REVIEW ON STEEL CONCRETE COMPOSITE COLUMN

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ABSTRACT - *Steel-concrete composite columns are used widely in modern buildings. Extensive research on steel concrete composite columns in which structural steel sections are encased in concrete have been carried out. In-filled composite columns, however have received limited attention compared to encased columns.*

This paper includes the review done on steel columns in which concrete are in-filled. Wire mesh is welded on the inside surface of steel column to increase the bond between steel and concrete. Three composite columns (short columns) are compared with three RC columns of same size. Ultimate strength, ductility, energy absorption capacity and stiffness of columns are noted. It is observed that composite columns show better structural behavior than RC columns.

Keywords: *Steel-concrete composite columns, In-filled composite columns, bond, Ultimate strength, ductility, energy absorption capacity and stiffness.*

1 INTRODUCTION

1.1 GENERAL

With the increasing use of composite construction worldwide, there is a growing interest in utilizing Concrete - Filled Tubes (CFTs) as a primary column member. The interest develops from the fact that properties of steel and concrete in the CFTs are fully utilized, so that the strength, stiffness and ductility of the structures constructed from CFTs can be enhanced simultaneously. Since the function of longitudinal reinforcement and transverse confinement can be acquired due to presence of the steel tubes, the traditional longitudinal and transverse reinforcement may be eliminated. This type of column also maintains sufficient ductility when high strength concrete is used.

CFT columns can replace conventional structural columns like reinforced concrete, structural steel with reinforced concrete and structural steel alone with enhanced performance and at the same time reducing costs to a minimum. It is especially useful in high-rise buildings where high strength is required and flexibility of open space is desired for a maximum range of applications.

1.2 DEFINITION

The general term “composite column” refers to any compression member in which a steel element acts compositely with a concrete element, so that both elements resist compressive force. There is a wide variety of composite columns of varying cross-section, but the most commonly used and studied types are

- Encased I-section
- Concrete in-filled steel tubes.

1.3 OBJECTIVE

- To make a comparison between RC column and concrete-filled steel columns.
- To study the characteristics such as ultimate strength, stiffness and ductility of a composite column.

2 LITERATURE REVIEW

2.1 INTRODUCTION

The study of literatures were done. The experiments had done by referring to those literatures. Various articles had collected from several national and international journals. Various international codes had also referred.

2.2 REVIEW OF LITERATURE

Dabaon et al. (2009) had done experiments on five hollow columns and ten concrete filled columns. Tests had performed to investigate the effect of concrete core. Comparison had made between stiffened hollow sections and concrete filled specimens. Results indicated that to increase the capacity of slender stainless steel stiffened tubular stub columns, in-filled concrete must be used. It also indicated that increasing the nominal compressive strength of the in-filled concrete leads to smaller column size.

Thayala et al. (2009) had done an experimental investigation to study the behavior under static and variable repeated push out loads. A total of 12 CFST and 7 HST columns were constructed. Results showed that the ultimate strength of composite columns had reduced after undergoing a number of cycles of repeated loads.

Lin-Hai Han et al. (2011) had done experiment by testing eighteen specimens. Main parameters studied were steel ratio, concrete type, and bond or unbonded between steel tube and its core. Compared with the hollow steel tube, the tensile strength of CFST specimen had enhanced due to infilling concrete. Bond or unbonded between the steel tube and its core concrete has moderate effects on the tensile strength of CFST.

Nakanish et al. (1999) tested eight composite columns with encased concrete and two steel columns without encased concrete with box cross section. Results showed that composite columns with encased concrete were not damaged severely.

Shanmugam et al. (2001) studied the behaviour of encased and hollow sections. The study of encased sections showed that fully encased sections were more effective in carrying load. Circular hollow sections provide a significant amount of confinement while this effect is negligible in the case of rectangular sections.

Zeghiche et al. (2005) tested columns under cyclic loading. For columns under cycling loads, the concrete-filled tubes showed a high level of ductility and tenacity; therefore, they were a practical solution for constructions subjected to dynamic loads such as earthquakes and wind pressure. The increase in the effective length of the columns considerably affected the column load carrying capacity with a load-decreasing rate much higher for higher concrete strength. The failure mode of these columns was overall instability. No sign of local buckling had recorded up to failure of the columns.

Prakash et al. (2012) presented a paper on modified push-out tests. This paper presents, modified push-out tests conducted for the determination of shear strength and stiffness of high strength steel (HSS) studs. The HSS studs having ultimate strength of 900 MPa and yield strength of 680 MPa were used in the modified push-out specimens. Novelty of this study may be considered in highlighting the importance of confined concrete strength while designing push out specimens. It could be concluded from present experimental study that confinement of concrete near HSS stud significantly enhanced the compressive strength as well as splitting resistance of concrete. Therefore, it must be considered while designing concrete specimens for push out specimens.

