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LOAD CAPACITY EVALUATION FOR ABNORMAL LOADS TRAVELLED OVER EXISTING BRIDGE

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Introduction

All bridges in our road networks are deliberately designed and capable to meet specified load as in code of practices. These loads are however based on the probabilistic basis that allow normal routine of haulage and logistic in standard transportation system. Often the bridges are required to cope with modern logistic vehicles and abnormal load such as stream boiler or power transformer for instances form time to time. This calls for methods of transport with the capacity to move larger objects from factory to site, commonly over public roads.

Figure 1: Typical haulage carrying steam boiler passing over a bridge

Such journeys are sometimes made with special vehicles and always pose a challenge to bridge engineers, entailing design experience, field experience (especially in bridge

inspection) and a good understanding of heavy vehicles and the operation at hand. Despite safety margins in design, an overloaded transport cargo or vehicle may endanger the public and adversely affect the sustainability of the structure and its life expectancy.

This document is intended to serve as a guideline for logistics and freight company carrying overweight and abnormal loads to cross over existing bridge within its en route that belong to Government's assets. This document also intended as assistance tools for bridge evaluation for the purpose of application for the logistics company.

Necessary Process

In Malaysia, any oversized or overweight vehicle that wish to pass a desired route must acquire approval the regulating body of the road owner. Apart from the approval, the ability of the bridges and structures to carry super heavy transportation loads, without causing any damage depend on the processes which related to relevant stakeholders i.e., road authorities. Listed below are some processes involved prior to the issuance of the approval to allow the bridge to be crossed over.

The work process includes:

i. Initial survey of the transport origin and destination and the vehicle characteristics.
ii. Recommendation of a preferred route, to minimise potential damage to bridges or in case of required bypasses.
iii. Analysis of bridges and road structures, using advanced tools and simulations, to ascertain the load capacity limits.
iv. Design and temporary strengthening if necessary to have marginal load capacity.
v. Documentation and calculation for each and every structure along the path and filing of the recommended process and route with the customer and the authorizing transportation authority.
vi. Inspection of the temporary strengthening, if needed, of the mentioned structures prior to the cargo transport.
vii. If required, the vehicle should be escorted during the transfer, to ensure proper implementation of given instructions and to provide real time solutions in case unexpected problems arise.
viii. Conducting damage assessment survey on all structures along the route after the transfer.
ix. Documentation and Reporting to relevant stakeholders.

Among the pertinent aspect in the process that requires the logistic company to undertake is the evaluation of strength capacity of the existing bridge structure as mentioned in item (iii) above. The evaluation shall be done by the consultant appointed by the logistic company.

Methodology of Evaluation

In principle the evaluation of existing bridge technique consists of among other are two most common methods. The first method is to evaluate directly from configuration of intended vehicle and load that is going to pass the bridge. The intended vehicle can be the conventional trailer or multiple axles with articulated steering modules. Figure 2 below depicts typical overloading vehicle configuration used for load application on the existing bridge. In this method, the information of the bridge configurations is known beforehand.

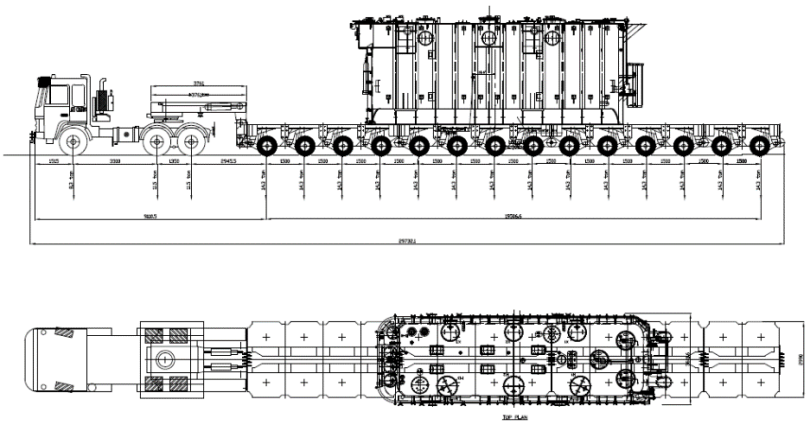

Figure 2: Typical outlook of multiple axles and articulated steering module

The second method is through the evaluation and analysis from JKR Bridge Management Systems (*BMS*) data information. This method provides the insight of the strength capacity of the existing bridge by using established proforma from the calibrated vehicle load. Once the existing bridge information is obtained, analysis can be carried out to ascertain the strength capacity of the bridge and hence comparison to the intended crossing load are made.

