

Australian Standard™

**Railway track material**

**Part 17: Steel sleepers**

This Australian Standard was prepared by Committee CE-002, Railway Track Materials. It was approved on behalf of the Council of Standards Australia on 29 November 2002 and published on 14 February 2003.

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The following are represented on Committee CE-002:

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Australian Chamber of Commerce and Industry  
Australian Industry Group  
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Rail Track Association Australia

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STANDARDS AUSTRALIA

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**RECONFIRMATION**

**OF**

**AS 1085.17—2003**

**Railway Track Material**

**Part 17: Steel Sleepers**

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Technical Committee CE-002 has reviewed the content of this publication and in accordance with Standards Australia procedures for reconfirmation, it has been determined that the publication is still valid and does not require change.

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## NOTES

Australian Standard™

**Railway track material**

**Part 17: Steel sleepers**

Originated as AS 1085.17—2000.  
Second edition 2003.

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Published by Standards Australia International Ltd  
GPO Box 5420, Sydney, NSW 2001, Australia

ISBN 0 7337 4949 6

## PREFACE

This Standard was prepared by the Standards Australia Committee CE-002, Railway Track Materials, to supersede AS 1085.17—2000, *Railway permanent way materials, Part 17: Steel sleepers*.

The objective of this Standard is to provide purchasers and suppliers including owners, operators, designers and manufacturers of railway sleepers with requirements for the specification, manufacture and testing of trough-shaped steel sleepers for use in railway track.

This revision includes only those changes necessary to accompany the publication of the new Standards in the series, AS 1085.18 and AS 1085.19. This implements the separation of the requirements for resilient fasteners from those for the sleepers.

This Standard includes the following changes to the previous edition:

- (a) Change of title of the AS 1085 series (previously *Railway permanent way material*.)
- (b) Requirements for resilient fastenings that are covered in AS 1085.19 have been removed and reference made to that Standard.
- (c) The referenced documents list has been updated.
- (d) Minor editorial changes implemented.
- (e) Appendix numbering has been updated following removal of a number of Appendices.
- (f) The most recent version of the informative Appendix ‘Means of demonstrating compliance with this Standard’ has been included.

Statements expressed in mandatory terms in notes to tables are deemed to be requirements of this Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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## FOREWORD

The performance of steel sleepers in track depends on the condition of the rail, the condition and type of rail joints, the ballast support and the rail fastening system. Accordingly, when considering performance, the sleeper and its fastening together with the rail must be regarded as interdependent components of a system.

The limits given in this Standard are based on the current state of knowledge of steel sleeper behaviour in service; however, service conditions are difficult to define and test criteria that are seen as the most appropriate for the current state of knowledge, have been adopted.

A critical design aspect of steel sleepers is the interaction of the fastening and the portion of sleeper around the hole in which the fastening is secured. The rail seat assembly repeated load test cannot be used to predict the expected in-track fatigue life. It does, however, provide a means of acceptance of a design by comparison with existing proven designs on the basis of experience.

The loads used in testing and design should reflect the use of the sleeper. For example, if sleepers are used in an interspersed pattern, a disproportionate amount of the load may be taken by a particular sleeper and early in-service failure may result.

This Standard does not cover sleepers for use in curves with a radius less than 200 m.

Track constructed using sleepers and fastener components meeting the requirements of this Standard is expected to give satisfactory performance when properly installed and under an appropriate maintenance program.

This Standard is intended for use by persons experienced in track design and performance and who have a good knowledge of the duty and environment of the track in which the sleepers are to be used.

Loads and calculation methods given in this Standard are in permissible stress format and are not based on limit states principles.

**STANDARDS AUSTRALIA****Australian Standard  
Railway track material****Part 17: Steel sleepers****SECTION 1 SCOPE AND GENERAL****1.1 SCOPE**

This Standard specifies the performance requirements and gives design and testing methods for trough-shaped steel sleepers and their associated components for use in railway track. It also sets out requirements for the performance of rail-insulating components.

**NOTES:**

- 1 Sleepers are generally designed to suit a specific rail profile and gauge with a given fastening.
- 2 Guidance on information that should be provided by the purchaser and supplier is given in Appendix A.
- 3 Guidance on means for demonstrating compliance with this Standard is given in Appendix B.
- 4 Guidelines on the design and manufacture of special sleepers and fastenings are given in Appendix C.

**1.2 PURPOSE AND CONTEXT OF USE****1.2.1 Function**

Sleepers are support members that are part of the structure of railway permanent way. They are embedded into the ballast and support the rails above. They tie the rails together maintaining gauge and rail position and resisting lateral and longitudinal movement of the rail system. Fastenings, as part of the sleeper assembly, secure the rails to the sleeper.

**1.2.2 Action**

Sleepers are subject to—

- (a) loads imposed by the passage of rolling stock on the rails and during maintenance;
- (b) loads generated by thermal effects on the rail and by ballast movement; and
- (c) fatigue, wear, damage and corrosion.

**1.3 TESTING**

Testing shall be conducted by a laboratory appropriately qualified to carry out the tests. Testing shall be carried out on sleeper assemblies or elements that have been produced using the processes and the plant, and with the materials that the manufacturer uses or intends to use in mass production. The tests given in this Standard are for the design and acceptance of steel sleepers.

Testing shall be carried out using the rail profile (or part of the rail profile, as appropriate) and the sleeper assembly, including rail fastening, which is intended to be used. This includes the use of spacers or other variation in configuration (e.g., multiple sets of holes).

## 1.4 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

### AS

- |         |   |
|---------|---|
| 1085    | Railway track material  |
| 1085.19 | Part 19: Resilient fastening assemblies   |
| 1171    | Non-destructive magnetic testing—Magnetic particle testing of ferromagnetic products, components and structures |
| 1199    | Sampling procedures and tables for inspection by attributes   |
| 1365    | Tolerances for flat-rolled steel products   |
| 1399    | Guide to AS 1199  |
| 1594    | Hot-rolled steel flat products  |
| 2312    | Guide to the protection of iron and steel against atmospheric corrosion by the use of protective coatings       |
| 2758    | Aggregates and rock for engineering purposes  |
| 2758.7  | Part 7: Railway ballast   |

### AS/NZS

- |          |  |
|----------|--|
| 1100     | Technical drawing  |
| 1100.101 | General principles   |
| 3678     | Structural steel—Hot-rolled plates, floorplates and slabs          |
| ISO 9001 | Quality management systems—Requirements                            |
| ISO 9004 | Quality management systems—Guidelines for performance improvements |

### SAI

- |         |  |
|---------|--|
| HB18    | Guidelines   |
| HB18.28 | Guide 28—General rules for a model third-party certification scheme for products |

### Australasian Railways Association

*Review of Track Design Procedures* Volumes 1 and 2, 1991  
(ISBN 0 909582 01 7)

HETENYI, M. *Beams on elastic foundation*. The University of Michigan Press: Ann Arbor, 1967

## 1.5 DEFINITIONS

For the purpose of this Standard, the definitions given below and those shown in Figure 1 apply.

### 1.5.1 Cant

The inward tilt of the rails with respect to the sleeper.

### 1.5.2 End spade

The turned-down end of the sleeper, which provides lateral resistance and stability.

### 1.5.3 Fastening

The component or group of components of a steel sleeper system, which fastens the rail to the sleeper.

### 1.5.4 Gauge corner

Transition surface separating the rail running surface from the rail side.

### **1.5.5 Gauge point**

The point on the side of the rail head 16 mm beneath the top surface of the rail at which track gauge is measured.

### **1.5.6 In-face**

Where sleepers are installed in every position rather than interspersed with other sleepers in between.

### **1.5.7 Lateral load**

A load or vector component of a load at the gauge corner of the rail parallel to the longitudinal axis of the sleeper and perpendicular to the longitudinal axis of the rail.

### **1.5.8 Longitudinal load**

A load along the longitudinal axis of a rail.

