STRUCTURAL BEHAVIOUR OF LONG AND SHORT REINFORCED CONCRETE COLUMNS SUBJECTED TO COMBINED IMPACT AND BLAST LOADING

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Abstract— When an event like explosion or terrorist explosion occurs, the associated blast impact loads results in the failure of critical load bearing members with subsequent social disruptions and economic losses. The most common failure mode of structures subjected to explosion is the progressive collapse and it occurs by the failure of load-bearing columns. Exterior columns are probably the most vulnerable structural components to terrorist attacks and accidental explosions. Therefore, the reliability of vulnerable columns under blast loading is of great importance. In this study, the structural behavior of long and short reinforced concrete columns under combined impact and blast loading are investigated. And also a parametric study is conducted to study the effect of shapes, longitudinal reinforcement ratio and transverse reinforcement spacings.

Keywords— Blast, Impact, Long column, short column

I. INTRODUCTION

Due to the various accidental or intentional events occurred, the behavior of structural components subjected to blast loading has acquired much research effort in recent years. Normally conventional structures are not designed to resist blast loads. Since the magnitudes of design loads are significantly lower than those produced by most explosions. Hence conventional structures are susceptible to damage from explosions and the architects and engineers are seeking solutions, to protect building occupants and the structures. Today, the shock resistance of engineering structures subjected to blast impact has great importance in the engineering communities and Govt. agencies against possible terrorist blast threats. The need for recognizing the response mechanisms of concrete structures under terrorist attacks and accidents are increased in recent years. Columns are the key load-bearing elements in framed structures and normally its failure is the primary cause of progressive failure in framed structures. Exterior columns are probably the most vulnerable structural components to terrorist attacks and accidental explosions. Due to the low redundancy of column members, investigating the responses, residual capacities, and vulnerability against explosions is very important to mitigate the human casualties and damages. RC structures may be subjected to the combined actions of impact and blast loading during the intentional terrorist attacks or accidental events arising from the collision of vehicles, vessels, etc, which is carrying explosive materials. The collision of such explosive carrying vehicles with the structures can cause the subsequent explosions after the start of impact loadings. Under such combined loadings, impact and blast loadings may apply simultaneously or subsequently with a significant time lag between their occurrence. Here both the loads are applied simultaneously to the long and short reinforced concrete columns.

II. OBJECTIVES

- To study behavior of long and short reinforced concrete columns subjected to combined impact and blast loading.

III. LITERATURE REVIEW

Various research studies are carried for investigating the response of blast impact on the RC bridge superstructures, piers, beams and columns. Limited studies are found on the response of structural members under combined impact and blast loading.

A Damage index based on the residual load-carrying capacity of RC columns under blast loads was defined by Shi Y et.al [7]. Many parametric studies are found on the resistance of reinforced concrete columns under the explosion loads. Xiaoli Bao et.al studied the Residual strength of blast damaged reinforced concrete columns and found that Reinforcement ratio has a positive and column height has a negative effect on the axial resistance of column. Astarlioglu et.al investigated the Behavior of reinforced concrete columns under combined effects of axial and blast-induced transverse loads and found that the Level of axial compressive load has a significant influence on the behavior of RC columns when subjected to blast loads [1]. The positive effect of column depth and height on the blast resistance of column is found by the Numerical study of concrete spall damage to blast loads [4]. Cui et.al investigated the Failure Analysis and Damage Assessment of RC Columns under Close-In Explosions [3] and found that Cross sectional dimensions has a positive and stirrup ratio has a negative effect on the axial resistance of column. Effects of transverse reinforcement spacing on the response of reinforced concrete columns subjected to blast loading was studied by Kyei and Braimah [6] and a negative effect on lateral resistance was found. Studies are found mainly focussed on improving the accuracy of the predictions instead of enhancing the structural capacity in the studies. Limited Studies are found on the behavior of reinforced concrete columns under combined impact and blast loading. In the studies the vulnerability of the RC column to several loading-related parameters are studied. But no structural related parameters are studied [4]. JunLi et.al found that Seismic detailing improves the blast resistance of column but no significant improvement under impact loading [5].

