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Dynamic Analysis of Steel Tube and Concrete-filled Steel Tube High-limit Protection Racks under Impact Loads

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Key Words: High-Limit Protection Rack; Internal Force; Displacement; Energy

Abstract: The purpose of high-limit protection rack under railway bridge is to protect railway bridge, and avoid passing vehicles under railway bridge colliding bridge. The paper discusses dynamic response and energy transfer of two different structures by analyzing the internal force, deformation, displacement and energy transfer of the steel tube and concrete-filled steel tube protection racks in collision. The result shows that the displacement of concrete-filled steel tube protection rack is smaller, and it can bear larger impact force and have good effect of energy absorption.

Introduction

With the rapid development of railway construction in China, it needs to impose a series of protective measures to protect the safety of railway operations, especially part of railway under that there are vehicles passing, and to ensure the normal operation of rail transport. *Regulations on Protection of Railway Transport Safety* clearly defined: the road under railway bridges and culverts should be installed Vehicle height limit sign and high-limit protection rack in accordance with the relevant national standards.

At present, the main railway bridge high-limit protection racks include steel tube, concrete, reinforced concrete and concrete-filled steel tube protection rack. Construction process of concrete and reinforced concrete structure is complicated, and it needs to spend a lot of manpower and resources, and longer duration, and its impact resistance is weak; But steel tube and concrete-filled steel tube structure supplements defects in the former, and has less impact on the surrounding environment, and is called green building. In recent years, researchers at home and abroad have done a great deal of research in the dynamic performance of concrete-filled steel tube structure, and have achieved good results. Ministry of construction, ministry of energy and the state administration of building materials promulgated design and construction procedures about concrete-filled steel tube structure. The paper uses ANSYS / LS-DYNA software to compare steel tube protection rack with concrete-filled steel tube protection rack, and get comprehensive assessment of the impact resistance of concrete-filled steel tube protection rack, and provide a reference for the design.

Finite element model

The paper uses ANSYS software to simulate and analyze the whole collision process. Taking into account there are a series of protective gears and the speed limit signs before protection rack, so vehicles are at low speed on arrival. The paper only considers that vehicle collides protection rack at low speed, and materials are in the elastic stage. Select accurately finite element model, and carry on dynamic analysis of vehicle collides protection rack reasonably.

Element type. Element types of the whole model are solid164, and it is an eight-node and three-dimensional solid element. In the case of default, the element uses single point of integration to carry on model calculation, and bring easy hourglass problem. In order to improve the accuracy of calculation, the paper uses full integration to calculate the model.

Structural dimensions and materials. In the paper high-limit protection rack is door frame. Radius of column is 250mm, and thickness of wall is 16mm, and height is 5m; Radius of beam is

150mm, and thickness of wall is 16mm, and length is 9m. Elastic modulus of steel tube is 2.06×105Mpa, and Poisson's ratio is 0.3, and density is 7800kg/m^3; Elastic modulus of concrete is 2.5×104Mpa, and Poisson's ratio is 0.2, and density is 2500kg/m^3.

The paper only considers dynamic response of protection rack in collision. Quality of vehicle is 10t, and its speed is 10m/s, and angle of impact is 90°, and elastic modulus is 2.06×107Mpa, and Poisson's ratio is 0.3 and density is 5000kg/m^3.

Establish model. The paper selects element size of vehicle quality mass that is 0.2m, and element size of protection rack that is 0.1m. In order to improve the accuracy and efficiency of analysis, it needs to mesh and select element size reasonably. Contact surface uses one-way contact type, and select quality mass's contact surface that is the main surface (master), and protection rack's contact surface that is the minor surface (slave), and make node penetrate the main surface and have high efficiency.

Figure 1 is a modeling and meshing diagram of protection rack and vehicle, and shows model diagram of concrete-filled steel tube protection rack that is similar to steel tube protection rack. Protection rack accesses column ground by fixing mode without considering the interaction between soil and structure. Use welded connections between the beams and columns.