### **1.5.9 Pod**

Volume enclosed by the top, end spades and sides of the sleeper.

### **1.5.10 Rail insulation pad**

A component of a steel sleeper system that electrically insulates the rail from the sleeper.

### **1.5.11 Rail seat**

The area on the top of the sleeper on which the rail sits extending between the field and gauge shoulders.

### **1.5.12 Shoulder**

A component that is attached to, fitted to or forms part of a steel sleeper, to prevent lateral movement of the rail.

### **1.5.13 Side**

Side of the sleeper projecting into the ballast layer (see Figure 1).

### **1.5.14 Sleeper design life**

The intended period during which fatigue cracking or bending failure does not occur when the sleeper is subjected to the specified loading and environmental conditions.

NOTE: Actual in-service sleeper life may vary from the sleeper design life depending on actual loading and environmental conditions applied to the sleeper. Actual in-service life may also depend on the extent to which minor deterioration (e.g., cracking, corrosion) may be tolerated using appropriate risk management techniques.

### **1.5.15 Toe**

Section at the tip of the side of a steel sleeper (see Figure 1(c)).

### **1.5.16 Top**

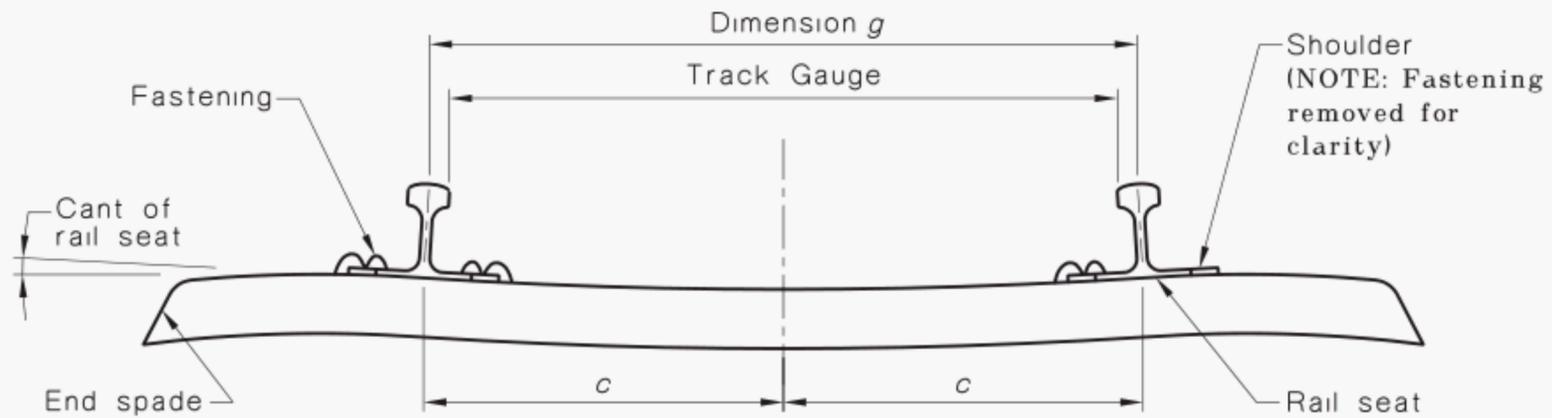
Top section of the sleeper (see Figure 1(c)).

### **1.5.17 Track gauge**

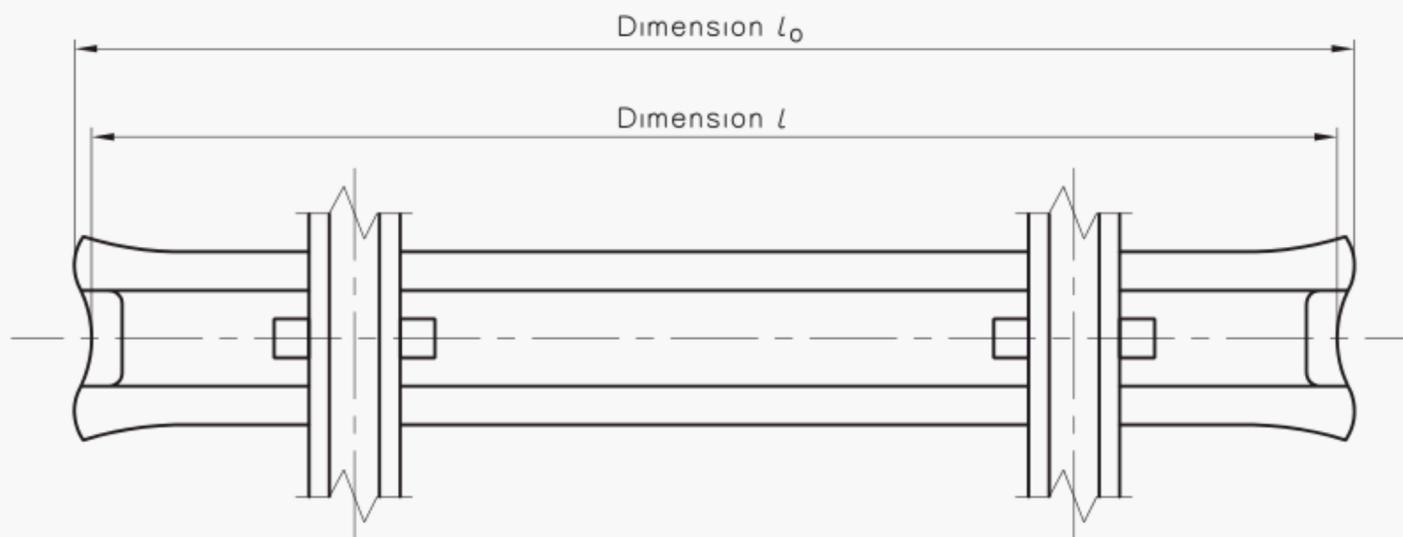
The distance between the gauge points of the rails.

### **1.5.18 Vertical load**

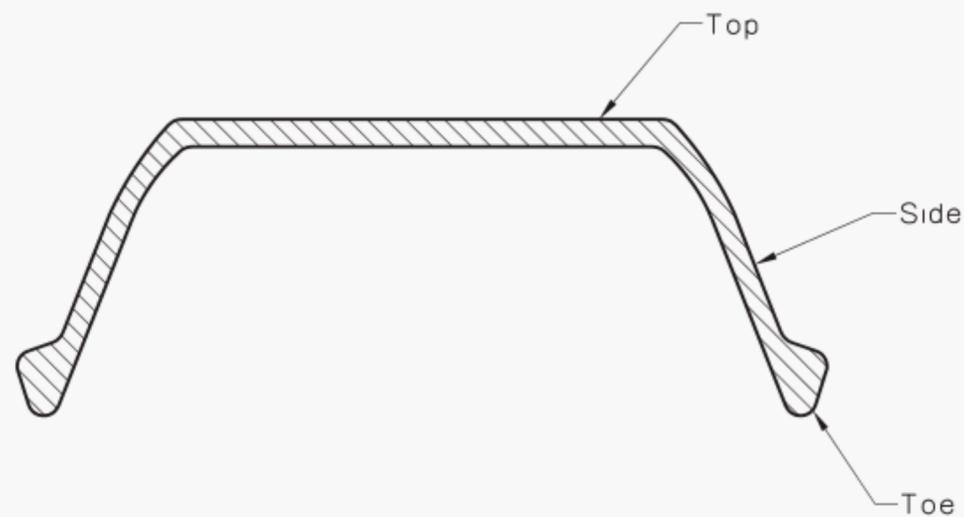
A load or vector component of a load, perpendicular to a line joining the midpoint of the rail seats of the sleeper and perpendicular to the longitudinal axis of the rail.



