Explicit Dynamic Behaviour of Textile Reinforced Concrete Retrofitted RC Column under Blast Loading

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Abstract— In the recent years, effects of blast load on building are serious matter because of the increase in the number of terrorist attack. Generally conventional structures are not designed for blast load due to the reason that magnitude of load caused by blast is huge and cost of design and construction is very high. Considering the fact that these attacks cause a catastrophic damage to the structure due to the limitations in the existing design methods, the usage of advanced engineering materials could resolve this issue. A finite element modelling methodology for the response of reinforced concrete (RC) columns strengthened with Textile Reinforced Concrete (TRC) were integrated to simulate the behaviour of retrofitted RC column. TRC comprises an innovative composite material consisting of fabric made of long fibre yarns and embedded in a cementatious fine- grained matrix. In light of the recent events, this paper showcases the behaviour of TRC retrofitted RC columns under blast loading. The nonlinear finite element analysis was carried out using ANSYS software. This paper aim to study the effect of blast load generated as a result of explosive charge on the existing exterior RC square columns of a multi-storied building and equivalent circular column was designed for the analysis. A parametric study of TNT has been performed to examine the effect of two sets of Jones-Wilkine-Lee (JWL) parameter.Further, Charge weight of 1000 kg equivalent weight of TNT at stand-off distance 4.5 m were considered for the study of dynamic explicit analysis of the different textile material. Besides, the effect of blast load at stand-off distances of 1.5 m, 3 m, and 4.5 m on un-retrofitted column and retrofitted column were studied. A procedure has been developed for evaluating the dynamic characteristics of the circular and square retrofitted column. Results described in this paper indicate that TRC strengthening could be an effective solution to limit the damage caused by moderate explosions. The result indicate that maximum deflection experienced by column decreased exponentially with the increase in the stand-off distance and also increased for the columns strengthened with TRC, compared with the un-strengthened column.

Keywords: *Textile Reinforced Concrete, Explicit analysis, Blast load, ANSYS*

1. INTRODUCTION

One of the major challenges we are facing the present world is failure of structures due to explosions. Many countries are in fear of Terrorists attack. Accidentally or intentionally explosions are occurring and leads to a terrible disaster. Most of the structures are not designed to accommodate blast load due to high complexity in design as well as uneconomical construction cost. So, such structures may damage or collapse. Nowadays engineers and architects trying adopt new methods to retrofit the structures economically against blast damage.

2. Methodology

- Modelling of reinforced concrete column and TRC column.
- Non-linear finite element analysis carried out using ANSYS Workbench.
- Parametric study of TNT
- Select elements to be used in the modelling of TRC and identify the material properties.
- Blast Load and support conditions are being applied on to the model.
- Analysis different types of TRC and find the best model.
- Comparison of un-retrofitted column and retrofitted column under blast load.
- Comparison of square retrofitted column and circular retrofitted column.
- Evaluation of structural response.

3. Findings

3.1 Parametric Studies

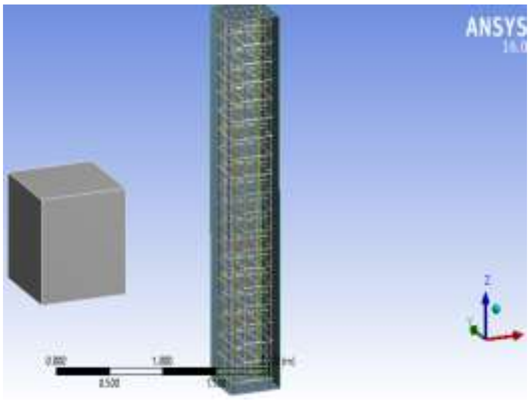
A parametric study of TNT has been performed to examine the effect of two sets of Jones-Wilkine-Lee (JWL) parameter. The JWL equation of state (EOS) is frequently used for the products (and sometimes reactants) of a high explosive (HE). The JWL EOS is of the Mie-Gruneisen form with a constant Gruneisen coefficient and a constants specific heat. ω is the Gruneisen coefficient and A, B, R1, R2 are parameters. The parameters A and B have dimensions of pressure, while R1, R2 and ω are dimensionless.

