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Research Article

BLAST LOADING ANALYSIS OF R.C.C. BRIDGE STRUCTURE

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ABSTRACT

Most of the literatures are limited to response of simple structures. These studies provide a good fundamental knowledge regarding blast load effects in actual blast explosions. The interaction between blast loads and structures, as well as the interaction among structural members may well affect the structural response and damage. Therefore it is necessary to analyze the structures under blast load effects. Among all the civilian structures bridges are considered to be most vulnerable to such threats and hence detailed investigation in the dynamic response of these structures is essential. This analysis requires accurate generation and application of blast loads and good understanding of the behavior of components of the bridges during high strain rate encountered during blast loads. In this study the response of the bridge structure is studied when subjected to the blast loads. Finite element modeling tool ETABS is used for the analysis of structure. A simply supported three span continuous bridge is to be taken for analysis purpose. The design and analysis of such structure requires a detailed understanding when subjected to blast phenomenon. The dynamic response on the various component parts of the bridge structure is also studied. This will give the complete understanding of blast effects on bridge structure.

INTRODUCTION

Military assaults, terrorist attacks and accidental explosion may cause serious damage to buildings and other infrastructures, as a result of terrorist threats and attacks, engineers and transportation office workers are becoming more active in physically protecting bridges from potential blast attacks. Blast incidents can also happen under accidental or intentional circumstances, which are both unpredictable since human behavior is involved. These blast events could cause critical injuries along with heavy causalities in addition to disastrous structural failure giving rise to detrimental economic and social impacts, both domestically as well as internationally, unintentional explosions are highly undesirable. In process industries, steps are frequently taken to minimize the causes and consequences of accidental explosions. When explosion occur attention shifts from prevention to attribution from the perspective of both cause and effect. Taking these concerns into serious consideration structural engineers have paid particular attention in damage effects analyses and assessments of bridges under blast loading. Blast engineering regarding civil infrastructure has only received rapidly evolving interest in recent years. More researches are conducted to advance the theoretical and experimental investigation technology, as well as to enhance the level of understanding of the blast implications on multistory buildings, bridges, industrial structures and public facilities. Blast solution which consists of retrofitting options, for existing provisions, design guidelines for future services and deterrent measures which aim to hinder blast occurrence and lower blast severity, are under the constant development, in recent years, many efforts are made for the development of reliable methods and algorithms for a more realistic analysis of structures and structural components subjected to blast loading. Furthermore with the rapid development of computer hardware over the last decades, it has become possible to make detailed analysis of explosive events in personal computers. Moreover, new developments in integrated computer hydro codes complete the tools necessary to carry out the numerical analysis successfully. New development in integrated computer hydro codes or computer makes the numerical analysis more convenient. Comparatively limited literature is available concerning to the blast study. In 2006 A.K.M. Anwarul Islam *et.al*. [1] investigated the common types of highway bridges. A 2 span 2 lane type III AASHTO girder bridges was analyzed for blast loading using STAAD PRO. It was found that type III AASHTO girder bridge is not capable to resist specified blast loads. Nitesh Moon [6] carried out prediction of blast loading and its impacts on buildings. This study provides a comprehensive overview of the effects of explosion on structures.

Aim and scope

This paper focuses on viewing the structural behavior of RCC Bridge due to blast for the charge weights at different stand-off

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distances. All the possible displacements and bending moments of the framed structure were computed by using and finite element package ETABS software (Extended 3D analysis of Building Systems). For the analysis purpose different vehicle blast conditions are used. The performance of deck slab and girder when subjected to the blast incidents are analyzed.

Basic Steps for the Analysis

Modeling of Bridge

For the analysis of bridge a 2 span 2 lane bridge is taken. Following are the parameters of the bridge that is modeled.

1. Total Length of the bridge = 72m.
2. Total width of bridge = 8.95m including 2 lanes with clear carriageway of 8m, and side barriers of 475mm on both sides.
3. Clear carriageway = 8m
4. No. of piers = 2nos.
5. No. of abutments = 2nos.
6. Concrete diaphragm or caps are used over the piers to enhance the continuity of the bridge.
7. Elastomeric bearings are provided below the girder.
8. Thickness of deck slab= 250mm.
9. Reduced Level of bridge= 97.165m w.r.t MSL.
10. The bridge lies in Seismic Zone II and assumed for moderate exposure.
11. IRC Class A loading or single lane of IRC 70R loading whichever produces worst effects is taken.
12. Size of Girder = b X D = 400 x 1000mm.
13. Grade of concrete used is M-40.
14. Size of Column = 1.2m diameter having a reinforcement cover of 70mm.
15. Size of Beam = b x D = 500 x 1000mm below girder and for deck with reinforcement cover of 30mm.