IV. MODELLING REINFORCED CONCRETE COLUMN

A three-dimensional finite element model of reinforced concrete column was developed using ANSYS 19.2. The concrete is modelled using SOLID 185. Solid 185 structural solids are suitable for modelling general 3-D solid structures. The reinforcements are modelled as beam elements. Mesh size provided was 10 mm. TABLE I shows the material properties used for the numerical modelling. An axial load of 750 kN is given as constant. The impact loading is modelled by providing an impactor of 100 mm diameter and 1440 kg weight located at 1 m depth from the bottom of the column. Fig 1 shows the impact load modelling. The scaled distance Z for the blast load is taken as 0.21 m/ kg 1/3 (in which the stand off distance is 0.5 m and the TNT charge weight is 13 kg). The blast load is located at 2.5 m from the bottom of column and the detonation time is given as 0.002 seconds. Fig 2 shows the details of blast load modelling.

TABLE I: MATERIAL PROPERTIES

		Value
concrete	Density of concrete	2400 kg/mm^3
	Unconfined compression strength	50 MPa
Rebar (Longitudinal and Transverse)	Mass density	7800 kg/mm^3
	Young's modulus	$2X10^5$ MPa
	Failure strain	0.15
	Poisson's ratio	0.3
Longitudinal rebar	Yield stress	523 MPa
Transverse rebar	Yield stress	507 MPa

V. PARAMETRIC STUDY

Parametric studies are conducted on the long and short reinforced concrete columns to study the behavior of reinforced concrete columns under combined impact and blast loading. And also, to compare their results with the conventional axially loaded column. The parameters considered are shapes of column (Square, Rectangle, Circle), Aspect ratio (Column length to breadth ratio), longitudinal reinforcement ratio, transverse reinforcement spacing of columns. A column of 300 x 300 mm cross section and 4 m length with 4, 25 mm dia bars as longitudinal reinforcement and 12 mm diameter bars @ 150 mm c/c as transverse reinforcement is taken as the reference long column. The length of short column is 2.5 m.

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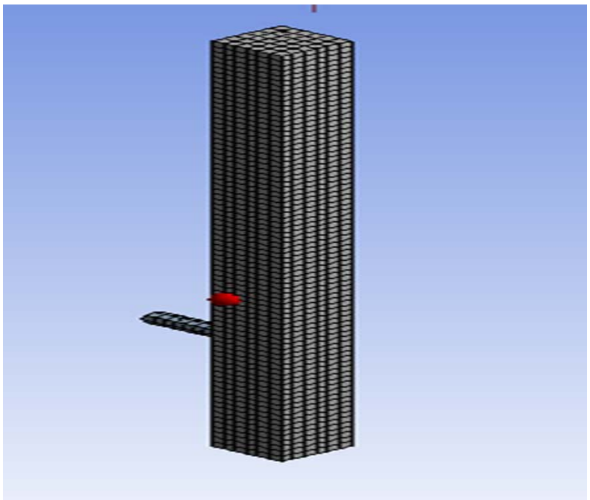


