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Blast Load Resistance of Cold Formed Steel Hollow and In filled Column

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Abstract:-- **Cold Formed Steel Tube (CFST) members are commonly used as columns in the construction of low to medium height industrial and domestic buildings. Their structural behaviour is enhanced by filling the tubes with concrete and other materials. The infilled members are superior to the hollow members in resisting axial and lateral loads due to the composite action. An attempt has been made in this paper to analyse the cold formed steel short hollow and infilled column of dimension 150mm x150mm x 5mm with column height 1.5m subjected to blast loading at the standoff distances of 0.5m,1m,1.5m respectively using the software LSDYNA. The grade of concrete used as infill is M30 grade. The intensity of blast remains constant and the blast load is applied at ground and mid-height of columns. Strain and stress levels are higher in hollow column than that of infilled column. The deflection is found to be less in infilled column.**

Index Terms:- Hollow column, Infilled column, Blast load, Standoff distance, Stress contour, Displacement

I. INTRODUCTION

In the past two decades, the terrorist attacks have become very frequent and damaging because of the use of explosive devices. Several factors including accessibility of information bomb devices manufacturing, mobility and portability, along with significant property damage and injuries, are responsible for the increase in bomb attacks all over the world. Lot of research work is going on related to blast load because of the disasters and damage caused due to it. Conventional structures get more affected by blast load because they are not designed for it and the explosions are much higher than the design loads of conventional structures. Developers, architects and engineers are showing a lot of interest in finding solutions for potential blast situations, to protect building occupants and the structures. In some cases, if one of the columns of the building got damaged due to blast then this may lead to the failure of beam-slab system above that column and it leads to progressive collapse of certain part or entire structure.

The phenomenon in which rapid and sudden release of energy takes place is called explosion. An explosion which takes place in air generates a pressure bulb, which grows in size at supersonic velocity. The resulting blast wave releases energy over a small duration and in a small volume, thus generating a pressure wave of finite amplitude, travelling radially in all directions. Explosives are generally used for demolition of structures when the life of the structure exceeds its limit.

II. METHODOLOGY

The methodology that followed in this study is shown in Fig. 1. Cold formed steel tube short column is studied for blast resistance with and without concrete infill. The blast resistance of the columns are compared based on the stress contours and displacement. The objectives of the current study are arrived at based on the previous research work.

Ngo et al (2007) considered the single degree of freedom system for the analysis. Time history analysis is used for examining the model. Newmark and Hansen formulae are used for predicting blast pressure. LS Dyna was used for analysis of a ground floor column of 6.4m height of a multi-storey building. It was found that 80Mpa column with reduced cross section have more lateral deflection and shows better energy absorption capacity compared to 40 MPa column. Bao and Li (2010) studied residual strength of RC column under blast load using LS Dyna. And blast point of columns were subjected to a small standoff distance. They have studied twelve columns to understand the effect of axial load ratio, longitudinal reinforcement ratio and traverse reinforcement ratio. The results have indicated that ratio of residual axial capacity increases as the longitudinal reinforcement ratio increases. Ke-Chiang et al. (2011) used LS Dyna for the analysis purpose. Numerical simulations of the dynamic response and residual axial capacity of reinforced concrete (RC) columns subjected to blast loads is studied. Two RC columns were tested by field tests using near-field explosive charge. Finite element model was validated by comparing test results with analytical results. Two empirical equations were derived.

Ashish et al. (2011) analysed the steel column. In this they have used ANSYS AUTODYNE 3D. Standoff distance of the TNT explosive was varied and effect was analyzed. It was found that as the protection of surface subjected to direct blast pressure is not possible, the standoff distance of blast has to be increased. Results were plotted in terms of deformation vs standoff distance graph and also Maximum principal strain vs. standoff distance graph. It was found that column fails above critical blast impulse.

Ruwan et al. (2011) studied the damage mechanism and extent of damage using principle stress plot along the plastic strain diagram. Time-history analysis using SAP2000 and explicit non-linear analysis using LSDYNA was done. Principle stress plots and plastic strain diagrams were used to determine damage mechanism. Amr et al. (2013) did the research on strength and stability of beam column under blast load. They have compared the experimental and analytical data. It has shown that the UFC method overestimates the column capacity for ductility ratios greater than one. Kulkarni and Sambireddy (2014) investigated the blast load on the ground floor column therefore pressure experienced by upper column is less because of the variation in standoff distance. Here vertical variation is considered in standoff distance. SAP2000 was used for the analysis purpose. It was found that infill frame shows low storey drift. Alex and Brian (2014) carried out both the analytical and experimental work is done and the results of both are compared. Analytical work was done to get some dynamic response parameters which were not possible to obtain from experiments.

