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COMPARISON BETWEEN STATIC AND DYNAMIC LOAD TEST APPLIED TO A STEEL-CONCRETE MIXED BRIDGE STRUCTURE

Maíra Rolla Campos

mairarc7@gmail.com

Centro Federal de Educação Tecnológica de Minas Gerais

Av. Amazonas, 7675 - Belo Horizonte, CEP 30510-000, Minas Gerais, Brasil

Clarissa Rafaela Pinto

clarissa.rafaelap@gmail.com

Universidade Federal de Viçosa

Av. P.H. Rolfs, Viçosa, CEP 36570-000, Minas Gerais, Brasil

Cláudio José Martins

cjmartins@civil.cefetmg.br

Centro Federal de Educação Tecnológica de Minas Gerais

Av. Amazonas, 7675 - Belo Horizonte, CEP 30510-000, Minas Gerais, Brasil

Abstract. *This paper introduces the results of a dynamic load test and its validation through a comparison with a static load test, both applied on a bridge over the Sebiu river localized between the cities of Sebiu and Bintulu, on the province of Serawak, Malaysia. The comparison of the results was made by simulating the static load test in a numerical model created with the experimental modal parameters obtained with the dynamic load test. The comparison of the deflections results for both methods showed a small difference (1,2mm) in relation to the size of the structure and the maximum deformation of the span in study. Additionally, both test allow to infer that the structure in study showed a good performance and a satisfactory level of security.*

Key Words: *Dynamic load test; Operational modal analysis; Static load test; Vibration analysis of mixed bridges.*

INTRODUCTION

The Civil Engineering structures are solicited by different types of loads, that can induce behaviours defined by the static and/or the dynamic response of the structure. The loads that have a static response, are constant throughout time, while the dynamic load will vary in amplitude and/or position (MENDES, 2012).

There are some structures in which considering the dynamic effects of loads is fundamental, such as bridges, especially due to the traffic and wind loads (PEETERS, 2000).

The modal analysis is a method capable of evaluate the dynamic characterises of a structure with data from experimental testing. These characteristics are described by the group of vibration modes and respective natural frequencies and damping ration (RODRIGUES, 2004).

Due to the dimension of most civil structures, it is not always possible the use of vibrators or impulse application systems to excite the structure. These excitation equipment would need to be of a substantial sizes, thus expensive and difficult to use. Because of this, a convenient alternative is to use the new analysis method that does not use the input data, but the response of the system to the loads that the system is being submitted to (wind, traffic, among others) (TAVARES, 2014).

In most cases for an operational modal analysis, as there is no control in the excitation forces, the response due to the ambient loads can be extremely low, making necessary the use of equipment with great sensibility, capable of measuring and registering low amplitudes and structural movements. The response measuring tests to ambient loads covers a large amount of information, requiring a method of calculus to process the data (RODRIGUES, 2004).

The structure's modelling is normally developed in a software based on the Finite Element Method, a method that is being useful to solve many Engineering problems such as the one in study (CUNHA & CAETANO, 2006).

With the objective of validating the operational modal analysis as an efficient technique to structural characterizing of mixed steel-concrete bridges, this article introduces the results of the comparison between a dynamic test (based on the operational modal analysis) and the static load test applied to a bridge localized in a road between the cities of Sebiu e Bintulu, in the province of Serawak in Malaysia. The second item in this document describes the geometry and mechanical properties of the structure in study, the numerical model used in the comparison of the results and the static and dynamic tests. On the third item it is shown the comparison that was made between the tests followed by the conclusions of this study in the fourth item of this document.

1. DESCRIPTION OF THE STATIC AND DYNAMIC TESTS OF THE BRIDGE

1.1 Description of the Bridge

The bridge is composed of three spams with a total length of 57,6m. The structure consists of a mixed system with steel beams and a reinforced concrete deck. The Figures 1 and 2 shows images referent to the bridge.

