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AN IN-SITU EXPERIMENT OF F-BENT DOUBLE DECKED FREEWAY BRIDGE

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ABSTRACT

In order to overcome the insufficient bearing capacity of soil due to the special geological condition, the F-bent double decked bridge column, which carries both the north- and south-bound traffic loadings simultaneously, was used as a part of the extension system of the northern national highway No.1 in Taiwan. As the bridge column may be influenced increasingly by the heavy dead loading caused by the high bridge columns and the long-term eccentric effect, the F-bent double decked bridge system was carefully monitored and examined. Ambient vibration, static loading test, and dynamic truck loading test were carried out to verify the dynamic characteristic of the bridge system.

For the purpose of long-term health monitoring on the new-constructed bridge, a finite element model was then establish, and the loading combinations executed in the in-situ experiment were analyzed numerically and compared with the collected data. The results have shown that the measured response of the bridge can be estimated reliably by the calibrated finite element model. By utilizing the deployed on-site health monitoring system and its corresponding numerical model, the safety of this special bridge can be protected.

Keywords: double decked bridge, health monitoring, truck loading test, finite element analysis

1. INTRODUCTION

For the insufficient bearing capacity due to the special geological composition observed in the east side of the northern national highway No.1 between mileage 37K＋500 and 40K＋000, the F-bent double decked bridge column was utilized to carry both bound traffic flows where the north bound lane was arranged on the top deck, and the south bound lane was located on the bottom. Due to the special design concept of double decks and super elevated column, the bridge system is prone to suffer long-term eccentric effect caused by the heavy self weight. As a result, stress concentration

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phenomenon may be observed in the substructure. In order to reduce the self weight of the bridge system, box girder was adopted as the main member of the superstructure, and rectangular reinforced column was used in the substructure as shown in Figure 1.

Figure 1 the F-bent double decked bridge column

2. IN-SITUEXPERIMENT OF THE F-BENT DOUBLE DECKED FREEWAY BRIDGE

2.1. Shaker test

In order to estimate the natural frequency (period) of practical bridges, ambient vibration or shaker tests are commonly adopted. As the measurement precision depends on the experimental condition of ambient vibration test largely, the shaker test was conducted in this study. Its basic theory is that by applying a sinusoidal wave of specific frequency, the velocity response of the bridge in the transverse direction can be easily excited and measured. As resonant phenomenon can be observed when the applied frequency coincides the modal frequencies of the bridge, significant amplification of the velocity response can be expected. The actual modal frequencies of the bridge can then be identified. The layout of the shaker test including the shaker and high-resolution velocity meters are shown in Figures 2 to 4.

The velocity spectrum calculated from the deployed velocity meters is shown in Figure 5 where similar trend can be found on each sensors. The individual frequency corresponding to each peak value was checked carefully to confirm if it represents the natural frequency of the structure. The obtained natural frequency in the transverse direction is listed in Table 1.