Zhao Gen-Tian et al. (2009) studied the behavior of ten slender steel concrete composite columns tested under eccentric loading conditions. The influence of eccentricity ratios, slenderness ratios and concrete strengths on slender steel concrete composite column strength had been studied in this paper. The load-carrying capacity was reduced with an increase of the slenderness ratio. For the eccentrically loaded columns, load-carrying capacity was found to drop significantly with an increase of eccentricity, but it was not strongly influenced by the concrete strength. This method was applicable for determining the material failure load or buckling failure load of a slender steel reinforced concrete composite column.

Serkan Tok goz et al. (2012) done an experimental study to investigate the influence of steel fibers on the structural behavior of biaxial loaded L-shaped high strength reinforced concrete and concrete encased composite columns. Sixteen column specimens had been prepared and tested in this study. The test variables included concrete compressive strength, load eccentricity, steel yield stress, slenderness effect and steel fiber content.

Radhika et al. (2012) presented an experimental study on circular concrete filled steel tubular columns. Parameters for this study included the length to diameter ratio of the steel tube, grade of concrete and the effect of addition of metakaoline in concrete. The effect was most pronounced for the stub column with bond strength between the concrete core and the steel tube, when the load applied only to the concrete section. The stiffness was also influenced by the changed bond strength for this loading situation. Increased bond strength resulted in a greater contribution from the steel tube, i.e. stiffness of the column increased. Finally, even though the efficiency of the steel tube in confining the concrete core was greater when the load is applied only to the concrete section, it seems not reliable to trust just the natural bond strength to get full composite.

L Di Sarno et al. (2007) carried out experimental tests on composite steel and concrete columns. Two layouts for the base column connections were assessed: the traditional system employing the bolted steel end plate and the innovative socket type. The experimental results demonstrated that the socket system was beneficial for the spreading of inelasticity at the base of the composite columns. As a result, socket-type joints can be reliably used for design of structures, which may experience significant inelastic excursions, such as those in earthquake prone regions.

Krishna Murthy (2012) studied that self-compacting concrete (SCC) possesses enhanced qualities and improves productivity and working conditions due to elimination of compaction. SCC was suitable for placing in structures with congested reinforcement without vibration and it helps in achieving higher quality of surface finishes. The relative proportions of key components were considered by volume rather than by mass. A simple tool has been designed for self compacting concrete (SCC) mix design with 29% of coarse aggregate, replacement of cement with Metakaolin and class F fly ash, combinations of both and controlled SCC mix with 0.36 water/cementitious ratio(by weight) and 388 litre/m^3 of cement paste volume.

Zhong Tao et al. (2011) carried out push-out tests on 64 concrete-filled steel tubular columns, which had been exposed to ISO 834 standard fire for 90 minutes or 180 minutes, respectively. At the same time, 12 unheated specimens were also prepared and tested for comparison. The variables investigated in the bond tests were selected as fire exposure time, cross-section type, and cross-sectional dimension, interface length to diameter ratio, concrete type, fly ash type and concrete curing condition. The effects of the above different parameters on bond behaviour were discussed. The test results indicate that fire exposure had a significant effect on the bond between a steel tube and its concrete core.

Ehab Elloby et al. (2011) presented a nonlinear 3-D finite element model for eccentrically loaded concrete encased steel composite columns. The columns were pin-ended subjected to an eccentric load acting along the major axis, with eccentricity varied from 0.125 to 0.375 of the overall depth (D) of the column sections. The finite element model had been validated against existing test results. The concrete strengths varied from normal to high strength (30–110 MPa). The steel section yield stresses also varied from normal to high strength (275–690 MPa). Furthermore, the variables that influence the eccentrically loaded composite column behaviour and strength comprising different eccentricities, different column dimensions, different structural steel sizes, different concrete strengths, and different structural steel yield stresses were investigated in a parametric study. Generally, it had shown that the EC4 accurately predicted the eccentrically loaded composite columns, while overestimated the moment.

Dennis Lam et al. (2006) presented the behaviour and design of axially loaded concrete-filled steel tube circular stub columns. The study had conducted over a wide range of concrete cube strengths ranging from 30 to 110 MPa. The external diameter of the steel tube-to-plate thickness (D/t) ratio ranged from 15 to 80 covering compact steel tube sections. Reliability analysis was performed to evaluate the current composite column design rules.

