STUDIES ON BEHAVIOUR OF COMPOSITE BEAMS AND COLUMNS WITH PARTIAL REPLACEMENT OF COARSE AGGREGATE BY STEEL SLAG

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***Abstract*- The cost of land and construction materials has been increasing in a consistent pace. A better utilization of both construction materials and cost will have more advantages regarding to savings in the floor area. The high rise buildings provide underground parking area in order to minimize the space scarcity in-order to save maximum floor area. The columns in these type of high rise buildings are larger in size and hence, it occupies more spaces in the floor area which results in increasing both construction and materials cost. In order to reduce the size of such columns, a special type of composite column known as concrete filled steel tubular is introduced. It is a special class of structural system where the properties of both steel and concrete are used up to their maximum advantage. When employed under favorable conditions, in-filled concrete inhibits the local buckling of the tubular shell and steel casing confines the core tri-axially creating a confinement for better seismic resistance. Two types of columns such as Long Columns and Short Columns. The Columns developed with two different cross sections such as solid and hollow. Concrete filled steel tubular beams are also investigated with square cross section. Concrete of grade M50 has been used for the investigation and six different mixes like conventional concrete, convention concrete with steel fibre reinforcement, conventional concrete with polypropylene fibre reinforcement, concrete with 40% of steel slag replaced against coarse aggregate, steel slag concrete with steel fibre reinforcement and steel slag concrete with polypropylene fibre reinforcement. Steel slag concrete filled steel tubular section members perform notably than the conventional concrete filled steel tubular section. The presence of fiber increases the load and deformation behavior of columns and beams. A high modulus steel reinforced concrete infill increases the load carrying capacity of members and low modulus polypropylene fiber improves the deformation behavior notably.**

***Keywords*: Concrete, Self-Compacting Concrete, Finite Element Analysis**

I. INTRODUCTION

The use of Self Compacting Concrete (SCC) has acquired global recognition in recent decades (Kou & Poon 2009). Flexible structural frameworks can be accomplished by using SCC, which also has the potential to compact without the intervention of physical vibration at each section of the formwork by its weight (Hajime Okamura & Masahiro Ouchi 2003). To make sure sufficient compaction and uniformity, SCC has been implemented to promote the efficiency of the same in systems with densely packed and complex reinforcements. Excellent flexibility, separation, and self-compactability are suitable characteristics of the SCC that makes it possible to position and compact concrete with the removal of noise pollution induced by vibration (Pandaa & Bal 2013).

Because of the urban growth, construction and demolition activities have been increasing slowly but surely. Such practices acted in field of Construction and Demolition (C&D) produce large amounts of solid waste. Many of the industrial waste is deposited on the earth‘s surface as vast piles of landfill. Such landfills bring a significant threat to the ecosystem. Recycled concrete aggregate makes up a large portion of the C&D wastes. The C&D waste can also be turned into materials that can be recycled effectively in concrete mix. RCA generated in C&D is relatively scarce, and thus it is possible to use significant amounts of the same as a substantial replacement with natural coarse aggregate. Furthermore, the characteristics and behavior need to be thoroughly investigated before usage.

Field research conducted worldwide in the SCC domain has not developed adequate requirements for the development and processing of SCC mixtures. Few kinds of research have been conducted on SCC mix proportion optimization utilizing recycled aggregates, and there is only minimal work involved utilizing RCA in SCC. Besides, no work has been identified using RCA in Beam-Column Joint fabrication (BCJ).

