Analysis of RCC Bridge Under Blast Loading Effect Using Different Loading Cases

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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 the most vulnerable to terrorist threat and hence detailed investigation in the dynamic response of these structures is essential. Analysis of structural failure of a bridge caused by an accidental fireworks explosion is becoming important to study. The analysis of the highway bridges under blast loads requires accurate generation and application of blast loads and good understanding of the behavior of components of the bridges during high strain rate loading encountered during blast loads. Blast-related issues have become extremely important for civil infrastructure, and no longer con-fined to petrochemical and military facilities, as proven from the history of this modern era. Blast incidents can 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 casual-ties in addition to disastrous structural failure, there-by giving rise to detrimental economic and social impacts, both domestically as well as internationally. 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.

Keywords: Accidental fireworks explosion, Blast loads, civil infrastructure, Dynamic response, Petrochemical and military facilities.

I.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 casualties in addition to the 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 effect analyses and assessments of bridge under blast loading.

Conventionally bridge structures were not designed for the blast loads. Since the magnitudes of potential explosive load are significantly higher than other design loads, conventional structures are more susceptible to damage from explosions. Since the 2001 terrorist attacks, numerous researches and demonstrations initiatives have been undertaken to find cost effective techniques and efficient retrofit, security and rapid reconstruction techniques for important buildings. The bridges and highways infrastructures face new challenges relating to the security of critical structures against terrorist attacks. In response to these need, the AASHTO Transportation Security Task Force sponsored the preparation of a guide to assist transportation professionals in identifying critical highway structures and to take action to reduce their blast vulnerability. In order to provide guidance to bridge owners and operators, the Federal Highway Administration (FHWA) formed the Blue Ribbon Panel (BRP) on bridge and tunnel security. AASHTO has probability based design methodology for designing bridges for various dynamic loads such as seismic, ship impact, vehicular collision. However it has no specific guidelines for design of bridges for blast loading. NCHRP has sponsored a research project to develop design and detailing guidelines for blast resistant highway bridges that can be adopted in the AASHTO bridge design specification.

II. METHODOLOGY

A. Objective and present study:

The experimental verification using scaled models is generally carried out in developing design guidelines for structures subject to hazards such as earthquakes, wind, etc., this is not practical in case of blast loads because of following three reasons.

It is very difficult to reproduce the same blast wave environment, even in the same test field and using the same amount of explosive charge because of the temperature, humidity and dust condition of the air. Consequently, it is very difficult to carry out systematic experimental study of different parameters affecting behavior of structures subject to blast loads.

It is difficult to ensure reliability of the data measurements, e.g., strain gauge, displacement sensors, etc., during explosion tests because of large deformation and fragmentation of the test structure.

Experimental blast tests are also cost-prohibitive and can only be carried out at select facilities.

Because of reasons described above, analytical tools such as hydro-codes have significantly shown more reliability and accuracy in the simulation of blast load effects on structures. Following are some objectives of dissertation.

To investigate the finite element tools for the simulation of blast load effects on various bridge components of a typical highway bridge.

To investigate the performance of different components during blast events, identify typical mechanism responsible for causing damage or failure of the components of structure.

B. Scope of study:

In order to achieve the objectives given above following tasks can be adopted,

To use the suitable hydro-codes (i.e., FEM modeling software like ETABS) for the simulation of these blast effects on the various components of bridge.

To study the dynamic response of the structure for different cases of blast phenomenon. Thus to investigate the study following are the cases that are to be adopted.

1) Vehicle Bomb Blast 1m height above deck.
2) Vehicle Bomb Blast 2m height above deck.

C. Effect of blast on structure:

The effects of explosions on structures are directly related to stress-wave propagation as well as impact and missile penetration. In all close-in explosions, where shock waves must travel through the surrounding medium to cause damage to a facility a realistic description of the wave-propagation phenomena is needed. The effects of explosion are varied. For explosions close to the targeted object the pressure-driven effects occur quickly, in the order of microseconds to a few milliseconds. The air-blast loads are commonly subdivided into

Loading due to the impinging shock front, its reflections, and the greatly increased hydrostatic pressure behind the front, all commonly denoted as overpressure and The dynamic pressures due to the particle velocity, or mass transfer, of the air. It is customary to characterize the pressure loadings in terms of scaled range, given by

$$Z = R / W^{1/3} \quad (3.1)$$

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).