Meichun Zhu et al. (2010) proposed a new design model for steel–concrete composite columns, namely square steel tubular columns filled with steel-reinforced self-consolidating high-strength concrete. In this type of steel–concrete composite column, a steel section was inserted into the square steel tube and self-consolidating high-strength concrete was filled into the tube. Eighteen composite column specimens were tested under axial compression.

Ben Young et al. (2011) investigated the behaviour of pin-ended axially loaded concrete encased steel composite columns. A nonlinear 3-D finite element model was developed to analyse the inelastic behaviour of steel, concrete, longitudinal and transverse reinforcement bars as well as the effect of concrete confinement. The main objective of the study was to understand the structural response and modes of failure of the columns and to assess the composite column strengths against current design codes. The study covered slender, non-slender, stub and long concrete encased steel composite columns. The concrete strengths varied from normal to high strength (20–110 MPa). The steel section yield stresses also varied from normal to high strength (275–690 MPa). It was shown that the increase in structural steel strength had a small effect on the composite column strength for the columns having higher relative slenderness ratios due to the flexural buckling failure mode. The composite column strengths obtained from the finite element analysis were compared with the design strengths calculated using the American Institute for Steel Construction AISC and Euro code 4 for composite columns.

Qing Quan et al. (2009) proposed in this paper, accurate constitutive models for normal and high strength concrete confined by either normal or high strength circular steel tubes.. A new design formula accounting for concrete confinement effects was also proposed for circular CFST columns. It was demonstrated that the generic fibre element model and design formula adequately predict the ultimate strength and behaviour of axially loaded circular CFST columns and can be used in the design of normal and high strength circular CFST columns.

L Di Sarno et al. (2007) assessed the experimental results of monotonic (pushover) tests carried out on partially encased composite steel–concrete columns connected to the foundation block through the traditional bolted steel end plate and an innovative socket type system. Weng et al. (2002) studied the difference between various codes. In the ACI-318 code (1999) and AISC-LRFD specification (1993), different approaches were used for the design of concrete-encased composite columns. This comparative study indicated that the ACI-318 approach generally gives closer predictions than the AISC-LRFD does.

Richard Liew et al. (2000) presented the results obtained from tests carried on six full-scale composite beam-to-column joints. The steelwork connection consisted of a flush end plate welded to the beam end and bolted to the column flange. Generally, the proposed model can predict the moment capacity of composite joints with good accuracy. However, the model tended to over predict the rotational stiffness.

Brian Uy et al. (2004) presented a comprehensive experimental study of thin walled steel sections utilising high strength steel of a thin walled nature and filled with normal strength concrete. A numerical model was developed herein in order to study the behaviour of slender concrete filled high strength steel columns incorporating material and geometric non-linearities.

You-Fu Yang et al. (2005) tested eight concrete-filled steel CHS specimens under constant axial load and cyclically increasing flexural loading. The parameters in the study included the concrete strength (f_{cu}) and the axial load level (n). A mechanics model was developed in this paper for concrete-filled steel CHS columns subjected to constant axial load and cyclically increasing flexural loading. The predicted cyclic responses for the composite columns were in good agreement with test results. Based on the theoretical model, parametric analysis was performed on the behaviors of the moment (M) versus curvature (ϕ) response, and the lateral load (P) versus lateral displacement (Δ) relationship, as well as the ductility coefficient (μ) for the composite columns. Finally, simplified models for the moment (M) versus curvature (ϕ) response, and the lateral load (P) versus lateral displacement (Δ) relationship were suggested. A formula for the calculation of the ductility coefficient (μ) of the composite columns under constant axial load and cyclically increasing flexural loading is developed.

Ben Young (2006) presented an experimental investigation of concrete-filled cold-formed high strength stainless steel tube columns. The behaviour of the columns was investigated using different concrete cylinder strengths varied from 40 to 80 MPa.

3 CONCLUSIONS

From the detailed review of literature the following conclusion was made.

- To optimise the mix proportion of conventional concrete by casting cubes and cylinder.
- To increase the capacity of empty steel columns, in-filled concrete must be used.
- Compared the hollow steel tube with the CFST specimen.
- Columns tested under axial loading showed that the increase of the concrete strength has a positive effect on the load carrying capacity of concrete-filled steel tubes.
- Since there is no use of formwork and reinforcement, steel concrete composite columns are cost effective.
- The only disadvantage in the case of concrete infilled steel column is that, fire protection is not ensured.
- Quality control in the of pouring of concrete is very important in achieving good strengths for concrete filled steel columns. Better compaction will result in higher member capacities.
- In short columns with the load applied axially to the section, the column showed better results than predicted due to the confinement of the steel tube.

