SIMULATION OF EXPLOSIONS IN TRAIN AND BRIDGE APPLICATIONS

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ABSTRACT

The application of practical engineering, propagation processes of shock waves is simulated using the ANSA/ LS-DYNA software. Explosion is carried out on the surface and underground. The analysis results interpreted to assess the damage to the intended target such as coach on the track over a bridge. The results are also extended to study the collateral damage to a bridge or to a nearby building. Material Pseudo Tensor and Linear Plasticity in LS-DYNA have been used for the simulation. Explosives were initiated at ground level, bottom of the bridge, between centers of the two abutments. The effects of the locations were studied to extent of damage to the bridge and to the coach on the track. The conclusions have also indicated that bridge after the blast encountered with some major cracks, and can be made blast resistant bridge structure by providing additional dampers and springs, suitable structural modifications to the bridge structure, rails, its anchorage structure on either side and also the abutments.

1. INTRODUCTION

In the current context, the emergence of non-conventional threats such as improvised explosive devices implies a need to constantly improve the Aero-defense structure or the bridges and the flyovers. Therefore, to assist the design of protection systems, finite element (FE) analysis are often used. However, one problem, which is addressed in this paper, is to use a numerical model of blast in near field that will accurately predict the structural response of the railway bridge. Several authors demonstrated that the smoothed particle hydrodynamics (SPH) method could be used to simulate mine blast detonation under a structure. Some studies [7 to 12] have investigated the Arbitrary Lagrangian Eulerian(ALE) method, as implemented in LS-DYNA ,to model blast. In the recent past, LS-DYNA with new feature, Load Blast Enhanced especially for the Blast simulation. An attempt has made to use this new Load Blast Enhanced card and Load Blast Segment, which don't require any medium to capture using ALE or SPH. Although this new technique seems promising, the Load Blast Enhanced technique was used in this study to generate the loading on the structure. The FE modelling is carried out using ANSA and post-processing is done using Meta-Post.

The first section of the paper describes brief introduction about the study. The second section presents the corresponding FE model of setup. The third section presents the material models used in the simulation. The fourth section presents about blast loading used. The fifth section describes the results using the Load Blast Enhanced technique to simulate and the severity of damage on the locomotive. Finally, conclusion and future work are presented.

2. FINITE ELEMENT MODEL OF THE SETUP

The modelling of the structure involved the creation of the geometrical model; the assignment of the materials, properties, mesh, contacts, the appropriate boundaries and the loadings is done using ANSA. The finite element model is presented in Figure-1 and was meshed with 79480 of solid elements in ANSA Pre-processor.

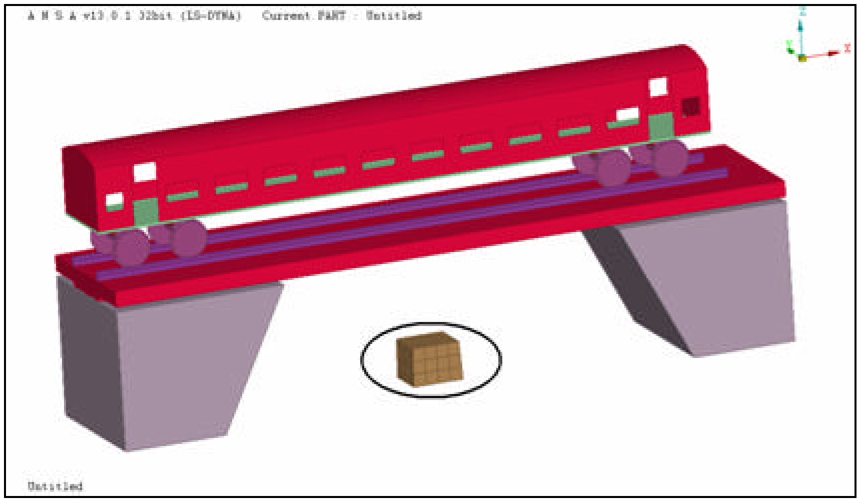

Figure 1: Finite Element model of the Train and Bridge structure setup.

