to be at any rate 70% of the yield strength, yet for hardened steel (stainless steel) as far as possible ranges around 36%– 60% of the yield strength .[4]. Standard specification for the design of cold-formed stainless steel structural members referred from the American Society of Civil Engineers (ASCE) codes [3], the Australian/New Zealand Standard (AS/NZS 4673) [5],and from Australian/New Zealand Standard (AS/NZS 4673) [5], and the European Code (Eurocode 3) design of steel structures, part 1.4: supplementary rules for stainless steels provide design rules of stainless steel structural members [7].

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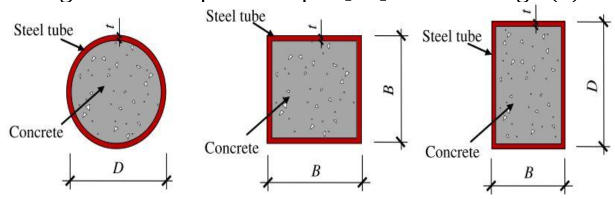
Cold formed steel Section is widely used in conventional construction as well as metal building system. Cold formed stainless steel member becoming popular nowadays. Annual consumption of stainless steel increase to 5% as compound growth rate. To counteract the high cost of stainless steel sections, utilization of concrete inside the stainless steel tubular section forms a new composite member called concrete filled stainless steel tubular section (CFSST)[8.9]. Recently many researches were carried on the concrete filled with different types of steel sections and it showed high performances in terms of greater strength, ductility, stiffness & earthquake resistance. Among those concrete filled stainless steel tubular system is most successful system. Composite column combined with steel & concrete has high qualities in all aspect like strength, ductility [13] etc..

II. TYPES OF CONCRETE-FILLED STEELS TUBULAR SECTIONS (CFST)

Column steel tubular cross sections are of so many types, circular, rectangular and square cross section. These tubular steel sections filled with concrete, it is well known that concrete is outstanding with high compressive strength than the tensile strength and steel have greater tensile strength compare to compressive load. Concrete is filled in steel tubular sections like circular, square and rectangular shapes shown in the fig 1(a).The concrete-filled steel tubes (CFST) with square and rectangular shapes provide benefits in construction, reasons behind are being easier in connection between beam to column junction design, higher bending stiffness in cross-section and in stylish point of view [2][5]. Different cross-sectional shapes have likewise been utilized for aesthetical purposes are hexagon, round-ended rectangular and elliptical shapes [10] as shown fig 1(b).



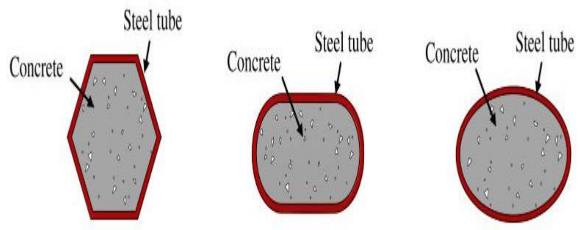


Fig1 Typical cross section for Concrete filled Steel tubular cross sections [10]

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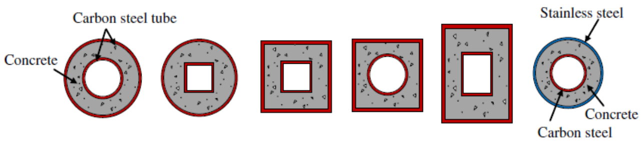
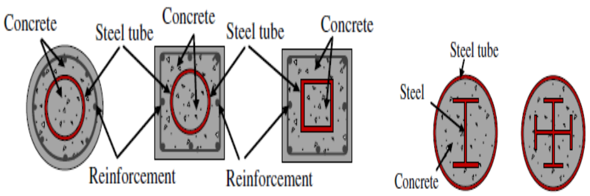
Apart from the shapes, there is a development in concrete filled steel tubes (CFST) family like double skinned CFST sections, encased CFST columns, Confinement CFST columns. Double skinned CFST columns looks like a hollow tube with greater thickness, outer layer and inner layer is arranged with are carbon steel and stainless steel or else external layer with hardened (stainless) steel tubes, internal layer with carbon steel and concrete is available in the middle of these two layers of steel, which is shown in fig 2(a).CFST column confined with concrete with additional reinforcement or rolled section inserted inside the tubular sections& additional stiffeners attached to the tubular sections for strength enhancement in the sections shown in the figure fig 2(b) & 2(c) respectively[10].

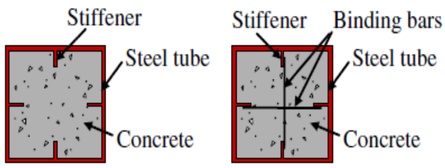


(a)Double Skinned Concrete filled steel tubular sections

(b)



(c)Encased Concrete filled steel tubular sections



(d)Concrete filled steel tubular (CFST) sections with Stiffeners

III. MATERIALS USED

The CFSST composite section consists of two different material called stainless steel tubular section and infilled concrete.