(a) Elevation along sleeper



(b) Plan



(c) Typical cross-section of sleeper

FIGURE 1 SCHEMATIC REPRESENTATION OF STEEL SLEEPER SHOWING PRINCIPAL DEFINITIONS

## 1.6 NOTATION

For the purpose of this Standard, the following symbols apply:

- $a$  = length of pressure distribution (ballast support) beneath each rail seat, in metres
- $B$  = maximum internal width of the sleeper section (see Figures D1 and D2), in millimetres
- $C_{BM}$  = sleeper bending moment coefficient
- $C_{BM(n)}$  = bending moment coefficient at the field side edge of the sleeper housing
- $C_{BM(max.)}$  = maximum sleeper bending moment coefficient (maximum of  $C_{BM(0)}$  and  $C_{BM(n)}$ )

$C_{BM(0)}$	= bending moment coefficient at the sleeper midpoint
$C_{BM(x)}$	= sleeper bending moment coefficient covering the region to the field side of the rail seat
$C_x$	= distance from horizontal neutral axis to the top surface of the sleeper (see Figures D1 and D2), in millimetres
$c$	= dimension of sleeper from the centre-line of the rail seat to the centre of the sleeper, in metres (see Figure 1(a))
$D$	= overall depth of the sleeper section (see Figures D1 and D2) in millimetres
$E$	= Young's modulus of rail steel, in megapascals
$E_s$	= Young's modulus of sleeper material, in megapascals
$F_y$	= yield strength of sleeper material, in megapascals
$F_1$	= factor applied to the rail seat load to incorporate the effects of the interaction of adjacent wheels to the design wheel load
$F_2$	= factor depending on the standard of track maintenance
$F_3$	= distribution factor for lateral loads on the rail seat
$G$	= track gauge, in millimetres
$g$	= distance between rail centres measured at the top of the rail, in metres (see Figure 1(a))
$g_1$	= distance between rail centres for larger of dual gauge measured at the top of the rail, in metres (see Figure C1)
$g_2$	= distance between rail centres for smaller of dual gauge measured at the top of the rail, in metres
$I_s$	= sleeper moment of inertia about the horizontal neutral axis, in millimetres <sup>4</sup>
$I_{s(new)}$	= moment of inertia about the horizontal neutral axis of newly rolled sleeper section, in millimetres <sup>4</sup>
$I_{xx}$	= rail moment of inertia about the horizontal neutral axis, in millimetres <sup>4</sup>
$L/V$	= ratio of lateral to vertical wheel loads
$l$	= sleeper length at the centre-line (see Figure 1(b)), in metres
$l_0$	= overall (maximum) sleeper length (see Figure 1(b)), in metres
$M_{C+}$	= maximum positive bending moment at the mid-span of the sleeper, in kilonewton metres
$M_{C-}$	= maximum negative bending moment at the mid-span of the sleeper, in kilonewton metres
$M_d$	= design sleeper bending moment, in kilonewton metres
$M_R$	= maximum bending moment at the rail seat, in kilonewton metres
$M_{R+}$	= maximum positive moment at the rail seat of the sleeper, in kilonewton metres
$n$	= dimension from end (on centre-line of bottom edge of end spade) to the centre-line of rail seat, in metres
$p_{ab}$	= average sleeper to ballast bearing pressure, in kilopascals
$P_{dL}$	= quasi-static lateral wheel load, in kilonewtons
$P_{dV}$	= quasi-static vertical wheel load, in kilonewtons

$Q$	= maximum static wheel load, in kilonewtons
$R$	= design rail seat load, in kilonewtons
$R_L$	= quasi-static lateral rail seat load, in kilonewtons
$R_V$	= quasi-static vertical rail seat load, in kilonewtons
$r$	= radius of curvature of track, in meters
$s$	= sleeper spacing, in metres
$T$	= thickness of sleeper top (see Figures D1 and D2), in millimetres
$t$	= thickness of sleeper side measured 10 mm above the toe (see Figures D1 and D2) in millimetres
$t_c$	= confidence limit
$U$	= track modulus ( $k$ is used in some publications) in megapascals
$U_s$	= sleeper support modulus, in megapascals
$v$	= vehicle velocity, in kilometres per hour
$W$	= a value used in the empirical method, see Clause 5.4.2 and Paragraph C4
$w$	= maximum external width of sleeper section excluding any localized widening around ends, in millimetres
$x$	= distance from the sleeper end along centre-line of sleeper, in metres
$x_\ell$	= distance (absolute) between load source and point of analysis, in metres
$y$	= vertical track deflection, in metres
$y_i$	= vertical track deflection due to a wheel load at a distance ' $x_\ell$ ' from the point under consideration, in metres
$y_{\max.}$	= maximum sleeper deflection (assumed to occur immediately beneath the rail seat) in metres or millimetres, as appropriate
$Z_{\text{toe}}$	= section modulus of sleeper toe about the horizontal neutral axis, in millimetres <sup>3</sup> (for design purposes, taken at the end of the sleeper design life)
$\beta$	= track stiffness parameter, in metres <sup>-1</sup>
$\delta$	= track condition factor used in determining the design impact factor/load distribution
$\eta$	= velocity factor used in determining the design impact factor/load distribution
$\lambda$	= sleeper stiffness parameter, in metres <sup>-1</sup>
$\sigma_{\text{all}}$	= allowable sleeper bending stress (see Clause 2.2.3) in mega pascals
$\sigma_{\text{cont}}$	= maximum contact pressure at the sleeper/ballast interface (see Clause 5.5.2) in kilopascals
$\sigma_d$	= design sleeper bending stress (see Clause 5.3) in megapascals
$\phi$	= dynamic impact factor

## SECTION 2 PERFORMANCE REQUIREMENTS

### 2.1 TRACK SYSTEM COMPATIBILITY

Sleeper assemblies shall maintain the track gauge within the tolerance given in Appendix D when tested in accordance with Appendix E.

### 2.2 SERVICE LIFE

#### 2.2.1 General

The performance requirements for the design service life of the sleeper assembly shall be deemed to be met when Clauses 2.2.2 to 2.2.8 are satisfied.

#### 2.2.2 Shape

The shape of the sleeper shall be such that it supports the rails and maintains the gauge under the expected conditions for its design service life. The requirements for sleeper shape for service life shall be deemed to be met when the sleeper complies with the minimum geometric section properties and end detail requirements and is within the tolerances given in Appendix D.

#### 2.2.3 Design stresses and ballast contact pressure

When designed in accordance with the service loads and track conditions specified, the calculated sleeper bending stress in tension and compression, calculated in Section 5, shall not exceed the allowable sleeper bending stress,  $\sigma_{all}$ , of  $0.66 F_y$ .

The average sleeper to ballast contact pressure, calculated in accordance with Clause 5.4 at a position equivalent to the bottom of the sleeper (on a plane intersecting the toes), shall not exceed 500 kPa for high quality, abrasion-resistant ballast. If lower quality ballast materials are used, the allowable ballast pressure shall be reduced accordingly.

Sleeper bending stresses, bending moments and contact pressures shall be calculated in accordance with Sections 4 and 5 and sleeper section properties shall be those assumed for the end of the service life of the sleeper (see Clause 5.2).

Where no other information is available, the value of  $R$  shall not be less than  $R_V$  as determined in accordance with Section 4.

NOTE: The value of  $R$  used for design may be subject to other information requiring engineering judgement

#### 2.2.4 Design of details

Sleeper design shall take into account the stresses induced in the sleeper by the interaction with the fastening system (e.g., stress concentrations).

#### 2.2.5 Sleeper materials

##### 2.2.5.1 Pre-formed sections

Sleepers manufactured from pre-formed section shall be made of steel with a characteristic yield strength of at least 250 MPa. The chemical composition of the steel shall conform to the limits given in Table 2.1. The steel shall not contain defects such as segregation, pipe, or non-metallic inclusions that reduce the expected sleeper life below the design life.

**TABLE 2.1**  
**BASIC CHEMICAL COMPOSITION**

Element	Percent, max.
Carbon	0.24
Manganese	1.5
Silicon	0.5
Sulfur	0.04
Phosphorous	0.04

### 2.2.5.2 Strip

Where the steel sleeper is manufactured from strip, the material shall conform to the requirements of AS 1365, AS 1594 or AS/NZS 3678 as appropriate.

