6TH REAAA CONFERENCE

Paper on

STANDARD JKR SPECIFICATION FOR BRIDGE LOADING

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ABSTRACT:

As the owner of about 80% of the nation's bridges, the Public Works Department Malaysia (JKR Malaysia) is often looked upon as a bridge authority with regard to standard practices in bridge design in Malaysia. There is a need for JKR to formulate and implement a national standard specification for bridge loading. In fulfilling such need, the Bridge Unit of the JKR Roads Branch had set up a "Bridge Loading Committee" to study and review various bridge design codes as well as the recommendations proposed by the National Axle Load Study Report (1987). It was hoped that the standardisation would achieve the best compromise fulfilling Malaysia's needs in terms of economy, utility and safety in the overall management of the road systems.

This paper reports the various considerations deliberated by the Committee in the formulation of the standard specification. It also discusses the proposed specification.

1.0 INTRODUCTION

1.1 Background

Due to the historical background of Malaysia as a British colony, Malaysia has traditionally adopted the British Standards in bridge design. BS 153 Pt.3A loading has been used with some slight modifications in the application of HB loading.

Adopting an established standard avoids having to duplicate research effort. However, it risks accepting something not truly representative of the local conditions. As the owner of some 80% of the nation's bridges, the JKR (Public Works Department, Malaysia) has often been looked upon as a bridge authority with regard to standard practices in Malaysia. The JKR has formalised the adoption of BS 5400 by requiring the consultants executing JKR projects to use this design code. However, due to the enormous efforts needed to revise the existing JKR standard bridge design, the JKR has continued to use BS 153 in the bridge design. This has led to non-uniform standard of bridges in the national network; and also created some confusions with regard to the design standards to use. There is a need for JKR to formulate a nationally accepted bridge loading specification.

In 1986, the Roads Branch of JKR has published a report which recommended some bridge loading criteria based on Limit States Method [1]. The recommendations proposed in the report had already been approved by the reviewing committee in JKR but fell short of full implementation.

The National Axle Load Study, completed in October 1987, had proposed to raise the present axle load limit in Malaysia. The Study also proposed a new set of loading curves to be used for future bridge design and assessment.

As a positive response to the National Axle Load Study, a committee called "Bridge Loading Committee" (henceforth called "the Committee") was set up by the Bridge Unit of the Roads Branch to review the recommendations and propose a new standard bridge loading specification.

1.2 The Specification

The proposed standard specification [4] was intended to supersede the earlier JKR standard bridge loading criteria (1986) and Section 6 of BS 5400 Pt. 2: 1978. It shall also be read in conjunction with the relevant clauses of the various parts of BS 5400. The specification covers only live load due to normal and abnormal vehicles, namely, the LTAL and SV loadings respectively. It shall be used in the design of highway bridges with loaded lengths not exceeding 50m.

2.0 THE APPROACH OF STUDY

Due to lack of resources, the Committee was not able to conduct its own research to derive parameters needed in the formulation of bridge loading models, for example, impact factor. The Committee had instead, relied on published data which included the National Axle Load Study Report, relevant bridge guides/codes and other technical papers on bridge loading.

In parallel with the literature research, a survey of abnormal vehicles in operation in Malaysia was done. This involved the gathering of data on the types, configurations, axle loads and other relevant characteristics of abnormal vehicles and also the composition of indivisible goods transported in Malaysia. The main objective was to get an accurate picture of the abnormal vehicles prevalent in Malaysia, hence establishing a basis upon which to develop the standard abnormal vehicle model. The survey was divided into 3 parts:

i. Inspection of abnormal vehicles owned and operated by major transporting companies in the country;

ii. Reviewing the records of past applications for movement permits submitted to JKR by the transporting companies through their consultants;

iii. Interviewing owners of the very heavy freights that are being transported.

3.0 THE NATIONAL AXLE LOAD STUDY

3.1 General

The National Axle Load Study started in December 1985 and completed in October 1987 was undertaken by Rendel Palmer & Tritton Ltd., UK in association with Minconsult Sdn. Bhd., Malaysia and JKR (Henceforth called the "Study Team"). The main objective of the study, among others, was to determine the optimum axle loading for the Malaysian road transport system and to formulate proposals for the new Malaysian motor vehicles regulations. Thus, the focus was mainly on the normal vehicular loading criteria.

3.2 Normal Loading

The Study Team's recommendations on normal loading were mainly based on an unpublished paper by the UK Department of Transport entitled "Revision of Short Span Loading".

According to the report, the HA loading in BS 153 which was based on Henderson's work in the fifties, is inadequate for the present day traffic. First, no allowance was made for overloading. Second, it represents the effect of a train of up to five 22-ton vehicles and as a consequence becomes inadequate for the longer spans.

BS 5400 and the DOT's document BD 21/84 have subsequently revised their respective normal loading (HA) standard to represent the present vehicle fleet in the UK. The Study Team was of the opinion that the loading model to be used in Malaysia should reflect the vehicle fleet currently available in the world market. As such, the loading curve in BD 21/84 was recommended with slight modifications for loaded lengths up to 20m. For loaded lengths exceeding 20m the loading curve in BS 5400 was recommended.

However, it had been observed that the variable notional lane width concept used in BD 21/84 and BS 5400, coupled with reduction in load intensity on any lanes in excess of two would lead to anomalies. For example, an increase in the width of a bridge produces a reduction in the total load it should be designed for (Fig.1). The Study Team had therefore recommended the use of fixed lane width of 2.5m.

