

# Challenges in Proof Load Test of Bridges – Malaysian Experience

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**Abstract.** It is a known fact that theoretical calculation for assessing the capacity of an existing bridge is grossly underestimating its actual capacity. The reasons are, among others, the safety factors adopted and assumptions made in modelling. The recommended alternative approach to assess the actual capacity of the bridge is by performing a proof load test. Proof load test is a useful tool where a bridge is incrementally loaded to a final targeted load. This approach has been used to check the bridges in Sarawak for their compliance with Weight Restriction Order (WRO) 2003. In these tests, bridges with Evaluation Load Ratings (ELR), which fall short of Public Work Department Malaysia (JKR) requirement related to WRO 2003 and hence recommended for replacement, were proof load tested with the intention to preserve these bridges. This paper presents the experience in conducting the proof load test on a few bridges in Malaysia. It describes the methodology for the proof load tests and the challenges faced during the tests. The proof load tests showed that the tested bridges can carry the full JKR standard of Medium Term Assessment Load (MTAL) loading, which is well within the legal load limits allowed under the WRO 2003.

## 1. Introduction

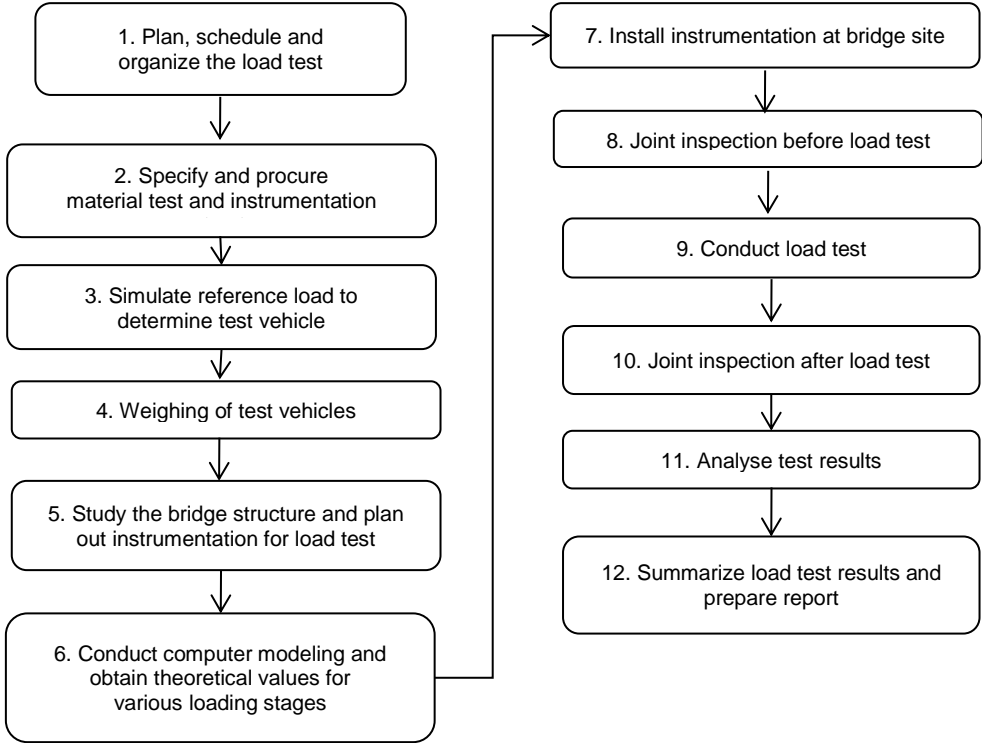
Bridge testing is a common bridge management tool used to support major bridge management decisions, whether to retain or replace a bridge. A bridge test can also be used to establish an initial signature on the performance of a newly constructed bridge. Supplemental load test, which is a type of bridge testing, is sometimes utilised to validate and calibrate a computer model to improve the estimation of a bridge load carrying capacity [1]. Another type of bridge testing known as proof load test can be used to verify the safe load carrying capacity of existing bridges subjected to a new load requirement [2, 3].