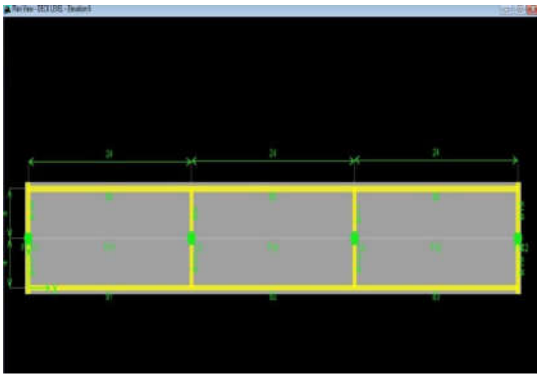

Figure 1 Plan of Bridge.

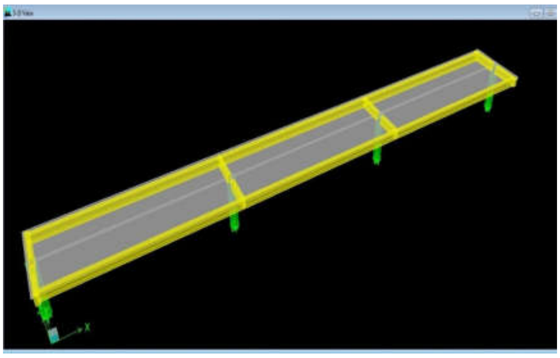

Figure 2 3D view of modeled bridge.

Calculation of Blast Pressures

The method of determining equivalent blast load due to an explosion is a complex phenomenon. The blast pressure diminishes with distance from the point of explosion. In TM 5-1300 manual, Structures to resist the Effects of Accidental Explosions, developed by the US Department of Defense, an empirical formula is given to find the scaled distance. The amount of blast pressure generated due to an explosion is inversely proportional to the scaled distance, which is presented in a chart in the TM 5-1300 manual. The formula is given as,

$$Z = R / W^{1/3} \tag{1}$$

Where, Z is the scaled range, R is the radial distance between the explosion center and the target and W is the explosive weight (normally expressed as an equivalent TNT weight)

Further these pressures are converted into equivalent static loads. For the explosion near the structure it is reasonable to assume that a regular vehicle carrying explosive cannot go closer than 1.22m, and hence the minimum standoff distance is taken herein. The maximum range in this model analysis is 8m, beyond which the impact of the probable explosion is found negligible. When the vehicle is travelling from deck it is assumed that truck bed is at 2m height considering the barrier effect and in case of car it is taken 1m above the deck. To obtain the loads for the modeled bridge, 226.8kg of TNT with minimum and maximum range of 1.22m and 8m respectively, with an increment of 800mm intervals. Figure 3 and table 1 represents the pressure computation at the intervals.

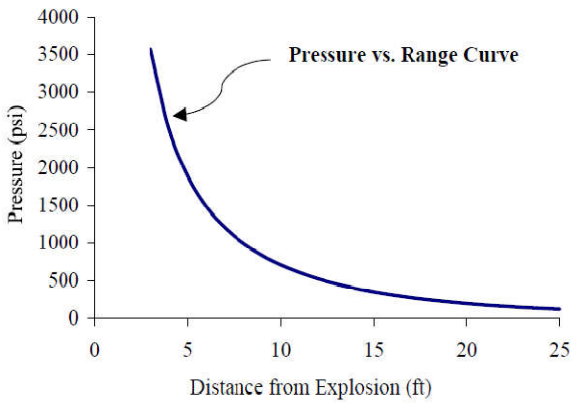

Figure 3 Variation of pressure with distance.