Therefore analysis of the behavior and effectiveness of RCA usage in SCC is necessary because of its extensive real-time usage. Incorporating different admixtures and materials into Normally Vibrated Concrete (NVC) and SCC (Mucteba Uysal & Mansur Sumer 2011) has also led to several research works. This investigation includes detailed research into the use of RCA in SCC and its behavior under typical loading in BCJ. The criteria relating to SCC‘s fresh and hardened characteristics were analyzed. An appropriate proportion of SCC was achieved using RCA using outcomes of the fresh state tests. They also observed the impact of incorporating steel fibers to SCC. In multi-storeyed reinforced concrete structural frames, an essential component is the joints in which the beam and the column intersect, called the Beam-Column Joint (BCJ). The densely populated framework at BCJ provides a specific region of SCC in building frameworks of reinforced concrete. SCC‘s intrinsic properties allow it suitable for use at BCJ. Research is, therefore, necessary to determine BCJ‘s behavior under vertical and axial loads. This thesis also aims to research the potential use of RCA in SCC and its eventual use in BCJ.

The mostly used construction material is concrete. Properly built, mixed, compacted, and cured concrete results in an issue with strength. Self-compacting concrete is a safer choice than traditional compacting concrete than sites that, due to specific site conditions, the usual method of compacting might not be beneficial. Self Compacting concrete or high-performance Concrete are revolutionary mix that did not involve compaction and placement vibration of any type. Cured SCC is compact, it is coherent and has the same material characteristics and resilience as standard concrete.

From ACI, Self - Compacting Concrete is easily flowable concrete does not segregate, with no structural contraction, it will extend between the reinforcement joints, fill the formwork, and comprise the reinforcements. SCC has become a vital building technology in many aspects; the most critical advancement is concrete development and positioning of concrete on building methods. Although aggregates make up a lower percentage of SCC than they do in typical vibrated concrete, they are still the most important component. It has a major impact on both hardened and fresh properties.

II. MATERIAL USED

The materials used for this investigation are: Ordinary Portland cement, coarse aggregate, fine aggregate of clean river sand, fly ash, portable water, steel slag and super plasticizer. CFST columns and steel tubular. The fibers used in this study are steel and polypropylene fibers. The detailed properties are given subsequently.

2.1 Cement

Cement used in this investigation is Ordinary Portland Cement of 43 grade, conforming to IS 8112-1989. Various tests have been carried out to find out physical properties of cement and the results are shown in Table 1.

Table 1 Physical Properties of 43 Grade Ordinary Portland cement

Physical Properties	Test Values	Requirements as per IS8112-1989
Standard Consistency	29.0%	-
Initial Setting Time	42 Minutes	Minimum of 30 minutes
Final Setting Time	285 Minutes	Maximum of 600 minutes
Specific Gravity	3.12	-
Compressive Strength in N/mm^2 at3 days	28.0	Not less than 22
Compressive Strength in N/mm^2 at7 days	37.5	Not less than 33
Compressive Strength in N/mm^2 at 28 days	47.6	Not less than 43

2.2 Fine Aggregate

Natural river sand is used as fine aggregate for this investigation. The results obtained from sieve analysis are shown in Table 3.2. From the results, it can be found that the sand conforms to Zone II of IS: 383 – 1970. The properties of sand has been determined by using various tests as per IS: 2386 (Part- I). The results are shown in Table 3.

Table 2 Grading of Fine Aggregate

I.S. Sieve Size	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative Percentage Weight Retained	Cumulative Percentage Weight Passing

10 mm	2	2	0.4	99.6
4.75 mm	6	8	1.6	98.4
2.36 mm	20	28	5.6	94.4
1.18 mm	76	104	20.8	79.2
600 microns	224	328	65.6	34.4
300 microns	114	442	88.4	11.6
150 microns	54	496	99.2	0.8
< 150 microns	4	500	100	0.0

Remarks: Conforming to Zone II of Table 4 of IS: 383-1970

Table 3 Physical Properties of Fine Aggregate (Tests as per IS: 2386– 1968: Part III)

Physical Properties	Values
Specific Gravity	2.7
Fineness Modulus	2.86
Water Absorption	0.78%
Bulk Density (kg/m^3)	1680
Free Moisture Content	0.11%

2.3 Coarse Aggregate

Crushed rock stones obtained from local quarries have been used as coarse aggregate. Coarse aggregate of size 12 mm is used. The properties of coarse aggregate have been determined by using tests as per IS: 2386 (Part – III). The results are tabulated in Table 4.

