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Analysis of Seismically DetailedRC Column under Combined Effect of Blast Loading and Axial Loading

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Abstract: In India, important buildings are exposed to terrorist attacks. The structures are usually not designed to resist such extreme loading condition and the structure will collapse when it subjected to extreme loading conditions. If seismically designed structures are resistant to extreme loads, ie.blast loading, then we can avoid the tedious calculations and produce economical sections. In this paper, the behavior of conventionally detailed column was compared with a seismically detailed column under both blast loading and axial loading conditions.

Keywords: conventional detailing, seismic detailing, shock wave, LS-DYNA, blast loading

I. INTRODUCTION

In framed structures columns plays a key role in load bearing. They are designed to support the loads from the upper floor and the self-weight of column. Outer colum of the structures are more vulnerable to terrorist attacks. So the columns of important building should designed to resist extreme loading conditions. Building all over the worlds has the probability to the treats of a terrorist attack. Public buildings, government offices, monuments, educational buildings, and the buildings, which are near to the exposure manufacturing or storage, are susceptible to terrorist attack. The primary objective of this paper is to study the response of a seismically designed and detailed column and compare the response with a conventionally detailed column. A general-purpose high fidelity-physics-based finite element software, LS DYNA, is used to develop numerical model and analysis. The seismic design and detailing of the column were carried out according to Indian standard codes ie.IS 456:2000 and IS 13920:2016. Effect of axial load ration on the response of the column also investigated in this paper. The numerical model was validated with the results obtained from the journal paper.

II. VALIDATION

The result obtained from the model was validated with the result reported by C.Kyei and A. Bhraimah (2017). The column of 3000 mm was modeled and a cross-sectional dimension of 300 mm x 300 mm. Four number of longitudinal reinforcement bars of 25 mm diameter were provided. 10 mm diameter were used as transverse reinforcement. The hinge region was spaced 75 mm center to center distance and 150 mm spacing was provided at the non-plastic hinge region.
The maximum displacement was reported by C.Kyei and A. Braimah was 66.2 mm and the obtained lateral displacement was 61.9. the error percentage was 6 %.

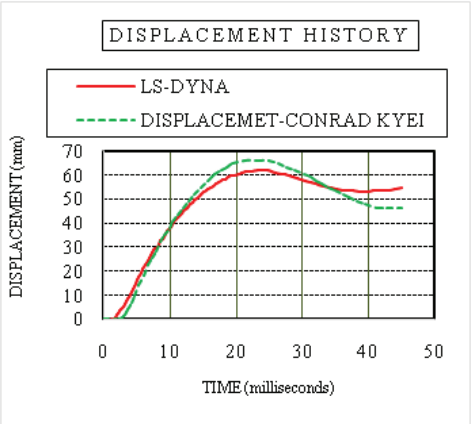

Fig.1 Validation curve

II. COLUMN DETAILING

Column dimensions are taken as per IS 13920-2016.

Colum Dimension

As per IS 13920-2016, the minimum dimension of the column shall not be less than 20 db, where db is the diameter of the largest longitudinal reinforcement bar in the beam passing through or anchoring into the column at the joint or 300mm. The here cross-sectional aspect ratio of the column also considered. As per clause 7.1.2 the cross-sectional aspect ratio ie. The ratio of smaller dimension to larger dimension shall not be less than 0.45.

Reinforcement Detailing

Reinforcement bars in a column provide tensile strength for the column. In this paper, the reinforcement bars selected according to IS 13920. As per the code, the rectangular column should have a minimum of 4 longitudinal bars. Here 2.2 % (AS/AC) of the area of steel is adopted ie.4 no.of 25mm diameter bars. The minimum cover provided for column 40mm. For conventional column design, the maximum spacing of the transverse reinforcing bar is 300mm. Cross ties are provided if the length of any side exceeds 300mm. The yield strength of steel is taken as 400 Mpa and characteristic strength of concrete is adopted as 40 Mpa. Seismic detailing of the column increases the ductility of the structure. The plastic hinge region is reinforced by special confining reinforcement, special confining bars of 8mm diameter is placed at 70mm center-to-center distance. When the blast wave hits the concrete column.