Load Combinations and Location of Calculated Blast Pressures

The amount of TNT explosive used herein is 226.8kg. This explosive loads were considered as an extreme event for which load factor used is 1.00. In addition to these blast loads, self weight of the structure was also considered with a factor of 1.5. The dead and live loads for an extreme event are presented in equation given below (2). The vehicle live load is not considered in the analysis for simplicity and because of its effect is negligible compared to that of the blast load.

$$W_T = 1.5\ DL + 1.5\ LL + 1.00\ EV \tag{2}$$

Where, W_T = Total load, DL = Dead load, LL= Live load, and EV = Extreme event load.

Table 1 Equivalent Static Pressure for 226.8 kg of TNT explosive.

Range (m)	Pressure (MPa)	Scaled time *to* (milli-sec)
0.91	24.66	0.65
1.22	17.31	0.66
1.52	12.99	0.66
1.83	10.20	0.67
2.13	8.26	0.68
2.44	6.83	0.70
2.74	5.74	0.73
3.05	4.88	0.76
3.35	4.18	0.80
3.66	3.61	0.84
3.96	3.14	0.89
4.27	2.75	0.95
4.57	2.42	1.01
4.88	2.14	1.08
5.18	1.90	1.15
5.49	1.69	1.23
5.79	1.51	1.32
6.10	1.36	1.41
6.40	1.22	1.51
6.71	1.11	1.61
7.01	1.00	1.72
7.32	0.91	1.84
7.63	0.83	1.96
7.94	0.76	2.09

Table 2 Load Cases.

Load Case	Location	Member Affected	TNT equivalent explosive	Blast Set-backs
Case 1	Over the bridge at mid-span.	Deck Slab, Girder.	226.8 kg	1 m above the deck.
Case 2	Over the bridge above pier	Deck Slab, Girder, Pier.	226.8 kg	1 m above the deck.

RESULTS

From the loading cases we have decided, following will be the obtained results which are seen one by one.

Case 1: The blast pressures are calculated differently considering incremental distance of 800mm. Following are the blast pressures and resulted figures due to application of blast at 1m above the deck. Due to the spherical nature of this wave-front some of the blast pressure intensities travel in upward direction too, and hence from the available literatures the pressure intensities acting on the structure, reduction factor of 50% can be applied.

Table 3 Pressure Intensities for case 1

Standoff Distance (m)	Pressure Intensities (Mpa)
4	22.52
3.2	18.016
2.4	13.512
1.6	9.008
0.8	4.501
0.0	1.465

The columns of the bridge will experience axial loads due to application of blast load above the deck slab. And hence due to these loads column will experience an axial thrust in vertical direction. It is also found that the deck slab and the girders subjected to the blast are most vulnerable parts of bridge. Since the load intensities are more heavy, stress strain displacement induced in the deck slab and girder are shown in figure 5. and figure 6.which makes to clearly understand the nature and behavior of the affected members due to application of blast loads. From figure 7.

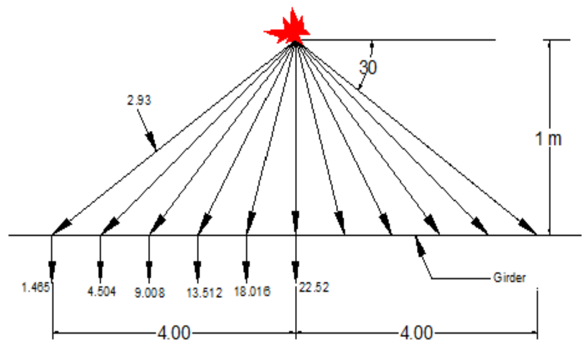

Figure 4 Blast pressure distribution for Case 1.

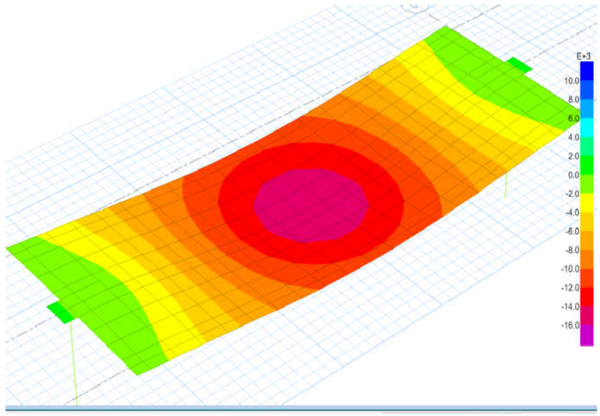

Figure. 5 Displacement Contour of deck slab.