Table 4 Physical Properties of Coarse Aggregate (Tests as per IS: 2386 – 1968 Part III)

Physical Properties	Values
Specific Gravity	2.6
Fineness Modulus	2.73
Water Absorption	0.5%
Bulk Density (kg/m^3)	1590
Free Moisture Content (%)	0.2%
Aggregate Impact value (%)	11.2
Aggregate Crushing value (%)	25.12

2.4 Water

Water is the key element and least expensive ingredient of concrete. Ordinary potable water available in the laboratory is used for the exploratory investigations and curing purpose. Water is a dominant ingredient of concrete as it participates in the chemical reactions with cement to form the hydration product, calcium-silicate-hydrate (C-S-H) gel. A higher water cement (w/c) ratio will reduce the strength, durability, water tightness and other related properties of the concrete. Portable Water, used for mixing and curing, should be free from any amount of oils, acids, alkalis, sugar, salts and organic materials or other substance that may be deleterious to concrete or steel confirming to IS : 456 – 2000. The water content mixed in the Steel Slag Concrete is proportionate to the total binders such as cement, fly ash etc. The pH value of water lies between 6 and 8 that indicates the water is free from organic substances.

2.5 Polypropylene Fiber (PP)

Synthetic fibers have attracted more attention for increasing the strength of concrete in recent years. Polypropylene fibers are characterized by low elastic modulus and poor physiochemical bonding with cement paste. It is quite apparent that the load carrying ability of a structure under flexural loading is considerably increased. Polypropylene fiber (PP) has shown considerable improvements in strain capacity, toughness and crack control. Mainly ductility of concrete has been improved.

The macromolecule has a satirically regular atomic arrangement, thus polypropylene fibers can be produced in a crystalline form. The polypropylene film consists of amorphous material and crystalline micro fibrils. Thus, using specially designed machines, splits are induced in the longitudinal direction to facilitate fibrillation. It is used as discontinuous fibrillated material for the production of FRC by the mixing method or as a continuous mat for production of thin sheet elements.

The modulus of elasticity of both the monofilament and the fibrillated polypropylene is usually about 3500 N/mm2, and the tensile strength is about 50 to 600 N/mm2 . The bundles of PP fibers added to concrete are separated into millions of individual strands due to the abrasion action of aggregates. The physical properties of PP fibers are shown in Table 5 and PP is shown in Figure 1.

Figure 1 Polypropylene fiber

Table 5 Properties of polypropylene fibre

Properties	**Value**
Length(mm)	15
Diameter (micron meter)	37
Tensile strength(MPa)	400
Elastic Modulus (MPa)	2.5
Density (kg/m^3)	910
Melting point (ºC)	165
Elongation (%)	6
Aspect Ratio	405

(Technical data sheet from fiber zone, Gujarat, India)

3.2.6 Steel Fiber

Steel fibers are the filaments of wire which are deformed, cut to lengths and used as a reinforcement of concrete, mortar and other composite materials. Steel fibers have good tensile and flexural behavior and hence, they are used in concrete and mortar to enhance their properties. The physical properties of steel fibers are shown in Table 3.6 and SF is shown in Figure 2

Table 6 Properties of steel fibers

Properties	Value
Length (mm)	15
Diameter (micron meter)	300
Tensile strength (MPa)	2000
Elastic Modulus (MPa)	175
Density (kg/m^3)	7900
Melting point (ºC)	1370
Elongation(%)	4.5
Aspect Ratio	50

(Technical data sheet from fiber zone, Gujarat, India)

Figure 2 Steel Fiber

III. RESULT ANALYSIS

The workability tests such as slump cone test and compaction factor test are conducted on the fresh state concrete with every 10% percentage of steel slag replaced with coarse aggregate. The workability test result values for these concrete mixes are shown in Table 7. The Slump cone test results on concrete with replacement of steel slag and compaction factor test results on concrete with replacement of steel slag are shown in Figure 3 and Figure 4 respectively. On analysing the test results, it can be found that steel slag does not made any changes in the aspects of workability of concrete.

