CHAPTER 3

Live Load on Road Bridges

3.1 GENERAL BACKGROUND

Loading specifications have a history which goes back to well before the general use of methods of structural analysis capable of simulating plate action, and some loading specifications were drawn up to enable the strength requirements for slab elements within steel girder bridges to be evaluated by means of simple hand calculations. However, methods of analysis which evaluate the design moments due to complex loading cases are now in widespread use, and it is therefore no longer considered necessary to enhance the distributed loading on short spans to give the appropriate design forces, because these can be evaluated directly from the concentrated wheel loads.

For major roads, and those giving access to certain types of industrial installations, provision has to be made for moving abnormal loads.

Abnormal loading has to be accommodated on all motorways and trunk roads.

The application of the normal *line load* is taken parallel to the supports. This is because the knife-edge load does not specifically represent an axle but is a load which, when combined with the distributed loads specified for the span effect, gives rise to design forces appropriate to the strength requirement for an element of a deck structure.

For the design of local structural elements within a bridge deck, such as the slabs spanning between longitudinal members, the requirement of a single wheel-axle load is common. Concentrated loads govern for short spans.

The distribution of the moments arising from concentrated wheel loads at the edges of a slab which is fixed along the line of support (as is commonly the case in a cellular or box deck) is subject to sharp peaks. Plotting the design bending moment along the length of a support will show the peak and illustrate how the area over which the load is applied becomes significant in evaluating design moments. It is therefore relevant to take the thickness of finishes and the wheel contact area into account in evaluating the load dispersion dimensions.

Simple types of bridge deck rarely produce stability problems but where narrow pier arrangements are used, as is frequently the case with lengths of elevated roadway, it becomes important to check that a structure remains stable with heavy vehicles on the outer extremities of the deck. Another form of instability is for uplift to develop at the bearings under some loading conditions where there are marked differences in the span on each side of a support.

The value of accuracy and refinement in design methods is very much diminished if it is not matched by similar qualities in the assessment of design live loads.

The early loading standards in some countries were not applied nationally; they were generally specified by local authorities who took into consideration the traffic which was likely to use the bridge concerned. These loadings often consisted of steam-rollers or some form of traction-engine.

The needs of military transport and its heavy equipment caused consideration to be given to the specification of a loading train for bridges representative of the actual and envisaged vehicles they would have to carry. This resulted in the introduction of the (then) Ministry of Transport's first 'standard loading train' in the UK in 1922, and the original loading standards of many other European countries at about the same time. This trend in the introduction of standard highway bridge loadings was almost a universal trend arising out of the technological advancements and industrial developments that were taking place at a fast rate all over the world.[1]

It was, however, the 1930s which witnessed the introduction of the most standard bridge loadings applied nationally and on a more scientific basis than hitherto. For example, in the UK the equivalent 'Ministry of Transport standard loading curve' was introduced in 1932, this was a new approach which proved to be very popular. Contemporary with this there was the British Standards (BS) train of loading. These two standards formed the basis of the present type HA loading of BS:153. In the USA, a loading standard consisting of truck-trains and equivalent loads was introduced by the American Association of State Highway Officials (AASHO)* in 1935. It is significant that even in some of the developing countries, like India, loading standards were introduced nationally during this period (in 1937).

* This name and abbreviation is now changed to the Association of American State Highway and Transportation Officials (AASHTO).

The highway bridge loading standards of most countries have developed gradually often with little regard to the standards prevalent in other countries. This has resulted in wide variations in loading standards, even among neighbouring countries, which is inhibiting the proper development of 'through' road transport all over the world. Therefore, there is a fundamental need to know how the loading standards of one country differ from those of others. Galambos[2], in a recent study made for the International Road Federation, has reported that many countries are currently engaged in revising their highway bridge loading standards.

Comparative studies reported[3-4] at ACI's second international symposium on *Concrete Bridge Design* (1969) were based on the loadings of different countries. However, in at least one of them, the dynamic effects were not considered. As the impact allowance varies considerably in different countries, it has to be added to the basic values for a realistic comparison. In one of them there are some obvious anomalies in the results. For example, the loading in the UK is shown to be more severe than that of West Germany and in fact, the heaviest, which is not the case.

3.2 LOADINGS OF DIFFERENT COUNTRIES

AASHTO Loadings

The Association of American State Highway and Transportation Officials (AASHTO), Washington DC, specified heaviest loading, designated as HS 20-44, comprises a tractor truck with a semi-trailer having a total load of 320.3 kN or the corresponding lane loading. The lane loading is made up of a ud load of 9.3 kN/m and a knife edge load of 80 kN for bending moment and 115.7 kN for shear. Impact is to be added in both the cases as per the formula given in the AASHTO specifications.

For the design of bridges, both the truck and lane loading are to be considered and the one which gives the worst effect is to be adopted. With the truck loading, only one truck is considered for each traffic lane for the whole of its length. There is no reduction in load intensity for up to two lanes of traffic loaded.

BS Loadings

The British Standards (BS), London specify two types of loading known as the type HA and type HB loadings. The HA type is also followed in Malaysia, Sri Lanka, Kenya, Zambia, Zimbabwe, etc. (with minor changes in some cases). The HA type is the normal design loading and consists of a uniformly distributed lane loading varying from 318.6 kN/m for 1 m loaded length (span) to 5.8 kN/m for 900 m loaded length (span), and a knife-edge load of 120 kN per lane. The values given are inclusive of impact. There is no reduction in the intensity of HA loading for up to two lanes of traffic loaded. An alternative axle load is also specified in this chapter on which impact must be considered.

The HB type is an abnormal unit loading. The number of units per axle (four axles in all) specified in the UK for bridges carrying the heaviest class of load is 45, amounting to a total load of 1800 kN. This is an idealised load on four axles which allows for the weight of the tractors accompanying trailers. With this loading, an overstress of 25% is allowed. No allowance is to be made for impact. Only one lane is to be loaded with type HB loading, all other lanes being considered as occupied by one-third full lane HA loading (latter only if its presence gives worst effect).

The type HA and HB loadings are currently under revision. In the UK, the Department of Environment has already effected certain changes in the type HA loading.

IRC Loadings

The Indian Roads Congress (IRC) specifies three classes of loads, designated as Class 70-R, Class AA and Class A for the design of permanent bridges, and all of them are followed in India. Pakistan has adopted Class AA* and Class A loadings for the design of bridges.

The Class 70-R and Class AA are of two types each. The first is a 700 kN tracked vehicle which is common to both the classes; the only difference is in the loaded length, which is slightly more for the Class 70-R. The second, which is of the wheeled type is a 1000 kN train of vehicles on seven axles for the Class 70-R, and a 400 kN vehicle on two closely spaced axles for the class AA. The Class A loading is a 554 kN train of wheeled vehicles on eight axles. Impact is to be allowed for in all the loadings as per the formulae given. The formulae are different for steel and concrete bridges.

All the three classes of loads are to be separately considered in the design and the worst effect is to be taken. For the design of two-lane bridges, only one lane of Class 70-R or Class AA load is considered, whereas both the lanes are assumed to be occupied by Class A loading if that gives worst effects.

Loadings of France

There are two normal systems of loads known as the System A and System B loads. The System A loading consists of a ud load which varies from 18.7 kN/m^2 for 10 m loaded length to 4 kN/m^2 for 199 m loaded length. This load, which is inclusive of impact, is given by a formula in terms of the loaded length. The System B comprises three types known as Systems B_c, B_r and B_t. While System B_c consists

* Tracked vehicle only.

of two trucks of 300 kN each per lane, B_r is a single wheel load of 100 kN, and B_t, a tandem axle of 320 kN. Impact is to be added to these according to a formula which takes into consideration the dead load of the structure as well.

In the design of bridges, systems A and B are to be considered successively and the worst effect is to be taken. There is no reduction in load intensity for up to two lanes of traffic loaded.

Loadings of West Germany

For federal autobahns (expressways), federal highways and rural highways of the first order, designated as Class 60, the loading per lane consists of a 600 kN vehicle on three axles and a ud load of 5 kN/m^2 in the remaining portion of the carriageway. Allowance for impact is to be made as per the formula given.