3.2 Dynamic Explicit Analysis of the Different Textile Material

The geometry of the model is prepared using workbench platform of ANSYS finite element analysis software. Blast analysis predicts the strength of textile reinforced concrete columns of different types of textile materials. Four models made with different textile materials. Models have same size of 500 mm x 500 mm and length of 3 m. M35 grade concrete is used. Analysis is done by 1000 kg equivalent weight of TNT at stand- off distances of 4.5 m were considered.

TNT equivalent is a convention for expressing energy, typically used to describe the energy released in an explosion. The primary reason for choosing TNT as the referent explosive is that most of the available experimental data regarding the characteristics of blast waves were collected using TNT. Several methods exist for determining the explosive characteristics of different explosives, but they do not yield the same values for the TNT equivalent. These values depend on the characteristic parameter of the blast wave, the geometry of the load, and the distance from the explosive charge. The TNT equivalence of terrorist-manufactured explosive material is difficult to define precisely because of the variability of its formulation and the quality control of its manufacture. Charge weight of 1000 kg equivalent weight of TNT is used for the analysis. Detonation point is at the center of TNT

3.2.1 Modeling TNT and TRC



The input needed for the application of blast load are charge weight in terms of equivalent mass of TNT and Stand-off distance. In this analysis the Explosive is at various stand-off distance of 1.5 m, 3 m and 4.5 m are considered. Chargeweight of 1000 Kg are applied to the both un retrofitted and retrofitted column. And the blast load is applied as a Dynamic/Explicit load in ANSYS.

Table 3.1: Properties of Materials

Input Parameters	Value
Concrete:	
Young's Modulus (MPa)	29500
Poisson's ratio	0.2
Fine grained concrete:	
Young's Modulus (MPa)	27500
Poisson's ratio	0.2
Steel:	
Modulus of elasticity (MPa)	$2x10^5$
Poisson's ratio	0.3
Yield stress (MPa)	415
Textile:	
Modulus of elasticity (GPa)	400
Poisson's ratio	0.2
Maximum tensile stress in yarn(MPa)	2200
Maximum tensile strain in yarn	0.012

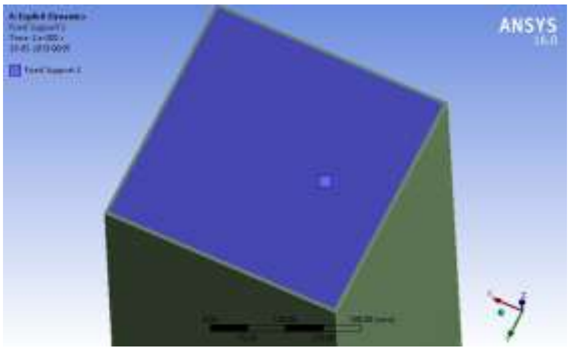


Figure 3.3 Boundary Condition

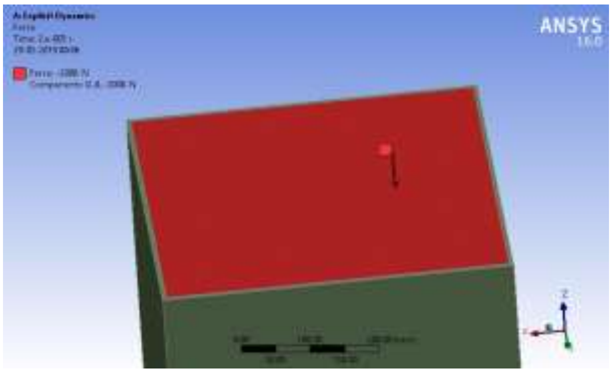


Figure 3.4 Axial load

3.3.1 Model of Reinforced Concrete

A reinforced Concrete Column of size 500 mm X 500 mm and Height 3.0 m with both ends fixed is considered for the analysis. The axial load on column is 2000 KN, which also included in the analysis. 12 number of 20mm diameter bars at 130 mm c/c and 8 mm diameter bars at 300 mm c/c is considered as Longitudinal and Transverse reinforcements respectively. The effective cover for main reinforcement is taken as 45 mm.