### 2.2.6 Surface finish

The sleeper shall be free of surface defects, cracks, scratches, sharp die marks and sharp tooling marks which are likely to initiate failure in service. Defects may be rectified by grinding, provided that the structural adequacy of the sleeper section is not impaired and tolerances are not exceeded.

### 2.2.7 Resilient rail fastening assemblies

The performance requirements for the service life of resilient rail fastening assemblies shall be deemed to be met when Clause 2.2.8 and Section 3 are satisfied.

### 2.2.8 Rail seat assembly repeated load test

When tested in accordance with Appendix F with lateral and vertical rail seat loads as calculated in Section 4, unless the loads are otherwise specified by the purchaser, no fatigue cracking of the sleeper, fastening components or failure of the insulation pad shall occur.

NOTE: This test provides for acceptance of the sleeper on the basis of existing knowledge; however, the test cannot be used to predict the expected in-track fatigue life. Sufficient data is not available on a correlation between the test and in-track performance. In the event of failure under the given loading conditions, full test details should be provided for the consideration of the purchaser.

## 2.3 RAIL RESTRAINT AND SUPPORT

### 2.3.1 General

The requirements for rail restraint and support shall be deemed to be met when Clauses 2.3.2 to 2.3.3 are satisfied and the resilient rail fastenings are in accordance with Section 3.

### 2.3.2 Shape

The requirements for sleeper shape for rail restraint and support shall be deemed to be met when Clause 2.2.2 is satisfied.

### 2.3.3 Lateral track stability test

When tested in accordance with Appendix G, the maximum load determined shall be not less than the minimum value specified by the purchaser.

NOTE: The ability of the track structure to resist track buckling is also affected by the resistance provided by the fastening system to rotation of the longitudinal rail axis in the horizontal plane. Alternative procedures for the determination of track stability may be used where agreement is reached between the manufacturer and the purchaser (see Appendix A).

## 2.4 INSTALLATION AND MAINTENANCE

Sleeper assemblies shall be designed to—

- (a) provide for safe and easy installation and removal in existing track;
- (b) allow for rails to be de-stressed or changed; and
- (c) allow for inspection by the provision of inspection holes 20 mm in diameter, located on each side of each rail seat and away from locations of high stress unless specified otherwise by the purchaser.

NOTE: Inspection holes allow assessment of ballast compaction within the sleeper pod when the sleepers are installed in the track.

## 2.5 MARKING

Each sleeper shall be marked by raised or indented letters of not less than 12 mm high, and not more than 2 mm raised or indented, with the following information:

- (a) The mark required by purchaser.
- (b) Year of manufacture.
- (c) Mark of manufacturer.
- (d) Sleeper identification marks as required.

All markings shall be such as to induce no inherent fatigue weakness zones in the steel sleeper.

All markings shall be located so that they can be readily seen when the sleeper is installed and so that a stack of sleepers can be fully identified.

NOTE: Manufacturers making a statement of compliance with this Australian Standard on product, packaging or promotional material related to that product are advised to ensure that such compliance is capable of being verified.

## 2.6 HANDLING

### 2.6.1 Stacking of sleepers

The finished sleepers shall be handled and stacked in such a manner that there shall be no damage to the sleepers. Stacked sleepers shall be able to be easily separated.

### 2.6.2 Surface finish

Sleepers shall be free of burrs that could cause injury when handled or that could prevent efficient stacking and installation (see Clause 2.2.5).

SECTION 3 RESILIENT RAIL FASTENING  
ASSEMBLIES

Resilient rail fastening assemblies shall be in accordance with AS 1085.19.

## SECTION 4      LOADS FOR DESIGN AND TESTING

### 4.1 GENERAL

Field measurements shall be used for determining loads to be used for testing and analysis, except that where field measurements are not available, Clauses 4.2 to 4.7 below set out theoretical means for calculating lateral and vertical loads.

Once determined, these loads are used for testing and for calculation of structural capacity.

NOTE: Quasi-static loads account for the effects of the geometrical roughness of the track vehicle response and the effect of unbalanced superelevation. Steel sleepers are not usually designed for high frequency dynamic load effects. Where steel sleepers are to be used in jointed track, dynamic effects may need to be considered.

### 4.2 TRACK CONDITIONS

All relevant track conditions shall be taken into account in determining the loading including dynamic effects. The effects of wheel flats, rail joints and other significant irregularities will determine the magnitude of the dynamic loads used in design.

The methods given in Clauses 4.3 to 4.7 apply to the use of steel sleepers in ballasted railway tracks where they are installed either in-face or in an interspersed pattern. Where sleepers are to be used in an interspersed pattern, the possibility that a disproportionate amount of the load may be taken by a particular sleeper shall be taken into account in determining the variables to be used (see Clause 4.5).

NOTES:

- 1 The purchaser should define track conditions (see Appendix A).
- 2 The purchaser should ensure that installation and maintenance procedures are suitable for the sleepers selected, including that the pod is correctly packed with ballast and that adjacent sleepers in an interspersed pattern are sound.

### 4.3 QUASI-STATIC VERTICAL WHEEL LOAD

Where in-field measurements have not been obtained, the theoretical design quasi-static vertical wheel load ( $P_{dv}$ ) shall be determined from the maximum of a combination of static wheel loads and vehicle operating speeds in combination with the track condition factor as specified. The quasi-static wheel load shall be calculated from the following equation:

$$P_{dv} = \phi Q \quad \dots 4.3$$

where

- $P_{dv}$  = quasi-static vertical wheel load, in kilonewtons
- $\phi$  = quasi-static impact factor
- $Q$  = maximum static wheel load, in kilonewtons

Where multiple traffic types exist, the maximum dynamic wheel load shall be used for structural design purposes.

### 4.4 IMPACT FACTOR

Where in-field measurements have not been obtained, the theoretical impact factor ( $\phi$ ) for steel sleeper design may be computed by the Eisenmann loading distribution as follows:

$$\phi = 1 + (\delta \eta t_c) \quad \dots 4.4$$

where

- $\delta$  = track condition factor
- $\eta$  = velocity dependent factor
- $t_c$  = confidence limit

The above expression represents a normal distribution of loading around the mean load in which term ' $\delta \eta$ ' defines the standard deviation of the loading and ' $t_c$ ' defines the required number of standard deviations that the design load lies above the mean static load. Impact factors calculated using this formula do not include allowance for the effects of wheel flats, rail joints and other significant irregularities. The factors used in Equation 4.4 shall be as follows:

- (a) *Track condition factor ( $\delta$ )* The track condition factor ( $\delta$ ) may be selected from one of the following:
  - (i) For track maintained in very good condition ..... 0.1.
  - (ii) For track maintained in average condition ..... 0.2.
  - (iii) For track in poor condition ..... 0.3.
  - (iv) For track in very poor condition..... 0.4.
- (b) *Velocity-dependent factor ( $\eta$ )* This factor may be selected from one of the following:
  - (i) For velocities up to 60 km/h ..... 1.0.
  - (ii) For velocities greater than 60 km/h .....  $1.0 + (v - 60)/140$ , where  $v$  is in km/h.
- (c) *Confidence limit ( $t_c$ )* For design purposes, an impact factor that gives a design load lying 3 standard deviations above the mean load ( $t_c = 3$ ), representing a design load lying at the 99.9 percentile shall be used.

