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Experimental behaviour of cold-formed steel welded tube filled with concrete made of crushed crystallized slag subjected to eccentric load

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ABSTRACT

This paper presents results of tests conducted on thin welded rectangular steel stubs filled with concrete that gravel was substituted by 10 mm crushed crystallized slag stone. The studied section was made of two cold steel plates with U shape and welded with electric arc to form a steel box section. The cross-section dimensions were: $100 \times 70 \times 2$ mm^3. the main studied parameters were the stub height (200, 300, 400, 500 mm), the effect of the in filled concrete, the continued weld and the eccentric force. The tests were carried out 28 days after the date of casting. A total of 20 stubs were tested in a 50 tf machine up to failure, 4 stubs subjected to axial load compression and 16 stubs subjected to eccentric load compression along the minor and major rigidity axis. The aim of the study is to provide some evidences that the use of crushed slag could be integrated in the manufacturing of non-conventional concrete. All failure loads were predicted by using the Euro code 4 and the design method proposed by Z. Vrcelj and B. Uy. From test results, it was confirmed that the length of stubs and the eccentric load had a drastic effect on the load carrying capacity. The failure mode of composite stubs was a local buckling mode with all steel sides deformed outwards. The Euro code 4 loads predictions were generally in good agreement compared with experimental loads and on safe side. The loads results of design method proposed by Vrcelj and B. Uy were generally on safe side compared with experimental load except the columns subject to eccentric load with 400 mm and 500 mm height.

1. Introduction

Hollow structural steel sections are often filled with concrete to form a composite column. Traditional concrete-filled steel columns employ the use of hot rolled steel sections filled with concrete. These columns have been used wide spread as they speed up construction by eliminating formwork and producing high load carrying capacity. This leads to use small steel wall thickness and thus more economy. However, the major difficulty encountered is the local buckling of the steel wall especially in the case of stocky columns. Very few experiments have been undertaken on built up thin cold formed and welded steel sections filled with concrete or recycled materials such as slag gravel concrete. Tests of concrete-filled carbon steel tube columns were conducted by Schneider [1], Uy [2,3], Huang et al. [4], Han and Yao [5], Mursi and Uy [6], and many other researchers. Hollow structural steel sections are often filled with concrete to form a composite column. Traditional concrete filled steel columns employ the use of hot rolled steel sections filled with concrete. These columns have been used wide spread as they speed up construction by eliminating formwork and producing high load carrying [7]. This leads to use small steel wall thickness and thus more economy. However, the major difficulty encountered is the local buckling of the steel wall especially in the case of stocky columns [8]. Very few experimental is done on built up cold formed welded steel sections filled with concrete or recycled materials [9] such as slag stone concrete designated here by SSC. The latter has been tested under direct compression and was used as a filling material to overcome the undesired effects of imperfections of built up cold formed sections. The gain in strength was found to reach a value of up to 2 and decreased linearly with the stubs height [9]. No evidence is available in the literature to confirm the effect of using slag concrete and thin cold formed thin steel stubs on the behaviour and load carrying capacity. Also, the built up steel cross-section arrangements and welding nature are parameters that could have an effect on the strength of steel and composite stubs. The present work is a contribution to the understanding of the behaviour of short slag concrete filled cold formed thin steel stubs with different cross section and welding arrangements subjected to axial and eccentric load compression.

2. Expérimental programme

To study the behaviour of cold-formed steel welded tube filled with concrete made of crushed crystallized slag subjected to

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eccentric load, 20 steel tubes were prepared. All specimens had the cross section dimensions $100 \times 70 \times 2\ mm^3$. The main parameters studied were the stub height, the eccentric load and concrete core. Steel coupons were prepared to investigate the tensile yield steel strength. Six concrete cylinders were tested under direct compression at 28 days. 4 Composite stubs with different height were tested under axial compression, 8 composite tubes were tested under eccentric load along major axis rigidity (xx) axis and 8 along minor axis rigidity (yy) axis. The columns had end eccentricity ration in the range of 20–50%. The stub height varied from 200 mm to 500 mm. the slag stone concrete mix propriety are presented in Table 1 (Fig. 1).

