Effect of Grade of Steel & Grade of Concrete in RCC Pier Viaduct Subjected to Air Blast

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Abstract— The rise within the world population day by day demands the same increase in infrastructure. Viaducts contribute to a serious portion of the infrastructure. Majority of those viaducts rests on concrete piers. Within the recent years, the terrorist activities within the nation has up to the very best. The rise within the range of terrorist attacks particularly within the previous couple of years has shown that the impact of blast hundreds on buildings may be a serious matter that ought to be taken into thought within the style method. Accidental or intentional blasts will harm the pier structures leading to loss of life and property. The journal is concerning the results of the grade of steel and concrete in these concrete piers in resisting the deformation caused by blast hundreds and also the stresses developed throughout identical. Resisting the deformation caused by blast hundreds and also the stresses developed throughout identical.

Key words: Blast, Explosion, Blast Waves, Blast loading, Concrete Piers, Viaduct, Blast Loading

I. Introduction

Due to all utterly completely different accidental or intentional events, the behaviour of structural parts subjected to blast loading has been the topic of goodish endeavor in recent years. Common place structures aren't titled to resist blast lots and so the magnitudes of favor lots unit of measure considerably below those created by most explosions. Sometimes commonplace structures unit of measurement liable to hurt from explosions. With this in mind, developers, architects and engineers increasingly unit of measurement seeking solutions for potential blast things, to safeguard building occupants and thus the structures.

II. Concepts of Blast

A. Blast Phenomenon

An explosion could be a speedy increase in volume associate degreed unharness of energy in an extreme manner, sometimes attended with the generation of high temperatures and therefore unharness of gases. Supersonic explosions created by high explosives area unit referred to as detonations and travel as supersonic waves. Subsonic explosions area unit created by low explosives through a slower burning method referred to as combustion. Once caused by an unreal device like associate degree exploding rocket or pyrotechnic, the perceptible element of associate degree explosion is mentioned as its report.

B. Sources

Expansion of the undulation causes air particles to maneuver outward throughout the positive part and inward throughout the negative part. The flow of air particles creates a pressure analogous to that caused by wind. The pressure made by this flow is mentioned because the dynamic pressure. This pressure is lower in magnitude than the shock or pressure wave and imparts a drag load just like wind masses on objects in its path.

Blasts involving chemical reactions are often classified by their reaction rates into two primary groups: combustion and detonations. A combustion is Associate in nursing oxidization reaction that propagates at a rate but the speed of sound within the unreacted material. The corresponding undulation is usually termed a pressure wave and contains a finite rise time, as illustrated in Fig.1. a quick combustion will produce a lot of abrupt rise in pressure. Against this, during a detonation, the reaction front propagates supersonically, sometimes over and over quicker than the speed of sound. This undulation is termed a blast wave and has a right away rise in pressure, as seen in Fig.2.Since pressure is closely related to reaction rate, detonation pressures are usually many times higher than deflagration pressures.

