Bridge Load Testing - The Malaysian Experience

Ku Mohammad Sani Ku Mahmud
(Assistant Director, Bridge Unit, Roads Branch, JKR Malaysia)

ABSTRACT

The Bridge Unit, Public Works Department Malaysia (JKR) is the custodian of over six thousand bridges on the Malaysian federal roads. A large number of these bridges were built soon after second world war and thus their capacities to carry the current traffic loads are in doubt. To resolve this problem JKR initiated a Bridge Capacity Study in November 1993 to institute a methodology to evaluate bridges in Peninsular Malaysia. Load testing of bridges form a major part of this study. This paper describes the methodology adopted for load testing and the findings from the test results. The load test results showed that it is very useful in confirming the safe load carrying capacity and the behaviour of the bridges.

1. INTRODUCTION

Malaysia has undergone rapid economic growth since the last decade as it strives to achieve a developed country status by the year 2020. The road network forms an important component of its economic infrastructure and bridges are a vital part of that network. There has been increasing demand to use larger and heavier vehicles on the road network as a means of providing significant cost savings and economic benefits. However, these demands for an increase in vehicle loads cannot be realized unless the roads and bridges have the capacity to provide for it.

There are 6647 bridges on the Malaysian major trunk roads i.e. federal roads that are under the custodian of the Bridge Unit, JKR [1,2]. A significant number of these bridges were built soon after World War II. At that time the aim was to provide a basic transportation link between population centers and many of these bridges do not have complete design details or have the design capacity to carry the present traffic loads [3]. Hence these bridges form the weak links in the road network if the level of service of the road network were to be increased.

Before the 1980's, JKR did not have a systematic inspection, maintenance and rehabilitation program for these bridges. However, from 1985 until 1990, JKR had inspected and inventoried 2600 bridges through the National Axle Load Study Phase I and II [3,4]. Realizing the need for a more effective management of the large number of bridges, the Bridge Unit had developed a computer base management tool called the JKR Bridge Management System (JKR-BMS) in 1991 [5]. The development of the JKR-BMS has been oriented towards data inventory and maintenance. Now there is a growing need to expand its functions to include assessment of bridge capacity.

To achieve this objective, the Bridge Unit initiated a pilot project in November 1993 to determine the structural capacity of existing bridges in Peninsular Malaysia. This project was awarded to a Canadian-Malaysian Consulting group and was funded by the World Bank. The main objective of the project was to develop a simple yet reliable methodology to determine the safe load carrying capacity of the bridges [7]. The project was completed in September 1995.

The scope of the project included performing theoretical strength evaluation of 200 bridges selected by JKR and physical load testing of 15 representative bridges. The project was divided into three phases where the first phase (from Nov. 1993 to Jan. 1994) involved developing a methodology for theoretical evaluation and load testing of the bridges. The second phase (from Feb. 1994 to Jun. 1994) involved application of the developed methodology on 23 representative bridges out of which four bridges were load tested to establish their actual capacity. In the third phase (from July 1994 to September 1995), the tested methodology was further fine-tuned and applied to the remaining bridges.

This paper describes the experience gained by JKR on the load testing aspect of the project.

2. LOAD TEST METHODOLOGY

2.1 General

Load testing of bridges has been used in the past in some countries to establish that the structures are capable of supporting service design loads. It typically demonstrates that theoretical capacity ratings are too conservative because in most bridges there exists a reserved residual load capacity. A substantial part of this project was devoted to full-scale load testing. Fifteen bridges, representative of most types of bridges encountered in Peninsular Malaysia, were selected for load testing.

The aim of load testing was to proof load test the bridges, i.e. to apply loads that would simulate the Long Term Axle Load (LTAL) load effects, thus confirming the safe load carrying capacity of the bridges. LTAL represents the design live load for Malaysia. The load test is also used to verify the load distribution in a bridge predicted in the analysis and to reveal any unusual structural behaviour not accounted for in the analysis. All tests were conducted using a procedure that could be replicated.