An equivalent ud load is also given as a substitute for the design vehicle.

Loadings of Japan

The live load specified for the design of main girders of the first class of bridges is known as the L-20 loading. There is a corresponding truck loading called T-20 loading for the design of floor systems. For a lane width of 5.5 m or less, the L-20 loading consists of a knife-edge load of 50 kN/m and a ud load of 3.5 kN/m^2 for spans up to 80 m reducing to 3 kN/m^2 for greater span lengths. For bridges having a width of more than 5.5 m, the knife edge load and the ud load are assumed to be reduced by one half on the portion of the roadway in excess of 5.5 m width. Impact is to be added as per the formula given.

Loadings of New Zealand

The HS 20-44 truck and the lane loading of the AASHTO and another truck loading designated H20-S16-T16 design vehicle are specified. The latter is the same as the HS 20-44 truck with a 142 kN trailer attached to it. Both the loadings are to be considered in the design and the one which gives the worst effect is to be taken. Impact is to be allowed as per the formula given; but for shear force, it is taken as 30% for all the spans. There is no reduction in load intensity for up to two lanes of traffic loaded.

Loadings of Sweden

Sweden specifies two types of loads. One is a lane loading, consisting of a 140 kN axle plus a ud load varying from 24 kN/m for 10 m span and less to 11 kN/m for a 90 m span and above. The other is a 1000 kN single truck on five axles. Impact is to be added only to the axle load of the lane loading. For the design of two lane bridges, either the lane loading in both the lanes or the single truck loading is considered.

NOTE: More details of the above loads, as also of certain other National (Highway Bridge) loads are given ahead.

3.3 SOME INTERESTING COMPARISONS[1] IN THE DIFFERENT TYPES OF LOADINGS

While many other countries specify the same ud load for bending and shear, Italy gives different values, those for shear being more than those for bending. This is understandable as there is no knife-edge load or axle load with it. It is, however, significant to note that France and West Germany do not distinguish between bending and shear in their equivalent ud load values, although they have no knife-edge load or axle load with the ud load.

Unlike other countries which specify ud loads for the full width of the traffic lane, Finland and Sweden specify it as a strip load in two strips of 0.6 m each running for the entire loaded length. As an alternative, Sweden allows the ud load to be applied uniformly over a width of 2.4 m.

The countries which specify a knife-edge load in combination with a ud load fall into two groups. While the HA type group gives the same value of knife-edge load for both bending and shear, the AASHTO type group, Iran and New Zealand, specify different values. In the latter case, the knife-edge load for shear is always more than that for bending.

With the exception of the HA type group, all countries which have an equivalent ud load system, have at least an alternative truck loading which is also to be considered in the design. Even in the HA type group, designs are generally to be checked for the type HB loading, although the number of units of the HB vehicle to be taken may vary from country to country. For example, the specifications of Kenya require the designs to be checked for 25 and 30 units respectively of the HB vehicle as against the UK practice of checking the designs of all the important bridges for 45 units for trunk roads and 37 1/2 units for principal roads. BS:153 permits an overstress of 25% with the type HB loading. There is, however, an ambiguity in the present provision in the code permitting this overstress, as it is not related to the number of units of the HB vehicle.

Italy, like some other countries, has separate civil and military loadings and all its important bridges are designed for the latter, which is heavier. Though not explicitly, military loadings are however covered in the standards of many other countries. In this category comes the IRC Class 70-R of India, the Caterpillar of Austria and the NK-80 loading of the USSR.

Lane Width

The design lane width of 5.5 m followed in Japan is an unusual one. Except for it, the lane width lies in the range 2.5–4.0 m, the most common value being 3 m. Norway specifies a range for the design lane widths and Sweden gives different widths for different types of loading. These practices do not conform to the ideal concept of a 'standard design lane width' and 'lane loading'. In countries like India, Pakistan and USSR, where there is no standard lane loading, only the minimum widths of carriageways for different number of lanes are specified. Therefore, they do not have any standard design lane width as such.

Impact Allowance

(i) BS:153 specifies an impact allowance of 25% to be added to the axle load (the pair of adjacent wheels) if it produces the greatest bending moment or shear, in the HA load case. The stipulations in the Norwegian standard are similar; the only difference is that instead of 25%, 38.5% impact is added to the heaviest axle load.

(ii) In the majority of countries, impact is related to the loaded length (span length) although the exact relationship varies considerably from country to country.

(iii) Some countries like Austria and India specify different impact factors for concrete and steel bridges, the factor for steel being more than that for concrete. This apparently is based on the principle that a lighter structure will be subjected to a more dynamic effect. Finland too has a similar approach, but it distinguishes only timber bridges from the others by specifying a lower impact factor for them presumably on account of the damping effect of timber.

(iv) At least West Germany and Italy ignore impact when the span length exceeds 50 and 100 m, respectively. But even for longer spans, countries like Australia and India specify certain minimum values of impact.

(v) Various standards give an upper limit for the impact allowance either with respect to the type of vehicle (tracked or wheeled) or in relation to the type of bridge (concrete, steel or timber) and the value of this varies from 25 to 64% in different standards.

(vi) Unlike other countries, Belgium and France relate the impact factor to the dead load of the bridge structure. The principle behind this is, however, implicit in the impact formulae being used by many other countries which relate impact to the type of bridge and length of span. The impact formula of Belgium is further complicated by including the speed of the vehicle in it.

(vii) Austria specifies different impact factors for the directly loaded and indirectly loaded main girders of concrete bridges, the factors for the former being more than that for the latter. Again in the case of steel bridges, it distinguishes between the first and second lanes of steel bridges, specifying higher impact factors for the first than the second and allowing no impact for lanes in excess of two.

Quantitative Comparison of Road Live Load from Various Countries

The following are the bases of comparison[1] of road live load:

(i) For comparing the loadings from the quantitative point of view, the maximum bending moment and shear force that would be caused by them in simply supported spans are taken as the basis. Simple spans were chosen since it was presumed that they are more common and are also indicative of what is likely to happen in other types of construction. A span range of 5–100 m was expected to cover the great majority of simple span bridges.

(ii) As the impact allowance varies considerably for different loadings, it is added to the calculated values of bending moment and shear force, and a comparison is made of the total values. Wherever the same standard gives different impact formulae for steel and concrete bridges, the one which gives the higher value is taken.

Computation of Bending Moment and Shear Force (Comparative Picture)

On the basis of the above assumptions, the values of the maximum bending moment and shear force, including impact, were calculated for each loading separately, for single and double lanes, for spans up to 100 m in 5 m increments. The results obtained are given in Tables 3.1 to 3.4[1].

Considering the predominant range of spans, the following general observations can, however, be made from the results of Tables 3.1 to 3.4:

(i) Although the IRC loadings appear to be the heaviest for a single lane, they are lighter than the French, West German, Japanese and Type HA loadings when two lanes are considered.

(ii) The West German loading, which is lighter than the IRC and Japanese loadings for a single lane is the heaviest when two lanes are considered.

(iii) For both single and double lanes, the AASHTO loading gives the minimum effect in bending and shear, being only about one half of that given by the West German loading.

(iv) The Type HA and French loadings are almost identical in effect for spans up to about 50 m, beyond that, the latter gives slightly higher values.

