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Dynamic response analysis of ship-bridge collisions experiment

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Key words:

Scaled model test; ship collisions; impact force; wavelet packet analysis; energy distribution

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Introduction

- Accidents resulting from ship-bridge collisions occur more frequently along waterways close to these bridges.
- It is necessary to accurately predict the dynamic response of the bridge structure and adequately design the bridge structure to resist the impact load.



The accident of ship-bridge collisions

Experimental Procedures

This paper takes the non-navigable span of a sea-crossing bridge in Zhejiang Province as the engineering background to carry out scaled model experiments and established a precise FEM

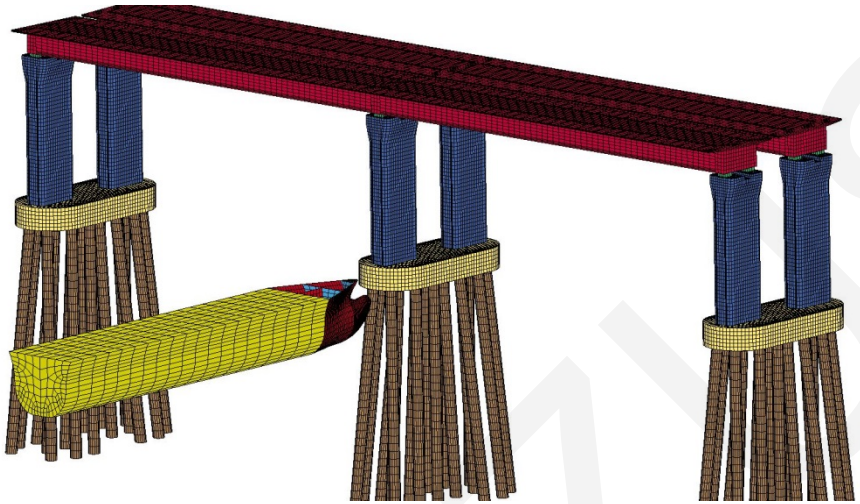

Fig. 1. Full scale FE model

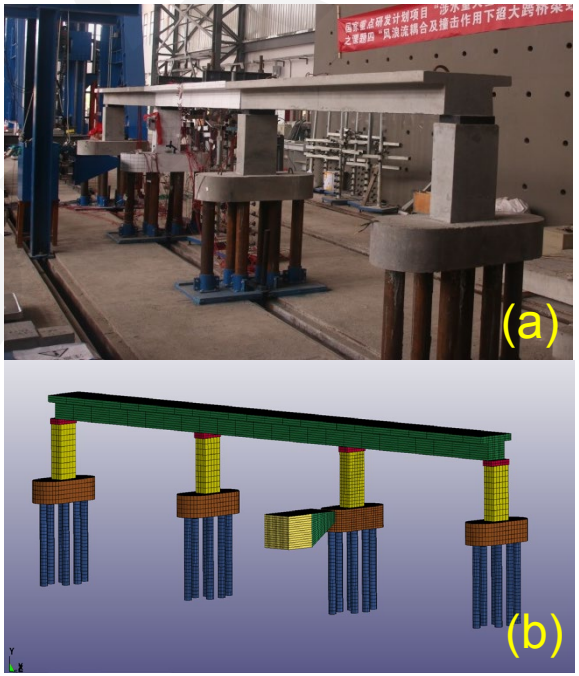

Fig. 2. (a) Layout of the impact test; (b) FE model

Cite Fig.1 as: Guo, J., Zheng, Y.F., and Song, S.Y.(2019), Study on Fluid-Solid Coupling of Ship Impact Bridge Considering Tide Level Change. *Bridge Construction* 49(06):24-29 (in Chinese).