III. FINITE ELEMENTAL MODELING

Hughes-Liu beam element

Hughes- Liu beam element was the first implemented beam element and its formulation is based on the shell (LS DYNA theory manual). It has many desirable qualities that make it simple computational efficiency and robustness. The element is based on the degenerated brick element and therefore it is compatible with the brick element

8 Nodded Under Integrated Solid Hexahedron Element

The fully integrated solid element may lead to volumetric locking or shear locking that will lead to an overly stiff element. Inaccurate results may be obtained due to this phenomenon. Under integrated solid element is computationally less expensive. The fully integrated solid element is less robust when for large deformation. The under-integrated solid element is associated with hourglass energy or negative energy deformation.

Material Model

Piecewise-Linear-plasticity material is used to model both longitudinal and transverse reinforcement. An elasto-plastic material with a discretionary pressure versus strain bend and subjective strain rate reliance can be characterized by using this type of material. Additionally, disappointment dependent on a plastic strain or a base time step size can be characterized. The Material_Piecewise_Linear_Plasticity (MAT 24) is an elasto-plastic material for which a subjective pressure strain bend can be characterized (LSTC 2013). Up to eight plastic strains and comparing yield emphasize focuses can be set to characterize practical non-straight pressure strain conduct. The material model can likewise characterize a discretionary strain-rate. MAT 24 can be set to come up short dependent on the plastic strain esteem or a base time-step estimate.

Bonding

The concrete structures are weak in tension and strong in compression. For the practical case, the concrete is made tensile force resisting by providing a steel reinforcement bar. Steel reinforcement bars are strong in tension, so the concrete can transfer tensile force to the reinforcement through bonding. In the case of developing a numerical model, the bonding of concrete and steel define this transfer of tensile force.

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In LS DYNA software there exist two methods to establish this bonding. The first method involves the creation of common nodes between steel reinforcement and concrete. However, this method is quite difficult and modeling will become complicated. In the second method, the bonding was achieved by using a keyword, LAGRANGIAN_IN_SOLID. This keyword enables the user to model and mesh the part separately then the bonding was created by using LAGRAGIAN_IN_SOILD keyword. The keyword only requires the parameter that the user specify which meshed part act as master and which part act as a slave. In this case-study concrete act as master and reinforcement set act as a slave.

IV. LOADING

Blast Loading

LOAD_BLAST_ENHANCE keycard was used to simulate the blast impact. This keycard will apply blast pressure to the nodes. More accurate results can be produced by using this keyword.

Axial loading

Axial loads were applied to the top surface of the column by using the keycard LOAD_NODE_SET.Axial load corresponding to axial load ratio is determined and applied as pressure on the top face of the column. Axial loads were applied to the structure as varying loads.

Parametric Studies

The column was analyzed under both axial loading and blast loading conditions. The parameter here considered are charge weight, scale distance, ductile detailing of the column and the axial load ratio.

Effect of Charge Weight

To study the effect of charge weight, the scale distance kept constant. Hopkinsons-Cranz scaling law is used to find the stand-off distance of explosives. According to Hopkinson-Cranz scaling law the detonation of a charge weight W1, at a set scale distance R1 will produce blast parameters like Incident pressure, impulse, blast duration which is similar to the parameters produced by another charge weight W2, at a corresponding scale distant R2, detonated in the same atmospheric conditions. Hopkinson - Cranz scaling law is given below.

