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Behavior of Concrete Filled Steel Tube Column

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***Abstract* - In recent days, due to the expansion of cities it is required to construct the high storey buildings. Composite buildings prove to be promising for multi storey building. As a result, composite columns have recently undergone increased usage throughout the world, which has been influenced by the improvement of high strength concrete enabling these columns to be considerably economized. Columns are designed to resist the majority of axial force by concrete alone can be further economized by the use of thin walled steel tube. The paper discusses about the behavior of the composite column and various codal provisions. It also focuses on the research activities done on the composite column over the last few years, which have impacted the use of composite column.**

***Keywords* - finite element analysis, composite column, concrete filled steel tube column, strength.**

I. INTRODUCTION

Composite columns are structural members, which are subjected mainly to axial compressive forces and end moments. The general term 'composite column' refers to any compression member in which the steel element acts compositely with the concrete as shown in fig 1. so that both elements contribute to the strength. These columns have been used widespread as they speed up construction by eliminating formwork and the need for tying of longitudinal reinforcement. Composite columns have recently undergone increased usage throughout the world, which has been influenced by the development of high strength concrete permitting these columns to be considerably economized. Columns designed to resist the majority of axial force by concrete alone can be further economized by the use of thin-walled steel columns. New developments, including the use of high strength concrete and the credit of the enhanced local buckling capacity of the steel has allowed much more economical designs to evolve. The main economy achieved by using high strength concrete in thin steel casings is that the structural steel cost is minimized and the majority of the load in compression is resisted by the high strength concrete. Furthermore, the concrete is enhanced in

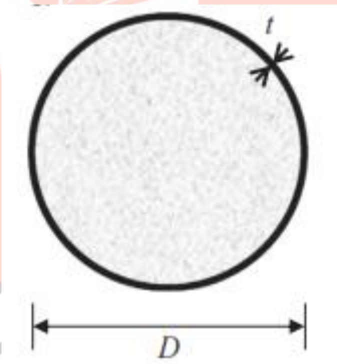

Fig.1.Schematic view of concrete filled steel tube column.

its performance as it suffers less creep and shrinkage and the quality improves, thus allowing a larger compressive stress to be resisted by the internal concrete. Conditions of the applied load are defined as axial, uniaxial and biaxial. This type of behavior is possible in concrete filled steel columns in multi-storey building.

II. REVIEW OF LITERATURE

A. *Review of Codes*

1. The building code requirements of reinforced concrete (ACI 318-89): According to ACI 318-89, a composite column is a concrete column reinforced with a structural steel shape or tubing in addition to reinforcing bars. The limiting thickness of steel tube to prevent local buckling are based on achieving yield stress in a hollow steel tube under monotonic axial loading which is not a necessary requirement for in-filled composite column. A parameter for the influence of creep in concrete that is subjected to sustained compressive loading is included.
2. Load and resistance factor design method (AISC-LRFD): This is based on the same principle as ACI code. The design is based on equations for steel columns. Nominal strength is estimated on the basis of ultimate resistance to the load, and reduction factor is then applied. The nominal axial load capacity is reduced according to the slenderness ratio. For calculating the strength interaction between axial and flexural effects in AISC-LRFD are based on the bilinear interaction formulae which have the same form as of steel columns. The influence of creep is ignored for concrete in composite column according to AISC-LRFD specification.
3. British Standard BS 5400-Part 5: Code provisions in BS 5400 are based on limit state design with loading factors and material safety factors. The ultimate moment is calculated from the plastic stress distribution over the cross-section, and an approximation of the interaction curve for axial load and moment is used. Reduced concrete properties are used to

account for the effects of creep and the use of uncracked concrete section in stiffness calculation. This method is applicable to symmetrical sections only and restricted to the range of section catered for in the European buckling curves. It underestimates the capacity of in-filled composite column with high-strength concrete.

4. European Code EC4: EC4 covers concrete encased and partially encased steel section and concrete filled sections with or without reinforcement. This code uses limit state concepts to achieve the aims of serviceability and safety by applying partial safety factors to load and material properties. Based on experimental results, it was recommended that the regulations of EC4 concerning the factor of 0.85 should not be applied to hollow sections filled with strength concrete. This is the only code that treats the effect of long-term loading separately.

