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EXPERIMENTAL TESTES OF IMBABA RAILWAY BRIDGE

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ملخص البحث:

تم تصميم جسور السكك الحديدية في مصر في الماضي لتعمل بشكل صحيح في ظل سيناريو تحميل محدد وظروف بيئية. لكن السيناريو الفعلي الذي يتعرض له الجسر يختلف تمامًا عما هو مصمم له. ذلك بسبب وجود الكثير من أوجه عدم اليقين في الحمولة القادمة على الهيكل وهناك دائمًا احتمال انهيار الهيكل تحت الحمل الديناميكي. تم إجراء اختبار ثابت وديناميكي لدراسة أداء جسر سكة حديد إمبابة على نهر النيل بمحافظة القاهرة في ظل اختبار ثابت وديناميكي ، وكذلك ، استخراج المعاملات المشروطه (النمط ، التخميد ، والتردد الطبيعي).

ABSTRACT :

The Railway Bridges in Egypt are designed at the past to perform properly under a definite loading scenario and environmental conditions. But the actual scenario to which a bridge is exposed is quite different than it is designed for. It is because there are lot of uncertainties in load coming over the structure and there is always a possibility for collapse of the structure under dynamic load. The static and dynamic test was carried out to study the performance of the Imbaba Railway Bridge over Nile River in Cairo governorate under ststic and dynamic test, also, extract modal parameter (mode shape, damping, and natural frequency).

KEYWORDS - *Imbaba Railway Bridge, Mode shape, tri-axial accelerometer, Field test.*

I. INTRODUCTION

The vast majority of Egypt’s railway bridges were built more than 100 years ago. Hence, many bridges are subjected to loads far higher than those envisaged during design. Also, due to insufficient investment in bridge maintenance, many of the existing railway bridges have significantly deteriorated over their years of service. The enlargement of the Egyptian Community and the continuous growth of its economy, have led to an increase in traffic loads and speeds on its railway lines, a trend that is expected to continue into the foreseeable future. Therefore, it is of vital importance to ensure that the existing railway network and its bridges, which form its critical links, can still provide adequate levels of safety. The performance of a steel truss bridge under dynamic testing. The researcher used the electromagnetic shakers to produce the excitation and obtained8 the natural frequency, mode shapes and damping ratios of the bridge. Furthermore, the researcher used the modal assurance criterion to back up the findings 0. Strain gages used for monitoring Soerstrom Bridge in central Stockholm to find out remaining fatigue life of stringers and cross beams. Also, explored differences between the theoretical strain values and the obtained field strain data in the predicting the damage of bridge members 0. The dynamic responses of the bridge located on the high-speed railway line between Paris and Brussels have been investigated experimentally 0. The deflections, the accelerations and the strains were measured by a laser velocity displacement transducer accelerometers and strain gauges, respectively. Many useful results have been obtained and reported from the analysis of the recorded data 0.

II. BRIDGE DESCRIPTION

Imbaba Railway Bridge is only Railway Bridge across the Nile River in Cairo and second oldest bridge in Egypt. The current Imbaba Bridge was constructed from 1913-1925 (construction was halted due to WWI). The current bridge replaced an older one which was constructed in 1890. The original bridge was designed to allow the railways to cross westward and head south connecting with the Giza Train Station, the gateway to Upper Egypt. Imbaba Bridge is a riveted steel truss bridge which is located in Imbaba city in Cairo governorate in Egypt. Imbaba Bridge crosses over the Nile River on main railway Alexandria Aswan line. Imbaba Bridge consists of seven bays simply supported, bay six from Cairo governorate is a movable bay for Nile River navigation service. Figure 9, Figure 10 shows Imbaba Railway Bridge.

The bays are of 68.65 m spans and width 19.50 m. the bridge is arch truss system, truss high at the middle 10.85 m and 6.00 m at the far ends. The bridge supports a one lane roadway on the both bridge sides as well as two passages designed for pedestrians with 3.80 m wide in addition to double railway track in the middle of the bridge width. In this research, the bay 1 near the abutment with span length 68.68 m has been considered. The general arrangement of all the spans of the bridge along with the location of the piers is shown in Figure 11.