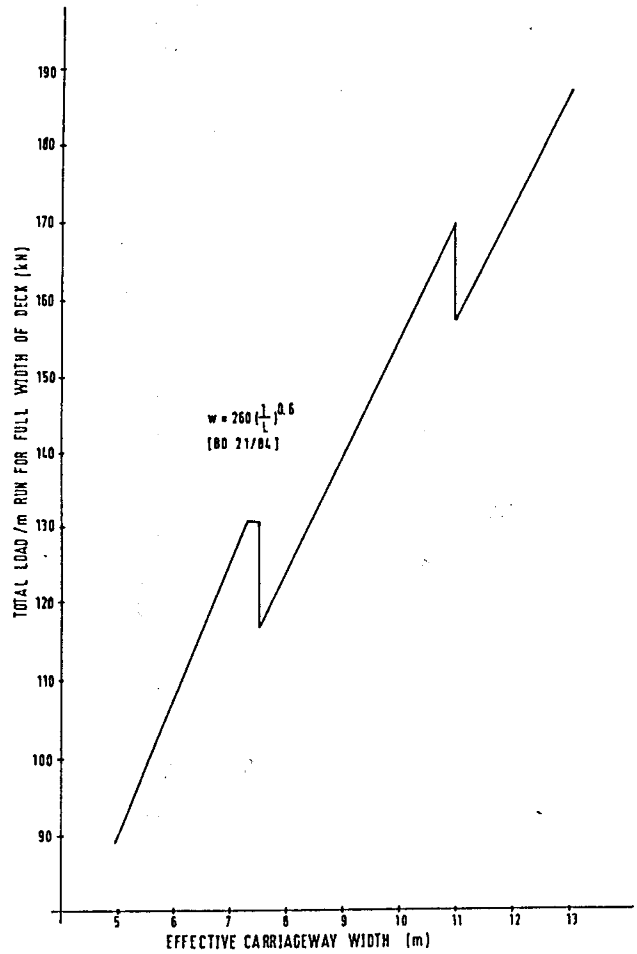


FIG.1 ANOMALY IN USING VARIABLE LANE WIDTH RULE
(APPLIED TO 10 m SPAN)
[From Ref.2]

The combined curve from BD 21/84 (adjusted to 2.5m fixed lane width) and BS 5400 curve constitutes the proposed UDL for normal loading (Fig.2). This proposed UDL shall be applied with BS 5400 KEL.

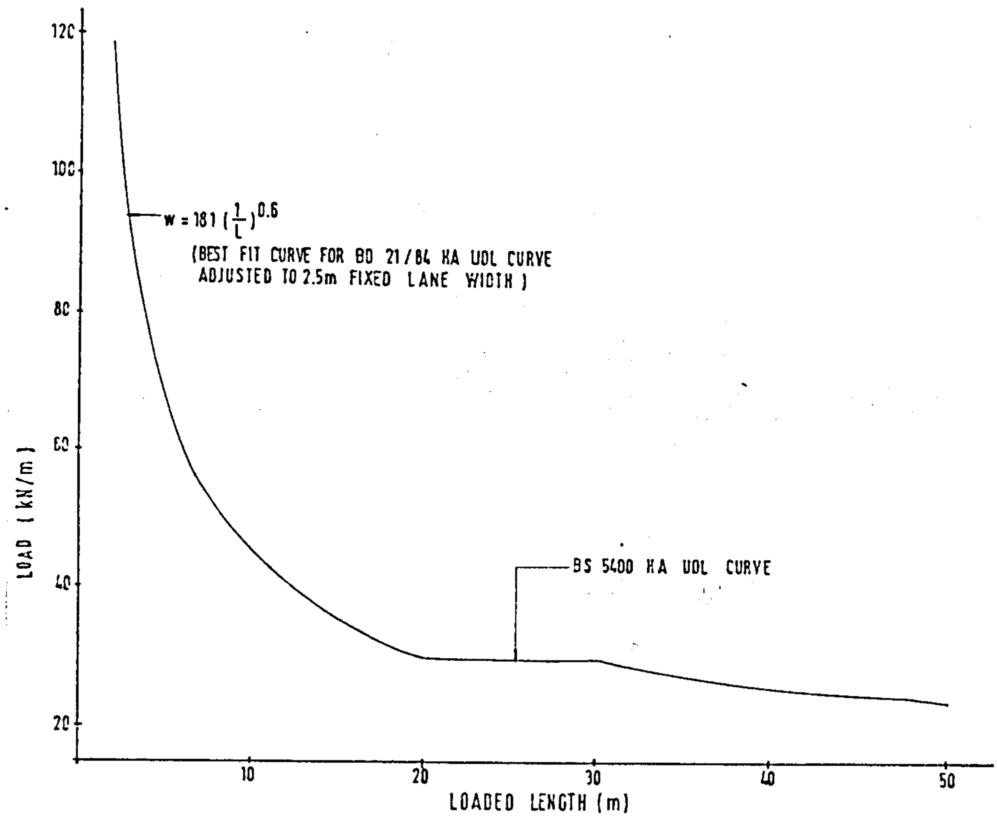


FIG. 2 LTAL LOADING CURVE AS PROPOSED BY THE STUDY TEAM.

3.3 Abnormal Loading

Although the Study Team's work focused mainly on the normal vehicular loading, its report on bridge loading does contain a few recommendations with regard to abnormal loading. They can be summarised as follows:-

i. A clear policy be adopted in which normal vehicles are covered by normal loadings and abnormal vehicles by abnormal loading;

ii. The passage of two classes of vehicles, namely the very heavy abnormal vehicles and the more routine general order vehicles or GOV's; be catered for by a provision for the passage of an abnormal loading, using either the BS 5400 HB loading or the JKR Special Vehicle loading or both. The configuration of the JKR Special Vehicle shall be as recommended in the JKR report on bridge loading criteria (1986). GOV's are not normal road vehicles as defined in the motor vehicle regulations but might not be sufficiently heavy to require a permanent police escort; examples would include the low-loaders (Fig.3). Permits for individual GOV's should only be issued when a check has been made on the effect of that particular vehicle, in a mix of normal vehicles, on the bridge it will be permitted to cross.