A simplified finite element (FE) model was generated for the locomotive and standing on the Reinforced Cement Concrete (RCC) Bridge. All though the model was symmetric the complete modelling was done to capture the effect of the blast on the structure and the Locomotive. The model consisted of a Bridge of 20 m in length supporting on two RCC abutments. The locomotive of length 18.3896 m is assumed to stationary, 2.54 m in width and 2.13 m in height supported on rails. In this model complete bridge deck bottom and the abutments inner faces were exposed to the blast loading. The total mass of the Locomotive was 28 tonnes, equivalent to the common locomotive available in any railways which is as shown in Figure 2. The entire system was modelled by using single integration point brick elements. The explosive was placed along the symmetric x & y axes. The distance from the explosive to the bottom of the Bridge deck is 2.90 m (114.596 in) and 5.67 m to the inner face of the abutments (223.703 in). Rigid connections are used to represent the joints in the model.

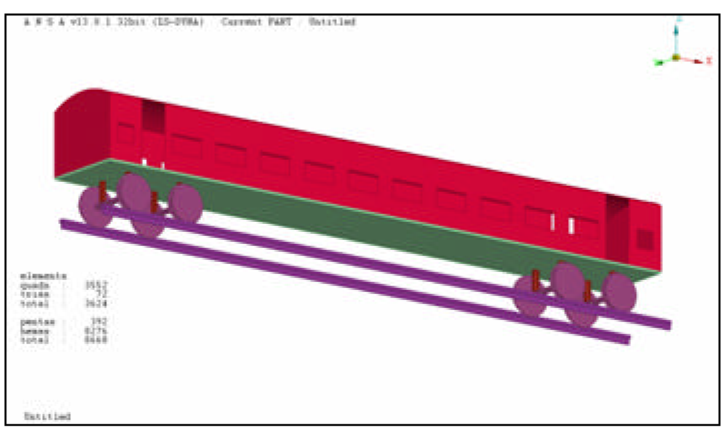

Figure 2: Locomotive and Rails

Load Blast segment is used for the Blast loading as shown in Figure 3. All the parts are made transparent for the clear visualisation for the load segment.

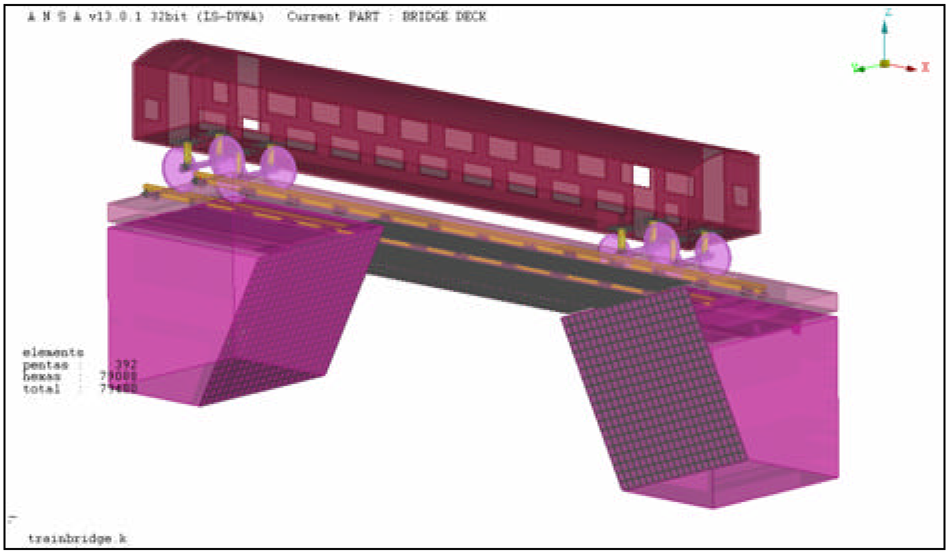

Figure 3: Load Blast Segment for the blast loading.