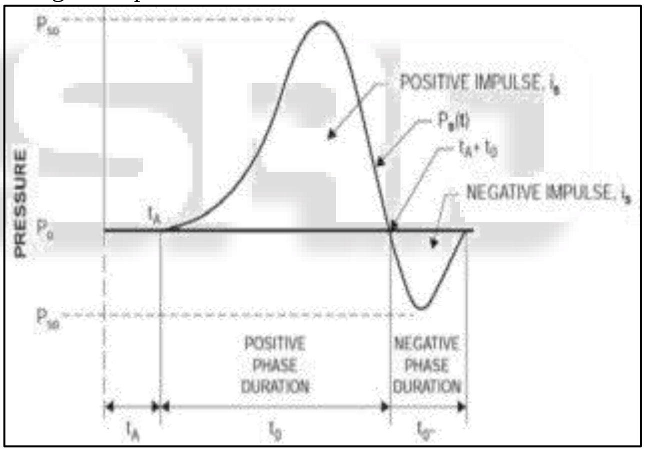


Fig. 1: Pressure Wave from Deflagration

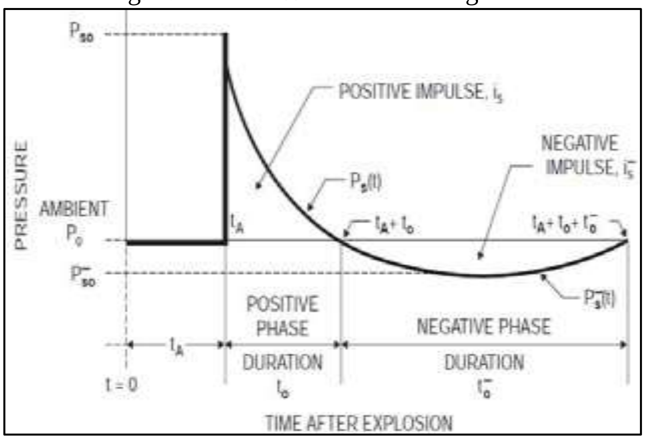


Fig. 2: Shock Wave from Detonation

C. Blast Wave Characteristics

In case of nuclear blast, the following undulation produces really high blast pressure and large impulse loading, that winds up in destruction of structures settled at even associate outsized distance from the provision. Blast gas pressure is expressed relative to shut condition (P0) rather than completely the pressure. Blast-induced pressure wave profile created from the proper detonation, in conjunction with the assorted loadings in relation with amplitude and frequency that govern the design of any structural half.

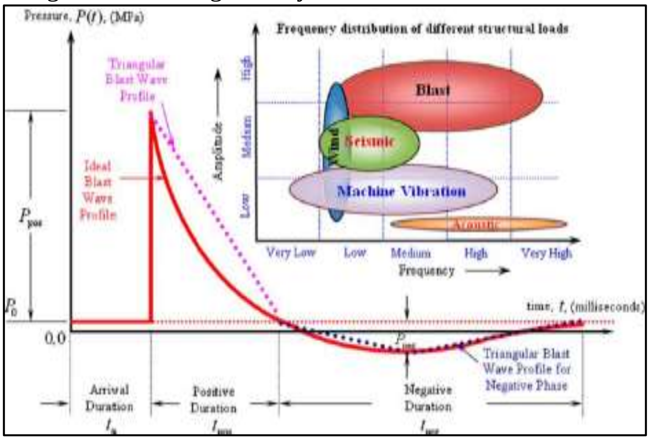


Fig. 3: Blast Wave & Amplitude-Frequency Relations of Structural Loadings

An ideal undulation illustration and its characteristics area unit an operate of the gap of a structure to the centre of the charge, R, and time, t. the peak pressure is known as peak positive gas pressure, P_{pos}. A negative half follows, throughout that the pressure is beneath shut pressure, known as stressed, P_{neg}. The lengths of peak positive gas pressure and stressed space known as positive (t_{pos}) and negative (t_{neg}) period, severally. However, for simplicity inside the analysis, a triangular blast load profile is typically applied, neglecting the negative half. For relatively agent components that space versatile, however, the negative half need to even be modelled.

D. Blast Load Calculation using Brode's Theory

The calculation of blast load may be a tedious method. During this work, solely blasts generated by spherical charges is taken into account. Spherical charges imply that the energy generated throughout the explosion propagates altogether directions. This happens once the explosions occur on top of the bottom surface. Solely unconfined explosions happening on top of the bottom surface is taken into account. The blast pressures generated attributable to these charges square measure calculated exploitation Brode's theory. In line with Brode's theory, the height atmospheric pressure for spherical blast rely upon the magnitude of the explosion.

Equations square measure valid where the peak atmospheric pressure is over 10 bars (=1MPa) (near field explosions) and for pressure values between zero.1 bar and one0 bars (0.01MPa-1MPa) (medium and far field explosions). The scaled distance is measured in m/kg1/3 and therefore the pressure Pso in bars,

$$P_{SO} = \frac{6.7}{Z^3} + 1, \text{for } P_{SO} > 10 \text{ bars} \qquad (2.1)$$

$$P_{SO} = \frac{.975}{Z} + \frac{1.455}{Z^2} + \frac{5.85}{Z^3} - 0.019, \text{for} 0.1 < P_{SO} 10 \text{ bars} \qquad (2.2)$$

III. ANALYSIS

The analysis is done in two methods. First one, by fixing the charge weight used for creating the explosion and the second one, by varying the standoff distance of the explosion. For this purpose, the charge weight is fixed as 250 kg of TNT. 250kg TNT is the maximum amounts of TNT that can be transported using a small car. The standoff distance is varied between 1 m to 3 m to study the effects of standoff distance to the deformations and stresses generated in the structure.