Table 7 Workability Test Results on concrete with replacement of steel slag

S.No	Mix I.D	Slump Value(mm)	Compaction Factor
1	CC	117	0.96
2	SSC1	117	0.95
3	SSC2	118	0.95
4	SSC3	117	0.95

5	SSC4	117	0.95
6	SSC5	117	0.94
7	SSC6	116	0.94
8	SSC7	115	0.93
9	SSC8	114	0.93
10	SSC9	114	0.93
11	SSC10	110	0.92

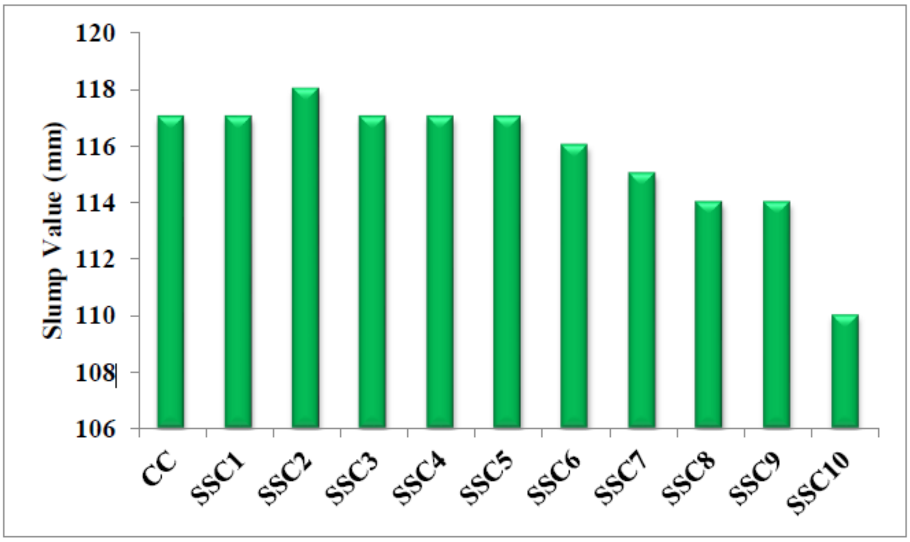

Figure 3 Slump cone test results on concrete with replacement of steel slag

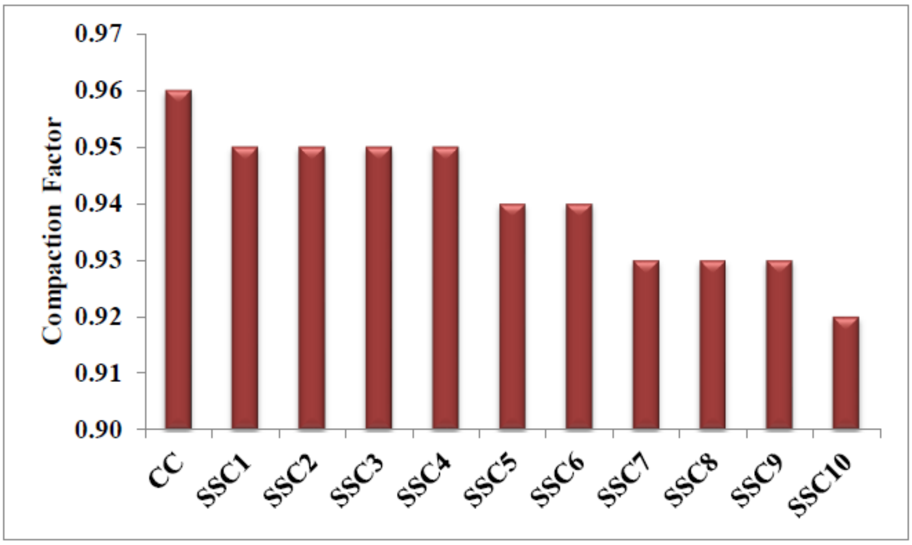

Figure 4 Compaction factor test results on concrete with replacement of steel slag