(v) In the higher span ranges, the global effect of Type

Table 3.1 *Simply Supported Span Versus Maximum Bending Moment for One Lane*

Span (m)	Maximum bending moment for one lane, including impact allowance (kN-m)								
	Loadings of New Zealand	L-20 Loading of Japan	Loadings of France	Class 60 Loading of W. Germany	IRC Loadings	HS 20-44 Loading of AASHTO	BS Loadings		Loadings of Sweden†
							Type HA	Type HB**	
5	231	551	390‡	612	687	231@	243	756	450
10	573	1237	816	1624	1548	573@	694	1863	1300
15	1137	2057	1539	2690	2725	1073@	1336	3331	2550
20	1797	3006	2371	3804	4198	1552@	2175	5654	3800
25	2485	4083	3290	4952	5680	2022@	3156	7862	5050
30	3157	5285	4280	6125	7058	2481@	4151	10085	6300
35	3817	6612	5338	7310	8412	2935@	5184	12315	7550
40	4465	8065	6454	8497	9739	3379@	6340	14550	8800
45	5107	9647	7637	9674	11059	3863	7501	16788	10050
50	5738	11344	8870	10830	12496	4597	8656	19029	11300
55	6367	13162	10151	12452	13933	5391	9780	21271	12550
60	6990	15115	11498	14168	15371	6243	11070	23515	13800
65	7607	17182	12884	15977	16808	7155	12354	25759	15050
70	8299	19376	14342	17880	18245	8125	13738	28005	16300
75	9155*	21682	15848	19877	19683	9155	15117	30251	17550
80	10244*	24119	17388	21968	22339	10244	16560	32497	18800
85	11392*	26387	18997	24152	25138	11392	17993	34744	20050
90	12631*	28714	20660	26430	27945	12631	19508	36992	21300
95	13872*	31080	22348	28802	30759	13872	21069	39239	22550
100	15184*	33494	24106	31268	33580	15184	22875	41487	23800

* Based on lane loading. Otherwise H20-S16-T16 truck loading governs
** 45 units. An overstress of 25% is permissible under this loading
† Truck loading governs throughout
‡ Based on System B_c loading. Otherwise System A loading governs
@ Based on standard HS truck loading. Otherwise standard lane loading governs

Table 3.2 *Simply Supported Span Versus Maximum Shear Force for One Lane*

Span (m)	Maximum shear force for one lane, including impact allowance (kN)								
	Loadings of New Zealand	L-20 Loading of Japan	Loadings of France	Class 60 Loading of W. Germany	IRC Loadings	HS 20-44 Loading of AASHTO	BS Loadings		Loadings of Sweden†
							Type HA	Type HB**	
5	212	441	359‡	571	549	212@	199	738	420
10	304	495	369‡	689	633	298@	278	927	590
15	375	549	454‡	743	820	337@	356	1218	700
20	420	601	523‡	779	927	358@	435	1364	775
25	447	653	569‡	807	978	369@	505	1451	820
30	465	705	592‡	828	997	375@	554	1509	850
35	478	756	610	845	1009	379@	592	1551	871
40	488	807	645	858	1015	387@	634	1582	888
45	495	858	679	867	1027	390@	667	1606	900
50	501	908	710	872	1090	410	693	1625	910
55	509	957	738	912	1181	433	711	1641	918
60	518	1008	767	950	1272	457	738	1655	925
65	545	1057	793	988	1351	481	760	1666	931
70	575*	1107	820	1026	1419	505	785	1675	936
75	606*	1156	845	1064	1477	529	806	1684	940
80	636*	1206	869	1102	1529	552	828	1691	944
85	666*	1242	894	1140	1574	576	847	1697	947
90	697*	1276	918	1178	1625	600	867	1703	950
95	727*	1309	941	1216	1695	623	887	1708	953
100	758*	1340	964	1254	1776	647	915	1713	955

* Based on lane loading. Otherwise H20-S16-T16 truck loading governs
** 45 units. An overstress of 25% is permissible under this loading
† Truck loading governs throughout
‡ Based on System B_c loading. Otherwise System A loading governs
@ Based on standard HS truck loading. Otherwise standard lane loading governs

Table 3.3 *Simply Supported Span Versus Maximum Bending Moment for Two Lanes*

Span (m)	Maximum bending moment for two lanes, including impact allowance (kN-m)								
	Loadings of New Zealand	L-20 Loading of Japan	Loadings of France	Class 60 Loading of W. Germany	IRC Loadings	HS 20-44 Loading of AASHTO	BS Loadings		Loadings of Sweden†
							Type HA	Type HB**	
5	462	827	780‡	1224	687	462@	488	838	640
10	1146	1856	1632	3248	1548	1146@	1388	2095	1580
15	2274	3086	3078	5380	2725	2146@	2672	3776	2775
20	3594	4509	4742	7608	4198	3104@	4350	6379	4198
25	4970	6125	6580	9904	5680	4044@	6312	8914	5819
30	6314	7928	8560	12250	7058	4962@	8302	11468	7609
35	7634	9918	10676	14620	8412	5870@	10368	14043	9537
40	8930	12098	12098	16994	9739	6758@	12680	16663	11572
45	10214	14471	15274	19348	11059	7726	15002	19288	13679
50	11476	17016	17740	21660	12496	9194	17312	21914	15838
55	12734	19743	20302	24904	14232	10782	19560	24531	18012
60	13980	22672	22996	28336	15598	12486	22140	27205	20172
65	15214	25773	25768	31954	17166	14310	24708	29877	22277
70	16598	29064	28684	35760	20046	16250	27476	32584	24316
75	18310*	32523	31696	39754	23486	18310	30234	35290	26250
80	20488*	36178	34776	43936	26650	20488	33120	38017	28048
85	22784*	39580	37994	48304	29908	22784	35986	40742	29662
90	25262*	43071	41320	52860	33620	25262	39016	43494	31095
95	27744*	46621	44696	57604	38050	27744	42138	46262	34129
100	30368*	50241	48212	62536	42880	30368	45750	49112	37300

* Based on lane loading. Otherwise H-20-S16-T16 truck loading governs
** One lane Type HB full and the other lane 1/3 Type HA as per the Code. An overstress of 25% is permissible under this loading
† Lane-loading governs throughout
‡ Based on System B_c loading. Otherwise System A loading governs
@ Based on standard HS truck loading. Otherwise standard lane loading governs

Table 3.4 *Simply Supported Span Versus Maximum Shear Force for Two Lanes*

Span (m)	Maximum shear force for two lanes, including impact allowance (kN)								
	Loadings of New Zealand	L-20 Loading of Japan	Loadings of France	Class 60 Loading of W. Germany	IRC Loadings	HS 20-44 Loading of AASHTO	BS Loadings		Loadings of Sweden†
							Type HA	Type HB**	
5	424	661	718‡	1142	594	424@	398	804	512
10	608	742	738‡	1378	692	596@	556	1020	632
15	750	823	908‡	1486	820	674@	712	1337	740
20	840	902	1046‡	1558	927	716@	870	1509	840
25	894	980	1138‡	1614	978	738@	1010	1619	931
30	930	1057	1184‡	1656	997	750@	1108	1694	1015
35	956	1134	1220	1690	1009	758@	1184	1748	1090
40	976	1210	1290	1716	1015	774@	1268	1793	1157
45	990	1286	1358	1734	1082	780@	1334	1828	1207
50	1002	1361	1420	1744	1174	820	1386	1856	1267
55	1018	1436	1476	1824	1274	866	1422	1878	1300
60	1036	1512	1534	1900	1368	914	1476	1901	1345
65	1090	1586	1586	1976	1446	962	1520	1919	1371
70	1150*	1661	1640	2052	1512	1010	1570	1937	1390
75	1212*	1735	1690	2128	1572	1058	1612	1952	1400
80	1272*	1809	1738	2204	1642	1104	1656	1967	1402
85	1332*	1863	1788	2280	1728	1152	1694	1980	1402
90	1394*	1914	1836	2356	1816	1200	1734	1992	1402
95	1454*	1963	1882	2432	1908	1246	1774	2004	1437
100	1516*	2010	1928	2508	1996	1294	1830	2018	1492

* Based on lane loading. Otherwise H20-S16-T16 truck loading governs
** One lane Type HB full and the other lane 1/3 Type HA as per BS 153. An overstress of 25% is permissible under this loading
† Lane loading governs throughout
‡ Based on System B_c loading. Otherwise System A loading governs
@ Based on standard HS truck loading. Otherwise standard lane loading governs

HB loading (consisting of 45 units of the HB vehicle in one lane and one-third of type HA in the second) is less than that of full type HA in both the lanes, when the former is adjusted for the permissible increase in stress of 25%.

(vi) The New Zealand loading is somewhat heavier than that of AASHTO for spans up to about 70 m. Beyond that, it gives the same values of bending moment as for the AASHTO loading; but in the case of shear force, it gives higher values throughout.

The loadings of different countries vary considerably both qualitatively and quantitatively. While the qualitative differences are understandable, it is difficult to see that such wide variations in intensity are warranted. This brings out the need for systematic surveys of vehicular loads on bridges. Apart from the intensity of traffic, the aspect of safety is closely linked with design loading and needs due consideration.