2.2 Selection Criteria

The main selection criteria of bridges to be considered for load testing were made by identifying the bridges according to their specific structural types. A few samples from each group were selected for load testing to understand their behaviour. Other contributory factors that influenced the bridge selection are as follows:

i) Traffic condition of the road. Load testing may not be possible if the road is heavily trafficked unless a diversion road exists in the vicinity.

ii) Suitable longitudinal road alignment with an adequate sight distance for safety purposes.

iii) Accessibility underneath the bridge for the instrumentation work to be carried out.

iv) Sufficient working space near the bridges to set up the data acquisition equipment; for storing concrete blocks; for parking test trucks, mobile crane and other vehicles; and for loading and unloading concrete blocks.

v) Availability of a stable power supply near the bridge site to provide electricity crucial for instrumentation work.

2.3 Equipment

The primary equipment required for load testing a bridge are instrumentation and loading equipment. In this study all the bridges load tested were instrumented using electrical resistance wire strain gauges, linear transducers and dial gauges. The strain gauges were installed at the bridge mid-span to measure maximum bending moment and near the support end to check for bearing restraints. Normally the gauges were installed on the bottom flange of the beams, the top flange and deck slab. This is useful for confirming the composite action of the deck. The deflection transducers and dial gauges were only installed at the mid-span. The readings from the wire strain gauges and deflection transducers were recorded via connections to a portable data logger and a 20 channel multiplexor. The number of gauges and transducers used for a test varied depending on the structural system of the bridge.