Fig 1 Impact load modelling in ANSYS

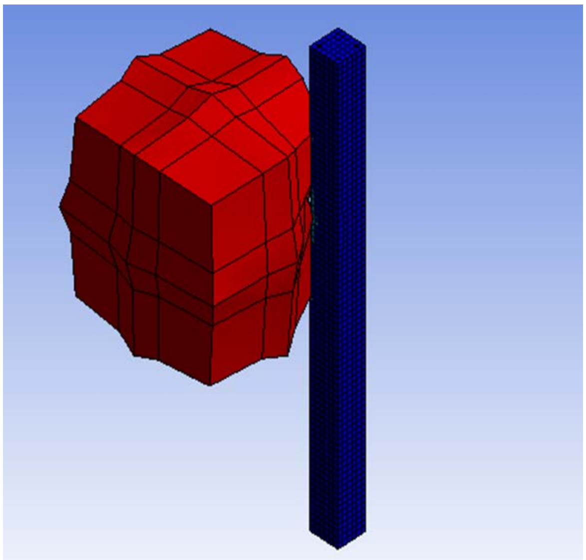
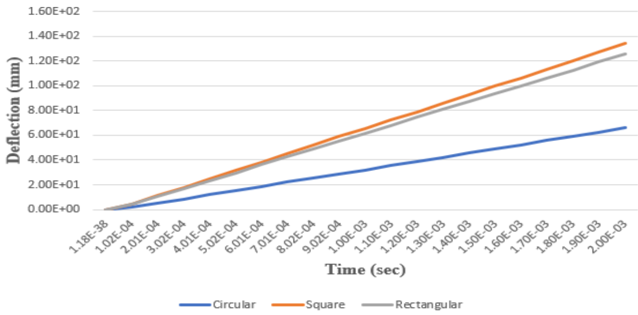


Fig 2 Blast load modelling in ANSYS

A) Shapes of column

Three commonly used shapes of columns are taken for the parametric study. The dimensions and reinforcements of circular and rectangular columns are found by equating to the volume to the reference column. From the Fig 3, showing the time-deflection graph of long and short columns it is found that for both the case of long columns and short columns, the circular column has 2 times lesser deflection compared to the square and rectangular columns. This may be due to the fact that circular shape has lesser reflected over pressure compared to other shapes. Also found that Short circular column has 57.36 % higher deflection than the long circular column and Short square column has 63.32 % higher deflection than the long square column. Fig 4 shows the deformed shapes of long and short columns studied.



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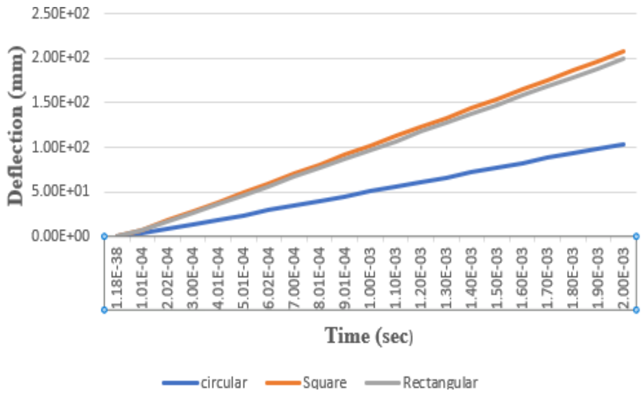
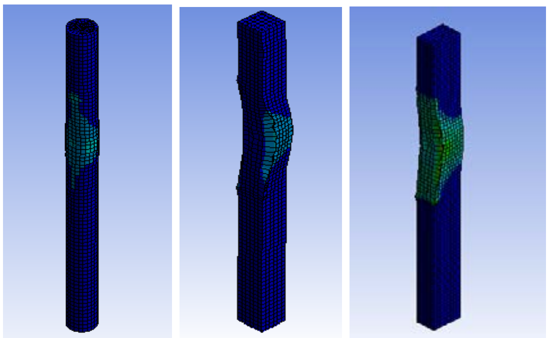


(b)

Fig 3 Deflection-Time graph for with various shapes of column (a) Long column (b) Short column



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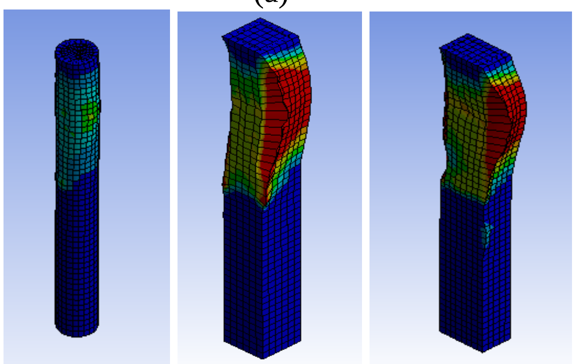