$$\frac{R_1}{R_2} = \frac{W_1^{1/3}}{W_2^{1/3}}$$

$$\frac{R_1}{W_1^{1/3}} = \frac{R_2}{W_2^{1/3}} = Z$$

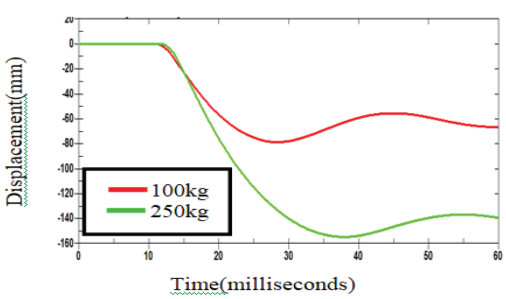


Fig.4Scale distance = 0.8 m/kg$^{1/3}$

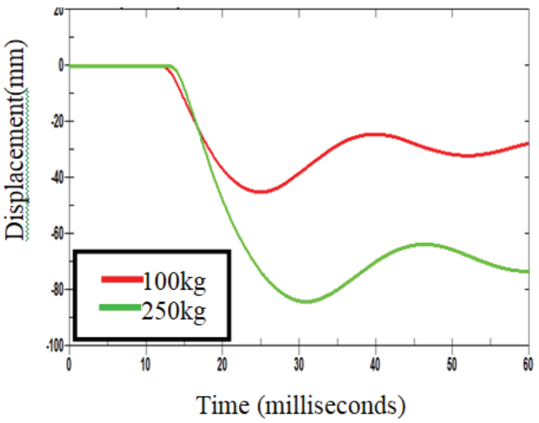


Fig.5Scale distance = 1 $m/kg^{1/3}$

The explosives of charge weight 100kg and 250kg were detonated at 0.8 m/ kg1/3 and 1 m/kg1/3 were selected. The displacement-time history obtained for ALR =0.1 is shown in Fig.4 and Fig.5.

From Fig.4 effect of charge weight can be seen. The lateral displacement obtained for the detonation of 100 kg TNT at a scale distance of 0.8 m/kg1/3 was 78.5 mm and for the detonation of 250 kg of TNT was 98.2 mm. From Fig. 3 also we can see the effect of charge weight. For 100 kg of TNT explosion resulted into 40.2 mm lateral displacement and 250 kg TNT explosion produce 84.5 mm displacement. So the charge weight have significant effect on the resulted lateral displacement.

Effect of Scale Distance

Different charge weight at same scale distance will produce same blast scale parameters ie.the blast pressure, blast duration etc. The increased lateral displacement was produced due to the increases impact effect for lower scale distance. The effect of scale distance can be found out by comparing both Fig.4 and Fig.5. The lateral displacement resulted from the detonation of 100 kg of TNT at a scale distance of 0.8 m/kg1/3 was78.5 mm and the displacement obtained from the detonation of 100 kg of TNT at a scale distance was 44.5 mm. from this result we can found out the effect of scale distance.

Effect of transverse reinforcement spacing

The ductile detailing of column will increase the ductility of column. Parametric studies were conducted to find out the effect of transverse reinforcement spacing on the lateral displacement of column subjected to both axial loading and blast loading. The transverse reinforcement detailing was done by using IS456-2000 and IS13920-2016. The transverse reinforcement will provide confinement to the reinforced cement concrete there by reduce the lateral displacements. Here 8 mm bars were used as transverse reinforcements. For conventional detailing of column, the reinforcements were placed at 300 mm center to center. For seismically detailed column, the stirrup were placed 70 mm center to center at the plastic hinge region and the portion except the plastic hinge region were spaced 150 mm center to center.

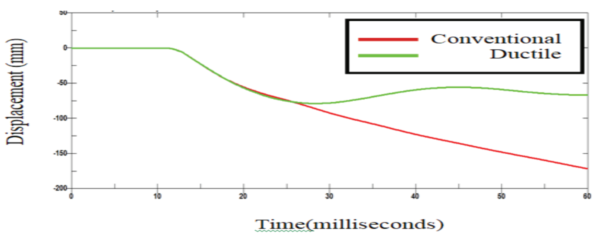


Fig.6100 kg of TNT at a scale distance of 0.8 m/kg1/3

Effect of transverse reinforcement were shown in table 1.

