

Full Load Test for the Sheikh Jaber Al-Ahmad Al-Sabah Causeway Bridge (PSC Girder: 35 M) [†]

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[†] Presented at the Second International Conference on Maintenance and Rehabilitation of Constructed Infrastructure Facilities, Honolulu, HI, USA, 16–19 August 2023.

Abstract: The Sheikh Jaber Al-Ahmad Al-Sabah Causeway consists of an asymmetric cable-stayed bridge (340 m) and a prestressed concrete (PSC) box girder bridge (35.80 km) linking Kuwait City and Northern Kuwait. The full load tests were performed on the PSC box girder bridge and the load scale was set to 14,092 kNm which was 98.47% of the maximum design moment (14,310 kNm). A total of 12 individual 40 tonf dump trucks were exerted on the bridge for the tests. Based on the influence line of the target bridge, displacement sensors, and strain gauges were installed at the points where the maximum bending moment would occur. The collected deflection and strain data were compared with the finite element method analysis to analyze the change in stiffness of the bridge. From the analysis, it was found that higher stiffness behavior was identified compared to the design load.

Keywords: full load test; stress analysis; finite element method analysis; stiffness; deflection; strain



Citation: Kim, K.; Cho, D.; Lee, R.; Lee, S.; Park, J.; Hwang, I. Full Load Test for the Sheikh Jaber Al-Ahmad Al-Sabah Causeway Bridge (PSC Girder: 35 M). *Eng. Proc.* **2023**, *36*, 41. <https://doi.org/10.3390/engproc2023036041>

Academic Editor: Hosin (David) Lee

Published: 14 July 2023



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1. Introduction

The target structure of this paper is a marine bridge with a total length of 36.14 km that connects Kuwait City to the new city of Subiyah, as shown in Figure 1.



Figure 1. Target facility location map.

The span composition of this marine bridge was constructed with an asymmetric cable-stayed bridge (340 m), which is the main bridge, and a PSC box girder bridge (35.80 km), and the initial value data, which are the basic foundation for the maintenance entity to carry out efficient maintenance work, were obtained.

Although the initial value data vary somewhat depending on the requirements of the ordering organization, which is the managing entity for the relevant bridge, the results of deflection and strain tests are basically obtained, and to that end, a full load test was performed.

Based on the acquired data, it is possible to quantitatively evaluate changes in the stiffness and sectional force of the bridge in use as of the time of completion, and it is expected that efficient maintenance work can be planned and executed based on the results [1,2].

2. Measuring Instrument Installation

In this load test, a total of three types of measuring instruments were used, which are LVDT, strain gauge, and total station. The linear variable displacement transducer (LVDT) was installed at the position of the elastomeric bearing at the supporting point to measure the amount of deflection of the bearing, and the strain gauges were installed inside the box girder to obtain the strain value as shown in Figure 2. In addition, considering that the space under the bridge is the sea, the amount of deflection was measured using the total station at the top of the bridge.

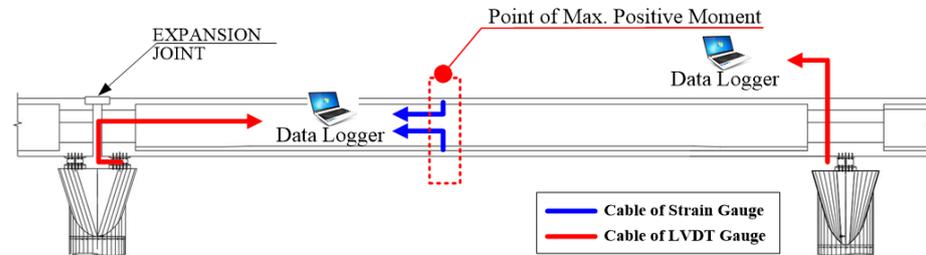


Figure 2. Diagram of the measurement system for data acquisition.

During the measurement, the data loggers were placed along the shortest moving line to minimize noise, and two data loggers were used to that end.

