Study on behaviour of cold formed hollow steel sections under compression with and without infill

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Abstract

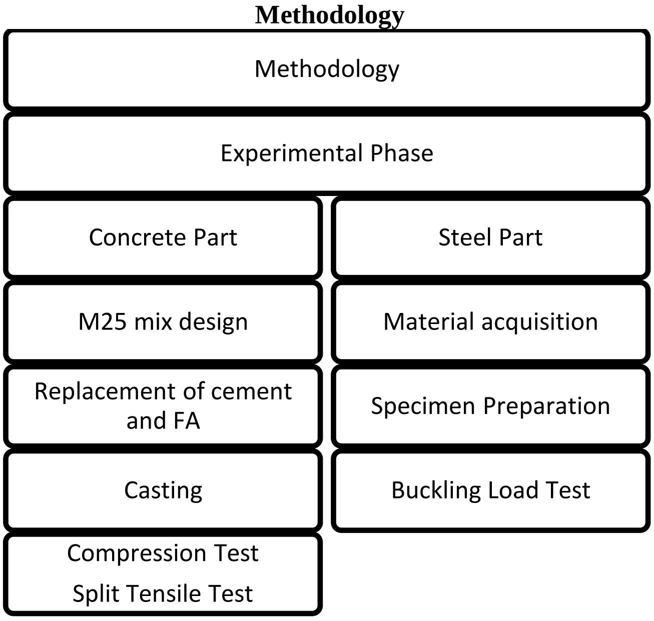
This paper presents the experimental study on buckling behavior of cold formed hollow steel sections with and without infill. It also studies the contribution of normal mix, fly ash and quarry dust mixes to the ultimate buckling load capacity of rectangular hollow stell sections under monotonic axial loading. Six specimens of 1400-mm long hollow steel sections filled with normal mix, fly ash and quarry waste and similar dimensions of hollow sections were experimented. Extensive measurements of such material properties, strain and deflection were carried out. Theoretical study of critical buckling load capacity of column specimens were also calculated for justification. These experimental investigation results showed that normal mix, fly ash and quarry dust enhance the load carrying capacity of steel hollow sections. Furthermore, in these studies it can be found that normal mix, fly ash and quarry dust concrete can be used in composite construction to increase the buckling load capacity of hollow steel sections.

Keywords: CFST, hollow, infill, buckling.

Introduction

For past few decades composite columns have been in high usage in construction industry. Composite column is a structural member that is a combination of structural steel and reinforced concrete to provide adequate load carrying capacity to sustain either axial compressive load or a combination of axial loads and bending moments. In concrete-filled steel tube (CFST) columns, the steel tube provides formwork for the concrete in turn the concrete prevents local buckling of the steel tube wall. Many in-fill materials are used to improve ductility of Concrete Filled Steel Tube (CFST) columns. Since infill material used here has no severe exposure condition an attempt is made to study the effect of replacement of cement and fine aggregate with fly ash and quarry dust respectively. The interactive and integral behaviour of concrete and structural steel elements makes the composite column a very cost effective and structural efficient member among wide range of structural elements in building and bridge constructions.

Methodology



Material properties

Concrete

Concrete mix for M25 grade is calculated with the testing carried out on locally available materials such as opc 53 grade cement, river sand and 10mm aggregate. 10mm aggregate is preferred for easy insertion and compaction of concrete mix inside steel tubes. Cement and fine aggregate are partially replaced with flyash and quarry dust respectively. Four replacement ratios of 10%,20%,30% and 40% are used for flyash and five replacement ratios of 0%,25%,50%,75% and 100%. Cubes are of 100mm×100mm×100mm size and cylinders are of 100mm diameter and 200mm height. Exactly 90 specimens of cubes and cylinders are casted for various replacement ratios of cement and fine aggregate and put under ambient curing for a period of 28 days.

Steel

Cold formed steel is used as concrete filled steel tube (CFST) here. Material properties of steel tube are as follows as mentioned by manufacturer itself. All values are in N/mm^2

Young's modulus E Mpa	Yield strength Mpa	Ultimate tensile strength Mpa
210000	310	500

Specifications of steel specimen used in this project are as follows

Cross section mm	Length mm	Thickness mm
80×40	1400	2.6

Concrete test results

Cube specimens are tested with the help of compression testing machine to find out the compressive strength of each mix after 28 days. Cylinder specimens are tested for finding out the split tensile strength of each mix after 28 days. Optimum percentage of ratio for replacement is chosen from the results obtained.