The floor system of Imbaba Railway Bridge is composed of 4 rails (2 for each track) spanning across the laterally placed wooden sleeper, supported across two stringers which are 1.50 m apart. The stringers of the Imbaba Railway Bridge intersects the cross girder. All stringer of the bridge are identical and are prismatic with cross section containing four angles and a 1.07 m deep web plate. The superstructure, under consideration, is supported by pin bearing (allow rotation) at the east and roller (allows translation) at west abutment.

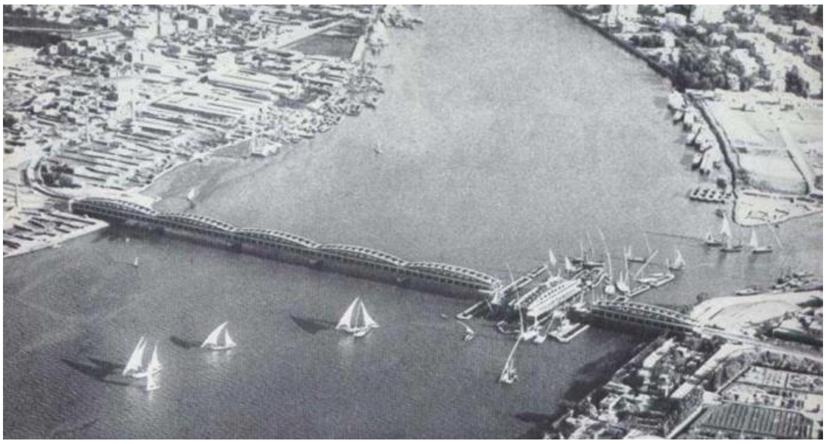

Figure 9: Old picture of Imbaba Railway Bridge.

Figure 10: New picture of Imbaba Railway Bridge.

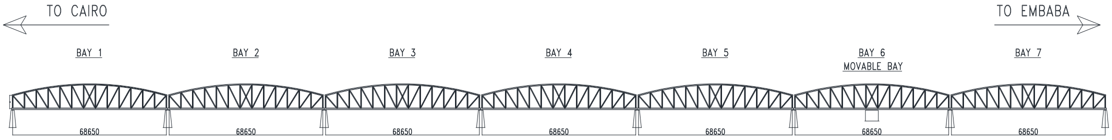

Figure 11: Imbaba Railway Bridge overall layout.

III. FIELD TESTS

Six series of Experimental tests were conducted on Imbaba Railway Bridge. The tests series were designed in order to obtain the static and dynamic behavior of bridge under a real train loading conditions to update the numerical structural analysis models of Imbaba Railway Bridge.

- Test series 1: is the unloaded bridges test series, the strain gauges was installed on the following structural elements stringer, cross girder, bottom chord, diagonal member, and in some cases the upper chords of the main truss.

- Test series 2: is the static load test series where the strain of each previously defined different structural element is recorded. Not only the strain of the different structural elements is recorded but also the deflection of the main steel trusses system is recorded.

- Test series 3: is the unloading static load test series where the strain of each previously defined different structural element is recorded. Test series 3 is performed in order to investigate whether the static loading conditions where in the elastic range of the bridge structural elements as a result of the strain rebounding percentages.

- Test series 4: is the dynamic load test series which is divided into two groups of tests. Group (A) is the test series where the strain of the previously defined structural elements is recorded under a dynamic loading condition. Group (A) test series is used in updating the numerical structural analysis models under dynamic loading conditions. Group (B) is a modal test which was performed under the excitation of bridge due to speeding passing real locomotives where the tri-axial accelerometer is recorded acceleration under a dynamic loading condition. Group (B) test series is used in updating the dynamic characteristics of the numerical structural analysis models of the railway bridge.

- Test series 5: is steel hardness test in order to define the different structural elements steel grade according to ISO-18265 0.
- Test series 6: is the Experimental test series where the temperature of the steel surface and. also the ambient temperature was recorded during the previously mentioned five test series.

a. INSTRUMENTATION AND TEST SETUP

Strain and dynamic modal tests including steel surface temperature measurements were performed using an NI (National Instruments) NI SCXI 1000 16-bit data acquisition chassis which is equipped with different types of strain gauge conditioning modules, voltage module, and thermocouples module forming a total capability of 56 simultaneous channels. NI SCXI 1000 data acquisition is a unit of a larger monitoring station NI PXI 8110 which have a total capability of 76 simultaneous Recording sensor measurements including strain gauges and piezoelectric accelerometers.

