EXPERIMENTAL STUDY ON STRUCTURAL BEHAVIOUR OF CONCRETE FILLED STEEL TUBE UNDER AXIAL LOADING

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Abstract

Concrete-filled steel tubes circular columns (CFSTC) are widely used in high-rise buildings, modern structures, and offshore platforms due to their high strength, stiffness, energy dissipation, and fire resistance. This study examines the structural performance of concrete with steel circular columns and coconut shell aggregates made from byproducts from the agriculture sector. The experimental maximum load of CFSTC1 is 280 KN, which exceeds the projected value of 251.12 KN, suggesting a larger capacity than expected. The study also discusses the impact of coarse plastic waste aggregates on the performance of concrete-filled steel tube columns and their life cycle assessment. The ultimate load capacity of CFSTC3 is 260 kilonewtons, indicating a high level of prediction accuracy

Keywords: CFSTC, column, axial loading , ultimate load

1.Introduction

Concrete-filled steel tubes circular columns (CFSTC) are commonly employed as lateral load-resisting elements due to its ability to offer high strength and stiffness, significant energy dissipation, and fire resistance. During seismic events, the steel tube in CFSTC frame structures may experience local geometric instabilities, which can weaken the overall seismic stability of the members[1]. This, in turn, affects the risk of collapse in these structures[2].CFSTC sections are beneficial in cases when the columns experience significant compressive stresses. The CFSTC section has exceptional ductility, strength, and energy absorption capability, making it very suitable for structures situated in earthquake-prone regions. It is approximately 55% less heavy than Reinforced Concrete. Therefore, the cost of the foundation can be decreased[3].CFSTC, or Concrete-Filled Steel Tubular Columns, are extensively utilized in the construction of high-rise buildings, super high-rise buildings, modern structures, offshore platforms, elevated storage tanks, and transmission towers. This is because CFSTC offer higher seismic performance when compared to ordinary reinforced concrete columns[4], [5]. Coconut shell concrete is categorized as a type of lightweight concrete that is used for structural purposes. The coconut shells are determined to be more appropriate as a lightweight aggregate with low strength. The steel is strategically placed at the outer perimeter to optimize its performance in tension and resistance against bending moment. Structural loads refer to the forces, deformations, or accelerations that are exerted on the components of a structure[6], [7]. The combination of concrete's excellent compressive strength and steel's superior tensile strength creates a structure that can withstand significant axial loads while maintaining structural integrity[8]. This study examines the structural performance of concrete with steel circular columns and coarse aggregates made of crushed coconut shells. As a greener substitute for traditional aggregates, coconut shell concrete (CSC) makes use of byproducts from the agriculture sector. Circular columns made of steel that are filled with CSC are tested for their compressive strength, load-bearing capacity, and general stability[9]. According to the experimental results, CSC offers enough strength for structural applications, and the addition of steel columns improves load distribution and deformation resistance. Combining CSC with steel columns shows that there is a way to build sustainably that doesn't sacrifice structural integrity or the use of environmentally friendly materials. This novel method helps to reduce the environmental impact of

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building processes while simultaneously solving waste management problems. The results show that CSC could be a beneficial material for reinforced concrete buildings, which is in line with current sustainability targets[10], [11].

2. Literature Study

Column cross-sections featuring circular portions filled with concrete. Diameter (D) and Breadth (B) represent the external measurements of the steel tube, whilst t denotes the thickness of the tube's wall[12]. The circular shape of the cross section provides the most effective containment for the central concrete. Concrete-filled steel tubes are still widely used in construction because they are easy to attach beams to columns, have a high resistance to bending, and are visually appealing. Additional cross-sectional shapes, such as polygons, rectangular shapes with rounded ends, and ellipsoids, have been utilized with the goal of enhancing aesthetics[13], [14]. This composite construction method represents a remarkable fusion of concrete's compressive strength and steel's tensile capacity, offering unparalleled structural resilience and and efficiency[15]. Moreover, this construction method offers versatility in design and construction, allowing engineers to tailor the dimensions and configurations of the steel tubes and concrete elements to meet specific project requirements[16], [17]. Additionally, the composite nature of this system enhances constructability, facilitating faster and more cost-effective construction processes compared to traditional methods. In conclusion, concrete filled with steel tubes under axial loading represents a cutting-edge solution in structural engineering, harnessing the collective strengths of concrete and steel to create resilient and efficient structures capable of meeting the demands of modern construction projects[18], [19].

3.Material Study

The experimental results show that CSC, when enclosed in steel tubes, has sufficient strength for structural applications[20]. As part of this experimental study, we look at how well coconut shell concrete (CSC) holds up when combined with steel tube its mix design is shown in Table 1. In addition to preserving the structural integrity needed for modern building methods, this innovative method makes the most of agricultural waste, which helps promote sustainability. At several points in the production process, conventional coarse aggregates are mixed with coconut shell aggregate in differing proportions to create CSC combinations. The mix design follows widely accepted standards to ensure consistency and affordability[21], [22]. tube is full. After the curing process is finished, remove the filled tubes from the moulds, if necessary. Conduct quality control examinations, such as compressive strength tests, on sample cubes or cylinders produced from the identical batch of CSC.