Of the different types of loadings, the equivalent ud load system appears to be the most popular one, possibly because it is simpler to apply. This explains the adoption of the Type HA and AASHTO loadings by many countries.

There are basic differences in the approach of different countries for assessing the dynamic effect of live loads on the bridge structure. The impact allowance formulae specified by some are unnecessarily complicated and not fully justified, particularly since the effect of live load on the bridge is comparatively less than that of dead load for span lengths of approximately 25 m and above. Thus there is need for more research in this field to ascertain the actual behaviour of bridge structures under dynamic loads and to evolve suitable design procedures (refer Ch. 39).

From a consideration of the simplicity of loading and the ease of its application in design, the Type HA loading appears to be the most favourable.

There is wide variation in the highway bridge loading standards of different countries. The extreme example is that of the USA where, for the range of spans covered, the effect of the design live load is only about one half of that in West Germany. (In fact, the loading of the Netherlands is even more severe than that of West Germany.) The loadings of the other countries generally fall in between the AASHTO and West German loadings.

3.4 DETAILS OF SOME NATIONAL (HIGHWAY) BRIDGE LOADINGS

AASHTO Loadings (Figs. 3.1 and 3.2)

(USA, Australia, Bangladesh, Canada, Ethiopia, Philippines, Turkey*)

* Axle loads followed in Turkey are 4 and 16 t in place of 8000 and 32,000 lbs respectively.

Truck Loading

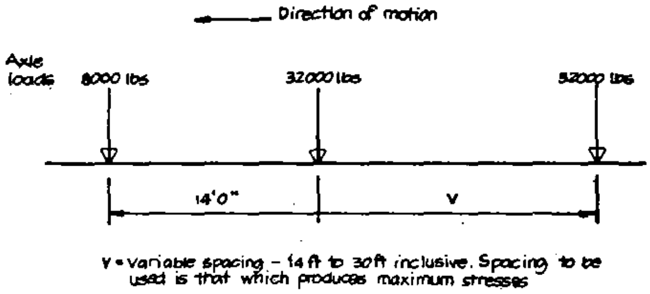

Fig. 3.1 *Standard HS 20-44 truck*

Impact Allowance

Impact allowance** is $50/(L+125)$ where L is the length in feet of the portion of the span to produce the maximum stress in the member. Maximum† impact allowed is 30%. For shear due to truck loads, L is taken as the loaded part of the span from the point being considered to the reaction, except for cantilever arms where the impact allowance is 30%.

Lane Loading

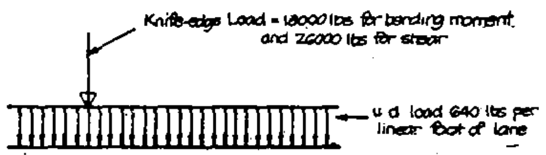

Fig. 3.2 *Standard HS 20-44 lane loading*

BS Loadings (Figs. 3.3 and 3.4)

(UK, Malaysia‡, Sri Lanka‡, Kenya‡§, Rhodesia‡)

Type HA Loading

The Type HA loading consists of:

(i) A ud lane loading as per the loading curve given plus a knife-edge load of 120 kN uniformly distributed across the width of the traffic lane, or

(ii) Two wheel loads§ each of 112 kN in line transversely to the direction of traffic flow, spaced at 0.9 m.

The ud load has a constant value of 31.5 kN per metre run of one lane for loaded lengths from 6.5 m to 23.0 m. For spans below 6.5 m, BS:153 gives separate curves for the ud load.

** Turkey specifies the impact allowance as $15/(L+37)$, where L is the span length in metres.

† Australia specifies also a minimum impact allowance of 10%.

‡ For Type HA loading only.

§ In Kenya, the wheel loads are specified as 40 kN each at the spacing of 1.0 m.

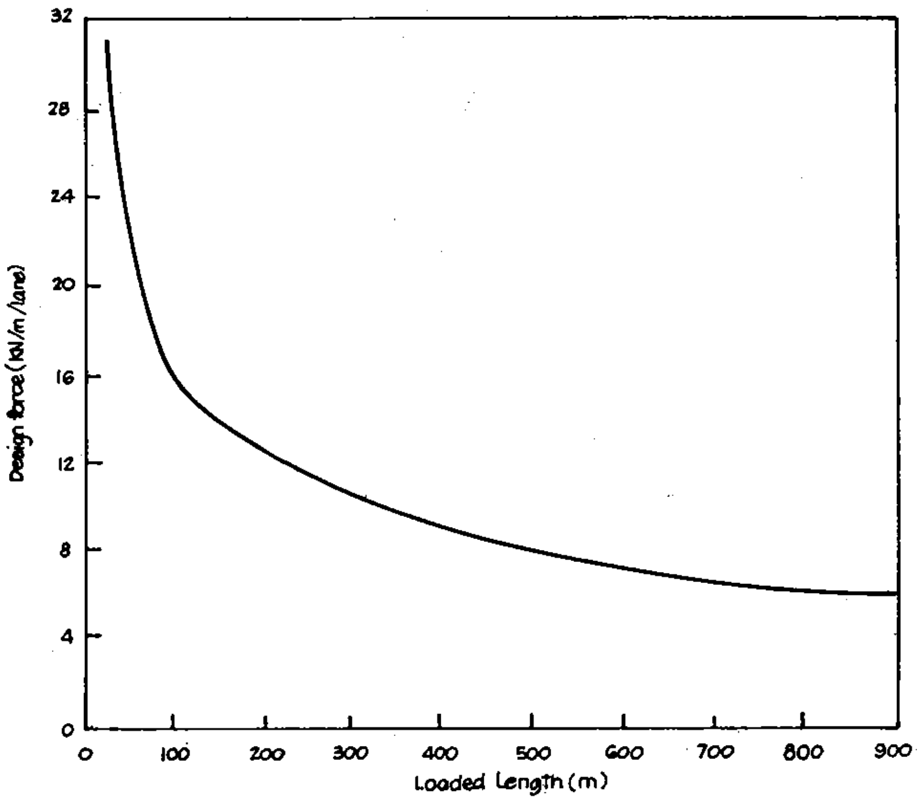

Fig. 3.3 *Loading curve for type HA loading*

Two lanes are always considered as occupied by full type HA loading while all other lanes in excess of two are considered as occupied by one-third the full lane loading.

The standard design lane width is 3.0 m. The number of traffic lanes to be considered for different widths of carriageway are specified.

In considering the effects of the 112 kN wheel loads, an overstress of 25% is permitted.

Impact Allowance

Type HB loading: no allowance is to be made for impact. Type HA loading incorporates an impact allowance of 25% on the heaviest axle in the train of vehicles from which the loading has been derived.

Type HB Loading

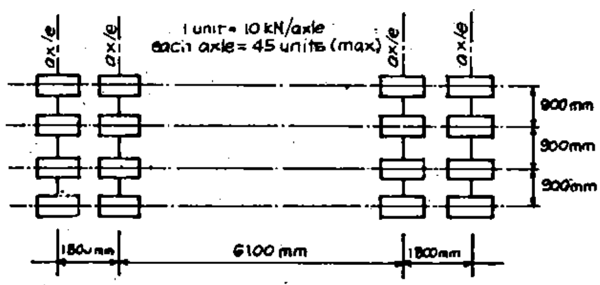

Fig. 3.4 *Plan view of type HB loading*

IRC Loadings (India and Pakistan*) (Figs. 3.5–3.10)

Class 70-R Loading

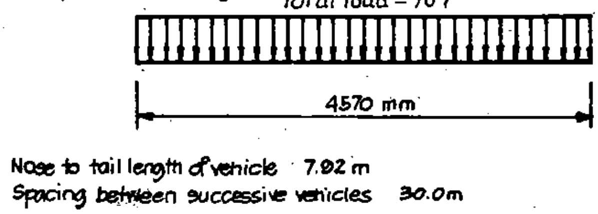

Fig. 3.5 *Class 70-R 'Tracked' loading*

* For the Class AA tracked and Class A loadings only.

