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Effect of Transverse Reinforcement Biased Spacing on Concrete Columns under Blast Load

Athira Rajan[1] and Jobil Varghese[2]

[1]Civil Engineering Department, APJ Abdul Kalam Technological University, Mar Baselios Institute of Technology and Science Nellimatom, Ernakulam, India

[2] Civil Engineering Department, APJ Abdul Kalam Technological University, Mar Baselios Institute of Technology and Science Nellimatom, Ernakulam, India

Abstract

Columns are the key load-bearing elements in frame structures and exterior columns are probably the most vulnerable structural components to terrorist attacks. Column failure is normally the primary cause of progressive failure in frame structures. A general purpose finite element analysis(FEA) software package ANSYS was utilized in this.The present study addresses the feasibility of blast response of reinforced concrete columns totally reinforced with composites bars by replacing the steel reinforcements along with variation of transverse reinforcement without considering the axial compressive loads and idealized boundary conditions using the software ANSYS, and to determine how the response of the column varies with variation in transverse reinforcement spacing. The results clearly show that properly designed and detailed composite-reinforced concrete columns have lower deformations compared to steel reinforced columns

Keywords: *Concrete Column,Blast, Steel Reinforcement, Composites, Displacement Time Histories, Damage.*

1. Introduction

Explosions, whether accidental or planned within or nearby a structure can cause catastrophic damage to the structure. The blast explosion mainly due to vehicle bomb or pressure or quarry blasting, cause significant damage to the lifeline structures like buildings, roads, bridges, dams and civilian structures. Since India is a developing country, the threat towards terrorist's attacks on the civil structures cannot be ignored now a days. About 85 terrorist attacks were reported from the year 1984-2016 in India. The rise in the number of terrorist attacks over the past few decades shown the effect of blast loads on structures is a serious matter that should be taken into consideration in the design process like earthquake and wind loads.

Conventional structures normally are not designed to extreme loading conditions like impact and blast etc. 95% of the civil structures are RC structures which have been proved to be vulnerable under explosion accident. An understanding of the dynamic response of RC components such as Slab, Column and Beam under blast loading is vital in the damage evaluation of RC structures and to make a blast resistant design. Columns are the key load-bearing elements in the structures. Exterior columns are probably the most vulnerable structural components to terrorist attacks. Column failure is normally the primary cause of progressive failure in frame structures. However, current knowledge in the evaluation of residual capacity of a blast damaged reinforced concrete column remains limited.

A better understanding of residual capacity in columns would aid in the prediction of the overall performance of buildings, its resistance to progressive collapse and determining the stability of damaged buildings especially during search and rescue operations.

Columns are structural elements which transmit the load on the superstructure to foundation through a defined path in such a way that failure of one element does not lead to the failure of entire structure. In the view of strength and stability, they should be the second strongest structural component next to the underlying foundation. Blast load though often ignored, have proved to be of vital importance in the present day world. Therefore, the endurance of such members under severe short duration loads is essential for the survivability of the building.

The primary objective of this paper is to investigate the blast response of reinforced concrete columns by replacing steel reinforcements by composites longitudinal rebars along with variation of transverse reinforcement without considering the axial compressive loads and idealized boundary conditions using the software ANSYS, and to determine how the response of the column varies with variation in transverse reinforcement spacing.

2. Objectives

To study the effect of transverse reinforcement spacing on concrete columns subjected to blast loading and column failure.

3.Effect Of Transverse Reinforcement Spacing

A study from recent years shows that most of the terrorist attacks on public structures were explosions within short standoff distance. RC columns on the periphery of a building could be exposed to high blast loads from proximate explosions and their failure can lead to progressive or disproportionate collapse. Many researchers have identified failure of RC columns under blast loading as a potential precursor to progressive collapse. For the past few decades ,a large number of researches have been conducted to explore the performance of various composite materials .This study is deals with effect of replacing steel rebars with composite rebars and effect of transverse reinforcement bias factor on concrete columns under blast load. Concrete of compressive strength 35 Mpa was selected.

3.1 Material properties

(i) Concrete

An appropriate material for concrete is critical for the reliable simulation of RC structures. For this reason .the concrete model will be described more in detail in the following. The RHT model with a ploynomial equation of state is used for concrete. This EOS has been proved to be capable of representing well the concrete thermodynamic behavior at high pressure and it also allows for a reasonable detailed description of the compaction behavior at low pressure ranges..The RHT default properties used in this study are shown in Table 1.

(ii) Air

An ideal gas equation of state (EOS) was used for the air. In an ideal gas , the internal energy is a function of the temperature. Table 2 shows the properties of the air used in this study.