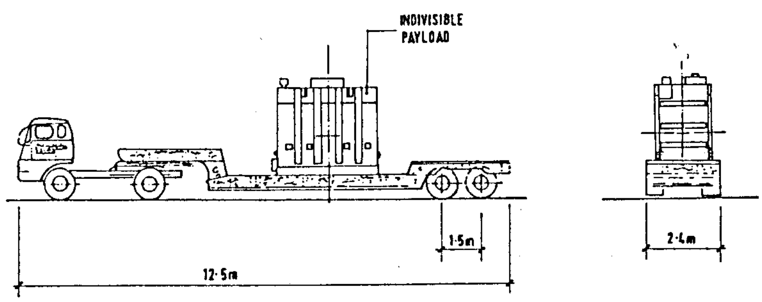


FIG. 3 LOW-LOADER : AN EXAMPLE OF GOV'S.

iii. The abnormal vehicle is to be unguided, or at least can stray 2m either sides of the centre-line, and that other vehicles may also be on the bridge at the same time. The policy of designing for HB guided should be dropped or significantly changed for all roads to permit flexibility in future for movement of both abnormal and general order vehicles.

4.0 THE COMMITTEE'S RECOMMENDATIONS

4.1 Normal Loading

The National Axle Load Study Report [2] was the main source of reference in the Committee's discussion on normal loading. Other UK bridge design specifications were also studied and compared.

After reviewing these bridge specifications and the Study Team's recommendations, the discussions by the Committee on normal loading mainly centred around two subjects:

i. What loading model to adopt for bridge design;

ii. Which lane width rule for determining the number of notional lanes.

4.1.1 Loading Model

A realistic relationship should always exist between actual vehicular loads and idealised design loading models. The Committee felt that the loading model to be adopted should represent future vehicle fleet in this country. The configuration and other characteristics of future vehicles very much depend on the technological advances in motor industries as well as the Government's future policies. Since these are hard to predict, the Committee had decided that the future vehicle fleets in Malaysia would resemble closely those in the U.K. As such, the loading models in BS 153, BS 5400 and BD 21/84 were considered and deliberated.

A comparison of the three loading models is given in Fig.4.

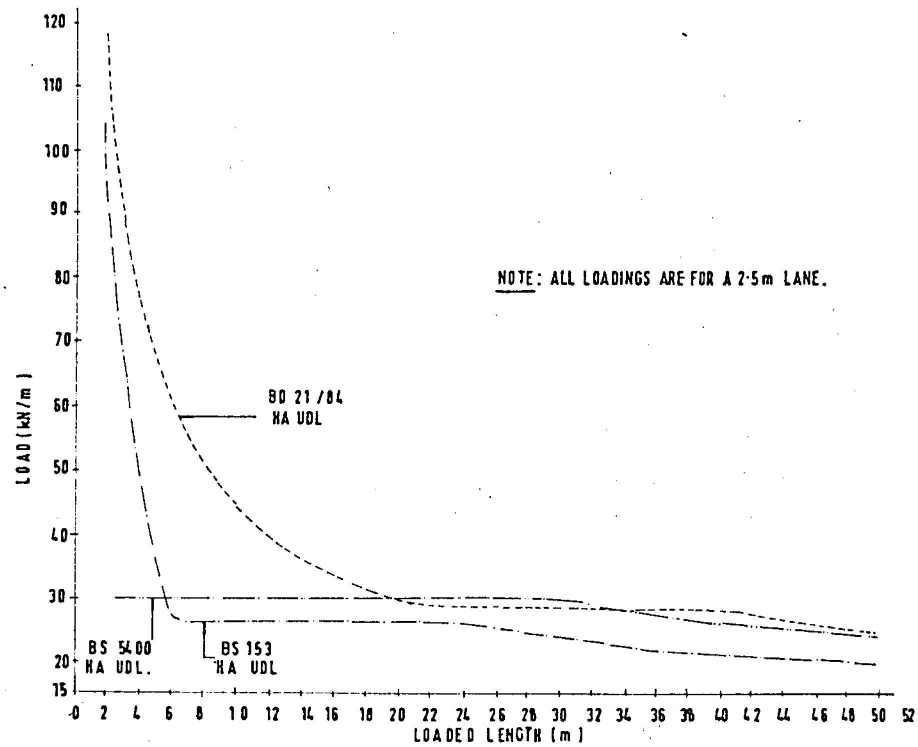


Fig. 4 COMPARISON OF LOADING MODELS.

The loading model of BS 153 is understood to be inadequate for the present day traffic and hence its adoption can be rejected. The loading model in BS 5400 is also considered inadequate in two aspects:

i. Loadings at very short spans are inadequate;
ii. Lateral bunching concept is not incorporated in the loading model.

The loading model in BD 21/84 seemed to be the most acceptable provided that there was no disagreement with regard to the adoption of the various parameters used in its derivation.

BD 21/84 is in fact meant for bridge assessment. Its derivation has been based on:

i. Allowance for lateral bunching of heavy vehicles. A factor of 1.45 has been assumed to be constant up to a span of 20m, reducing linearly to unity at 40m.

ii. Allowance for overloading of 1.4 up to 10m reducing linearly from 10m span to unity at 60m span.

iii. Allowance for impact of 1.8 applied to only 1 axle of a single vehicle. No impact assumed for multiple vehicle train.

iv. Nominal loading = ultimate loading/1.5

v. Ultimate loading effect
$= P \times F_i \times F_o \times (1/F_w) \times 1.1$

where P = maximum loading effect (shear force or bending moment)

F_i = impact factor

F_o = overload factor

F_w = lane width factor

$1/F_w$ = lateral bunching factor

The *1.1* factor is to allow for unforeseen changes in the make-up of the vehicle fleet.

4.1.2 *Lane Width Rule*

For the purpose of applying the specified live loads the carriageway shall be divided into notional lanes. BS 153 and BS 5400 tabulate the number of notional lanes to the carriageway widths. BD 21/84 recommends the use of actual lane marking to determine the number of notional lanes.

If there is no lane marking the number of notional lanes shall be obtained from appropriate table in the code. The widths of the notional lanes in these codes are variable. As was pointed out by the Study Team, the use of variable lane width coupled with reduced intensity for lanes in excess of two would lead to anomalies described in 3.2. A fixed lane width of 2.5m had been proposed.

