AN EXPERIMENTAL STUDY ON SEISMIC RESPONSE OF SKEW AND CURVED DECKS POUNDING WITH ABUTMENT

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1. INTRODUCTION

Skew and curved decks of highway bridges have fallen after the pinned and rocker bearings had fractured in the Kobe earthquake. Rubber bearings were then applied to eliminate such troubles, but bring the ability in largely moving for the deck. By allowing pounding, the small clearance has high capability on restraining the deck displacement and the pounding damage at deck ends and abutment. Although the time-dependent responses of pounding were in chaotic forms, their maximum responses clearly formed in a certain tendency during the different intensities of input excitations. The ratios among the clearance, the input intensity of earthquake and the maximum pounding response were verifiable steady. According to that such theoretical similarity, the prospecting equation by estimating absorbed energy at collision can be presented to approximate the damage of the abutments and the bridge deck end. To verify that similarity, the experimental study on seismic response of skew and curved decks pounding with abutment during earthquake excitation is presented in this paper, and their results satisfyingly agree with the computational one.

2. SKEW AND CURVED DECKS

When a center of rotation of deck is in the domain shown in Fig. 1, the deck can rotate without the restrain from the abutments during shaking. Generally, the clearance has to obtain the appropriated size in order to accommodate the length changes of the superstructure resulted by thermal, creep and shrinkage effects. But in the case of Fig.1, these problems can be ignored. Even though with zero clearance, the deck also can independently rotate without the restrain by abutments.

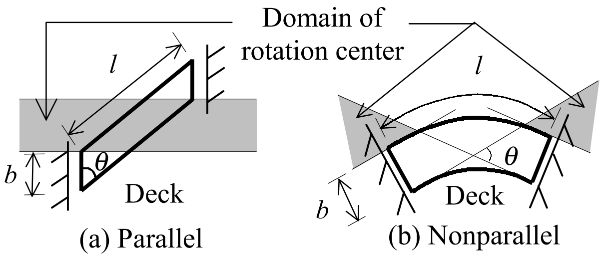

Fig.1 Domain of center around which the decks can rotate

When $x >= b$ the deck can rotate. If $x < b$ the deck can not rotate and be not considered in this paper. For skew deck $x = l\cos\theta$ and for curved deck $x = R\sin^2(\theta/2)$. Where x is the cosine value of deck length into the contact surface and b, l, θ, R are the width, length, angle and external radius of the decks respectively

3. EXPERIMENTAL PROCEDURES

The simple based isolative model Fig. 2 was transformed in the analytical model as in Fig. 3. The shaking table 0.40 m x 0.40 m was horizontally connected with ten tendril springs symmetrically in around four sites obtains 7 Hz and 3.5 Hz of natural frequencies excludes rotation and represented artificial ground excitation. The skew and curved decks ($\theta = 60°$, l=180mm, b=50mm) and ($\theta = 60°$, R=180mm, b=40mm), are connected with four springs which represented rubber bearings. The mass of decks were considered small and do not influence to excitation of shaking table.

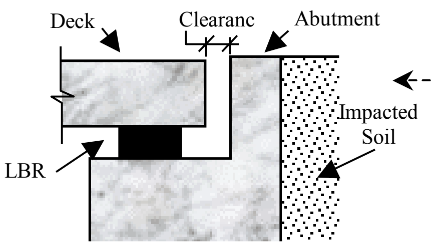

Fig. 2 Base Isolation

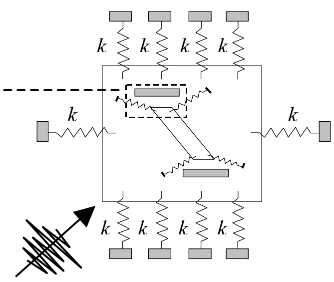

Fig. 3 Analytical model

Fig. 4 Ensemble of experiment

In Fig. 4, the table was gradually oscillated with primary displacements generated by one cutting of the string per each tensile pendulum. Each weighting obtains 20g increasing of gravitational tension. During 5 seconds of free vibration of the table, the seismic responses at a corner of the deck were transferred through a vibration transducer and recorded in a digital scope in every time interval 0.0005 second. The maximum responses of decks which depended on the intensity of input earthquakes were principally dealt, but the seismic responses depended on time histories were not.

Keywords: Skew and curved decks, pounding response, experiment, computational simulation, prospecting equation.

