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Specification for **Steel girder bridges**

Part 3A. Loads

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Association of Consulting Engineers
British Constructional Steelwork Association
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British Railways Board
British Steel Corporation
Cement and Concrete Association
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Institution of Municipal Engineers
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Ministry of Defence (Army)
Ministry of Development (Government of Northern Ireland)
Scottish Development Department
Welding Institute



Specification for
**Steel girder
bridges**

Part 3A. Loads

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Foreword

The present edition of BS 153 Part 3A is a metric edition of those parts of BS 153 Part 3A 1954 which covered highway loads, including the three amendments made to it.

A revised British Standard on bridges is in the course of preparation, but is not due for publication for some time. As many designers are working in SI units, the reprinted edition has been written in SI units in place of the previous imperial units.

An exception has been made for railway loading where the number of users is small and the amount of reprinting and reworking extensive. In the circumstances it has been decided to leave all references to forces working on railway bridges in imperial units and to recommend that moments, shears and other effects on the structure should be computed in these units.

Where the design is being executed in SI units the sum of any particular effect, derived in accordance with the specification should be converted to SI units using the appropriate conversion factors. (See PD 6203 for conversion tables.)

The values of the SI units given represent the equivalents of the values in imperial units rounded to convenient numbers.

For further information on SI units, reference should be made to BS 3763 'The International System of units (SI)' and PD 5686 'The use of SI units'.

BS 153 was first published in two volumes: Parts 1 and 2 (Materials and workmanship) in 1922 and Parts 3, 4 and 5 (Stresses, construction and erection) in 1923. These two volumes were then revised in 1933 and 1937 respectively.

As a result of modifications in the loading requirements for railway and highway bridges and of advances in experimental research leading to developments in design procedure, a further revision became necessary. Agreement having been reached on loading requirements, it was considered advantageous to precede the revision of 1958 with the issue in 1954 of Part 3A, 'Loads'. This part replaced Clauses 1 to 12 of Part 3 : 1937 and Appendix No. 1 of Part 3 : 1925.

The work of revising the remaining parts of BS 153 was completed in 1958; these were re-grouped and all the Parts were published under the authority of the Iron and Steel Industry Standards Committee in three volumes:

- Part 1. Materials and workmanship.
- Part 2. Weighing, shipping and erection.
Published 1958
- Part 3A. Loads. *Published 1954*
- Part 3B. Stresses.
- Part 4. Design and construction.
Published 1958

The standard was considerably enlarged in that revision, and the design and fabrication procedures were brought up to date with a view to ensuring consistent methods leading to maximum efficiency in the finished structure.

Except where otherwise stated, references in this standard to bolts and nuts apply to bolts and nuts in accordance with 1.2.1 and 1.2.2 of Part 1. The use of high strength friction grip bolts in accordance with 1.2.3 of Part 1 is governed by 4.1.2 of Part 4.

For convenience the amendments made to BS 153 Part 3A : 1954 are as follows:

Amendment No. 1 (PD 3262, issued in January 1959 and incorporated in the 1962 reprint) merely corrected an error in the first column of Table 5.

Amendment No. 2 (PD 4070, issued in March 1961 and incorporated in the 1962 reprint) introduced the following changes:

New paragraphs were added to Clause 4 to deal with dual carriageways.

Clause 12, Wind pressure effects, was replaced by a new clause.

A number of minor changes and additions were made to Appendix A.

Amendment No. 3 (PD 5748, issued in March 1966) introduced the following changes:

The foreword was rewritten, the title of 4.1.3 was changed and a new Subclause 15.2 was added to make reference to the Ministry of Transport memorandum on parapets for motorway and highway bridges.

In Appendix A, a note was added to Fig. 1. New Subclauses were added to Clauses 2 and 3 in Appendix B; the new Subclauses are now designated B.2.3 (the former B.2c being redesignated B.2.4) and B.3.2 and B.3.3. A new Appendix E, Table 9 and Fig. 7 were added.

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British Standard Specification for Steel girder bridges

Part 3A. Loads

1. Scope of BS 153

This specification is primarily intended to apply to the superstructure of simply supported steel bridges of spans up to 100 m. Where appropriate, the requirements of the specification may be adopted for larger spans or other types of steel bridges, but care should be taken, in these circumstances, to make whatever amendments are necessary for fixity at the supports, continuity and other indeterminate or special conditions, such as, for instance, may apply to opening bridges.