**4.5 QUASI-STATIC VERTICAL RAIL SEAT LOAD**

The beam-on-elastic-foundation (BOEF) method may be used to determine the proportion of loading applied to individual sleepers. The general BOEF relationship for the calculation of the rail seat load is as follows:

$$R_v = s U y_{max} \dots 4.5(1)$$

and

$$y_{max} = \sum_{i=1}^n y_i \dots 4.5(2)$$

where

- $R_v$  = quasi-static vertical rail seat load, in kilonewtons
- $s$  = sleeper spacing, in metres
- $U$  = track modulus, in megapascals
- $y_{max}$  = maximum sleeper deflection resulting from multiple wheels, in metres
- $y_i$  = vertical track deflection due to a wheel load at a distance ' $x_i$ ' from the point under consideration, in metres

NOTE: The track modulus should be chosen to suit the application in which the sleepers are to be used, including use in an interspersed pattern.

Vertical track deflection, using the BOEF analysis, is given by the following equation:

$$y_i = \frac{P_{dV} \beta}{2U} e^{-\beta x_\ell} (\cos \beta x_\ell + \sin \beta x_\ell) \quad \dots 4.5(3)$$

where

$P_{dV}$  = quasistatic wheel load, in kilonewtons

$x_\ell$  = distance (absolute) between load source and point of analysis, in metres

$\beta$  = track stiffness parameter, in metres to the power of minus one  
 $(U/(4 E I_{xx}))^{0.25} \times 10^3$

where

$E$  = Young's modulus of rail steel, in megapascals

$I_{xx}$  = rail moment of inertia about the horizontal neutral axis, in millimetres to the power of four

Application of this equation allows the track deflection to be computed both immediately beneath a wheel ( $x_\ell = 0$ ) and at adjacent wheels. Thus, the effects of wheel interaction on the total deflection ( $y$ ) may be computed.

If wheel interaction is not computed, the design rail seat load may be calculated from the following equation:

$$R_V = 0.5 F_1 P_{dV} s \beta \quad \dots 4.5(4)$$

where

$F_1$  = factor to account for wheel interaction

For this case, a nominal value of 1.25 for  $F_1$  may be adopted based on the typical combinations of track modulus and wheel distribution. This assumption is valid where the track modulus is greater than 20 MPa and two-axle bogie vehicles are used which have a minimum distance between axles of not less than 1.75 m and between axles on adjacent vehicles of not less than 2.30 m. Where rail smaller than 68 kg/m, or track moduli greater than 20 MPa are used in combination with these wheel spacings, the value of 1.25 is conservative. Conversely, a track modulus less than 20 MPa or closer wheel spacings may lead to  $F_1$  values greater than 1.25 and a full analysis of wheel interaction is required.

#### 4.6 QUASI-STATIC LATERAL WHEEL LOAD

Quasi-static lateral wheel load ( $P_{dL}$ ) shall be established from one of the following:

- (a) In-field measurements.
- (b) Calculated from the quasi-static vertical wheel load ( $P_{dV}$ ) as calculated using Clauses 4.3 and 4.4 and adjusted for the effect of curve radius by means of the  $L/V$  ratio as follows:

$$P_{dL} = P_{dV} \left( \frac{L}{V} \right) \quad \dots 4.6$$

where the  $L/V$  ratio shall be determined as follows (see Figure 4.1 for a graphic representation):

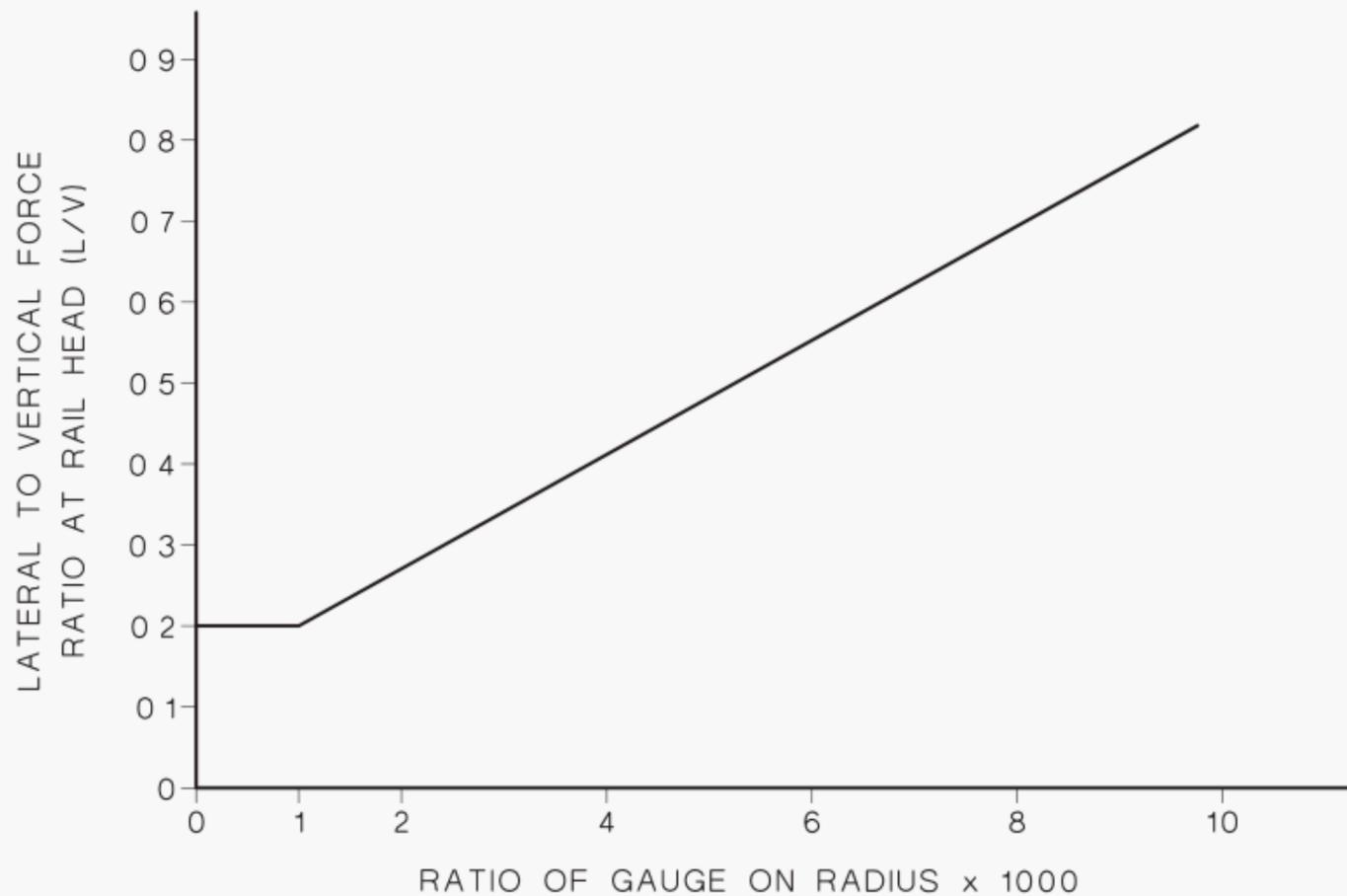
$$L/V = 0.13 + (0.07 G/r)$$

but not exceeding the range 0.2 to 0.8.

where

$G$  = track gauge, in millimetres

$r$  = curve radius, in metres



NOTE: For radii less than 200 m, in-field measurements are recommended.

NOTE: Gauge is in millimetres and radius is in metres.

FIGURE 4.1 L/V RATIO VERSUS RATIO OF GAUGE ON CURVE RADIUS

#### 4.7 QUASI-STATIC LATERAL RAIL SEAT LOAD

The quasi-static lateral rail seat load ( $R_L$ ) shall be calculated using the quasi-static lateral wheel load ( $P_{dL}$ ), which is adjusted for the distribution of the lateral load on the rail seat as follows:

$$R_L = F_3 P_{dL} \quad \dots 4.7$$

where

$F_3$  = distribution factor for lateral loads on the rail seat

NOTE: The factor  $F_3$  may be selected from direct field measurement or finite element modelling, or a nominal value of 0.75 may be used if the actual measurement is not available.