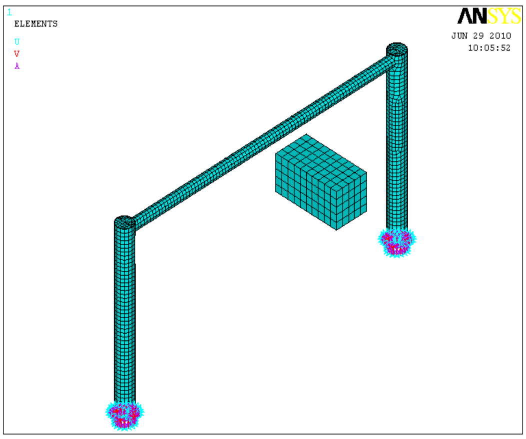

Fig. 1 Meshing diagram of protection rack and vehicle

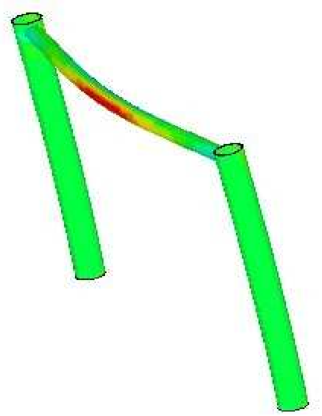

Fig. 2 Deformation diagram of protection rack

Analysis of deformation and displacement of protection rack in collision

The overall deformation of protection rack is shown in Figure 2, and it can be seen from the figure that there is a concave deformation in contact surface of protection rack beam, at the same time , and a little of column bending. The paper selects two kinds of steel tube and concrete-filled steel tube structures in comparison, because concrete-filled steel tube not only has high strength, but also good seismic resistance and impact resistance. By analyzing deformation and displacement of protection rack, design strength and stiffness of protection rack better, and effectively protect the safety of the railway. Figure 3 shows the displacement time graph of collision points of the two protection rack structures along the collision direction (Z direction) in collision.

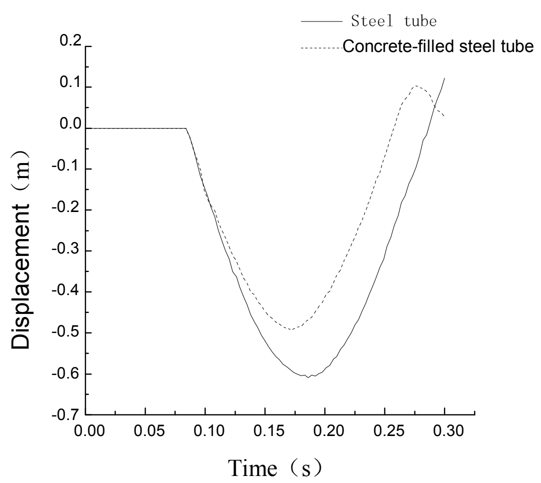

Fig. 3 Displacement time graph of collision points along Z direction

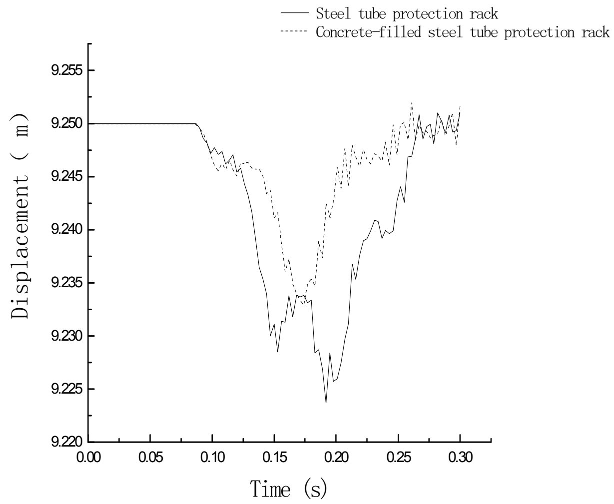

Fig. 4 Displacement time graph of collision points along X direction

It can be seen from the Figure 3 that displacement of concrete-filled steel tube protection rack collision point is smaller than steel tube protection rack collision point, and the maximum amplitude of displacement is 0.48m and 0.63m respectively, so displacement of steel tube protection rack collision point is 15cm more than concrete-filled steel tube protection rack collision point under the same impact loads, and more likely to first reach the yield strength and more likely to be undermined. Concrete-filled steel tube protection rack reaches maximum displacement amplitude of the reverse at about 0.27s, then slowly returns to equilibrium position and does simple harmonic motion. But steel tube protection rack has larger maximum displacement amplitude of the reverse and decreases seismic resistance clearly.

Figure 4 shows the displacement time graph of collision points of the two protection rack structures along the horizontal direction (X direction) in collision. The figure shows the maximum amplitude of displacement is 2.7mm and 1.8mm respectively, and displacement is relatively small, and illustrates that with increase of displacement along Z direction, displacement along X direction will increase.