B. Behavior of CFST column

1. Dennis Lam, EhabEllobod and Ben Young [2005]: The behavior and design of axially loaded concrete-filled steel tube circular stub columns were presented. The study was carried over a wide range of concrete cube strengths ranging from 30 to 110 MPa. The external diameter of the steel tube-to-thickness (D/t) ratio ranged from 15 to 80. An accurate finite element model was developed to carry out the study. Accurate nonlinear material models for concrete and steel tubes were used. The column strengths and load–axial shortening curves were evaluated. The results obtained from the FE analysis were verified against experimental results. An extensive parametric study was carried out to investigate the effects of different concrete strengths and cross-section geometries on the strength and behavior of concrete-filled compact steel tube circular stub columns. The column strengths predicted from the FE analysis were compared with the design strengths calculated using the American, Australian and European codes. Based on the results of the parametric study, it is found that the design strengths given by the American Specifications and Australian Standards are conservative, while those of the European Code are generally not much conservative.

2. Qing Quan Liang and Sam Fragomeni [2009]: Quin and Sam had presented accurate constitutive models for normal and high strength concrete confined by either normal or high strength circular steel tubes. A generic fiber element model that includes the proposed constitutive models of confined concrete was created for simulating the nonlinear inelastic behavior of circular CFST short columns under axial loading. The confinement effect provided by the steel tube with a concrete-filled steel tubular (CFST) short column increases the strength of the concrete core. The generic fiber element model developed was verified by comparisons of computational results with existing experimental data. Extensive parametric studies were conducted to inspect the accuracy of various confining pressure models and the effects of
    - The tube diameter-to-thickness ratio,
    - Concrete compressive strengths and
    - Steelyield strengths

   On the fundamental behavior of circular CFST columns. A new design formula accounting for concrete confinement effects was also proposed for circular CFST columns.
   It is demonstrated that the generic fiber element model and design formula adequately forecast the ultimate strength and behavior of axially loaded CFST columns and can be used in the design of normal and high strength CFST columns.

3. Paul J. Barr, Baochun Chen and ZhijingOu [2011]: An experimental and analytical investigation of concrete-filled steel tubular (CFST) laced columns was carried out. The columns consist of four concrete-filled steel tubes which are laced together. A total of 27 experimental tests was carried out to quantify the column failure mechanism at ultimate loads. The experiments were performed to obtain the load-deflection curves. Experimental results showed that the compression force in the longitudinal members dominated the failure mechanism in the CFST columns. The forces in the lacing members (diagonal and horizontal bracing) were found to be small. The experimental study was used to validate an analytical parametric study. The analytical study showed that increasing slenderness ratios and eccentricities reduced the ultimate load carrying capacity. On the basis of the analytical results, a new methodology for calculating the ultimate load-carrying capacity was proposed. The proposed methodology was compared with five different building codes like AISC, Eurocode4 and china codes (DL/T 5085-1999, JCJ 01-89, CECS 28:90) to quantify the accuracy.

4. J.M. Portolés, M.L. Romero, F.C. Filippou and J.L. Bonet [2011]: An efficient numerical model for the simulation of the behavior of slender circular concrete-filled tubular columns subjected to eccentric axial load for the cases of both normal and high strength concrete had been proposed by authors. The authors had focused on the study of the influence that the variables affecting beam–column behavior like length and relative slenderness and the variables affecting section behavior like diameter/thickness ratio, have on the overall buckling of the column. An extensive parametric study was carried out to establish the importance of the use of high strength concrete compared with that of normal strength concrete. The results showed that for slender elements the optimum design was reached when the capacity of the steel was slightly lower than that of the concrete contribution.

5. Yu-Feng A, Lin-Hai Han and Xiao-Ling Zhao [2012]: The behavior of very slender, thin-walled concrete filled steel tubular (CFST) columns under axial compression was studied by the author. A finite element analysis (FEA) was used to carry out the behaviour of compressive columns. Generally a good agreement was obtained between the predicted and calculated results. The FEA model was then used to perform analysis on very slender circular CFST columns. Parametric studies were conducted and the ultimate strengths from tested results and design codes were compared and discussed.

The reliability analysis method was used to calibrate the existing design formulas given in DBJ/T13-512010, ANSI/AISC 360-05 and Eurocode 4.