Elsanadedy (2014) presented the progressive collapse analysis of a multi-storey steel framed building using LS Dyna software to stimulate the building response under generated waves of blast. Mitigation for the progressive collapse potential of building was recommended based on finite element analysis. Umesh and Vanakudre (2015) used ETabs for the analysis purpose. In this it was observed that as the standoff distance goes on increasing, storey drift is decreasing and with the increase in explosive weight, the storey drift increases. Time history analysis is done for this purpose. Tuan et al. (2015) did numerical stimulation of response of tubular steel beams to close range explosions. Concrete-filled and hollow cold formed steel tube simply supported at both ends were used. High explosive TNT with different standoff distance is considered above the top of beam. Analysis is done using LS Dyna and performance of both tubes for blast load resistance was assessed.

Zhang (2017) carried out a large-scale blast experimental program on concrete filled double-skin steel tube (CFDST) columns. The parameters that are investigated during the blast experiment include: cross-sectional geometry, explosive charge weight and magnitude of axial load. The proposed CFDST columns are able to retain more than 60% of its axial load-carrying capacity even after being subjected to close-range explosion. The main focus of the study is

- To analyze the cold formed steel tube infill and hollow column subjected to blast loading at different standoff distance and positions of blast load with constant blast load intensity.
- To determine the stress and strain level of the column subjected to blast load.

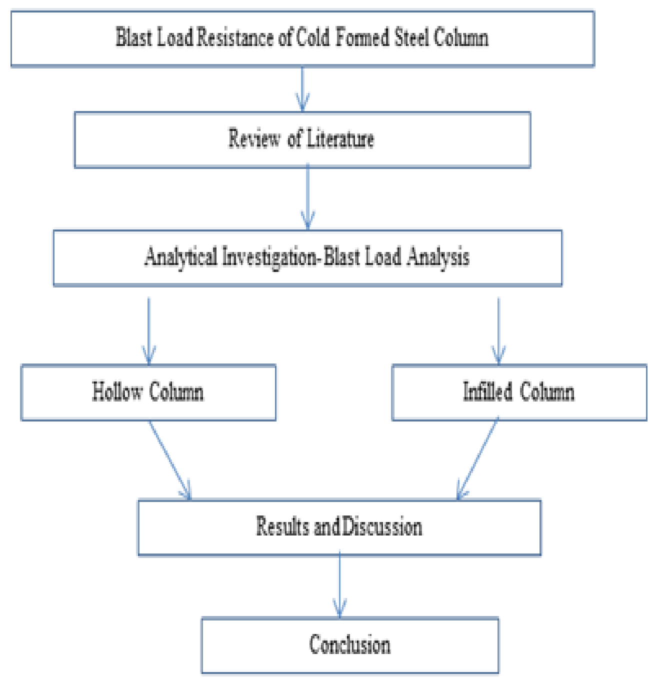


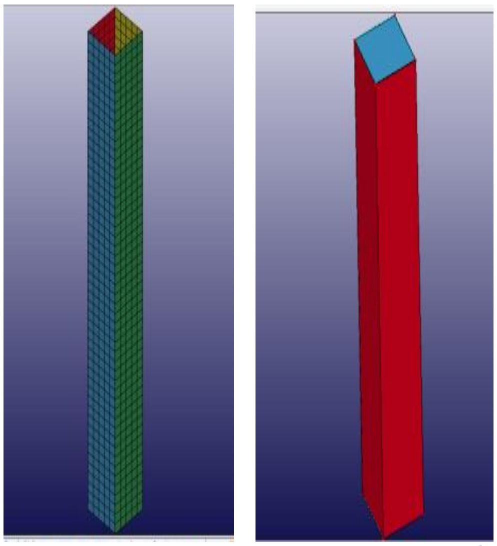
Fig.1. Methodology

IV. ANALYTICAL INVESTIGATION

A. Modelling of Columns

In this study, Cold Formed Steel Tube (CFST) hollow and infilled short columns are used for the analysis. It is assumed that the column is vulnerable to blast loading which is being located at the middle and ground level of the column. The selected length of the column is 1.5 m with a cross-section of 150 mm x 150 mm and the thickness of the CFST column is 5 mm. Modeling was done using the software LS DYNA. For hollow column, shell element of elastic material is used and for infilled column, M30 concrete is used with the material model Continuous Surface Cap Model - CSCM Concrete.