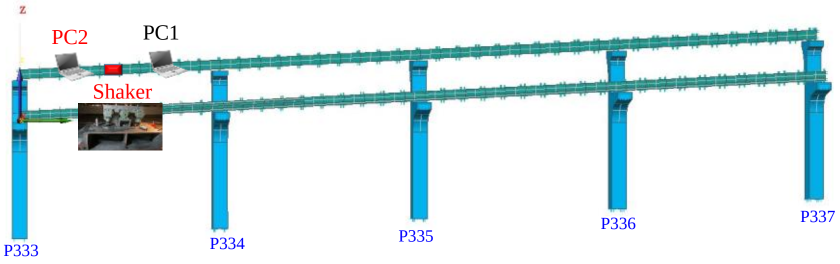


Figure 2 Position of the shaker

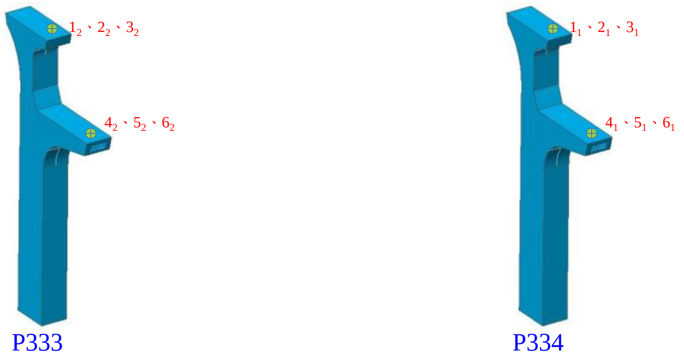


Figure 3 Deployment of velocity meters on the bridge pier

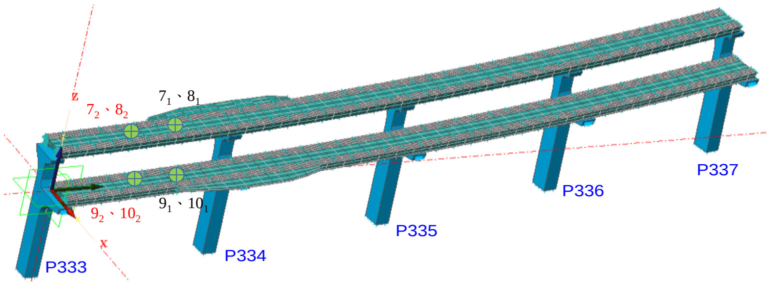


Figure 4 Deployment of velocity meters on the bridge deck

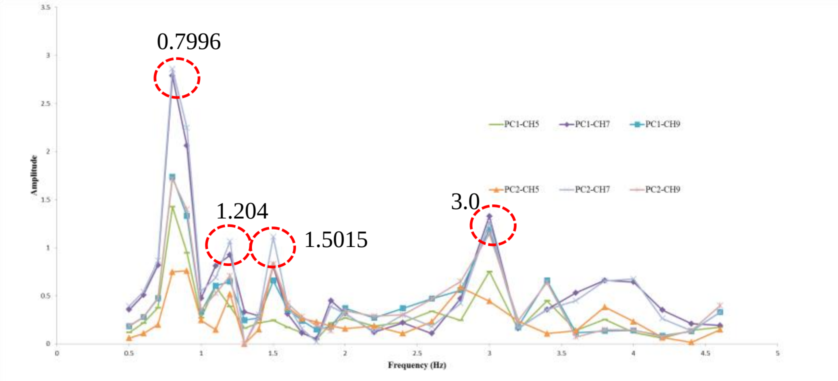


Figure 5 Spectra measured from different velocity meters

Table1 The identified natual frequencies in the transverse direction

Natural Frequency (Hz)	0.7996
	1.2040
	1.5015
	3.0000

2.2. Static Truck Loading Test

The static truck loading test was conducted on the north- and south-bound three-lane decks between Pier 333 and 335 where the length of each section (P333-P334, P334-P335) is 55 meters. In order to reach the critical loading of 240 tons designed in the experiment, 12 trucks occupied with 20 tons each were deployed. The experimental schedule is shown in Table 2.

The deformation of the bridge deck was measured through leveling and laser range finder. As shown in Figure 6, deflections of the mid- span points between piers P333, P334 and P335 and the quarter point between P334 and P335 were observed. The numbering used in the leveling is listed in Figures 7 and 8 to check the variation in each case.

Table 2 The experimental schedule of the static truck loading test

Case1- Uniform loading on the left side of the top and bottom decks (4 trucks)
Case2- Uniform loading on the right side of the top and bottom decks (4 trucks)
Case3- Uniform loading on the top and bottom decks (8 trucks)
Case4- Uniform loading on the left side of the top and bottom decks (12 trucks)
Case5- Uniform loading on the right side of the top and bottom decks (12 trucks)
Case6-Torsional experiment(12 trucks)
Case7-Eccentric loading on the right side of the top and bottom decks (12 trucks)