2. Forces to be taken into account

For the purpose of computing stresses the following items shall, where applicable, be taken into account:

- (1) Dead load.
- (2) Live load.
- (3) Impact effect.
- (4) Lurching effect.
- (5) Nosing effect.
- (6) Centrifugal force.
- (7) Longitudinal force.
- (8) Wind pressure effect.
- (9) Temperature effect.
- (10) Resistance of expansion bearings to movement.
- (11) Forces on parapets.
- (12) Erection forces and effects.
- (13) Forces and effects due to earthquakes, ice packs, subsidence and other similar causes.

Subject to the provisions of other clauses, all forces shall be considered as applied and all loaded lengths chosen in such a way that the most adverse effect is caused on the member under consideration.

3. Dead load

The dead load is the weight of the structure and any permanent loads fixed thereon. The dead load initially assumed shall be checked after the design is made and the design shall be revised as found necessary.

In determining the dead load, actual ascertained unit weights shall be used, but if these are not available unit weights as given in BS 648 may be used, as appropriate.

4. Live load

The live load is the weight of traffic and shall be of the type and magnitude specified.

The following standard loadings shall be adopted where appropriate:

4.1 Standard highway loading

4.1.1 Loading. Standard highway loadings are given in Appendix A.

These are:

Type HA. Equivalent lane loading which is the normal design loading for Great Britain but may be varied in intensity where conditions are other than those prevailing in Great Britain.

Type HB. Abnormal unit loading. To be used when specified by the appropriate authority. In Great Britain 45 units shall be taken for bridges carrying the heaviest class of load. This is an idealized load which allows for the weight of tractors accompanying trailers.

4.1.2 Width and number of traffic lanes to be used in conjunction with standard highway loadings

4.1.2.1 *Bridges having a carriageway width of 4.60 m or more.* Traffic lanes shall be taken to be not less than 2.30 m nor more than 3.70 m wide. The carriageway shall be divided into the least possible number of traffic lanes having equal widths as follows:

Carriageway width	No. of lanes
m	
4.60 up to and including 7.40	2
7.40 up to and including 11.1	3
11.1 up to and including 14.8	4
14.8 up to and including 18.5	5

4.1.2.2 *Bridges having a carriageway width of less than 4.60 m.* Where the carriageway on a bridge is less than 4.60 m in width it shall be taken to have a number of traffic lanes.

$$= \frac{\text{width of carriageway in metres}}{3.00}$$

4.1.2.3 Where dual carriageways are carried on one single superstructure, the number of lanes on the bridge shall be taken as the sum of the number of lanes in each of the single carriageways, as provided in the table above.

Where hard shoulders and marginal strips are provided these shall be considered as forming part of the carriageway and the number and width of traffic lanes calculated accordingly.

Where marginal strips are provided without hard shoulders the number of traffic lanes shall be calculated after deducting the widths of the marginal strips from the overall width of the carriageway between the verges or raised kerbs; the intensity of loading on the marginal strip shall be taken as equal to that for the adjacent carriageway lane, except where the adjacent carriageway lane carries HB loading, in which case the marginal strip is unloaded.

4.1.3 Application of standard loading on a single superstructure

Type HA loading. Type HA loading shall be taken to occupy one carriageway lane and to be uniformly distributed over the full width of the lane.

Two lanes shall always be considered as occupied by full Type HA loading, while all other lanes shall be considered as occupied by one-third the full lane loading, except where otherwise specified by the appropriate authority.

Type HB loading. One lane shall be loaded with Type HB loading only.

Where one carriageway only is carried on a superstructure, all other lanes shall be considered as occupied by one-third of the full lane loading, except where otherwise specified by the appropriate authority.

Where dual carriageways are carried on one single superstructure two lanes on the carriageway not carrying HB loading shall be taken as occupied with full HA loading. All other lanes shall be taken as carrying $\frac{1}{3}$ HA loading.