## SECTION 5 STRUCTURAL ANALYSIS

### 5.1 GENERAL

This Section gives methods for determining the bending stress, sleeper bending moment ( $M_d$ ) and the sleeper to ballast contact pressure. The Section does not include methods for designing the details of sleepers affected by fatigue and localized stress concentrations. The two methods given are the empirical method in Clause 5.4 or the BOEF method in Clause 5.5.

The empirical method is usually more conservative than the BOEF method.

Other methods of analysis may be used provided that they result in sleeper performance equal to or better than the performance resulting from the methods given in this Standard.

NOTE: A method for determining maximum sleeper spacing is given in Appendix H.

### 5.2 CORROSION AND WEAR

Allowance shall be made for corrosion and wear appropriate to the specified sleeper design life, climate and corrosive environment in track. Section properties for use in design shall be appropriate to the expected sleeper cross-section at the end of the specified sleeper design life. In the absence of site-specific data, corrosion rates may be estimated in accordance with AS 2312.

NOTE: Corrosion should be assumed from both top and bottom surfaces. Consideration of higher corrosion and wear rates may be necessary where sleepers are used with reactive ballast or in poor ballast conditions.

### 5.3 DESIGN BENDING STRESS

Maximum stresses in the sleeper due to bending generally occur in the sleeper toe. The magnitude of this stress shall be calculated from the following equation:

$$\sigma_d = M_d / Z_{\text{toe}} \quad \dots 5.3$$

where

$\sigma_d$  = design sleeper bending stress, in megapascals

$M_d$  = design sleeper bending moment, in kilonewton metres

$Z_{\text{toe}}$  = section modulus of sleeper toe about the horizontal neutral axis, in cubic millimetres

### 5.4 EMPIRICAL METHOD

#### 5.4.1 Ballast contact pressure

The average sleeper to ballast contact pressure, in kilopascals, shall be calculated from the following equations:

$$P_{\text{ab}} = \frac{R}{w10^{-3}(l-g)} F_2 \quad \dots 5.4(1)$$

or for narrow gauge,

$$P_{\text{ab}} = \frac{R}{w10^{-3}(l-g)0.8} F_2 \quad \dots 5.4(2)$$

where

$p_{ab}$  = average sleeper to ballast bearing (contact) pressure, in kilopascals

$R$  = design rail seat load, in kilonewtons

$w$  = maximum width of sleeper section, in millimetres

$l$  = sleeper length at centre-line, in metres

$g$  = distance between rail centres measured at the top of the rail, in metres

$F_2$  = factor depending on the standard of track maintenance

NOTE: Current experience indicates  $F_2 = 1$  is adequate.

#### 5.4.2 Bending moment calculation by the empirical method

An empirical method of calculating the sleeper design bending moment ( $M_d$ ) where  $M_d$  is taken as the greater of the values of  $M_R$ ,  $M_{C+}$  and  $M_{C-}$  is as follows:

(a) *Moments at rail seat* The maximum bending moment at the rail seat ( $M_R$ ) and the ballast support conditions may be calculated as follows:

(i) For standard gauge 1435 mm and broad gauge 1600 mm:

$$a = l - g \quad \dots 5.4(3)$$

$$M_R = R(l - g)/8 \quad \dots 5.4(4)$$

where

$a$  = length of ballast support, in metres

$l$  = length of sleeper, in metres

$g$  = distance between rail centres measured at the top of the rail, in metres (see Figure 1(a))

(ii) For narrow gauge 1067 mm:

$$a = 0.8(l - g) \quad \dots 5.4(5)$$

$$M_R = R(l - g)/6.4 \quad \dots 5.4(6)$$

(b) *Positive moments at the centre of the sleeper* The maximum positive moment at the centre of the sleeper ( $M_{C+}$ ) may be based on a pressure distribution beneath each rail seat as shown in Figure 5.1(a) and may be calculated as follows:

(i) *For standard gauge and broad gauge:*

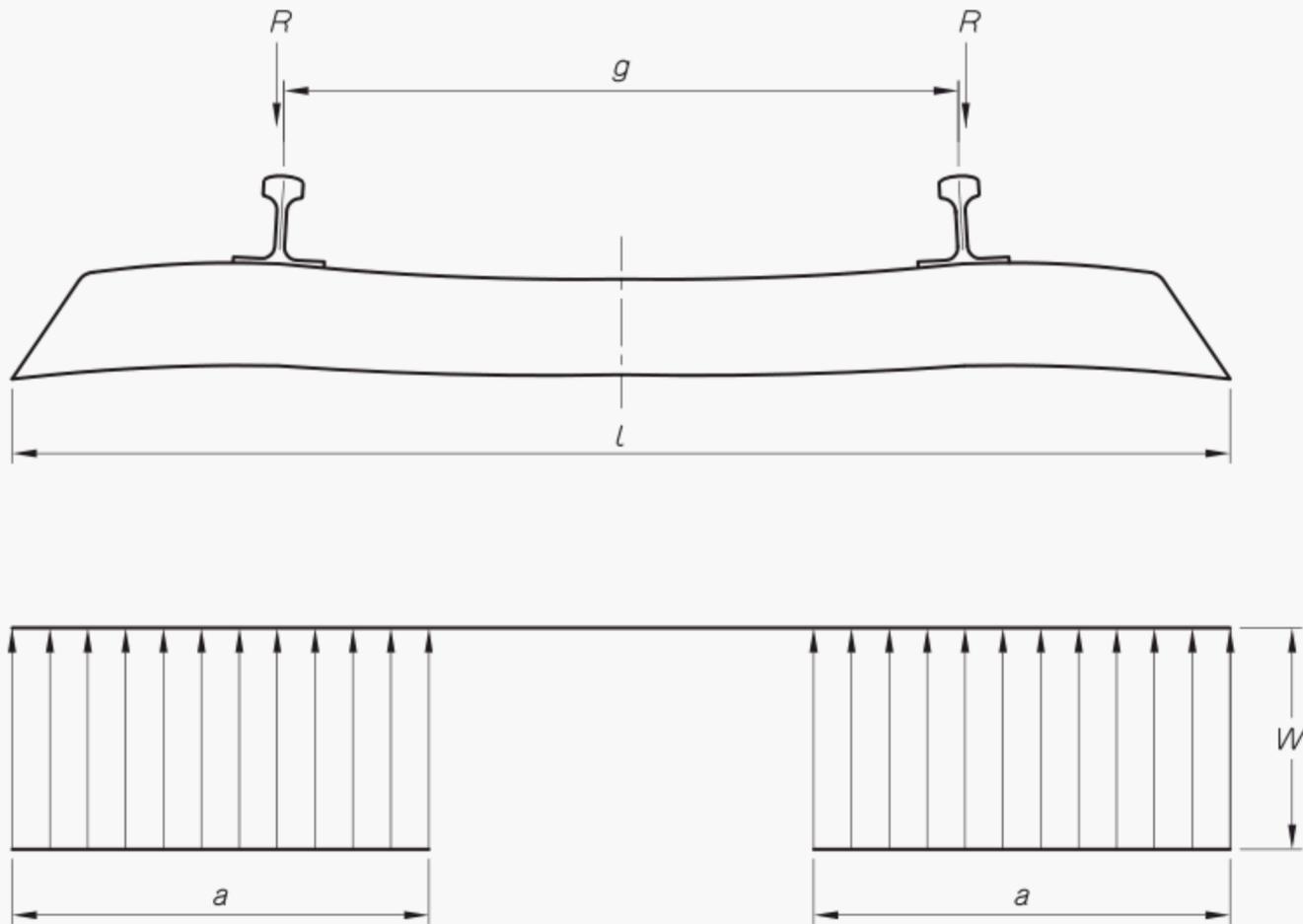
$$a = 0.9(l - g) \quad \dots 5.4(7)$$

$$M_{C+} = 0.05R(l - g) \quad \dots 5.4(8)$$

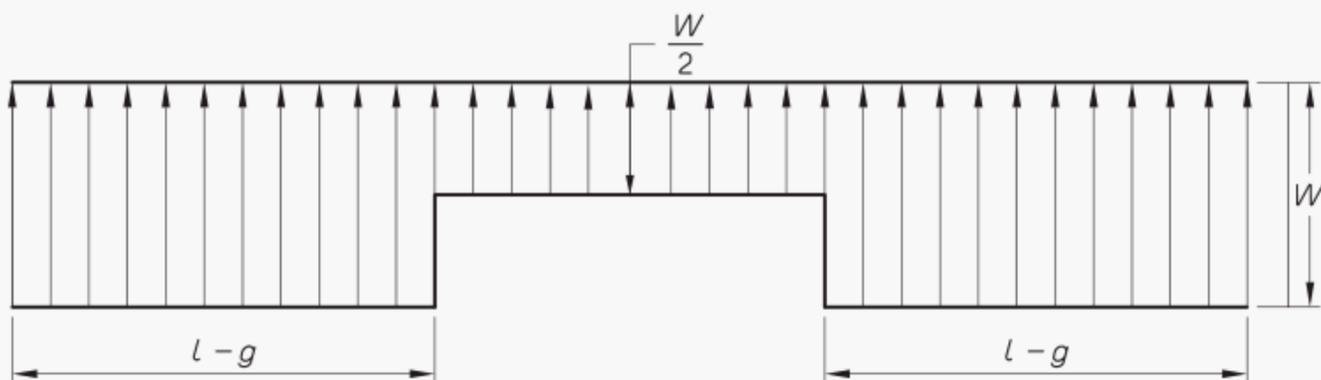
(ii) *For narrow gauge:*

$$a = 0.8(l - g) \quad \dots 5.4(9)$$

$$M_{C+} = 0.1R(l - g) \quad \dots 5.4(10)$$



(a) Pressure distribution for maximum positive rail seat and centre moments



(b) Pressure distribution for maximum centre moment (negative) for track gauge of 1600 mm and greater

FIGURE 5.1 PRESSURE DISTRIBUTION

- (c) *Negative moments at the centre of the sleeper* The maximum negative design moment at the centre of the sleeper ( $M_{C-}$ ) may be based on a pressure distribution beneath the sleeper for partially or totally centre bound conditions as shown in Figure 5.1(b) and may be calculated as follows:

- (i) *For broad gauge:*

$$M_{C-} = 0.5 \left[ Rg - Wg(l-g) - \frac{W(2g-l)^2}{8} \right] \quad \dots 5.4(11)$$

where

$$W = 4R/(3l - 2g)$$

(ii) For standard gauge:

$$M_{C-} = R(2g - l) / 4 \quad \dots 5.4(12)$$

(iii) For narrow gauge:

$$M_{C-} = M_R \quad \dots 5.4(13)$$

## 5.5 BEAM ON ELASTIC FOUNDATION (BOEF) METHOD

### 5.5.1 General

The calculations in this Clause give sleeper bending moment coefficients and sleeper deflections for determining bending moments and sleeper to ballast contact pressure. They are based on the BOEF analysis. Figure 5.2 shows schematically the case considered.

NOTE: The full derivation has been presented by HETENYI, M. *Beams on elastic foundation*. The University of Michigan Press: Ann Arbor, 1967, and represents the case of a finite beam loaded by two equal concentrated forces placed symmetrically (at the centre of the two rail seats).

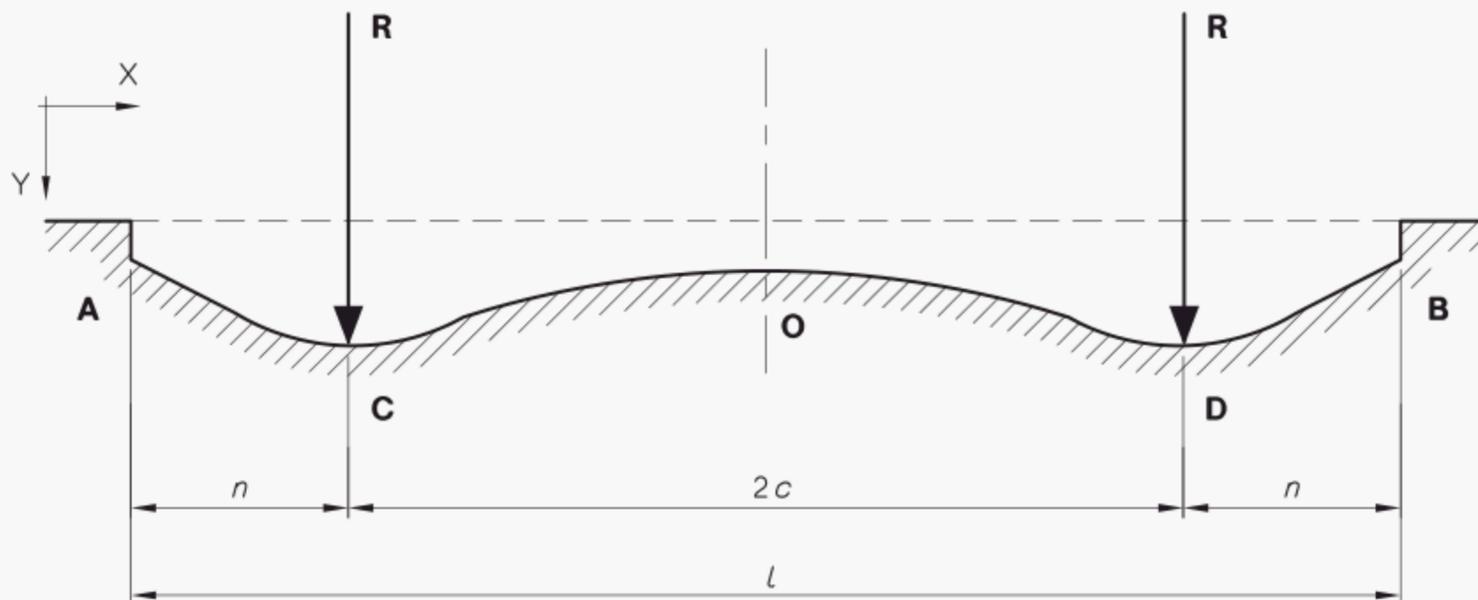


FIGURE 5.2 BOEF FORMULATION FOR SLEEPER MOMENTS AND DEFLECTION CALCULATIONS

### 5.5.2 Sleeper to ballast maximum contact pressure

The maximum sleeper deflection and, hence, sleeper to ballast contact stress occurs immediately beneath the rail seat and assumes a uniform contact pressure distribution over the estimated effective area of the sleeper for ease of calculations. The BOEF analysis gives the maximum contact pressure at the sleeper to ballast interface by the following equation:

$$\sigma_{\text{cont}} = \frac{y_{\text{max.}} U_s 10^3}{w} \quad \dots 5.5(1)$$

where

$\sigma_{\text{cont}}$  = maximum contact pressure at the sleeper to ballast interface, in kilopascals

$y_{\text{max.}}$  = maximum vertical sleeper deflection, in millimetres

$U_s$  = sleeper support modulus, megapascals

$w$  = maximum external width of sleeper section, in millimetres

It is noted that, in general, the sleeper support modulus is approximately half the track modulus. More accurate values can be computed by equating the track deflection defined in Clause 4.5 and the sleeper deflection at the rail seat given in Clause 5.5.3.

NOTE: In the case of a soft insulation pad, track deflection as described by the track modulus will exceed the sleeper deflection.