Measuring Instrument Installation Location

The location of the prism installed on the top of the bridge and the location of the strain gauge installed inside the box are shown in Figure 3, and the total station was located outside the expansion joint of the relevant span to eliminate the influence of loaded vehicles.

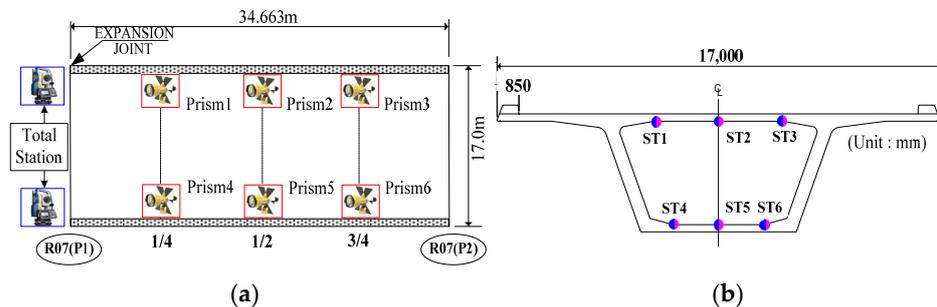


Figure 3. Diagram of the location where the measurement instrument was installed. (a) Locations of the total station and prism; (b) Location where the strain gauge was installed.

3. Load Test

3.1. Loading Vehicle Location Map

The target load for the load test was set as the design moment (14,310 kNm), and to that end, the number of trucks and the size of the load were determined through finite element analysis in advance. The sectional moment generated by the truckload used in this case was set as 14,092 kNm, which is 98.47% of the design load. Twelve 40 tonf dump trucks were loaded in the longitudinal and transverse directions as shown in Figure 4.

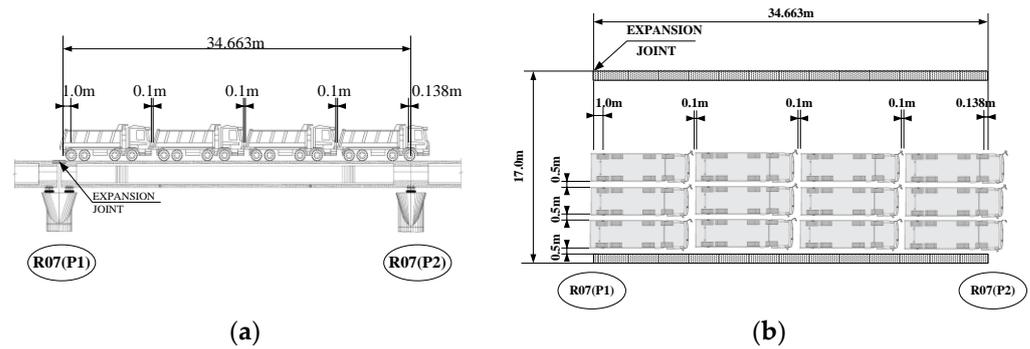


Figure 4. Diagram of longitudinal and transverse positions of the loaded vehicles. (a) Longitudinal positions of the loaded vehicles; (b) Transverse positions of the loaded vehicles.

3.2. Finite Element Analysis

It was determined to set the target load as close to the design moment as possible, and to that end, the load positions, and the load, which was 98.47% of the design moment, were determined through repetitive finite element analyses [3,4].

The deflection and strain values calculated as a result of the finite element analyses were compared and analyzed with the measured resultant values to verify the adequacy of the behavior of the theoretical structure and to quantitatively calculate the variation in the stiffness of the actual structure compared to the design, as shown as Figure 5.

