LOAD TESTING OF BRIDGE FT009/035/80 OVER MUAR RIVER IN KUALA PILAH

Ku Mohd. Sani Ku Mahmud[1] and Dr. Ng See King[2]

[1] *Assistant Director, Bridge Unit, Roads Branch, Jabatan Kerja Raya, Malaysia*

[2] *Senior Assistant Director, Bridge Unit, Roads Branch, Jabatan Kerja Raya, Malaysia*

ABSTRACT

The Public Works Department Malaysia (JKR) is currently doing a joint study with Universiti Teknologi Malaysia (UTM) on Carbon Fibre Reinforced Polymer (CFRP). The aim of the study is to investigate the effectiveness of CFRP in enhancing the flexural capacity of reinforced concrete (R.C.) beams. This involves laboratory investigations on R.C. beams as well as on actual structure. For the investigation on an actual structure, a seven span R.C. beam bridge, namely FT009/035/80 in Kuala Pilah was selected. The investigation was carried out by checking the strength of the beams before and after application of CFRP. The flexural capacities of the bridge superstructure were determined by load testing the bridge. This paper presents the load tests carried out on bridge FT009/035/80 in Kuala Pilah. The paper describes the preparatory work involved in the load test, the instrumentation and procedures adopted in carrying out the load test. The results and their comparisons with the theoretical values are discussed and important findings and conclusions presented.

1. Introduction

Load testing of bridges has been used in some countries to determine their true safe load carrying capacities [1]. Even with the availability of modern day analytical methods, load test is still considered an effective means of proving structural theory and soundness of assumptions used in the design and construction [2,3,4]. Bakht and Csagoly (1979) and Bakht and Jaeger (1988) reports that load test carried out in Ontario frequently reveals that the actual load carrying capacity of a bridge is very much higher than what the theory predicts. The Government Of Malaysia Report (1992 and 1995) reported similar findings and attributed this phenomenon to the bridge inherent residual load capacity.

In Malaysia, bridge load testing was first carried out in 1991 on a single span reinforced concrete (R.C.) frame bridge and a steel bridge in Kuala Langat District, Selangor [5]. The two bridges, which were earmarked for replacement were load tested to failure in order to determine their ultimate capacities. Then in November 1991, under the JICA Study on Bridge Maintenance and Rehabilitation full scale load tests were carried out on three bridges [6]. The objective of the load tests in the Study was to determine the structural reserved loading capacity of the main component part of the bridge. In 1994, JKR Malaysia gained considerable experience in bridge load testing under the Bridge Capacity Study in Peninsular Malaysia as reported by Ku Mohd Sani (1996). The aim of the load test in the Study was to proof load the bridges to Long Term Axle Load (LTAL) i.e. the Malaysian design load at the time. The load test results showed that all the 15 bridges load tested in the Study were able to carry loads higher than LTAL [1,7].

The experience gained by JKR on load testing had made it recognised that load testing is an indispensable approach in the determining the actual bridge safe load carrying capacity. However, JKR has not conducted any load test since then until recently when an opportunity arises through a joint study between JKR and UTM on the application of carbon fibre reinforced polymer (CFRP) composites. The aim of the study is to investigate the effectiveness of CFRP sheets or laminates in enhancing the flexural capacity of R.C. beams. This involves laboratory investigations on R.C. beams as well as on actual structure.

For the investigation of CFRP composites on an actual structure, a seven-span R.C. beam bridge, namely FT009/035/80 in Kuala Pilah was selected. It was decided that full-scale load test be carried out on the bridge before and after the application of CFRP in order to determine the actual gain in strength after application of CFRP.

This paper presents the load tests carried out on bridge FT009/035/80 in Kuala Pilah prior to installation of CFRP. A paper on the effect of CFRP on the bridge will be presented later. The present paper will describe the preparatory work involved in the load test, the instrumentation and procedures adopted in carrying out the load test. The results and their comparisons with the theoretical values will be discussed and important findings and conclusions presented.