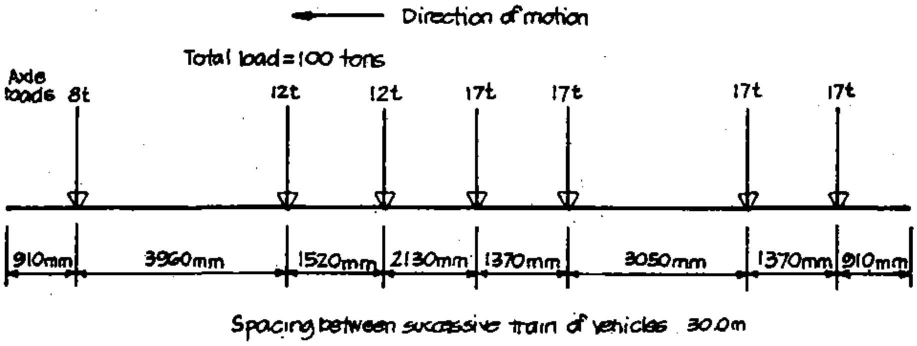

Fig. 3.6 *Class 70-R 'Wheeled' loading*

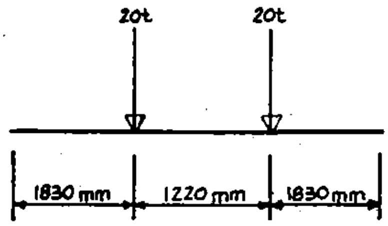

Fig. 3.7 *Class 70-R 'Bogie' loading*

Class AA Loading

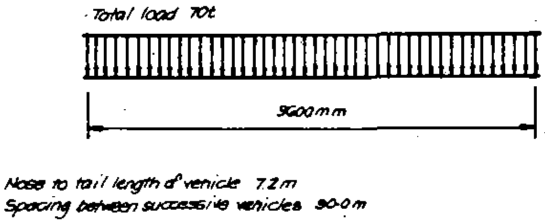

Fig. 3.8 *Class AA 'Tracked' loading*

Impact Allowance

When L is the length of span in metres, impact allowance for concrete bridges is equal to $4.5/(6 + L)$ subject to a maximum of 50% and minimum of 8.8%.

The impact allowance for steel bridges is $9/(13.5 + L)$ subject to a maximum of 54.5% and minimum of 15.4% with the following exceptions in the case of Class 70-R loading and Class AA loading:

(i) *For spans less than 9 m:*

- Tracked vehicles — 25% for spans up to 5 m reducing to 10% for spans of 9 m.
- Wheeled vehicles — 25%

(ii) *For spans of 9 m or more:*

- Tracked vehicles on concrete bridges — 10% up to a span of 40 m
- Wheeled vehicles on concrete bridges — 25% for spans up to 12 m

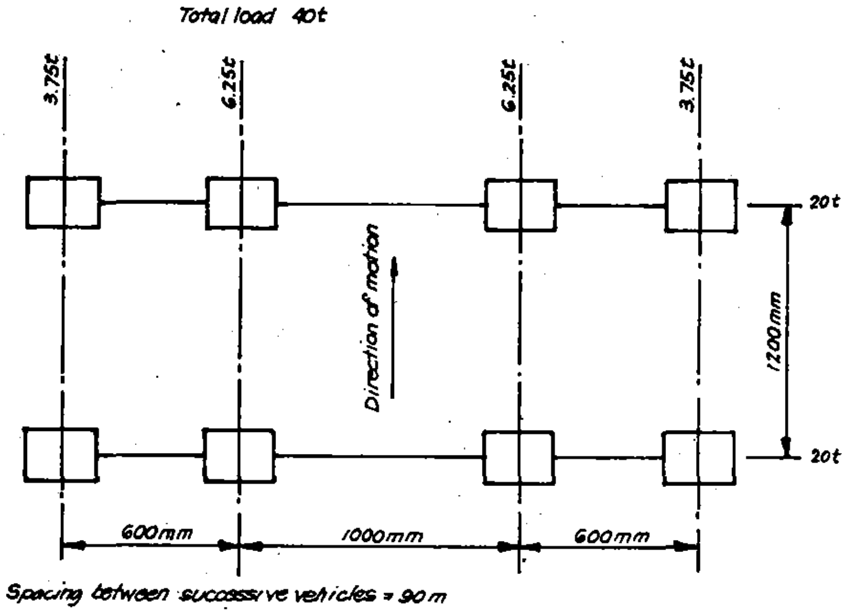

Fig. 3.9 *Plan view of the class AA 'Wheeled' vehicle*

Class A Loading

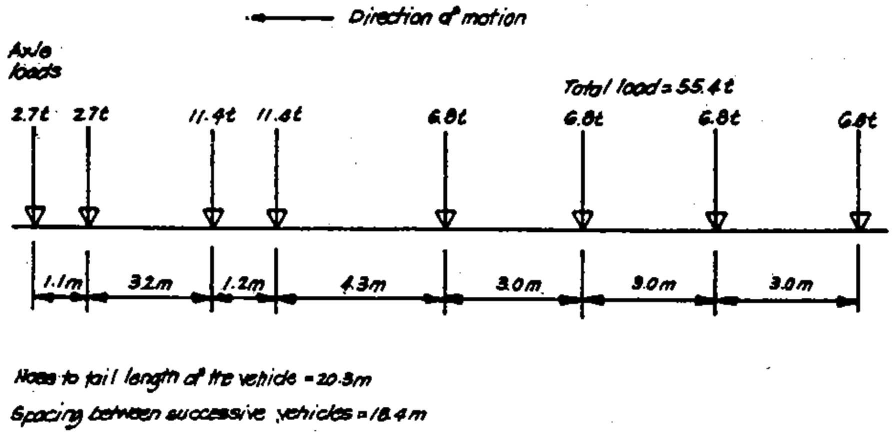

Fig. 3.10 *Class A train of vehicles*

- Tracked vehicles on steel bridges — 10% for all spans
- Wheeled vehicles on steel bridges — 25% for spans up to 23 m

Loadings of France (Figs. 3.11 and 3.12)

System A Loads

$$\text{ud load } A(l) = 230 + \frac{36{,}000}{l + 12} \text{ kg/m}^2$$

where l is the loaded length in metres.

The ud load $A(l)$ obtained from the above formula is to be multiplied by a coefficient a_1 whose value is 1.0 up to two lanes and then reduces with an increase in the number of lanes.

$a_1 A(l)$ is not to be less than $(400 - 0.2\ l)$ kg/m^2.

For class 1 roads, if the lane width is different from the standard lane width of 3.50 m, the value of $A(l)$ is to be multiplied by a coefficient a_2 also, so as to keep the total load per linear metre of lane unaltered for any loaded length.

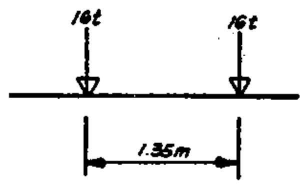

Fig. 3.12 *System B_t tandem axle loading*

System B Loads

System B_r is a single wheel load of 10 t.

Impact Allowance

System A loading is inclusive of impact. For System B loading, the impact factor, δ, is given by the formula

$$\delta = 1 + \frac{0.4}{1 + 0.2L} + \frac{0.6}{1 + 4\frac{G}{s}}$$

where L = length of the element in metres

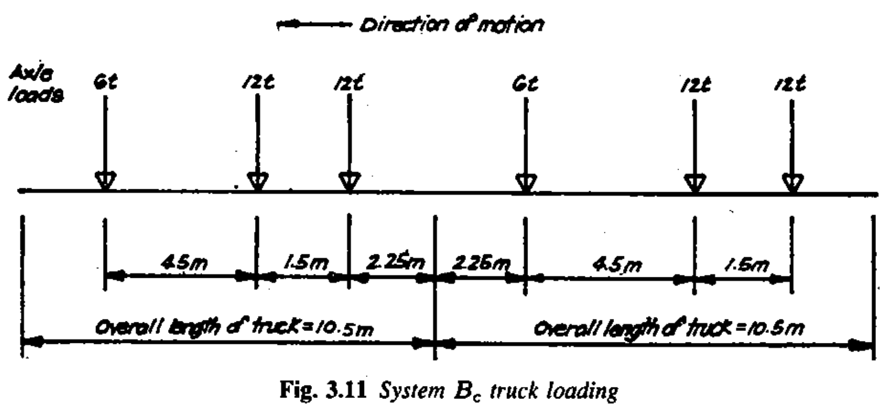

Fig. 3.11 *System B_c truck loading*

G = permanent weight of the bridge
s = maximum load of the truck

Loadings of West Germany (Fig. 3.13)

Class 60 Loading

The Class 60 loading consists of a 60 t heavy truck and a ud load of 0.5 t/m^2 in the portion of the lane not occupied by the truck. The substitute ud load for the 60 t heavy truck is 3.33 t/m^2.