Figure 12: piezoelectric accelerometers.

Figure 13: Accelerometer attached on the cross girder of the bridge.

Steel hardness tests were performed by a portable hardness device which is recalibrated each time before testing in the experimental. The vertical displacement measurements were performed by level instrument accurate surveying device Figure 14.

Static load tests were performed by positioning a well-known locomotive axels load (Total weight 132 ton) in a position which grantee that the previously defined structural elements in the Experimental test plan of a bridge would deform the maximum possible deformation under the applied locomotive load. The number of the used locomotives in Imbaba Railway Bridge tests were two locomotives and one test which is sufficient for testing the bridge Figure 15 and Figure 16.

Figure 14: Level instrument recording point.

Due to high rigidity of the bridge under study, it is not possible to rely on the ambient vibration duo to wind or small seismic effect to measure the dynamic characteristic of this type of bridges. So, external source is required to excitation of bridge either by using a shaker with a suitable weight or use of the movement of trains on the bridges. In the current study were used two consecutive locomotives weighing 130 tons each and the speed of about 60-80 km/h Figure 17.

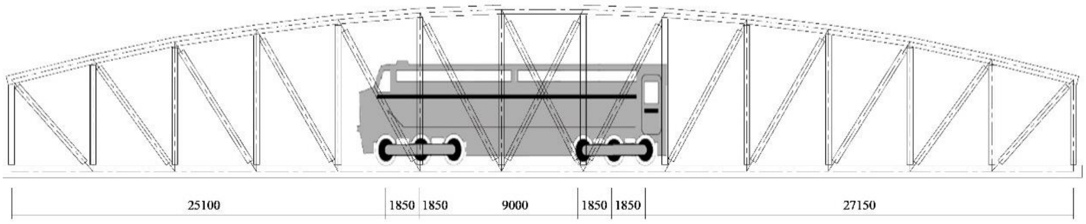

Figure 15: Locomotive test position of Imbaba Railway Bridge.

Figure 16: Locomotive test position at field test of. Imbaba Railway Bridge.

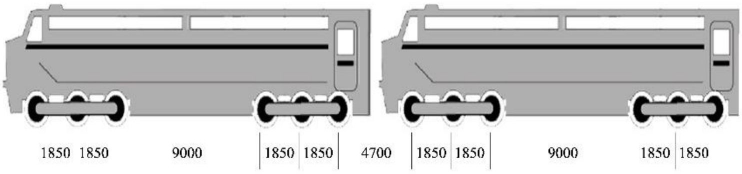

Figure 17: Configuration of two locomotives were used to excite Imbaba Railway Bridge.

Figure 18 shows strain gauges installing location along the tested bay. Where the used mechanical strain gauges were installed in the absolute maximum expected induced strain values under the applied loads. Figure 19 shows vertical deflection surveying marks location along the tested bay. Figure 20 shows accelerometers location along the tested bay. Where the accelerometers were installed in order to detect dynamic characteristics (damping, natural frequency and mode shape) of the bridges structural system.

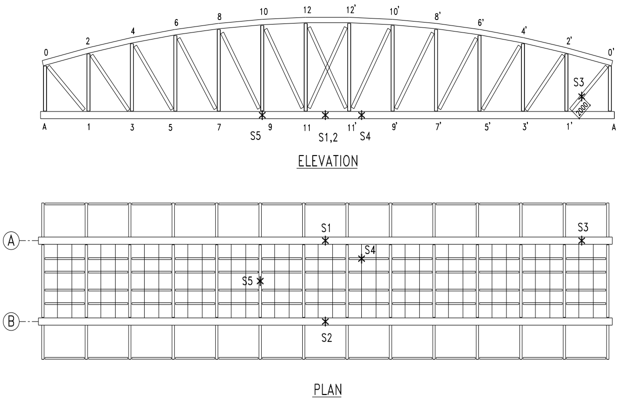

Figure 18: Imbaba Railway Bridge static testing plan layout for strain gauge locations.