Figure 1. Bridge over the Sebiu river

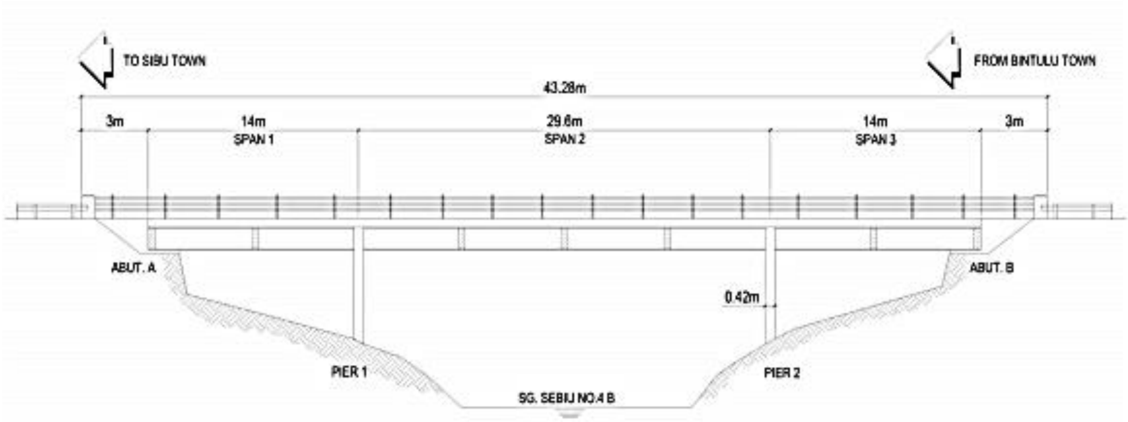

Figure 2. Elevation of the bridge

1.2 Static Test

To perform the static test, trucks were used with a total weigh of 628,90 KN, distributed through it axes. The trucks were positioned with the intention to measure bending, shear and deflections.

The test was planned in two stages, using two different load positions on the bridge. In the first stage, four test vehicles were positioned over the spams 2 and 3 with the objective to measure the maximum negative moment in the pier 2 (Fig. 3), while in the second stage, two test vehicles were positioned over the spam 3 to measure the vertical deflection (Fig. 4)

The spam 3 was selected to measure the bending due to the following factors: the accessibility over the amplitude was easier than the spam 2, and as the river runs through spam 2 and the cost of a temporary platform for the spam 3 would be lower.

The following Table 1shows the results of the deflections found in each point where the steel beams are positioned (Points B1, B2, B3 e B4, Fig. 5).

Table 1. Maximum deflections in the spam 3 for each beam

Load Level	Total Weight (KN)	B1 (mm)	B2 (mm)	B3 (mm)	B4 (mm)
3	628,9	-4,91	-4,71	-2,12	-0,23