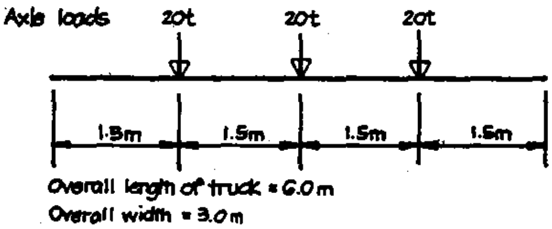

Fig. 3.13 *60 t heavy truck (SLW)*

The standard design lane width is 3.0 m. There is no reduction in intensity of load for up to two lanes of traffic. A ud load of 0.3 t/m^2 is specified in the area outside the main lanes.

Impact Allowance

The impact factor ϕ with which the live load values are to be multiplied is given by the formula

$$\phi = 1.4 - 0.008\, l_\phi \text{ but } \geq 1.0$$

where l_ϕ is the governing length in metres.

Loadings of Japan (Fig. 3.14)

L-20 Loading

For a lane width of 5.5 m or less, the L-20 loading consists of a knife-edge (line) load, P, of 5000 kg/m and a ud load, p, which has the following values,

For $l < 80$ m, $p = 350$ kg/m^2
For $l > 80$ m, $p = 430 - l$ but ≥ 300 kg/m^2

For bridges with a width of more than 5.5 m, the values of P and p are to be reduced by one-half on the portion of the roadway in excess of 5.5 m.

The full values of P and p are known as 'main loads' and the reduced values (50% of the main loads) are known as 'subloads'. The main loads are to be so placed on a 5.5 m wide part of the roadway and the subloads in the remaining part of the roadway as to produce maximum stresses.

In the expressions for the ud load p, l denotes the span length in metres.

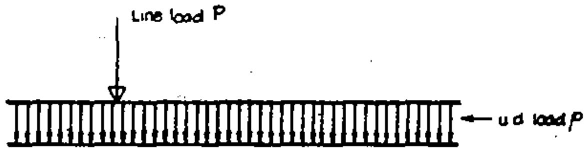

Fig. 3.14 *Composition of L-20 loadin~*

Impact Allowance

Impact allowance i is determined by the formula,

$$i = \frac{20}{50 + l}$$

where l is the length of the element in metres.

Loadings of New Zealand (Fig. 3.15)

Design Load

The design load per lane consists of the HS 20-44 truck and lane loading of the AASHTO or the H20-S16-T16 truck loading whichever gives the worst effects. The standard design lane width is 10 ft. (Fig. 3.15).

Impact Allowance

The impact allowance specified is the same as that given by the AASHTO, but there is, however, no upper limit to it.

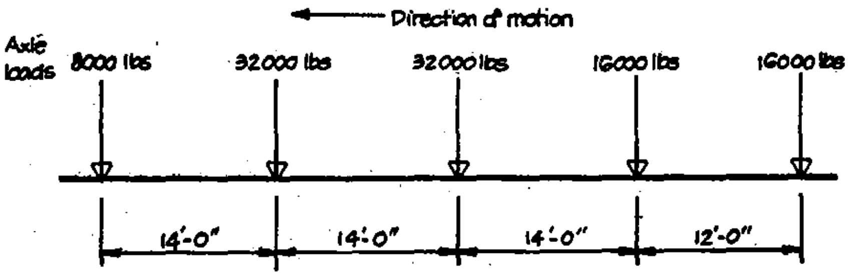

Fig. 3.15 *H20-S16-T16 truck*

Loadings of Sweden (Figs. 3.16 and 3.17)

Lane Loading

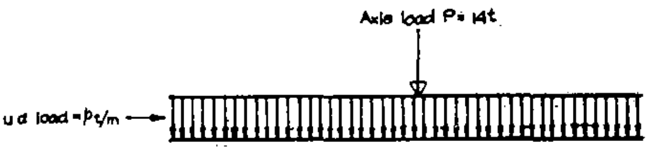

Fig. 3.16 *Composition of lane loading*

$$p = 2.4 \text{ t/m for } L < 10 \text{ m}$$

$$p = 2.4 - \frac{1.3(L-10)}{80} \text{ t/m for } 10 < L < 90 \text{ m}$$

$$p = 1.1 \text{ t/m for } L > 90 \text{ m}$$

where L = loaded length in metres
Design lane width = 3.0 m

Truck Loading (see Fig. 3.17)

Two lane bridges are designed with lane loading in both the lanes or only with single truck loading whichever gives the worst results. For continuous structures, there is a separate loading consisting of two axle loads and a ud load.

Impact Allowance

The axle load, P, of the lane loading is to be increased by 40% for impact effects. No allowance for impact is to be made for the ud load and for the single truck loading.

Loadings of Austria (Figs. 3.18 and 3.19)

Tracked Loading

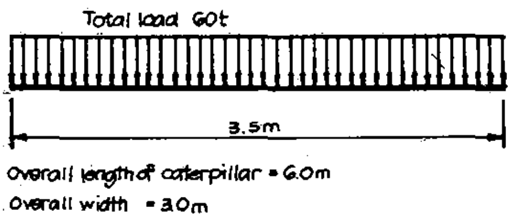

Fig. 3.18 *60 t caterpillar*

Truck Loading

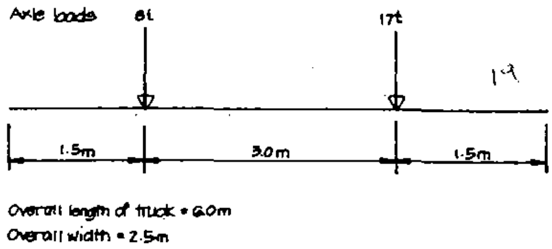

Fig. 3.19 *25 t truck*

A ud load of 0.5 t/m² is to be assumed on the portion of the lane not occupied by the truck.

On two adjoining lanes, the truck loading is assumed in both the lanes, the portion of the carriageway not occupied by the trucks being assumed to be carrying a ud load of 0.5 t/m². With the tracked loading, however, only one caterpillar is to be assumed for the whole carriageway and there will be no ud load with it. Both the cases are to be tried and the worst effect taken in the design.

The specifications also give the following equivalent weights of the caterpillar and truck loading which are to be used for the design of spans more than 30 m.

60 t Caterpillar	3.33 t/m²
25 t Truck	1.67 t/m²

Impact Allowance

The following are the impact factors given:
(i) Concrete bridges

Impact factor for different spans

Span of structural part (m)	0	10	30	50	70
Direct loaded main girder	1.40	1.30	1.20	1.10	1.00
Indirect loaded main girder	1.40	1.25	1.10	1.00	1.00

Impact factor for floor slab = 1.4

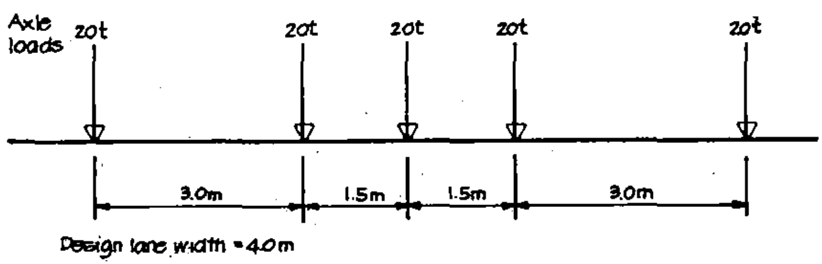

Fig. 3.17 *100 t single truck*

(ii) Steel bridges

Impact factor for different spans

Span of structural part (m)	2	6	10	20	40	60	80	100
Lane I	1.64	1.41	1.30	1.18	1.10	1.07	1.05	1.04
Lane II	1.32	1.20	1.15	1.09	1.05	1.03	1.02	1.02

For all remaining lanes impact factor is 1.00.