The only main reason to introduce the fixed lane width rule by the Study Team was to avoid the anomaly described above. In fact, if the number of lanes is taken as that would be marked on the structure based on JKR road standards stipulated in JKR Technical Instructions (Roads) 8/86 this problem does not arise. In this Technical Instruction, carriageways are classified into five standards depending on the carriageway widths. The five standards represent five discrete points on the 'carriageway width' axis in Fig.5. There is no road standard (corresponding to a certain carriageway width) that will have a lower load intensity compared to the adjacent lower standard. Indeed the load intensity will be increasing from the lower road standards to the higher ones. However, the Committee felt that the lane markings on the bridge carriageway could be changed from time to time with the revision of the policy and thus the use of actual lane marking to determine the number of lanes was not recommended.

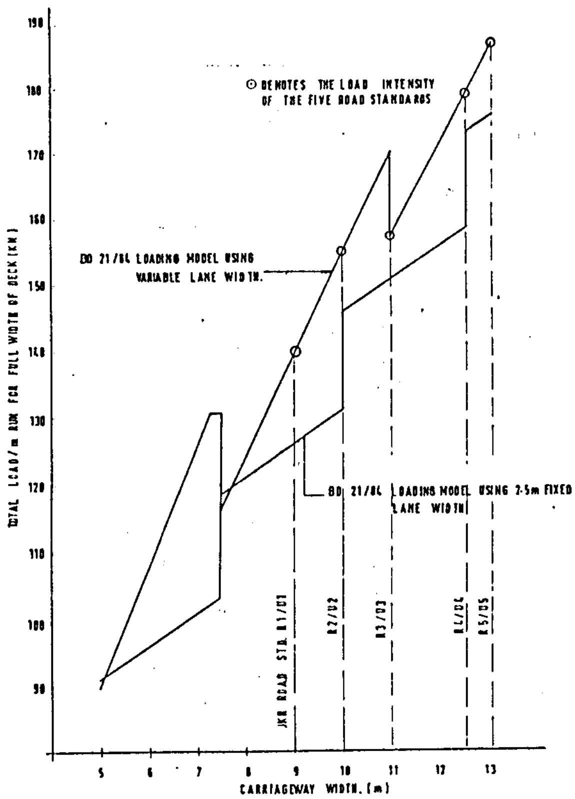


Fig. 5. COMPARISON OF LANE WIDTH RULES (APPLIED TO 10m SPAN.)
[FROM Ref 2]

On the other hand, the adoption of a standard 2.5m fixed lane width seems reasonable. However, there was concern for the inadequacy of this rule to cater for the expected reduction in lateral bunching for loaded lengths exceeding 20m. Analyses carried out by the Committee had shown that the load difference was insignificant even though full lateral bunching up to 50m was assumed (Fig.6). For a 13m-wide carriageway the maximum amount of load divergence between the variable lane width rule (represented by BD 21/84) and the fixed lane width rule is about 20%. Besides, the probability of having two convoys of heavy vehicles bunching together over a length of 40m is not that remote in Malaysia.

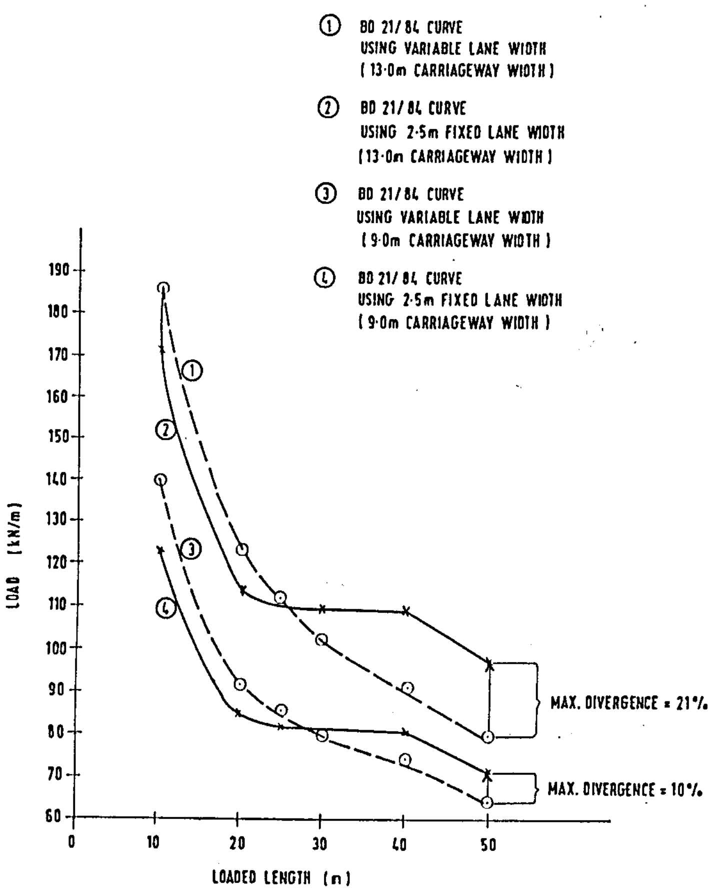


FIG.6 COMPARISON OF LANE WIDTH RULES

Based on the above discussions the following decisions had been made:

i. Adoption of the 'fixed lane width' rule with a 2.5m standard width.

ii. The adoption of BD 21/84 loading model adjusted to 2.5m fixed lane width (i.e. $w = 260 \times (1/L)^{0.6} \times F_{w-2.5}$)

where $F_{w-2.5}$ is the lane width factor (see Fig.7) corresponding to 2.5m lane width.

The proposed loading curve is called the LTAL (Long Term Axle Load) loading and is valid up to 50m loaded length only.

iii. A uniform reduction factor of 0.6 (to cater for reduced intensity for lanes in addition to two fully loaded lanes) shall be used throughout for all loaded lengths up to 50m.

iv. This LTAL UDL shall be used in conjunction with a knife edge load (KEL) of 40 kN/m.