Fig 1: Overview of the CFSTC under axial loading

4. Experimental work

Utilize vibrators to compress each layer, eliminating any air pockets and guaranteeing thorough filling. Continue the process of filling and compacting until the By adhering to this methodology, it is possible to efficiently manufacture lightweight coconut shell concrete that is filled with steel tubes, resulting in a sustainable and effective construction material. The combination utilizes the lightweight characteristics of coconut shells and the structural durability of steel tubes required dimensions and immerse in water for 24 hours to improve malleability and reduce water absorption during the blending process. Crushing the concrete after stuffing it into steel tubes helps eliminate air gaps. The next step in getting the specimens to the right strength is to put them under controlled conditions. time, which is usually around twenty-eight days. Compressive strength and axial load tests When making CSC, it's necessary to combine OPC with sand, water, and crushed coconut shells. The next step, after mixing the concrete, is to pour it into steel tubes and squeeze them.The specimens are left to cure for a set period of are performed using a universal testing machine. Notation is made of both the failure modes and the deformation[23]. The process of creating lightweight coconut shell concrete (CSC) filled with a steel tube is a complex procedure that comprises multiple steps, including the combination of materials, preparation, and building procedures. The coconut shells are thoroughly washed to eliminate any debris and organic material.

5. Fresh and hardened Properties of concrete

Coconut shell concrete (CSC) is a type of concrete that replaces standard coarse aggregates with coconut shells, either partially or completely. The slump test results in CSC can provide important information about the mixture's behaviour and suitability for construction. The coarse and uneven surface of coconut shells results in heightened friction among the particles, which in turn reduces workability and slump value of concrete is shown in Figure 3. Table 2 represents a CFSTC 1 with a whereas the CFSTC 4 slump value is 58 mm, which is high due to the water-cement ratio of 0.38 lower slump value compared to all other mixes because its water-cement ratio is 0.3, The decreased density can lead to reduced pulse velocities. Table 1 displays the average UPV values for CSC, which typically range from 4.3 to 5.0 km/s, as Ultrasonic Pulse Velocity (UPV) testing is a non-destructive technique employed to evaluate the integrity and uniformity of concrete. UPV testing in the context of coconut shell concrete (CSC) can offer useful insights about the material's internal structure, density, and general quality. Table 1 displays the outcomes of CFSTC (Concrete-Filled Steel Tubular Columns) when subjected to axial force at their maximum capacity. The table specifically highlights the column's buckling, alterations in diameter, and variations in length. These variances indicate disparities in the material characteristics, loading circumstances, or geometric elements that affect each column's performance and failure mechanism.

Table 1: Comparison of CFSTC at Experimental load(KN) and Theoretical Ultimate load(KN)

CFSTC Column Testing at Ultimate Load					Theoretical Ultimate Loads(KN)		
Specimen Name	Load (KN)	Buckling of Column(mm)	Change in Diameter (mm)	Change in Length(mm)	P_{EN} (KN)	P_{gupta} (KN)	P_{GG} (KN)
CFSTC1	280	7.6	4.5	1192.4	158.49	176.72	251.12
CFSTC2	380	8.4	5.7	1291.8	205.33	258.78	373.09
CFSTC3	260	8.2	4.3	1191.6	168.49	196.22	265.12
CFSTC4	360	7.1	5.6	1292.9	208.43	268.63	355.09

In Fig 2 specimens with the greatest buckling (8.4 mm) and change in diameter (5.7 mm) demonstrate substantial deformation. The increase in length (1291.8 mm) demonstrates significant elongation, suggesting a substantial ability to deform before reaching failure. Understanding the structural performance and reliability of CFSTC columns under axial loads is required. The measured buckling (7.6 mm) and diameter alteration (4.5 mm) suggest a significant degree of deformation prior to failure. The observed increase in length (1192.4 mm) indicates a substantial elongation when subjected to a load.