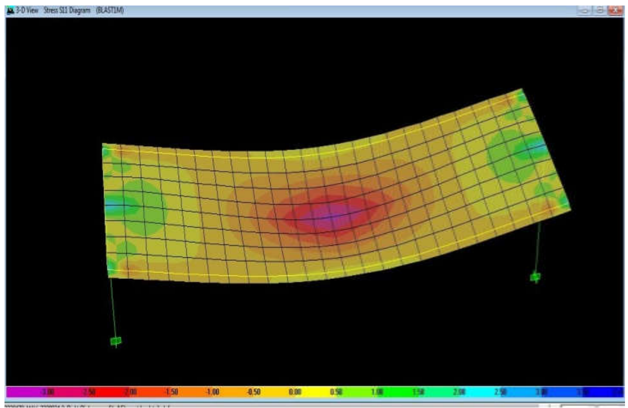

Figure. 6 Stress Contour of deck slab.

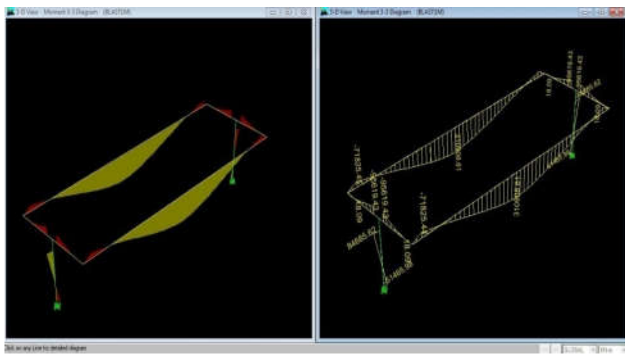

Figure. 7 Bending of deck slab.

It is observed that the girder at the mid-span experiences the maximum tension and fails at such loads. The maximum deformation and the stresses are observed where directly blast load is directly perpendicular to the deck. From these figures there is no scope of such girder when subjected to such types of loads and hence it is evident that the model bridge underwent complete collapse to Case 1 loading requiring complete immediate replacement.

Case 2: The calculated blast pressures are represented in table 4 considering incremental distance of 800mm. the blast location is above the pier at 1m distance. Due to the spherical nature of this wave-front some of the blast pressure intensities travel in upward direction too, and hence from the available literatures the pressure intensities acting on the structure, reduction factor of 50% can be applied.

Table 4 Pressure intensities for case 3

Standoff Distance (m)	Pressure Intensities (Mpa)
4	22.52
3.2	18.016
2.4	13.512
1.6	9.008
0.8	4.501
0.0	1.465

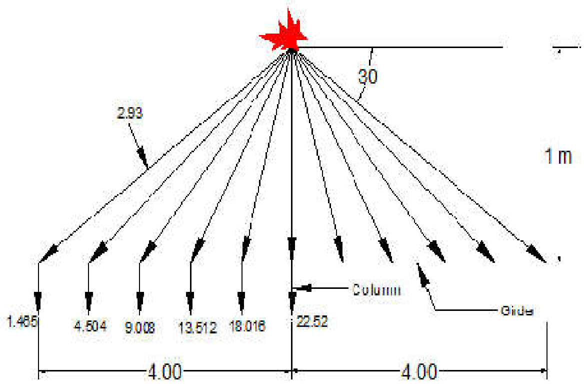

Figure 8 Blast pressure distribution for Case 2.

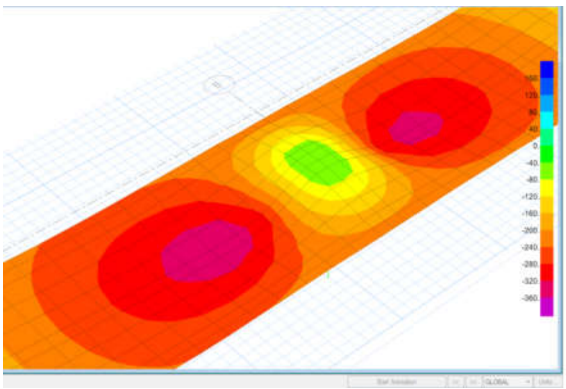

Figure 9 Displacement Contour of deck slab.