Loadings of Belgium (Figs. 3.20 and 3.21)

Normal Truck Loading

Impact Allowance

The impact factor, ϕ, is given by the formula:

$$\phi = 1 + \frac{0.377v}{\sqrt{l\alpha}} \cdot \sqrt{1 + \frac{2Q}{P}}$$

where v = the speed in km per hour (always greater than 60)

l = the distance between supports in metres

$\alpha = \dfrac{l}{fs}$

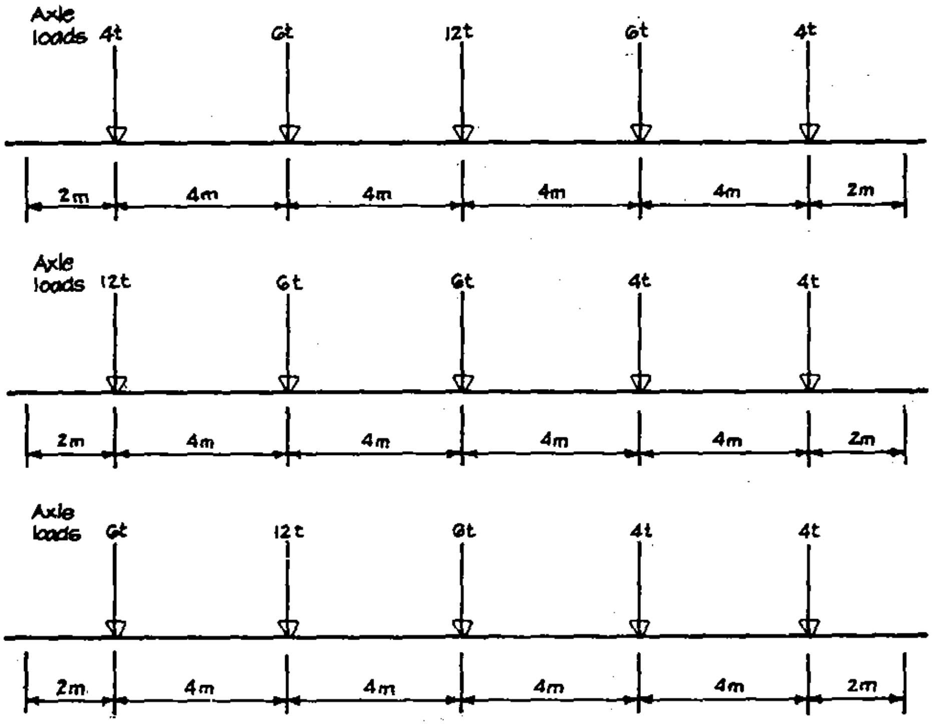

Fig. 3.20 *Different combinations of 32 t normal truck*

Heavy Truck Loading

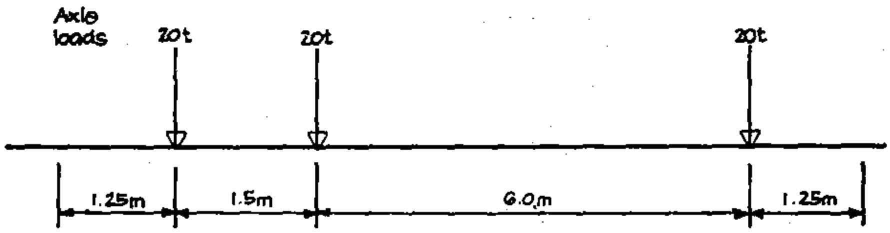

Fig. 3.21 *60 t heavy truck*

For two lane bridges on important roads, the loading consists of a 60 t truck in one lane in combination with a 32 t truck plus a ud load of 400 kg/m^2 in the other lane.

fs = static deflection in metres due to dead weight

Q = moving loads on the bridge deck in tonnes

P = dead weight of the bridge in tonnes

Loadings of Italy (Figs. 3.22, 3.23 and 3.24)

Design Loading

For the design of category 1 bridges, any one of the following three types of loads, flanked by one or more trains of 12 t trucks, producing the worst effect is to be taken:

The width of the three types of loadings is 3.5 m. An equivalent ud load having different values for bending moment and shear is also specified in tabular form.

Impact Allowance

For spans up to 100 m, the impact factor ϕ is given by the formula,

$$\phi = 1 + \frac{(100 - L)^2}{100(250 - L)}$$

where L is the span of the bridge in metres.

For spans exceeding 100 m, ϕ is assumed to be unity.

Loadings of Netherlands (Fig. 3.25)

Class 60 Loading

This is the highest class of loading and it consists of a 600 kN vehicle on three axles of 200 kN each plus a ud load as shown in Fig. 3.25. The standard design lane width for this loading is 3.0 m.

Impact Allowance

The magnitude of the impact coefficient, S, for bridges carrying normal traffic is given by the formula,

$$S = 1 + \frac{40}{100 + L}$$

where L is the span in metres.

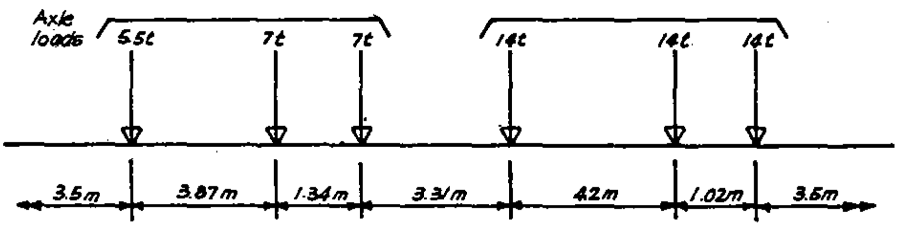

Fig. 3.22 *Continuous train of military load of 61.5 t*

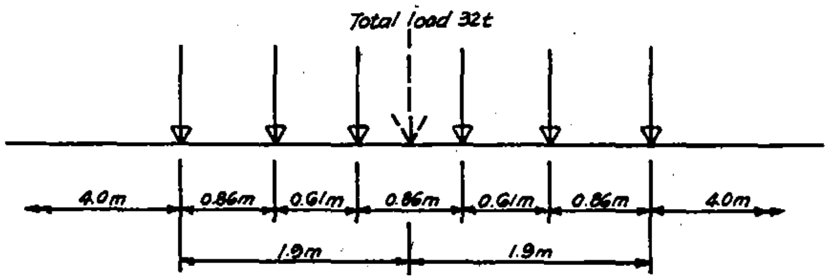

Fig. 3.23 *Continuous train of military load of 32 t*

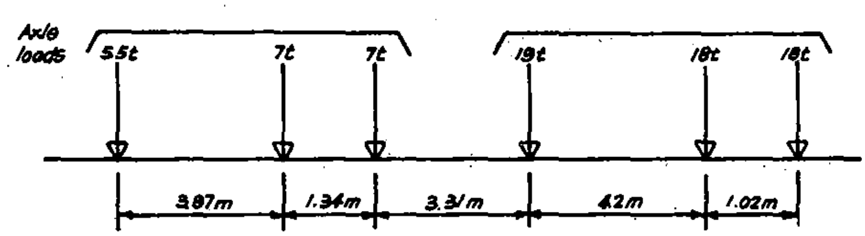

Fig. 3.24 *Single military load of 74.5 t*

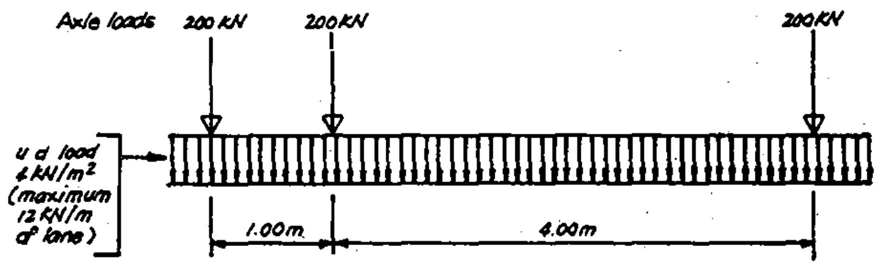

Fig. 3.25 *Class 60 loading*

Loadings of Norway (Fig. 3.26)