The boundary conditions provided for the column is fixed at both ends. Fig 2 shows the model of hollow and infilled CFST columns.



(a) Hollow column (b) Infilled column

Fig.2. Model of CFST columns

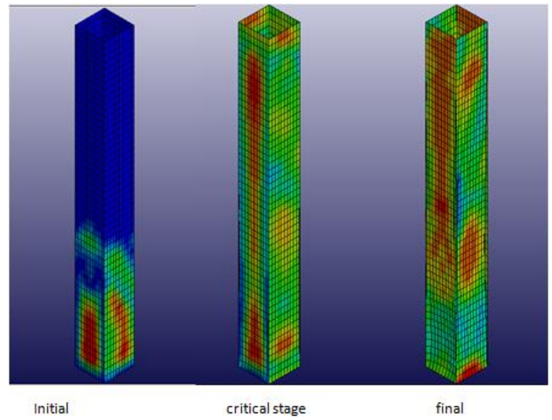
B. Analysis of Columns

Blast load acting on the column is having a charge weight of 1kg of TNT at a standoff distance of 0.5m, 1m and 1.5m. The main aim of the blast loading at different standoff distance is to investigate the response and level of damage of hollow and infilled CFST columns. A termination time of 3 millisecond is considered for the analysis. Here blast is provided at the ground and middle height of the column.

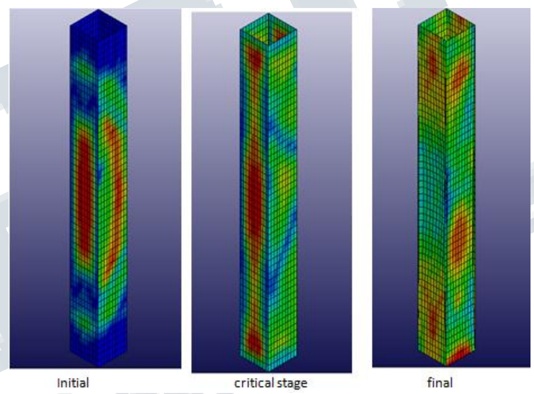
V. RESULTS AND DISCUSSION

A. Comparison of Stress Level in Hollow and Infilled Columns

In hollow column, the effect of blast load is more when compared to infilled column. When blast occurs, the side of the column facing the blast undergoes greater stress and later it is transferred to the rear of the column and it gets spread all over rear side. Due to the fixed support at the ends of the column, blast effect at the ground level is less than that at the mid height. Fig.3 to 8 shows the stress distribution in hollow and infilled columns when blast is at ground and at mid-height with standoff distances of 0.5 m, 1.0 m and 1.5 m, respectively. It can also be seen that the blast effect is reduced when there is an increase in the standoff distance and this is clearly visible in the stress distribution.

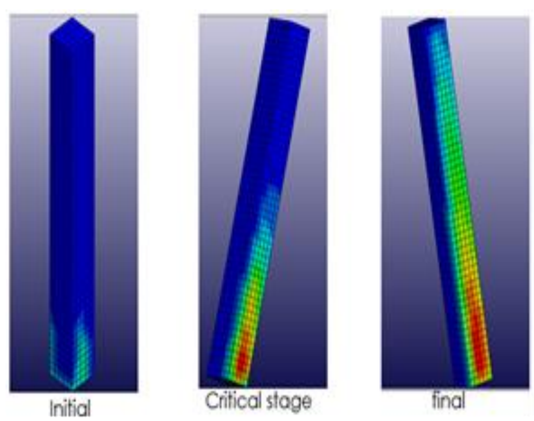


(a) At ground level



(b) At mid-height level

Fig. 3. Stress Distribution in Hollow Column when Blast at 0.5m standoff distance