3.3.2 Model of Textile Reinforced Concrete

The textile material used for the retrofitting model is boron textile of 5 mm thickness is considered . The Young's Modulas of boron Textile is taken as 400 GPa, Poisson's Ratio of 0.2 and yield stress of 2200 MPa at zero plastic Strain.A textile reinforced Concrete Column of size 500 mm X 500 mm and Height 3.0 m with both ends fixed is considered for the analysis. The axial load on column is 2000 KN, which also included in the analysis. 12 number of 20 mm diameter bars at 130 mm c/c and 8 mm diameter bars at 300mm c/c is considered as Longitudinal and Transverse reinforcements respectively. The effective cover for main reinforcement is taken as 45 mm.

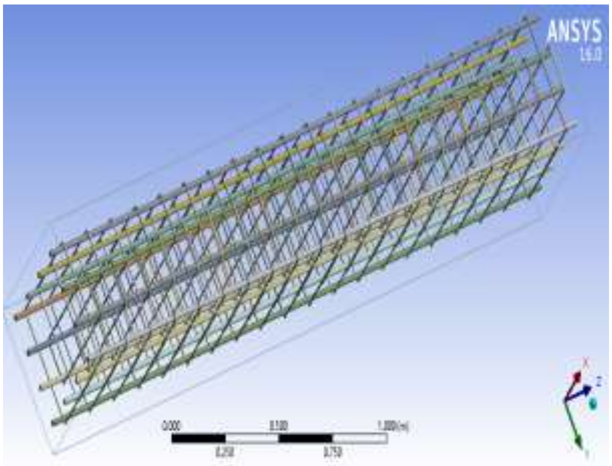


Figure 3.5 Reinforcement in RC column

3.4 Effect of Blast Load on Circular and Square Retrofitted Column

3.4.1 Model of Circular Retrofitted Column

A reinforced Concrete Cicular Column of 636 mm diameter and Height 3.0 m with both ends fixed is considered for the analysis. The axial load on column is 2000 KN, which also included in the analysis. 12 number of 20 mm diameter bars at equal spaceing and 8 mm diameter bars at 300mm c/c is considered as Longitudinal and Transverse reinforcements respectively. The effective cover for main reinforcement is taken as 45 mm. The textile material used for the retrofitting model is boron textile of 5 mm thickness is considered .

The input needed for the application of blast load are charge weight in terms of equivalent mass of TNT and Stand-off distance. In this analysis the Explosive is at various stand- off distance of 1.5 m. Charge weight of 1000 Kg are applied to the both un-retrofitted and retrofitted column. And the blast load is applied as a Dynamic/Explicit load in ANSYS.

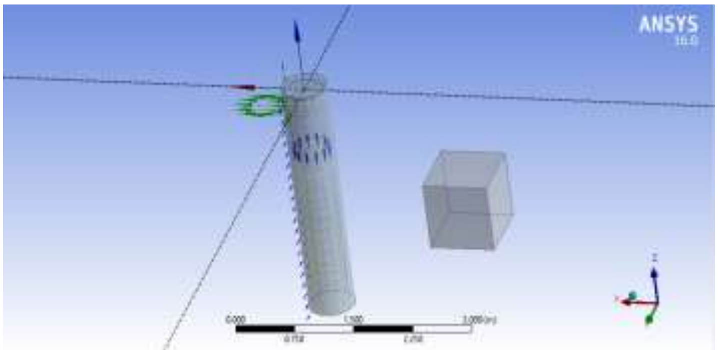
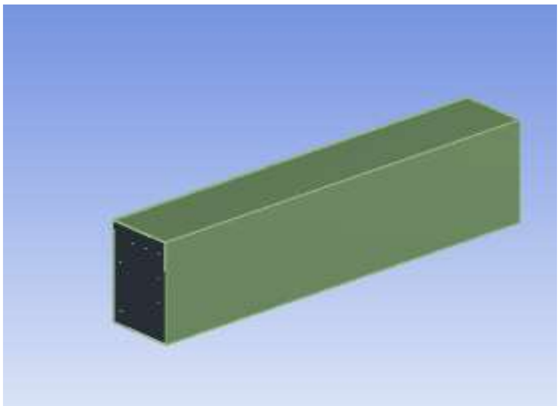


Figure 3.7 Column at 1.5 m stand-off distance from TNT



4. Results and Discussion

4.1 Results and Discussion of Parametric Studies

Two sets of TNT was analyzed and can concluded that TNT 1 is more effective. Thus for the further study TNT 1 was used