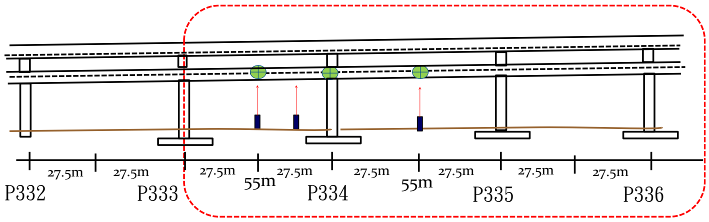
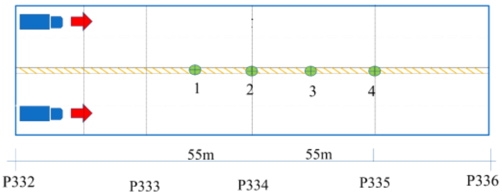


Figure 6 the position of laser range finder



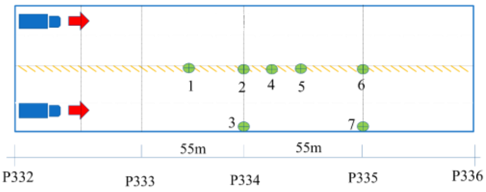


Figure 7 Sensing modes of the top deck for leveling

Figure 8 Sensing modes of the bottom deck for leveling

2.3. Dynamic Loading Test

The dynamic loading test was conducted by using moving vehicle with constant speed of 20 km/hr, 40 km/hr, and 60 km/hr, respectively. The instrumentation layout on both decks for the dynamic loading test is shown in Figure 9 where the velocity meters were deployed in both directions.

According to the experimental schedule, two trucks of 20ton each were arranged to move in parallel, and the induced velocity response of the deck was recorded. The vertical velocity response of point 2 with the truck speed of 20 km/hr is shown in Figure 10. It is found that the velocity increased significantly when the truck entered the measurement area and then decreased with phenomenon similar to free vibration.

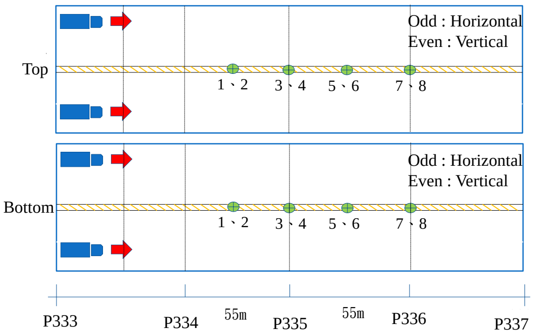


Figure 9 The instrumentation layout on both decks

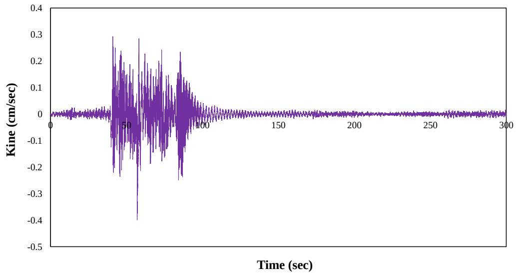


Figure 10 The vertical velocity response of point 2

3. ESTABLISHMENT OF NUMERICAL MODEL AND VERIFICATION

In order to capture the practical behavior of the F-bent double decked bridge, a numerical model was established by software Midas Fx+ based on the actual structural characteristic. The model was then integrated with Midas Civil for time history analysis. The deformation and internal force can be easily evaluated through the numerical model proposed.

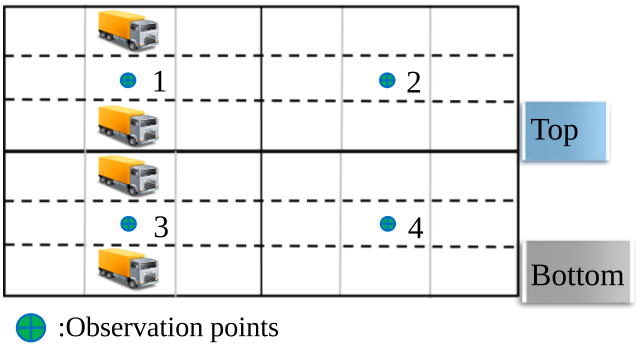
3.1. Comparison on modal frequency with the result from forced vibration

The loading and mass were applied on the joints of the numerical model in Midas Civil to represent the practical bridge. Due to the complex behavior of the whole bridge, totally 70 modes were considered in the numerical analysis. The first three modal frequencies obtained from the numerical model in the transverse direction are 0.8053 Hz, 1.077 Hz, and 2.9623 Hz, respectively where the results from experiment are 0.7996 Hz, 1.204 Hz, and 3.0 Hz. As only a slight difference exists in the4 second mode, the performance of the numerical model is acceptable.

