VOLUME 3 HIGHWAY STRUCTURES: INSPECTION AND MAINTENANCE

SECTION 4 ASSESSMENT

PART 19

BD 86/01

THE ASSESSMENT OF HIGHWAY BRIDGES AND STRUCTURES FOR THE EFFECTS OF SPECIAL TYPES GENERAL ORDER (STGO) AND SPECIAL ORDER (SO) VEHICLES

SUMMARY

This Standard gives criteria for the assessment of highway bridges and structures for the effects of Special Types General Order (STGO) and Special Order (SO) vehicles.

INSTRUCTIONS FOR USE

This is a new Standard to be incorporated in the Manual.

1. Remove existing contents page for Volume 3 and insert new contents page for Volume 3 dated November 2001.
2. Insert BD 86/01 in Volume 3, Section 4, Part 19.
3. Archive this sheet as appropriate.

Note: A quarterly index with a full set of Volume Contents Pages is available separately from The Stationery Office Ltd.

Volume 3 home page

THE HIGHWAYS AGENCY

SCOTTISH EXECUTIVE DEVELOPMENT DEPARTMENT

THE NATIONAL ASSEMBLY FOR WALES
CYNULLIAD CENEDLAETHOL CYMRU

THE DEPARTMENT FOR REGIONAL DEVELOPMENT
NORTHERN IRELAND

The Assessment of Highway Bridges and Structures for the Effects of Special Types General Order (STGO) and Special Order (SO) Vehicles

Summary: This Standard gives criteria for the assessment of highway bridges and structures for the effects of Special Types General Order (STGO) and Special Order (SO) vehicles.

Volume 3 home page

REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

Volume 3 home page

REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

Volume 3 home page

VOLUME 3 HIGHWAY STRUCTURES: INSPECTION AND MAINTENANCE

SECTION 4 ASSESSMENT

PART 19

BD 86/01

THE ASSESSMENT OF HIGHWAY BRIDGES AND STRUCTURES FOR THE EFFECTS OF SPECIAL TYPES GENERAL ORDER (STGO) AND SPECIAL ORDER (SO) VEHICLES

Contents

Volume 3 home page

1. INTRODUCTION

General

1.1 This Standard gives guidance for the determination for Vehicle Ratings (3.53) and Reserve Factors (3.51) for highway bridges and structures. The Vehicle Ratings and Reserve Factors indicate the load carrying capacity of structures to support Special Type General Order (STGO) and Special Order (SO) vehicles.

1.2 Annex D is intended to be used, when specified by the Overseeing Organisation, as a basis for checking the load carrying capacity of structures to support particular notified STGO and SO vehicles which may need to cross the structure from time to time.

1.3 Road vehicles in the United Kingdom are categorised for regulatory purposes into three broad groups as given below:

1.3.1 **Vehicles complying with The Road Vehicles Construction and Use (C&U) Regulations[4] and Authorised Weight (AW) Regulations[4].** This group includes cars, light goods vehicles, and rigid and articulated heavy goods vehicles up to a gross weight of 44 tonnes. These vehicles are covered by the C&U and AW Regulations and are not subject to permit and notification requirements. For convenience, the term AW referred to hereinafter will be taken to include C&U. The effects of these AW vehicles are to be assessed in accordance with BD 21 (DMRB 3.4.3) when assessing highway bridges and structures.

1.3.2 **Vehicles complying with The Motor Vehicles (Authorisation of Special Types) General Order (STGO Regulations)[4].** This group includes vehicles that do not comply with the AW Regulations such as those used for carrying or drawing abnormal indivisible loads (see Annex A). Notifications of movements of these vehicles are required in accordance with STGO Regulations. The effects of these STGO vehicles are to be assessed in accordance with this Standard when assessing highway bridges and structures.

1.3.3 **Special Order (SO) Vehicles.** This group includes vehicles that do not comply with the AW or STGO Regulations and is covered by Section 44 of the 1988 Road Traffic Act. Application for an individual Special Order authorising the movement of an SO vehicle shall be submitted to the Department of Transport, Local Government and the Regions Vehicle Standards and Engineering (VSE) branch. In Northern Ireland the equivalent vehicles are covered by Article 60 of the Road Traffic (Northern Ireland) Order 1995 and applications for individual Special Orders authorising movements shall be submitted to Roads Service Headquarters, Network Development Branch. The effects of an SO vehicle are to be assessed in accordance with this Standard when assessing highway bridges and structures.

1.4 If amendments are made to the Regulations affecting the allowable weights and dimensions of vehicles and axles, this Standard will be amended as necessary.

1.5 This Standard allows the load effects from real STGO and SO vehicles to be assessed more accurately than does the HB load model in BD 37 (DMRB 1.3), and in general should offer the following benefits:

(i) Attainment of higher load capacity ratings, particularly for structures with loaded lengths of less than about 10m.

(ii) Flexibility to modify the Overload Factor, Dynamic Amplification Factor and associated HA loading.

(iii) Consistent levels of safety for highway bridges and structures of different spans and for different STGO and SO vehicle movements.

Scope

1.6 This Standard is intended for use, when carrying out assessment of highway bridges and structures, to assess the effects of STGO and SO vehicles in combination with the effects of AW vehicles and permanent loads.

1.7 The loads given in this Standard can be used for the assessment of bridges constructed of steel, concrete, wrought iron and cast iron, as well as the assessment of brick and stone masonry arches. It may be used for timber structures or stone slab bridge decks. It may also be used for the assessment of spandrel walls and buried structures. However, the Standard should not be used for the assessment of retaining walls, abutments and wing walls.

> 1.8 The applicability of the load model given in this Standard shall be limited to structures with loaded lengths of less than 50m.
>
> 1.9 The design of strengthening schemes for structures is not covered by this Standard and shall be based on current design loading standards as required by the Overseeing Organisation.

Implementation

> 1.10 This Standard shall be used, where specified, for the assessment of highway bridges and structures for the effects of STGO and SO vehicles. The specific structures and structural elements chosen for assessment shall be agreed with the Overseeing Organisation.

Mandatory Requirements

1.11 Sections of this Standard, which are mandatory requirements of the Overseeing Organisations, are highlighted by being contained within boxes. The remainder of the document contains advice and enlargement, which is recommended for consideration.

Definitions

1.12 For the purpose of this Standard the following definitions apply:

(i) Abnormal Indivisible Load. A load which cannot, without undue expense or risk of damage, be divided into two or more loads for the purpose of carriage on roads.

(ii) Assessment. Inspections of a structure and determination of its load carrying capacity of a structure in terms of the SV, STGO or SO vehicles, and the associated loading from Type HA or AW vehicles.

(iii) Assessment Loads. Loads determined for the assessment of the structure by applying the partial factors for load, γ_{fL}, to the nominal loads.

(iv) Assessment Load Effects. Load effects determined by applying the partial factor for load effect, γ_{f3}, to the effects of the assessment loads.

(v) Assessment Resistance. The resistance determined by the application of a Condition Factor to the calculated resistance.

(vi) AW Regulations. Authorised Weight (AW) Regulations governing the weights of normal vehicles using the highway.

(vii) AW Vehicles. Vehicles conforming to the Authorised Weight regulations, also refers to the AW vehicles given in BD 21 (DMRB 3.4.3).

(viii) Basic Axle Loads. Notified or specified axle loads excluding the effects of Overload Factor (OF) and Dynamic Amplification Factor (DAF).

(ix) Calculated Resistance. The capacity of the structure or element determined from its material strengths and section properties by applications of the partial factors for material strength, γ_m.

(x) Centrifugal Effects. Radial forces and changes to vertical live loading due to vehicles travelling in a horizontally curved path.

(xi) Condition Factor. A factor which accounts for deficiency in the integrity of the structure as defined in BD 21 (DMRB 3.4.3).

(xii) Dead Load. Loading due to the weight of the materials forming the structure or structural elements but excluding superimposed dead load materials.

(xiii) Dynamic Amplification Factor. A factor to model the dynamic effects induced by the vehicles moving over a highway bridge or a structure (see 3.25).

(xiv) Loaded Length. Where there is only one adverse area, the loaded length is the base length of that area under the live load influence line, which produces the most adverse effect at the section being considered. For Type HA loading, where the influence line has a cusped profile this may be taken as given in BD 37 (DMRB 1.3). Where there is more than one adverse area, as for example in continuous construction, the loaded length is:

(a) for Type HA loading, the sum of the full base lengths of adverse areas

(b) for SV Vehicles, the sum for the full base lengths of adverse areas plus any non-adverse areas required to place the vehicle without truncation to achieve the most adverse overall effect.

(xv) Notional Lane. A notional part of the carriageway assumed solely for the purpose of applying specified live loads.

(xvi) Overload Factor. A factor to model the increase in axle loads above the nominal axle load arising from the overloading of vehicles and the uneven distribution of a vehicle's total weight to its individual axles.

(xvii) Reserve Factor. The ratio of the capacity of a structure available to support loading from an SV vehicle to the load effect from an SV vehicle.

(xviii) SO Vehicle. A Special Order vehicle that does not conform to the AW or STGO Regulations, but is covered by Section 44 of the 1998 Road Traffic Act. In Northern Ireland the equivalent vehicles are covered by Article 60 of the Road Traffic (Northern Ireland) Order 1995.

(xix) STGO Regulations. Special Types General Order (STGO) Regulations governing vehicles that do not conform to the AW Regulations for reasons of gross weight, height, length and/or axle weight and spacing configurations.

(xx) STGO Vehicle. A Special Types General Order vehicle conforming to the STGO Regulations.

(xxi) Superimposed Dead Load. The weight of all materials imposing loads on the structure but which are not structural elements, such as surfacing, parapets, spandrel walls, service mains, ducts, miscellaneous street furniture, etc.

(xxii) SV Vehicles. The Special Vehicles intended to represent a range of real STGO vehicles as defined in 3.9 to 3.13.

(xxiii) Type HA Loading. Loading from AW vehicles as defined in BD 21 (DMRB 3.4.3).

(xxiv) Type HB Loading. A model to represent loading from vehicles not conforming to the AW Regulations as defined in BD 37 (DMRB 1.3).

(xxv) Ultimate Limit State (ULS). Loss of equilibrium or collapse. See BS 5400: Part 1 for a more comprehensive definition.

(xxvi) Vehicle Rating. The most onerous SV vehicle that can safely pass over the structure (ie the vehicle which produces the smallest Reserve Factor greater than 1.0).

Symbols

1.13 The following symbols and abbreviations are used in this Standard.

b_L	Notional lane width
DAF	Dynamic Amplification Factor
DAF_{STGO}	Dynamic Amplification Factor for STGO vehicle (see Annex D)
DAF_{SV}	Dynamic Amplification Factor for SV vehicle (see Annex D)
M_{STGO}	Mid-span bending moment due to STGO vehicles (see Annex D)
M_{SV}	Mid-span bending moment due to SV vehicles (see Annex D)
N_{HB}	Number of units in HB rating (see Annex C)
OF	Overload Factor applied to each axle of an SV, STGO or SO vehicle
OF_{STGO}	Overload Factor applied to each axle of an STGO vehicle (see Annex D)
OF_{SV}	Overload Factor applied to each axle of an SV vehicle (see Annex D)
$Q_A{}^*$	Assessment loads

q_{ka}	Basic axle load of an SV, STGO or SO vehicle (kN)
R_A*	Assessment resistance
$S*$	Load effect due to an SV, STGO or SO vehicle
S_A*	Assessment load effect
S_D*	Assessment load effects due to dead and superimposed dead loads
$S_{HA(SV)}$	Unfactored load effect due to Type HA loading (or AW vehicle loading) associated with the SV vehicle (see Annexes C and D)
$S_{HA(STGO)}$	Unfactored load effect due to Type HA loading (or AW vehicle loading) associated with the STGO vehicle (see Annexes C and D)
S_{HB45}	Unfactored load effect due to 45 units of HB loading (see Annex C)
S_{STGO}	Unfactored load effect due to an STGO vehicle (see Annex D)
S_{SV}	Unfactored load effect due to an SV vehicle (see Annex D)
W_{STGO}	Gross weight of an STGO vehicle (see Annex D)
W_{SV}	Gross weight of an SV vehicle (see Annex D)
Ψ_{SV}	Reserve Factor against an SV vehicle with the associated HA loading
$\Psi*_{SV}$	Reserve Factor against an SV vehicle without the associated HA loading
γ_{fL}	Partial factor for load
γ_{f3}	Partial factor for load effect
$\lambda_{HB45 \rightarrow SV}$	Conversion Factor from 45 units of HB loading to an equivalent SV vehicle (see Annex C)

2. OBJECTIVES AND PROCEDURES

General

2.1 The objectives of assessment shall be to determine, in terms of vehicle loading, the load that a given structure can carry such that, with a reasonable probability, it will not suffer serious damage endangering any persons or property on or near the structure.

2.2 The procedures for the assessment of highway bridges and structures shall generally follow the provisions of BD 21 (DMRB 3.4.3) with additional requirements given or as specified otherwise in this Standard.

Limit States

2.3 The Standard generally adopts the limit state format as described in BD 21 (DMRB 3.4.3). The limit state to be adopted for this Standard is the Ultimate Limit State (ULS), using appropriate partial factors. However, for masonry arch bridges and cast iron bridges alternative assessment methods shall be adopted in accordance with BD 21 (DMRB 3.4.3).

2.4 In composite and steel bridges there are a number of cases where ULS checks are not required because ULS and Serviceability Limit State (SLS) criteria are closely related and it is known that SLS will govern. In these cases the checking for ULS only would be unsafe and SLS criteria shall be checked.

For example the relevant clauses are:

(i) BD 56/96 (DMRB 3.4.11)

(a) Annex A, Clause 9.10.3.3 (Stiffened flanges subject to local bending when local bending stresses are neglected at ULS).

(ii) BD 61/96 (DMRB 3.4.16)

(a) Annex A, Clause 5.3.3 (Assessment of shear connection)

(b) Annex A, Clause 8.5 (Longitudinal shear in cased and filler beams)

(c) Where cased and filler beams are assessed using BA 16 (DMRB 3.4.17) and the "yield moment" is used as the ultimate moment, the interface shear should be assessed at SLS.

Assessment Loads

2.5 The assessment loads, Q_A*, shall be as defined in BD 21 (DMRB 3.4.3). The γ_{fL} values for SV, STGO and SO vehicles and associated Type HA or AW vehicles shall be taken as given in Table 2.1, except for arch bridges, see 3.44.

Loading		γ_{fL} Cast Iron Bridges	γ_{fL} Other Structures
Live	SV vehicle	1.0	1.10
	STGO vehicle	1.0	1.10
	SO vehicle	1.0	1.10
	Associated Type HA or AW vehicles combined with SV, STGO or SO vehicle	1.0	1.30

Table 2.1: Additional values of γ_{fL} - Partial Factor for Live Loads at ULS

2.6 γ_{fL} at SLS shall be taken as 1.0 for all live loads in Table 2.1.

2.7 Nominal dead, superimposed and live loads are given in Chapter 3.

Load Combinations

2.8 Dead and superimposed dead loads shall be combined with live loads using the factors given in 2.5.

2.9 When other loads not specified in this document are considered to be necessary for assessment purposes, reference shall be made to BD 37 (DMRB 1.3) for the details of these loads, the appropriate load combinations and their respective γ_{fL} values (except for cast iron bridges, where the values of γ_{fL} shall be taken as 1.0). However, for load combinations 2 and 3, γ_{fL} for SV, STGO or SO loads shall be taken as 1.0.