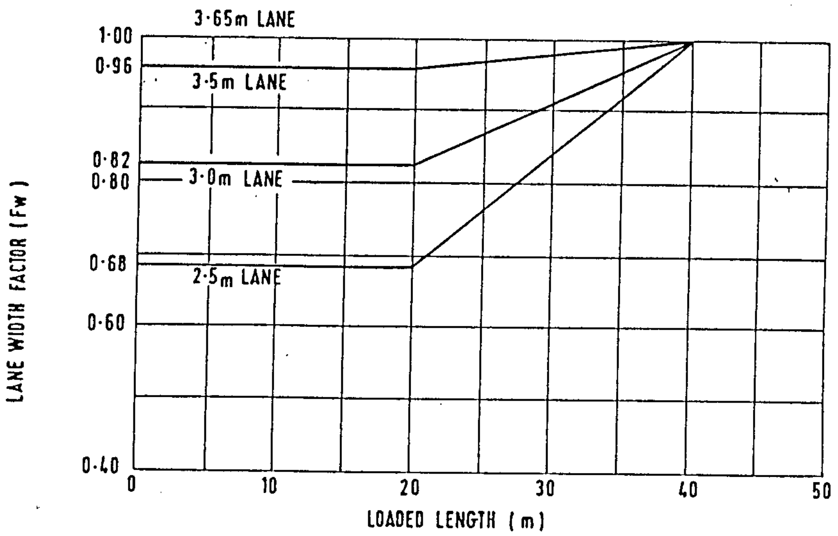


FIG.7 LANE WIDTH FACTOR (Fw) [FROM BD 21/84]

With the adoption of the above specification, the Committee had impliedly assumed that:

a) Full lateral bunching of heavy vehicles occurs up to a loaded length of 50m.

b) The probability of having additional convoy(s) of heavy vehicles in excess of two fully loaded lanes is constant up to 50m loaded length.

c) The future normal vehicles in this country will resemble those modelled by the loading curve in BD 21/84.

Assumptions a) and b) above result in a more conservative design; especially for longer loaded lengths. Then again, the adoption of BD 21/84 curve for all loaded lengths up to 50m (instead of switching to BS 5400 curve at and after 20m as was proposed by the Study Team) means that the JKR specification is less conservative than the Study Team's proposed specification for loaded lengths between 20.0m and 33.5m but is more conservative for loaded lengths between 33.5m and 50.0m (see Fig.8).

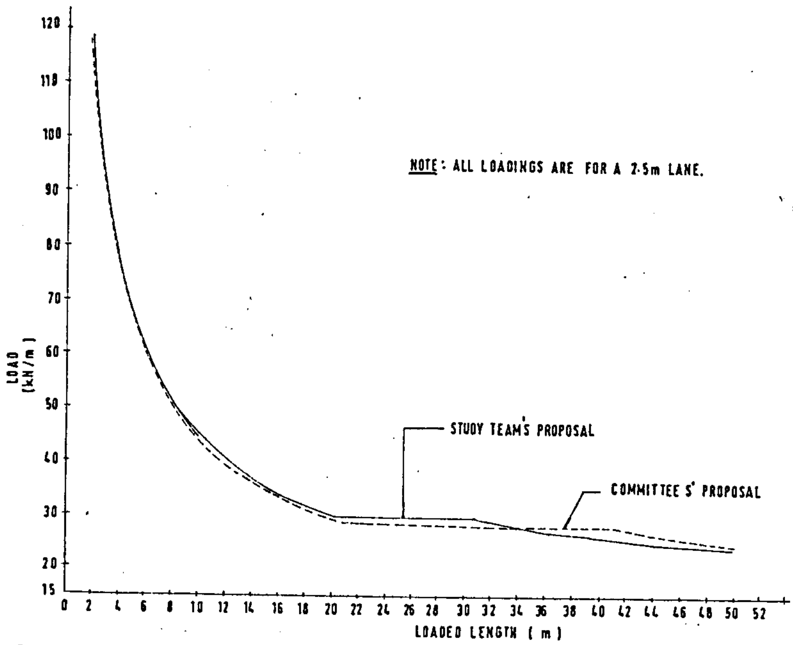


Fig. 8 COMPARISON OF THE STUDY TEAM'S AND THE COMMITTEE'S PROPOSAL

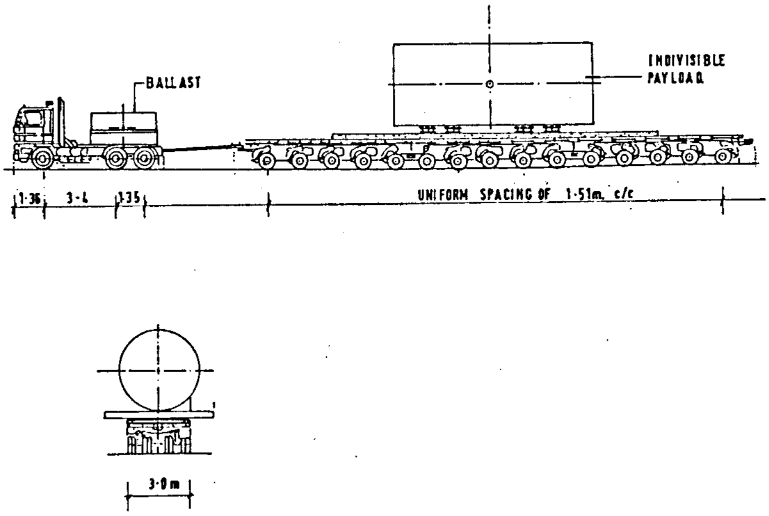


Fig 9 'COMETTO' TRAILER TOWED BY 'SCANIA' TRUCK
(SHAPADU HOLDING SDN. BHD.)