A. Steel

Hardened stainless steel gives a greater number of points of interest than the carbon steel inferable from the strength, high resistance towards corrosion, ductility,etc when compare to carbon steel. Recently many works were research carried on cold formed duplex type stainless steel and its types. The stainless steel mechanical properties like yield strength, maximum (ultimate strength) and elasticity of modulus are obtained conducting standard tensile coupon test [8] shown in the fig 3.The typical stress-strain curve for carbon steel & stainless steel shown in fig 4(a) & (b).

A sample specimens information like column label, dimension versus thickness, recycled aggregate replacement ratio (r%) for infilled material varied in proportion , Elasticity young's modulus of composite stub column (Esc) and experimental bearing capacity of stub column for both circular and square stub column is given in the Table 1.

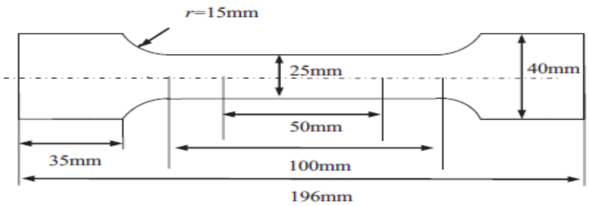


Fig 3 Tensile coupon test standard specimen dimension [8]

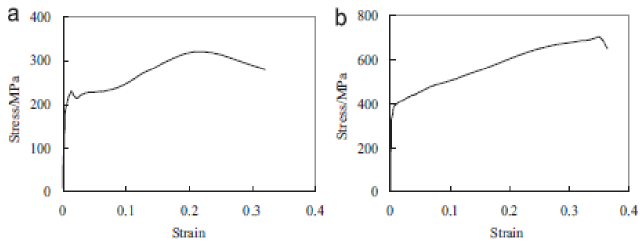


Fig 4 Typical stress-strain curve for (a) Carbon steel & (b) Stainless steel [8]

Table 1 Sample information of the stub specimens [11]

Section Type	Specimen Label	D x t mm	E_{sc} N/mm^2	r(%)	N_{ue} (kN)
Circular	C-S-N	120 X 1.77	40,828	0	823.2
	C-S-C1	120 X 1.77	38,351	25	813.8
	C-S-C2	120 X 1.77	36,388	50	802.2
	C-S-C3	120 X 1.77	34,867	75	774.3
	C-S-F1	120 X 1.77	37,019	25	806.7
	C-S-F2	120 X 1.77	35,373	50	768.4
	C-S-F3	120 X 1.77	33,861	75	777.2
Square	S-S-N	120 X 1.77	34,709	0	923.4
	S-S-C1	120 X 1.77	32,093	25	871.5
	S-S-C2	120 X 1.77	30,077	50	848.5
	S-S-C3	120 X 1.77	28,446	75	830.0
	S-S-F1	120 X 1.77	31,404	25	857.1
	S-S-F2	120 X 1.77	29,100	50	826.9
	S-S-F3	120 X 1.77	26,351	75	831.1

B. Infill Materials

Conventional concrete acted as infill material for CFSST columns. Major research carried research on with concrete filled in stainless steel tubular (CFSST) columns. Very few research works were carried on the partial or full replacement of conventional concrete. You-Fu Yang et.al..,[11] studied the behavior of recycled aggregate concrete filled in stainless tube.Y.L.Li [12] carried out the experiment with sea sand concrete filled GFRP in stainless steel tubular stub columns. NameerA. Alwash [13] conducted the experimental investigation with steel tubular stub columns infilled self-compacting concrete and studied the behavior of the stub column. Yiyan Lu et. al., [15] study the behavior of fibre reinforced polymer (FRP) confined with concrete filled steel tube (CFST) columns and prediction is load carry capacity done by review expert equation to validate the experimental results.. A sample mix proportions used for experimental work as infilled material is shown in the table 2.

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The concrete for this mix proportions are recycled fine aggregate (RFA), recycled course aggregate(RCA), natural course aggregates(NCA), water and water reducing agent.

Tabel 2 Sample mix proportions of concrete kg/m^3[11].

r(%)	Cement	Sand	RFA	NCA	RCA	Water
0	473	636	-	1072	-	213.3
25	473	636	-	804	268	213.3
50	473	636	-	536	536	213.3
75	473	636	-	268	804	213.3
25	473	477	159	1072		213.3
50	473	318	318	1072		213.3
75	473	159	477	1072		213.3

IV. SIMULATION AND EXPERIMENTAL BEHAVIOUR

Stub columns with various shapes like square, rectangular and circular modeled and analyzed using ABAQUS compared with experimental results [8]. The stub columns are tested by using hydraulic compression testing machine capacity is more than 3000kN. Boundary condition for applying load on stub column may be both ends are fixed, hinged condition or eccentrically loaded. For stub column mostly axial load under compression are tested. Axial strain is observed by using strain gauges with increasing load gradually till a failure occurs. Lateral displacement is also noted by either LVDT or by displacement transducer. Modes of failures observed and analyzed [15]. The experimental results are validated with different codal provisions. The general stub column test setup is shown in fig 5.