Analytical Evaluation

In this section, the analytical approach to estimate the allowable load rating for the existing bridge is outlined. Analysis methods i.e., grillage method and member resistance are described in this section. The recommended material and relevant standards codes also stated in this part.

Evaluation Codes through established guides

Reference and guides to the following standard should be referred when using this method to carry out the analytical evaluation of the bridge.

i. JKR Terms of Reference for Bridges and Viaducts Structures
ii. BD 44/95 - The Assessment of Highway Bridges and Structure, Department of Transport UK
iii. BD 21/01 - The Assessment of Concrete Highway Bridges and Structures, Department of Transport UK.

These documents should be referred as in the list. Where higher level of document should be used when there is conflicting usage. As for example, when evaluating the concrete bridges, BD 44/95 should be used instead of BD 21/01. The hierarchy of above documents need to be aware by the designer.

The evaluation of existing bridge call for the in-situ material strength of the member components. Thus, Table 1 below provides the recommended value for material strength and corresponding partial factor used for the evaluation of the existing bridge while Table 2 provides the recommended partial factor values for related loads that are applied in evaluation analysis.

Table 1: Recommended value of material strength and partial factor for existing bridge

Material Strength			Partial Factor		
f_y	=	230 N/mm^2	γ_{ms}	=	1.10
f_{yv}	=	230 N/mm^2	γ_{mv}	=	1.15
f_{cu}	=	20 N/mm^2	γ_{mc}	=	1.20

Table 2: Recommended value of corresponding partial factor against loads.

Loads	Partial Factor
Dead Load	1.15
Superimposed Dead Load	1.75
If premix was measured	1.25
Live Load	1.50
Live Load SV	1.30

Permanent Load

Permanent loads on bridge consist of dead load and superimposed dead load. Dead load can be defined as load that unlikely to change through the service life of the bridge i.e., self-weight of the bridge beams, decks and parapet. While superimposed dead load is a

permanent load that might change during service such as asphaltic concrete, railing and architectural features. The recommended value for density of material for those permanent load as given in Table 3 below:

Table 3: Recommended value of density for material on existing bridge

Material	Density
Reinforced Concrete / Concrete	24 kN/m^3
Prestressed Concrete	25 kN/m^3
Premix	22 kN/m^3
Steel	77 kN/m^3

Live Load

In making the comparison to the intended overweight load, the selection of the live load for the evaluation of the existing bridge is crucial. The deployment of the live load in the evaluation is depending upon the year of existing bridge were built. Generally, in the absent of the document, for analysis purposes, the live load shall be using JKR Specification for Bridge Live Loads listed below:

i. Long Term Axle Load (LTAL) combine with KEL
ii. Special Vehicle (SV20) Loading.

The detail of the loads and their application can be retrieved upon request from Bahagian Rekabentuk Jambatan, Cawangan Jalan JKR Malaysia. Freight Company may also deploy other type of established live load for the purpose of evaluation of the crossing bridge upon agreement with abovementioned JKR office.

Structural Responses

Getting the structural responses in the sense of stresses and forces acted upon the bridge can be done through the grillage method at least. Other sophisticated method that yield to similar results may also be used. Generally, grillage analysis is the most common method used in bridge analysis. It was found that the outcomes obtained from grillage analysis compared with more complex methods are accurate enough for design and analytical purposes. Figure 3 shows typical arrangement of existing bridge girder modelled in grillage analysis.

