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The numerical simulation of damage characteristics of the bridge under cruise missile attack

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Abstract. Bridge is an important transport network, and is an key target of breaking and blockade battlefield. In order to provide reference information for reinforcement scheme after damage at war, it is necessary to study damage characteristics of bridges which undertake main transportation task. The paper is to study damage Characteristics of The Bridge which is serving through numerical simulation. Create the model of cruise missile and real model of major bridge through pre-process software. Set two speed to realize contact explosion and penetration explosion; Adjust attack position and the amount of TNT. Be solved through the software LS-DYNA. Obtain dynamic response and different degrees of damage effect of certain important position of the bridge. The results can be used to provide certain reference as antiknock design of and safety assessment after damage long-span bridges.

1. Introduction

Bridges are more special than other ground objects. Once damaged, it is not easy to recover in a short period of time [1]: there is a correlation in the whole transportation system, and a small number of key Bridges can paralyze the entire transportation system. [2] in recent decades, with the development of national economy and the progress of science and technology, especially the rapid development of bridge design and construction technology, our country has built a batch has the world's advanced level of long-span Bridges. These Bridges play an irreplaceable role in China's transportation. However bridge engineers in the design process and no special consider antiknock safety of Bridges [3], the bridge construction drawing design principles, seismic and wind resistance of bridge pier anticollision [4] clear specification, such as antiknock party did not consider structure and design requirements of bridge antiknock analysis is a new topic and challenge [5-7]. Therefore, the research on the damage effect of the bridge under the impact of explosion provides a reference for the safety assessment and comprehensive protection of the whole bridge.

In recent years, some scholars have carried out numerical simulation for dynamic response analysis of bridge under explosive load, but these studies are based on simplified model of bridge. Based on ls-dyna software in the actual bridge as a prototype for modeling in detail, using cruise missiles to attack loaded, and considering different attack position of zhaoqing bridge dynamic response and damage degree, the closer to the actual numerical simulation.

2. Introduction to LS-DYNA Software and Algorithm

2.1. Software Introduction

LS-DYNA software by J. Dr O. Hallquist 1 in 976 at the Lawrence Livermore national laboratory in the United States are leading the development is complete, can be used for analysis of explosion and the large deformation dynamic response in the process of problem such as high speed impact, can the generation, transmission and coupling process of explosion shock wave simulation and numerical calculation, has been widely used in national defense and civil fields such as [9].

2.2. Algorithm Introduction
The ls-dyna program has Lagrange, Euler and ALE algorithm [10]. Though laser algorithm are attached to the material of the unit grid, as the flow of materials and produce units of the grid deformation, but the structure deformation is too large, could make the finite element mesh generating serious distortion, cause the difficulty of numerical calculation, and even the program terminates operation. The Euler algorithm is that materials flow in a fixed grid. ALE algorithm and Euler algorithm can overcome the difficulty of numerical calculation caused by serious unit distortion and achieve dynamic analysis of fluid-solid coupling. Ls-dyna can also easily combine Euler grid with full Lagrange finite element to deal with the interaction between fluid and structure under various complex loading conditions.

3. Establishment of Finite Element Model
The total length of the bridge is 2529m, and its span is (10 x 20m+11 x 20m)+(5 x 40m+6 x 40m+6 x 40m)+(86m +4 x 136m +86m)+(6 x 30m+5 x 30m+10 x 20m+9 x 20m). For the main (86 m + 4 x 136 m + 86 m) six large single box single room cantilever straight abdominal prestressed concrete continuous box girder, 716 m long and bridge 22 m wide, box 10 m wide, on both sides of the cantilever each 6 m, liang for 3 m to 8 m high, bottom plate thickness of 1.0 m ~ 0. 3 m, adopting longitudinal, vertical and horizontal three-way prestressed system; The pier body is thin - walled hollow reinforced concrete structure.

Grid model

3.1. Bridge Concrete Grid Model
The finite element model models the main bridge with a length of 716m in detail and simplifies the model of the bridge. The main bridge is divided by hexahedron grid.

The bridge and pier are divided by hexahedron grid, and tetrahedron cells are used only at the grid transition. The number of grids is 1.42 million. The unit USES a single point integration algorithm.

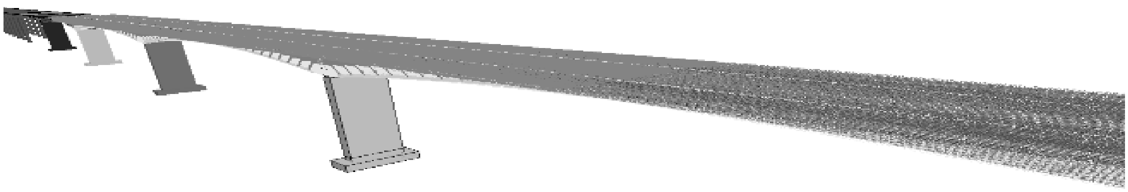

Figure1. The finite element model of reinforcement

3.2. Reinforcement Mesh Model
The bridge's steel bar consists of ordinary steel bars and prestressed bars, which slide through the concrete when subjected to explosive loads (both ends of which are fixed). In ls-dyna, the pretensioning bars need to be created using the no. 9 spot weld unit and applied by the keyword *initial_axial_force_beam. The arrangement of reinforcement consists of three - way ordinary reinforcement bars and three - way pretension bars.

3.3. Cruise Missile Grid Model
The finite element model of cruise missile is based on American AGM86C cruise missile. The content of warhead is 0.2911m3, and the internal TNT quality is 497.8kg.