4.2 Standard railway loading

Standard railway loadings are given in Appendix B, in imperial units only. Where the remaining calculations are in SI units, the values obtained in imperial units shall be converted into SI units using the appropriate conversion factor. These are:

Type RA. British Standard unit loading, for various gauges.

Type RB. Total uniformly distributed load, including impact, for gauges of 4 ft 8½ in (1 432 mm) and over.

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This loading is based on the Bridge Stress Committee's report of 1928, a brief précis of which is given in Appendix D. It is suitable for railways in Great Britain and abroad with a gauge 4 ft 8½ in (1.432 m) and over and with locomotive and track characteristics similar to those obtaining on the main railways in Great Britain.

4.3 Standard footway loading

The live load due to pedestrian traffic shall be treated as uniformly distributed over the footway. For loaded lengths up to and including 23.0 m it shall normally be taken as 4 kN/m² and, for lengths over 23.0 m as the standard uniformly distributed loads given in Fig. 1 multiplied by a reduction factor of 4.0/31.5. Where crowd loading is likely the live load for the design of members exclusively supporting or forming the footway shall be taken as 5 kN/m².

In the case of highway bridges each part of the footway shall be capable of carrying a wheel load of 40 kN, which shall be deemed to include impact, distributed over a contact area 300 mm in diameter; the working stresses shall be increased by 25 % to meet this provision. This provision need not be made where vehicles cannot mount the footway.

5. Impact effect on highway bridges

Where Types HA and HB loadings given in Appendix A are not adopted, the allowance for impact on highway bridges shall be taken as follows:

(1) An impact allowance of 25 % shall be added to the axle-load, or (where there is more than one lane of traffic) the pair of adjacent wheel loads, which produces the greatest bending moment or shear, as the case may be, under the condition of loading for which the member being considered is designed.

(2) Where the loaded length required to produce the maximum stress in any member exceeds 30.0 m impact shall be ignored.

No addition for impact shall be made to the live load due to pedestrian or equivalent light traffic.

6. Impact effect on railway bridges

Appropriate additions shall be made to the live load specified in 4 for impact effects caused by the hammer blow of locomotives, rail joints, and track and wheel irregularities.

In determining these additions due consideration shall be given by the engineer to the standard and maintenance of track and rolling stock, the types and characteristics of locomotives, and the type and characteristics of the bridge.

Type RB loading, which is suitable for the main line railways of Great Britain and other railways having similar locomotive and track characteristics, already includes an allowance for impact and no further additions shall be made. For all other loadings, including type RA, the additions for impact shall be specified by the engineer. For his guidance three methods of calculating the additions, those of Foxlee and Greet, the Government of India and the American Railway Engineering Association, are described in detail in Appendix C.

7. Lurching on railway bridges

A separate allowance shall be made for lurching, unless this has already been included in the impact effect.

Lurching results from the temporary transfer of part of the live loading from one rail to the other, the total load on the track remaining unaltered. The transfer shall be taken to increase the load on the rail which most adversely affects the member under consideration.

The proportion Q_L of live load on one rail so transferred shall be calculated from the expression:

$$Q_L = \frac{160kn}{l+100}$$

where k is a coefficient depending on the type of spring suspension, the weight and height of the rolling stock, and the type of construction and lateral rigidity of the bridge structure;

n is the number of revolutions per second of the driving wheels of the locomotives (see Fig. 6, Appendix B);

l is the effective span in feet, as defined in 1.4 of Part 4.

NOTE. For conditions corresponding to those ruling on the railways of Great Britain (4 ft 8½ in gauge = 1.432 m gauge), and provided the structure is adequately stiffened laterally, $k = 1/24$ and $n = 6$ for maximum speed, but with a maximum value of Q_L of 0.25. For conditions other than those ruling on the railways of Great Britain, and where provision for a greater lurching effect is necessary, it is recommended that the value of the coefficient k be increased but to not more than 1/15 with a maximum value for the factor Q_L of 0.40.

Where a member supports or assists in supporting more than one track, provision for the effect of lurching need only be made in respect of one of the tracks where these are two, or in respect of alternate tracks where there are more than two, the track or tracks selected being those on which the transfer of the load has the greatest effect on the member.

Lurching need not be taken into account in the case of an inner main girder assisting in supporting more than one track.

No addition for impact shall be made to the lurching effect.