Units for charge weight and distance should be pounds and feet.

C. Codal provision:

The conventional chemical charge is considered spherical. The shock front at the ground surface from a contact burst is considered almost vertical. The effective yield of the contact burst is almost double of an equal explosion high in the air. This condition is assumed to give most serious effect.

D. Shok Wave:

As a result of explosion, a shock wave is generated in the air which moves outward in all directions from the point of burst with high speed causing time-dependent pressure and suction effects at all points in its way. The shock wave consists of an initial positive pressure phase followed by a negative (suction) phase at any point as shown in Figure.3.1. The shock wave is accompanied by blast wind causing dynamic pressures due to drag effects on any obstruction coming in its way. Due to diffraction of the wave at an obstructing surface reflected pressure is caused instantaneously which clears in a time depending on the extent of obstructing surface.

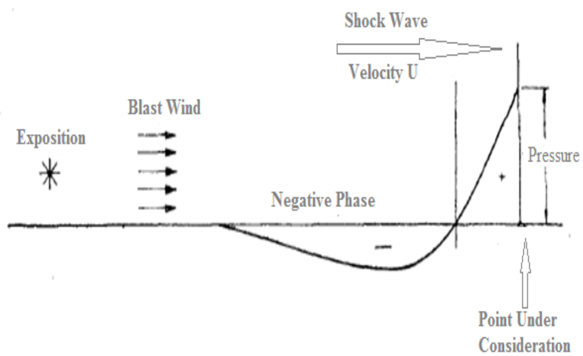

Figure. Shock Wave produced by Blast

E. Basic Parameters of explosion:

Use of TNT (Trinitrotoluene) as reference for determining the scaled distance Z, is universal. The first step in quantifying the explosive wave from a source other than the TNT, is to convert the charge mass into an equivalent mass of TNT. It is performed so that the charge mass of explosive is multiplied by the conversion factor based on the specific energy of different explosives types and their conversion factors to that of the TNT are given in Table.

F. Blast Load Cases:

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 below 3.5. 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.

$$WT = 1.5\ DL + 1.5\ LL + 1.00\ EV$$

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

Following are some of the load cases taken for the analysis purpose.

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	1m above the deck.
Case 2	Over the bridge above pier	Deck Slab, Girder, Pier.	226.8 kg	1 m above the deck.
Case 3	Over the bridge at mid-span.	Deck Slab, Girder.	226.8 kg	2 m above the deck.
Case 4	Over the bridge above pier	Deck Slab, Girder, Pier.	226.8 kg	2 m above the deck.

Table. Various Load Cases

III.RESULT AND DISCUSSION

Considering the above cases now next part we arrives is at the result and discussions. From the loading cases we have decided, following will be the obtained results which are seen one by one.

A. Case 1:

In this case the location of the blast is above the deck at the mid-span at 1m height. The TNT equivalent used here is 226.8 kg. Affected members mainly due to this case are deck slab and girder. The obtained result shows the deformed shapes of the slab, deflection at the nodal intervals, stress resultant, and bending nature. Following are the pressures that are calculated for case 1. As the blast waveform is spherical in nature hence for calculating the pressure for the sake of simplicity the pressure distribution is considered to be symmetric at an interval of 800mm.Due to the spherical nature of this wave-front some of the blast pressure intensities travels 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. Pressure intensities for case 1.

Explosive	*Specific Energy (Qx/ kJ/kg)*	*TNT equivalent (Qx/ QTNT)*
Compound B (60% RDX, 40% T NT)	*5190*	*1.148*
RDX (Ciklonit)	*5360*	*1.185*
HMX	*5680*	*1.256*
Nitroglycerin (liquid)	*6700*	*1.481*
TNT	*4520*	*1.000*
Explosive gelatin (91% nitroglycerin, 7.9% nitrocellulose, 0.9% antracid, 0.2% water)	*4520*	*1.000*
60% nitroglycerin dynamite	*2710*	*0.600*
Semtex	*5660*	*1.250*
C4	*6057*	*1.340*