2.0 Bridge Description

Bridge FT009/035/80 is located in Kuala Pilah Town along Federal Route 9 (i.e. Tampin – Karak road). The bridge, which was constructed in 1960's, has 7 simply supported spans with each span having equal length of 9.1 m. This bridge is ideal for the intended study as 7 CFRP material suppliers have agreed to supply their materials for the study. The superstructure consists of 2 independent structures with each one comprising 3 rectangular R.C. beams casted monolithic to an R.C. slab.

The details of the bridge are shown in Figure 1 and 2. Structural drawings for this bridge were not available, hence most of the structural details were obtained from field measurements and investigations.

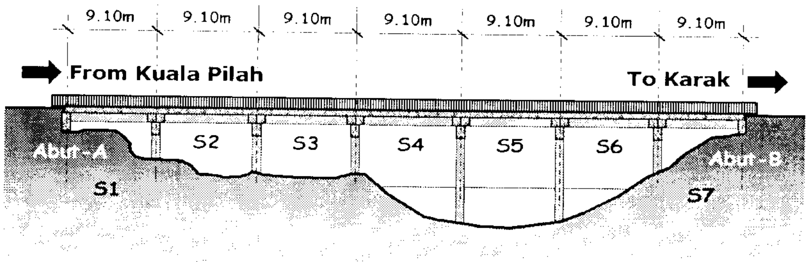

Figure 1: Longitudinal section of the bridge

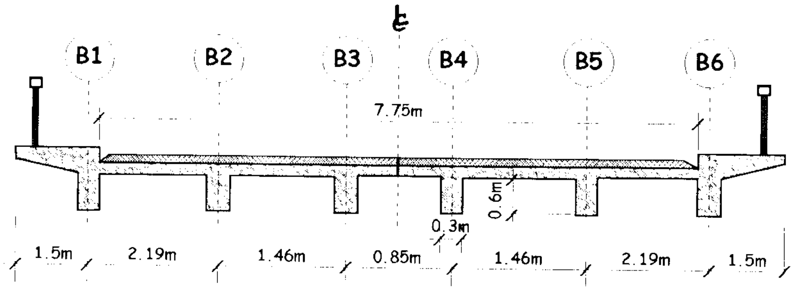

Figure 2: Cross-section of the bridge

A detailed investigation of the bridge showed that it is generally in good condition with no signs of serious defects except for some fine shrinkage cracks detected at the sides and soffits of beams. Carbonation tests carried out on the beams indicated carbonation depth of between 7 to 39 mm against the concrete cover of between 25 to 50 mm. Estimated in-situ concrete cube strength of seven cores taken from the beam of each span gave a range of between 20.5 N/mm^2 and 33 N/mm^2. Whereas the estimated in-situ concrete cube strength from the rebound hammer test gave a range of between 37 N/mm^2 and 48 N/mm^2. The higher rebound hammer readings were expected as the carbonated concrete surface has higher strength [8]. Some concrete breakouts were carried out at the soffit of the beams to obtain the rebar sizes and their cover and also to provide access for installation of strain gauges directly on the rebar. Concrete at the soffit of Beam 3 on Span 1 was totally removed until the rebar to obtain the actual amount of steel. This is necessary in order to calculate the theoretical capacity of the beam.

3. Load Test

3.1 General

The purpose of the study is to investigate the actual strength gained on the beams strengthened with CFRP. In order to achieve this purpose, load tests were carried out before and after the installation of the CFRP and observing the effects on the beams. In this study, the effects on the beams were studied by fixing strain gauges and deflection transducers at the mid-span and measuring their responses when the bridge was loaded.

3.2 Load Test Organisation

Load testing is a complex operation, which involves a large manpower utilisation. Various teams were organised to perform specific tasks to ensure that the load test would be carried out smoothly and successfully. The teams set up for the load test were as follows:

- Bridge Unit, JKR involved in the overall organisation of the load test including detailed planning; preliminary works such as bridge inspection, investigation and analysis; coordination between the various teams and responsible in the actual execution of load test.
- UTM was responsible for fixing of strain gauges and linear transducers and data acquisition through the data-logger during the load test.
- JKR Kuala Pilah was responsible for providing site assistance such as clearing of site, erecting tents for data-loggers and guests, staging for video camera; providing watchmen when instrumentation were installed; liaising with local police and radio for traffic control; and controlling the traffic during the load test.
- JKR Workshop was responsible for transporting concrete blocks to and from the bridge site and providing the test vehicle during load test.
- CFRP suppliers were responsible for installing their products on their respective spans after the first load test.
- A contractor was engaged to erect staging to provide access for installation of gauges, transducers and CFRP.
- Tenaga Nasional to provide steady power supply for gauges installation, other site preparation and data-logger during load test.