3. MATERIAL PROPERTIES

Material properties used for performing LS-DYNA analysis of the RCC Bridge and Locomotive model were obtained from the literature. *MAT_PSUDO_TENSOR (material type 16) was used to represent the Bridge deck & Abutments i.e. Reinforced Cement Concrete material model. Finally modelling and representing the locomotive and rails was done using *MAT_PIECEWISE_LINEAR_PLASTICITY (material type 24) for cast iron. Material properties for the concrete and cast iron are tabulated in Table 1 and Table 2 respectively.

Table 1: Material Properties for RCC	
Mass Density	2400 Kg / m^3
Shear modulus	1.710e+009 N / m^2
Poisson's ratio	0.2
Maximum principal stress for failure	4.000e+007 N/m^2
Cohesion	-6894.7598
Percent reinforcement Elastic modulus for reinforcement	8 % 2.180e+011 N/m^2
Poisson's ratio for reinforcement	0.28
Initial yield stress for reinforcement	5.100e+008 N/m^2
Tangent modulus / plastic hardening modulus	2.900e+008 N/ m^2

Table 2: Material Properties for Cast Iron

Mass Density	7800 kg / m^3
Young's modulus	185000000000 N / m^2
Poisson's ratio	0.17
Yield stress	4.000e+008 N / m^2
Tangent modulus	1.680e+010 N / m^2
Failure Strain	0.02

4. BLAST LOADING

The ConWep blast pressure function with LS-DYNA was used to provide the blast loading exerted on the Bridge Bottom surface and Abutments inner faces[3]. The inputs include equivalent TNT mass, type of blast (surface or air), detonation location, and surface identification for which the pressure is applied. From this information, ConWep calculates the appropriate reflected pressure values and applies them to the designated surfaces by taking into account the angle of incidence of the blast wave. It is important to note that ConWep, adopted within LS-DYNA, updates the angle of incidence incrementally, and thus, accounts for the effect of surface rotation on the pressure load during a blast event.
Both ConWep and ALE techniques have been investigated and reported in the literature for simulating blast loading [5-7]. In general, the ConWep air blast function, which has the advantage of computational simplicity, is adequate for predicting the air blast loading on simple structural surfaces. *LOAD_BLAST_ENHANCED along with *LOAD_BLAST_SEGMENT is used for the blast loading on the structure. An equivalent mass of TNT about 10 kgs is placed with symmetric centre of the abutments at the ground level as shown in Figure 1.

5. RESULTS AND DISCUSSIONS

Blast makes the bridge deck to get detonated from the supports. The maximum displacement recorded with the 10 Kgs of equivalent mass of TNT is 0.505 m (1.6564 ft). Since the explosive is placed at the bottom of the bridge, the governing displacement will in Z-Direction and next it will be Y-Direction. The Figure 4 and Figure 5 show the maximum global contours plots.

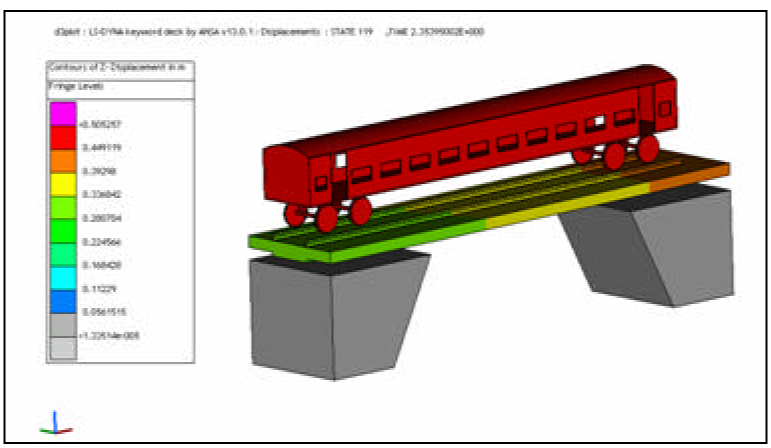

Figure 4: Z-Displacement contours plots.