4.2.2 Workability Tests on Concrete with Replacement of Steel Slag and Addition of Steel Fiber

The workability tests such as slump cone test and compaction factor test are conducted on the fresh state concrete with every 10% percentage of steel slag replaced with coarse aggregate and addition of steel fiber of volume fraction 2%. The workability test result values for these concrete mixes are shown in Table 8.

Table 8 Workability Test Results on concrete with replacement of steel slag and addition of Steel fiber

S.No	Mix I.D	Slump Value(mm)	Compaction Factor
1	CC	117	0.96

2	CC+S2.0	106	0.90
3	SSC1+S2.0	107	0.89
4	SSC2+S2.0	107	0.89
5	SSC3+S2.0	106	0.89
6	SSC4+S2.0	106	0.88
7	SSC5+S2.0	105	0.88
8	SSC6+S2.0	105	0.87
9	SSC7+S2.0	105	0.87
10	SSC8+S2.0	104	0.87
11	SSC9+S2.0	104	0.85
12	SSC10+S2.0	104	0.83

The Slump cone test results on concrete with replacement of steel slag and addition of steel fiber and compaction factor test results on concrete with replacement of steel slag and addition of steel fiber are shown in Figure 5 and Figure 6 respectively. On analyzing the test results, it can be found that steel slag does not made any changes in the aspects of workability of concrete.