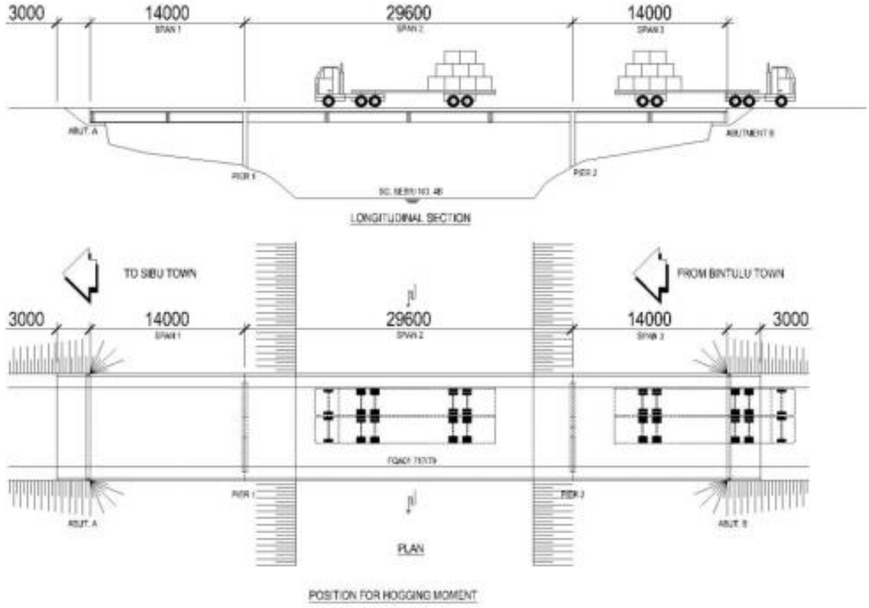

Figure 3. Position of the vehicles to simulate the effect of the moment in the pier 2 (measures in mm)

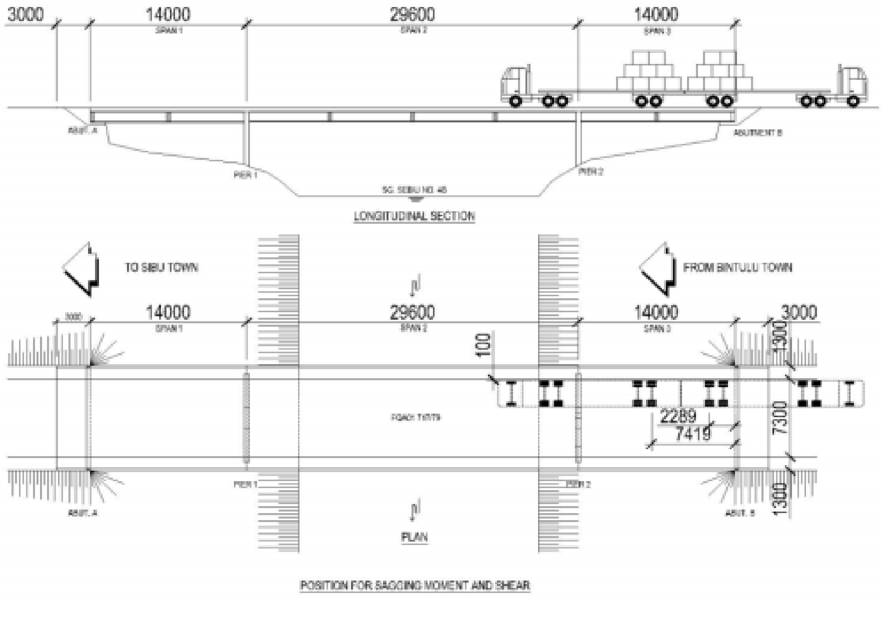

Figure 4. Position of the vehicles to simulate the effects of deflection in the spam 3 (measures in mm)

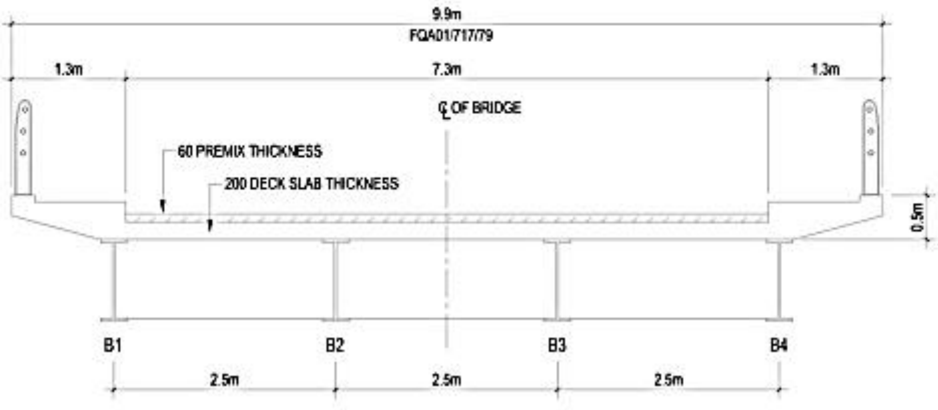

Figure 5. Cross section of the bridge

1.3 Dynamic test

The dynamic load test was made with the natural vibrations caused by wind and traffic, therefore without producing artificial excitations. Six independent measurements were made on the side of the principal platform, to not interrupt the traffic.