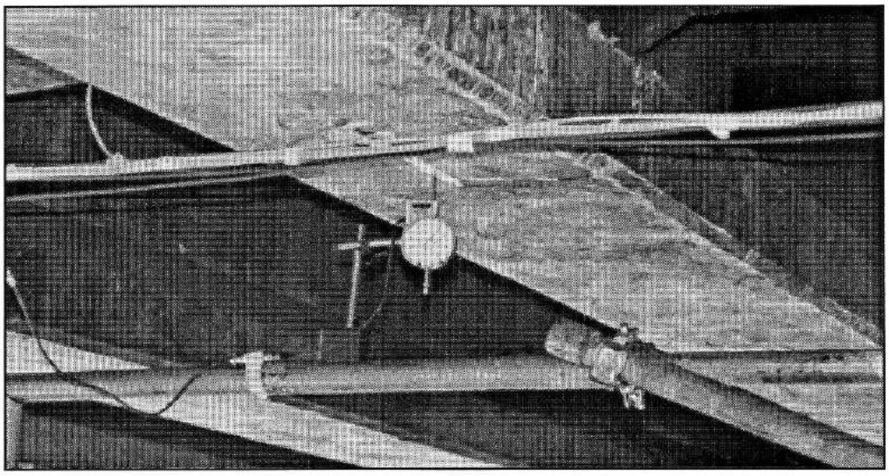

Fig 1 : Instrumentation of r.c. beam using strain and dial gauges

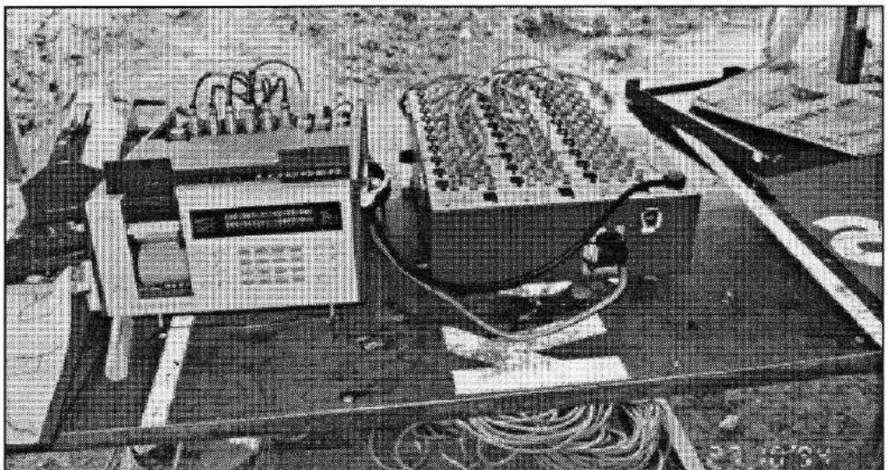

Fig. 2 : Data Acquisition using a data logger and a 20 channel multiplexor

The bridges were load tested using two JKR Scania low-loaders. The trucks were selected for their ability to carry loads that would simulate the load effects of LTAL loading. During the load test the trucks were incrementally loaded with concrete blocks weighing about 2 tonnes each. The test truck configuration and the loads imposed during load test are shown in Figure 3 and Table 1.

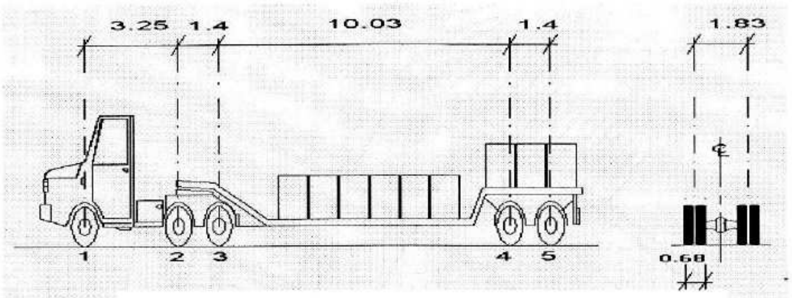

Fig. 3 : Configuration of SCANIA Truck

Load Level	No. of Blocks	Axle Weight, kN					Gross Weight
		1	2	3	4	5	
1	0	57	44	41	38	40	220
2	12	70	88	88	108	108	462
3	16	70	88	88	148	148	542
4	18	70	90	90	167	167	584
5	20	70	90	90	187	187	624
6	22	70	90	90	207	207	664
7	24	70	90	90	227	227	704
8	25	70	90	90	233	233	717

Table 1 : Axle Loads and Truck Loads

2.4 Test Procedure

The load test was carried out by slowly moving the loaded trucks along the bridge and subsequently measuring the bridge responses when the trucks were at the pre-determined positions. The loading is considered to be static, because the trucks were moved along the bridge at a very low speed. Several transverse positions, as illustrated in Fig. 4, were tested to measure the capacity of the deck to distribute the load laterally. To locate the maximum positive moment the test trucks were positioned longitudinally as shown on Fig. 5. The transverse and longitudinal positions were clearly marked on the bridge so that it would be easy for the truck driver to position the truck correctly.