(a) At ground level

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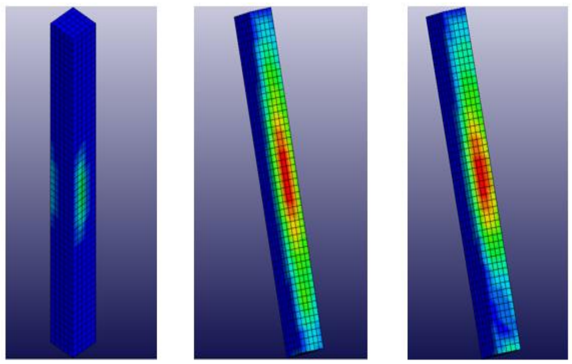
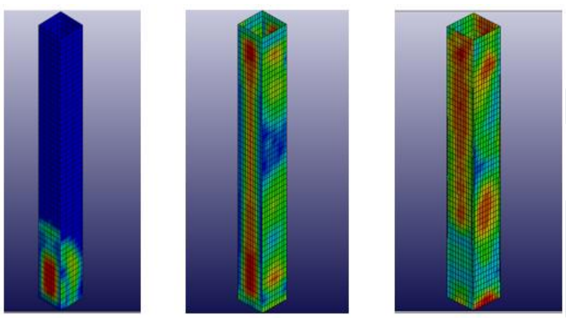


Initial Critical stage final

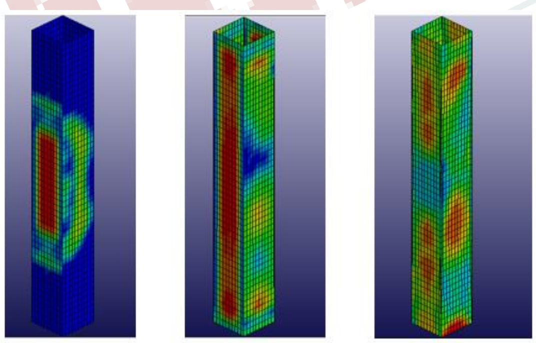
(b) At mid-height level

Fig. 4. Stress Distribution in Infilled Column when Blast at 0.5m standoff distance



Initial Critical stage final

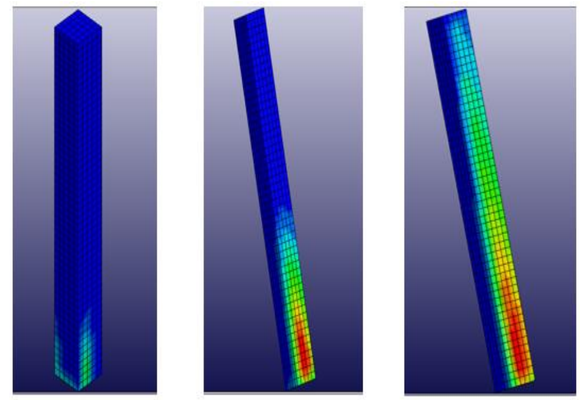
(a) At ground level



Initial Critical stage final

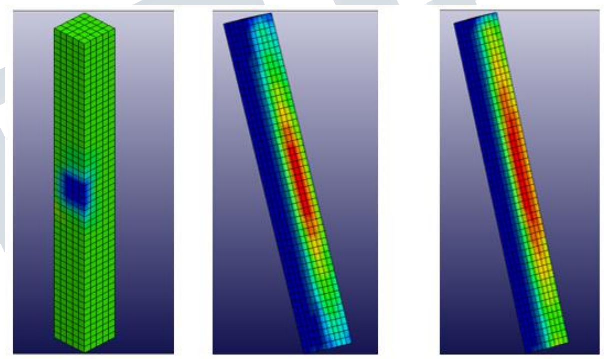
(b) At mid-height level

Fig. 5. Stress Distribution in Hollow Column when Blast at 1.0 m standoff distance



Initial Critical stage final

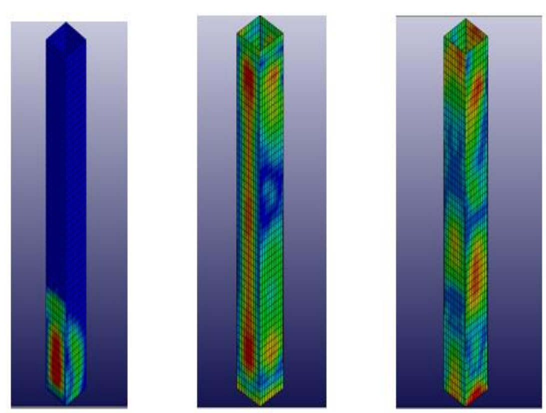
(a) At ground level



Initial Critical stage final

(b) At mid-height level

Fig. 6. Stress Distribution in Infilled Column when Blast at 1.0 m standoff distance