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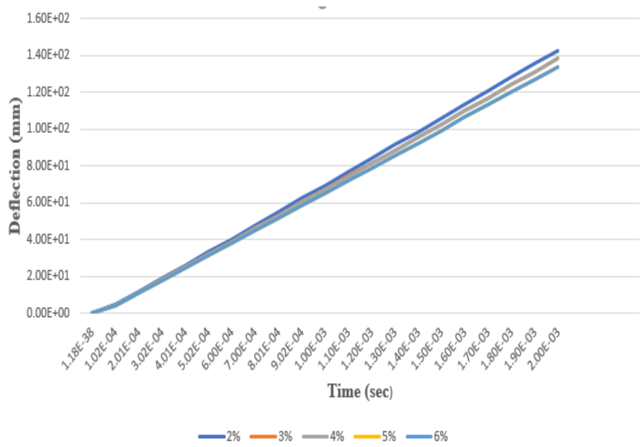
Fig 4 Deformed Shapes of columns studied (a) Long columns (b) short columns

B) Longitudinal reinforcement ratio

The longitudinal reinforcement ratios are taken as 2 ,3, 4, 5, 6 % of the reference column cross section for both the long and short columns.The reinforcement details are calculated for each of the column. Fig 5 shows the time-deflection graph of long and short columns for various longitudinal reinforcement ratio.



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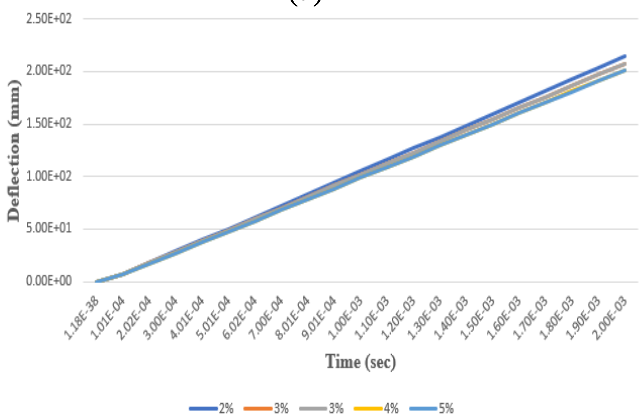


(b)

Fig 5 Deflection-Time graph for with various shapes of column (a) Long column (b) Short column

From the graph, the deflection of long column is found to be decreased by 6.30 % and deflection of short column is found to be decreased by 6.08 % with increase in percentage of longitudinal reinforcement from 2 % to 6%. Fig 6 shows the deformed shapes of long and short columns with 2 % longitudinal reinforcement. Other models are also show same nature in both the case of long and short columns.

C) Transverse reinforcement spacing

The transverse reinforcement spacing taken are 75 mm, 100 mm, 150 mm, 225mm, 300 mm for both the long and short columns. Fig 7 shows the time-deflection graph of long and short columns for various transverse reinforcement spacing. From the graph, The deflection of long column is found to be increased by 13.18 % and deflection of short column is found to be increased by 15.55 % with increase in transverse reinforcement spacing from 75 mm to 300 mm. Fig 8 shows the deformed shape of reference column for both long and short cases. Other columns are also shows the same nature of deformation.

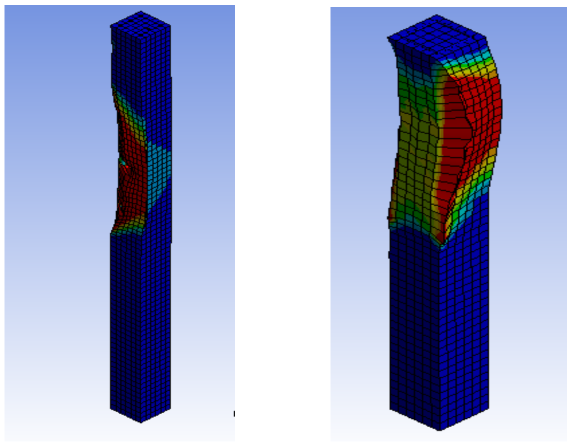
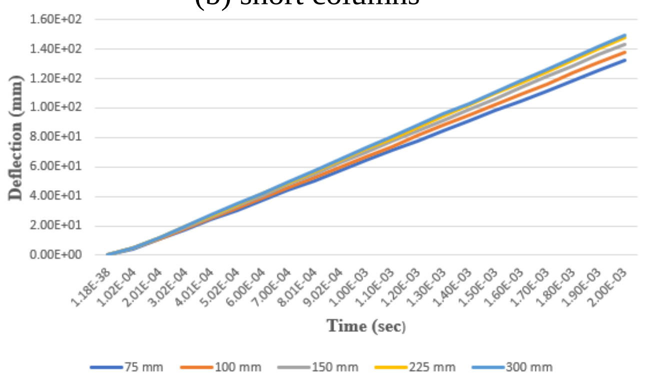