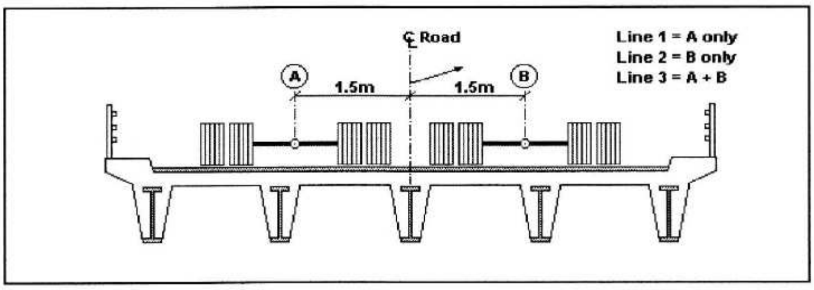

Fig. 4 : Typical Truck's Transverse Position

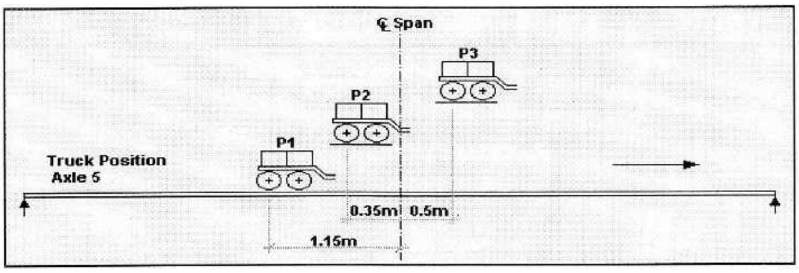

Fig. 5 : Typical Truck's Longitudinal Load Positions

Typically the bridges were load tested in the following manner; one lane was loaded first at the pre-determined load positions followed by the opposite lane, and then with trucks on both lanes. At each load position the trucks remained in place long enough for vibration to dissipate and for strain and deflection measurements to be made before proceeding to the next load position.

The test loads were applied incrementally over eight load levels (see Table 1), starting from the lowest load level (twelve concrete blocks) to the maximum load level (twenty five concrete blocks). Each time after the measurements are taken, the measured data were compared with the tabulated and plotted theoretical values. When sufficient data had been measured, the data were checked for linearity to ensure that the testing remained within the elastic range of the structure. Although the capacity of the bridge may determine the final load level applied to it, all the bridges tested were able to carry the maximum truck loads.

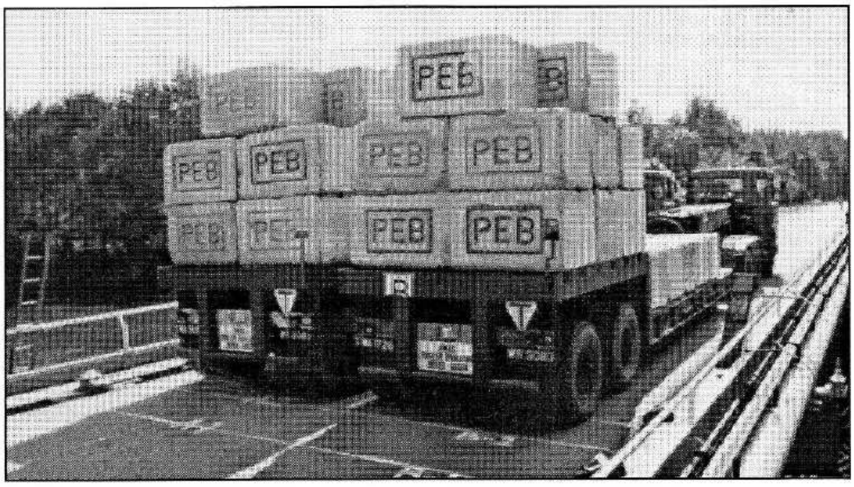

Fig.6 : Two trucks carrying maximum loads during load testing

3. LOAD TEST RESULTS

The data collected during the test were analysed and graphs were plotted to visualise the results. Typically the graphs of strains at the bottom flanges of the beams at the mid-span and at the support were plotted to check for the deck transverse distribution and bearing restraint. For slab on girder structures, strains at the bottom flange, the web, top flange and deck soffit were plotted to check for composite action. Graphs of bending moments at mid-span of the bridges induced by various loading types were also plotted to compare with the test results.

Fig. 7 shows a graph of bending moments due to various loadings on Bridge No. FT005+356/6 in Sepang. This is a steel encased beam and slab bridge, which spans 15.15m, having a width of 7.98m and beam spacing at 1.70m. The graph shows that the maximum moment induced by the theoretical load level 8 is higher than LTAL loading but lower than SV-20 loading i.e. having values of 780kNm, 680kNm and 1050kNm respectively. Hence, for this bridge the test truck is able to simulate a loading higher than LTAL but lower than SV-20. However the maximum measured moment of load level 8 is only 520kNm which is much lower than the moment induced by its theoretical value and LTAL loading. Therefore it can be concluded that the bridge has a capacity higher than LTAL. However, Table 2 shows that the theoretical capacity of the bridge is only 0.87 times LTAL i.e. the bridge is incapable of carrying LTAL loading. Hence the load test has proven that the bridge is able to carry loads heavier than LTAL loading.