(iii) ANFO

The explosive is modeled using the well known “Jones-Wilkins-Lee”(JWL) equation of state. The properties used in this study are shown in Table 3.

(iii) Steel

The reinforcement steel is modelled as isotropic, linear elastic and strain hardening. It is strain rate dependent with thermally softening plasticity. For hydrostatic pressure, steel compression is approximately proportional to pressure level .Thus the elastic response is defined by a linear EOS. The yield strength of steel was taken as 500N/mm^2.

Table 1. RHT strength model, default parameter setting

Shear modulus, G(kPa)	1.67x10^7
Compressive strength, f_c (kPa)	3.5x10^7
Tensile strength f_t/f_c	0.1
Shear strength, f_s/f_c	0.18
G (elast/elast-plas)	2
Elastic strength/f_c	0.7
Elastic strength/f_t	0.53

Table 2. Properties of the air

Reference density ρ(Kg/cm^3)	1.22x10^6
γ	1.4
Reference temperature(K)	288
Specific heat C_v(J/Kg/K)	717.6
Internal energy e(KJ/m$^{3)}$	2.068x10^5

Table 3. ANFO properties (EOS JWL)

Density ρ(g/cm^3)	0.84
Parameter A(kPa)	4.946 x10^7
Parameter B(kPa)	1.891 x10^6
Parameter R_1	3.907
Parameter R_2	1.118
C-J Detonation velocity $V_{C\text{-}J}$ (m/s)	4.16 x10^3
C-J energy/unit volume $e_{c\text{-}j}$ (kJ/m^3)	2.68 x10^6
C-J pressure $p_{c\text{-}j}$(kPa)	5.15 x10^6

3.2 Modelling

The finite element model was developed using steel and concrete elements in ANSYS- AUTODYN. The model had a rectangle section of 200 mm X 600 X 3000 mm dimension.Geometry of concrete columns with uniform transverse reinforcement spacing and varying bias factor as shown in the Fig.1,Fig.2,Fig.3,Fig.4 and Fig.5.In the base column model a uniform transverse reinforcement spacing of 300 mm provided. The column had 8-20 M longitudinal bars and 8M transverse reinforcements at various spacing.But in the case of model 1 and model 2 minimum reinforcement spacing ie 75 mm were provided at the

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center .Then the minimum reinforcement 75 mm is multiplied with a factor 1.1 to get the next spacing. Similarly in this way spacing were calculated till the ends. In model 2 a factor of 1.2 was used. To study the effect of transverse reinforcement spacing on columns under blast load, in model 3 and model 4 maximum spacing of 300 mm were provided at the center .In model 3 the maximum spacing ie 300 mm was multiplied by a factor 0.9 and in the case of model 4, a factor of 0.8 was multiplied to get the successive spacing. The specimen was tested in vertical position. For the test 100 kg ANFO was used as explosives charges. The standoff distance was measured from the centre of explosive to the centre of specimen. The same column with same properties, boundary, conditions, air location ,blast location and different bias factor was modeled to compare the effect transverse reinforcement spacing on columns under blast loads

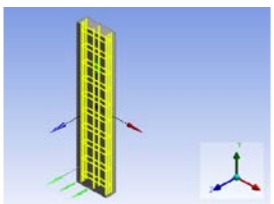

Fig. 1 Reinforcement detailing of base column

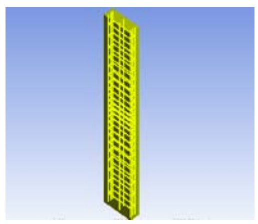

Fig. 2 Reinforcement detailing of column model 1

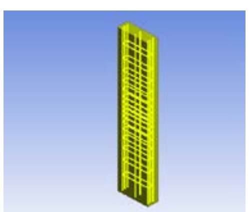

Fig.3 Reinforcement detailing column model 2

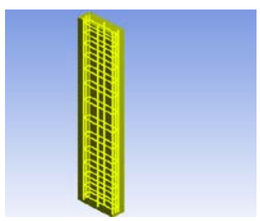

Fig.4 Reinforcement detailing of column model 3

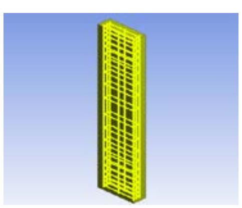

Fig.5 Reinforcement detailing of column model 4

3.3 Boundary Condition And Loading

Geometric modeling and meshing of columns were done by ANSYS. Then the models were imported to Autodyn. For the application of explosion ,an air medium introduced around the columns. Fixed support was provided at the bottom of column while on the top displacement was provided as shown in the Fig.5.