Initial Critical stage final

(a) At ground level

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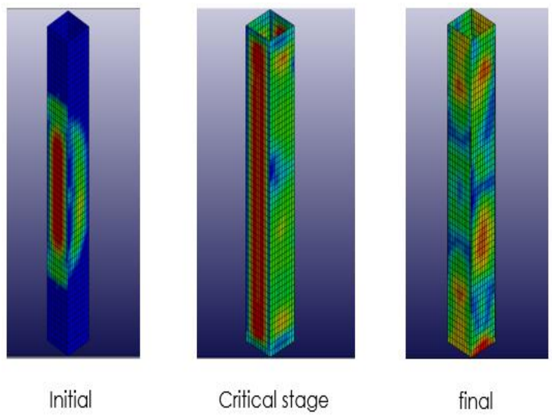
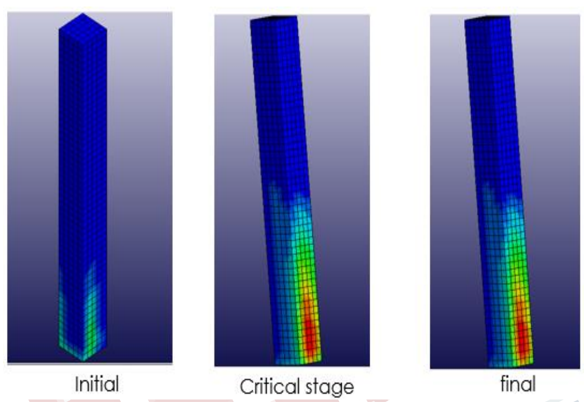
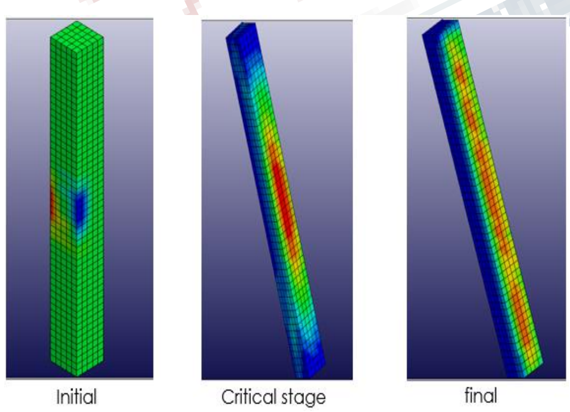


(b) At mid-height level

Fig. 7. Stress Distribution in Hollow Column when Blast at 1.5 m standoff distance



(a) At ground level

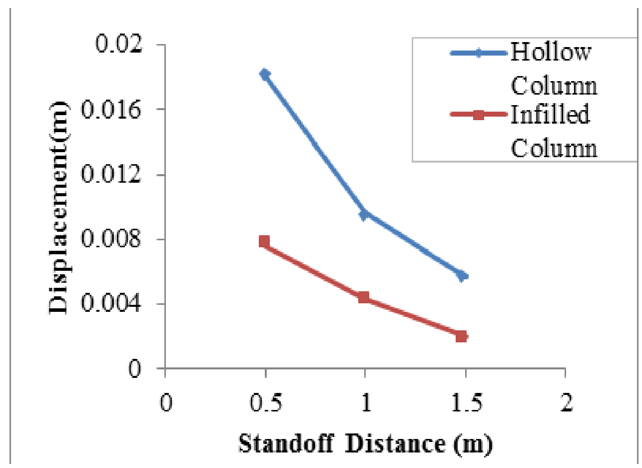


(b) At mid-height level

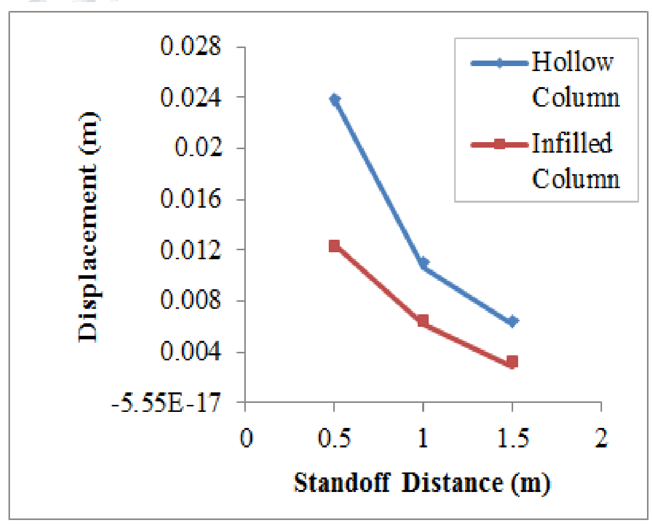
Fig. 8. Stress Distribution in Infilled Column when Blast at 1.5 m standoff distance