In the second method, the standoff distance is kept fixed and the charge weight causing the explosion is varied. This helps in analyzing the effects of charge weight on the stresses and deformations generated. For this purpose, the standoff distance is adopted as 1 m. The value of 1 m is adopted because two lane roads are running on either side of the metro. The charge weight causing the explosion is varied between 25 kg to 100 kg of TNT.

The blast loads acting on the structure was calculated and all the cases are modeled in ANSYS and solved by the explicit dynamic solver using Autodyn. Loads are applied on the curved surface area of the circular piers having a diameter of 1.6 m and a height of 5.5 m exposed to the blast. Support conditions are assigned. The bottom of the pier has a fixed support condition while the top is free. M 40 and M 50 grades of concrete and Fe415 and Fe500 steel are considered in this work. The behavior between the contact region of steel and concrete is also specified. Earth gravity was also modelled.

The percentage reinforcement of 2.5% has been considered in the analysis. This range of percentage reinforcements was adopted for the analysis since 0.8% is the minimum and 6% is the maximum theoretical values of the percentage of steel to be provided in a column or a pier according to the Indian standards. The diameter of main bars is taken as 32 mm. Thus, while arranging the bars in the pier and considering the clauses regarding the spacing of the reinforcement in a pier as per the Indian standards, upto 2.5% reinforcement satisfies the clauses. According to the Indian standards, the spacing between the bars should be greater than the diameter of the largest diameter bar used. Above 2.5% of reinforcement this is not satisfied. Thus, for analysis purpose, percentage reinforcements 2.5% is considered. A clear cover of 40 mm is also provided to the piers according to the Indian standard codes. The analysis is done for 100mm spacing ties. Circular ties of Fe 415 and Fe 500 bar of 8 mm diameter are provided as the stirrup. The maximum load in the pier is considered.

Meshing was done automatically by the software. The longitudinal bars as well as the stirrups were assigned line elements and the concrete was assigned solid elements. In line elements only axial forces are considered. This is done to minimize the number of elements and to reduce the computation time. While considering the analysis results, tensile stresses are considered to be critical for concrete, as the concrete is weak in tension. The value of tensile strength of concrete is very less compared to its compressive strength. The failure of concrete due to crushing was not obtained in any of the analysis cases. Thus, the stress values taken represents the tensile stresses developed in the concrete. The stress and deformation values are obtained from ANSYS.

IV. RESULTS

Analysis is conducted for percentages of reinforcement 2.5% for this purpose. This is often in dire straits concretes of grade M40 and M50 and steel grade Fe415 and Fe500. The analysis is additionally done by varied the situation of blast, charge weight, spacing of the ties. All cases are analysed and varies graphs are generated for the comparison and typical graphs are given below.

A. Effect of Grade of Concrete

Analysis is conducted for M40 and M50 grade concrete. The analysis is conducted for percentage reinforcement for 2.5% and for Fe415 grade of steel and ties with 100mm centre to centre spacing is provided. The analysis is done to find out the effect of grade of concrete in variation in deformation and variation in stress under maximum load case.

For finding the variation in deformation in the first set of analysis charge weight kept constant as 250 kg of TNT and standoff distance varied from 1m to 3m. Typical graphs generated for the comparison is given in sections below.

