STEEL COLUMN BUCKLING DUE TO IMPACT LOAD

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Introduction

Collapses of the World Trade Centre (WTC) towers are attributed to progressive buckling of columns induced by falling upper block. (Bazant, Z. P. And Zhou, Y, 2002). However validity of this theory is dependent on several factors. The slenderness of the columns and the impact velocity are two major factors that influence the type of failure of columns under axial impact.

The steel column design curves and associated column theories generally divide the columns as short, intermediate or slender based on the mode of failure under static load. The short steel columns fail by squashing and absorb large amount of energy. The slender columns fail by overall buckling and absorb less energy only at well defined plastic hinges leading to rapid collapse. This type of column failure mode is needed to justify the progressive collapse of steel high rise buildings of the type of WTC.

There were not much research works in the past for axial impact of structural steel columns. However in the field of mechanical and automobile engineering, research work on varying speed and collapse mechanism of columns have been performed to study the effect of energy absorption(Kargiozova and Marcilio Alves, 2004; Portillo Oscar and Names James,2006). These studies indicate that velocity of impact will affect the mode of failure of compression members. The objective of this study is to experimentally verify the change in failure mode of axially impacted columns with the impact velocity.

Methodology

For this study, 12.7 mm X12.7 mm square hollow seam welded square cross section with wall thickness of 0.78 mm is used. Initially compression tests were carried for these columns with varying slenderness ratios in order find the load carrying capacity. An experimental setup schematically shown as in Fig.1 was constructed for impact test by dropping a measured weight on top end of the column. The weight used for each column is taken as half the load carrying capacity of a particular column as the normal service load is expected to be around this range in buildings. The height of drop is calculated based on single floor free fall drop of the WTC tower as given by Bazant, Z. P. And Zhou, Y, 2002. The first set was simulated based on the Elastic simulated based on the Elastic dynamic load Magnification Factor, (EMF) of WTC single story fall. The second set was simulated considering the Plastic Energy dissipation Factor, (PEF) of WTC single story fall. The collapse modes of the columns were observed and recorded.

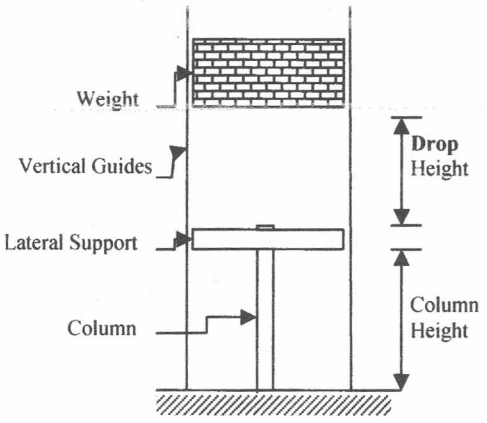

Fig.1. Experimental setup

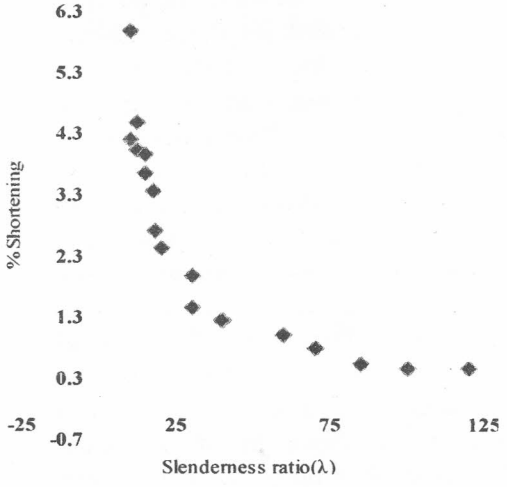

Fig.2. Variation of axial shortening (%) vs.slenderness

Results and Discussion

The static compression test results of columns gives strength versus slenderness ratio curve which is similar to the normal steel design curves available for structural steel in design standards. The percentage shortening of members at maximum load versus slenderness ratio is plotted in Fig.2.

It can be noted that for short columns, the percentage of shortening is large indicating high energy absorption even under static conditions. Squashing of this column section under static load (Loading rate 10 kg/s) was noted for slenderness ratio less than or equal to 14 which can be termed as very short columns. The squashing was associated with crippling of component plates of the section.

The first set is based on EMF which had much smaller impact velocity of $0.7ms^{-1}$. The second set is based on PEF with impact velocity of $2.1ms^{-1}$. The slenderness ratio limit at which failure mode changes from quash failure to overall buckling are tabulated in Table.1 for both static and these two impact load cases. With this limited results, it can be noted that slenderness ratio limit is increasing with the speed of impact. Fig.3 shows photographs of samples indicating their failure modes.

Conclusions

With increasing velocity the slenderness ratio limit of squashing increases for columns under axial load. Further studies are needed to verify the relationship between

limiting slenderness and velocity of impact.

WTC columns at level of initial failure had slenderness ratio in the range of $\lambda<27$. Therefore the assumption of progressive collapse theory for collapse mechanism needs clear justification.

References

Bazant, Z.P and Zhou, Y. "Why did the World Trade Centre Collapse?-Simple Analysis" Journal of Engineering Mechanics, Vol.128, No.1, January 2002.

D.Karagiozova, Marcilio Alves (2004) Transition from progressive buckling to global bending of circular shells under axial impact-part I: Experimental and Numericalobservations.International journal of solids and structures 41 (2004) 1565-1580.

Portillo, Oscar Nemes, James (2006) Impact modeling of Spot-welded columns fabricated with advanced high strength steel. International federation of Automobile engineering societies 22-27 Oct., Japan.

Table 1. Limiting slenderness ratio vs. speed of impact.

Parameters	Static	EMF	PEF
Limiting Slenderness Ratio(λ)	14	17	22
Speed of Impact(m/s)	0	0.7	2.1

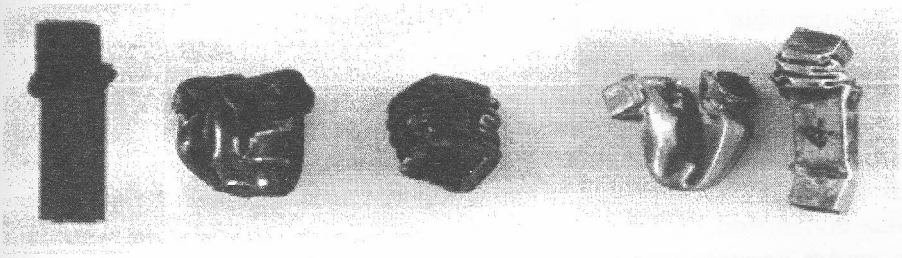

Fig.3. Photographs of some samples