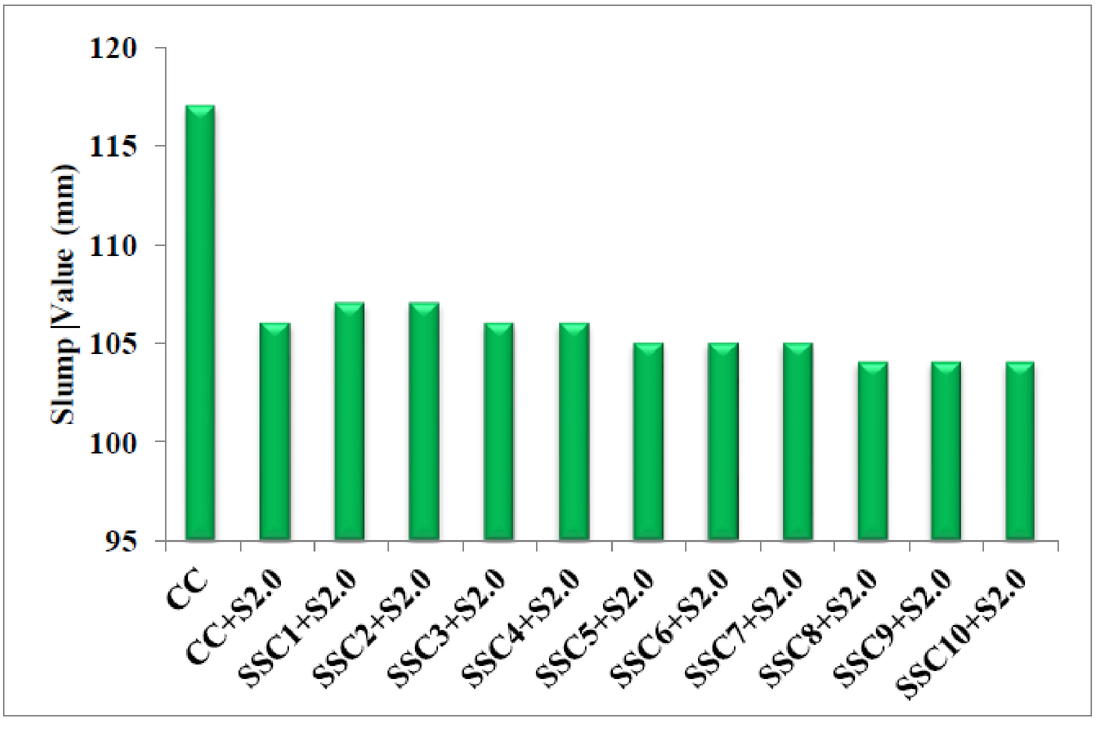

Figure 5 Slump cone test results on concrete with replacement of steel slag and addition of Steel fiber

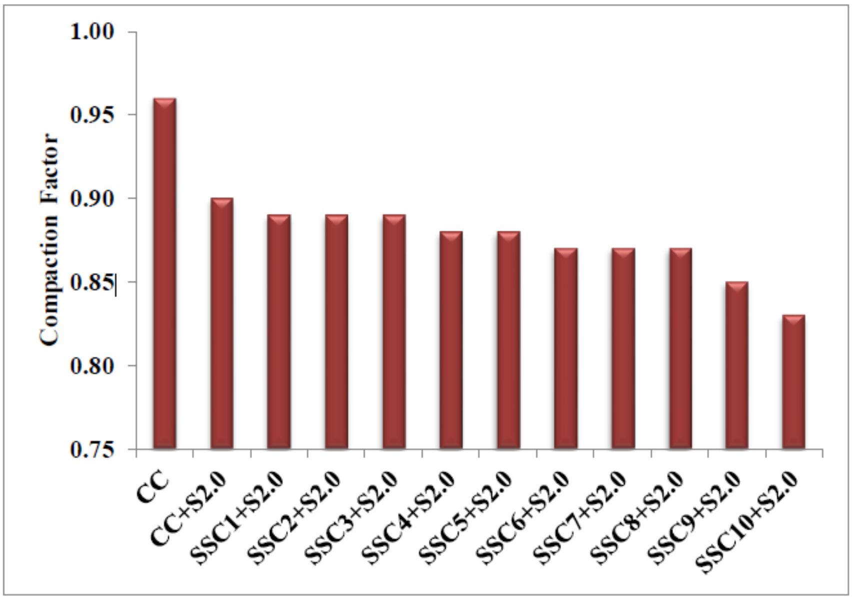

Figure 6 Compaction factor test results on concrete with replacement of steel slag and addition of Steel fiber

IV. Conclusions

The section deals with literature concerning recycled concrete aggregates (RCA) produced from C & D waste and its usage in concrete constructions, the application for Recycled concrete aggregates for futuristic development of self - compacting concrete (SCC) comprising both unprocessed and processed. The mechanical, flexural and structural performance of CFST columns and CFST beams are discussed in this conclusion chapter. From the mechanical property test results, the following conclusions have been arrived;

On analyzing the mechanical properties, it is found that replacement of coarse aggregate by steel slag influences the strength characteristics of concrete. The replacement of coarse aggregate with steel slag by 40% gives the optimum mix proportion. Moreover the 40% replacement of coarse aggregate by steel slag performs better on addition of steel and polypropylene fiber of 2% volume fraction.