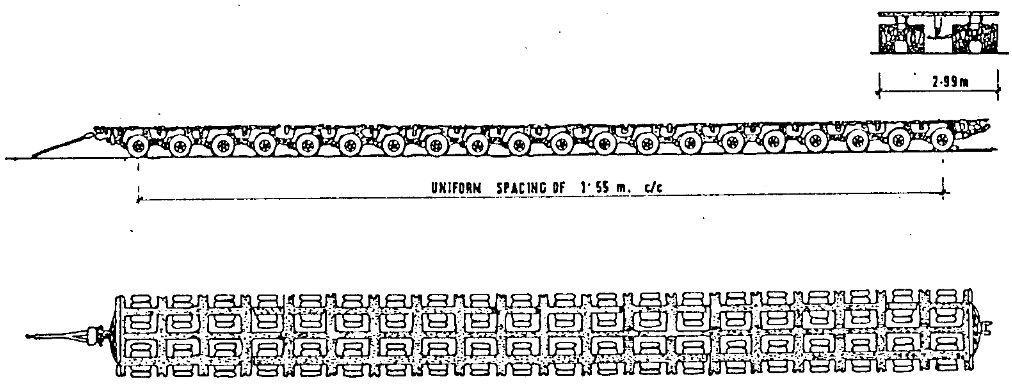


Fig 10 'NICOLAS' TRAILER (ASIA GENERAL TRANSPORT.)

and restriction of the heaviest abnormal vehicle in the interest of economy and utility.

From the survey outlined in 2.0, there were some observations about the characteristics of abnormal vehicle in Malaysia. They are:

i. There were no abnormal vehicles on Malaysian roads that resemble the British HB vehicle. The heaviest abnormal vehicles observed were the modular multi-axle trailers towed by tractors.

ii. The majority of abnormal vehicles in Malaysia (not including GOV's) are operated by two major transporting companies; Shapadu Holding Sdn, Bhd. and Asia General Transport Sdn. Bhd.

iii. 75% of the abnormal loads transported in 1987 and 1988 were transformers and related items transported from the ports to various NEB (National Electricity Board) power stations around the country. There were 16 passages of abnormal loads heavier that 40 tons recorded during those 2 years. The heaviest recorded pay load was 240 tons generator stator transported from Port Klang to Port Klang power station. The gross load was close to 400 tons.

iv. 94% of the trailers used to transport abnormal loads in 1987 and 1988 were the "Cometto" and "Nicolas" types as shown in Fig.9 and Fig.10. The number of axles utilised range from 5 to 20. The heaviest gross trailer weight recorded was 310 tons and the heaviest axle weight recorded was 16.35 tons.

v. All the abnormal vehicles recorded travelled along the centre-line of the bridge with all other vehicles from either direction stopped until the trailer had passed the bridge. A speed limit of 5 km/hr without sudden stops and starts was also imposed. Steel plates were placed across the expansion joints to prevent damage.

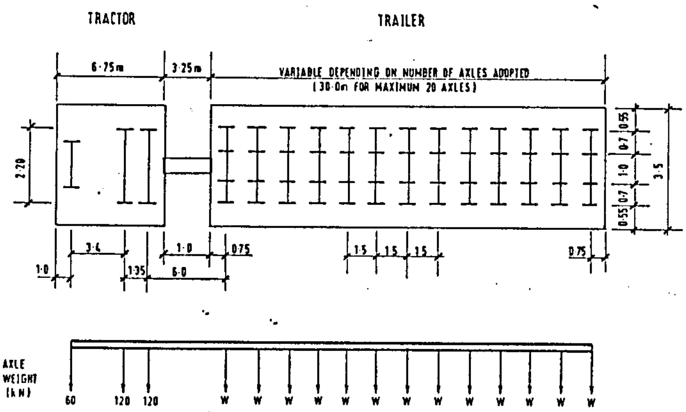
vi. All the bridges along the route taken by the abnormal vehicles were inspected before and after the movement by qualified engineers . Only in one instant was there a bridge damage attributed to the passage of an abnormal vehicle. The cracked concrete beam was subsequently repaired by the transporting company responsible.

vii. The consultant's reports evaluated that all the affected bridges designed to 45 units HB loading along the centre-line were capable of withstanding the recorded abnormal vehicles but those designed to HA loading were estimated to be 25% overstressed.

viii. Four routes had been used in 1987 and 1988 with a total distance of about 520 km. Three of them were from ports to power stations. The other was from an industrial area to a port.

ix. Most of the future indivisible goods will be owned by the National Electricity Board. They consist of transformers and turbines to be used in hydro-power plants.

From the information collected about the abnormal traffic in this country, a new class of abnormal design loading model was proposed. The configuration of the model is as shown in Fig.11. The model consists of a tractor and a multi-axle trailer.



NOTE : 1 UNIT SV HAS TRAILER AXLE WEIGHT OF 10 kN EACH.
THE DIMENSIONS AND AXLE WEIGHT OF THE TRACTOR IS CONSTANT.

FIG. 11 CONFIGURATION OF SV

The Committee felt that it was justifiable to have more conservatism in longer-span structures since failure of such structures will have a comparatively greater impact.

4.2 Abnormal Loading

The Committee had felt the need to create a new loading model for abnormal vehicle in place of the UK HB loading. The rationale was that HB loading is not at all realistic. At the same time there emerges a class of long vehicles used for transporting indivisible goods like transformers. It has become necessary for JKR to check for the effect of such heavy load when application for movement permit is being considered.

Besides, there is also another class of vehicles known as the general order vehicles or GOV's as discussed above. The Committee agreed with the Study Team that those GOV's that do not satisfy the normal LTAL loading limits should be catered for by the provision of an abnormal vehicle.

The Committee decided not to adopt the recommendation put forward by the Study Team with regard to the uncontrolled passage of the abnormal vehicles. In the JKR document on bridge loading criteria (1986), it was reported that a bridge deck designed for 45 units HB unguided can be up to 30% heavier than that designed for 45 units HB guided along the centre line. In view of the finding and the fact that the frequency of the heaviest abnormal vehicles is very low, it was deemed not cost-beneficial to allow unrestrictive passage of such vehicles on bridges. As the speed of the abnormal vehicle will be very slow and the centre-line of the bridge clearly marked, there will be no reason for the abnormal vehicle to stray even 2m from the centre-line. Flexibility of unguided movement should only be allowed for the lighter abnormal and general order vehicles. As these vehicles are quite frequent and marginally heavier than those allowed under LTAL loading, the resulting increase in bridge construction cost will be nominal and can be economically justified. In the later sections of this paper, a new type of standard abnormal vehicle model based on a graduated scale of axle loadings as proposed by the Committee will be highlighted. It is hoped that the loading model and its recommended mode of application will satisfy the contradicting needs for flexibility of lighter abnormal and

The tractor is modelled after "Scania" truck. It has a single 6-ton axle; plus tandem axles of 12 tons each. Its weight and dimensions are fixed for any length of trailer adopted.