Lane Loading

The equivalent lane loading per lane for Class 1 bridges consists of a knife-edge load, A, and a ud load, p, as shown in Fig. 3.26.

$$A = 12 + \frac{8x}{L}\text{t}$$

$$p = 0.5 + \frac{35}{L+5}\ \text{t/m of lane}$$

L = Actual loaded length of lane in metres

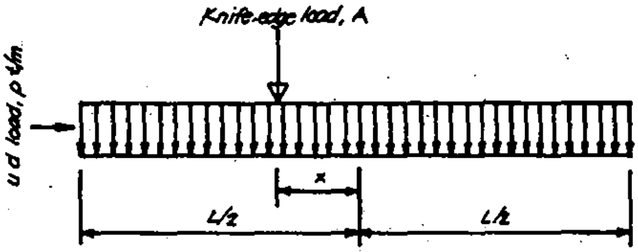

Fig. 3.26 *Equivalent lane loading per lane*

The above lane loadings are normally considered over lane widths from 3.0 to 3.75 m. For two lane bridges, the full equivalent loading is assumed in both the lanes. Besides the lane loading, the structure is designed for a local loading of two axles, each of 13 t.

Impact Allowance

It is assumed that 38.5% impact is to be added to the heaviest axle and it is unnecessary to add any impact to the remaining axles. The values of the knife-edge load, A and ud load, p, are inclusive of impact calculated on this basis. An impact of 38.5% is to be added to the axle loads.

Loadings of the USSR (Figs. 3.27 and 3.28)

Wheel Loadings

There are three types of wheeled loadings (Fig. 3.27).

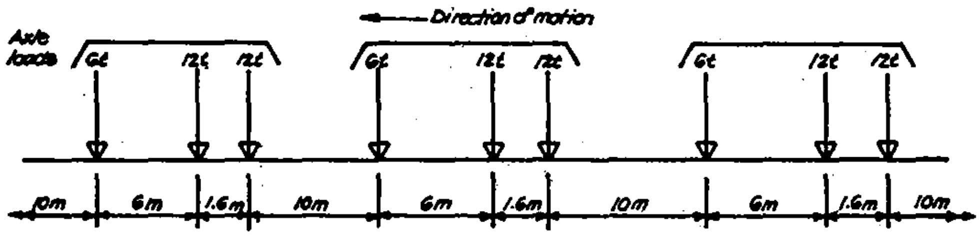

Fig. 3.27(a) *N-30 loading*

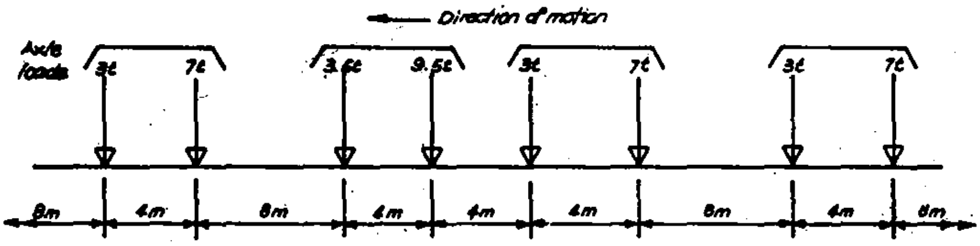

Fig. 3.27(b) *N-10 loading*

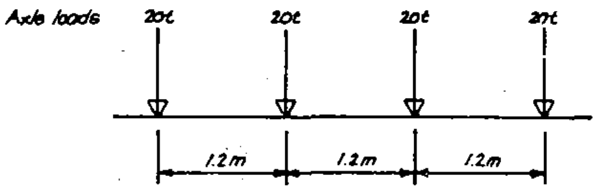

Fig. 3.27(c) *NK-80 loading*

Tracked Loading

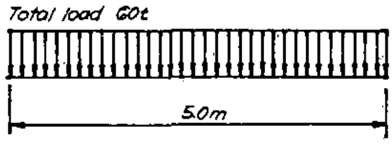

Fig. 3.28 *NG-60 caterpillar loading*

Saudi-Arabian Highway Bridge Loading (Fig. 3.29)

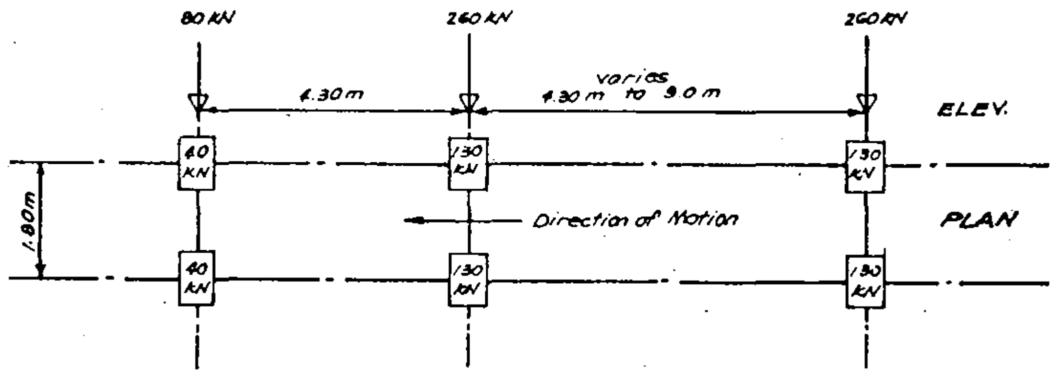

Fig. 3.29(a) *600 kN Truck (each lane can be loaded by a truck but only one truck/lane longitudinally)*

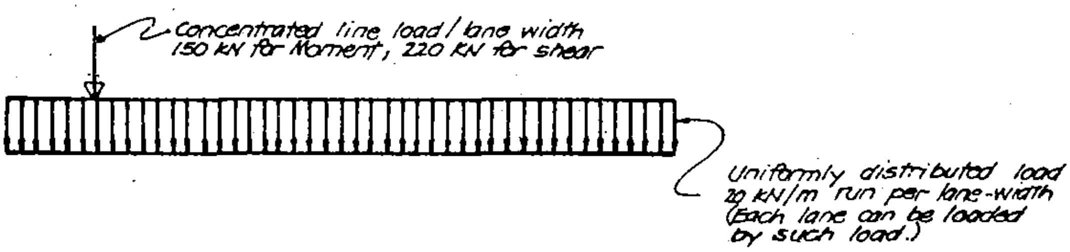

Fig. 3.29(b) *Uniformly distributed lane load plus one line load*

NOTE

(i) Design Load either (a) or (b), whichever produces the maximum effect.

(ii) Impact allowance as per AASHTO specifications.

(iii) For more than two lanes loaded, reduction factor on live load effect as per AASHTO specifications.

REFERENCES

1. Thomas, P.K., "A Comparative Study of Highway Bridge Loadings in Different Countries", *Supplementary Report 135UC*, Crowthorne, 1975. Transport and Road Research Laboratory.
2. Galambos, C.F., "International Road Federation In-depth Study on Fatigue, Fracture and Stress Corrosion Problems of Highway Bridges", *World Survey of Current Research and Development on Roads and Road Transport*. (International Road Federation, Washington, DC. 1972). pp. 332–365.
3. Seni, A., "Comparison of Live Loads Used in Highway Bridge Design in North America with Those Used in Western Europe", *Second International Symposium on Concrete Bridge Design* (Chicago, April 1969), (American Concrete Institute), Detroit, 1971, pp. 1–34.
4. Rajagopalan, K.S., Comparison of Loads Around the World for Design of Highway Bridges", *Second International Symposium on Concrete Bridge Design* (Chicago, April 1969), American Concrete Institute, Detroit, 1971, pp. 35–48.
5. Rowe, R.E., *Concrete Bridge Design* (CR Books, London, 1962), Wiley, New York, 1963.