B. Comparison of Displacement Level in Hollow and Infilled Columns

As the standoff distance increases, displacement decreases. And the displacement is found to be more when the blast point is at the mid-height than at the ground level of the column. There is 60% reduction in the displacement of infilled column as compared to hollow column when blast load is at ground. There is 50% reduction in the displacement of infilled column as compared to hollow column when blast load is at mid-height of column.



(a)At ground level



(b) At mid height level

Fig.9.Displacement of Columns at different standoff distance

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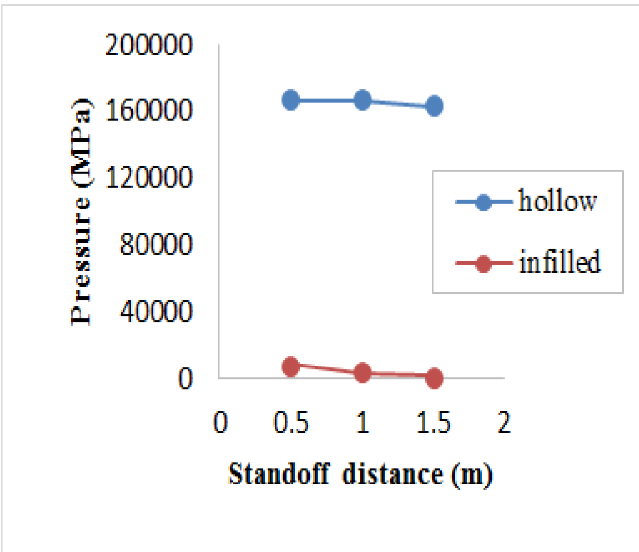
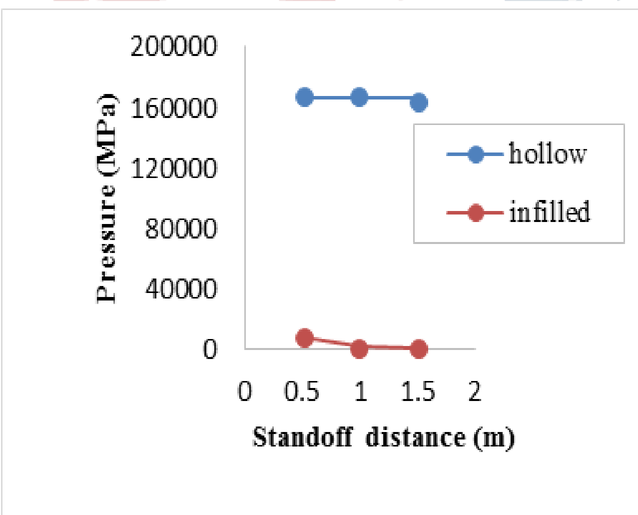
C. Comparison of Pressure Level in Hollow and Infilled Columns

The pressure versus standoff distance behavior of hollow and infilled columns when blast at ground and mid-height is shown in Fig. 10 (a) and (b), respectively. It is observed that the response pressure in the infilled column is much lower than that in hollow column irrespective of the position of blast load.



(a) At ground level



(b) At mid height level

Fig.10. Pressure Vs standoff distance

V. CONCLUSION

Cold Formed Steel hollow and concrete infilled columns are investigated for blast resistance using the software LS-DYNA and the following conclusions are drawn.

• The stress and strain level of both hollow and infilled columns is lower when the distance of the source is away. The infilled column shows less stress and strain level than the hollow column.
• Around 50- 60 % reduction in displacement is found in infilled column than the hollow column.
• Pressure wave graphs shows that pressure on infilled column is less compared to hollow column.
• The results of the dynamic analysis gives useful suggestion of using infilled cold formed steel columns for better blast resistance.

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