Standoff Distance (m)	Maximum Deformation (mm)	
	M40	M50
1	2694.7	2697.2
1.5	796.48	799.53
2	347.68	348.1
2.5	185.31	185.75
3	113.79	111.83

Table 1: Standoff Distance Vs Deformation

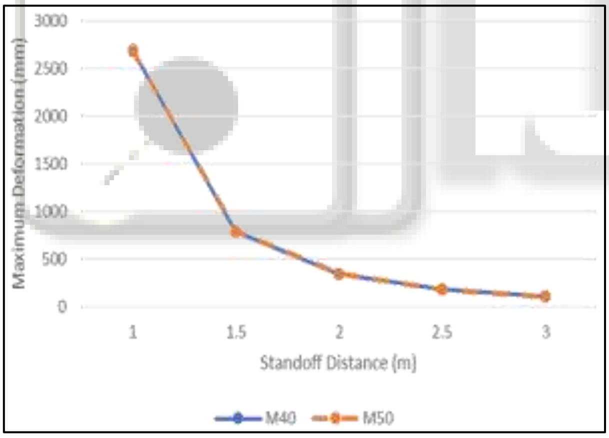


Fig. 4: Standoff Distance Vs Deformation

In the second set analysis charge weight varied from 25 to 100 kg of TNT and location of the blast fixed as 1m. All possible combinations are considered and analysed. Typical graphs generated for the comparison is given in sections below.

Charge Weight (kg)	Maximum Deformation (mm)	
	M40	M50
25	281.55	279.98
50	544.44	546.91
75	806.43	808.88
100	1064.5	1071.6

Table 2: Charge Weight Vs Deformation

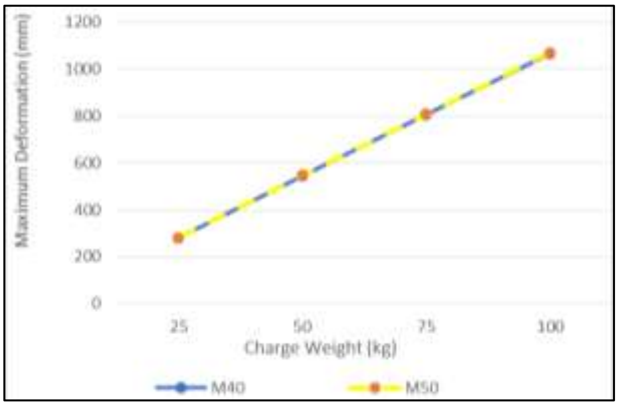


Fig. 5: Charge Weight vs Deformation

Considering the deformation result, it are often seen that deformation is nearly similar for M40 and M50 grade of concrete altogether cases wherever the charge weight is mounted as 250 kilogram of TNT and pier with 2.5% longitudinal reinforcement of grade of steel Fe415 and centre to centre spacing between ties at 100mm.

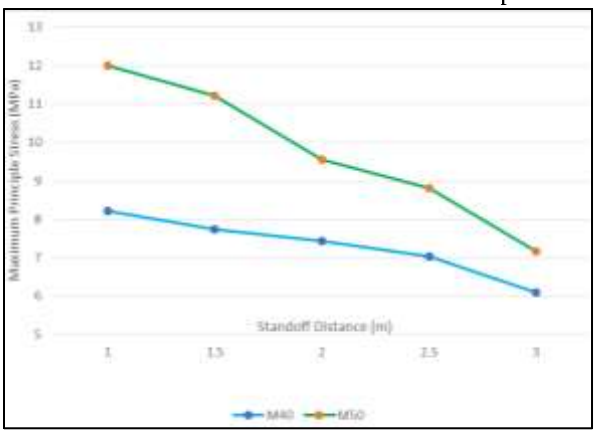
For a charge weight of 250 kilogram, at a standoff distance of 1 m, the deflections made square measure terribly high. When the standoff distance increases the deformation decreases to a specific price. This deformation is likely generated by the propagating air blast waves whose energy is dissipated on the trail.

In the cases wherever the standoff distance is unbroken mounted at 1 m, and ranging the charge weight used between 25kg and 100 kg of TNT, the deformations will increase with increase responsible weight.

For finding the variation in stress due to the effect of concrete same criteria considered as in the case of deformation and maximum principle stress obtained for M40 and M50 concrete is compared fixing the grade od steel and spacing of ties as same as above.