Assessment Load Effects

2.10 The assessment load effects, S_A*, shall be as defined in BD 21 (DMRB 3.4.3).

Verification of Structural Adequacy

2.11 The verification of structural adequacy shall be as defined in BD 21 (DMRB 3.4.3).

3. LOADING

General

3.1 The Load Ratings and Reserve Factors of highway bridges and structures shall be determined by the loading requirements given in this Chapter. Assessment loading will generally be limited to the application of dead and superimposed dead loads, a SV, STGO or SO vehicle and associated Type HA loads. All loads specified in this Chapter are nominal loads unless otherwise stated and shall be multiplied by the appropriate partial factors given in 2.5.

3.2 When the carriageway on the bridge is horizontally curved, the structure shall be assessed for the live loading requirements given in 3.5 to 3.45 and, in addition, a separate assessment for centrifugal effects may be required in accordance with the requirements of 3.39.

Notional Lane Width (b_L)

3.3 The carriageway shall be divided into notional lanes in accordance with BD 21 (DMRB 3.4.3).

Nominal Dead Load and Nominal Superimposed Dead Load

3.4 The nominal dead load and nominal superimposed dead load shall be taken as defined in BD 21 (DMRB 3.4.3). Where available, these loads shall be calculated based on the measured dimensions and densities of materials.

Nominal Assessment SV Vehicles

General

3.5 Assessment shall be carried out for the load effects of SV vehicles, which cover the range of vehicles specified in 3.8 to 3.13. For loaded lengths of up to 50m the following loads shall be applied:

(i) Nominal axle loads: Basic axle loads (3.17 to 3.21) multiplied by the appropriate Overload Factor (3.24) and Dynamic Amplification Factor (3.25).

(ii) Associated Type HA loading or AW vehicles (3.26 to 3.45).

3.6 For loaded lengths in excess of 50m, advice shall be sought from the Overseeing Organisation.

3.7 Accidental wheel/vehicle loading and footway loading are not required when assessing for SV vehicles.

Assessment SV Vehicles

3.8 The following five models simulate the vertical effects of different types of STGO vehicles (see Annex A) with basic axle weights not exceeding 16.5 tonnes and military tank transporter vehicles with basic axle weights of up to 25 tonnes. They do not describe actual vehicles, but have been chosen so that their effects, including dynamic amplification, represent the extreme effects that could be induced by the actual STGO vehicles. The axle weight and spacing of SV vehicles are therefore close to, but not exactly equal to, the allowable limits of the STGO Regulations. The Type HA loading covers the effects of STGO Category 1 vehicles with a maximum gross vehicle weight of 46 tonnes.

3.9 ***SV 80.*** The SV80 vehicle (3.17) is intended to model the effects of STGO Category 2 vehicles with a maximum gross vehicle weight of 80 tonnes and a maximum basic axle load of 12.5 tonnes.

3.10 ***SV 100.*** The SV100 vehicle (3.18) is intended to model the effects of STGO Category 3 vehicles with a maximum gross vehicle weight of 100 tonnes and a maximum basic axle load of 16.5 tonnes.

3.11 ***SV 150.*** The SV150 vehicle (3.19) is intended to model the effects of STGO Category 3 vehicles with a maximum gross vehicle weight of 150 tonnes and a maximum basic axle load of 16.5 tonnes.

3.12 ***SV-Train.*** The SV-Train (3.20) is intended to model the effects of a single locomotive pulling a Category 3 trailer.

3.13 ***SV-TT.*** The SV-TT (3.21) is intended to model the effects of military tank transporter vehicles with a maximum basic axle load of 25 tonnes.

Vehicles Outside the Scope of SV Models

3.14 For a specific STGO or SO vehicle that is outside the scope of the SV models defined in 3.8 to 3.13, the vehicle shall be assessed initially by comparing its load effect against the load effect from an SV vehicle with the associated Reserve Factor using one or more influence lines considered most appropriate for the structure. The procedures given in D.2 to D.6 may be used for this purpose.

3.15 In the above, if the load effect from the vehicle exceeds the load effect from the SV vehicle, then the structure shall be assessed directly using this vehicle, with the values of DAF, OF, γ_{fL} and γ_{f3} applied in the same way as they are for SV vehicles. For an SO vehicle, values for DAF and OF may be reduced as given in Annex D if the speed is restricted and there is a greater control over the gross weight and axle weights.

Basic axle load and configuration of vehicles

3.16 Basic axle loads are taken as the notified or specified axle weights transmitted to the surface of the road or as specified in 3.17 to 3.21.

3.17 ***SV 80.*** Figure 3.1 shows the basic axle loads, plan and axle configuration of the SV80 vehicle. The spacing of 5.0m and 9.0m between the two bogies need be checked only for load effects with two or more peaks in the influence line/surface for loaded lengths of greater than 12m.

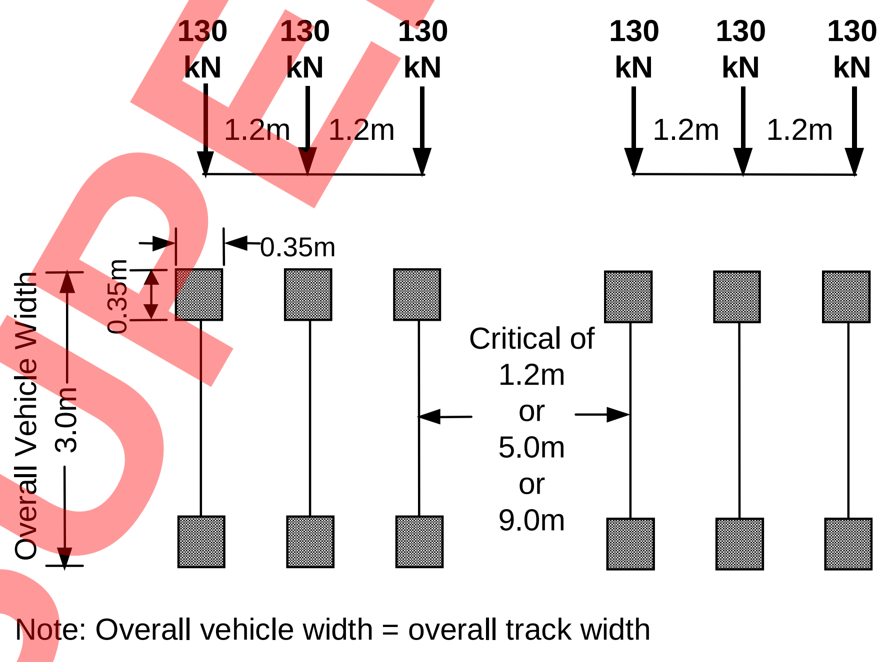


Figure 3.1: SV80 vehicle

3.18 ***SV 100.*** Figure 3.2 shows the basic axle loads, plan and axle configuration of the SV100 vehicle. This model is critical for loaded lengths typically less than 10m. The spacing of 5.0m and 9.0m between the two bogies need be checked only for load effects with two or more peaks in the influence line/surface for loaded lengths of greater than 12m.

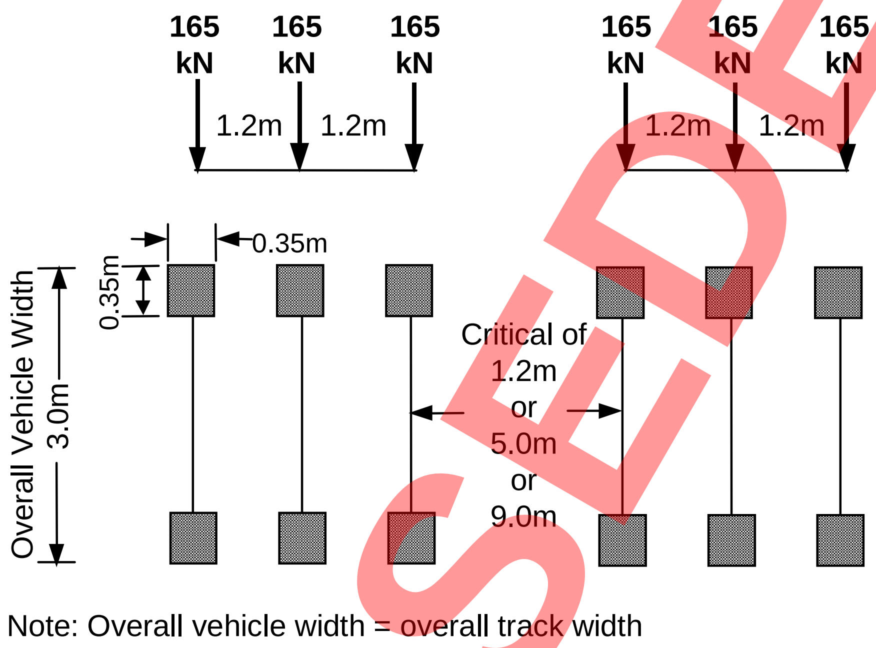


Figure 3.2: SV100 vehicle

3.19 ***SV 150.*** Figure 3.3 shows the basic axle loads, plan and axle configuration of the SV150 vehicle. The spacing of 5.0m and 9.0m between the two bogies need be checked only for load effects with two or more peaks in the influence line/surface for loaded lengths of greater than 17m.

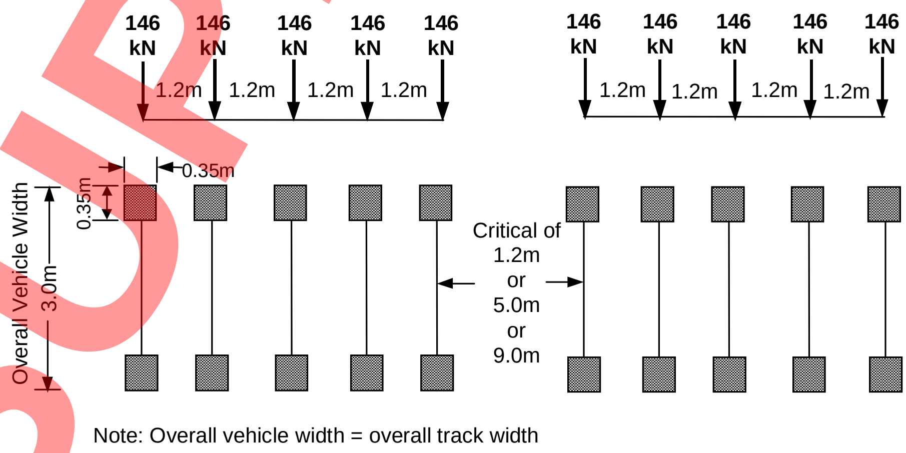
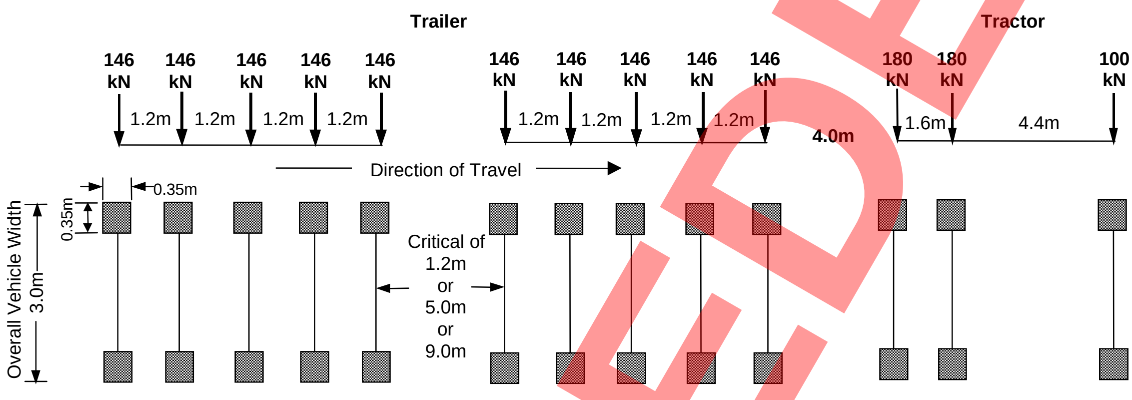


Figure 3.3: SV150 vehicle

3.20 ***SV-Train.*** Figure 3.4 shows the basic axle loads, plan and axle configuration of the SV-Train. This model generally governs for all structures with loaded lengths greater than 10m. The spacing of 5.0m and 9.0m between the two bogies need be checked only for load effects with two or more peaks in the influence line/surface for loaded lengths of greater than 40m.



Note: Overall vehicle width = overall track width

Figure 3.4: SV-Train

3.21 ***SV-TT.*** Figure 3.5 shows the basic axle loads, plan and axle configuration of the SV-TT vehicle. This model is only critical for loaded lengths of typically less than 5m.

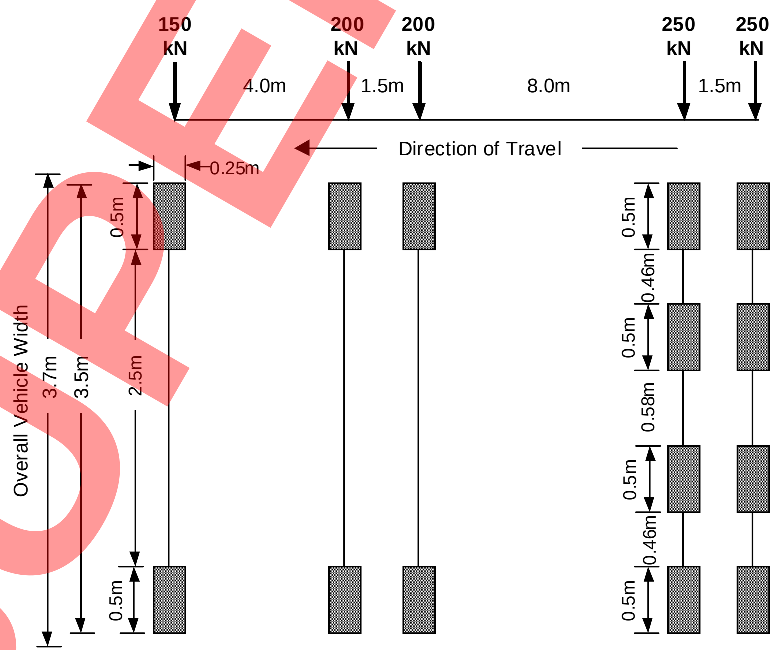


Figure 3.5: SV-TT vehicle

Wheel Contact Areas

3.22 The wheel loads shall be uniformly distributed over a square or rectangular contact area as shown in Figures 3.1 to 3.5. For specific STGO or SO vehicles the contact areas shall be as given in the notifications by the hauliers. In the absence of such information, the load from each tyre of the vehicle may be taken as uniformly distributed over a square contact area of 0.35m x 0.35m.

Dispersal of Wheel Loads

3.23 The dispersal of wheel loads of SV vehicles and AW vehicles through surfacing, filling material and structural concrete slabs shall follow the procedures given in BD 21 (DMRB 3.4.3). This also applies to trough decks and masonry arches.

Overload Factor

3.24 The Overload Factor models the overloading of SV vehicles in excess of the gross weight and axle weights notified by the hauliers to highway authorities. The Overload Factor (OF) shall be taken as 1.2 for the worst critical axle and 1.1 for all other axles.

Dynamic Amplification Factor

3.25 The Dynamic Amplification Factor (DAF) for each axle shall be calculated as given below:

$$DAF = \left[1.7\text{x}\left(\frac{q_{ka}}{10}\right)^{-0.15}\right] \geq 1.05 \qquad (3.1)$$

where q_{ka} is the basic axle load in kN. Note that the DAF values could be different for the different axles depending on their loads. The variation of DAF with basic axle load is illustrated in Figure 3.6.

