Based on Magnetorheological Bridge Rubber Bearing Isolation Test Bench Similarity Relation Theories

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Abstract

Traditional pier bearings can adaptively adjust its parameters, as well as large-scale research projects isolation bridge cost is very high and the physical disadvantages difficult to achieve using magnetorheological device parameters adjustable features from the angle of similarity theory of bridge barrier vibration system theory. In this paper, a three-span continuous bridge as the prototype, its model design and finite element model of the prototype and dynamic analysis under seismic action, the results show prototypes and dynamics model has better similarity . And at the level of excitation of seismic waves on the pier piers traditional seat mounted rubber bearings and magneto-rheological simulation contrast, show magnetorheological rubber isolation bearings have a better buffer capacity.

Keywords

Pier Bearing, Similarity Theory, Magnetorheological Rubber Bearing.

1. Introduction

Bridge is an important part of the transportation lifeline, facing the vehicle in service overload and crash, the ship hit the pier, earthquakes, explosions and other large loads threats, often between the beams, piers have a huge destructive impact and displacement, ranging from causing pier - beam structure damage, it caused heavy collapse of life and property and harm economic development [1]. Traditional pier bearing vibration loads in general, while having a certain interval damping properties, but under earthquake loads or large impact can not intelligently adjust their own rigidity, enhance the vertical strength to resist impact and large deformation, can not produce larger damping, instant large deformation to dissipate energy, which in large horizontal shear force will have devastating displacement often lead pier - beam displacement, falling beams [2,3]to pier - impact protection beam structure It brings great risks. In recent years there have been some new smart materials are widely used in every other field of vibration, and have achieved good results [4], magnetorheological material is one of the most typical representatives of which, it is under the effect of the applied magnetic field within milliseconds to change its shear modulus, tensile modulus and elastic properties, and in the large tension, compression or shear deformation under the action still has a good energy dissipation capacity [5].

Magnetorheological rubber bearings used in bridge isolation system, its experimental research is an integral part. However, large-scale projects in the laboratory for physical research, not only has a high cost, difficult to operate, difficult and other shortcomings, but simple geometric similarity can not reflect the actual dynamics of engineering systems. Therefore, its similarity Similarity Theory is an effective method to model engineering problems to solve. Such as: Tang Xiaohong [6]and other similarity theory box structure welding stress and deformation are simulated; Anyan Tao [7]and other marine platforms similar model design and experimental modal analysis.

This article will use magneto-rheological characteristics of rubber adjustable parameters proposed by stiffness and damping parameters adjustable magnetorheological rubber mainly composed of rubber bearings to replace traditional magnetic bearing pier, the typical three-span continuous beam bridge engineering background, starting from a similar theoretical approach will be analyzed by modeling, dynamic simulation. Bridge vibration isolation system performance modeling theory.

2. Bridge bearing isolation system

Three-span continuous bridge shown in Fig. 1 herein chosen as the research object, the substructure of the bridge by a rigid reinforced concrete components. In the process of seismic excitation, the isolation of the bridge superstructure and piers holding linear elasticity, assumed fixed bottom of the pier (pier in rigid consolidation basis), without considering the pier - soil interaction, rigid abutment on each pier are isolation bearing arrangement. Also assume that isolated bridge deck is straight in the direction along the bridge piers supporting the bridge, and the bridge piers and orthogonal.

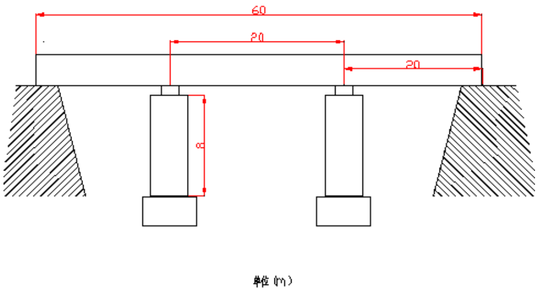


Fig1. overall structure size

Pier by the MRF rubber bearings, winding, core and metal shell and other components, and is applied to the coil windings on its piers - Structural Mechanics beam state of shock excitation control voltage signal, you can adjust the stiffness of the damping, Figure 2 is a self-developed magnetorheological bearing.

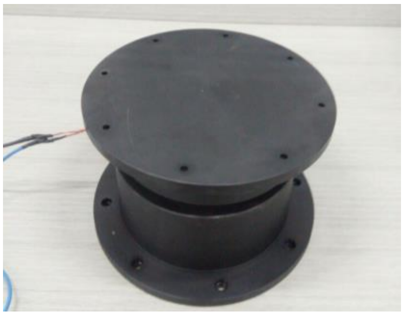


Fig.2 Magnetorheological bearing

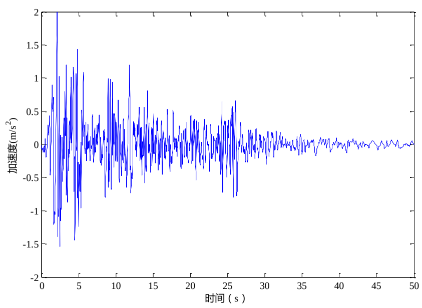


Fig.3 EI-Centro wave velocity-time curve

The experimental test, at zero current excitation input, piers magnetorheological rubber bearing has a certain stiffness and damping, which still has a traditional pier bearing function, to ensure that "fail safe."