Standoff Distance (m)	Maximum Principle Stress (MPa)	
	M40	M50
1	8.2133	12.012
1.5	7.7298	11.225
2	7.4342	9.5593
2.5	7.0381	8.8019
3	6.0918	7.1657

Table 3: Standoff Distance Vs Maximum Principle Stress



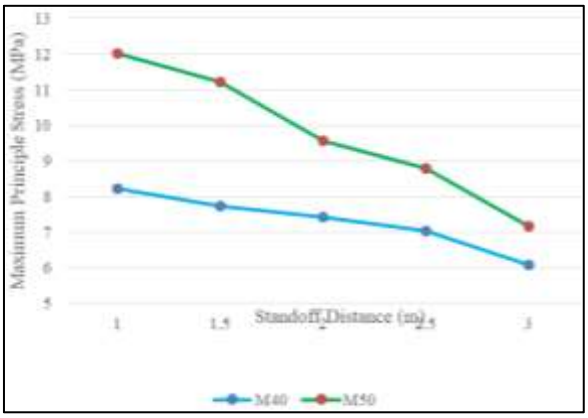


Fig. 6. Standoff distance vs Maximum Principle Stress

Charge Weight (kg)	Maximum Principle Stress (MPa)	
	M40	M50
25	7.6039	8.9332
50	7.9626	10.663
75	8.608	11.263
100	9.0002	11.813

Table 4: Charge Weight Vs Maximum Principle Stress

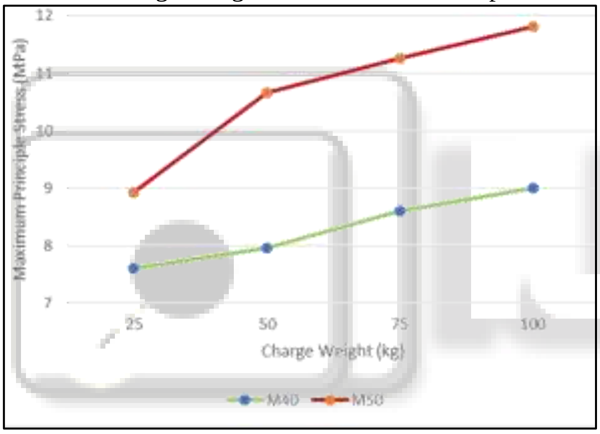


Fig. 7: Charge Weight vs Maximum Principle Stress

Considering the stresses obtained from the analysis, in each the cases with fixed cost weight and glued standoff distance the utmost principle stress is a smaller amount for M40 concrete compared to M50 concrete. It's found that the stresses decrease because the standoff distance will increase, presumably because of the energy dissipation on the trail.

Within the cases wherever the standoff distance is unbroken constant, the stress increases with increase in charge weight. For M 40 grade concrete, the utmost tensile stress the concrete will resist while not developing cracks is 4.42 MPa, and for M 50 grade concrete, this price is 4.94 MPa as per Indian standards. Thus, altogether the cases wherever the utmost principle stress is larger than the higher than values, tensile cracks are developed over the surface. The intensity of cracking will increase with the rise within the most principle stress values.

B. Effect of Grade of Steel

Analysis is conducted for Fe415 and Fe500 grade steel. The analysis is conducted for percentage reinforcement for 2.5% and fixing M50 grade of concrete with ties spacing 100 mm. The analysis is done to find out the effect of grade of steel in variation in deformation and variation in stress.

For finding the variation in deformation and variation in stress, in the first set of analysis charge weight kept constant as 250 kg of TNT and standoff distance varied from 1m to 3m and in the second set analysis charge weight kept constant and location of the blast fixed as 1m and deformation and stresses obtained for Fe415 and Fe500 is compared. All possible combinations are considered and analysed. Typical graphs generated for the comparison is given in sections below.