Table 1. Effect of transverse reinforcement

Scale distance (m/kg1/3)	Weight of TNT (kg)	DISPLACEMET (mm)	
0.8		Conventional column	Ductile column
	100	39.5	25
	200	96	39.3
	500	182	158
	1000	421	157
1.0	100	25	21.9
	200	39.3	36.7
	500	72.1	70
	1000	329	144

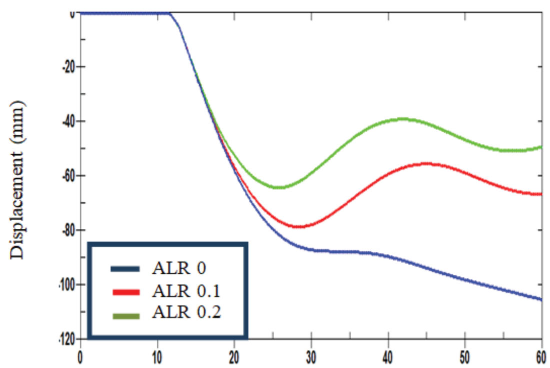
Effect of axial load ratio

The effect of axial loading on the RC columns was investigated at scaled distances of 0.8 m/kg1/3 and 1.0 m/kg1/3. The two different RC column types were subjected to 100-kg and 250-kg charge masses, at various scaled distances, while the RC columns were simultaneously subjected to different axial load ratios of 0.0, 0.1, and 0.2. The effect due to axial load can be find out by applying point load on the top surface of the column. The axial load corresponding to each axial load ration was computed as per IS 456. The axial load ratio can be defined as the ratio between applied load to the axail load resistance of the column. Table 2 shows the applied load corresponding to each ALR.

Table.2 effect of axial load ratio

Axial load ratio	Applied load(kN)
0.0	0
0.1	257.131
0.2	514.263

Fig 8 and Fig 9 shows the effect of axial load ratio of ductile detailed column under the explosion of 100 kg of TNT at 0.8 m/ kg1/3and 1 m/kg1/3.



Time (millisecond)
Fig.8 Scale distance 0.8 m/kg1/3

From fig 8 we can see that the lateral displacement was reduced by applying axial load on the column. For example, the lateral displacement produced by the explosion of 100 kg of TNT detonated at a scale distance of 0.8 m/kg1/3 was 105 mm (which is not the maximum displacement)

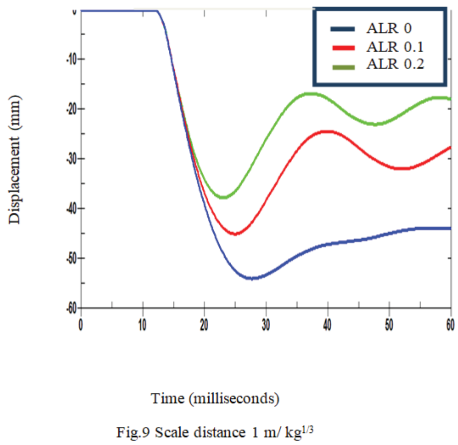


Fig.9 Scale distance 1 m/ kg1/3

Table 3. Effect of axial load ratio

Scale distance (m/kg1/3)	Weight of TNT (kg)	DISPLACEMENT (mm)		
0.8		ALR 0	ALR 0.1	ALR0.2
	100	106	78.4	63.9
	250	240	154	146
1.0	100	53.9	44.8	37.5
	250	98.3	84.8	68.9

V. CONCLUSIONS

From this study, we can conclude that the damage of the column can be minimized by providing seismic detailing. By reducing the spacing of transverse reinforcement, we can reduce the lateral displacement of the column. The effect of special confining bars is more effective at low scale distance. There is only a minimum effect for higher scale distance. For the same scale distance, the charge weight plays a key role in the whole damage of the RC column. There will be in-creasing lateral displacement for increasing charge weight. For the same charge weight, lateral displacement can be reduced by increasing the scale distance.
Axial load ratio also plays a key role in the lateral displacement. Axial load increases, the stiffness of the structure increases, there by reducing the lateral displacement of the structure. But if we increase the axial oad beyond a limit, the structure will collapse due to crushing of concrete.

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