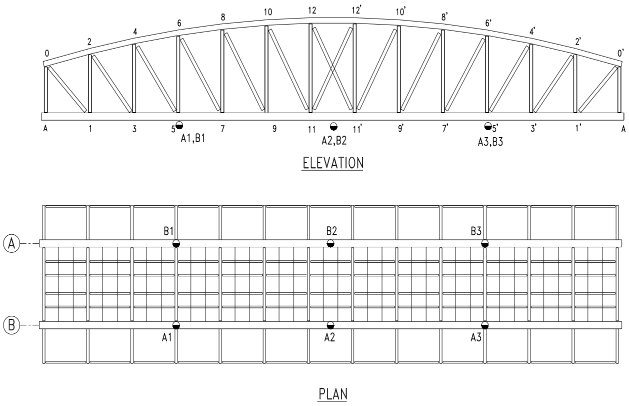

Figure 19: Imbaba Railway Bridge static testing plan layout for deflection locations.

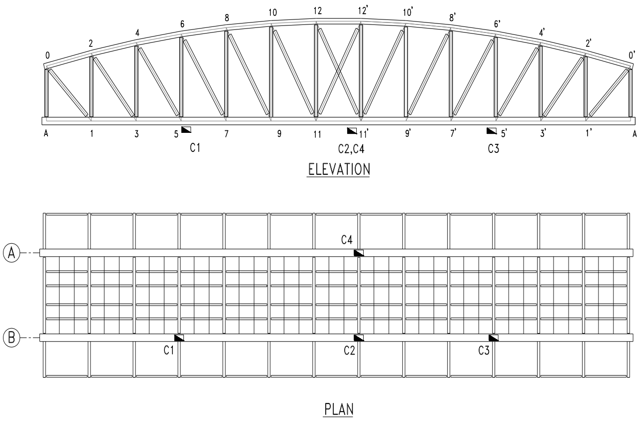

Figure 20: Accelerometer attached on the cross girder of Imbaba Railway Bridge.

IV. FIELD TEST RESULTS

a. STATIC TEST RESULTS

Table 3 present Imbaba Railway Bridge strain for different structural element (Bottom cord member, Diagonal member, stringer and cross girder) under applied static loading test. The induced strain values signs are negative for top flange of both of cross girders and stringers while the induced strain values signs are positive for diagonal and bottom chord member. Which is expected as per the structural analysis basis. A significant portion of the strain and deflection data obtained by the static tests was used to calibrate the finite element.

Table 3: Imbaba Railway Bridge static strain test results.

Member	Micro strain
Bottom cord member on axis A	64
Bottom cord member on axis B	65
Diagonal member on axis A	48
Stringer	-32
Cross Girder	-128

Table **4** shows Imbaba Railway Bridge of main trusses vertical displacement under the applied static loading test.

Table 4: Imbaba Railway Bridge vertical deflection at axis (B).

	Normalized span length %	vertical deflection (mm)
Bottom cord member on axis B	0.25 L	-4.50
	0.50 L	-9.10
	0.775 L	-4.40

Steel hardness test was performed on two random points among the tested bay steel structural elements. Table 5 present Imbaba Railway Bridge steel hardness test results.

Table 5: Imbaba Railway Bridge steel hardness test results.

	Hardness test result	
Testing point	Brinell Hardness	Vicker Hardness
Point 1	95	100
Point 2	96	100

As per ISO-18265 0, the bridge structural element are of steel grade 37.

b. DYNAMIC TEST RESULTS

Peak-picking method used to estimate the dynamic characteristics of Imbaba Railway Bridge. The signal from the acceleration sensor was recorded during and after the train passage of the bridge. The free vibration frequency and damping ratio of the bridge were obtained through spectral analysis of the pulsation and residual oscillation waveforms after the trains passed over the bridge, to preclude the influence of the large mass of the train. Figure 21 shows the captured time history of vibrational acceleration under dynamic loading test after removing the part recorded during passage of train. Where the horizontal axis of the captured time history is expressing the dynamic load test time values in seconds, and the vertical axis of the chart is expressing the tested bay vibrational acceleration during the dynamic loading test in mm/sec^2.