REFERENCES:

1. Baalamurugan, J, Kumar, V G, Chandrasekaran, S, Balasundar, S, Venkatraman, B, Padmapriya, R & Raja, V B 2019, ‘Utilization of induction furnace steel slag in concrete as coarse aggregate for gamma radiation shielding’, Journal of hazardous materials, vol. 369, pp. 561-568.
2. Biao Li, YinChi, Lihua Xu, Yuchuan Shi, Changning Li, “Experimental investigation on the flexural behavior of steelpolypropylene hybrid fiber reinforced concrete”, Construction and Building Materials, Vol.191, pp. 80-94, 2018.
3. Cai J, Pan, J & Lu, C 2018, ‘Mechanical behavior of ECC-encased CFST columns subjected to eccentric loading’, Engineering Structures, vol. 162, pp. 22-28.
4. Cai, J, Pan, J & Li, X 2018, ‘Behavior of ECC-encased CFST columns under axial compression’, Engineering Structures, vol. 171, pp. 1-9.
5. Cai, J, Pan, J, Su, H & Lu, C 2018, ‘Experimental study on the hysteretic behavior of ECC-encased CFST columns’, Engineering Structures, vol. 173, pp. 107-121.
6. Chen, Y, Wang, K, He, K, Wei, J & Wan, J 2018, ‘Compressive behavior of CFRP-confined post heated square CFST stub columns’, Thin-Walled Structures, vol. 127, pp. 434-445.
7. Dong, H, Li, Y, Cao, W, Qiao, Q & Li, R 2018, ‘Uniaxial compression performance of rectangular CFST columns with different internal construction characteristics’, Engineering Structures, vol. 176, pp. 763-775.
8. Douglas, K & Billington, S 2011, ‘Strain rate dependence of HPFRCC cylinders in monotonic tension’, Materials and structures, vol. 44, pp. 391-404.
9. Ekmekyapar, T, Alwan, O H, Hasan, H G, AShehab, B & Al-Eliwi, B J M 2019, ‘Comparison of classical, double skin and double section CFST stub columns: Experiments and design formulations’, Journal of Constructional Steel Research, vol. 155, pp. 192-204.
10. Elchalakani, M, Hassanein, M F, Karrech, A, Fawzia, S, Yang, B & Patel, V I 2018, ‘Experimental tests and design of rubberised concrete filled double skin circular tubular short columns’, Structures, vol. 15, pp. 196-210.
11. Eom, S-S, Vu, Q-V, Choi, J-H, Park, H-H & Kim, S-E 2019, ‘Flexural behavior of concrete-filled double skin steel tubes with a joint’, Journal of Constructional Steel Research, vol. 155, pp. 260-272.