8. Nosing on railway bridges

An allowance shall be made for nosing, and this shall be taken as a single force of 10 tonf, acting horizontally, in either direction, at right angles to the track, at the rail level and at such a point in the span as to produce the maximum effect in the member under consideration. This value is appropriate to the conditions obtaining on railways in Great Britain. In other cases the amount of force may be amended at the engineer's discretion.

Vertical effects shall be disregarded.

On multi-track bridges, a single force as specified above shall be deemed sufficient.

9. Centrifugal force on railway bridges

Where the track or tracks are curved, allowance for centrifugal action of the moving loads shall be made in designing the members, all tracks on the structure being considered as occupied. The centrifugal force due to the load per track shall be calculated from the following formula:

$$C = \frac{w v^2}{15R}$$

where C = the centrifugal force per linear foot considered as a moving load, acting at a height of 6 ft (1.83 m) above the level of the rails, unless otherwise specified by the engineer;

w = the equivalent distributed live load, without impact, per linear foot per track;

v = the allowable maximum speed of the train in miles per hour, as specified by the engineer; and

R = the radius of the track curve in feet.

No addition for impact shall be made to the centrifugal force.

10. Longitudinal force on highway bridges

The following longitudinal force resulting from the traction or braking of vehicles shall be taken as acting horizontally at the level of the carriageway surface, and having the following values for all widths of bridge. The force shall be applied over an area 3.00 m wide by 9.00 m long, or the length of the bridge, whichever is less, and in that position which will have the worst effect on the member under consideration.

	Type HA loading	Type HB loading for 45 units
Spans up to 3.00 m	100 kN	} 450 kN for all spans
Spans above 3.00 m	100 kN plus 17 kN for each metre of span over 3.00 m but not exceeding 253 kN	

No increase for impact effect shall be made to the stresses due to longitudinal forces.

Only one such force shall be considered.

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11. Longitudinal force on railway bridges

Provision shall be made for the forces due to traction and the application of brakes. These forces shall be considered as acting on the rail, and, for the purpose of the design of the structure, shall be taken as the larger of:

(1) A force due to traction of 20 % of the total axle loads on the coupled or driving wheels on one track without impact. When type RB loading is used, 20 units of type RA loading shall be taken for this purpose.

(2) A force due to braking of 10 % of the total load on one track without impact.

Where the structure carries two tracks, one up and one down, both tracks shall be considered as being occupied simultaneously, and the force due to braking shall be applied to one track and the force (in the same direction) due to traction to the other.

Where the structure carries more than two tracks, the longitudinal forces shall be considered as applied to two tracks only, unless otherwise specified by the engineer, the worst case being taken as regards its effect on any part of the structure.

Some relief in the effect of the longitudinal force on the bridge and its supports may be taken into account where the tracks are capable of transmitting part of these forces to resistances outside the bridge structure.

No addition for impact shall be made to the longitudinal force.

12. Wind pressure effects

12.1 General

Where the effect of wind has to be taken into consideration, it shall be treated as a moving load (i.e. taken of such length along the span as to produce the maximum stress in the member under consideration) acting at the centroids of the exposed areas as defined below.

The maximum effects from the wind blowing in either lateral direction on the loaded or unloaded structure shall be taken, having regard to the disposition of the live load.

For conditions normally prevailing in Great Britain the wind pressures specified below shall be used, but where owing to the position of the bridge or any special conditions the assumed wind speeds cannot be realized or may be exceeded, the engineer shall at his discretion specify different values. For this purpose the wind pressure shall be assumed to vary as the square of the wind speed.

12.2 For maximum lateral effect

12.2.1 On unloaded structures. A wind pressure of 1.4 kN/m^2 corresponding to a wind speed of 40 m/s shall be taken as acting horizontally and normal to the sides of the bridge on a total exposed area of the superstructure made up of the following areas as applicable:

Windward girder, deck and bracing. The net exposed area in normal projected elevation of the windward girder, deck construction, bracing and parapet.

Leeward girders. The following fractions (not exceeding unity) of the net exposed area in normal projected elevation of the leeward girder:

$$\frac{n}{16} \text{ when the windward girder is a plate girder}$$

$$\frac{n}{8} + 0.5 \text{ when the windward girder is a trussed girder}$$

where n = ratio of distance, centre to centre between the windward and outermost leeward girder, to the depth of the windward girder.