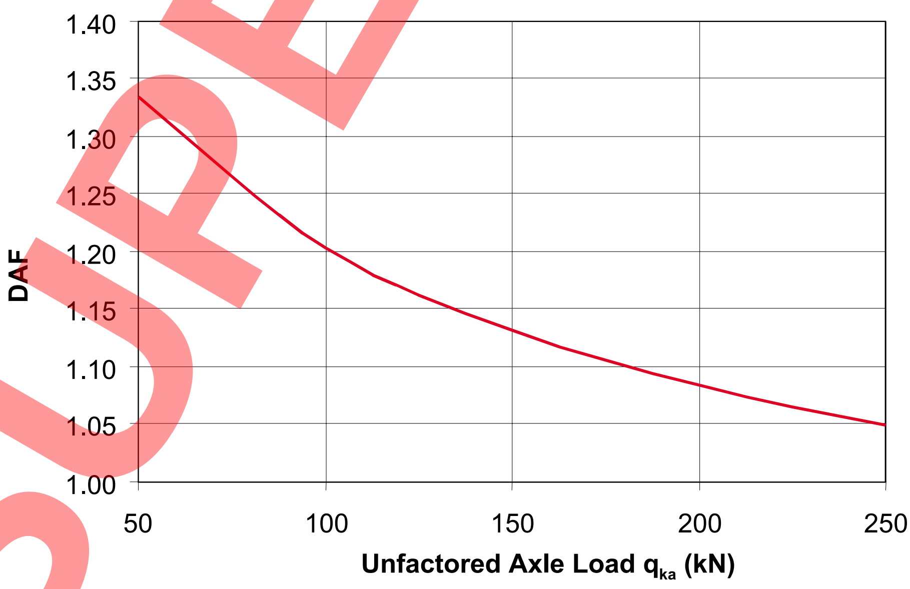


Figure 3.6: Dynamic Amplification Factor as a function of basic axle load q_{ka}

Associated Type HA loading or AW vehicles

3.26 The effects of normal vehicles (those that conform to the AW Regulations) associated with SV vehicles shall be represented by the associated Type HA loading or AW vehicles in accordance with BD 21 (DMRB 3.4.3).

3.27 Separate assessments are not required for single wheel loads or single axle loads from AW vehicles associated with an SV vehicle.

Application of SV vehicles and associated Type HA Loading or AW vehicles

3.28 SV vehicles and associated Type HA loading or AW vehicles shall be combined and applied as follows:

(i) Associated Type HA loading shall be applied to the notional lanes of the carriageway as 2.5m wide strips in accordance with BD 21 (DMRB 3.4.3), modified as given in (ii) below. Where appropriate, the Type HA loading can be replaced by the AW vehicles given in BD 21 (DMRB 3.4.3).

(ii) Only one SV vehicle shall be considered on any one superstructure.

(iii) SV vehicles shall be applied on influence lines in their entirety and shall not be truncated.

(iv) Where there is more than one adverse area, the loaded lengths for applying SV vehicles and Type HA loading are different as defined in 1.12.

3.29 The SV vehicle can be placed at any transverse position on the carriageway, either wholly within one notional lane or straddling between two adjacent lanes, with its side parallel to the kerb. The SV vehicle shall be placed at the most unfavourable position transversely and longitudinally over the loaded length, in order to produce the most severe load effect at the section being considered.

3.30 The design load effects shall be determined from the maximum of the two cases:

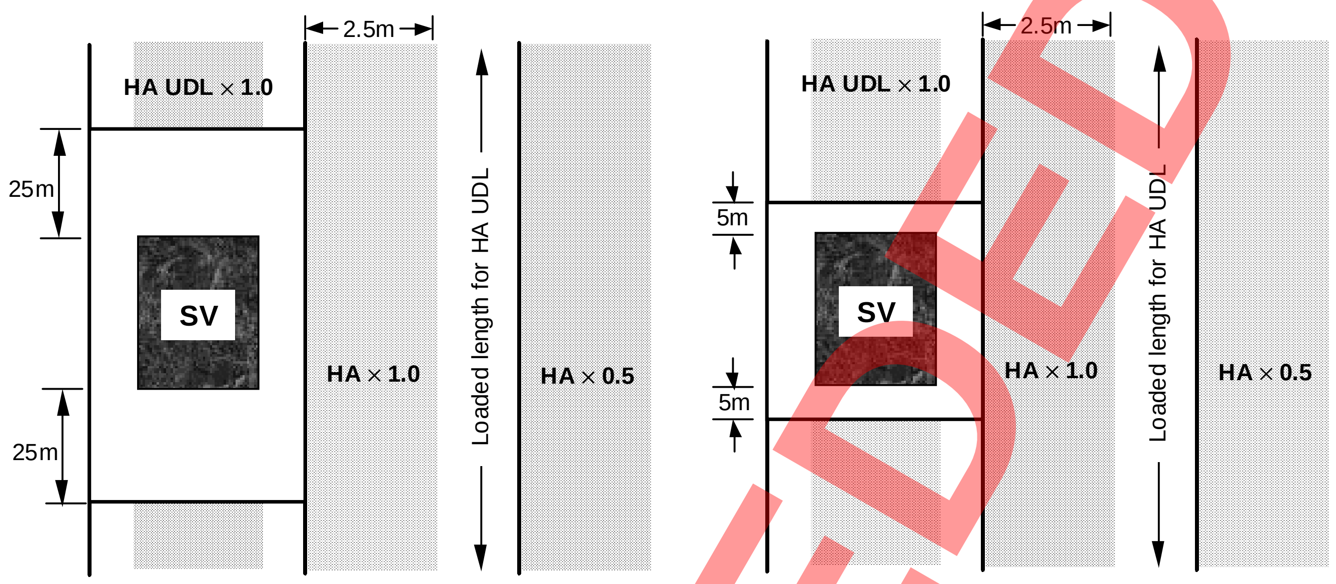
(i) SV vehicle moving at “normal” speed, and

(ii) SV vehicle moving at “low” speed (< 10 mph).

3.31 Where the SV vehicle lies fully within a notional lane and is moving at “normal” speed the associated Type HA loading or AW vehicles shall not be applied within 25 metres from the centre of outer axles (front and rear) of the SV vehicle in that lane. The Dynamic Amplification Factor shall be taken as given in 3.25. This is illustrated in Figure 3.7(a).

3.32 Where the SV vehicle lies fully within a notional lane and is moving at “low” speed the associated Type HA loading or AW vehicles shall not be applied within 5 metres from the centre of outer axles (front and rear) of the SV vehicle in that lane. The Dynamic Amplification Factor shall be taken as 1.0. This is illustrated in Figure 3.7(b).

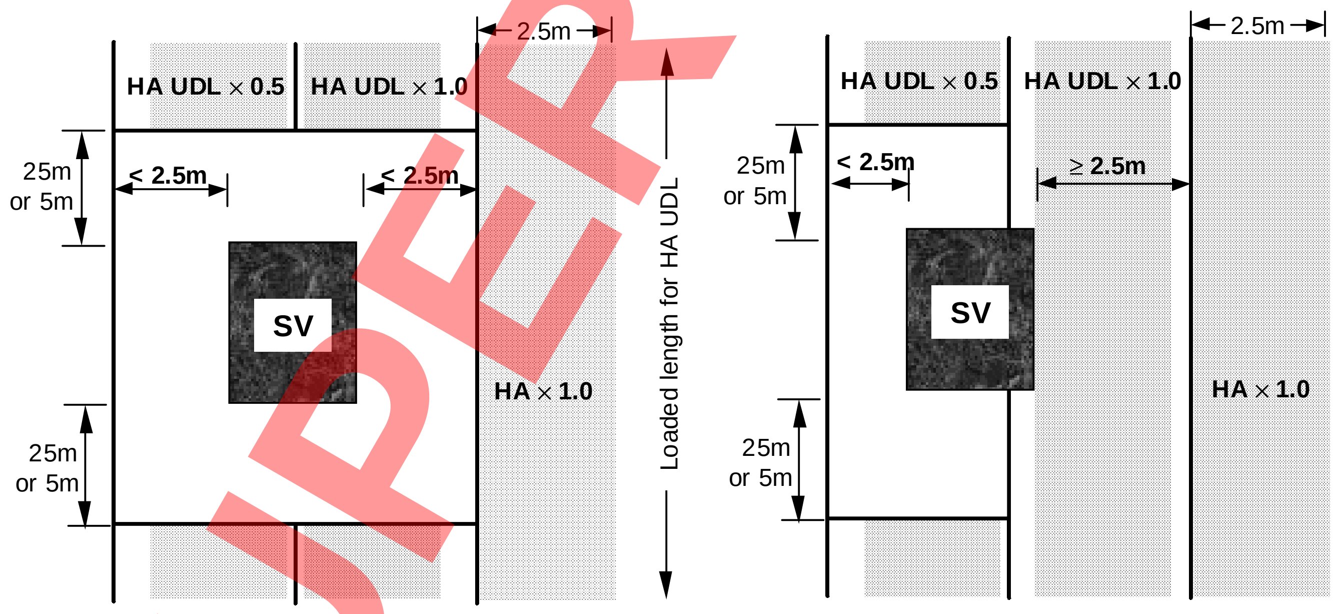
3.33 The remainder of the adverse areas within the loaded length in the lane occupied by the SV vehicle shall be loaded with associated HA UDL (uniformly distributed load) only; HA KEL (knife edge load) shall be omitted. The intensity of the HA UDL shall be based on the total loaded of the adverse areas within the length and not the reduced length over which the HA UDL is applied. This is illustrated in Figures 3.7 (a) and (b).



(a) SV Vehicle at Normal Speed (b) SV Vehicle at Low Speed

Figure 3.7: Typical application of Type SV and associated loading when the SV vehicle lies fully within a notional lane

Note: Type HA loading can be replaced where appropriate by AW vehicles



(a) Distance to the far edge < 2.5m (b) Distance to the far edge ≥ 2.5m

Figure 3.8: Typical application of Type SV and associated Type HA loading when the SV vehicle straddles between two adjacent notional lanes

Note: Type HA loading can be replaced where appropriate by AW vehicles

Volume 3 home page

3.34 Where the SV vehicle lies partially within a notional lane and the remaining width of the lane, measured from the side of the SV vehicle to the far edge of the notional lane, is less than 2.5m (Figure 3.8(a)), the associated HA UDL shall not be applied to that lane within 25m of the centre of the outer axles (front and rear) of the SV vehicle, for the "normal" speed case. At "low" speeds, the HA UDL shall not be applied within 5m of the centre of the outer axles (front and rear) of the SV vehicles. Where the remaining width of the lane is greater or equal to 2.5m, the HA UDL loading in that lane shall remain (Figure 3.8 (b)) but the HA KEL shall be omitted.

3.35 On the remaining lanes not occupied by the SV vehicle, the associated Type HA loading (UDL and KEL) or AW vehicles with appropriate Lane Factors shall be applied in accordance with BD 21 (DMRB 3.4.3). This is illustrated in Figures 3.7(a) and (b) and 3.8(a) and (b) for typical configurations of Type HA loading in combination with Type SV loading.

3.36 All of the notional lanes and their corresponding Lane Factors are interchangeable for producing the most severe load effect.

Transverse Members

3.37 As an exception to 3.28 to 3.36, for transverse cantilever slabs, slabs supported on all four sides, cross-girders and slabs spanning transversely (including skew slabs with significant transverse action), and buried concrete box type structures with cover greater than 0.6m, the associated Type HA loading shall be replaced with the loading from AW vehicles and applied as a single vehicle or convoy of vehicles in accordance with Annex D of BD 21 (DMRB 3.4.3). The travelling speed of SV vehicles may be different from that of the associated AW vehicles. However if convoy of vehicles is assumed for the associated AW vehicles, SV vehicles should only be considered at the "low" speed case.

3.38 Transverse trough decks shall be assessed for SV vehicles considering loading from all the axles, including OF and DAF. The associated HA loads shall be assessed on the basis of a single axle and/or single wheel load of AW vehicles per lane with trough enhancement factors as given in BD 21 (DMRB 3.4.3).

Centrifugal Effects

3.39 The vertical effects arising from centrifugal forces on horizontally curved carriageways shall be determined for the assessment live loading using the method given in BD 21 (DMRB 3.4.3).

Longitudinal Loading

3.40 Where appropriate, the longitudinal load effects caused by braking or traction shall be assessed in accordance with BD 37 (DMRB 1.3), with the exception that the longitudinal loads shall be taken from 3.40.1 for SV and STGO vehicles and from 3.40.2 for SO vehicles.

3.40.1 15% of the basic axle loads, applied to each corresponding axle of the SV or STGO vehicle.

3.40.2 Whichever of the following produces the most severe effect for SO vehicles:

(i) a braking force of 15% of the gross weight of the SO vehicle distributed proportionally to the loads carried by the individual braking axles;

(ii) a traction force of 10% of the gross weight of the SO vehicle distributed proportionally to the loads carried by the individual driving axles.

Masonry Arches

3.41 As an exception to 3.28 to 3.36, when alternative methods to MEXE (see BD 21 (DMRB 3.4.3) and BA 16 (DMRB 3.4.4)) are used for the assessment of masonry arches, the associated Type HA loading shall be replaced with the loading from single, double and triple axles of AW vehicles given in BD 21 (DMRB 3.4.3) with the corresponding conversion factors to account for axle lift-off. For arch spans greater than 20m, a separate assessment shall also be made with the Type HA UDL and KEL loading.

3.42 Where conditions on an arch bridge are likely to cause lift-off (see BA 16 (DMRB 3.4)), a triple-axle bogie shall be assumed within the SV vehicle comprising the worst effective axle and the following two axles. For the case of an SV vehicle travelling at “normal” speed, a lift-off factor of 1.2 shall be applied to the leading axle and a factor of 0.8 to the trailing axle of this bogie. No lift-off shall be applied to the remaining axles of the SV vehicle. The lift-off requirement shall not apply to SV vehicles for the “low” speed case.

3.43 Alternative analysis to the MEXE method shall be used where the geometry of the arch is such that three or more axles of the SV vehicle can be applied in half of the span whilst the remaining half is not loaded.

3.44 The factors of safety γ_{fL} for the assessment of masonry arches when using alternative methods to MEXE shall be 2.0 for SV loading and associated HA loading or AW vehicles. In addition, the effects of OF and DAF shall be included.

Buried Structures

3.45 For buried concrete box type structures (cover greater than 0.6m), the wheel loads shall be dispersed from the carriageway to the top of the buried structure in accordance with BA 55 (DMRB 3.4.9). The Overload Factor given in 3.24 shall apply; but the Dynamic Amplification Factor in 3.25 shall be taken as 1.0 if the cover exceeds 1.0m.

Choice of SV vehicles for assessment

3.46 The following general guidance will assist in reducing the number of load cases that may need to be considered. However, when using the Screening Assessment given in Annex D for the management of STGO vehicles, it is recommended that Reserve Factors are established for at least the SV100 and SV-Train vehicles.

3.47 By reference to Figures C.7 to C.12 of Annex C, ascertain the governing SV vehicles for the loaded length and the load effect being considered, and assess the structure for this vehicle. The following is a general guide:

(i) For loaded lengths of less than 5m, where heavy axle loads dominate, the SV-TT vehicle generally gives the most onerous loading.

(ii) For loaded lengths of between 5m and 10m, the SV 100 vehicle generally governs.

(iii) For loaded lengths of greater than 10m, the SV-Train generally governs.

(iv) If the Reserve Factor is greater than 1.0 for the above appropriate load case, no other SV vehicles need to be considered, as these vehicles should generally be less critical.

3.48 For structures where the capacity is less than the load effects from the above vehicles, the structure can generally be assessed for SV vehicles in the following order:

(i) ***SV-Train.*** When a structure can sustain the SV-Train, it can generally sustain the SV-150, SV-100 and SV-80 vehicles.

(ii) ***SV-150 vehicle.*** When a structure can sustain the SV-150 vehicle, it can generally sustain the SV-100 (for spans greater than 10m) and SV-80 vehicles.