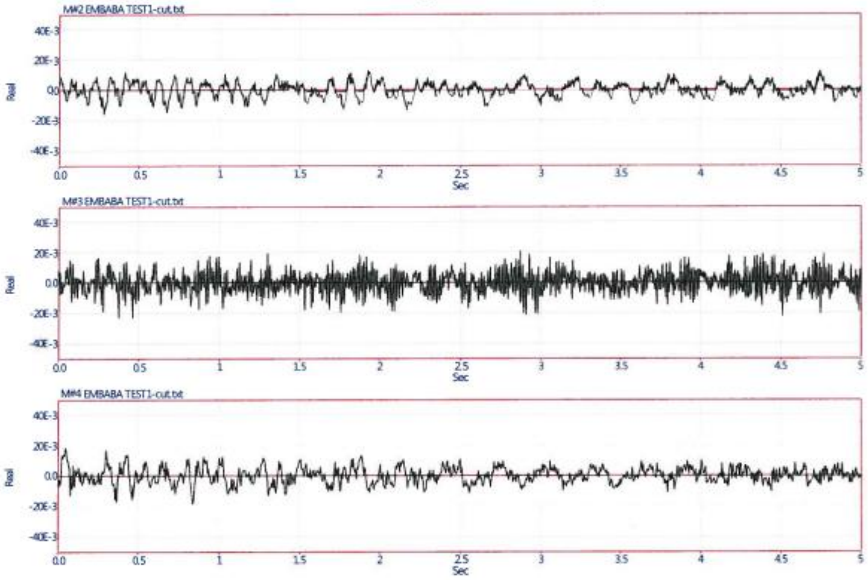

Figure 21: Samples of Registered Acceleration.

Table 6 present the measured results for the free vibration characteristics of the Imbaba Railway Bridge, and the measured frequency spectrum graphs are presented in Figure 22.

Table 6: Imbaba Railway Bridge Measured Modes frequencies.

Mode	Measured Natural Frequency (Hz)	Description of Modes
1	2.15	1st Horizontal bending mode
2	3.30	1st Torsional mode
3	3.51	1st Vertical bending mode

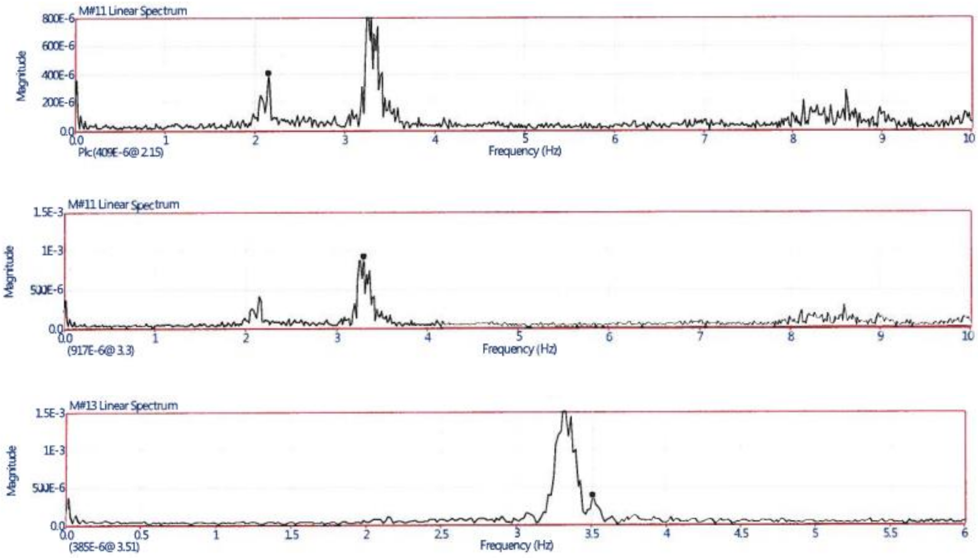

Figure 22: Imbaba Railway Bridge measured natural frequency.

SUMMARY AND CONCLUSIONS

The response of Imbaba Railway Bridge over the Nile River in Imbaba city in Cairo governorate in Egypt. Imbaba Railway Bridge has been studied using field test data under static and moving trains. For this paper bay 1, the eastern most span of the bridge close to abutment, of the bridge has been considered. The field test bridge response data obtained under the moving trains (Henschel 130 ton) was processed to obtain the bridge response under the actual field conditions.

From this paper following conclusions could be deduced:

i. With regards to data acquisition time during the real ambient vibration testing on civil engineering structures, it often quoted as 10–15 min of data acquisition in order to achieve stationarity of the data. However, it is desirable to use less data acquisition time since this is very important for large-scale civil engineering structures where many setups are required and test time is limited. For this particular bridge, even though the data recording time is 60 s, most of the important modes are identified.

ii. The Peak-picking method is very fast and efficient since no model has to better to the data.

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