The trailer is based on the "Cometto" and "Nicolas" type multi-axle trailer, which the Committee believed to be the most representative of Malaysian abnormal vehicles. Besides, due to its modular structure it is capable of carrying a very heavy pay load and thus can satisfy future needs. A maximum total of 20 axles was specified for the trailer, with each axle having four wheels. The number of axles can be reduced to suit the influence line diagram of a particular bridge structure to produce the worst load effect.

The model is being called JKR Special Vehicle or SV loading. One unit of SV shall be taken as equal to 1 ton per trailer axle plus the tractor weight. From the survey that had been carried out, the upper bound for the gross weight of the SV trailer considered suitable for adoption was 400 tons. This represents 20 units of SV.

5.0 IMPACTS

Increases in the allowable weight limits can certainly reduce the operating costs of freight transportation. However, this benefit is achieved at the expense of accelerated wear on the nation's pavements and bridges as well as other disbenefits. A complete axle load study should consider the impacts of the increased load limits on various factors; as outlined in the OECD report [3]. This has been the scope of work in the National Axle Load Study (1987).

The Committee was only concerned about the strengths of existing and future bridges with respect to the new loadings.

5.1 Structural Analysis

The effects of the proposed loading models on simple concrete slab and beam bridges of various spans were investigated using the GRIDP grillage analysis program. The analysis can be divided into three parts. They are as follows:

a) Analysis to obtain the bending moment and shear force envelopes for the following load cases:

   i) LTAL (UDL + KEL)
   ii) 20 units SV in controlled condition
   iii) 10 units SV uncontrolled condition
   iv) 45 units HB guided along centre-line

   The relationship between the critical load cases and spans was noted for both load effects.

b) Analysis to find the maximum number of units of SV loading that can be carried by bridges designed for LTAL loading only. This was done for both the controlled and uncontrolled movement of SV.

c) Analysis to find the maximum number of units of SV loading that can be carried by bridges designed for 45 units of BS 153 HB loading. This was done for the controlled movement of both SV and HB guided along the centre-line of the carriageway. The purpose was to investigate the relative capacities of bridges designed to SV loading and HB loading.

5.2 Analysis Results

5.2.1 Critical Loads

The load effects at critical sections due to the various loadings are tabulated in Table A1 of Appendix A. Values were obtained for spans of 10m, 20m, 25m, 31m and 40m. Maximum values of the bending moments and shear forces for the various spans are plotted and shown in Fig. 12 and Fig. 13 respectively.