(iii) ***SV-100 vehicle.*** When a structure can sustain the SV-100 vehicle it can generally sustain the SV-80 vehicle.

3.49 The assessments should initially be carried out with the associated HA loading. If the Reserve Factor is greater than 1.0 for any SV vehicle, assessment without the associated HA loading is not necessary.

Volume 3 home page

3.50 For short span structures (less than 20m), the normal speed case will generally govern, due to the application of the Dynamic Amplification Factor. For the SV-Train, only the normal speed case need be considered.

Reserve Factors

3.51 For each SV vehicle considered, a Reserve Factor, Ψ_{SV},shall be established. This is defined as the factor on the assessment SV load required to reach the first failure. For example, where elastic methods are used and there is no interaction between load effects, the Reserve Factor Ψ_{SV} can be calculated as follows:

With Associated HA loading

$$\Psi_{SV} = \frac{R_A^* - (S_D^* + S_{HA}^*)}{S^*} \qquad (3.2)$$

Without the Associated HA loading

$$\Psi^*_{SV} = \frac{R_A^* - S_D^*}{S^*} \qquad (3.3)$$

where:

R_A^* assessment resistance (flexure, shear, etc.)

S_D^* assessment load effect due to combined dead and superimposed dead loads

S_{HA}^* assessment load effect due to the associated Type HA (or AW vehicles)

S^* assessment load effect due to the SV vehicle

Vehicle Rating

3.52 The Reserve Factors for each SV vehicle may be given in a tabular form similar to that shown in Table 3.1. Certain types of structures (cast iron, masonry arches, for example) may not yield a directly comparable Reserve Factor, and their ability to sustain vehicles needs to be considered separately for each load case.

3.53 The Vehicle Rating for a structure shall be taken as the most onerous SV vehicle that can safely pass over the structure (ie the vehicle with the smallest Reserve Factor Ψ_{SV} greater than 1.0).

HB-to-SV Conversion Charts

3.54 Where existing HB ratings for highway bridges and structures are available and the Overseeing Organisation is satisfied with the manner in which these have been derived, the corresponding Reserve Factors for SV vehicles can be obtained approximately using the HB-to-SV Conversion Charts given in Annex C.

Vehicle Assessment

Structure Name:

Structure Key:

Vehicle Type*: SV 80/SV 100/SV 150/SV-Train/SV-TT

Vehicle Speed*: Normal/Low

Method of Assessment*: HB-SV Chart/Line Beam/Grillage/FEM/Other (state)

Limit State*: SLS/ULS

* Delete as applicable

Element	Location on Structure	Load Effect	R_A*	S*	S_D*	S_{HA}*	Ψ	Ψ*

Table 3.1 Reserve Factors

4. REFERENCES

The following documents are referred to in the text of this Standard:

1. Cooper, D.I. (1997): Development of short span bridge-specific assessment live loading, In *Safety of Bridges* (Ed.) Parag C. Das, Thomas Telford.

2. Ricketts, N.J. (1997): Collection of statistical data, In *Safety of Bridges* (Ed.) Parag C. Das, Thomas Telford.

3. The following is a list of documents in the Design Manual for Roads and Bridges to which reference is made in this Standard:

BD 37 Loads for Highway Bridges (DMRB 1.3)

BD 21 The Assessment of Highway Bridges and Structures (DMRB 3.4.3)

BA 16 The Assessment of Highway Bridges and Structures (DMRB 3.4.3)

BA 55 The Assessment of Bridge Substructures and Foundations, Retaining Walls and Buried Structures (DMRB 3.4.9)

BD 56 The Assessment of Steel Highway Bridges and Structures (DMRB 3.4.11)

BD 61 The Assessment of Composite Highway Bridges (DMRB 3.4.16)

4. The following is a list of Statutory Instruments to which reference is made in this Standard:

The Road Vehicles (Construction and Use) (Amendment) (No.7) Regulations 1998 (SI 1998 No.3112)

The Road Vehicles (Authorised Weight) Regulations 1998 (SI 1998 No.3111)

The Motor Vehicles (Authorisation of Special Types) General Order 1979 (SI 1979 No.1198)

The Motor Vehicles (Construction and Use) Regulations (Northern Ireland) 1999

The Motor Vehicles (Authorisation of Special Types) Order (Northern Ireland) 1997 (SR 1997/109) as amended

The Motor Vehicles (Authorised Weight) Regulations (Northern Ireland) 1999 as amended

5. ENQUIRIES

All technical enquiries or comments on this Standard should be sent in writing as appropriate to:

Chief Highway Engineer The Highways Agency St Christopher House Southwark Street London SE1 0TE	G CLARKE Chief Highway Engineer

Chief Road Engineer Scottish Executive Development Department Victoria Quay Edinburgh EH6 6QQ	J HOWISON Chief Road Engineer

Chief Highway Engineer The National Assembly for Wales Cynulliad Cenedlaethol Cymru Crown Buildings Cathays Park Cardiff CF10 3NQ	J R REES Chief Highway Engineer

Director of Engineering Department for Regional Development Roads Service Clarence Court 10-18 Adelaide Street Belfast BT2 8GB	G W ALLISTER Director of Engineering

ANNEX A STGO VEHICLE CATEGORIES

A1. Introduction

The maximum gross vehicle and axle weights allowable under Article 18 of the STGO Regulations are briefly described below. In Northern Ireland the article numbers differ from the equivalent legislation in Great Britain. For full details, including other vehicles such as Engineering Plant and Military Vehicles, the Regulations should be consulted.

A2. Abnormal Individual Loads and Vehicles

Vehicles used for carrying or for drawing abnormal individual loads (eg industrial plant) are covered by Article 18 of the STGO Regulations, and these vehicles are grouped into three Categories given below.

(a). Category 1 Vehicles

Vehicles in this category will normally comply with the AW or C&U Regulations with regard to axle weights and spacing. However, for articulated vehicles with five or more axles, the gross weight can be up to 46 tonnes provided the relevant axle spacings shown in Table A.1 below are observed. The Type HA loading covers the effects of these vehicles and hence these are not specifically included in the Type SV loading.

Distance from rearmost tractor axle to rearmost trailer axle (m)	Maximum Gross Weight (tonnes)
At least 6.5	40
At least 7.0	42
At least 7.5	44
At least 8.0	46

Table A.1: Maximum gross weight and minimum spacing for Category 1 vehicles

(b). Category 2 Vehicles

A vehicle or a combination of vehicles carrying the load in this category shall have a minimum of five axles and the spacing between any two adjacent axles shall not be less than 1.1m. Maximum permitted values of axle weight and gross weight relate to axle spacing as shown in Tables A.2(a) and (b).

Where the axles are in two or more groups and adjacent axles of different groups are more than 2m apart, then the total weight from all axles in any one group shall not exceed 50 tonnes.

Spacing between any two adjacent axles (m)	Maximum Axle Weight (tonnes)	Maximum Wheel Weight (tonnes)
At least 1.10	12	6
≥ 1.35	12.5	6.25

Table A.2(a): Maximum axle weight and minimum spacing for Category 2 vehicles

Distance between foremost and rearmost axles (m)	Maximum Gross Weight (tonnes)
5.07	38
5.33	40
6.00	45
6.67	50
7.33	55
8.00	60
8.67	65
9.33	70
10.00	75
10.67	80

Table A.2(b): Maximum gross weight and minimum spacing for Category 2 vehicles

(c). Category 3 Vehicles

A vehicle or a combination of vehicles carrying the load in this category shall have a minimum of six axles and the spacing between any two adjacent axles shall not be less than 1.1m. Maximum permitted values of axle weight and gross weight relate to axle spacing as shown in Tables A.3(a) and (b).

Where the axles are in two or more groups and adjacent axles of different groups are more than 1.5m apart, then the total weight from all axles in any one group shall not exceed 100 tonnes. This will be limited to 90 tonnes for a group if the spacing between adjacent axles for that group is less than 1.35m.

Spacing between any two adjacent axles (m)	Maximum Axle Weight (tonnes)	Maximum Wheel Weight (tonnes)
At least 1.10	15	7.5
≥ 1.35	16.5	8.25

Table A.3(a): Maximum axle weight and minimum spacing for Category 3 vehicles

Distance between foremost and rearmost axles (m)	Maximum Gross Weight (tonnes)
5.77	80
6.23	85
6.68	90
7.14	95
7.59	100
8.05	105
8.50	110
8.95	115
9.41	120
9.86	125
10.32	130
10.77	135
11.23	140
11.68	145
12.14	150

Table A.3(b): Maximum gross weight and minimum spacing for Category 3 vehicles

Note that the above weight limits apply to a vehicle or a combination of vehicles carrying the load. Vehicles drawing the abnormal individual load but not carrying any part of the load are assessed separately. Thus for example, the total weight of the vehicle train, ie a locomotive pulling a trailer carrying the abnormal load, can exceed the maximum limits for the above respective vehicle categories.

ANNEX B BASIS OF THE TYPE "SV" ASSESSMENT LOADING

B1. Background

Highway bridges and structures have been assessed for the effects of STGO vehicles using the design Type HB loading model given in BD 37 (DMRB 1.3) as there was no assessment standard available. Studies have shown that the HB loading model does not represent accurately the effects of real STGO vehicles. In particular, because of the high axle weights, the HB model is excessively conservative for very short span structures. However, this conservatism reduces for spans of 15 to 30m, and in fact it is seen that real STGO vehicles can produce more severe load effects than an HB model vehicle of the same gross weight. This is because the real STGO vehicles have more axles which are more closely spaced than those of the HB model vehicle.

Figures B.1 and B.2 compare the load effects produced by STGO Category 3 and Category 2 vehicles, respectively, against various units of HB loading. The effects from STGO vehicles are based on an extensive database of STGO vehicle notifications and the data from a weigh-in-motion station on the M40 motorway, and represent the maximum values obtained at each span. Effects from hypothetical vehicles that conform to the extreme allowable limits of the existing STGO regulations are also included for comparison.

In the above comparison, overloading and dynamic amplification factors are not included in calculating STGO load effects and no partial factors are applied to the effects from HB vehicles. The influence line for the mid-span moment of a simply supported beam is used, and it is assumed that there will be only one abnormal vehicle on the bridge at any one time. Associated HA or AW loads have not been applied.

From these figures it can be seen that the HB45 units of loading (used for the design of structures carrying motorway and trunk roads), although encompassing the effects of all STGO vehicles, can be excessively conservative for structures less than about 10m span.

37.5 units of HB loading (with a gross weight of 150 tonnes), on the other hand, although it is conservative for spans of less than 10m, on longer spans it does not cater for the effects produced by STGO Category 3 vehicles with gross weights of up to 150 tonnes. Similarly, 25 units and 20 units of HB loading do not cater for the effects of Category 3 vehicles of up to 100 tonnes and Category 2 vehicles of up to 80 tonnes gross weight respectively.

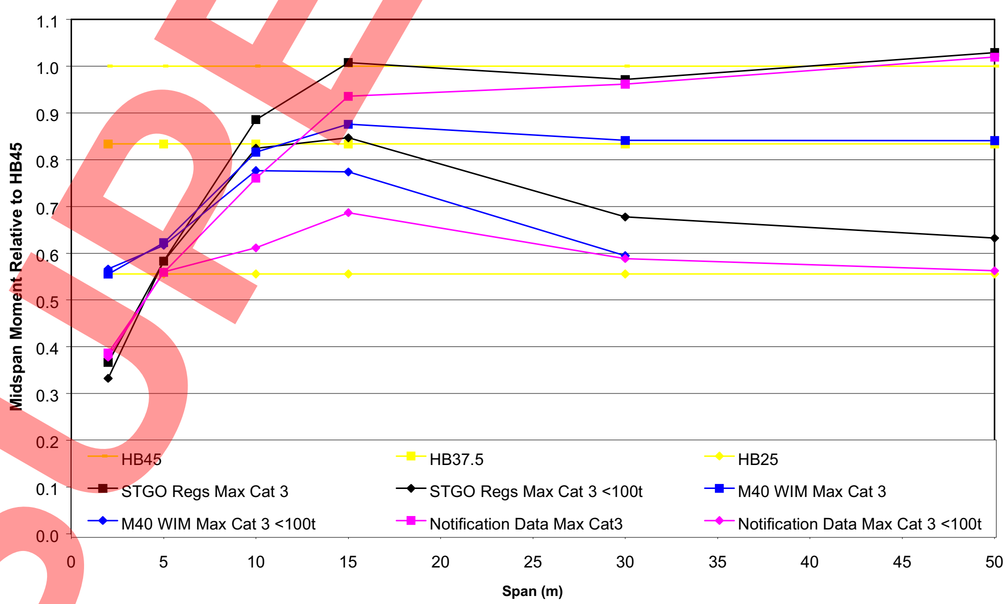


Figure B.1: Comparison of STGO Category 3 vehicle effects against HB loading

Volume 3 home page

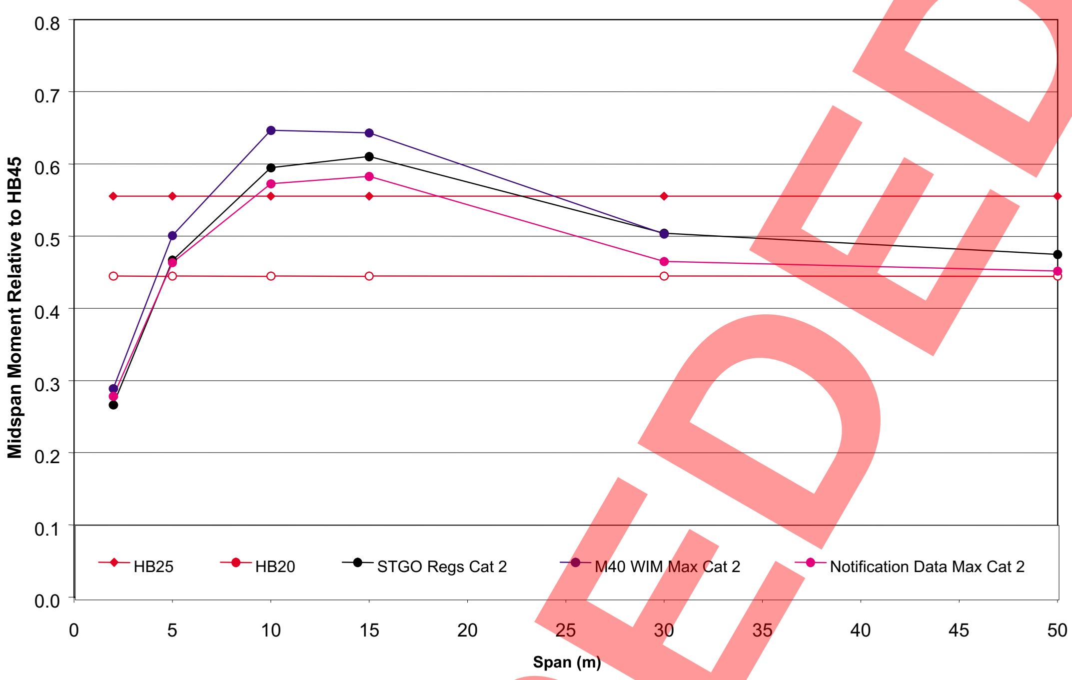


Figure B.2: Comparison of STGO Category 2 vehicle effects against HB loading

B2. SV Vehicle Configurations

In developing the SV vehicle configurations, the following data sources were used:

(i) Data from some 15000 STGO and SO vehicle transit notifications received by Kent County Council from 1997 to 1999.

(ii) Weigh-in-Motion (WIM) data from the M25 and M40 motorways over a three-month period during the year 2000.