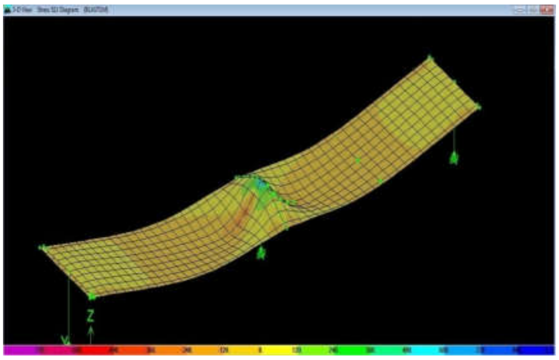

Figure 10 Stress Contour of deck slab.

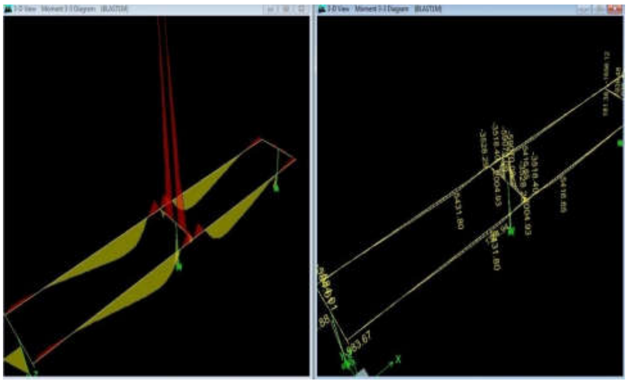

Figure 11 Bending of deck slab.

Under this case it is seen that blast takes place above the pier and deck slab at the mid-span and does not experiences more deflection as compared to first case, while columns are affected in shear which experiences maximum axial thrust. The stress strain displacements are shown in figure 9. and figure 10. which makes to clearly understand the nature and behavior of the affected members due to application of blast loads. The maximum deformation and the stresses are observed where blast load is directly perpendicular to the deck. The bending nature of the beam is shown in figure 11. The negative moments are induced on the span above the column of bridge and hence the displacement pattern is observed to go upward. The girder fails due to lack of shear capacity under this case. The columns failed due to resulting moments and shears or axial forces. From these figures we can say that somewhat vulnerability is reduced when location of blast is changed compared to previous case and also it is evident that the model bridge for Case 2 loading requires complete and immediate repair or replacement.

Stress Comparison of Both Cases

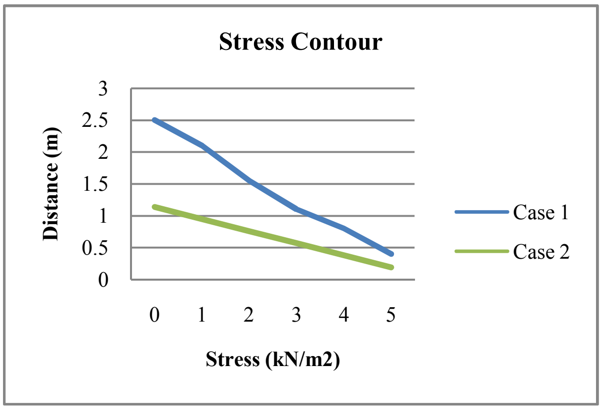

Figure 12 Comparison of stresses of 4 cases.

CONCLUSION

Based on this study, following conclusions can be made.

1. From the obtained results we can say that blast loads are the most vulnerable attacks of very high intense pressures and hence structure undergoes progressive collapse under these loads (refer table 1 and figure 3.)
2. It was found from the analytical study that the RCC girder bridge will fail to probable blast load generated by

an explosion of 226.8kg of TNT when applied over the bridge at mid-span and above the column.

3. In case of the blast occurring on the pier or column, the vulnerability of blast is reduced and hence some parts of the bridge seems to survive.
4. Bridge damage is more when blast occurs at the mid-span. The structure completely fails in this case and hence immediate replacement is needed (refer figure 4.12).
5. Blast loads were determined as a record of pressure-time history with the parameters calculated as per available literatures (refer table 1).
6. Basic aim behind the analysis was to determine the structural behavior of the structural members subjected to blast loads and hence take necessary precautions and changes in structure to sustain it.
7. It illustrates that the characteristic of damage effect of a blast load to the whole bridge is limited to destruction zone near the blast, which corresponds to the general law of explosion.

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