JKR has relied on the analytical strength evaluation as one of the three criteria for bridge replacement [3]. It is thus common that bridge owners, frustrated by failure of their bridges in the theoretical strength evaluation, resorted to testing their bridges. However, analytical strength evaluation most often than not, under estimate the actual safe load carrying capacity of the bridge; as exemplified by a load test carried out by JKR in Year 1991 [4]. In this test, a bridge, commissioned for replacement was load tested to failure. The failure load was found to be much higher than the theoretical capacity.

## 2. Proof Load Test

Almost all the load test carried out in Malaysia involved proof loading test. The authors had participated in the proof load tests while in JKR and in the private practice. The experience of the

authors in proof load test was summarised and compiled in Road Engineering Association of Malaysia’s (REAM) Publication “A Manual on Bridge Asset Management” [5]. A load test is a complex operation, which requires an extensive planning, analyses, specialised equipment, test vehicles, concrete blocks and lifting crane, and large manpower utilisation. Figure 1 below presents the workflow for a proof load test.



**Figure 1.** Workflow of Proof Load Test [5]

The workflow in conducting a proof load test can be categorised as:

- i. Before the test (step 1 – 8),
- ii. During the test (step 9),
- iii. After the test (step 10 – 12).

Before the test, planning, scheduling and organizing of the load test are necessary to ensure that the load test would be conducted smoothly and in a safe manner. During the test, data acquired from the instrumentations was used to monitor the bridge responses under load to prevent the bridge from undergoing any damage.

After the test, the results were analysed and conclusion made. Besides verifying the safe load carrying capacity of the bridge by the proof load, analysis of the test result may reveal the behaviour of the bridge much as composite action, lateral load distribution characteristic.

**3. Challenges**

The fundamental concept of a proof load test is rather simple; it comprises the loading of the bridge in question incrementally to the intended proof load. However, as the well-known bridge testing engineer, Baidar Bahkt had stated in his paper “Bridge testing: A surprise every time”, testing of bridges very often would encounter problems and challenges [6].

### 3.1. Pre-Test Phase

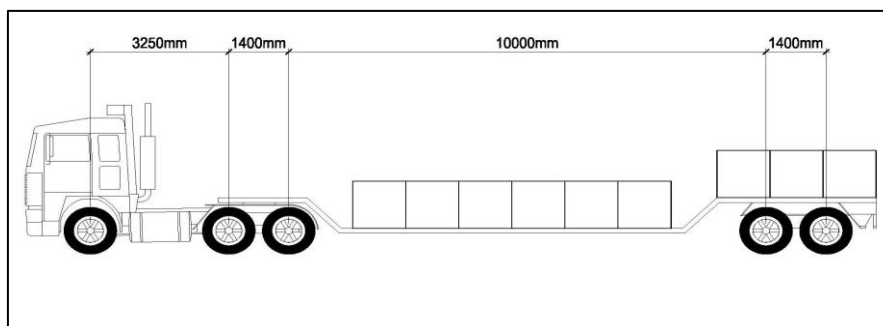
*3.1.1. Compliance to the local authorities' requirements.* Compliance to the local authorities' requirements is one of the main challenges in conducting a bridge testing. The main concerns to the local authorities are the safety of road users and public complaints resulted from the traffic obstruction during the load test. Therefore, the local authorities impose stringent guidelines to be followed in order to ensure the safety of the road users. Traffic management plan (TMP) that meets all the requirements along with schedule of work at site need to be prepared for the approval of the local authorities. Usually there would be several revisions to the proposed TMP in the process of getting the approval from the local authorities. The challenge is in having to obtain the approval from the local authority within the scheduled time frame without too many rounds of submission. In certain cases, the local authority may even require inputs from a professional traffic consultant to come out with an acceptable TMP.