The Fig. 6 shows the accelerometers positioned over the bridge's deck and the Fig. 7 shows the measuring positions along the structure. The points S1, P1, S2, R8, P2 and S3 represent the positions where the accelerometers were placed to make the measurement. The nomenclature was defined to facilitate the study.

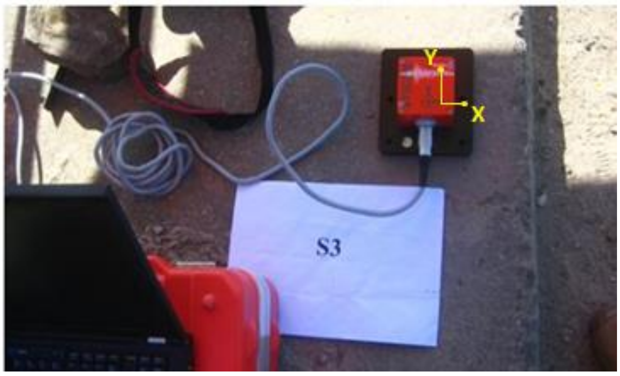

Figure 6. Accelerometers over the bridge

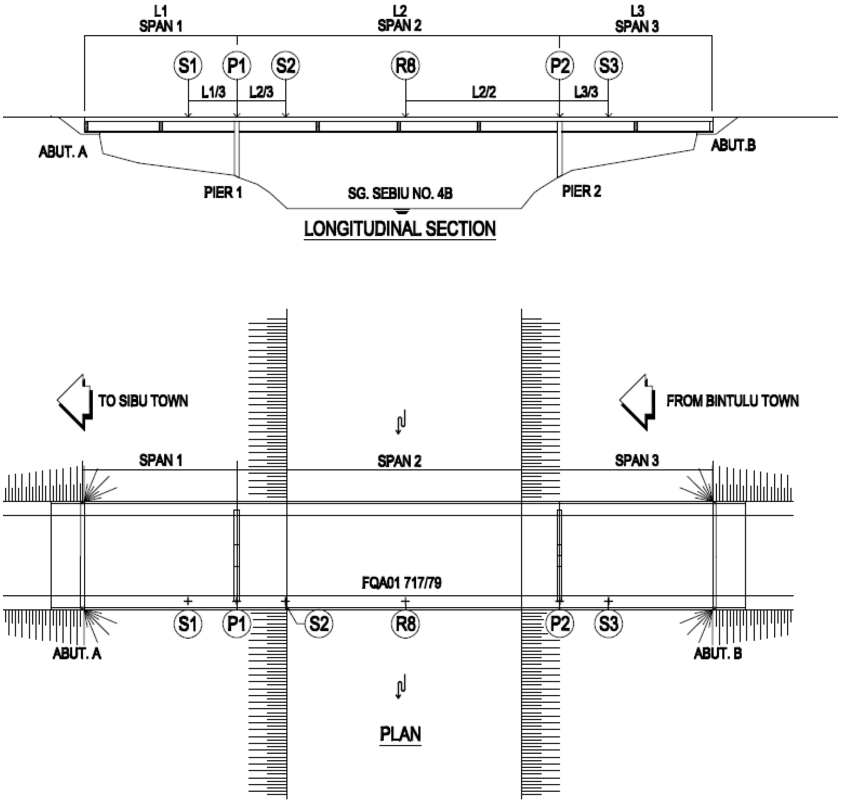

Figure 7. Measuring positions of the bridge

The data processing was made with the records of the accelerations in time for the six points indicated in the Fig. 7. To extract the modal parameters, it was determined the spectral density matrix for each six positions, according the Fig. 8.