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*

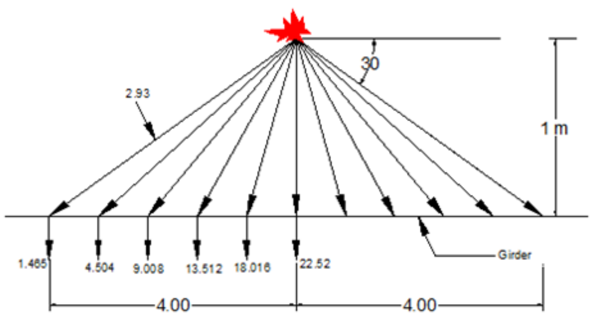

Figure. Blast pressure distribution for Case 1

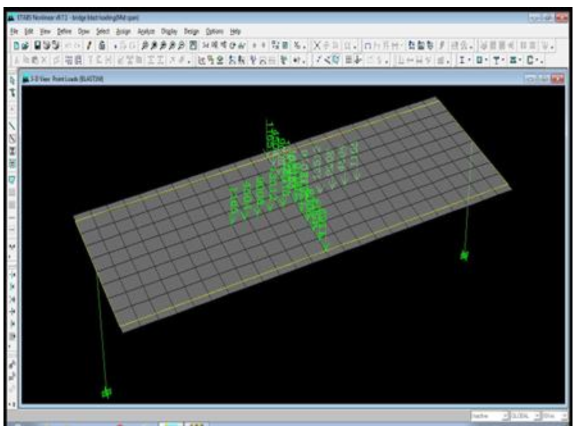

Figure. Blast Load Distribution for Case 1 in ETABS

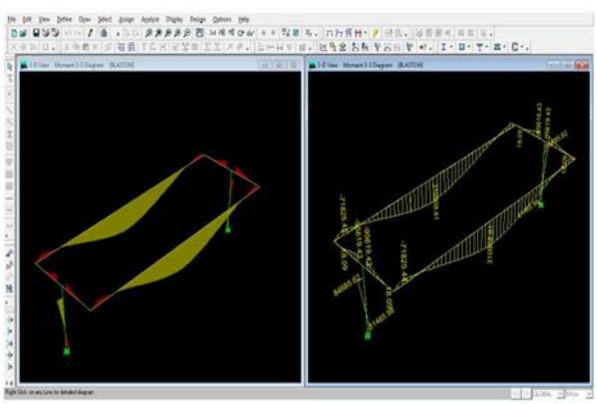

Figure. Bending Moment diagram of girder due to Blast Load.

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 on column they will experience an axial thrust in vertical direction which is shown in fig 4.6. 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 4.3. and figure. 4.4. to clearly understand the nature and behavior of the affected members due to application of blast loads. From figure 4.7.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

IV.CONCLUSION

Based on this study, following conclusions can be made. 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 .

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.

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.

Bridge damage is more when blast occurs at the mid-span. The structure completely fails in this case and hence immediate replacement is needed.

Blast loads were determined as a record of pressure-time history with the parameters calculated as per available literatures.

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.

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.

Future Scope of Study:

Although the detailed study regarding blast analysis is done in this work, the study presented here can lay a foundation for further detailed study regarding analyses of blast effects on bridges. Following are some future needs that can be studied in this area.

In this study we have used 4 cases for the analysis. For further work these cases can be changed considering different intensities of blast explosives.

Further study can be also done by changing the location of the blast event. The location can be considered below the deck with variable conditions of blast intensities.

Structural failure and its response for different components parts of bridge can be simulated.

To protect bridges from the act of terrorist explosion, blast resistant bridge design should be developed and adopted by the applicable code and practices.

REFERENCE

[1] K. M. Anwarul Islam, NurYazdani, "Performance of AASHTO Girder Bridges under Blast Loading",Engineering Structures 30(2008) 1922-1937.

[2] Andrew Sorenson, William L. McGill, "Utilization of Existing Blast Analysis Software Packages for the Back-Calculation of Blast Loads",ASCE Journal of Performance of Constructed Facility, 2012, 26(4): 544-546.

[3] Cimo, R. "Analytical modeling to predict bridge performance under blast loading." Newark, Delaware: University of Delaware; 2007.