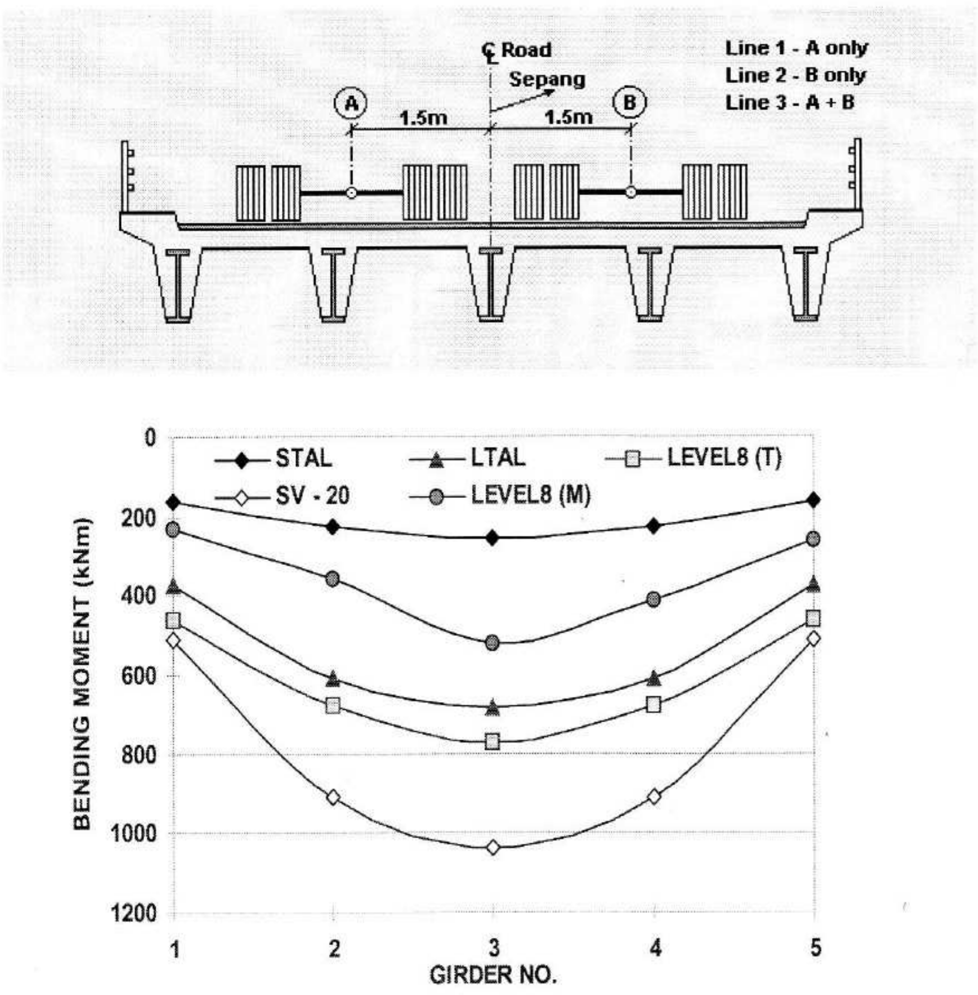

Fig. 7 : Comparison of Moment Induced by Various Loadings

The summary results of the load test for all the bridges are presented in Table 2. All the bridges load tested generally have the theoretical capacity to carry the present Malaysian legal loads i.e. STAL (Short Term Axle Load), but inadequate for LTAL. However the load test proved that they are capable of carrying more than LTAL loading.