With a large number of personnel involved, a comprehensive program was formulated for all the participating teams to adhere in order to ensure that the load test went on smoothly. Regular meetings were conducted to discuss the progress or problems faced by the teams. At the same time the Bridge Unit was in constant contact with all the teams to ensure that all teething problems were resolved before the load test.

3.3 Equipment

The instrumentation used to measure the beams' response to the applied loads were resistance wire strain gauges to measure strains and linear voltage deflection transducers (LVDT) to measure deflections. The gauges and LVDT were installed at the mid-span of Beam 3 and 4 at every span at locations as shown in Figure 3. Gauges installed on the bottom reinforcement would measure maximum strain/moment while gauges installed at the middle and top of the beams would be able to obtain the neutral axis of the deck, thus confirming the composite action of the deck. The LVDT were installed on independent supports and positioned at the mid-span of Beam 3 and 4 to measure maximum deflection of the beams due to each load case.

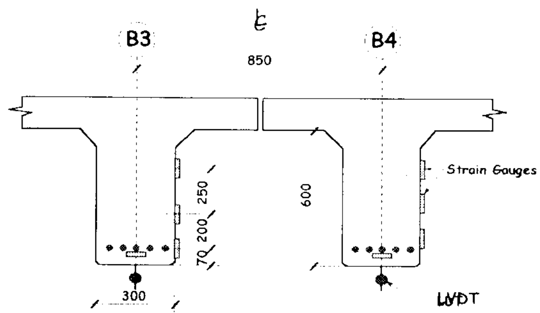

Figure 3: Location of strain gauges and LVDT

The readings from the strain gauges and LVDT were recorded via connections to two portable data loggers with multiplexors on each side of the river. Instrumentation on Span 1, 2, 3 and 4 were connected to the data logger stationed at the Kuala Pilah riverbank while instrumentation on Span 5, 6, and 7 were connected to the data logger stationed at the Karak riverbank. This was to avoid errors in readings if some connecting wires were too long. Concurrently, precise level measurements were also taken to check for any settlement at the supports and also as a counter check for the LVDT readings.

For the applied load, a JKR low loader was used as a test vehicle. This was because the low loader was used before during previous load test carried by JKR thus its axle configurations and weights were known [1,7]. However, as this time the low loader would be incrementally loaded with concrete blocks weighing 2.5 tonnes each instead of previously 2 tonnes, the axles were weighed at JKR Workshop for each load level to be imposed on the bridge prior to the load test. The test truck configuration and the loads imposed during load test is shown in Figure 4 and Table 1.

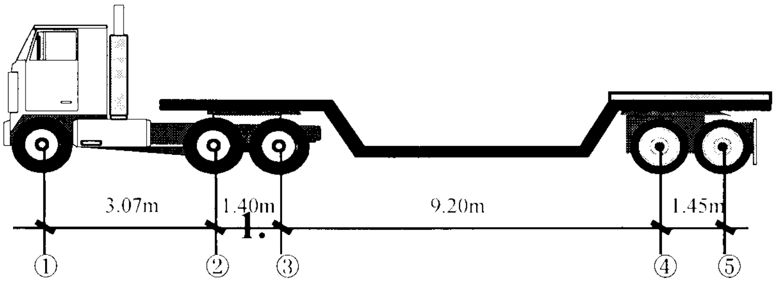

Figure 4: Configuration of low loader

Table 1: Axle Loads and Vehicle Loads

Load Level	No. of Blocks	Axle Weight, kN					Gross Weight
		1	2	3	4	5	
0	0	59	44	43	40	41	227
1	10	68	77	78	112	112	447
2	14	68	82	82	152	155	540
3	16	70	82	82	176	179	589

3.4 Test Procedure

The load test was carried out by slowly moving the low loader along the centerline of the bridge and measuring the bridge responses when its tandem axles straddled over the mid-span. The travel line and stop positions were chosen to produce the worst and equivalent load effect on the Beam 3 and 4 at each load level (LL). The travel and stop positions were clearly marked on the bridge prior to the load test for ease of guiding the low loader along the right track. During the load test key personnel were positioned at the front, back and side of the low loader to ensure that it traveled and stopped at a correct position.