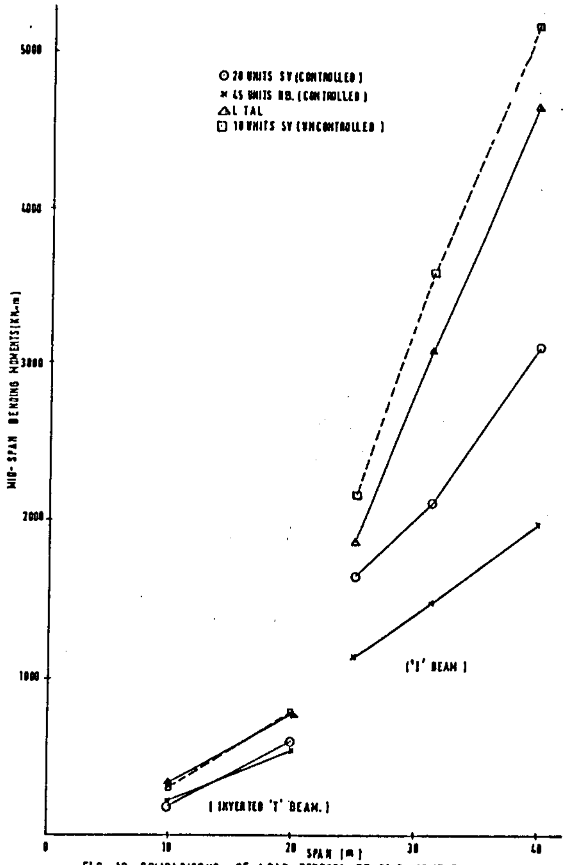


FIG. 12 COMPARISONS OF LOAD EFFECTS-BENDING MOMENT

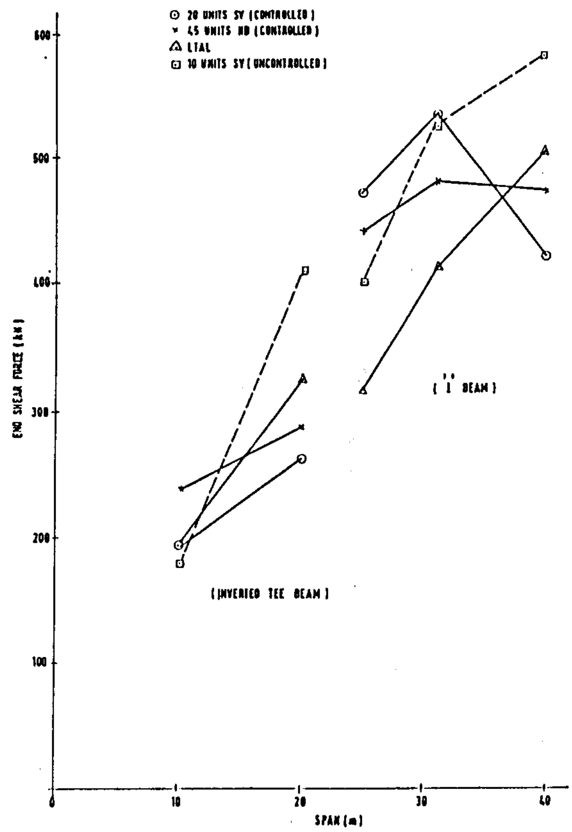


FIG. 13 COMPARISONS OF LOAD EFFECTS - SHEAR FORCE

From the graphs it is evident that the effects of 10 units of SV (uncontrolled) are very severe as compared to other loading models. Hence, it would be superfluous to require the nation's bridges to be designed to such high standards; and to allow uncontrolled passage of 10 units of SV. The LTAL loading is also very severe, being most critical in bending moment effect. In terms of shear force, 20 units of SV loading (controlled) is the most critical at the spans of 25m and 31m; while 45 units of HB loading (controlled) is most critical at 10m span. Specifying LTAL loading as well as 20 units of SV loading (controlled) appears to be the most logical conclusion.

5.2.2 *Comparisons of Loadings*

There is no exact equivalence among the LTAL, SV and HB loadings. A bridge structure designed for LTAL loading is capable of carrying a certain equivalent units of SV loading. Conversely, a bridge structure when designed for this same units of SV loading may fall short of LTAL loading capacity. Comparisons can thus only be made in terms of allowable equivalent load; as shown in Table A2 of Appendix A. Table 1 below gives a summary of the load comparisons.

Table 1 : Comparisons of Loading Models

No.	Design Loading	Allowable Equivalent Load
1.	LTAL	a) 11.4 units SV (controlled) b) 7.2 units SV (uncontrolled) c) 21.4 units HB (controlled)
2.	45 units HB (controlled)	a) 12.7 units SV (controlled) b) 0.4 LTAL
3.	20 units SV (controlled)	a) 27.1 units HB (controlled) b) 0.5 LTAL
4.	10 units SV (uncontrolled)	a) 13.1 units SV (controlled) b) 0.6 LTAL

If bridge structures were to be designed for LTAL loading, uncontrolled passage of at least 7 units of SV could be allowed. This represents a maximum gross SV loading of 140 tons. Permitting uncontrolled movements of SV's with a maximum gross trailer weight of 140 tons may be a feasible solution.

6.0 CONCLUSION

This paper has discussed the considerations made by the "Bridge Loading Committee" in the formulation of a standard JKR Bridge Loading Specification. The specification covers only live load due to normal and abnormal vehicles; namely the LTAL and SV loadings respectively.

The LTAL loading (UDL) curve has been derived based on the loading model used in BD 21/84 adjusted to 2.5m fixed lane width. SV loading, on the other hand, is modelled after some multi-axle trailers that have been used by local transporting companies for transporting indivisible goods like the transformers.

The proposed specification shall be read in conjunction with other parts of BS 5400. All references to HB and HA loadings shall be replaced with SV and LTAL loadings respectively. The load factors and other design requirements specified in BS 5400 for HB and HA loadings shall be used for SV and LTAL loadings; at least for the time being. The present specification shall cover up to a loaded length of 50m. The Committee may continue to formulate a specification for loaded lengths exceeding 50m.

7.0 ACKNOWLEDGEMENT

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Appendix 'A'

Table A1 : Load Effects of various Load Cases for Various Spans

No.	LOAD CASES	LOAD EFFECTS	CRITICAL SECTIONS	SPANS 10 m INV. 'T' BEAM	20 m INV. 'T' BEAM	25 m 'I' BEAM	31.24 m 'I' BEAM	40 m 'I' BEAM
1	45 - HB Controlled	B.M. (kN-m)	1/4	161	417	907	1273	1552
			1/2	219	535	1141	1468	1977
		S.F. (kN)	0	238	288	440	481	472
			1/4	96	92	198	367	192
			1/2	83	72	109	322	138
2	20 - SV Controlled	B.M. (kN-m)	1/4	132	452	1145	1595	2384
			1/2	178	600	1641	2109	3104
		S.F. (kN)	0	192	262	471	534	419
			1/4	60	84	141	298	261
			1/2	50	62	127	211	136
3	LTAL	B.M. (kN-m)	1/4	247	572	1358	2312	3492
			1/2	332	767	1859	3077	4648
		S.F. (kN)	0	195	325	316	412	504
			1/4	96	131	119	290	277
			1/2	63	81	72	154	141
4	10 - SV Uncontrolled	B.M. (kN-m)	1/4	193	576	1631	2688	-
			1/2	261	776	2163	3588	5172
		S.F. (kN)	0	182	412	404	525	582
			1/4	75	144	216	286	-
			1/2	38	68	116	138	-

Table A2 : Comparisons of Loading Models for Various Spans

No.	LOADING MODELS	SPANS 10 m INV. 'T' BEAM	20 m INV. 'T' BEAM	25 m 'I' BEAM	31.24 m 'I' BEAM	40 m 'I' BEAM
1	STRUCTURE DESIGNED FOR LTAL :					
	- Unit of SV (controlled) allowed	20.4	24.7	11.4	14.6	20.9
	- Unit of SV (uncontrolled) allowed	10.7	7.7	7.5	7.2	7.25
	- Unit of HB (controlled) allowed	34.0	48.9	27.1	21.4	45.9
2	STRUCTURE DESIGNED FOR 45-HB (CONTROLLED) :					
	- Unit of SV (controlled) allowed	24.4	17.8	13.8	13.9	12.7
	- x LTAL allowed	0.7	0.7	0.6	0.5	0.4
3	STRUCTURE DESIGNED FOR 20-SV (CONTROLLED) :					
	- Unit of HB (controlled) allowed	27.1	40.9	32.1	29.0	39.8
	- x LTAL allowed	0.5	0.6	0.8	0.7	0.6
4	STRUCTURE DESIGNED FOR 10-SV (UNCONTROLLED) :					
	- Unit of SV (controlled) allowed	15.1	22.0	17.1	13.1	27.8
	- x LTAL allowed	0.6	0.8	1.2	0.9	1.1