The data was carefully screened and SO vehicles were removed from the data set. In addition, a number of hypothetical vehicles that conform to the extreme allowable limits of the existing STGO regulations were included. The data was analysed to produce histograms of speeds, gross weights, vehicle lengths, vehicle widths, number of axles, maximum axle weights, and minimum axle spacings.

For each vehicle in the data set, the load effects were calculated considering influence lines for the midspan moment and for the end shear of a simply supported beam and for the support moment of a continuous beam. Maximum load effects at each span were determined and compared against the load effects from 45 units of HB loading. The comparisons for midspan moment of a simply supported beam are shown in Figures B.3 and B.4. Partial Factors, Overload Factor, DAF and associated HA or AW loads are not included in these comparisons.

Trial SV vehicle axle configurations were chosen to match closely with those of the real STGO vehicles and their load effects were calculated. The configurations were refined until the load effects from the SV vehicles enveloped the maximum load effects from the STGO vehicles in the data set. The load effects from the proposed SV vehicle configurations are compared with the load effects from STGO vehicles and HB loading in Figure B.3 for Category 3 vehicles and in Figure B.4 for Category 2 vehicles. It can be seen that, compared to the HB model, the SV vehicles provide a better match to the load effects from the STGO vehicles in their respective categories.

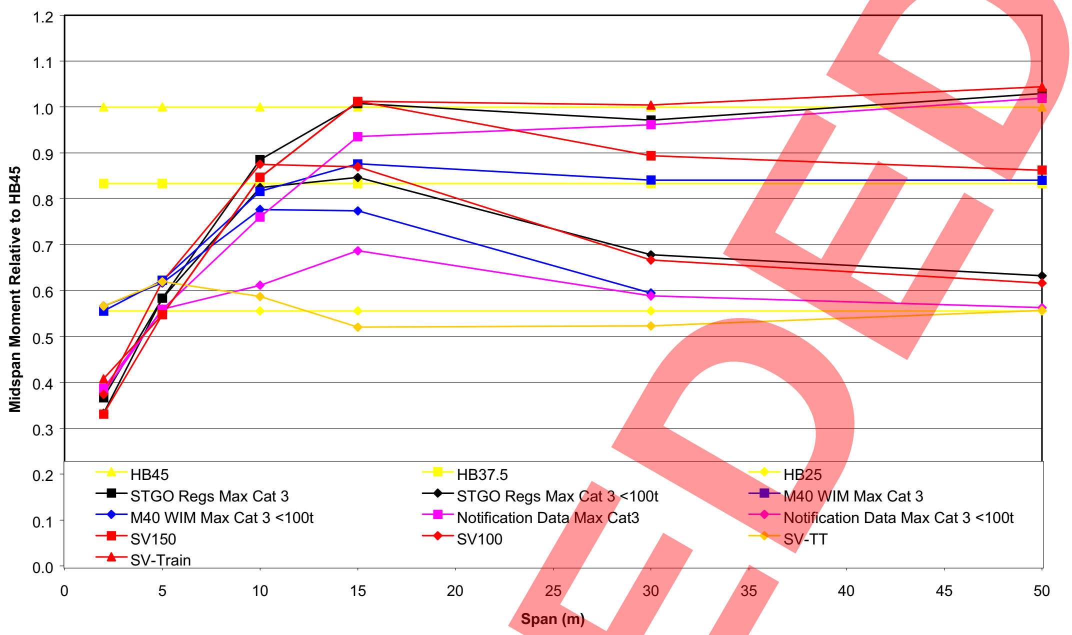


Figure B.3: Comparison of STGO Category 3 vehicle effects against SV loading

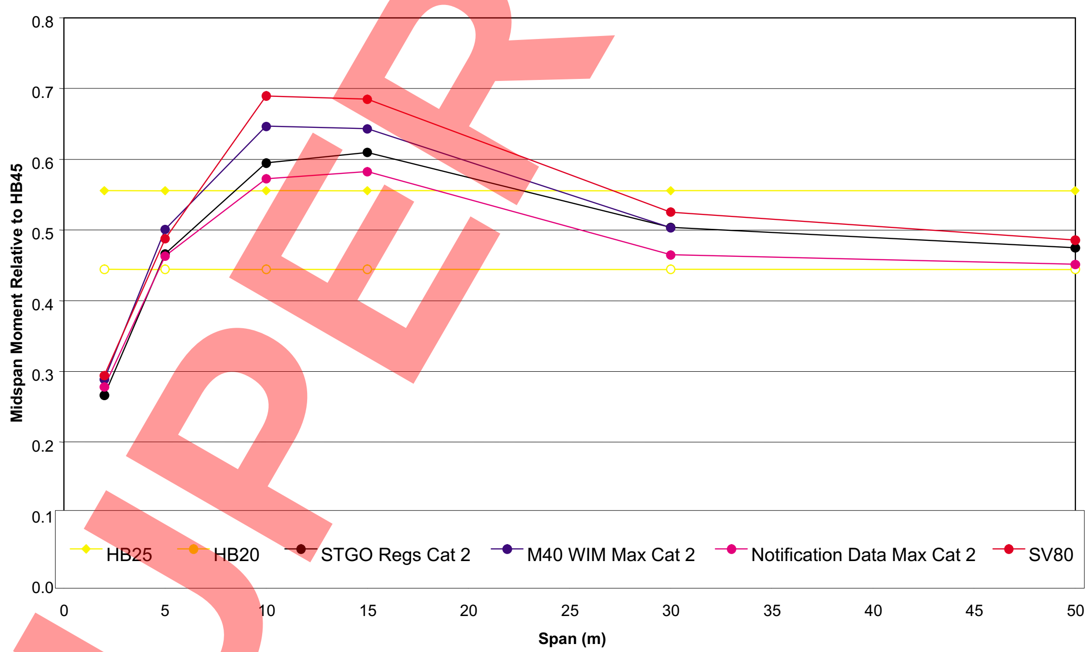


Figure B.4: Comparison of STGO Category 2 vehicle effects against SV loading

Volume 3 home page

B3. Overload Factor

STGO vehicles may be overloaded above the weights notified by the hauliers. At present there is no systematic data available from roadside surveys to determine the level of overloading. The WIM data was compared with the data from notifications for the same route and the same period to get some indication of the overloading. Although it is not possible to identify individual vehicles from the WIM data, generally a greater number of heavier vehicles were observed in the WIM data compared to the notifications. In particular, there was a large number of vehicles with axle weights heavier than 16.5 tonnes (the upper limit for Category 3 STGOs) and further examination revealed that these were not SO vehicles. Significant overloading can occur on individual axles because of an uneven distribution of the total load to the different axles.

Based on the above observations, the Overload Factor was assumed to be 1.2 for the worst effective axle and 1.1 for all other axles. As the number of axles present over the loaded length increases, the overall Overload Factor should reduce.

B4. Dynamic Amplification Factor

Dynamic effects from vehicles arise principally from two sources: (i) whole-body bounce, and (ii) individual axle impact. A study carried out by Flint & Neill Partnership[1] based on measurements undertaken by TRL[2] established characteristic Dynamic Amplification Factors (*DAF*) for normal HGVs of 1.25 for "good" road surfaces and 1.38 for "poor" road surfaces. For structures close to 40m in span, where typical vehicle frequencies may match bridge frequencies, higher values than the above are possible. Although the dependency on speed was less significant at higher speeds, slow speed transits (at less than 10 mph) were seen to cause little dynamic response. Another important observation was that the dynamic component of the loading (not the factor) was relatively independent of the weight of the vehicle; so that the *DAF* actually decreases as the vehicle weight increases. This observation has been confirmed by a number of other studies carried out overseas.

There is no data available at present on the dynamic effects caused by abnormal vehicles. The STGO vehicles could be expected to have lower *DAF* values than normal HGVs because of their heavier weights, lower speeds and generally better suspension systems.

It is also likely that axle impacts from different axles would be uncorrelated and hence the overall dynamic load should reduce as the number of axles on the loaded length increases, however, this effect could not be incorporated in the expression for *DAF* due to lack of data. Where the speed of the STGO vehicle is restricted to less than 10 mph, the *DAF* factor is reduced to 1.0.

B5. Partial Load Factors for ULS

The partial load factor of 1.3 currently used on Type HB loading was assumed to cater for overloading and dynamic effects. Since these effects are explicitly considered in deriving the Type SV assessment live load, a lower partial load factor of 1.10 was adopted. The values of the partial factor, the Overload Factor and the Dynamic Amplification Factor were chosen together to ensure that the new SV model was no more onerous than the 45 units of HB loading which is the current design load level for motorway structures. The partial load factor on the Type HA loading associated with the Type SV loading is retained at 1.3 at present.

B6. Lift-off Factors for Masonry Arches

Double and triple axle bogies do not compensate well over the crest of hump arch bridges. The current requirements in BD 21 are recognition that, with AW vehicles, the worst case in this respect occurs with steel suspension systems. For air or fluid suspension systems the lift-off factor is 1.0. This does not infer that there is no load transfer with air or fluid suspensions but that it is a significantly lower proportion. A large proportion of STGO vehicles however have robust all-terrain fluid suspensions with high-unsprung axle weights. The inertia in these systems is likely to be significant and therefore a lift-off factor will need to be applied to the SV vehicle on structures where the lift-off condition is likely to occur.

B7. Limitations

The Type SV assessment loading model has the following limitations:

(i) The likelihood of two or more STGO vehicles occurring simultaneously within a lane over a bridge is not accounted for.

(ii) The simultaneous occurrence of two or more abnormal vehicles in adjacent lanes over a bridge is not considered.

(iii) The Overload Factor and the Dynamic Amplification Factor have been determined based on very limited available data.

(iv) It does not cater for the possibility of locomotives heavier than that used for the SV-Train vehicle or for the possibility of more than one locomotive pushing or pulling the trailer.

ANNEX C HB-TO-SV CONVERSION CHARTS

C1 General

Where existing HB ratings for highway bridges and structures are available and the Overseeing Organisation is satisfied with the manner in which these have been derived, the corresponding Reserve Factors for SV vehicles can be obtained approximately using the HB-to-SV Conversion Charts given in this Annex. Worked examples using these Conversion Charts are given in C5 and C6.

C2 Conversion Factor

The Reserve Factor Ψ_{SV} for an SV vehicle should be calculated from the HB rating, N_{HB} number of units, for a structure as below:

$$\Psi_{SV} = \lambda_{HB45 \rightarrow SV} \times \frac{N_{HB}}{45} \qquad (C.1)$$

In the above, $\lambda_{HB45 \rightarrow SV}$ is the Conversion Factor from 45 units of HB loading to an equivalent SV vehicle calculated as below:

$$\lambda_{HB45 \rightarrow SV} = \frac{S_{HB45}}{S_{SV}} \qquad (C.2)$$

where S_{SV} and S_{HB45} are, respectively, the factored load effect due to an SV vehicle and that due to 45 units of HB loading, both calculated using an influence line appropriate for the structure being considered. The Conversion Factor should be obtained from the Conversion Charts given in Figures C.7 to C.12.

C3 Conversion Charts

In producing the Conversion Charts, the load effect S_{SV} has been calculated including the Overload Factor (*OF*), the Dynamic Amplification Factor (*DAF*) and a partial factor for load of γ_{fL}=1.1, while the load effect S_{HB45} has been calculated with a partial factor for load of γ_{fL}=1.3.

The effect of associated HA loading (in the same lane as the abnormal vehicle and in adjacent lanes) has been assumed to be the same for the SV and HB vehicles, and hence is not included in calculating the load effects. Since the HB vehicles are wider than the SV vehicles, they displace more of the HA loading in adjacent lanes than the SV vehicles do. The Conversion Charts should not be used for two or more notional lanes of widths 2.75m to 3.0m as the HA loading associated with the HB vehicles would be significantly lower than that associated with the SV vehicles for these cases.

Where the previous HB ratings have been derived without the associated HA loading in any of the lanes, the use of the Conversion Charts and equation C.1 gives the Reserve Factors Ψ^*_{SV} for SV vehicles **without the associated HA loading**.

The Conversion Charts have been developed for the following influence lines:

- Single simply supported span: Mid-span moment
- Single simply supported span: Support shear/ support reaction
- Continuous spans: Mid-span moment
- Continuous spans: Internal support moment
- Continuous spans: Internal support shear
- Continuous spans: Internal support reaction

The influence lines for the above load effects are illustrated in Figures C.1 to C.6 for a loaded length (L) of 15m. For continuous spans, various proportions of individual span lengths were considered and the lowest Conversion Factor was used in producing the Conversion Charts.

For each influence line, Conversion Factors $\lambda_{HB45 \rightarrow SV}$ have been produced for each of the five SV vehicles (SV80, SV100, SV150, SV-Train and SV-TT) and are presented in Figures C.7 to C.12.

The assessing engineer should use the Conversion Chart which is based on the influence line that is the most appropriate for the structure being considered and the governing load effect. If none of the influence lines shown in Figures C.1 to C.6 is appropriate then the Conversion Charts should not be used. In this case the Conversion Factor should be derived from equation C.2

based on the load effects calculated for the 45 units of HB vehicle and the various SV vehicles using the influence line/surface specific to the structure being considered. Alternatively the structure could be assessed directly using the SV vehicles.

C4 Limitations

The following limitations apply to the Conversion Charts:

1. Only the "normal flow" case with full impact has been considered for the SV vehicle for comparison with the HB load effect.

2. The charts do not take into account the associated HA loading explicitly but assume that the HA load effects are the same for the HB and SV assessments.

3. The influence lines for which the conversion charts are produced may not be appropriate for transversely spanning decks/members, trough decks, masonry arches, buried structures, and bridges curved in plan with radius of curvature of less than 600m.

Taking account of the above limitations, the assessing engineer should ensure that the use of the Conversion Charts for the specific structure being considered provides a conservative estimate of the Reserve Factor for SV vehicles.

C5 Example 1

A simply supported RC slab bridge with a span of 10m has an HB rating of 34 Units with the associated HA loading included and 48 Units without the associated HA loading. The Conversion Factors for 45 Units of HB loading for mid-span moment and support shear can be obtained from Figures C.7 and C.8, and these are listed in Table C.1 below. The minimum value of the Conversion Factors for moment and shear are then used to calculate the Reserve Factors for SV vehicles. In using Equation C.1, the HB rating of 34 Units is used to calculate the Reserve Factors **with** the associated HA loading (Ψ_{SV}) and 48 Units for Reserve Factors **without** the associated HA loading (Ψ^*_{SV}). The Vehicle Rating, which is the least Reserve Factor greater than unity, is SV80 **with** associated HA loading and SV-Train or SV150 **without** the associated HA loading.

Vehicle	Conversion Factors $\lambda_{HB45 \rightarrow SV}$			Reserve Factors	
	Moment	Shear	Minimum	Ψ_{SV}	Ψ^*_{SV}
SV80	1.34	1.58	1.34	1.01	1.43
SV100	1.12	1.28	1.12	0.85	1.19
SV150	1.12	1.28	1.12	0.85	1.19
SV-Train	1.12	1.28	1.12	0.85	1.19
SV-TT	1.70	1.95	1.70	1.28	1.81

Table C.1: Conversion Factors $\lambda_{HB45 \rightarrow SV}$ and Reserve Factors for single span of 10m

C6 Example 2

A three span continuous RC slab bridge with spans 10m:15m:10m has an HB rating of 37.5 units with the associated HA loading included. The Conversion Factors for 45 units of HB loading for the various load effects can be obtained from Figures C.9 to C.12, and these are listed in Table C.2 below. The minimum value of the Conversion Factors for the different load effects are then used to calculate the Reserve Factors for SV vehicles based on equation C.1. The Vehicle Rating of the structure is therefore SV80.