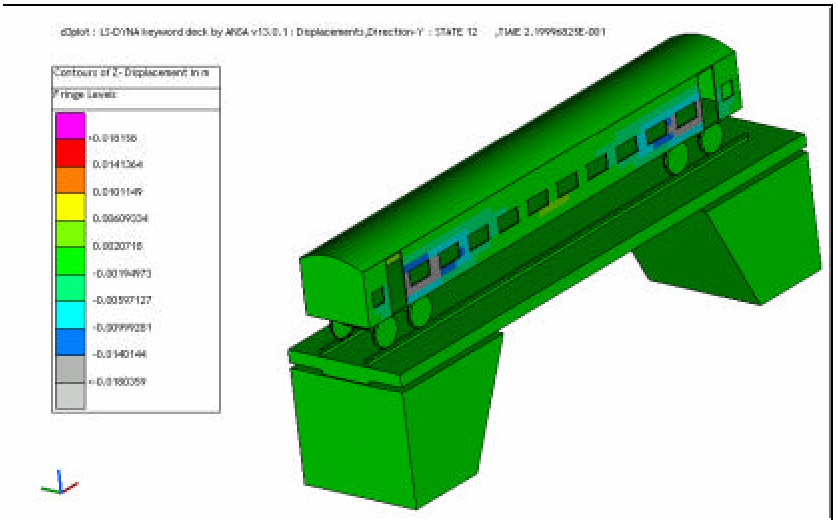

Figure 5: Y-Displacement contours plots.

Figure 7 shows the stress contour plot for the global, from which it can be observed the maximum stress occurs in the rails. The value is crossing the failure stress of the material. Hence it can be concluded that rails fail first. Rigid connections are used between the rails and the Bridge deck and hence lot of stress will be induced as it can be modelled as the flexible joints.

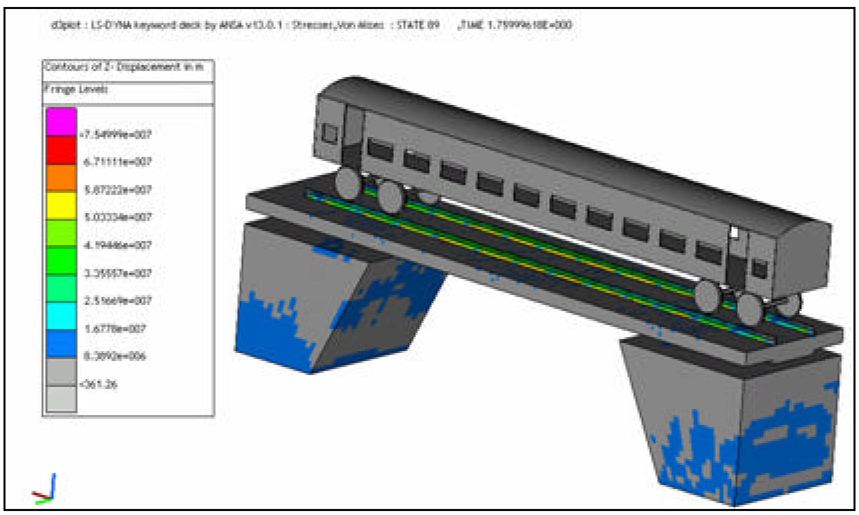

Figure 6: Stress Contour plots

6. CONCLUSIONS

This paper presented results obtained using the Load Blast Enhanced card to simulate loading on representative Locomotive and Bridge. The presented representative Locomotive and Bridge structure and provided with the report. The presented with result for the effect of blast (TNT) on Locomotive and Bridge Deck. For all compared points, the time response of the structure was well captured by the numerical analyses. The current model has shown it can be used to predict structural response of the mock-up structure and can be used to compare protection system options for the given initial conditions. However, to be able to use this Load Blast Enhanced for other scenarios, numerical analyses will be performed with other initial conditions and apply to different Locomotives / Vehicles and flyovers / bridges. Further work is required to add dampers and springs additionally, also wide ranges of concrete material models are available in LS-DYNA, finally reduce the damage to the locomotive and rails and make the blast resistant structure .

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