Energy change in collision

By analyzing energy change in collision, compare performance of the two material protection racks. The total energy of the system before the collision is the kinetic energy of vehicle, and vehicle is at the speed of 10m/s, so the total energy is 500 KJ. According to energy conservation, analyze and compare Similarities and differences of transformation of internal energy in the two systems, and by analyzing energy change in vehicle collision, analyze the energy absorption capacity of protection rack further. The results show that vehicle is close to the speed of 8m / s after the collision with the two structures, and kinetic energy of vehicle is similar, but its speed is smaller after the collision with concrete-filled steel tube protection rack, so energy absorption effect of concrete-filled steel tube protection rack is slightly better. Figure 5, 6 are energy change curves of vehicle colliding with steel tube protection rack and concrete-filled steel tube protection rack respectively.

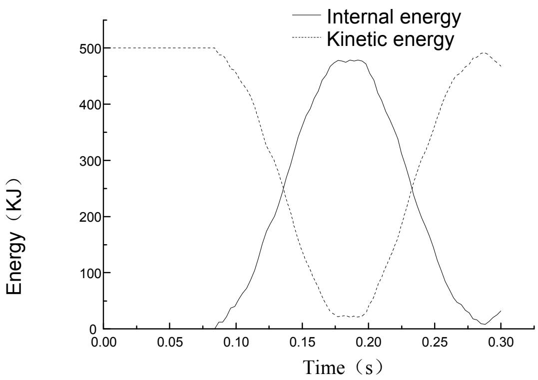

Fig. 5 Energy change curves of vehicle and steel tube

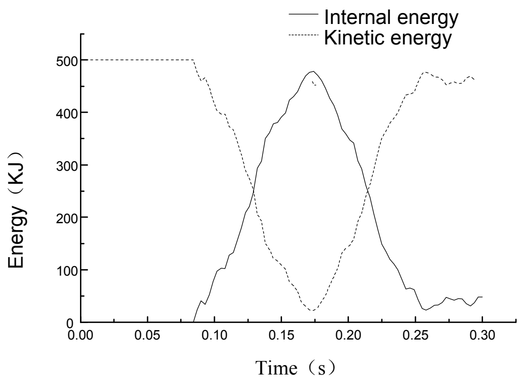

Fig. 6 Energy change curves of vehicle and concrete-filled steel tube

Figure 5, 6 shows that energy change in collision is internal energy and kinetic energy into each other and their energy change curves are similar. Among them, the hourglass energy is zero. But time is different when total kinetic energy reaches the second maximum amplitude (that separation time is different), and they are at about 0.25s and 0.28s respectively. It illustrates vehicle departs relatively early from concrete-filled steel tube protection rack about 0.03s. The internal energy of the system does not reach maximum amplitude when vehicle departs protection rack, and will not increase until collision point reaches reverse maximum displacement.

The notable feathers of Figure 5, 6 are:

(1) The two systems have not been resting state, and the minimum kinetic energy of steel tube structure has lasted for 0.025s.

(2) At the same time there is mutual transformation between the kinetic energy in parts of the system, and internal energy of components can be transformed into each other, and internal energy of vehicle is very small and it can be ignored.

(3) In the 0.025s of energy level shock, changes in the total internal energy is almost internal energy change of protection rack, but internal energy change of protection rack is slow, and shows kinetic energy of protection rack is very small, so total kinetic energy can be considered as vehicle's kinetic energy.

(4) There is a longer time for the second separation when vehicle collides with steel tube protection rack; But there is no energy level shock stage when vehicle collides with concrete-filled steel tube protection rack, and it illustrates there is a shorter time for the second separation, and a small separation direction, so concrete-filled steel tube protection rack has good toughness and seismic effects.

Conclusions

The paper uses ANSYS/LS-DYNA software to analyze dynamic characteristics of vehicle colliding protection rack effectively. Compare deformation and displacement and energy transformation of the two material structures under the same impact force. The following conclusion:

(1) The displacement of the two material protection rack collision point is larger along the collision direction than along the horizontal and vertical direction, so it is necessary to reinforce the structure along the collision direction when designing protection rack.

(2) Displacement of concrete-filled steel tube protection rack collision point is smaller than steel tube protection rack collision point in collision, and can bear greater impact loads, and there is no energy level shock stage and the second clear separation from each other in collision. So concrete-filled steel tube protection rack has good effect of buffer and seismic and energy absorption. The paper provides a reference for the design and material selection of protection rack and the formulation of relevant norms.

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