Standoff Distance (m)	Maximum Deformation (mm)	
	Fe415	Fe500
1	2697.2	2697.2
1.5	799.53	799.53
2	348.1	348.1
2.5	185.75	185.75
3	111.83	111.83

Table 5: Standoff Distance Vs Deformation

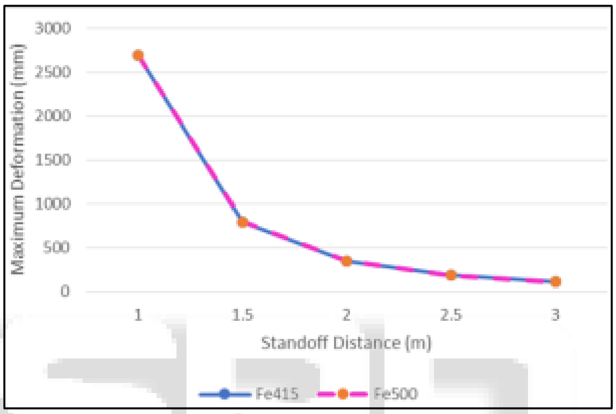


Fig. 8: Standoff distance vs Deformation

For finding the variation in stress due to the effect of grade of steel same criteria considered as in the case of deformation and maximum principle stress obtained for Fe415 and Fe500 stee is compared fixing the grade of concrete and spacing of ties as same as above.

Charge Weight (kg)	Maximum Deformation (mm)	
	Fe415	Fe500
25	279.98	279.98
50	546.91	546.91
75	808.88	808.88
100	1071.6	1071.6

Table 6: Charge Weight Vs Maximum Principle Stress

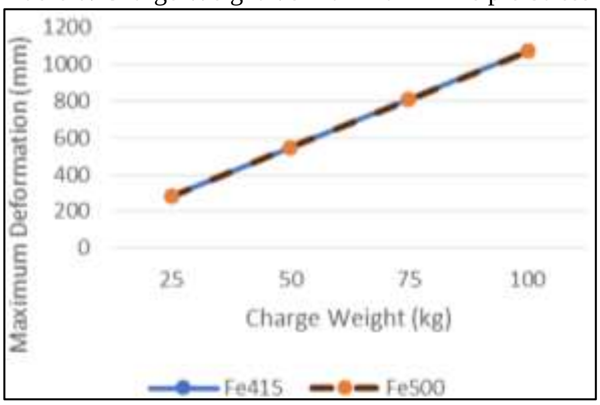


Fig. 9: Charge Weight vs Maximum Deformation

Standoff Distance (m)	Maximum Principle Stress (MPa)	
	Fe415	Fe500
1	12.012	12.012
1.5	11.225	11.225
2	9.5593	9.5593
2.5	8.8019	8.8019
3	7.1657	7.1657

Table 7: Standoff Distance Vs Maximum Principle Stress

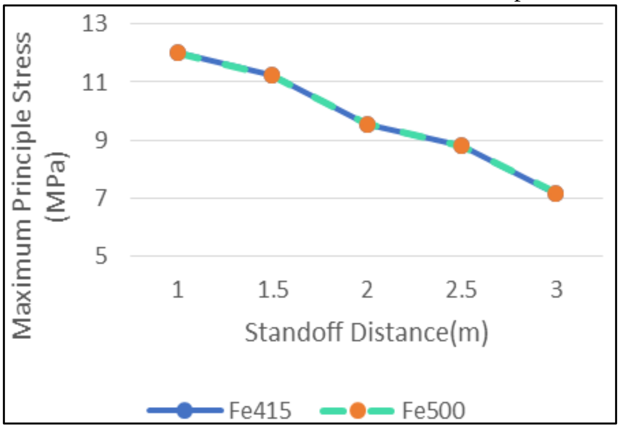


Fig. 10. Standoff distance vs Maximum Principle Stress

Charge Weight (kg)	Maximum Principle Stress (MPa)	
	Fe415	Fe500
25	8.9332	8.9332
50	10.663	10.663
75	11.263	11.263
100	11.813	11.813