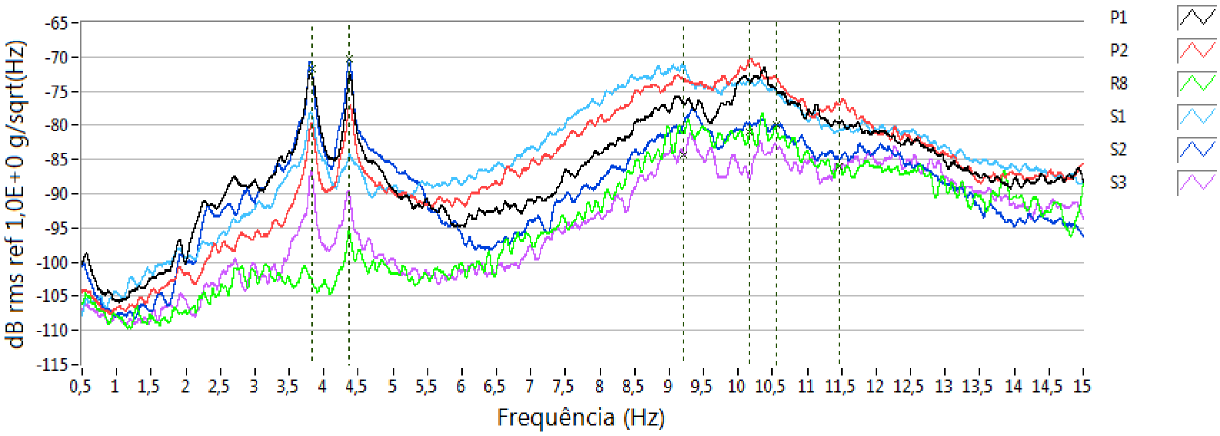

Figure 8. Spectral density matrix for each six position

The natural frequencies and damping presented in Table 2 were obtained through the frequency domain decomposition technique.

Table 2. Field modal parameters

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Frequencies (Hz)	38.303	436.802	9.289	10.150	105.527	114.629
Damping (%)	0.8311	0.3536	0.18078	0.26077	0.1793	0.113

1.4 Numerical Model

According to the available documents, a finite element model of the structure was created in the software SAP2000.

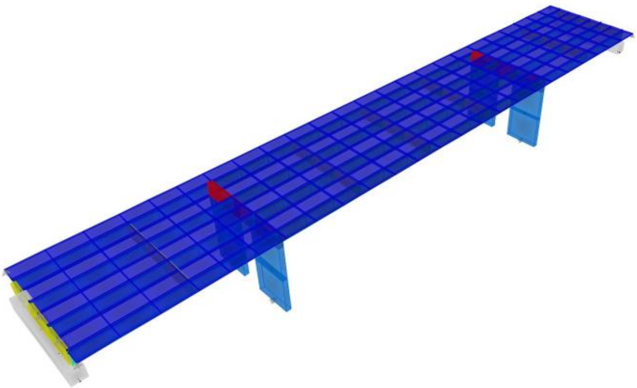

Figure 9. 3D view of the numerical model

1.5 Adjustment of the model

This phase of the analysis constituted on the adjustment of the model until modes and proper values calculated were similar to those measured in the field. The adjustment was achieved by changing the calculated values until it converges to the measured values. The numerical model was simulated for all the structural changes done in every attempt. First the stiffness of the foundation elements were changes. Followed by that, the stiffness of the supporting elements of the deck were changed. Finally, the moment of inertia of the piers and beams were altered. For every modification, it was evaluated the modal parameters and after many modifications it was obtained the errors of these parameters compared to the experimental.

The Table 3 contains the final results of this procedure. The obtained model is considered adjusted and will be used in the validation of the dynamic load test, as the errors associate to the natural frequencies are at a maximum 5% and, because of this, it is able to be used in the structural analysis.