The load test was conducted in the following manner; initially the low loader with LL1 would load Span 1 at the predetermined position, and then proceed to Span 2 when all the readings were taken. This procedure was repeated to the rest of the spans until Span 7. At each load position the low loader will remain in place long enough for vibration to attenuate and for strain and deflection measurements to be taken before proceeding to the next load position. After finish loading on Span 7, the low loader would return to its loading area to add concrete blocks to LL2. Then the low loader would resume loading all the spans again following the exact procedure. The load test ended when all the spans had been tested with every LL.

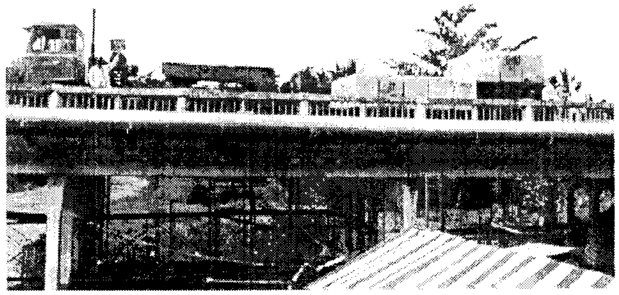

Figure 5: Load test on one of the spans with low loader at LL3

During the entire duration of the load test, the bridge was closed to all traffic to ensure that the load test were carried out smoothly and to ensure safety of all personnel involved with the load test. Traffic was diverted to a detour road by JKR Kuala Pilah with the assistance of local traffic police. The proceeding of the load test were recorded by the Library Unit of JKR using video recorder and camera.

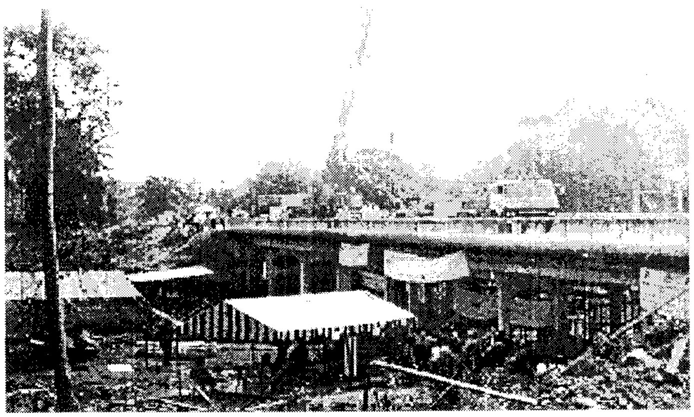

Figure 6: General scene at the bridge site during load test

4. Load Test Results and Discussions

The data collected during the test were brought back to the office to be processed and analysed. The deflection results were fairly good as they follow similar trend as the theory predicted as shown in Figure 7. The results showed that the deflections of the two beams were fairly the same and were consistently much lower than the theoretical deflections. Table 2 showed that the actual deflections were lower than the theoretical values by about 16% to 52%.