[4] Chopra A.K. (2001), "Dynamics of Structures: Theory and applications of Earthquake Engineering", Prentice Hall, Upper Saddle River.

[5] David G. Winget, Kirk A.Marchand, Eric B. Williamson, "Analysis and Design of Critical Bridges Subjected to Blast Loads",ASCE Journal of Structural Engineering, 2005, 131(8):12432-1255.

[6] Edmond K.C. tang, Hong Hou, "Numerical simulation of cable stayed bridge response to blast loads",Engineering Structures 32(2010) 3180-3192.

[7] Fujikura, S., Bruneau, M., and Lopez-Garcia, D. "Experimental investigation of multihazard resistant bridge piers having concrete-filled steel tube under blast loading." Journal of Bridge Engineering 2008, 13(6): 586-594.

[8] G. Daniel Williams, Eric B. Williamson, "Response of RC Bridge Columns Subjected to Blast Loads",ASCE Journal of Structural Engineering, 2011, 137(9): 903-913.

[9] HrvojeDraganic, VlamidirSigmul, "Blast Loading on Structures", UDC/UDK, ISSN 1330-3651.

[10] Indian Standard IS 4991-1968 "Criteria for Blast resistant Design of Structures and Explosions above and below Ground surface", Bureau of Indian Standard, August 1993.

[11] Indian Road Congress IRC 112-2011 "Code of Practice for Concrete Road Bridges", Indian Road Congress.2011.

[12] Jin Son, Ho. Jung Lee, "Performance of Cable stayed bridge pylons subjected to blast loading", Engineering Structures 33(2011) 1133-1148.

[13] Mahoney, E. E. "Analyzing the effects of blast loads on bridges using probability, structural analysis, and performance criteria." College Park, Maryland: University of Maryland; 2007.

[14] Matthews, D. S. "Blast effects on prestressed concrete bridges." Washington: Washington State University; 2008.

[15] Nitesh N. Moon, Thesis on "Prediction of Blast Loading and its Impact",National Institute of Technology, Rourkela, (2009).

[16] Rong – Bing Deng, Xian Long Jin, "Numerical Simulation of Bridge Damage under Blast Loads", ISSN: 1009-2750 (2009).

[17] S. Fujikura, M. Bruneau. 14, "Blast Resistance of Seismically Designed Bridge Piers",WCEE, 2008, Beijing, China.

[18] SomnathKarmarkar, "Response of a T-Beam Reinforced Concrete two lane bridge under blast loading", International Journal of earth Sciences and Engineering. ISSN 0974-5904 Vol.5,6.

[19] Son, J., and Lee, H.-J. "Performance of cable-stayed bridge pylons subjected to blast loading." Engineering Structures 2011, 33(4): 1133-1148.

[20] Suthar, K. "The effect of dead, live and blast loads on a suspension bridge." College Park, Maryland: University of Maryland; 2007.

[21] T.W.Y. Lua, P. Mendis, T. Ngo, L. Zhang, D. Mohotti, M. Sofi, "Blast Studies on Bridges – A State of the Art Review", Electronics Journal of Structural Engineering 14 – 2014.

[22] TM 5-1300, "Structures to Resist the Effectsof Accidental Explosion", Department of Army, Navy and Air Force.

[23] Wei Wang, Ruichao Liu, Biao Wu, "Analysis of a Bridge Collapsed by an Accidental Blast Loads", Engineering Failure Analysis 36(2014) 353-361.

[24] Williamson E.B. and Marchand, "Analysis of blast effects on highway bridges and roads", Journal of Bridge Engineering, 2011.

[25] Yuxin Pan. Ben Y.B. Chan, Moe M.S. Cheung,

"Blast Loading Effects on an RC Slab-on-Girder Bridge Superstructure using Multi-Euler Domain Method",ASCE Journal of Bridge Engineering, 2013, 18(11): 1152-1163.

[26] Z. Yi, A.K. Agrawal, M. Ettouney, S. Alampalli, "Blast Load Effects on Highway Bridges, I: Modelling and Blast Load Effects", ASCE Journal of Bridge Engineering. 2014.19.

[27] Zhihua Yi, Anil K. Agrawal, "Blast Load Effects on Highway Bridges", Region 2, University of Transportation Research Centre, 2009.