The local authorities would usually allow for a full road/bridge closure at daytime if alternative road is available for traffic diversion. Temporary road diversion and traffic management plan (TMP) need to be designed and endorsed by a qualified traffic management officer (TMO). The TMP proposal would then be reviewed and commented by the road safety audit prior to the approval by local authority.

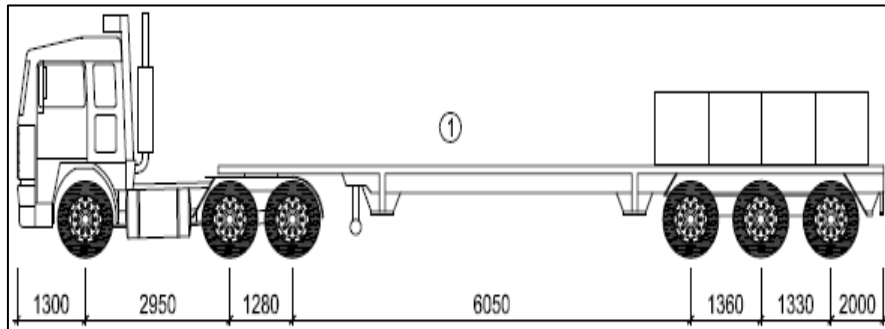
In case there is no alternative road for traffic diversion, the local authorities would only allow the road/bridge to be intermittently closed during the load test. In this situation, the requirements imposed are even more stringent. The load test is allowed to be carried out only at night and very often, the test needed to be stopped before 6.00 am when the traffic begins to build up. This is to minimize disruption to traffic. In addition to that, the maximum duration allowed for the closure in most cases is not more than 30 minutes.

*3.1.2. Availability of suitable test vehicles.* JKR has established a standard procedure of proof load test involving a standard test vehicle comprising a low-loader trailer with two tandems at the back (see Figure 2) [7]. The use of the standard vehicle rather than having the concrete blocks loaded directly on the bridge deck has a few advantages, such as:

- i. Loading and unloading of concrete block onto the test vehicle could be carried out away from the bridge.
- ii. Removal of the test load from the bridge could be done quickly with the test vehicle.
- iii. The axles impose on the bridge as point loads would be more deterministic than that due to a distributed load from the concrete blocks, which may have uncertain load distribution due to the development of arching effect within the concrete blocks.



**Figure 2.** Configuration JKR Standard Test Vehicle



**Figure 3.** Configuration of test vehicles (high-loader) which are easily available in the market

Low-loader trailer has better capacity in carrying the concrete blocks as compared to the other types of trailer. However, it is hardly available in some part of the country. In some cases, to get as many as 4 to 6 numbers of identical configurations and dimensions of low-loader trailers for a load test is a big challenge. Considering this difficulty, high bed trailers were chosen as an alternative, as they are easily available in the market. However, the high bed trailer which tends to have the payload concentrated on the rear axles would often have the difficulty moving under heavy load. The use of standard test vehicles with known axle load under each loading level would avoid the need to weigh the test vehicle prior to the test.

Prior to carrying out the load test at site, the test vehicle has to be weighed to get the load from each axle (See Figure 3). The weighing of test vehicle is usually done at the nearest Jabatan Pengangkutan Jalan (JPJ) weighbridge station (see Figure 4). The axle loads are then used in the bridge modelling to obtain the theoretical responses of the bridge when subjected to load from the test vehicle. However, the test vehicles supplied at site for the load test sometimes are of different dimensions from the vehicle weighed prior to the load test. As a result, the targeted load effect might not be as accurate as desired. In this case, if the dimensions of the test vehicle is significantly different from the vehicle that had been weighed, the test vehicle shall have to be reweighed and the bridge model redone.