3.2. Simulation and Analysis of Static Loading Test

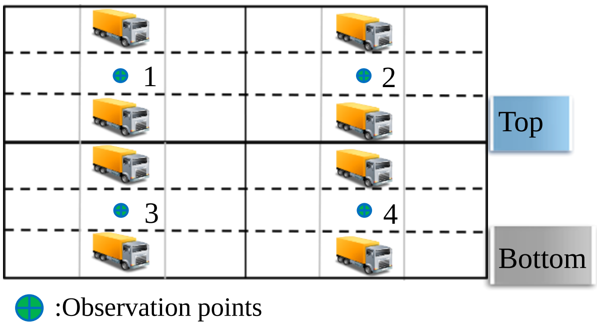
The numerical simulation was executed following the loading combination, and the analysis result was compared with the experimental deformation. As mention above, two measurement methods including the laser range finder and leveling were applied. Due to the restriction of the on-site condition, the leveling was only applied to the upper deck while both methods were used in the bottom deck. The result is shown in Tables 3 and 4 to prove that the stiffness of the bridge system can be precisely evaluated by the numerical model, which will be used in the following simulation on dynamic loading test.

Table 3 Case 1 Numerical analysis and experimental result of the static loading test



Observation points	Experimental	Laser Experimental	Analysis
1	0.31 cm		0.479 cm
2	0.25 cm		0.140 cm
3	0.45 cm	0.4 cm	0.503 cm
4	0.16 cm	0.1 cm	0.123 cm

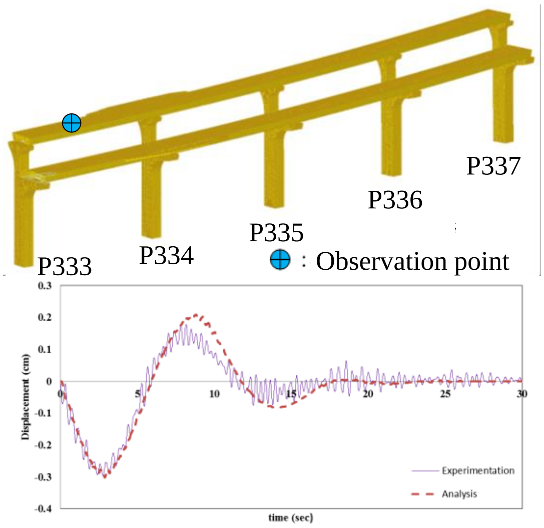
Table 4 Case 3 Numerical analysis and experimental result of the static loading test



Observation points	Experimental	Laser Experimental	Analysis
1	0.24 cm		0.339 cm
2	0.19 cm		0.247 cm
3	0.44 cm	0.2 cm	0. 379 cm
4	0.37 cm	0.1 cm	0.275 cm

3.3. Simulation and Analysis of Dynamic Loading Test

As the numerical model established from the static loading test has been verified for it accuracy and adaptability, it is further applied to analyze the dynamic loading test. The velocity response recorded during the experiment was first integrated into displacement for better comparison. A designated digital filter was also applied to avoid the possible interference from environmental noise. The displacements of the midpoint between piers P333 and P334 under the vehicle velocity 20 km/hr, 40 km/hr, and 60 km/hr was observed and compared as those from numerical analysis as shown from Figures 11 to 12. The compatible results have demonstrated that the practical behavior of the F-bent double decked freeway bridge can be predicted by the numerical model successfully.