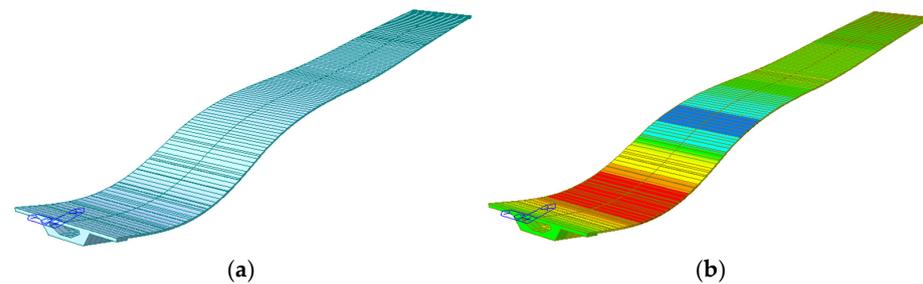


Figure 5. Results of finite element analyses. (a) Diagram of deflection by the loaded vehicles; (b) Diagram of stress by the loaded vehicle.

3.3. PSC Results of Test of the Resilience of the PSC Girder

After the load test, additional amounts of deflection were checked while maintaining the loaded vehicles for 24 h, but there was no change. In addition, it was identified that when all 12 loaded vehicles were removed, all the deflection was restored.

3.4. Results of Measurement of the Amount of Deflection and Strain

The measured values of the amount of deflection and strain were compared with the values obtained analytically, and as a result of the comparison at the maximum point of the positive moment, a maximum response ratio of 1.12 was derived in the deflection, and a result exceeding the predetermined reference value was obtained in strain, as shown in Figure 6 and Table 1.

Table 1. Results of analysis and measurement of stress.

Classification		Analysis (MPa)	Measurement (MPa)	Limit Stress (MPa)	
				Compression	Tensile
PSC Girder (35 m)	Top	-0.94	-1.01	-22.50	1.767
	Bottom	1.37	1.13	-24.88	

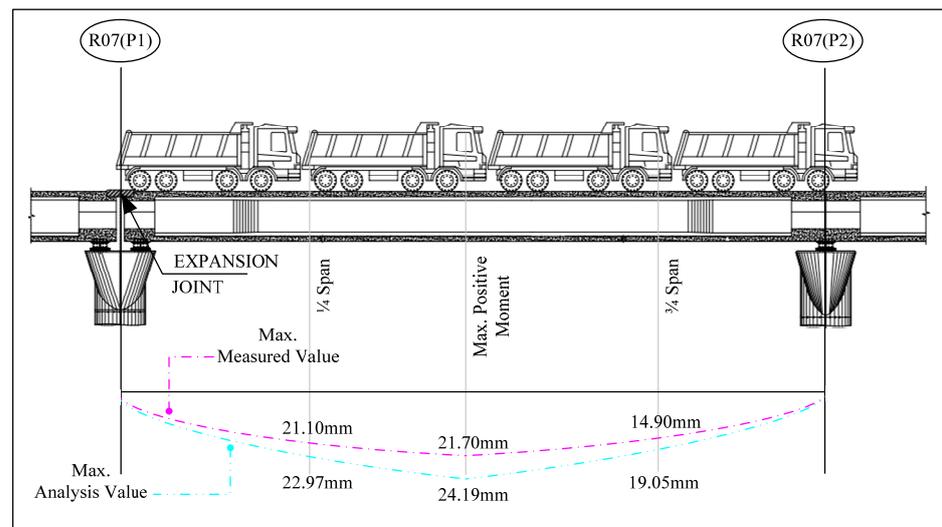


Figure 6. Results of analysis and measurement of deflection.

4. Conclusions

This study was conducted to provide basic data for planning and execution of maintenance work in use hereafter by performing load tests at the time of completion of the bridge and analyzing the measurement results. By analyzing the results of the test performed in a limited range, it was confirmed that the stress range and mechanical behavior characteristics were similar to the results of the analysis.

Author Contributions: Conceptualization, K.K. and R.L.; methodology, K.K.; software, J.P.; validation, J.P., I.H. and S.L.; formal analysis, K.K.; investigation, S.L.; resources, R.L.; data curation, I.H.; writing—original draft preparation, K.K.; writing—review and editing, D.C.; visualization, D.C.; supervision, D.C.; project administration, S.L.; funding acquisition, R.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Not Applicable.

Data Availability Statement: Not Applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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