Table 4.1 Un-Retrofitted column at 1.5 m stand-off

Results	TNT 1	TNT 2
Displacement (mm)	451.82	428.15
Equivalent plastic strain	0.4581	0.43798

Table 4.2 Retrofitted column at 1.5 m stand-off distance

Results	TNT 1	TNT 2
Displacement (mm)	361.81	316.63
Equivalent plastic strain	0.22797	0.20842

4.2 Results and Discussion of Dynamic Explicit Analysis of the Different Textile Materials

From this blast analysis, we can say that boron textile fiber is better when campared to others textile fiber.Displacement should be minimum for a good textile fiber.Blast effect can be reduce by using these textile material.

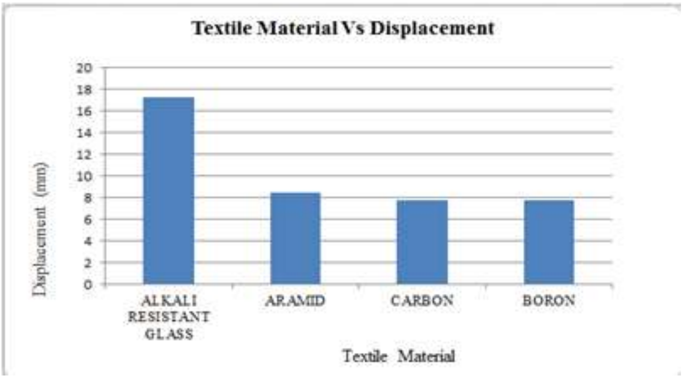


Figure 4.1 Textile Material Vs Displacement graph

4.3 Results and Discussion of Effect of Blast Load on Un-Retrofitted and Retrofitted Column

The maximum displacement in the un-retrofitted and retrofitted column under 1.5 m, 3 m, 4.5 m stand-off distance were studied. The retrofitting of column reduces the displacement considerably. Pressure of TNT in BTRC is higher then un-retrofitted column .Equivalent plastic strain of un-retrofitted column is greater then retrofitted column. The stand-off distance plays a very important role in mitigating the adverse effects of a blast. Figure 4.2 to 4.7 shows the Displacement, Pressure of TNT and Equivalent plastic strain of un-retrofitted column and retrofitted column at 4.5 m stand-off distance.

Table 4.4 Max Displacement at 1000 kg charge weight

Stand-off distance	1.5 m	3 m	4.5 m
Max Displacement of Un-Retrofitted Column (mm)	451.82	46.499	11.619
Max Displacement of CTRC Retrofitted Column (mm)	385.92	34.258	7.7804
Max Displacement of BTRC Retrofitted Column (mm)	369.81	33.142	7.7563