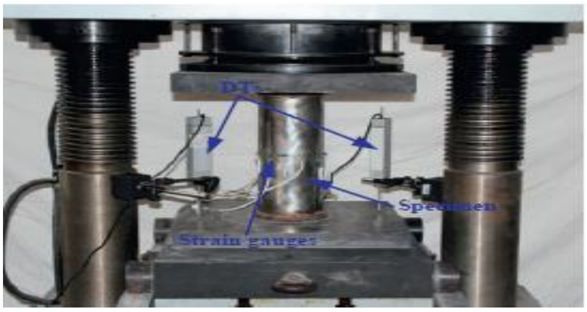

Fig 5.Stub column test setup [11]

Elephant & outward buckling failure are observed in the circular shape and square stub column. Horizontal relocation is ascertained on fibre reinforced (FR) CFST stub column which loaded eccentrically.

(a)

(b)

Fig 6 Failure modes pattern for stub columns (a) circular and (b) square columns [11]

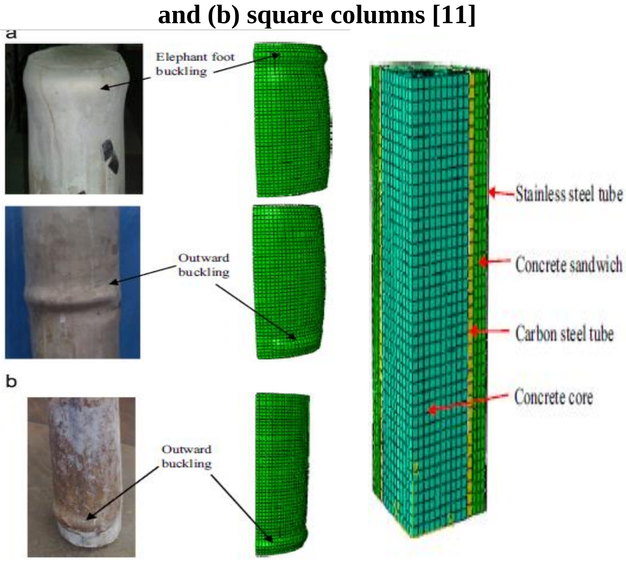

Fig 7(a) Failure occurred in Stainless (b) In Carbon steel (c) Model & Element division stainless steel with concrete [8]

V. APPLICATIONS

In order to concise the size of the columns, rapid increase in the usage of concrete filled stainless steel tubular (CFST) columns in various structures like tower, framed building, tall building structures, hybrid structural system i.e., CFST with RC shear wall, bridges etc., SEG Plaza in Shenzhen is an example for CFST in high rise building, etc. few applications are shown in the fig 8.

(a)SEG Plaza in Shenzhen (b) Canton Tower in Guangzhou

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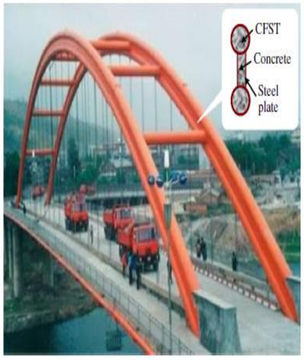
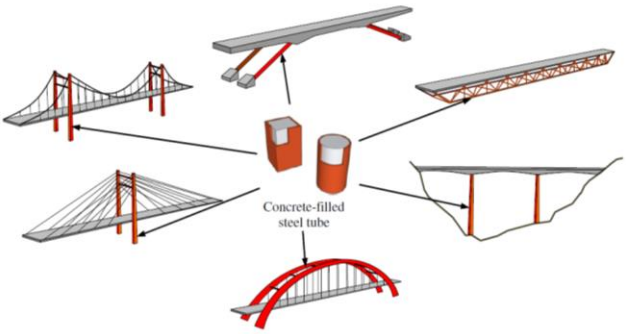


(c) Rujfeng building in Hangzhou (d) Wangcang East River Bridge



(e) CFST used in bridges

Fig 8 Applications of CFST columns [10]

VI. CONCLUDED REMARKS

❖ In past decades, research and usage of CFST column is being popular.

❖ Typical local outward buckling are observed in the circular stub column

❖ Elephant foot buckling is observed near top end of the circular stub column.

❖ For the square columns only outward buckling is observed.

❖ Predicted failure for circular column using FEM software almost similar to the experimental result.

❖ Confining the concrete material by steel section failure in concrete is extended.

❖ Due to composite action of steel and concrete, concrete filled steel tubular column has more advantages when compared to reinforced structural system like strength enhancement, stiffness and stability.

❖ It can be recommended as an alternative for structures made up of steel or reinforced structures.

❖ High performance of CFST system with RC system is called Hybrid system in high rise buildings.

❖ Rectangular or square shapes of CFST have benefits during connection

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