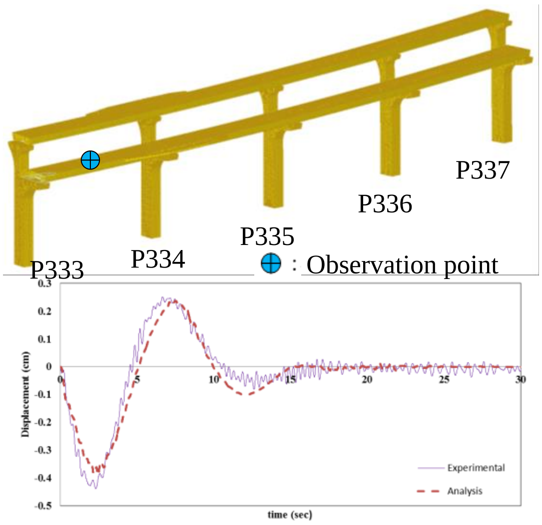
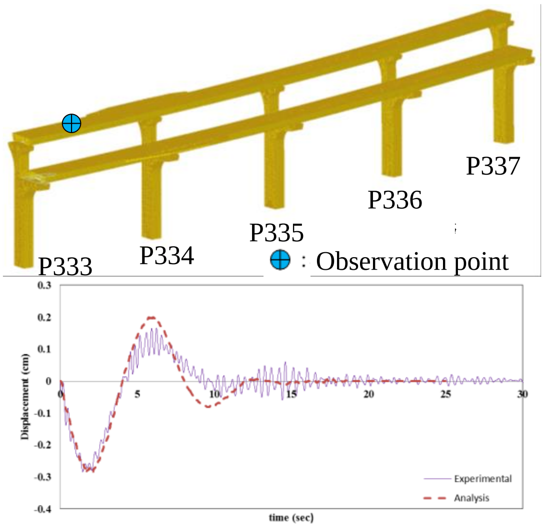


Figure 11 Comparison of the midpoint of upper deck under truck velocity 40 km/hr

Figure 12 Comparison of the midpoint of bottom deck under truck velocity 40 km/hr



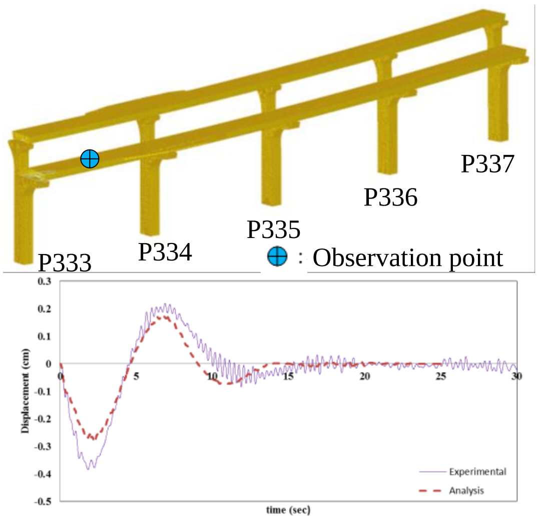


Figure 13 Comparison of the midpoint of upper deck under truck velocity 60 km/hr

Figure 14 Comparison of the midpoint of bottom deck under truck velocity 60 km/hr

4. CONCLUSIONS

Accompany with the establishment of the numerical model, a series of experiments including the forced vibration, static loading, and dynamic loading tests was conducted between piers P333 and P337 of a F-bent double decked freeway bridge. The collected data were used to verify the applicability of the numerical model, and some concluding remarks are listed as follows:

1. Based on the forced vibration result, the fundamental frequencies can be reliably estimated by the numerical model to reflect the basic vibration characteristic of the bridge
2. Totally 7 cases were arranged in the static loading test where the deformation of the upper deck was measured by leveling, and the deformation of the bottom deck was achieved by both leveling and laser range finder. As shown in table 3 and 4, the practical stiffness can be estimated successfully.
3. Two trucks in parallel with the velocity of 40 km/h and 60 km/h were used to conduct the dynamic loading test, and the repose of the bridge was collected by high-resolution velocity meters. The velocity response was first integrated into displacement, and a designated digital filter was also applied to avoid the possible interference from environmental noise. As shown in Figures 11 to 14, the reliability of the numerical model has been verified through the three experiments conducted.

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