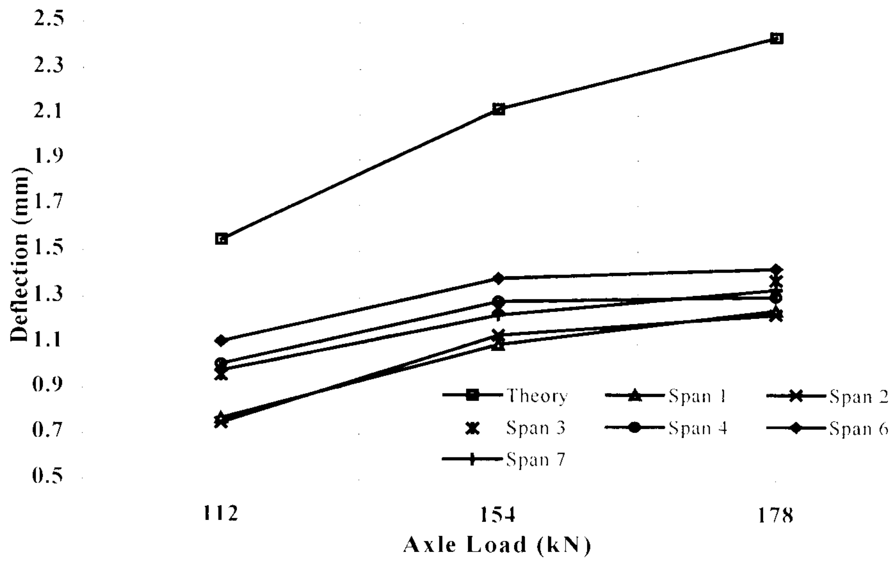

Figure 7: Deflection results of Beam 3 on every spans

Table 2: Deflections results as percentage difference from theoretical values

LOAD LEVEL	DEFLECTION (% Diff. from theoretical values))													
	Theory (mm)	Span 1		Span 2		Span 3		Span 4		Span 5	Span 6		Span 7	
		B3	B4	B3	B4	B3	B4	B3	B4	B4	B3	B4	B3	B4
LL1	1.55	50	44	52	41	38	38	35	32	23	28	16	37	38
LL2	2.13	48	45	46	43	41	39	39	36	37	35	31	42	43
LL3	2.44	49	43	50	45	43	41	46	41	43	41	26	45	46

The disparity in the results could be attributed to inherent stiffness in the bridge in which the theoretical model fails to account for. The stiffness in the bridge could be due to:

- better lateral distribution of the deck slabs than those predicted by simple analysis,
- friction or rigidity of the bearings. In theoretical analysis, the bearings should allow the beams to freely move or rotate. However, in reality the bearing stiffness restrained these free movements allowed for in the design,
- stiffness of non-structural elements. The presence of parapets, water mains and premix surfacing of about 230mm not considered in theoretical calculations as structural members do contribute in increasing the decks' stiffness.

The strain results as demonstrated in Figure 8 and Table 3 did not compare well with the theoretical values. Unlike the deflection results, the strain results do not even exhibit similar trend as the theoretical values. It is observed that generally, the strain readings increased as the load were increased from LL1 to LL2 but somehow decreased when loads were increased from LL2 to LL3.

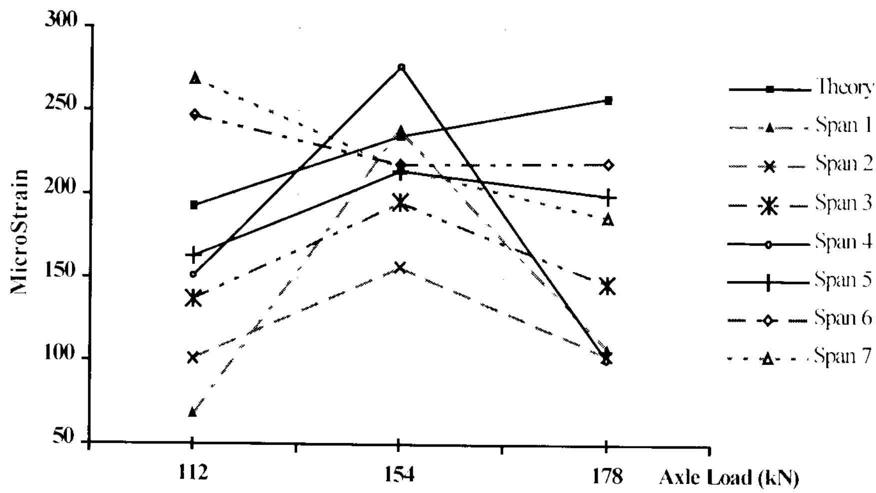

Figure 8: Strain results at soffit of Beam 3

These strange results could be explained by the presence of fine shrinkage cracks on the beams. These shrinkage cracks represent weak points in the beams and when the tensile stresses in the concrete bottom fibre exceeded its tensile strength, internal microcracks might propagate from these cracks [9]. As all the strains readings were reduced after LL2, it is predicted that these cracks may have developed at LL3 and thus would relieve the strains in the concrete and resulting in lower strain readings than at LL2.