6. K.Z. Soliman, A.I. Arafa and Tamer M. Elrakib [2012]: The aim of the author was to assess experimentally the current methods and codes for evaluating the ultimate load behavior of concrete encased steel short columns. The design provisions for composite columns from the Egyptian codes ECP203-2007 and ECP-SC-LRFD-2012, as well as, American Institute of Steel Construction, AISC-LRFD-2010, American Concrete Institute, ACI-318-2008, and British Standard BS-5400-5 was reviewed. The axial capacity portion of both the encased steel section and the concrete section was also studied according to the mentioned codes. Encased steel concrete columns have been investigated experimentally to study the effect of concrete confinement and different types of encased steel sections like steel pipe, Plastic pipe, steel S.I.B and wood S.I.B sections. The measured axial capacity of the tested composite columns was compared with the values calculated by the mentioned codes. The confining effect was influenced by the shape of the encased steel section. The tube-shaped steel section leads to better confinement than other section. According to the author, the ECP- SC-LRFD-2012 led to the most conservative results.

7. K. K. Choiand Y. Xiao [2010]: The author had described a numerical program to analyse the behavior of the concrete-filled steel tubular (CFST) stub columns, and predict modes of interactions between steel tube and filled-in-concrete under axial compression. The behavior of the CFST columns was affected by both the strength and the confinement effect of steel tube and filled-in-concrete in the columns. Various lateral interactions between the steel tube and filled-in-concrete in CFT columns are classified into eight different cases by the contact between the steel tube and filled-in concrete at different stress stages. The authors had examined the analytical models with experimental results. The comparisons showed that the numerical analysis was reasonable to capture the mechanical behavior of concrete-filled circular steel tubes.

III. SUMMARY OF LITERATURE AND CONCLUSION

The authors had concluded with their own experimental data and analytical data. The followings gives a few of the conclusions related to the composite column.

- All codes assume full interaction, but some impose restrictions on the shear stress at the steel-concrete interface. It is customary to use direct bearing or provide shear connectors, if used where the specified limiting shear stress is exceeded.

- Dennis Lam, EhabEllobod and Ben Young had concluded that, the results of the parametric study showed that the column design rules specified in the American Specifications and Australian Standards are conservative. However, the design strengths predicted by theEurocode 4 are generally unconservative. The column design rules in the American Specifications and Australian Standards Are capable of producing reliable limit state design when calibrated with the resistance factor Ø = 0.85 for the axially loaded concrete-filled compact steel tube circular stubcolumns.

- Qing Quan Liang and Sam Fragomeni had concluded that, increasing the tube diameter to thickness ratio reduces the ultimate strength of the column and axial ductility performance. Increasing the concrete compressive strength increases the axial ultimate load, but reduces the section. The use of high strength steel tube in circular CFST column significantly increases the section performance of CFST column.

- Paul, Chen and Zhijing had concluded that, the forces in the lacing tubes at failure were relatively small. For the stability factor, JCJ 01-89 design criteria result in the smallest mean squared error. The global strength reduction factor for lacing columns= (The stability factor φ) * (eccentricity reduction factor φ e), Where The factors, φ and φ e, are calculatedwith the JCJ 01-89 and CECS 28:90 design criteria.

- Portolés, Romero, Filippou and J.L. Bonethad concluded that,If the parameter strength index (SI) is studied, it seems that the reduction of SI is higher for normal strength concrete than for high strength concrete, being not greatly affected by the thickness of the section. It is concluded that to make better use of HSC, it is more effective to select lower L/D and lower e/D than higher D/t.

- It appears to be more suitable to use medium strength concrete for high strength is very expensive to use and does not provide sufficient benefits.

- According to Yu-Feng An, Lin-Hai Han and Xiao-Ling Zhao, There was good agreement obtained between the predicted and measured results. The ultimate strength decreases as slenderness increases. The design formula for compressive strength of very slender CFST columns provided by AISC 360-05 and Eurocode 4 satisfy the reliable require in parameter limits.

- K.Z. Soliman, A.I. Arafa and Tamer M. Elrakib had concluded that, confining effect is influenced by the shape of the encased steel section. The tube shaped steel section led to better confinement, which resulted in a noticeable increase in both ductility and the ultimate axial capacity of columns.

- K. K. Choiand Y. Xiao had concluded that, Due to the limited assumptions of the analytical model, the analytical behavior of the CFT columns after yielding does not follow the behavior of some experimental results such as strain hardening or strength degradation behavior due to local buckling.

IV. FUTURE SCENARIO

The authors had given future scenario from their experimental as well as analytical studies.

- Major work is done on CFST is experimental. Still, there is a need for numerical study is needed to check the parameters which affect the ultimate strength.
- Less research is done on interface friction characteristics of steel tube and concrete.
- Role of reinforcement bars in CFST column can be studied in greater detail.
- Effect of Confinement co-efficient and its value is another imp focus of this area.
- As the Indian code has not thrown light, for calculating the strength of CFST column, further research is needed.

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