Consolidated average result of specimens tested are

Compression test result

Flyash %	Quarry dust %				
	0%	25%	50%	75%	100%
0 %	31	29.3	27.4	24.5	31.7
20%	29.2	28.6	27.5	27	28.6
30%	28.8	27.4	26.9	26	25.5
40%	28.4	27.2	26.2	25.9	25.5

Table 1

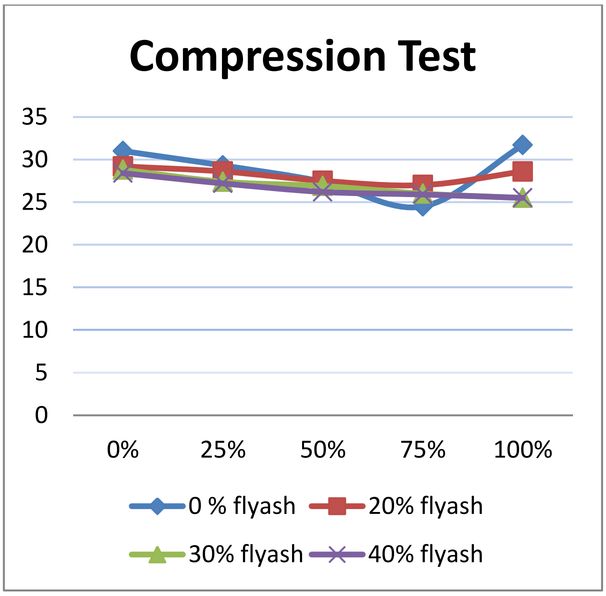


Chart 1

Split tensile test result

Flyash %	Quarry dust %				
	0%	25%	50%	75%	100%
0 %	3.37	2.29	2.20	2.36	3.25
20%	3.08	2.83	2.67	2.38	2.29
30%	2.99	2.73	2.51	2.22	2.13
40%	2.83	2.64	2.48	2.22	2.13

Table 2

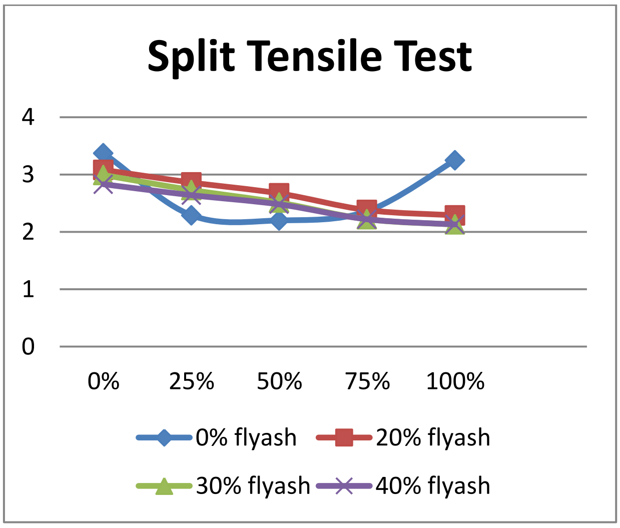


Chart 2

From the results obtained optimum percentage of ratio for replacement of cement and fine aggregate with flyash and quarry dust is 30% and 50% respectively. Compressive strength and split tensile strength for the selected replacement ratio are 26.9 N/mm^2 and 2.51 N/mm^2. Since the replacement ratio chosen has reasonable strengths, same can be used in CFST as infill.

Test setup

Automated column testing machine is used here for testing. Specimens are held perfectly straight in order to avoid any eccentricity in loading. At both top and bottom end plates are packed to avoid any slippage during loading. LVDTs are kept in position, one at centre on both sides and one at some distance from top to monitor deflection of specimen in any direction. Monotonic axial loading is gradually applied over the top of specimen to get deflection in the monitor. As the load is applied, load and deflection values are recorded with respect to time. Following image shows the test setup

Figure 1

Specimen test result

Elements are tested to its plastic limit beyond which it fails. Therefore the maximum compressive load the element takes and its corresponding deflection are recorded down for analysis.
From the results obtained it is clear that the elements with infill take more load than the same without infill. And also the elements with normal mix take more time to buckle than the elements with replacement mix of flyash and quarry dust.