Vehicle	Conversion Factors $\lambda_{HB45 \rightarrow SV}$						Reserve Factor Ψ_{SV}
	Mid-span Moment L=15m	Support Moment L=25m	Support Shear L=10m	Support Shear L=15m	Support Reaction L=25m	Minimum	
SV80	1.38	1.60	1.51	1.70	1.84	1.38	1.15
SV100	1.12	1.30	1.23	1.39	1.50	1.12	0.93
SV150	1.02	1.04	1.24	1.20	1.10	1.02	0.85
SV-Train	1.05	0.96	1.20	1.15	1.00	0.96	0.80
SV-TT	1.75*	1.70	1.83	2.00	1.95	1.70	1.42

Note: * Based on L=10m

Table C.2: Conversion Factors $\lambda_{HB45 \rightarrow SV}$ and Reserve Factors

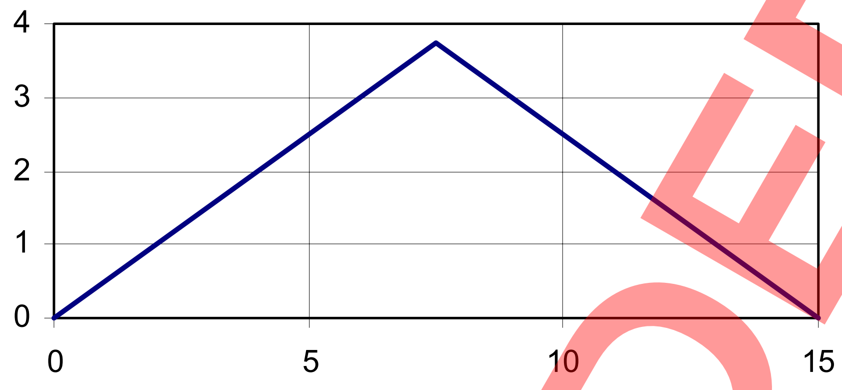


Figure C.1: Influence Line for Single Span: Mid-span Moment (L=15m)

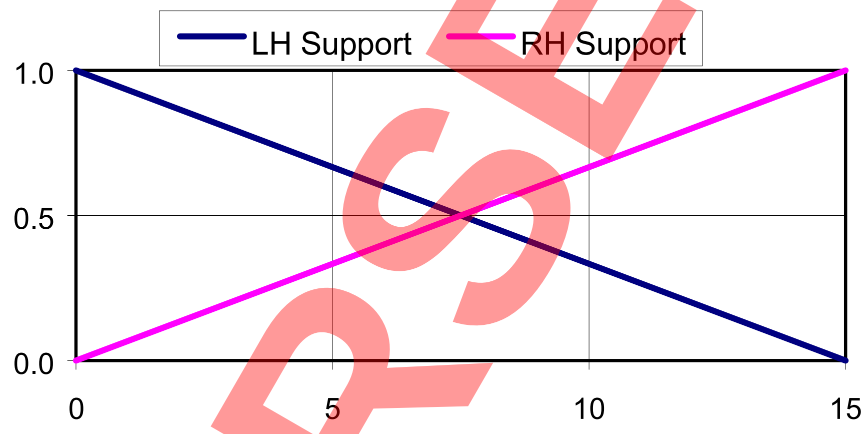


Figure C.2: Influence Line for Single Span: Support Shear/Reaction (L=15m)

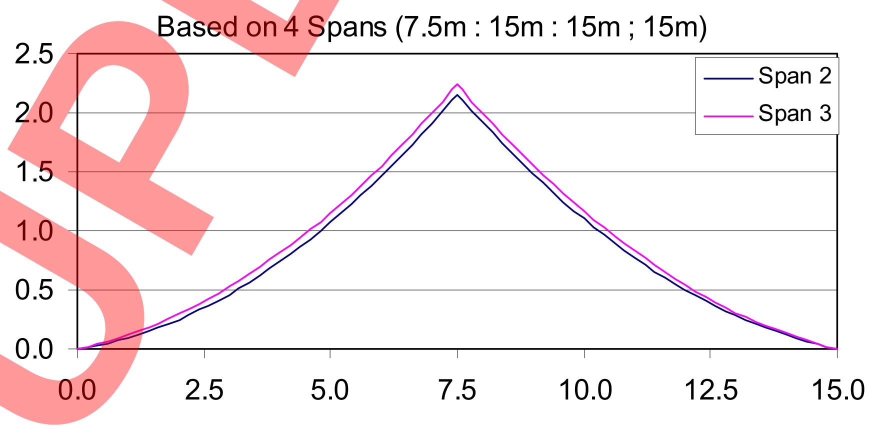


Figure C.3: Influence Line for Continuous Spans: Mid-span Moment (L=15m)

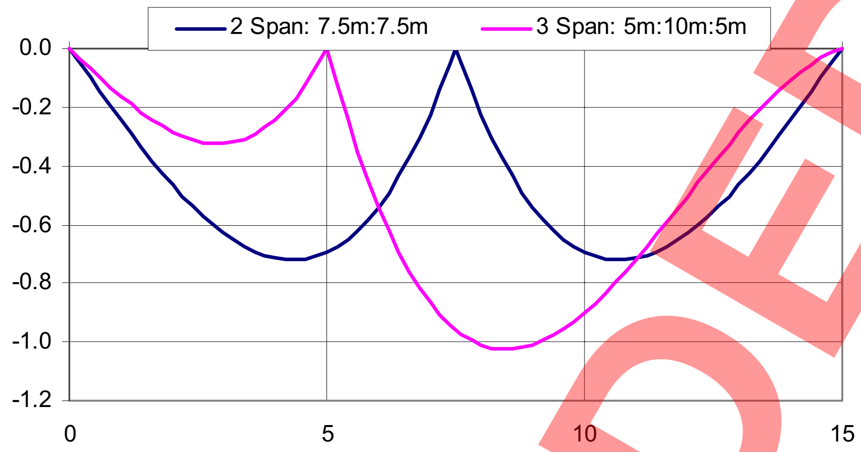


Figure C.4: Influence Line for Continuous Spans: Internal Support Moment: (L = Sum of adjacent span lengths = 15m)

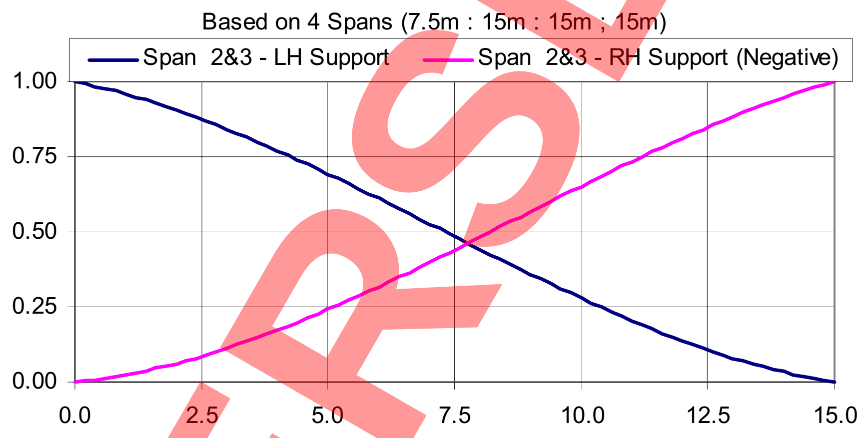


Figure C.5: Influence Line for Continuous Spans: Internal Support Shear (L=15m)

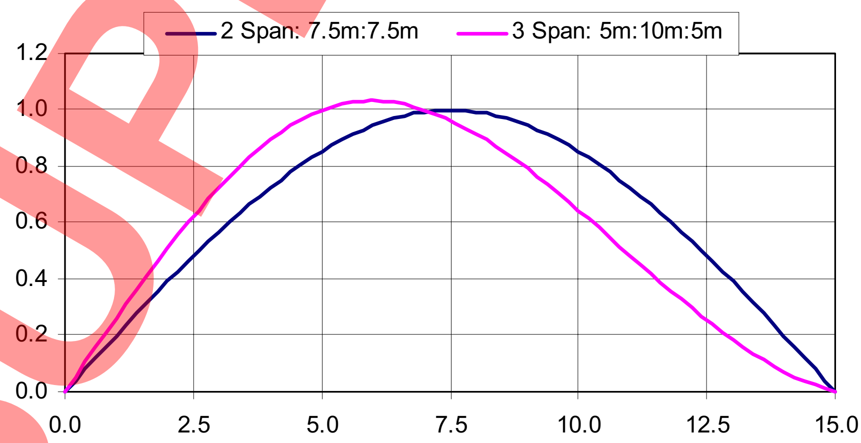


Figure C.6: Influence Line for Continuous Spans: Internal Support Reaction: (L = Sum of adjacent span lengths = 15m)

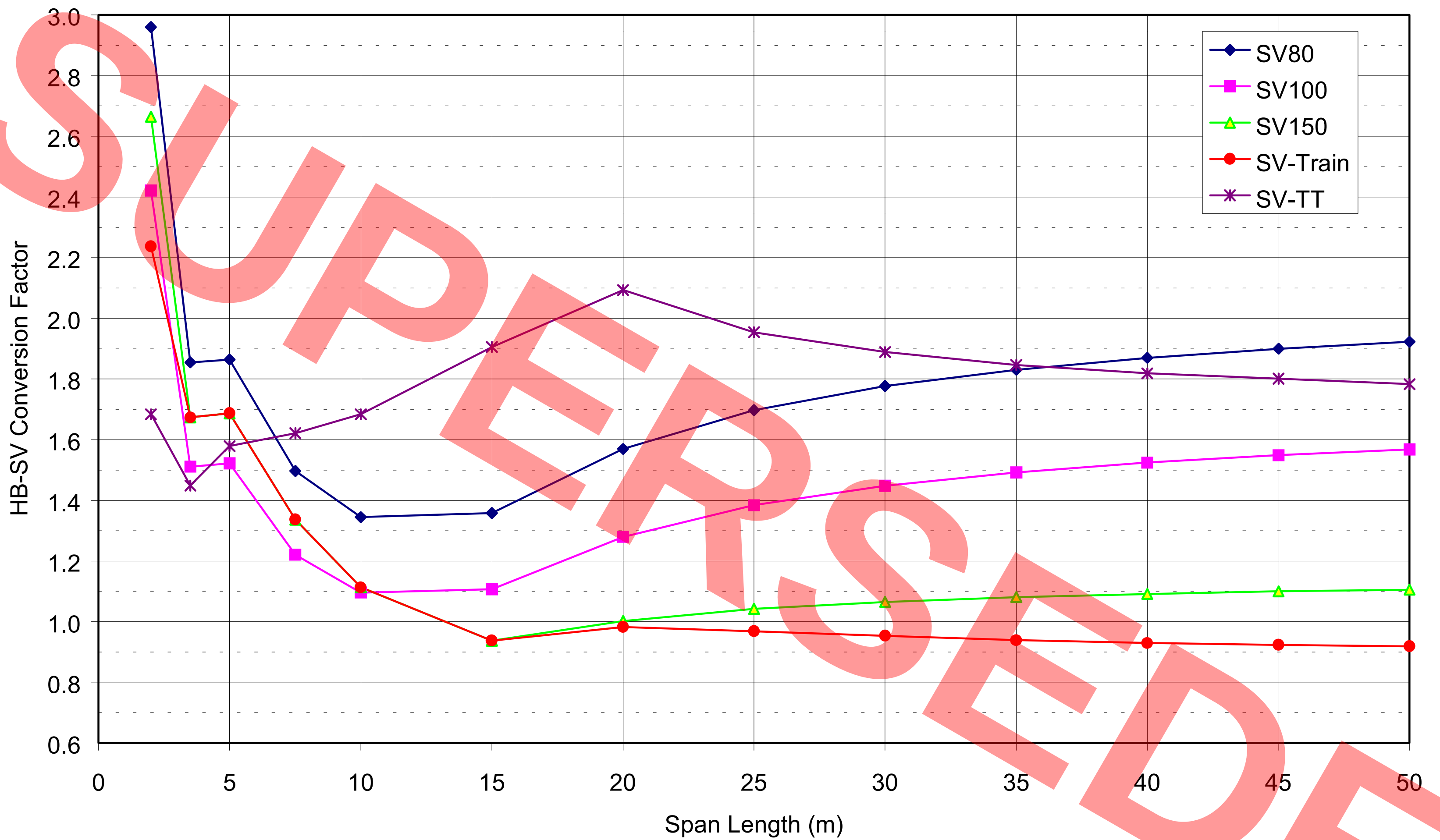


Figure C.7: $\lambda_{HB45 \rightarrow SV}$ for Single Span: Mid-span Moment

Volume 3 home page

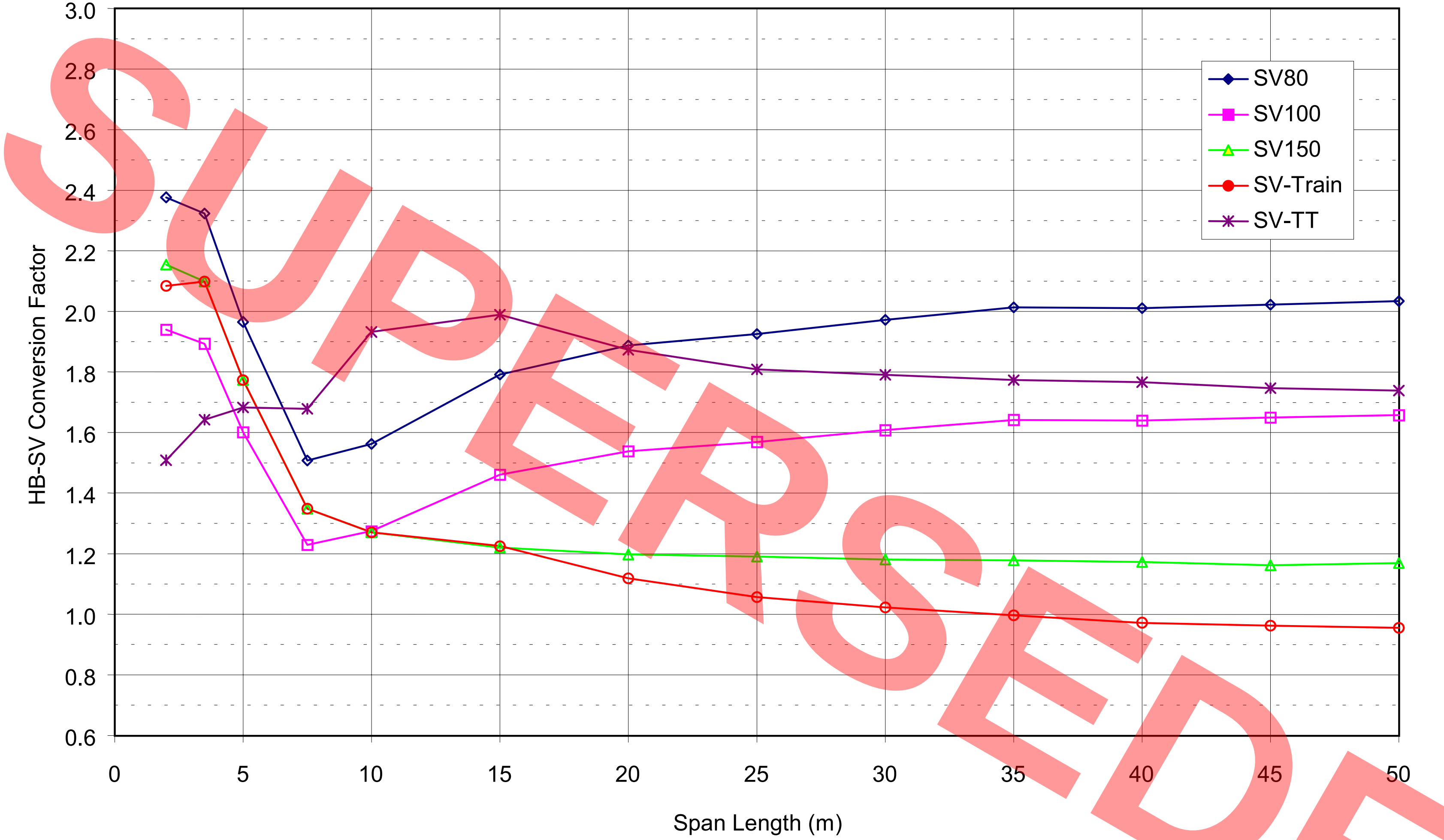


Figure C.8: $\lambda_{HB45 \rightarrow SV}$ for Single Span: Support Shear/Reaction