Where there are more than two main girders, only that fraction of the area of the outmost leeward girder as calculated above shall be taken.

In cases where a leeward girder projects in elevation beyond the windward girder, the full net exposed area of the projection as seen in elevation shall be treated as subject to full wind pressure.

12.2.2 On loaded structures. In arriving at the total effective area exposed to wind on a loaded structure, allowance shall be made for the screening effect, based on projected areas, of the structure on the live load, or of the live load on the structure, or of live loads on each other.

12.2.2.1 Highway and footway bridges. A wind pressure of 0.7 kN/m^2 , corresponding to 28 m/s , shall be taken as acting horizontally and normal to the sides of the bridge on the exposed area of the superstructure (calculated as in 12.2.1) and of live load taken as a single vertical plane surface having a continuous height of 2.50 m above the carriageway or 1.25 m above footway and cycle tracks, as applicable.

12.2.2.2 Railway bridges. A wind pressure of 1.4 kN/m^2 (30 lbf/ft^2) corresponding to a wind speed of 40 m/s , shall be taken as acting horizontally and normal to the sides of the bridges on the exposed area of the superstructure (calculated as in 12.2.1) and of live load taken as a single vertical plane surface having a continuous height of 3.75 m (12 ft) above the rail.

12.3 For longitudinal effect

A longitudinal wind force shall be combined with a corresponding lateral wind force equal to half the total lateral force given in 1.2.2 and the two shall be distributed compatibly.

The longitudinal wind forces shall be determined as follows:

(1) *For plate girder bridges:* a quarter of the total lateral wind forces on the superstructure in the unloaded condition (see 12.2.1); or a quarter of the total lateral wind forces on the superstructure and half the total lateral wind forces on the live load, in the loaded condition (see 12.2.2).

(2) *For trussed girder bridges:* half the total lateral wind forces on the superstructure in the unloaded condition (see 12.2.1); or, half the total lateral wind forces on the superstructure and live load, in the loaded condition (see 12.2.2).

12.4 For maximum overturning effect

On the bridge and its supports, the following shall be taken into account:

(1) In addition to the lateral and longitudinal wind forces specified above, an upward vertical pressure of 0.24 kN/m^2 acting over the net exposed area of the bridge in plan.

(2) In considering the overturning effect due to wind on live load, the live load shall consist of standard loading or of unloaded wagons or vehicles of the lightest tare, whichever produces the maximum overturning effects. The latter shall be taken as not greater than 12 kN per linear metre of bridge for railway bridges and not greater than 6 kN per linear metre of bridge for highway bridges.

13. Temperature effect

Allowances shall be made for the forces resulting from the following conditions:

(1) Any portion of the superstructure being restrained from moving when subjected to variations of temperature.

For this purpose in Great Britain a minimum of -7°C and a maximum between 27°C and 49°C , depending on the location of the structure, shall be taken. Elsewhere the temperature limits shall be based on local conditions.

(2) Any portion of the superstructure being at a temperature different from the rest of the structure, due to the effect of sun and shade. For this purpose the maximum difference of temperature shall be taken as 8°C .

In determining forces and movements due to change of temperature the coefficient of expansion of steel shall be taken as 1.17×10^{-5} per $^\circ \text{C}$.

14. Frictional resistance of expansion bearings

For expansion and contraction of the structure due to variations of temperature or to other causes, the forces due to friction on the expansion bearings under dead load only shall be taken into account and the following coefficients of friction shall be used:

For roller bearings with 1 or 2 rollers	0.01
For roller bearings with 3 or more rollers	0.05
For sliding of steel on hard copper alloy bearings	0.15
For sliding of steel on cast iron or steel	0.25

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15. Forces on parapets

15.1 Footbridge parapets

Consideration shall be given to the strength and stability of parapets. Parapets may be subject to horizontal loads acting at a height of 1.00 m above the level of the footway, ranging from 0.7 kN per metre to 1.4 kN per metre, according to circumstances. The maximum load will only be encountered in extreme cases of crowd loading.

The value of the loading shall be taken at the discretion of the engineer.