Table 8: Charge Weight Vs Maximum Principle Stress

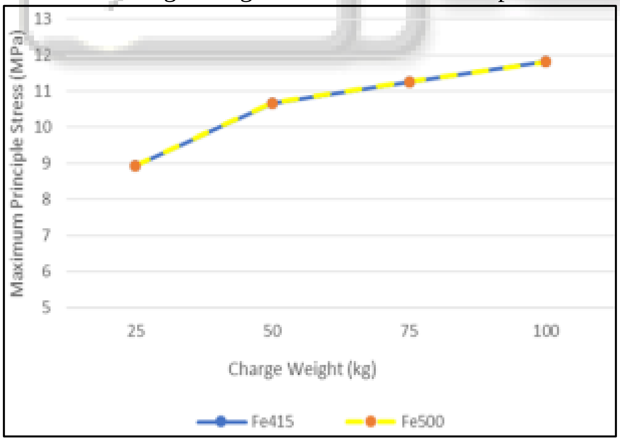


Fig. 11: Charge Weight vs Maximum Principle Stress

Considering the deformation and stresses there's no impact for grade of steel all told cases of research. within the case of fixed cost weight most deformation and principle stress decreases with increase in standoff distance for each Fe415 and Fe500 steel for M50 concrete with a pair of 2.5% longitudinal reinforcements at 100mm spacing of ties. In variable charge weight and stuck standoff distance maximum deformation and principle stress increases with increase in charge weight.

V. CONCLUSIONS

The problem of a reinforced concrete pier subjected to blast loading is considered as the core of this paper. Various cases possible is considered by varying some of the parameters associated with the problem. These various cases were modelled and analyzed. The analysis of the different cases was done using a finite element software package, ANSYS Workbench 17.0 and results were obtained. The results give the deformations and stresses developed for the different cases. Graphs are plotted, compared and the general trends and abnormalities in the graphs are identified, and tried to explain the possible causes for the results in this paper.

Grade of concrete is not effective in deformation for fixed charge weight and varying standoff distance, but when charge weight increases for a standoff distance M50 gives more stress compared to M40 concrete. M50 concrete shows more stress than M40 for fixed charge weight and varying standoff distance and vice versa. Grade of steel has no effect in deformation and stress in any cases analysed.

VI. REFERENCES

[1] Alexander M. Remennikov, "A review of methods for predicting bomb blast effects on buildings", Journal of Battlefield Technology, Vol. 6 (3), July 2003, pp. 155-16
[2] B.M. Luccioni, R.D. Ambrosini and R.F. Danesi, "Analysis of building collapse under blast loads", Engineering Structures, Vol. 26, 2004, pp. 63-71
[3] T. Ngo, P. Mendis, A. Gupta and J. Ramsay, "Blast Loading and Blast Effects on structure", Electronic Journal of Structural Engineering, Special Issue: Loading on Structures, 2007, pp. 76-91
[4] Zeynep Koccaz, Fatih Sutcu and Necdet Torunbalci, "Architectural and Structural Design for Blast Resistant Buildings", The 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China, 8 pages
[5] HANDBOOK FOR BLAST-RESISTANT DESIGN OF BUILDINGS edited by Donald O Dusenberry,
[6] Hrvoje Draganić, Vladimir Sigmund, "Blast Loading on Structures", Tehnički vjesnik, Vol. 19 (3), 2012, pp. 643-652
[7] Parag Mahajan, Pallavi Pasnur, "Prediction of Blast Loading and Its Impact on Buildings", International Journal of Latest Technology in Engineering, Management and Applied Science, Vol. 3(10), October 2014, pp. 88-94
[8] Mohammed Alias Yusof, Rafika Norhidayu Rosdi, Norazman M Nor, Ariffin Ismail, Muhammad A Yahya, Ng Choy Peng, "Simulation of RC Blast Wall Subjected to Air Blast Loading", Journal of Asian Scientific Research, Vol. 4 (9), 2014, pp. 522-533
[9] Aditya Kumar Singh, Md. Asif Akbari and P. Saha, "Behaviour of Reinforced Concrete Beams under Different Kinds of Blast Loading", International Journal of Civil Engineering Research, 2014, Vol. 5 (1), pp. 13-20
[10] Russell P. Burrell, Hassan Aoude, and Murat Saatcioglu, "Response of SFRC Columns under Blast Loads",

Journal of Structural Engineering, Vol. 15, October 6 2014, pp. 1-15
[11] Yazan Qasrawi, Pat J. Heffernan and Amir Fam, "Numerical Modelling of Concrete-Filled FRP Tube's Dynamic Behaviour under Blast and Impact Loading", Journal of Structural Engineering, Vol. 106 (13), July 20, 2015, 13 pages