REFERENCE

1. Amar Prakash., N.Anandavalli., C.K.Madheswaran and N.Lakshmanan (2012), “Modified push-out tests for determining shear strength and stiffness of HSS stud connector- experimental study”, International journal of composite materials, Vol. No.2, pp 22-31.
2. Ben Young and Ehab Ellobody (2006), “Behavior of normal high strength concrete-filled compact steel tube circular stub columns”, Journal of structural engineering, ASCE, Vol. No.62, pp 706-715.

3. Ben Young and Ehab Ellobody (2006), "Experimental investigation of concrete-filled cold formed high strength stainless steel tube columns", Journal of structural engineering, ASCE, Vol. No.62, pp 484-492.
4. C.C.Weng and S.I.Yen (2002) "Comparisons of concrete encased composite column strength provisions of ACI6 code and AISC specification", Thin walled structures, Vol. No. 24, pp 59-72.
5. Ehab Elloby and Ben Young (2011) "Numerical simulation of concrete encased steel composite columns", Journal of structural engineering, Vol. No. 67, pp 211-222.
6. Ehab Elloby., Ben Young and Dennis Lam (2011) "Eccentrically loaded concrete encased steel concrete composite columns",Journal of structural engineering, Vol. No.49, pp 53-65.
7. J.Y.Richard Liew., L.H.Teo., N.E.Shanmugam and C.H.Yu (2000) "Testing of steel-concrete composite connections and appraisal of results", Thin walled structures, Vol. No.56, pp 117-150.
8. J.Zheghiche and K.Chaoui (2005) "An experimental behavior of concrete-filled steel tubular columns", Journal of constructional steel research, Vol. No. 61, pp 53-66.
9. K.S. Radhika and K.Baskar (2012) "Bond stress characteristics on circular concrete filled steel tubular columns using mineral admixture metakaoline",International journal of civil and structural engineering, Vol. No.3.
10. Katsuyoshi Nakanish., Toshiyuki Kitada and Hiroshi Nakai (1999) "Experimental study on ultimate strength and ductility of concrete filled steel columns under strong earthquake", Journal of constructional steel research, Vol. No.51, pp 297-319.
11. L Di Sarno., M.R.Pecce and G.Fabbrocino (2007) "Inelastic response of composite steel and concrete base column connections", Journal of consrtructional steel research, Vol. No.63, pp 819-832.
12. L.Di Sarno., M.R.Pecce and G.Fabbrocino (2007) "Inelastic response of composite steel and concrete base column connections", Thin walled structures, Vol. No.63, pp 819-832.
13. Lin-Hai Han and Guo-Hang Yao (2003) "Influence of concrete composite on the strength of concrete-filled steel RHS column", Construction and building material, Vol. No.59, pp 751-767.
14. Lin-Hai Han., Shan-Hu He and Fei-Yu Liao (2011) "Performance and calculations of concrete filled steel tubes (CFST) under axial tension", Thin walled structures, Vol. No.67, pp 1699-1709.
15. M.A.Dabaon., M.H.El-Boghdadi and M.F.Hassanein (2009) "Experimental investigation on concrete filled stainless steel stiffened tubular stub columns", Journal of constructional steel research,Vol. No.31, pp 300-307.
16. Meichun Zhu., Jianxin Liu., Qingxiang Wang and Xiufeng Feng (2010) "Experimental research on square steel tubular columns filled with steel reinforced self consolidating high strength concrete under axial load", Journal of structural engineering, ASCE, Vol. No.32 pp (2278-2286).
17. Mohanad Mursi and Brian Uy (2004) "Strength of slender concrete-filled high strength steel box columns", Thin walled structures, Vol No.60, pp 1848-1852.
18. N.E.Shanmugam and B.Lakshmi (2001) "State of the art report on steel-concrete composite columns", Constructional and building material, Vol No.57, pp 1041-1080.
19. P.Thayalan.,T.Aly and I.Patnaikuni (2009),"Behavior of concrete-filled steel tubes under static and variable repeated loading", Thin walled structures, Vol. No. 65, pp 900-908.
20. You-Fu Han and Lin-Hai Han (2005) "Cyclic performance of concrete-filled steel CHS columns under flexural loading", Thin walled structures, Vol. No.61, pp 423-452.
21. ZHAO Gen-tian., ZHANG Meng-xi and LI Yong-he (2009) "Behavior of slender steel concrete composite columns in eccentric loading", International science journal of Inner Mongolia, Vol. No. 13, pp 481-488.
22. Zhong Tao., Lin-Hai Han., Brian Uy and Xian Chen (2011) "Post-fire bond between the steel tube and concrete in concrete in-filled steel tubular columns", Journal of structural steel research, Vol. No. 67, pp 484-496.