No.	Bridge ID.	District	Bridge Structural Type	Tested Span (m)	Theoretical Capacity		Load Test Capacity
					STAL	LTAL	
1	FT005+448/8	Kelang	Precast R.C. Beams	6.70	1.18	0.89	> LTAL
2	FT005+500/6	K. Selangor	Precast R.C. Beams	6.30	1.07	0.82	> LTAL
3	FT060+028/5	Manjong	Precast R.C. Beams	7.16	1.19	0.77	> LTAL
4	FT001+425/5	H. Selangor	Prestressed I-Beam	25.18	1.27	1.17	> LTAL
5	FT005+328/5	Port Dickson	R.C. Beams & Slab	10.97	1.02	0.76	> LTAL
6	FT001+149/2	Segamat	R.C. Beams & Slab(2-Span Cont.)	2@6.6	1.01	0.77	> LTAL
7	FT001+520/2	Btg. Padang	R.C. Beams & Slab(2-Span Cont.)	2@8.12	1.19	0.86	> LTAL
8	FT005+569/0	Teluk Intan	R.C. Slab	7.16	1.19	0.88	> LTAL
9	FT005+409/1	K. Langat	Steel Beam Buckle Plate	6.30	1.39	1.06	> LTAL
10	FT001+286/8	Rembau	Steel Beam Buckle Plate	12.30	1.54	1.15	> LTAL
11	FT001+364/7	Kajang	Steel Beam Composite	18.50	1.36	1.21	> LTAL
12	FT003+365/5	Kuantan	Steel Beam Composite	9.25	1.42	1.00	> LTAL
13	FT003+373/5	Kuantan	Steel-Encased Beams & Slab	12.39	0.94	0.77	> LTAL
14	FT005+356/6	Sepang	Steel-Encased Beams & Slab	15.15	1.07	0.87	> LTAL
15	FT001+511/7	Btg. Padang	Triple Box Culvert	3@2.75	0.72	0.68	> LTAL

Table 2: List of Load Tested Bridges

4. LOAD TEST FINDINGS

Load testing in this project has allowed JKR to confirm the load bearing capacity of the bridges under heavy loadings and comment on the validity of theoretical analysis. However, it is a complex operation, which requires extensive planning, analysis and specialised equipment and incurs a high cost and large manpower utilisation. Therefore load testing should only be used as a last alternative to obtain the capacity of bridges.

The results of the load test have led to some interesting and useful findings as described below:

- Observed lateral distribution generally corresponds well to theoretical distribution using grillage analysis implying that grillage analysis provides an adequate model. However all bridges showed higher stiffness than the model assumed. The higher stiffness could be a combination of the following:
  - Better load distribution than theory predicts
  - Horizontal movement restriction at bearing
  - Stiffness action due to non-structural elements (parapet)
  - Induced rotational stiffness at hinge bearing
- All bridges remained under linear elastic behaviour up to the maximum truck loads i.e. loads corresponding to actual design live load (LTAL and SV-20). No cracking or permanent deformations have occurred. The results also showed that the tested bridges have significant strength reserves. This could be attributed to the reasons given above.
- All slab on girder bridges exhibited composite action.
- Existence of bearing restraints (friction) at support. Compression strains were recorded at the bottom flanges of the girders near the support. This bearing restraint restricted the longitudinal movement of the girders thus increasing the stiffness.

5. CONCLUSIONS

The experience obtained from load testing of the bridges is beneficial to JKR. This will significantly help JKR in the management of its bridges. Load testing can be used to verify that some important bridges need not be replaced thus avoiding the unnecessary wastage of public funds and inconvenience of the road user.

Based on the results and findings of the load test it can be concluded that:

i. Load testing can be used to establish the safe load carrying capacity of the bridges. However it is a complex operation which requires extensive planning, analysis and specialized equipment and incurs a high cost and manpower utilization.

ii. Load testing can be used to check on the behaviour of the bridges.

iii. All bridges tested had some strength reserves and did not show any sign of permanent deformation.

6. REFERENCES

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