**Figure 4.** Weighing of test vehicle in Stesen Penguatkuasa JPJ

3.1.3. *Superstructure over river or high in elevation.* Superstructure that crosses over the river or is high in elevation often poses many challenges in a proof load test. They are:-

- i. Site measurement for dimension verification,
- ii. Collection of samples for material test,
- iii. Installation of instruments,
- iv. Joint inspection.

When as-built drawing of the bridge is not available, a comprehensive site measurement would be necessary. Other than that, sampling and testing of bridge material are also required to assess the in-situ material properties of the existing bridge elements. All these are needed for the structural modelling and analysis. In addition, joint inspection to check if there is new damage to the bridge is usually carried out at arm's length distance.

Therefore, in order to carry out the aforementioned activities, construction of a cantilevered working platform is required at locations of interest as a means of access (see Figure 5). The installation of cantilevered working platforms would often require a contractor specialized in scaffolding installation.

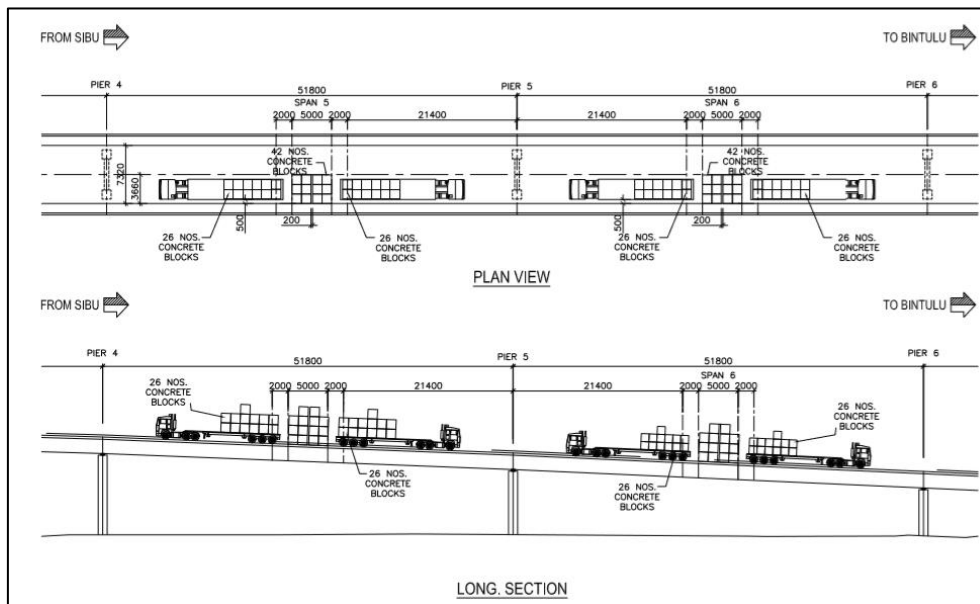


**Figure 5.** Working platform at a superstructure that crosses over river and high in elevation

Also, a linear Variable Displacement Transducer (LVDT) is not suitable to be used at a bridge that crosses over river or high in elevation. This is because the LVDT requires an independent and firm support so that it can measure the movement of the bridge component accurately. A survey instrument such as total station with prisms would be often used as an alternative. However, this would compromise the precision of deflection reading to certain degree.

3.1.4. *Safe procedure for loading and unloading.* During the planning stage, a safe procedure for loading and unloading has to be established. The challenge is to ensure that the loading and unloading activities would not cause damage to the bridge at any stage of loading and unloading activities. To minimise the risk of a bridge being loaded beyond its capacity, the proof load is often applied incrementally in stages with smaller increments towards the later stages.

One should also bear in mind that any mistake in unloading sequence of one span could result in a higher bending effect to the adjacent span of the bridge. For example, to obtain the maximum hogging moment at pier, the test vehicle would be loaded incrementally on the left and the right side of the pier (see Figure 6).