Table 3: Strain results at beam soffit

Load Level	STRAIN (MICRO)														
	Theory	Span 1		Span 2		Span 3		Span 4		Span 5		Span 6		Span 7	
		B3	B4	B3	B4	B3	B4	B3	B4	B3	B4	B3	B4	B3	B4
LL1	193	68	88	101	116	137	142	151	150	163	184	247	263	269	263
LL2	235	239	257	157	170	196	208	277	284	214	259	218	228	216	217
LL3	258	107	106	103	117	147	125	101	77	200	224	219	233	187	192

It was also observed that the lengths of the connection cables might have affected the strain results. Table 3 showed that the strain readings on Beam 3 and Beam 4 at each span are fairly closed but differ quite a lot at different spans.

The test to check the neutral axis of the beams also did not yield good results. This can be attributed to similar reasons above i.e. shrinkage cracks at beams and unequal length of connecting wires. Apart from that GOM 1995 [1] reported that discrepancies in concrete strain readings arise due to inhomogeneity of concrete and presence of voids in concrete. Nevertheless the results did show that there are composite actions between the beams and deck slab as the strain readings at all positions were positive i.e. always in tension.

5. CONCLUSIONS

Notwithstanding the fact that the original objective of the load test was to verify the effectiveness of CFRP in enhancing the capacity of the bridge, the load test results have led to some useful findings as described below:

- The bridge has a capacity of at least 0.7LTAL. Even though the highest load imposed on the bridge was equivalent to 0.7LTAL, the results showed that the bridge has plenty of reserves to carry much higher loading. This is in line with the report by Ku Mohd Sani (1996) that all the 15 bridges load tested during the Bridge Capacity Study, exhibited capacities higher than LTAL.

- The bridge deck exhibit composite actions between the beams and the slab.

6. ACKNOWLEDGEMENTS

The authors wish to thank the CFRP Committee for their permissions to publish this paper. The authors also wish to thank the Senior Superintending Engineer of Bridge Unit, Ir. Chin Wei Choong for his continued support, encouragement and advice in setting up the CFRP Committee and publishing this paper. Sincere thanks are also extended to the staff of Rehabilitation Section of the Bridge Unit, JKR Kuala Pilah, JKR Workshop and Kuala Pilah's District Police in ensuring the smooth execution of the load test. Last but not least, thanks are due to JKR Library for recording the test proceedings and Mr. Tan Chee Kean for helping with the preparation of this manuscript.

7. REFERENCES

1. Government Of Malaysia, '*Findings On The 200 Bridges - Volume II - Determination of the Structural Capacity of Existing Bridges in Peninsular Malaysia*', Report submitted to JKR Malaysia by Dessau International Ltd./Ranhill Bersekutu, 1995.

2. Bakht, B., Csagoly, P.,'*Load Testing*', Technical Report No. 79-SSR-10, Ministry of Tranportation and Communications of Ontario, Canada, 1979.

3. Bakht, B., Jaeger, L.G.,'*Load Testing-A Surprise Every Time*', Technical Report No. SSR-88-04, Ministry of Tranportation and Communications of Ontario, Canada, 1988.

4. Japan International Cooperation Agency, '*Seminar on Full-Scale Bridge Loading Test*', Kuala Lumpur, 1991.

5. Khoo, C.L., Ng, S.K., Amir, I., '*Full Scale Load Testing to Failure of a R.C. Rigid Frame Type Bridge*', 1991

6. Government Of Malaysia, '*The Study on the Maintenance and Rehabilitation of Bridges in Malaysia*', Report submitted to JKR Malaysia by JICA, 1992.

7. Ku Mohd Sani, K.M., 'Load Testing of Bridges in Peninsular Malaysia', *2nd Malaysian Road Conference*, Kuala Lumpur, 1996, pp399-406.

8. Neville, A.M., Brooks, J.J., *Concrete Technology*, Longman, Singapore, 1993.

9. Dr. Siti Hamisah Tapsir, Assistant Professor of UTM, *Private Communication*, 12th May 2000.