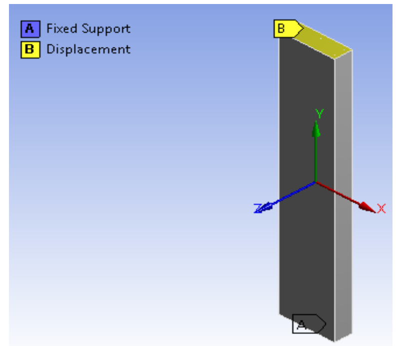

Fig. 6 Boundary condition

3.4 Location Of Air And Guage

For the application of blast load an air medium introduced around the concrete section. Location of air medium given in Table 4.

Table 5.Location of air medium

Axis	Air location(mm)	Delta (Δ)mm	No of cells
X	-350	700	14
Y	-1500	3000	60
Z	-400	4100	82

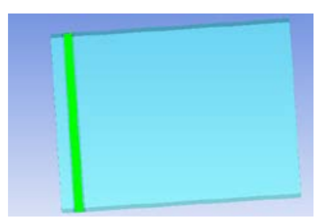

Fig. 7 Air medium provided

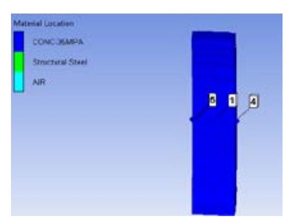

Fig. 8 Location of gauges

3.3 Meshing

It is the most important part of an analysis and is done to discretize the structure. Meshing divides the structure in to elements. Therefore, a lot of time is given to meshing of complex models. In the present study, the bodies are meshed with an element size of 25 mm.

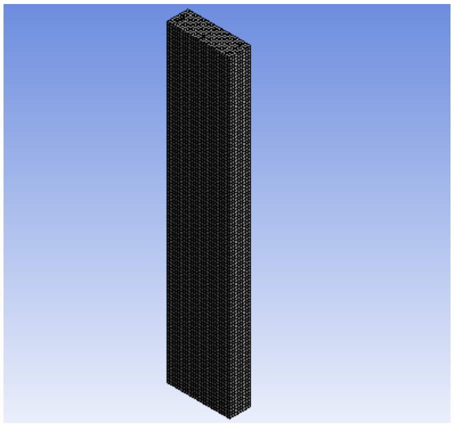

Fig. 9 Meshed View

4. Results and Discussions

In order to study the effect of transverse reinforcement spacing on concrete columns under blast loading 5 models were considered. Columns with different transverse reinforcement spacing were studied. Displacement time history of column models with different spacing shown in the following figures

The Fig.10 shows the deflection of base column. Gauge 5 has maximum deflection 163.23 mm as it is nearest impact point to the blast. The Fg.11 shows the deflection of concrete column model 1.The maximum deflection was observed at gauge 5 and it was about 149.5 mm. Maximum deflection of the concrete column model 2 was 159.1 mm and as shown in Fig.12. Fig.13 shows the maximum deflection of column model 3.It was about 138.03 mm.The maximum deflection was about 143.79 mm in the case of column model 4 as shown in Fig.14.

From the graph it is clear that, the maximum displacement of column under blast load is lower for the columns with minimum reinforcement spacing at center. When transverse reinforcement spacing increases at the center of column, displacement also increases under blast load. Column model 1 shows lower deformation and better resistance to blast load. Column model 3 shows the maximum deformation under blast loading.