Graphs below show the load deflection curve of specimens

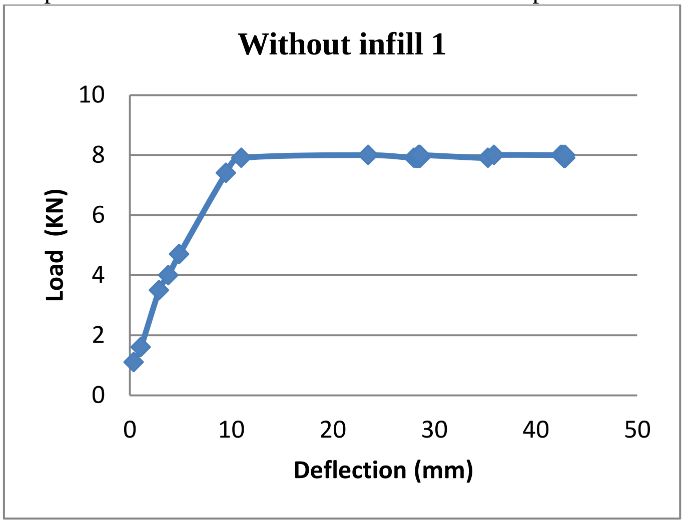


Chart 3

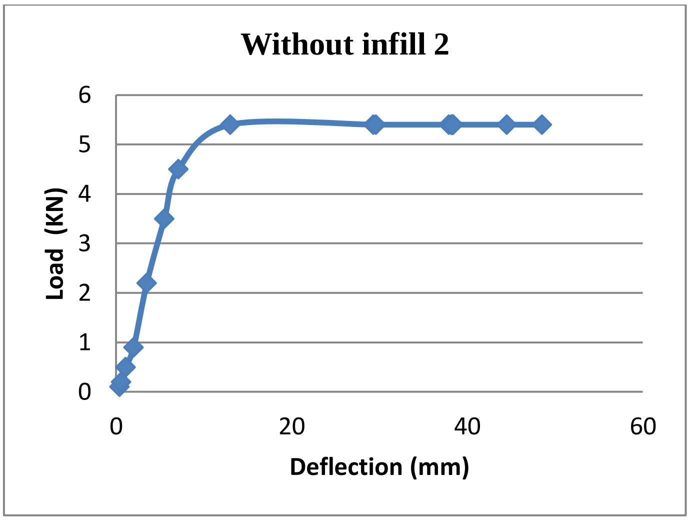


Chart 4

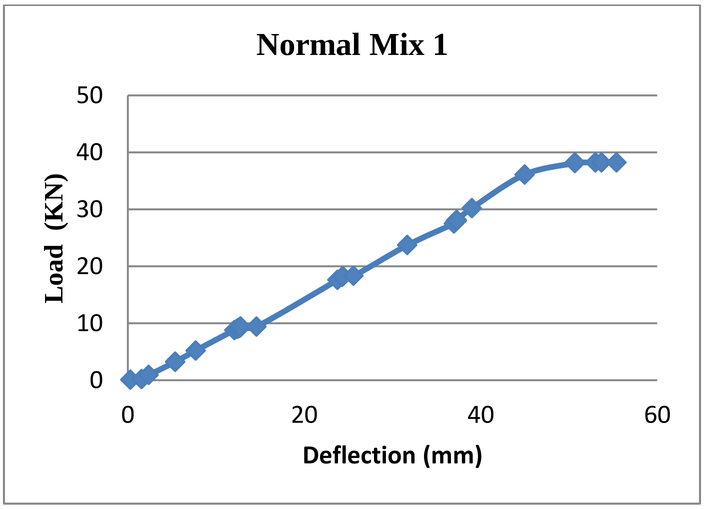


Chart 5

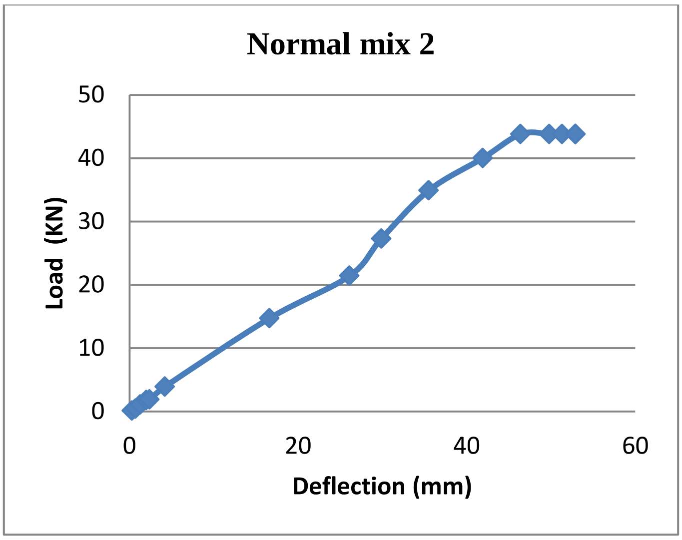


Chart 6

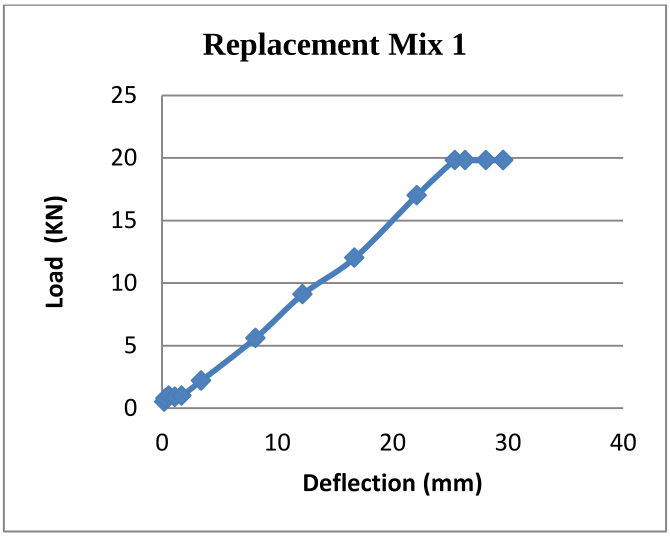
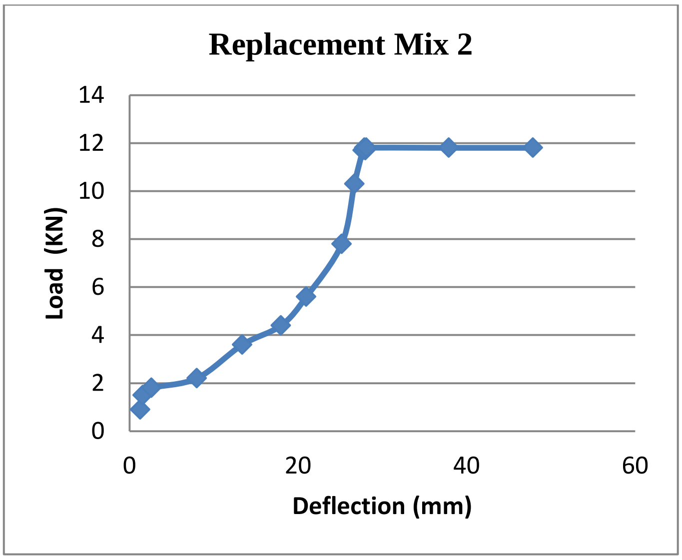


Chart 8



Following images show the failure of all elements with and without infill

Figure 2

Figure 3

Remarks

1. It is clearly evident that the infilled specimens carry more load than hollow specimens by filling the void.
2. In most of the cases failure occurs at ¼ th height from top. It shows that long coulmns tend to buckle at this height not exactly at mid height.
3. Normal mix specimens take more time to buckle than replaced mix specimens because of high integrity.

Conclusion

The idea of partial replacement of cement and fine aggregate by flyash and quarry dust with chosen percentage of replacement did not yield expected result in this small scale project. This discrepancy may be due to the tendency of buckling of column at any height and mispositioning of LVDTs along longitudinal axis. Since specimens fail quickly with the chosen percentage of replacement it does not mean replacement of cement is not advisable in compression members, there are chances of it could work well in large scale projects or with some other percentages of replacement. Hence this paper suggests us to go for some other percentage of replacement of cement and fine aggregate with flyash and quarry dust.

Limiting the usage of cement and fine aggregate in construction industry can save huge economy and reduce emission of carbon during cement manufacturing process. Thereby carbon emission can be controlled and waste products be utilised efficiently.

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