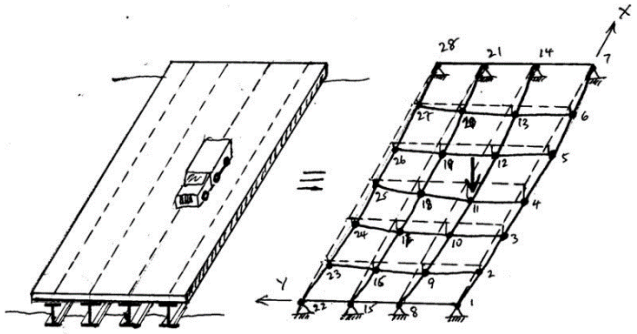

Figure 3: Typical grillage model

This method used by converting the bridge structure into the skeletal member connected by nodes. The load-deformation relationships are expressed in term on stiffness properties at two ends of a skeletal element. This relationship referred to member coordinate axis, and transferred using transformation matrix to the global axis of the structure. The structural responses obtained from the grillage analysis will then be used for the evaluation of bridge member or component resistance capacity.

Member resistance by statistical method

The critical part of the evaluation of any existing bridge is to determine how much load the structural member or the components would able to carry. Section properties, geometry, material in the form of concrete and steel are the important information in assessing the strength of the existing bridge. The evaluation exercise however would become exacerbate and not easy to asses for those bridges which were built during 20 or 30 years back. In view of this, JKR has proposed the statistical method to evaluate the member resistance of these bridges. This method is meant for the calculation for member resistance of simply supported reinforced concrete bridge or bridge with steel encase with concrete. It can only be applied for certain bridges as follow:

i. Simply supported reinforced concrete bridges
ii. Bridges in Peninsular Malaysia
iii. Bridges constructed between 1950 and 1972
iv. Bridges spanning between 6 -15 metres

The following equation using statistically method to estimating the percentages off steel reinforcement area in a girder. The method was derived from 55 numbers of bridge with the probability of steel reinforcement area using the 95% occurrence.

$$\% \text{ steel area} = 0.016 - RC_{Index} - 0.20 \quad \ldots\ldots\ldots (1)$$

And the RC_{Index} can be calculated from equation below:

$$RC_{Index} = 100\,\frac{S.L^{1.326}}{W.D^2} \qquad \text{..... (2)}$$

Where;

S = spacing of the girder (mm)
L = span length (mm)
W = width of the girder (mm)
D = effective depth of the girder (mm)

The load carrying capacity of a bridge is assessed based on the ratio of the available resistance of a member to the effective of live load from the application of either LTAL (Long term axle load) or Special Vehicle (SV) 20 type. It can be expressed in the term of rating as:

$$\text{LTAL Rating} = \frac{(\emptyset R)-(\alpha D)}{\alpha L} \qquad \text{..... (3)}$$

where ϕR = factored resistance of member
αD = Effect of the factored dead load on a member
αL = Effect of the factored live load LTAL (Long Term Axle Load) on member

$$\text{SV Rating} = 20 \times \frac{(\emptyset R)-(\alpha D)}{\alpha L_{sv}} \qquad \text{..... (4)}$$

where αL_{sv} = Effect of the factored SV20 loading on member

From either one of these ratings, a comparison to the intended live load to be carried over the bridge can be evaluated. The rating limit of 0.8 is taken as the margin where the decision of allowing the carrier to pass over the bridge. It can be deduced into two cases as below:

Case 1: Rating LTAL or SV20 > 0.8. It implies that the bridge is capable of carrying the load of LTAL or SV20. The comparison of LTAL or SV20 is made against the intended load by carrier and permission is granted if the intended carrier laod is less than LTAL or SV20.

Case 2: Rating LTAL or SV20 <0.8. It implies that the bridge is incapable of carrying the load of LTAL or SV20. The comparison of LTAL or SV20 is made against the intended load by carrier and permission is denied if the intended carrier load is more than LTAL or SV20.

Conclusion

Assessment of the existing bridge capacity within the en route of overweight or abnormal load must be carried in a right manner to safeguard government's assets. In the nutshell, the comparison between the existing capacity with the actual loads from the logistic company should be able to provide the custodian of the bridge/structure i.e., JKR to made a decision whether to accept or to decline the application from the freight company. Apart from the capacity assessment, lacking of anticipating potential risk hazard during the activity may also undermine the serviceability function of the bridge.

References:

1. *JKR Term of Reference for Bridge and Viaduct Structure 2018.*
2. *JKR Specification for Bridge Live Load 1990*