Seismic wave has a strong randomness, even if the same response peak acceleration, the same structure in different seismic wave excitations are not the same. Therefore, during the time of isolation experiment, we need to consider the dynamic characteristics of the site and type of structure [8]. Select a representative in Figure 3 EI-Centro wave along the bridge to enter.

3. Model Bridge Design and production

Affect the performance of the physical quantity bridge are: the size(l), the stress(σ), the elastic modulus of the material(E), the density of the material(ρ), the mass of the structure(m), the frequency of vibration of the structure(ω), the stiffness of the material(k), time(t) and acceleration(a). Similarity theory is similar to the relationship between the various parameters such as the following formula 1:

$$\begin{cases} S_\sigma = S_E & S_\rho = S_\sigma / S_a S_l & S_m = S_\rho S_l S \\ S_k = S_l S_\sigma & S_t = \sqrt{S_l^2 S_\rho / S_\sigma} & S_w = \sqrt{S_\sigma / S_l^2 S_\rho} \end{cases} \tag{1}$$

Designed for shaking table test of the scale model, the main constraints include:

vibration table size - determines the length of the model is similar to the rate(s_l);

vibration table carrying capacity - determine the quality of the model is similar to rate(s_m);

shaker output - by similar acceleration rate (s_a) indirectly affect the quality of the model is similar to the rate (s_m);

Scale model material - elastic modulus of the decision model, similar stress rate ($s_E = s_\sigma$).

On the model design principles should be strictly in accordance with the similarity theory, but to do exactly like the prototype model is very difficult, usually model design, there will be one or several similar conditions difficult to meet. In the structure shaking table test, often used in length, stress, similar to the constant acceleration of three similar physical quantity as a controllable constant [9].

According to the above restrictions, shaking table model test similar to the design of the flow chart shown in Figure 4:

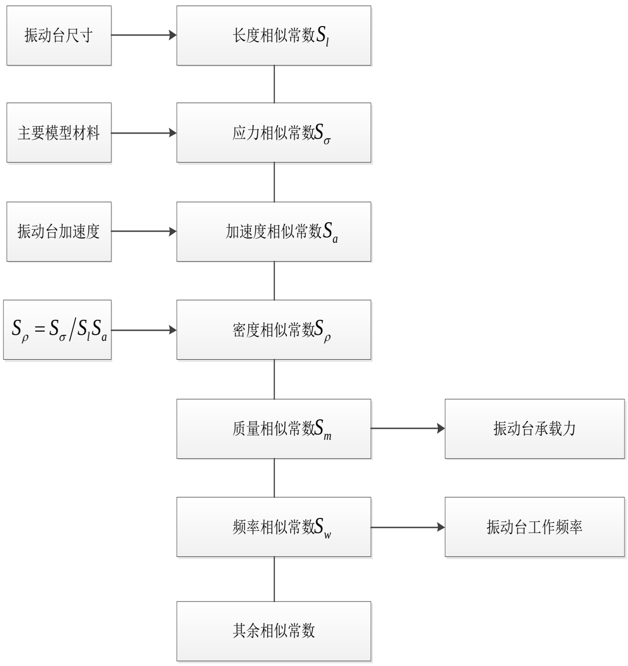


Fig.4 similar to shaking table test design flow

Considering model making easy, practical shaker affordability and other factors, select the length of the model structure similar constant of 0.05, plexiglass model material selection, similar to the constant stress of about 0.125, similar acceleration constant of 2.5.

4. Two system dynamics simulation

4.1 The main parameters of comparison of the two systems

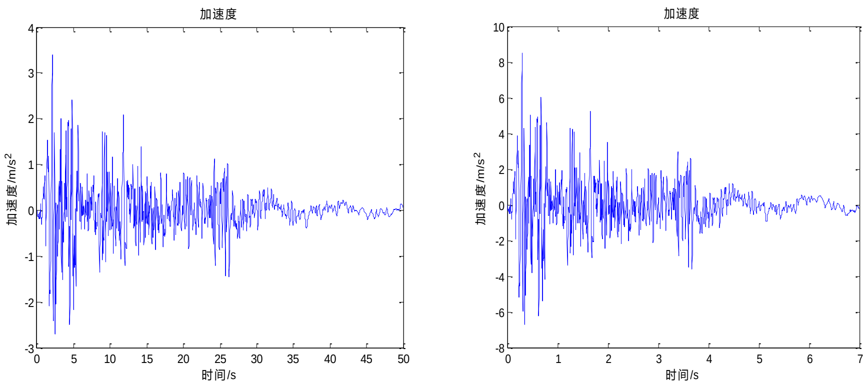
According to the design principles of Section 3, between the two main parameters of the system shown in Table 1:

Table 1 The main parameters between two systems

	Bridges true model system	Bridge small model systems
Elastic Modulus (GPa)	32.5	2.5
density (kg/m^3)	2400	1200
Stiffness (N/m)	1.9×10^6	5.4×10^5
Quality Deck (kg)	1.19×104	168.75

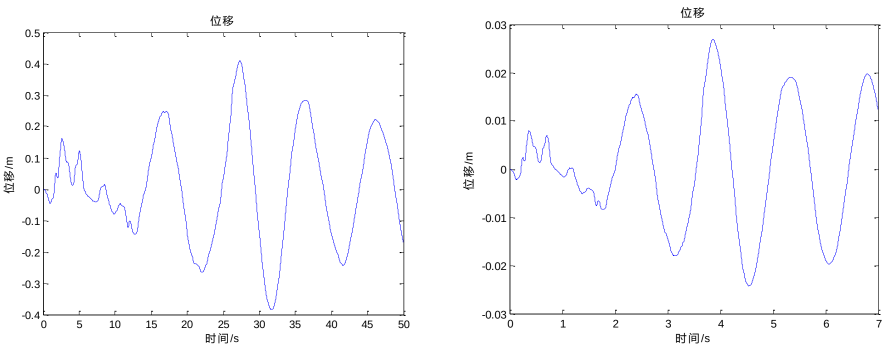
4.2 Comparison of the two systems dynamics similarity

According to design a small bridge model system parameters and system parameters bridge true model by finite element simulation software, compared to their respective deck acceleration of seismic waves at the relationship between displacement, whether previously designed similar relationship consistent. Obtained by the simulation in Figure 5 below deck acceleration, Figure 6 is a comparison chart of displacement:



(a) (b)

Fig.5 deck drive acceleration curve (a) a realistic model of the system drive acceleration curve (b) a small model of the system drive acceleration curve



(a) (b)

Fig.6 Deck displacement-time curve (a) True model system drive displacement curve (b) Small displacement time history curve model system

By the third quarter shows that the real bridge system is similar to the relationship between acceleration and displacement of small model systems were 2.5,0.05. As can be seen from Fig. 5 and 6 are consistent, it can prove that the two systems have good similarity.

4.3 Compare bearing isolation capability

To understand the MRF bearing isolation performance, based on the above real bridge were selected magnetorheological carriage bearing the traditional simulation carried out at the level of seismic waves, as shown by the simulated bearing 7,8acceleration, displacement comparison Chart:

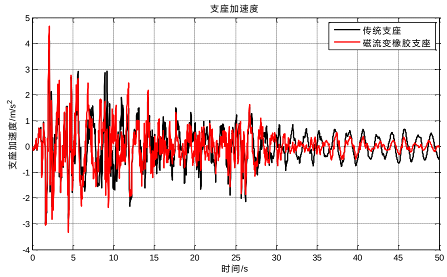


Fig. 7 Time history curve of the acceleration

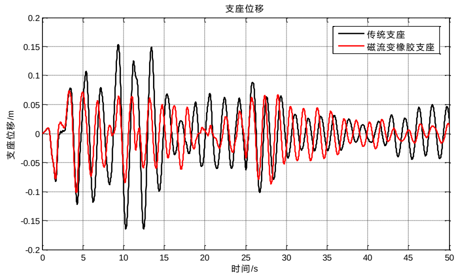


Fig.8 time history of bearing displacement

As shown in Figures 7, 8, compared with the traditional MRF bearing holder, both in acceleration and displacement have declined, indicating magnetorheological seat under the action of the moment an earthquake wave input by adjusting parameters bearing so that bearing shear stiffness is improved instantly change the overall mechanical properties of the bridge structure, the displacement of the bearing active control. Meanwhile, in the latter part of the role of seismic wave, which compared to conventional bearings have a better ability to make energy bridge structure is subjected to an impact energy has been dissipated quickly, showing good energy characteristics.

5. Conclusion

(1) The use of non-dimensional analysis based on similarity theory, deduced the true model system similar to the relationship between the bridge and the small model systems by simulation of the actual model and simulation model has similarities in acceleration and displacement.

(2) The holder of traditional magnetorheological pier abutment compared MRF bearing not only show itself has a traditional pier bearing function, while MRF seat can be adjusted according to the state of the earthquake itself stiffness, damping , showed a better isolation buffering capacity.

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