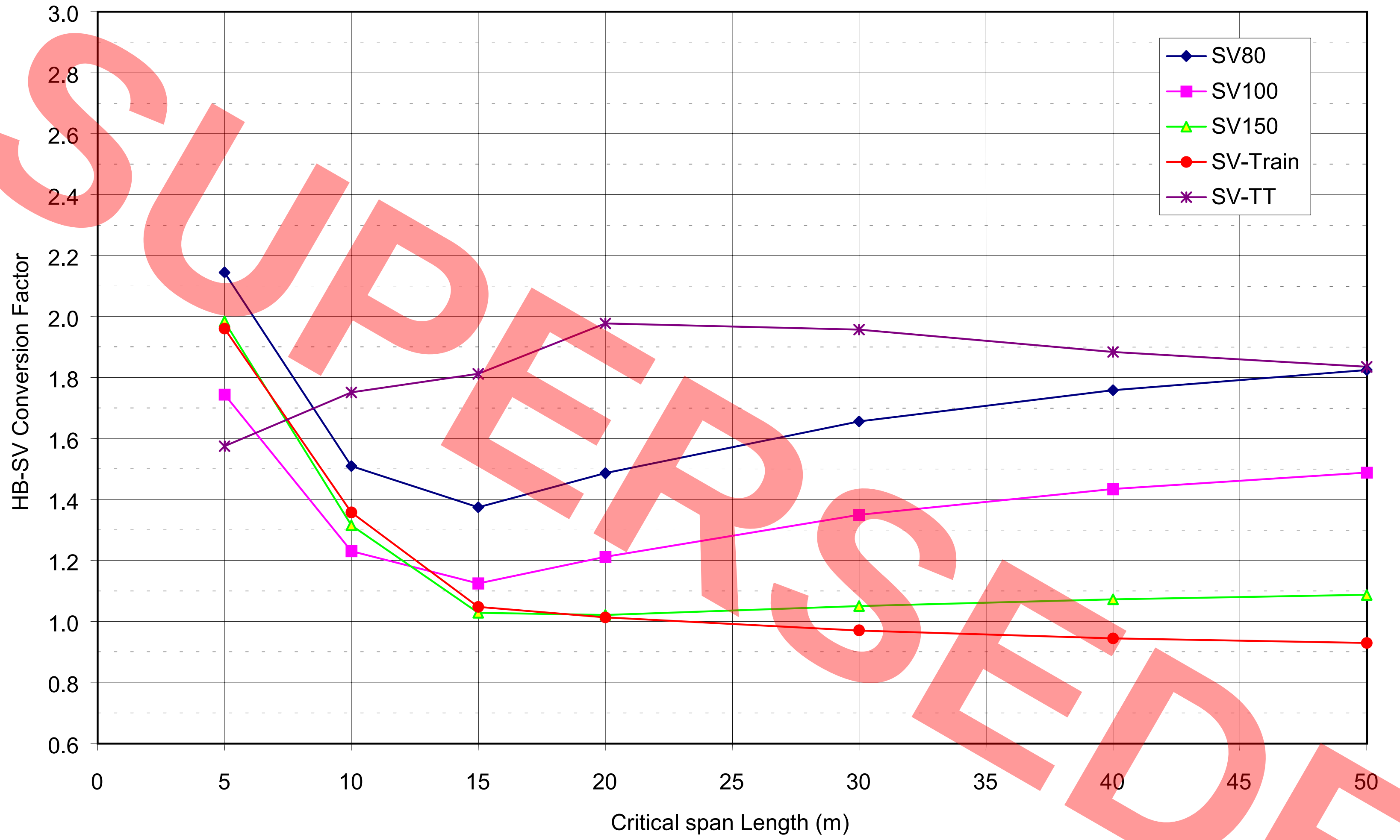


Figure C.9: $\lambda_{HB45\rightarrow SV}$ for Continuous Spans: Mid-span Moment

Volume 3 home page

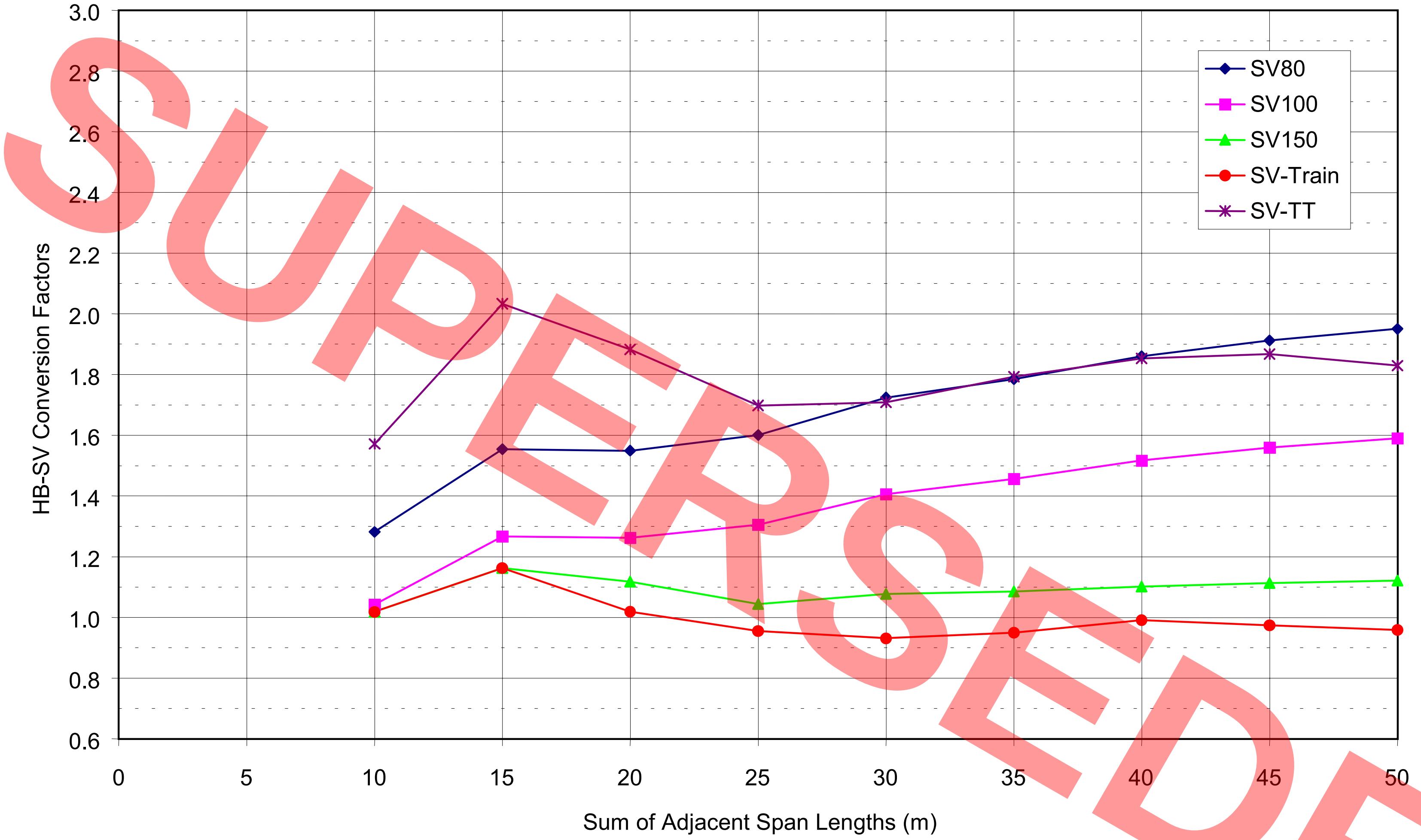


Figure C.10: $\lambda_{HB45 \rightarrow SV}$ for Continuous Spans: Internal Support Moment

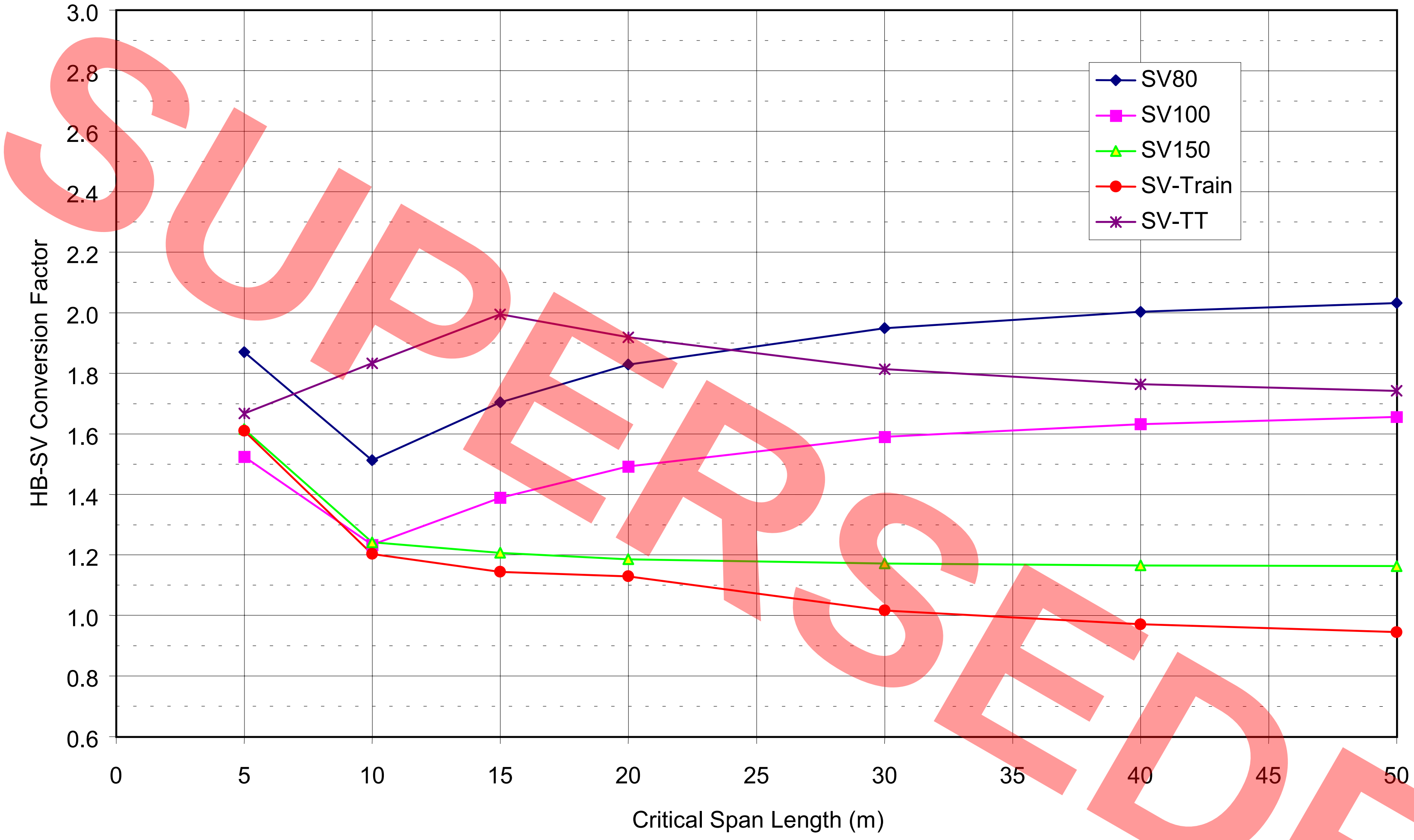


Figure C.11: $\lambda_{HB45 \rightarrow SV}$ for Continuous Spans: Internal Support Shear

Volume 3 home page

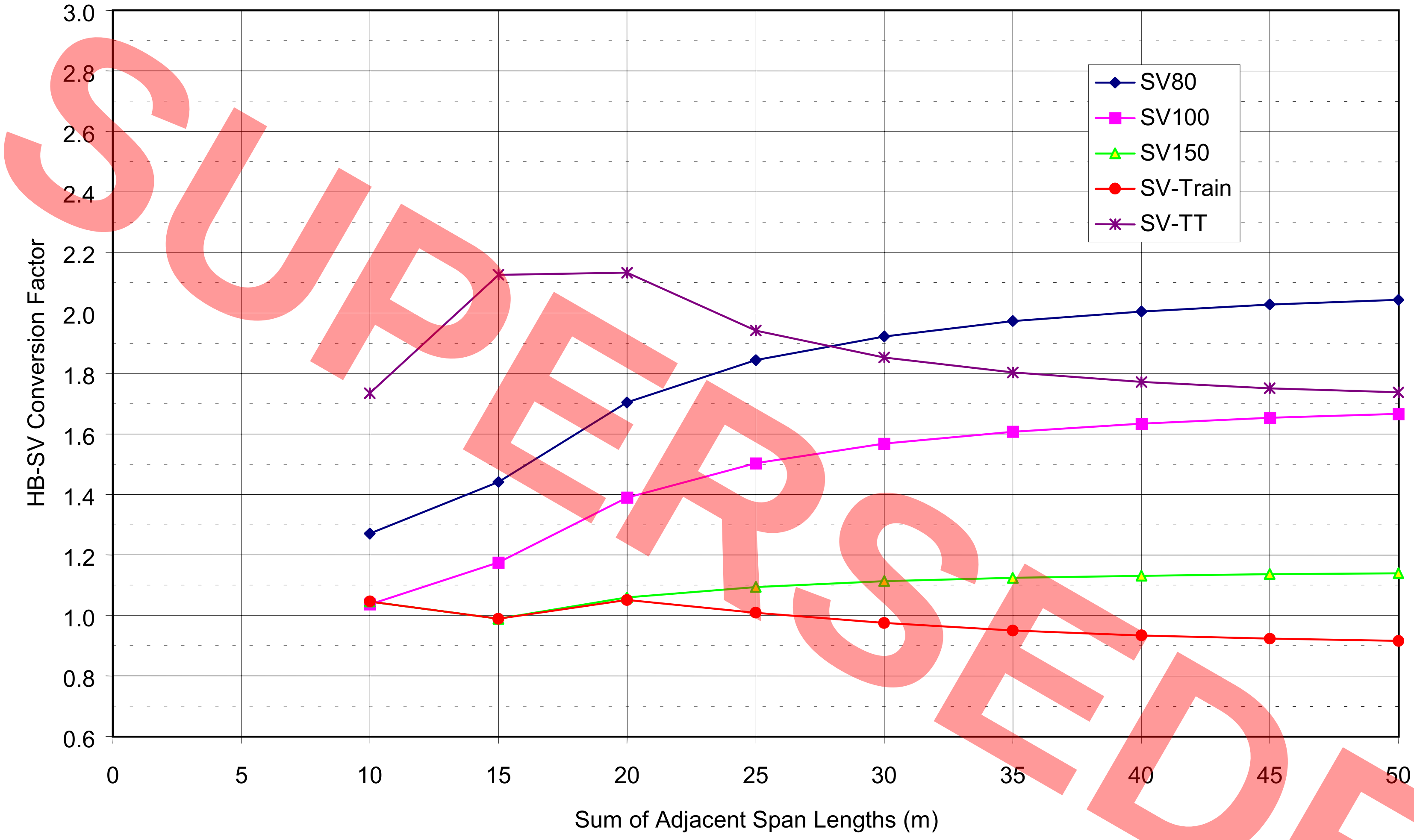


Figure C.12: $\lambda_{HB45 \rightarrow SV}$ for Continuous Spans: Internal Support Reaction

Volume 3 home page

ANNEX D MANAGEMENT OF STGO VEHICLE MOVEMENTS

D1 General

When the highway authority or its appointed agent receives a notification from a haulier for the movement of an STGO vehicle, the suitability of the vehicle to pass over a specific structure can be assessed using the procedures given in this Annex. A separate check should be made for adequate height and width clearances for the safe travel of the STGO vehicle.