12. Farahi, M, Heidarpour, A, Zhao, X-L & Al-Mahaidi, R 2016, ‘Compressive behaviour of concrete-filled double-skin sections consisting of corrugated plates’, Engineering Structures, vol. 111, pp. 467-477.
13. Han, L-H, He, S-H & Liao, F-Y 2011, ‘Performance and calculations of concrete filled steel tubes (CFST) under axial tension’, Journal of Constructional Steel Research vol. 67, pp. 1699-1709.
14. Han, L-H, Li, Y-J & Liao, F-Y 2011, ‘Concrete-filled double skin steel tubular (CFDST) columns subjected to long-term sustained loading’, Thin-Walled Structures, vol. 49, no. 12, pp. 1534-1543.
15. Hassanein, M F & Kharoob, O F 2014, ‘Compressive strength of circular concrete-filled double skin tubular short columns’, Thin-Walled Structures, vol. 77, pp. 165-173.
16. Hassanein, M F, Elchalakani, M, Karrech, A, Patel, V I & Yang, B 2019, ‘Behaviour of Concrete-filled Double-skin Short Columns Under Compression Through Finite Element Modelling: SHS Outer and SHS Inner Tubes’, Structures, vol. 14, pp. 358-375.
17. Hassanein, M F, Kharoob, O F & Gardner, L 2015, ‘Behaviour and design of square concrete-filled double skin tubular columns with inner circular tubes’, Engineering Structures, vol. 100, pp. 410-424.
18. Heniegal, A M, Amin, M & Youssef, H 2017, ‘Effect of silica fume and steel slag coarse aggregate on the corrosion resistance of steel bars’, Construction and Building Materials, vol. 155, pp. 846-851.
19. Huang, Z, Liew, J Y R, Xiong, M & Wang, J 2015, ’Structural behaviour of double skin composite system using ultra-lightweight cement composite’, Construction and Building Materials, vol. 86, pp. 51-63.
20. Leone M, Centonze, Colonna, Micelli, Aiello, “Fiber-reinforced concrete with low content of recycled steel fiber: Shear behaviour”, Construction and Building Materials, Vol.161, pp. 141-155, 2018.
21. Li, D, Uy, B, Patel, V & Aslani, F 2018, ‘Behaviour and design of demountable CFST column-column connections subjected to compression’, Journal of Constructional Steel Research, vol. 141, pp. 262-274.
22. Li, W, Han, L-H & Zhao, X-L 2012, ‘Axial strength of concrete-filled double skin steel tubular (CFDST) columns with preload on steel tubes’, Thin-Walled Structures, vol. 56, pp. 9-20.
23. Li, W, Ren, Q-X, Han, L-H & Zhao, X-L 2012, ‘Behaviour of tapered concrete-filled double skin steel tubular (CFDST) stub columns’, Thin-Walled Structures, vol. 57, pp. 37-48.
24. Liang Q Q 2018, ‘Numerical simulation of high strength circular double-skin concrete-filled steel tubular slender columns’, Engineering Structures, vol. 168, pp. 205-217.
25. Liang, Q Q 2017, ‘Nonlinear analysis of circular double-skin concrete filled steel tubular columns under axial compression’, Engineering Structures, vol. 131, pp. 639-650.
26. Liang, W, Dong, J & Wang, Q 2019, ‘Mechanical behaviour of concrete-filled double-skin steel tube (CFDST) with stiffeners under axial and eccentric loading’, Thin-Walled Structures, vol. 138, pp. 215-230.
27. Palankar, N, Ravi Shankar, A U & Mithun, B M 2016 ‘Durability studies on eco-friendly concrete mixes incorporating steel slag as coarse aggregates’, Journal of Cleaner Production, vol. 129, pp. 437-448.
28. Panjwani, P & Dubey, D S 2015, ‘Study of Reinforced Concrete Beam-Column Joint’, International Journal of Engineering Research, vol. 4, pp. 321-324.
29. Pi, T, Chen, Y, He, K, Han, S & Wan, J 2019, ‘Study on circular CFST stub columns with double inner square steel tubes’, Thin-Walled Structures, vol. 140, pp. 195-208.
30. Prakash, A, Madheswaran, A N C & Lakshmanan, N 2012, ‘Modified Push-out Tests for Determining Shear Strength and Stiffness of HSS Stud Connector-Experimental Study’, International Journal of Composite Materials, vol. 2, pp. 22-31.
31. Radhika, K S & Baskar, K 2012, ‘Bond stress characteristics on circular concrete filled steel tubular columns using mineral admixture metakaoline’, International Journal of Civil and Structural Engineering, vol. 3, pp.1-8.
32. Sabapathy, Y K, Balasubramanian, V B, Shiva Shankari, N, Yeshwant Kumar, A & Ravichandar, D 2017, ‘Experimental investigation of surface modified EOF steel slag as coarse aggregate in concrete’, Journal of King Saud University - Engineering Sciences, vol. 29, no. 4, pp. 388-393.
33. Shea, O M & Bridge, R 2019, ‘Tests of Thin-Walled Concrete-Filled Steel Tubes’ Twelfth International Specialty Conference on Cold- Formed Steel Structures.
34. Shekastehband, B, Taromi, A & Abedi, K 2017, ‘Fire performance of stiffened concrete filled double skin steel tubular columns’, Fire Safety Journal, vol. 88, pp. 13-25.
35. Shen, Q, Wang, J, Wang, J & Ding, Z 2019, ‘Axial compressive performance of circular CFST columns partially wrapped by carbon FRP’, Journal of Constructional Steel Research, vol. 155, pp. 90-106.