Table 3. Natural frequencies of the adapted model (Hz)

Mode	Experimental values	Values from the adapted moel	Error (%)
1	38.303	3.807	0.79%
2	436.802	4.190	3.91%
3	9.289	9.143	1.58%
4	10.150	9.762	3.82%
5	105.527	10.625	0.74%

The validated model indicates that the maximum vertical deflection was 37 mm, corresponding to a deflection of L/783, which is in accord to the limits of the BS5400-2 (Standard code of practice for concrete and steel in force in the country).

2. COMPARISON BETWEEN THE STATIC AND DYNAMIC TESTS FOR THE BRIGE IN STUDY

It was compared the results of maximum deflection for the second stage, measured in each beam of the deck in spam 3 (the static test only provided these data), with the result of the numerical model as indicate in the Fig. 10. Thus, only the values of the maximum deflection (-4,91 mm) of the static test, over the most solicitated beam, was compared with the one showed in Fig. 10 (-6,13).

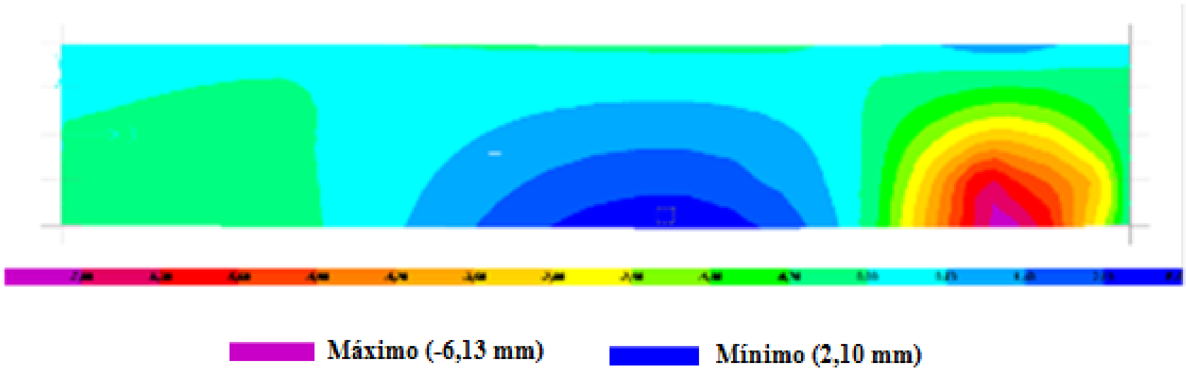

Figure 10 – Maximum deflection for the spam 3 with the 628,90KN load

Comparing these two values, it is observed a difference of 1,22mm (20% of difference in relation to the numerical value). Regarding the safety condition of the structure, it is observed that both tests indicate that the structure has a satisfactory structural and safety performance and that the dynamic load test provided similar results to the static load test, thus, being able to be used in the structural evaluation of this type of structures.

Regarding the experimental methodology of the dynamic test to define the modal parameters that characterize the structure of the bridge, it is possible to say that it is extremely practical and reasonably precise, since the experimental parameters shown are close to those in the computational model.

3. CONCLUSION

Despite not being largely reported in the technical and scientific sector of the construction, there is a growing interest in the validation of the experimental analysis of the dynamic characteristics of bridges through the modal analysis, especially because it allows the structural integrity monitoring an evaluation of these structures without the necessity of introducing restriction in their use and enabling a precise evaluation of the safety conditions, and in order to help the development of a program suited to the maintenance of these constructions.

It has been presented the adopted procedures and the obtained results of the static and dynamic test that were made in the bridge localized between the Sebiu and Bintulu, on the province of Serawak, Malaysia. Through these tests it was possible to simulate the loads for the static load test acting in the adapted model that was obtained by the dynamic load test.

The comparison between the maximum deflection results for both methods showed a difference of 1,22mm for the spam in study (20% in relation to the numerical simulation). It is possible to conclude that the dynamic load test is adequate to the structural evaluation, as the values are not expressive analysing the deflections of a structure with such size and considering the inaccuracy of both methods. Furthermore, both tests allow to infer that the structure has a good performance and acceptable safety.

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