Material model and parameters

Reinforced material model USES can consider strain rate hardening of ls-dyna in the follow-up * MAT_PLASTIC_KINEMATIC hardening model. The concrete material model USES the *

MAT_CSCM_CONCRETE in ls-dyna, the concrete model is the same strain rate hardening effect could be considered.

Because the deformation of TNT and air is very severe in the simulation process, TNT and air are modeled using ALE unit.

The material model of TNT explosives adopts the MAT-HIGH- magma slve-burn material model in ls-dyna, and the relationship between detonation pressure P and energy per unit volume and relative volume V is described by JWL state equation.

Air using MAT_NULL material model and linear polynomial equation of state EOS _LNIEAR_POLYNOMIAL is described.

Table 1 material parameters of TNT

Material	density	initial internal energy	detonation velocity
TNT	1630 kg/m3	7GJ/m3	6930m/s

For different levels of explosives, different levels of explosives can be regulated by adjusting the initial internal energy in JWL equation of state.

3.4. Other Settings

The coupling between explosives and Bridges and steel bars USES the special coupling keyword *CONSTRAINED_LAGRANGE_IN_SOLID provided by ls-dyna, where the coupling type CTYPE is set to 5 to achieve penetration coupling. No reflection boundary is set for the outer boundary of ALE unit to simulate the air field in infinite domain.

4. Simulation Results

By setting the initial velocity of the missile to zero, the contact explosion to the bridge is realized. The initial speed of the missile is set at 300m/s for penetration. When the explosive is around 0.015s, its subsequent damage power can be ignored, so we set the solution time to 0.02, which can fully observe the damage to the bridge.

The middle of the main span was attacked by cruise missiles

4.1. Contact Detonation (General Grade)

The cruise missile is placed in the middle position of the main span, and the initial speed is set to zero to realize contact explosion.

After the contact explosion of the bridge, a hole about 9m in diameter appeared in the middle, and the steel bar of the hole broke and fell. Cracks appeared in the web and the edge of the bridge roof was damaged due to shock wave vibration.

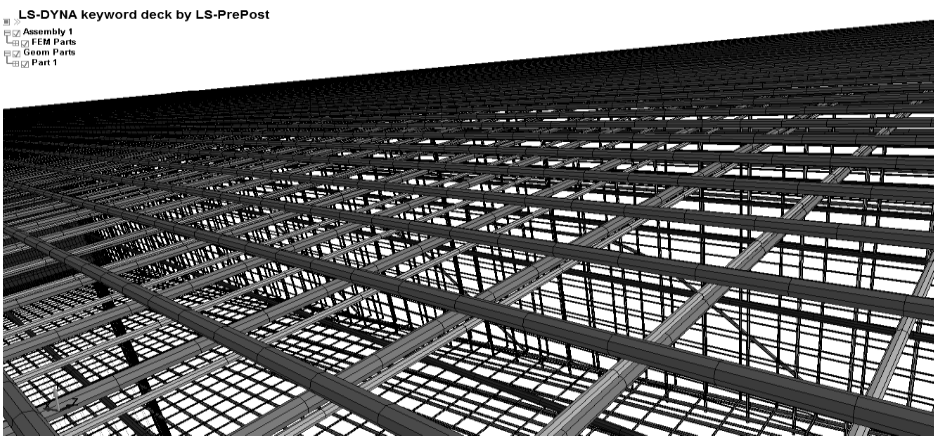

Figure 2. The finite element model of reinforcement

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4.2. Contact Detonation (Increase By One Level)

The initial internal energy in the explosive state equation was changed to 9.2 times of the normal grade.

About 12.5m holes were found in the roof of the bridge and the roof was damaged in a larger area and the cracks in the floor were wider and wider.

4.3. Contact Explosion (Increase Two Levels)

The initial internal energy in the explosive state equation was changed to 31.8 times of the normal level.

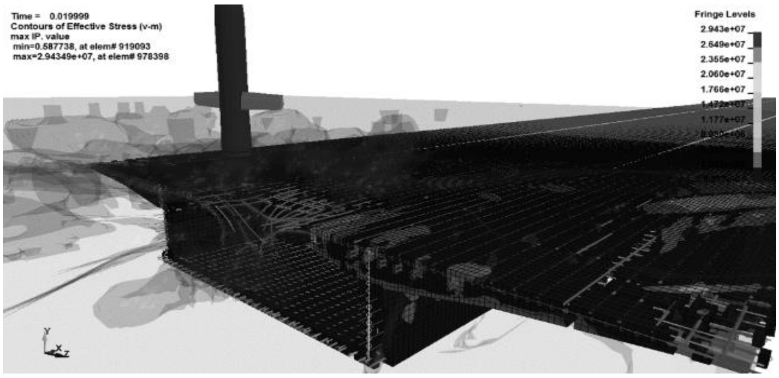

Figure 3. The damage profile of bridge

It can be seen that the crushing damage in the middle of the bridge is 52m wide and 22m wide (22m wide). And the abdomen and the bottom plate also appeared the crushing damage.

5. Conclusion

Based on bridge prototype in detail modeling, simulation of cruise missiles to fry bridge, under various working conditions, compared with the previously published research work in this paper, modeling more real, conforms to the development trend of the simulation of fine, for similar bridge bridge cruise missile attack damage forms such as anticipation with reference.

In this paper, the related parameters is regular, not to carry on the calibration with the experiment, so, the next step of work, the need for an explosion targeting calibration experiment, to the related parameters of the model calibration, which can further improve the accuracy of the models.

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