**Figure 6.** Load vehicle for hogging moment at Pier 5

During unloading, removal of test load in Span 5 could result in an increase in bending effect in Span 6. Thus, to avoid from this situation, it is advised that the test load in both spans to be removed concurrently. To establish this load sequences, the movement and sequence of load crossing over the bridge span to the positions of test loads are analysed and studied. The safe loading and unloading sequences are identified and any related procedures are formed. The time taken to complete the whole cycle of loading and unloading are analysed to ensure that the proposed load stages in loading and unloading procedure could be done within the test period.

**3.2. During the Test Phase.** During the test, common problems include slow progress of works, machineries breakdown, actual measurement conflicting with theoretical values and sign of failure occurs.

**3.2.1. Load test within a short time frame.** Usually, the time available for the load test is short, especially when the load test is only allowed to be conducted at night and need to be stopped in the morning. In this situation, efficient management of the resources is crucial to ensure that the test could be carried out smoothly and successfully within the short time frame. Time analysis is carried out in order to get a best work sequences that suite to that short time frame. The work and time schedule is then established to guide the tester during the load test. This schedule is used as a baseline to monitor the progress of works during the test.

Sometimes, inexperienced worker could cause slower work progress. Other than that, high volume of traffic during the load test could also delay the progress of works during the test. It resulted in longer time required to ease the traffic after every 30 minutes of closure.

**3.2.2. Machinery problems.** Machinery problems related to the test vehicles and crane can happen during the test. It is thus important to prepare a backup plan during the planning stage, e.g. having an extra test vehicle and crane.

**3.2.3. Measurement deviated from the theory.** The use of instruments in bridge load testing is to monitor the behaviour of critical bridge members during the test. The measured readings are closely monitored and compared to the theoretical values to ensure that the bridge behaves in a linear elastic way when subjected to the test load. Precautionary action would be taken when the measured readings

significantly exceeded the theoretical values or the bridge started to show non-linear behaviour. This is to ensure that the bridge is not be overloaded or deformed excessively during the test. However, sometimes the readings are not as expected, for example:

- i. readings that are out of order of the magnitude,
- ii. strain readings that shows the location is in compression when theoretically it was expected to be in tension and vice versa.

The instrument could also be damaged due to impact from boat, barge, vehicles moving under the bridge. If the bridge being tested is located in rural area, there is possibility for wild animals fiddling with the instrument thus damaging it.

*3.2.4. Accident.* One should anticipate for accident that could happen during the load test. Therefore, an accident response plan should be prepared prior to the load test, which shall include, but not limited to the following:

- i. The action to be taken to minimize the risk of accident,
- ii. Action to be taken when accident occur to minimize the damage.

*3.3. Post-Test Phase.* If a bridge has been successfully tested to the final targeted load, and did not show any signs of failure, i.e. behaving in linear-elastic way to the load increments and no damage on the bridge after the load test; this is actually an indicator that the bridge has the capacity of at least the targeted test load.

Deviation of some of the test results from the theories is quite a common occurrence in proof load test. It is because the model developed did not be behave exactly as the actual bridge. However, as long as the measured values did not deviate significantly from the theoretical values; and behaved linearly with the incremental load stages, the test results can be considered as acceptable.

24-hour readings of deflections and strains are taken one day before and after the load test, without loads, to study the behaviour of strains and deflections due to temperature changes. The measured strains and deflection should be corrected to compensate the variations affected by temperature changes.

#### **4. Conclusions**

Proof load test involves the positioning of the load (known as “proof load”) to a bridge, to verify that the bridge is capable of sustaining it without causing severe damage or permanent deformation to the bridge. Though this appears simple, the actual challenges come from the planning, inspection and execution of the test, not only technical but also logistics aspects, which requires extensive planning, analysis and specialized equipment.

In this paper, the challenges encountered by the authors while conducting a proof load test are presented. The intention is to share the authors’ experience in conducting proof load test, as a reference for engineers who may perform such tests in the future.

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