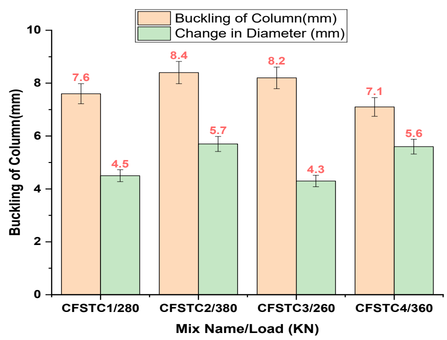

Fig 2: Buckling of column corresponding change in diameter

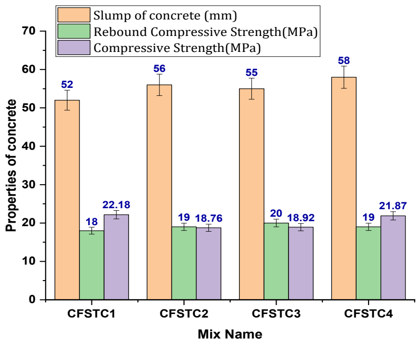

Fig 3: Fresh and Hardened properties of concrete

Table 2 shows the measurements of deformation (DL) and diameter change (DLD) over time for four concrete-filled steel tubular columns (CFSTCs) named CFSTC1, CFSTC2, CFSTC3, and CFSTC4. The measurements are collected at different time intervals (ranging from 0 to 380 seconds), documenting the reaction of each column under the applied stress. In general, the data demonstrates the response of CFSTCs to axial stress over time, where differences in initial deformation and diameter change affect their structural behaviour. It indicates that concrete core has a failure in compression, resulting in crushing and spalling. The steel tube may still offer partial confinement, but the core's load-bearing capacity is respalling. Although the steel tube may still provide partial confinement, it reduces CFSTC structures' load-bearing capacity, core performance, and dependability when subjected to axial loading.

Table 2: Load (KN) to Deformed length(DL) /Deformed Lateral Diameter (DLD)

Load (KN)	Deformed Length (DL) /Deformed Lateral Diameter(DLD)							
	CFSTC1		CFSTC2		CFSTC3		CFSTC4	
	(DL) mm	(DLD) mm	(DL)mm	(DLD) mm	(DL)mm	(DLD) mm	(DL)mm	(DLD) mm
0	1200	80	1200	100	1300	80	1300	100
20	1200	80	1200	100	1300	80	1300	100
40	1199.3	80.4	1199.6	100.3	1299.4	80.2	1299.7	100.2
60	1198.5	80.7	1199.1	100.5	1298.4	80.5	1299.1	100.5
80	1197.8	81	1198.7	100.8	1297.7	80.9	1298.6	100.8
100	1197.2	81.4	1198.2	101.3	1296.9	81.2	1298.2	101.1
120	1196.5	81.8	1197.8	101.7	1296.2	81.6	1297.7	101.5
140	1195.9	82.3	1197.2	102	1295.4	82	1297.3	101.8
160	1195.2	82.6	1196.6	102.3	1294.8	82.5	1296.8	102.1
180	1194.4	83	1196.2	102.7	1294.2	82.9	1296.4	102.5
200	1193.9	83.3	1195.6	103.1	1293.5	83.2	1295.9	102.8
220	1193.8	83.7	1195.1	103.5	1292.9	83.6	1295.5	103.2
240	1193.4	84	1194.5	103.9	1292.4	84.1	1295.1	103.6
260	1192.9	84	1194	104.3	1291.8	84.3	1294.6	103.9
280	1192.4	84.3	1193.4	104			1294.2	104.2
300		84.5	1193	104.4			1293.7	104.6
320			1192.5	104.8			1293.3	105
340			1192.2	105.1			1292.5	105.4
360			1191.9	105.5			1292.3	105.5
380			1191.6	105.7				

Concrete-filled steel tubular columns (CFSTCs) have diverse failure modes when subjected to axial compression. Fig 4 illustrates the failure patterns, which include external buckling, internal buckling, and crushing behaviour. Gaining a comprehensive understanding of these failure modes is essential for the construction of secure and efficient CFSTC structures. The concrete core within the steel tube experiences buckling or instability. This phenomenon is more common in columns with high slenderness ratios or poor confinement.

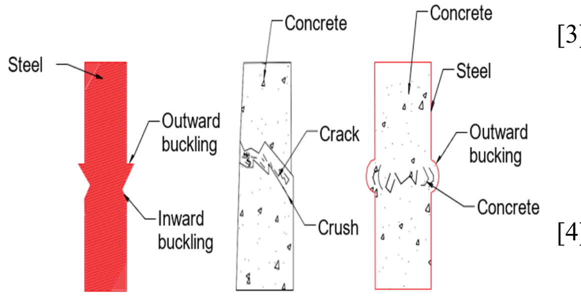

Fig 4: Failure pattern of CFSTC

6.Conclusion

Concrete-filled steel tubes circular columns (CFSTC) are a popular choice for high-rise buildings, modern structures, offshore platforms, and transmission towers due to their high strength, stiffness, energy dissipation, and fire resistance. This study examines the structural performance of concrete with steel circular columns and coconut shell aggregates made from byproducts from the agriculture sector. The results show that CSC offers sufficient strength for structural applications, and the addition of steel columns improves load distribution and deformation resistance[23]. This innovative method helps reduce the environmental impact of building processes and solves waste management problems, making CSC a beneficial material for reinforced concrete buildings in line with current sustainability targets.The process of creating lightweight coconut shell concrete (CSC) filled with steel tubes involves washing, pulverizing, and immersing them in water for 24 hours. The compressive strength of CSC is influenced by factors such as mix design, the fraction of coconut shells used as aggregate, the water-cement ratio, and curing conditions. The study also explores the impact of coarse plastic waste aggregates on the performance of concrete-filled steel tube columns and their life cycle assessment.

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