Fig 6 Deformed Shapes of columns with 2 % longitudinal reinforcement (a) Long columns (b) short columns



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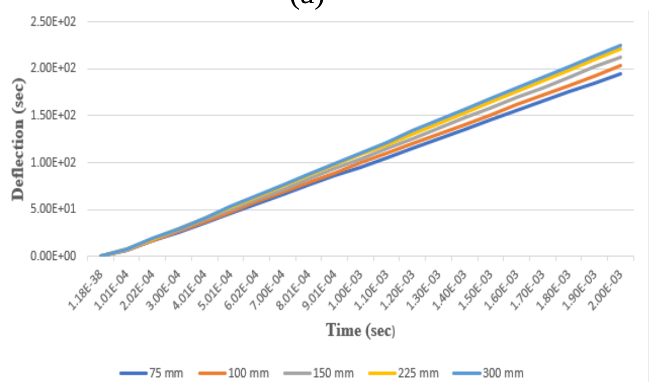

(b)

Fig 7 Deflection-Time graph for with various shapes of column (a) Long column (b) Short column

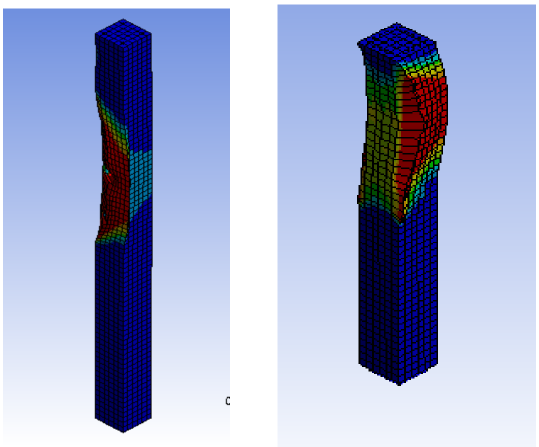

Fig 8 Deformed Shapes of reference columns (a) Long columns (b) short columns

VI. RESULT AND CONCLUSIONS

Parametric studies are conducted to investigate the effect of different structural related parameters on the behavior of long and short reinforced concrete columns under combined impact and blast loading. The study compared the response of long and short columns under combined impact and blast loading. And also, a compared with the conventional axially loaded concrete column. Generally, it is found that Larger longitudinal reinforcement ratios, lesser transverse reinforcement spacings can improve the performance of RC column under combined impact and blast loading and Transverse reinforcement spacing has more effect on the performance of RC columns than the longitudinal reinforcement ratio. The conclusions drawn from this work are;

- For both the case of long and short columns, the circular column has 2 times lesser deflection compared to the square and rectangular columns. Short circular, square, and rectangular columns have 57.36 %, 63.32 % and 67.18 % higher deflection than the long circular, square and rectangular columns respectively.
- The deflection of long and short column is found to be decreased by 6.30 % and 6.08 % with increase in percentage of longitudinal reinforcement from 2 % to 6% whereas for a conventional case the decrease is 25.81 % and 23.21 % respectively.
- The deflection of long and short column is found to be increased by 13.18 % and 15.55 % with increase in transverse reinforcement spacing from 75 mm to 300 mm whereas for a conventional case the increase is 37.5 % and 43 % respectively.

VII. REFERENCES

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