Experimental results and analysis

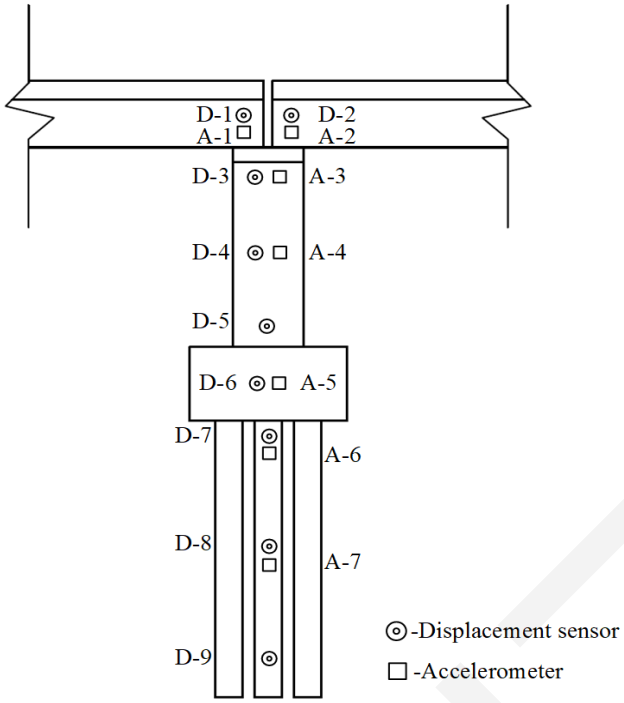

Fig.3. Sensors Layout

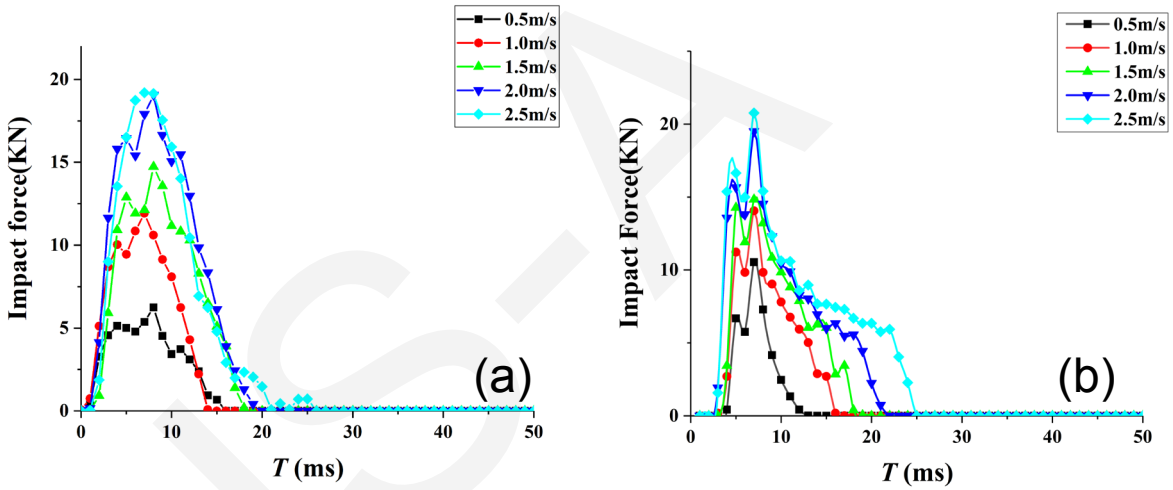

Fig. 4. Force time history data for Cup series; (a) experimental results; (b) FE results

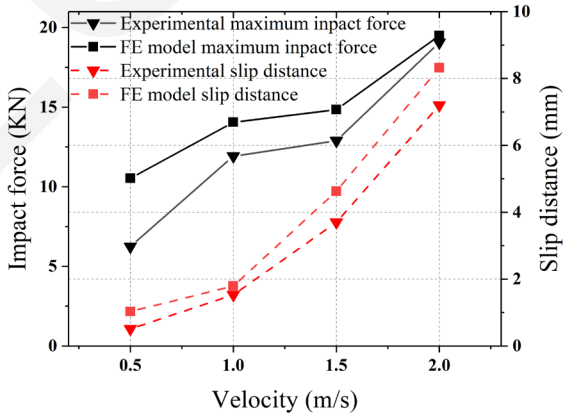

Fig. 5 Slip distance between beam and rubber bearing

Experimental results and analysis

Wavelet packet theory

The expression of discrete wavelet packet:

$$S(t) = \sum_{j=0}^{2^n-1} f_{n,j}(t_j) = f_{n,0}(t_0) + f_{n,1}(t_1) + \cdots\cdots + f_{n,j}(t_j)$$

original signal

restructure signal

The energy of the signal component in layer n is defined as:

$$E_{i,j}(t_j) = \int_T |f_{i,j}(t_j)|^2 dt = \sum_{k=1}^{m} |x_{j,k}|^2$$

the energy of the wavelet packet band at the j node of layer i

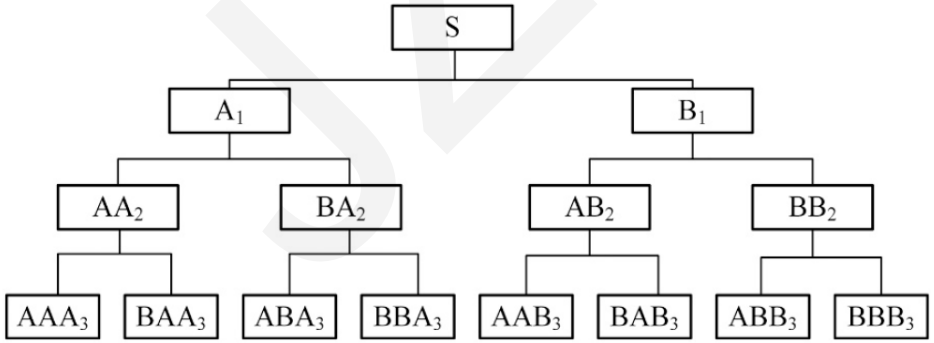

Fig. 6 Schematic diagram of wavelet packet

Experimental results and analysis

Table 4 The percentage of first 8 bands of wavelet packet decomposition.

Band	1	2	3	4	5	6	7	8
Frequency domain	0~	31.25~	62.5~	93.75~	125.0~	156.25~	187.5~	218.75~
(Hz)	31.25	62.5	93.75	125.0	156.25	187.5	218.75	250.0
Percentage (Cap)	55.63	30.64	2.76	0.84	0.34	0.92	1.27	3.25
Percentage (Pier)	50.56	22.47	4.87	1.06	0.24	0.23	0.10	1.09
Percentage (Force)	76.04	19.90	1.97	0.83	0.40	0.16	0.18	0.24

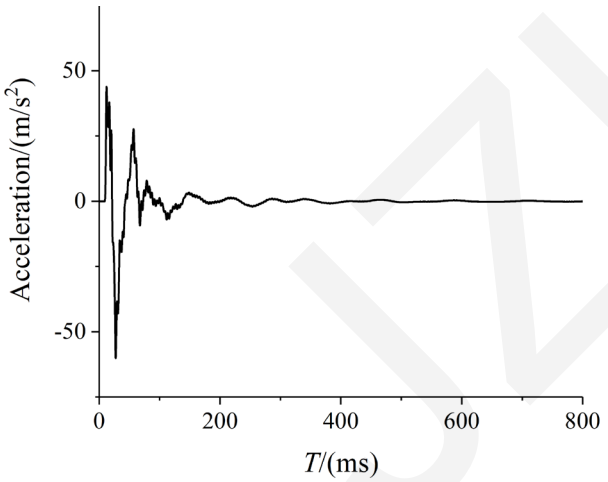

Fig. 7. Acceleration signal of cap.

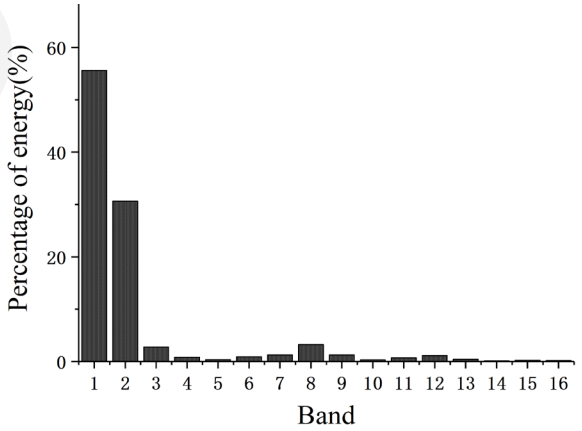

Fig. 8. The percentage of each frequency band

Conclusions

- The response of ship collision test with different impact velocities was compared and analyzed. The results show that the impact force can be explained in two stages: the rising stage and the plastic range. In the first stage, the impact force rises abruptly to its maximum. During the second stage, the impact force decreases due to the plastic deformation of the bow.
- A particular phenomenon that was generally ignored has been observed in the test. It is the relative displacement between the beam and pier due to the transverse inertial force. The maximum displacement in this experiment was 8.32 mm. In bridge design, the possibility of unseating superstructures should be considered after the pier is impacted.
- During the ship-bridge collision, the ship absorbed most of the energy due to the deformation of the bow, which is more than 80% of the total energy. For bridge structures, most of the energy was concentrated on the deformation of the pile foundation and support.
- Based on the analysis of the wavelet packet, it was observed that the energy absorbed by the test bridge structure was mainly concentrated in the low-frequency band, in which the first two natural frequencies of the structure were located. The analysis can provide a reference for structural damage identification and bridge design.