15.2 Motorway and other highway bridge parapets

Reference should be made to the Ministry of Transport memorandum on the subject.

16. Combination of forces

The following combinations of forces shall be considered:

- (1) The worst combination possible of dead load with live load, impact, lurching and centrifugal force.
When a member whose primary function is to resist longitudinal and nosing forces due to live load is under consideration the term live load shall include these forces.
- (2) The worst combination possible of any or all of the forces listed under (1) to (11) inclusive in 2.
- (3) The worst combination possible of forces during erection.
- (4) The worst combination possible of any or all of the forces listed in 2, at the discretion of the engineer.

17. Erection forces and effects

The weight of all permanent and temporary material, together with all other forces and effects which can operate on any part of the structure during erection, shall be taken into account.

18. Anchorage

The stability of the structure and its parts shall be investigated and weight or anchorage shall be provided so that the least restoring moment, including anchorage, is not less than the sum of:

- 1.1 × dead load overturning moment
- and 1.4 × overturning moments due to applied loads.

Account shall be taken of possible variations of dead load for repair or other temporary purposes to ensure stability at all times.

This margin of stability in so far as stresses are concerned shall be deemed to be covered in respect of all parts of the structure which have been designed for their working loads to the permissible stresses in this British Standard.

In complying with the requirements of this clause it is necessary to ascertain that the resulting pressures and shears deemed to be communicated by the bearings to the substructure will not produce failure.

19. Clauses to be referred to the engineer

The following clauses in Part 3A contain points on which the decision of the engineer is required and concerning which information is to be supplied at the time of inviting tenders.

Clauses 4.1.1, 6, 7, 8, 9, 11(2), 12.1, 13(1), 15, 16(4).

Appendix A

Standard highway loading

A.1 Type HA loading

Type HA loading consists of (1) and (2), or (3), viz.:

(1) A uniformly distributed lane loading. The values for this load per linear metre of traffic lane are given in Table 1 and Fig. 1.

(2) One knife edge load uniformly distributed across the width of the traffic lane. The values of this load, which shall be applied in accordance with A.3.1, are given in Fig. 1.

(3) Two wheel loads each 112 kN force in line transversely to the direction of traffic flow spaced at 0.90 m centres and having a contact area of 375 mm x 75 mm, the smaller dimension being in the direction of travel, to be used in the following cases:

a. Where the member supports a small area of roadway, such that it may be called on to carry the weight of one or two wheels, and where the proportion of distributed load and knife edge load which would be allocated to it is small and on cantilever projections not exceeding 1.80 m.

b. Where deck slabs are designed as supported on all four sides and the distance between supports in one direction is less than twice the distance in the other direction.

In this respect the edge stiffening of slabs as required by A.3.9 of this appendix shall not be deemed as providing adequate support for this purpose.

A.2 Varied intensities of type HA loading

Where a different intensity of loading is required, Type HA loading may be varied proportionately, each item of the loading being varied pro rata.

When making any reduction it should be borne in mind that an impact allowance of 25 % as specified in A.5.1 has been taken into account in this loading. This allowance is considered adequate for conditions in Great Britain, but may not necessarily be sufficient elsewhere.

A.3 Application of type HA loading

A.3.1 The knife edge load shall be taken as acting as follows:

A.3.1.1 *On reinforced concrete slabs effectively supported on two sides and on cantilever slabs exceeding 1.80 m.* In a direction parallel to the supporting members.

A.3.1.2 *On longitudinal girders, stringers, etc.* In a direction at right angles to the member.

A.3.1.3 *On cross members, including transverse cantilever girders.* In a direction in line with the member.

A.3.2 Where longitudinal members are spaced at less than half the width of the lane the loading to be taken on these members shall be that appropriate to a half lane width.

A.3.3 The total end live load shear on any longitudinal beam shall be taken as not less than 90 kN per metre width of carriageway supported by the member.

A.3.4 No allowance shall be made for impact or dispersal of load in respect of the distributed load or knife edge load.

A.3.5 No allowance shall be made for impact under the wheel loads.

A.3.6 Dispersal under the wheel loads, where it can occur, shall be taken at 45°.

A.3.7 It shall be permissible in considering the effects of the 112 kN loads to allow a 25 % overstress.