The assessment should be performed in stages, starting with the simple screening method given in D2, which should be sufficient for the majority of the vehicles. When the vehicle fails the screening level check, a more detailed assessment should be performed using the method given in D3.

Reductions to Dynamic Amplification Factor, the associated HA loading, and the Overload Factor may be made, eg where the transit is well regulated and there is a greater confidence in the weight of the STGO vehicle as given in D4 to D6.

Highway authorities and their appointed agents should be aware that checking for ULS only may result in serviceability problems and possible permanent damage. This is most likely where methods of analysis are used at ULS, which rely on large amounts of redistribution eg concrete structures.

Worked examples using the procedures in this Annex are given in D9 to D11.

D2 Screening Assessment

Comparing the vehicle type, gross weight, axle weight and axle spacing characteristics of the notified STGO vehicle against the limits set out in Table D.1 identify the applicable SV vehicles for which these limits are satisfied. The STGO vehicle or vehicle train with a total weight of W_{STGO} tonnes may be considered suitable to pass a specific structure if:

$$W_{STGO} \leq W_{SV} \times \Psi_{SV} \tag{D.1}$$

where W_{sv} is the gross weight of the applicable SV vehicle from Table D.1 and Ψ_{SV} is the corresponding Reserve Factor determined as in 3.51.

STGO Vehicle Characteristics[1]			Corresponding SV Vehicle		
Vehicle Type		Max. Axle Weight (tonnes) & Min. Axle Spacing (m)	Vehicle		Gross Weight W_{sv}(tonnes)
Single Vehicle ≤ 150t gross weight[2]		16.5t @ 1.2m, OR 15.0t @ 1.1m	SV80		80
			SV100		100
Single Vehicle ≤ 150t gross weight		16.5t @ 1.35m, OR 15.0t @ 1.2m	SV150		150
Vehicle Train[3]	Trailer ≤ 150t gross wt.	16.5t @ 1.35m, OR 15.0t @ 1.2m	SV-Train	Trailer	150
	Locomotive ≤ 46t gross wt.	Two axles 18t @ 1.6m; additional axles min. 4m apart		Loco-motive	46

Note: [1] The axle weights and spacings do not necessarily correspond to the STGO Regulations but are related to the parameters for which STGO vehicles may be directly compared to SV vehicles in the Screening Assessment
[2] A single STGO vehicle greater than 80t or 100t gross weight can be covered by the SV80 or SV100 vehicles with adequate Reserve Factor using equation D.1
[3] Vehicle train comprises a single locomotive pulling a trailer.

Table D.1: STGO and SV vehicles characteristics for Screening Assessment

Volume 3 home page

D3 Detailed Assessment

The detailed assessment should be based on a comparison of the load effects caused by the STGO vehicle with those of the SV vehicle using one or more influence lines considered most appropriate for the structure. Overload Factor (*OF*), Dynamic Amplification Factor (*DAF*) and partial factors γ_{fL} and γ_{f3} should not be applied in calculating the load effects due to both the SV and STGO vehicles as these factors would have already been incorporated in the calculation of the reserve factor for SV.

The calculation of load effects due to the STGO vehicle and the SV vehicle should be refined in two steps as below:

(i) Calculate the unfactored load effects due to the STGO vehicle, S_{STGO}, and the SV vehicle, S_{SV}, ignoring the associated HA (or AW vehicle) loading. The STGO vehicle should be considered suitable to pass the structure if:

$$S_{STGO} \leq S_{SV} \times \Psi_{SV} \qquad \text{(D.2)}$$

The above assumes that the load effects due to the associated HA (or AW vehicle) loading is the same for both SV and STGO vehicles.

(ii) Where the inequality (D2) is not satisfied, calculate the unfactored load effects due to both STGO and SV vehicles including the unfactored associated HA loading applied using 3.26 - 3.45 with the *DAF* set to 1.0. The STGO vehicle should be considered suitable to pass the structure if the following condition is satisfied for both the “normal speed” and “low speed” cases:

$$\left(S_{STGO} + S_{HA(STGO)}\right) \leq \left(S_{SV} \times \Psi_{SV} + S_{HA(SV)}\right) \qquad \text{(D.3)}$$

where $S_{HA(STGO)}$ is the unfactored load effect due to the HA loading associated with the STGO vehicle, while $S_{HA(SV)}$ is the unfactored load effect due to the HA loading associated with the SV vehicle. This refinement is likely to be beneficial for loaded lengths greater than about 15m. In this case, since the real STGO vehicles would in general be longer than the SV vehicles, $S_{HA(STGO)}$ would be lower than $S_{HA(SV)}$.

D4 Reduction in Dynamic Amplification Factor

For an STGO vehicle that marginally exceeds the assessed capacity of a structure, it may be possible to permit its passage provided its speed over the structure can be restricted to less than 10 mph. The STGO vehicle should be considered suitable to pass the structure if:

$$\left(S_{STGO} \times DAF_{STGO}\right) \leq \left(S_{SV} \times DAF_{SV} \times \Psi_{SV}\right) \qquad \text{(D.4a)}$$

where DAF_{STGO} =1.0 is the Dynamic Amplification Factor applied to the STGO vehicle, while DAF_{SV} is the Dynamic Amplification Factor applied to the SV vehicle taken as in 3.25.

Alternatively, when the effect due to the associated HA loading is taken into account the STGO vehicle should be considered suitable to pass the structure if the following condition is satisfied for both the “normal speed” and the “low speed” case:

$$\left(S_{STGO} \times DAF_{STGO} + S_{HA(STGO)}\right) \leq \left(S_{SV} \times DAF_{SV} \times \Psi_{SV} + S_{HA(SV)}\right) \qquad \text{(D.4b)}$$

In this case the HA loading should be applied using 3.26 - 3.45 assuming that the SV and STGO vehicles lie fully within a notional lane (see Figure 3.7). The value of DAF_{sv} should be taken as in 3.25 for the “normal speed” case and as 1.0 for the “low speed” case. For masonry arches the lift-off can be ignored for the “low speed” case.

D5 Reduction in Associated HA Loading

For an STGO vehicle that marginally exceeds the assessed capacity of a structure, it may be possible to permit its passage provided the vehicle is escorted and the structure is kept clear of associated normal traffic. Two cases can be considered:

(i) When the associated traffic in the same lane as the STGO vehicle is kept clear over the span, the STGO vehicle should be considered suitable to pass the structure if the following condition is satisfied for both the “normal speed” and the “low speed” cases:

$$S_{STGO} \leq \left(S_{SV} \times \Psi_{SV} + S_{HA(SV)}\right) \qquad \text{(D.5)}$$

Where $S_{HA(SV)}$ is the load effect due to the HA (or AW vehicle) loading in the same lane as the SV vehicle.

The load effects due to the SV vehicle and the associated HA loading should be calculated using 3.26 - 3.45 with the *DAF* set to 1.0. The reduction in the *DAF* can also be allowed for as in D4 if the speed of the STGO vehicle over the structure is restricted.

(ii) When the associated traffic in all lanes of the carriageway is kept clear of the structure, the STGO vehicle should be considered suitable to pass the structure if:

$$S_{STGO} \le \left(S_{SV} \times \Psi^*_{SV}\right) \qquad \text{(D.6)}$$

where Ψ^*_{SV} is the Reserve Factor without the associated HA loading as determined in 3.51.

The reduction in DAF can also be allowed for as in D4 if the speed of the STGO vehicle over the structure is restricted.

D6 Reduction in Overload Factor

Where there is a greater confidence in the gross weight and axle weights of the STGO vehicle, the value of the Overload Factor can be reduced as shown in Table D.2. The STGO vehicle should be considered suitable to pass the structure if:

$$\left(S_{STGO} \times OF_{STGO}\right) \le \left(S_{SV} \times OF_{SV} \times \Psi_{SV}\right) \qquad \text{(D.7a)}$$

OR

$$\left(S_{STGO} \times OF_{STGO} \times DAF_{STGO} + S_{HA(STGO)}\right) \le \left(S_{SV} \times OF_{SV} \times DAF_{SV} \times \Psi_{SV} + S_{HA(SV)}\right) \qquad \text{(D.7b)}$$

where OF_{STGO} is the Overload Factor from Table D.2 applied to the STGO vehicle, while OF_{SV} is the Overload Factor from 3.24 applied to the SV vehicle. Using equation D.7b, the reduction in Overload Factor can be combined with reductions in the Dynamic Amplification Factor and the associated HA loading as given in D4 and D5.

Level of confidence in the weight of the STGO vehicle	Overload Factor
Independent certification of the "load" carried or the total weight of the vehicle(s)	0.95 × OF
Independent certification of all axle weights and spacing	1.0

Table D.2: Overload Factor OF_{STGO} applied to the STGO vehicle
(*OF* is the Overload Factor from 3.24)

D7 Route Assessment

Highway authorities may pre-assess all structures on identified heavy load routes (including slip roads and interchanges on the way) using the procedures given in D1 to D3 and assign a rating for the route. The Route Rating should be taken as the lowest of the Vehicle Ratings for all the structures on that route. This can facilitate a speedier assessment of STGO notifications.

D8 Vehicle Assessment

Some STGO vehicles (for example mobile cranes) have fixed axle weight and spacing configurations and they perform frequent transits around the country. These vehicles may be pre-assessed by the haulier (or the highway authority) using the simple screening assessment method given in D2 to determine their equivalent SV ratings or Reserve Factors against SV vehicles. This information could then be supplied on the notification forms to facilitate speedier assessments.

D9 Example 1: Screening Assessment

A notification has been received from a haulier for moving a mobile crane of 98 tonnes gross weight over a stretch of the road comprising four bridges. The axle loads and configuration of the vehicle are shown in Fig. D.1. The Reserve Factors for the four bridges are given in Table D.3. All the bridges have simply-supported reinforced concrete slab decks.

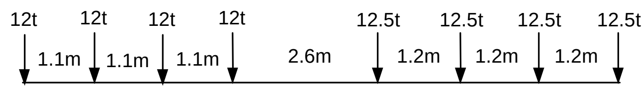


Figure D.1: Notified Vehicle 1

Bridge Ref.	SV Reserve Factors, Ψ_{SV}, for Flexure			
	SV80	SV100	SV150	SV-Train
A	1.58	1.28	1.00	0.99
B	1.54	1.21	1.04	1.04
C	1.25	1.02	1.12	1.12
D	1.28	1.01	1.13	1.13

Table D.3: SV Reserve Factors for bridges

Referring to Table D.1, it can be seen that the STGO vehicle satisfies axle weight and spacing limits corresponding to SV80 and SV100 vehicles and hence the screening assessment is applicable for this case.

The gross weight, W_{SV}, for the SV80 and SV100 vehicles can be obtained from Table D.1 and these have been multiplied by the corresponding Reserve Factors from Table D.3. The results are summarised in Table D.4.

Bridge Ref.	$W_{SV} \times \Psi_{SV}$	
	SV80	SV100
A	126	128
B	124	121
C	100	102
D	102	101

Table D.4: SV vehicle load ratings (tonnes) for bridges

Since the total weight of the STGO vehicle, W_{STGO} = 98t, is less than the product of W_{SV} x Ψ_{SV} for all the four bridges, the STGO can be considered to be safe to travel on the specified route. A check was also made for shear load effect and the STGO vehicle was seen to be acceptable for this case.

D10 Example 2: Detailed Assessment

A second notification for the movement of an abnormal individual load has been received for the same stretch of the road as in Example 1. The total weight of the vehicle is 146 tonnes and the axle weight and configuration are as shown in Figure D.2.

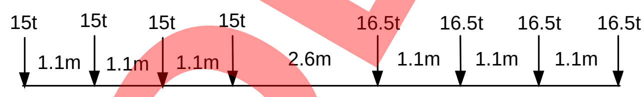


Figure D.2: Notified Vehicle 2

Referring to Table D.1, the vehicle does not satisfy the axle weight and spacing limits for single STGO vehicles and hence the Screening Assessment cannot be applied.

Mid-span bending moments due to the STGO vehicle and the various SV vehicles were calculated for the four bridges and multiplied by the corresponding Reserve Factors from Table D.3. The results are summarised in Table D.5. The partial factor, the Overload Factor and the Dynamic Amplification Factor were not included in calculating the load effects for STGO and SV vehicles.

Bridge Ref.	Span (m)	M_{STGO}	$M_{SV} \times \Psi_{SV}$			
			SV80	SV100	SV150	SV-Train
A	20	4391	5053	5196	5110	5170
B	15	2847	3433	3417	3431	3431
C	7.5	861	951	981	966	966
D	5.0	453	442	443	439	439

Table D.5: Mid-span bending moments (kN-m) due to STGO and SV vehicles

From Table D.5, it can be seen that the mid-span moment due to the STGO vehicle is less than the mid-span moment due to each of the SV vehicle multiplied by the corresponding Reserve Factors, ie equation (D.2) is satisfied for bridges A, B and C. However, this requirement is not satisfied for bridge D for which further assessment is required as considered in Example 3. The refinement given in Clause D3 (ii) was not applied as the loaded length for bridge D is less than 15m. A check was also made for the support shear and similar results were obtained.

D11 Example 3: Regulated Movement of the STGO

The detailed results available from the assessment of bridge D for the SV100 vehicle are given in Table D.6. The load effects do not include partial factors, the Overload Factor and the Dynamic Amplification Factor.

Load Effect	$S_{HA(SV)}$	S_{SV100}	Ψ_{SV100}	Ψ^*_{SV100}
Moment (kN-m)	150	437	1.01	1.35
Shear (kN)	125	429	1.06	1.35

Table D.6: Detailed assessment results for bridge D

The load effects due to the STGO and SV vehicles were calculated for the following three alternative measures for regulating the movement of the STGO vehicle:

1. The STGO vehicle passes over the bridge at a speed of less than 10mph (see D4). The comparable load effects (see equation D.4a) for the SV100 vehicle are given in column 3 of Table D.7.

2. The STGO vehicle is escorted with the associated normal traffic kept clear of the bridge in all lanes (see D5). The comparable load effects (see equation D.6) for the SV100 vehicle are given in column 4 of Table D.7.

3. The haulier produces an independent certification of all axle loads and spacing of the STGO vehicle. The comparable load effects (see equation D.7a) for the SV100 vehicle are given in column 5 of Table D.7.

Volume 3 home page

Load Effect	S_{STGO}	$S_{SV} \cdot \Psi_{SV} \cdot DAF_{SV}$	$S_{SV} \cdot \Psi^*_{SV}$	$S_{SV} \cdot \Psi_{SV} \cdot OF_{SV}$
Moment (kN-m)	453	495	591	501
Shear (kN)	433	508	580	488

Table D.7: Comparison of STGO and SV load effects for bridge D with alternative management measures

Based on the above results, it can be seen that the passage of the STGO vehicle over bridge D can be permitted with any one of the above three management measures.