2.1. Materials and fabrication

The concrete mix proportioning is presented in Table 1. The natural crushed stones were substituted by crushed crystallized slag of 10 mm size brought from iron manufacture ELHADJAR-ALGERIA. The use of such artificial stone instead of natural stone would contribute to environment protection by recycling such industrial waste. Steel coupons were prepared to investigate the tensile yield steel strength and concrete cylinders were tested under direct Compression after 28 days. The 28 days compression strength of SSC was 20 MPa. Young's modulus of concrete at 28 days was 21 GPa. The steel yield strength was 270 MPa with a Young's modulus of 205 GPa. The concrete core was vibrated externally by a shaking table for 2–3 min. All composite specimens were lefts in the curing room for a period of 28 days. Both, top and bottom faces of composite stubs were mechanically treated to remove surface irregularities and ensure that both steel and concrete are loaded during test. Al measured dimensions, material proprieties and the values of eccentricity are presented in Table 2.

2.2. Test rig and procedure

All specimens were tested in a 500 kN compressive machine, Figs. 2 and 3. Special attention was given to verifying the correct position of the stubs before any loading. For the first load increment, a complete check of strains and load was carried out. The load was applied on the composite section (concrete and steel), the top metal plate is the fixed plate (al degree of freedom were restrained except rotation belong X and Y axis), and the bottom metal plate is the moving plate (al degree of freedom were restrained, except rotation belong X and Y axis and displacement at load direction "belong Z axis") as shown in Fig. 2.

The specimen P1C, P2C, P3C and P4C had two strain gages, one in the vertical position and the second in the horizontal position at the opposite side to record vertical and horizontal steel strains ε_v and ε_h respectively. The other specimens subject to the eccentric load had only one strain gage in the vertical position Fig. 4. All strain gages were placed at mid-length section. During tests, graphical monitoring of load–strain relationships was carried out

Table 1
Slag stone concrete mix properties.

Cement content	**350 kg/m^3**
Water–cement ratio	0.50
Aggregate-Sand	2.0
10 cm crushed slag stones	700 kg/m^3
Sand	400 kg/m^3
Slump	70 mm
Compressive strength at 28 days	20 MPa
Ec	21 GPa

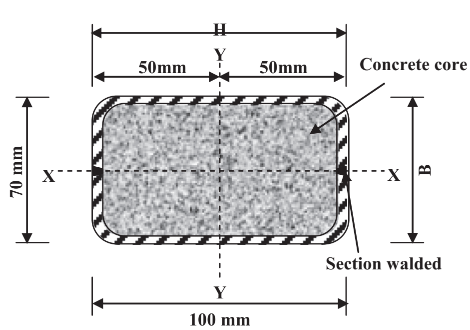

Fig. 1. Thin cold formed and welded steel cross section details.

Table 2
Measured dimensions and material properties.

Stubs no.	B (mm)	H (mm)	t (mm)	L (mm)	Eccentricity belong (XX) axis "EX" (mm)	Eccentricity belong (YY) axis "Ey" (mm)	f_y (MPa)	σ_{b28} (Mpa)
P1C	70	100	2.1	200	0	0	270	20
P1EX1	70	99	2	200	19.8	0	270	20
P1EX2	69	98	2.1	200	49	0	270	20
P1EY1	70	100	2	200	0	14	270	20
P1EY2	69	99	2	200	0	34.5	270	20
P2C	71	100	2	300	0	0	270	20
P2EX1	68	103	2	300	20.6	0	270	20
P2EX2	71	98	2	300	49	0	270	20
P2EY1	72	98	2	300	0	14.4	270	20
P2EY2	68	101	2	300	0	34	270	20
P3C	70	99	2	400	0	0	270	20
P3EX1	69	98	2.2	400	19.6	0	270	20
P3EX2	69	100	2	400	50	0	270	20
P3EY1	68	100	2.1	400	0	13.6	270	20
P3EY2	68	98	2.1	400	0	34	270	20
P4C	68	100	2.1	500	0	0	270	20
P4EX1	68	101	2	500	20.2	0	270	20
P4EX2	69	99	2.1	500	49.5	0	270	20
P4EY1	70	99	2.1	500	0	14	270	20
P4EY2	69	101	2	500	0	34.5	270	20

Fig. 2. View of test rig and sample P1EX1 after test.