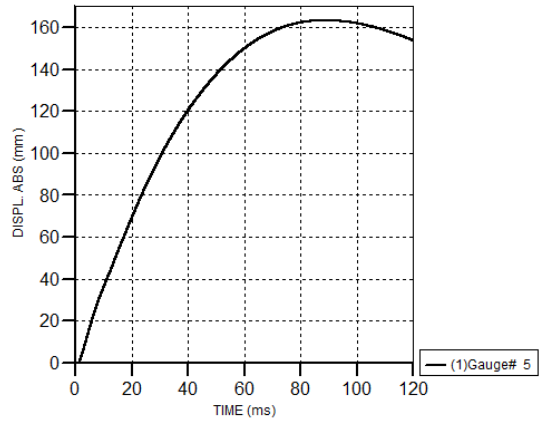

Fig. 10 Displacement Vs Time graph of base

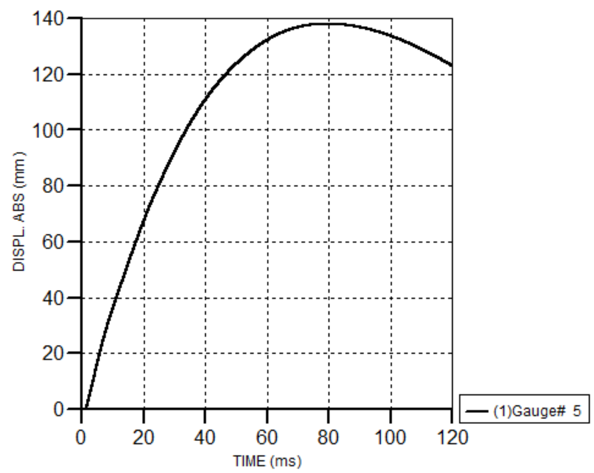

Fig. 11 Displacement Vs Time graph of column model 1

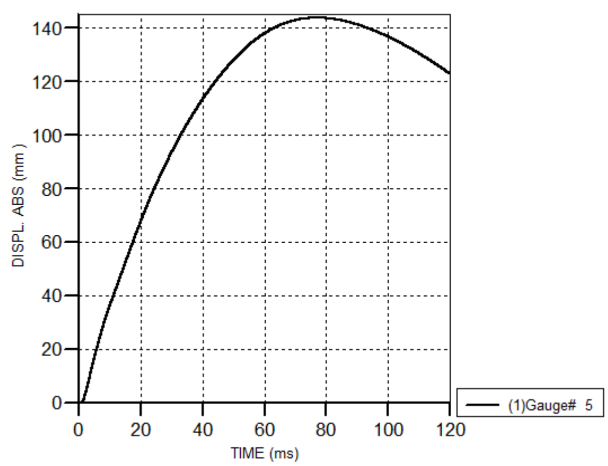

Fig. 12 Displacement Vs Time graph of column model 2

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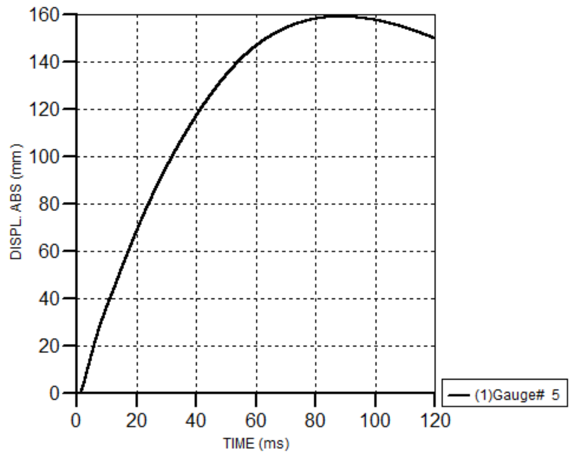

Fig. 13 Displacement Vs Time graph of column model 3

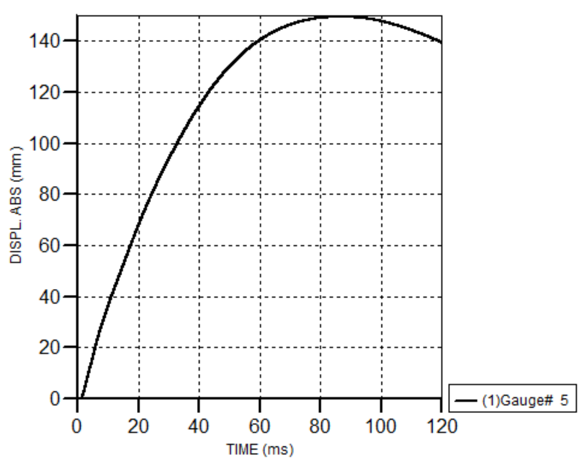

Fig. 13 Displacement Vs Time graph of column model 4

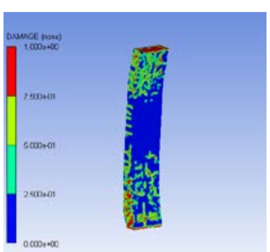

Fig. 14 Damage profile of column

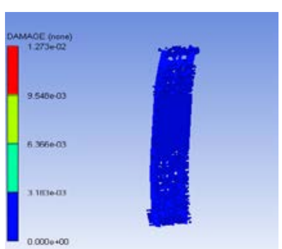

Fig. 15 Fragment plot of column

Conclusions

On comparing blast performance of column with varying transverse reinforcement spacing that reduced transverse reinforcement spacing at the middle portion of the column has lower displacement compared to other models.As the transverse reinforcement spacing of concrete column at the center increases ,the displacement of column also increases.

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