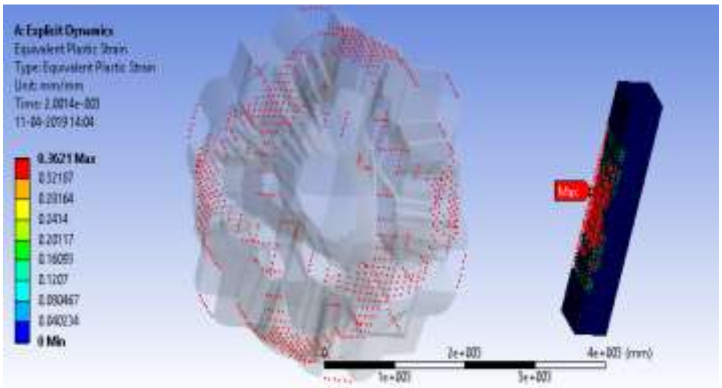


Figure 4.6 Equivalent plastic strain of un-retrofitted column

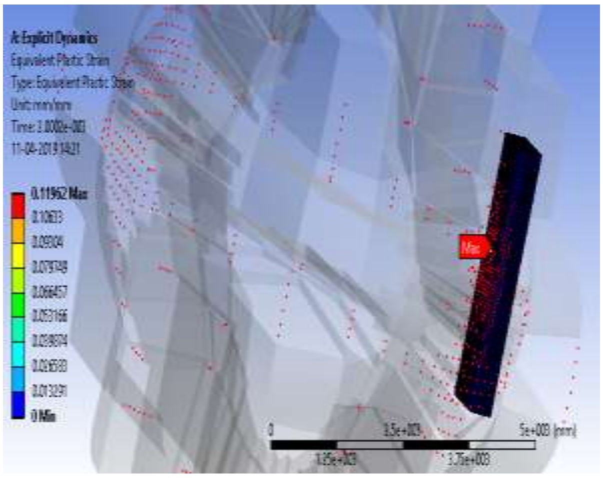


Figure 4.7 Equivalent plastic strain of BTRC

Table 4.5 Pressure at 1000 kg charge weight

Stand-off distance	1.5 m	3 m	4.5 m
Pressure of Un-Retrofitted Column (MPa)	30.38	4.742	1.9601
Pressure of CTRC Retrofitted Column (MPa)	34.741	8.7721	2.0182
Pressure of BTRC Retrofitted Column (MPa)	39.284	12.217	2.0213

Table 4.6 Equivalent plastic strain at 1000 kg charge weight

Stand-off distance	1.5 m	3 m	4.5 m
Equivalent plastic strain of Un-Retrofitted Column	0.4581	0.37208	0.3621
Equivalent plastic strain of CTRC Retrofitted Column	0.2812	0.21275	0.13549
Equivalent plastic strain of BTRC Retrofitted Column	0.22797	0.11962	0.11122

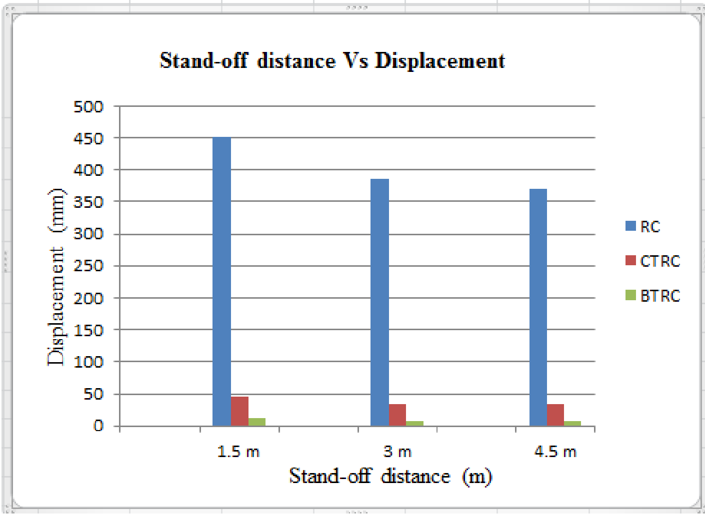


Figure 4.8 Stand-off distance Vs. Displacement graph

4.4 Results and Discussion of Effect of Blast Load on Circular Retrofitted Column and Square Retrofitted Column

Model	Displacement (mm)
Square Un-Retrofitted Column	451.82
Circular Un-Retrofitted Column	72.68
Square Retrofitted Column	369.81
Circular Retrofitted Column	57.143

Effect of blast load on square retrofitted column and equivalent circular retrofitted column were studied. When compared with square retrofitted column the displacement of circular retrofitted column is lesser.

5. Conclusions

Textile reinforcement structures produced from fibers represent an excellent alternative for existing reinforcement materials made from steel. It is found that textile reinforced concrete has better performance compared to conventional concrete. Blast analysis was carried out to evaluate the structural response under blast load.

- Two sets of TNT was analysed and can concluded that TNT 1 is more effective.

- Dynamic explicit analysis of the different TRC was carried out and BTRC is taken as the best model.
- Effect of Blast Load on Un-Retrofitted and Retrofitted Column were analysed.
- Results indicate that TRC strengthening could be an effective solution to limit the damage caused by moderate explosions.
- The result indicates that maximum deflection decreased with the increase in the stand-off distance.
- The retrofitting of column reduces the displacement considerably.
- Pressure of TNT in BTRC is higher compared to un-retrofitted column.
- Equivalent plastic strain of un-retrofitted column is greater than retrofitted column.
- Compared with square retrofitted column the displacement of circular retrofitted column is lesser.

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