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4. EXPERIMENTAL RESULTS

Fig. 5 is a sample picked from computational results and computed from the real model with a curved deck ($\theta=30°$, l=100m, b=10m) with the clearances (ε_v) 0cm, 1cm and 5cm, generated by Kobe earthquake. In the graphs it can be clearly seen that, the responses from 1cm and 5cm obtain similar forms and almost differ five times of maximum responses. But the 0cm one obtains the particular form and fluctuates in some input intensities, however it almost reaches zero value. Although the response is complex, the relations among the clearance, the input intensity and the response can be written by the linear assumption of impact model as:

$$\varepsilon_{v1} : I_1 : O_1 = \varepsilon_{v2} : I_2 : O_2 \tag{1}$$

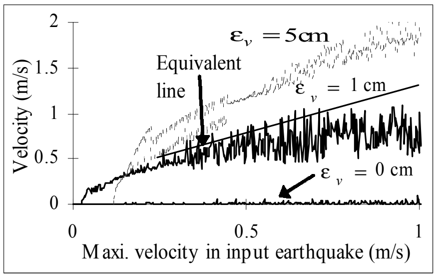

Fig. 5 Computational results

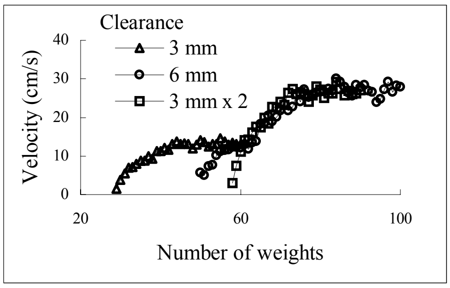

Fig. 6 Experimental results

Fig. 6 shows the results from the experimental one of skew deck with clearance 3mm and 6mm. The graphs demonstrate the similar forms as the computational results. To clarify the similarity, the responses with 3 mm clearance were duplicated. The result is that, the tendency of duplicated values almost agrees with the responses of 6 mm clearance and can sufficiently confirm the preciseness of the linear assumption in the computational results.

5. EVALUATION OF MAXIMUM POUNDING RESPONSE

By the properties and geometries of the contact surfaces, thus: $\dot{x}_+ = v\,\dot{x}_-$. Where $\dot{x}_-$, $\dot{x}_+$ are the velocities before and after impact. In Eq. (2), r is the radius of gyration of deck. e_f, e_r are coefficients of friction and restitution. x_P, y_P, l_P are coordinates and distant to contact point. α is the impact angle. The difference between the strain energy in no pounding and the strain energy of the response with the clearance Δ can be written as in Eq. (3). S_D is the value of linear response specttrum, n is the natural circular frequency in no pounding. Hence, the impact velocity can be obtained.

$$v = 1 + \frac{(r^2 + x_P^2)(e_f \cos^2\alpha - e_r \sin^2\alpha - 1) + x_P y_P (e_f + e_r)\sin\alpha\cos\alpha}{r^2 + l_P^2} \tag{2}$$

$$\frac{1}{2}kS_D^2 - \frac{1}{2}k\Delta^2 = 2\left(\frac{1}{2}M\dot{x}_-^2 - \frac{1}{2}M\dot{x}_+^2\right) \tag{3}$$

$$\dot{x}_- = n\sqrt{\frac{S_D^2 - \Delta^2}{2(1-v^2)}} \tag{4}$$

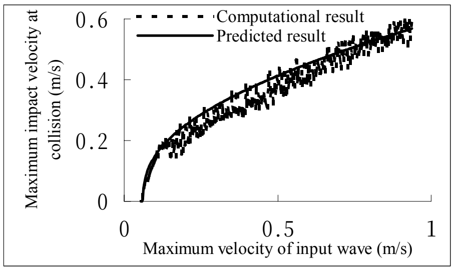

Fig. 7 Results of prediction

Fig. 7 shows the comparisons between the computational and predicted results of skew deck (l = 100 m, b = 10 m and θ = 60 degree). It can be seen from the graphs that the predicted results sufficiently agree to the computational one. By the linear relations among the clearance, the input intensity of earthquake and the maximum response in pounding can be simply approximated.

6. CONCLUSIONS

The experiment results qualitatively verified the results of computational one. The smallest response can be obtained for very small clearance. The deck geometries can provide the possibility in applying zero clearance. Enlarging the clearance is not economical and disturbs the traffic on the deck. Furthermore, some influent factors such the restitution, the friction, structural free vibration etc., cannot improve much on reduction of the maximum impact velocities which represented the pounding forces, but just effect on the deck displacements which represented the bearing deformations. The responses of these parameters will be displayed in the presentation day.

In order to evaluate the maximum impact responses, the predicting equation by estimating absorbed energy at collision significantly leaded by clearance and input velocity of earthquake wave was offered.

7. REFERENCE

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