### 5.5.3 Sleeper stiffness and deflection

The sleeper stiffness may be computed by solving the following equation iteratively, equating the maximum sleeper deflection to the maximum track deflection by using Equations 4.5(3) and 4.5(4) as necessary:

$$y_{\max.} = \frac{R\lambda}{2U} \frac{1}{\sinh \lambda l + \sin \lambda l} \left[ 2 \cosh^2 \lambda n (\cos 2\lambda c + \cosh \lambda l) \right. \\ \left. + 2 \cos^2 \lambda n (\cosh 2\lambda c + \cos \lambda l) + \sinh 2\lambda n (\sin 2\lambda c - \sinh \lambda l) \right. \\ \left. - \sin 2\lambda n (\sinh 2\lambda c - \sin \lambda l) \right] \quad \dots 5.5(2)$$

where

- $y_{\max.}$  = maximum vertical track deflection, in millimetres
- $R$  = design rail seat load
- $U$  = track modulus, in megapascals
- $l$  = sleeper length at centre-line, in metres
- $c$  = dimension of sleeper from centre-line of rail seat to centre of sleeper, in metres
- $n$  = dimension from end (on centre-line at toe) to centre-line of rail seat, in metres
- $\lambda$  = sleeper stiffness parameter, in metres to the power of minus one  
 $= [U_s / (4E_s I_s)]^{0.25} \times 10^3$
- $U_s$  = sleeper support modulus, in megapascals
- $E_s$  = Young's modulus of sleeper material, in megapascals
- $I_s$  = sleeper moment of inertia about the horizontal neutral axis, in millimetres to the power of four

NOTE: Typical values for the sleeper support modulus ( $U$ ) lie in the range 10 MPa to 40 MPa.

### 5.5.4 Bending moment

Using the BOEF analysis, the design moment ( $M_d$ ) may be calculated from the following equation:

$$M_d = RC_{\text{BM}(\max.)} \quad \dots 5.5(3)$$

where

- $M_d$  = design sleeper bending moment, in kilonewton-metres
- $R$  = design rail seat load, in kilonewtons
- $C_{\text{BM}(\max.)}$  = maximum sleeper bending moment coefficient, in metres

Two equations are utilized in the derivation of the sleeper bending moment coefficients ( $C_{\text{BM}}$ ). One covers the region to the field side of the load source (region A-C in Figure 5.2), and is used to determine the moment coefficient adjacent to the rail foot ( $C_{\text{BM}(n)}$ ). The second covers the midpoint of the sleeper (location 0) and is used to determine the bending moment at the sleeper centre ( $C_{\text{BM}(0)}$ ). Although larger bending moments will be computed immediately beneath the load source (due to the assumption of a point load), these values will in practice be reduced due to the rail foot distributing the load.

The value of  $C_{\text{BM(max.)}}$  for use in calculating  $M_d$  is the larger of  $C_{\text{BM(0)}}$ , and  $C_{\text{BM(n)}}$ , which shall be calculated as follows:

(a) Bending moment along portion A-C ( $x$  varies from 0 to  $n$ )—

$$C_{\text{BM}(x)} = \frac{1}{2\lambda} \frac{1}{\sinh \lambda l + \sin \lambda l} \left\{ 2 \sinh \lambda x \sin \lambda x \left[ \cosh \lambda n \cos \lambda(l-n) \right. \right. \\ \left. \left. + \cosh \lambda(l-n) \cos \lambda n \right] + (\cosh \lambda x \sin \lambda x \right. \\ \left. - \sinh \lambda x \cos \lambda x) \left[ \cosh \lambda n \sin \lambda(l-n) - \sinh \lambda n \cos \lambda(l-n) \right. \right. \\ \left. \left. + \cosh \lambda(l-n) \sin \lambda n - \sinh \lambda(l-n) \cos \lambda n \right] \right\} \quad \dots 5.5(4)$$

(b) Bending moment at sleeper centre ( $x = l/2$ )—

$$C_{\text{BM}(0)} = \frac{1}{2\lambda} \frac{1}{\sinh \lambda l + \sin \lambda l} \left\{ \sinh \lambda c \left[ \sin \lambda c + \sin \lambda(l-c) \right] \right. \\ \left. + \sin \lambda c \left[ \sinh \lambda c + \sinh \lambda(l-c) \right] \right. \\ \left. + \cosh \lambda c \cos \lambda(l-c) - \cos \lambda c \cosh \lambda(l-c) \right\} \quad \dots 5.5(5)$$

where

- $C_{\text{BM}(x)}$  = sleeper bending moment coefficient covering the region to the field side of the rail seat, in metres
- $C_{\text{BM}(0)}$  = bending moment coefficient at sleeper midpoint, in metres
- $x$  = distance from sleeper end, in metres

APPENDIX A  
INFORMATION TO BE PROVIDED BY PURCHASER AND SUPPLIER  
(Informative)

**A1 GENERAL**

This Appendix contains guidance on the information that should be provided by the purchaser and supplier, and includes forms for providing information on fastening systems.

**A2 INFORMATION TO BE PROVIDED BY THE PURCHASER**

The following information should be provided by the purchaser:

- (a) The number of this Australian Standard, i.e., AS 1085.17.
- (b) General information, as follows:
  - (i) Name of railway system.
  - (ii) Section or sections of track where steel sleepers are to be installed.
  - (iii) Expected life before replacement
  - (iv) Proposed track standard or Eisenmann track condition factor ( $\delta$ ).
  - (v) Maximum gradient.
  - (vi) Design curve radii, including respective super elevation and speed envelopes for each curve.
  - (vii) Insulation requirements for and type of track signal circuits.
  - (viii) Voltage of traction supply if traffic is electrified.
  - (ix) Geographic and climatic extremes.
  - (x) Factors that may affect the corrosion rate of the sleepers.
  - (xi) Requirements for inspection holes.
- (c) Traffic information, as follows:
  - (i) Annual gross tonnage, in million gross tonnes per year.
  - (ii) Maximum static axle load, in tonnes.
  - (iii) The traffic mix as a combination of static wheel loads, in tonnes, and maximum train speeds, in kilometres per hour.
  - (iv) Centre of gravity of vehicle types above top of running rail.
- (d) Track information, as follows:
  - (i) Nominal track gauge.
  - (ii) Rail size.
  - (iii) Nominal cant of rails.
  - (iv) Depth of ballast.
  - (v) Type and quality of ballast.
  - (vi) Quality of formation.
  - (vii) Track modulus ( $U$ ).

- (viii) Minimum value of lateral track stability in kilonewtons per panel of three sleepers (see Clause 2.3.3).
- (ix) Installation requirements.
- (e) Sleeper assembly design information, as follows:
  - (i) Sleeper spacing.
  - (ii) Minimum length of sleeper and any additional limits on cross-sectional dimensions not given in Appendix D.
  - (iii) Sleeper design life.
  - (iv) Lateral load and vertical load, in kilonewtons (see Section 4).
  - (v) Design lateral-to-vertical-force ratio ( $L/V$ ).
  - (vi) Where appropriate, minimum clamping force (toe load) on one rail seat, in kilonewtons.  
NOTE: See AS 1085.19 for requirements for resilient fastening assemblies.
  - (vii) Requirements for type of pad for fastening assembly.
  - (viii) Where appropriate, insulation requirements and level of resistivity, in ohms (where different to that established by AS 1085.19).
- (f) Packaging information, as follows:
  - (i) Maximum weight of sleeper bundles.
  - (ii) Number of sleepers per bundle.
  - (i) Rail wagon loading details.
  - (ii) Associated fastenings packaging requirements.
- (g) *Additional information* The purchaser should ensure that, in addition to the information set out above, all other matters and options included in this Australian Standard are specified to the manufacturer to permit the design, manufacture and testing of a suitable sleeper and fastening assembly for the particular purpose required.

### **A3 INFORMATION TO BE PROVIDED BY THE SUPPLIER**

The following information should be provided by the supplier:

- (a) Schedule of technical data specifying sleeper shape and dimensions including end details (spade).
- (b) The standard and grade of all materials to be used in the manufacture of sleepers if other than basic materials are to be used.
- (c) The calculated maximum mass of the sleeper.
- (d) Where appropriate, fastening details including the rail fastening clip deflection range.  
NOTE: AS 1085.19 gives appropriate data sheets for presenting test results and performance histories of fasteners.
- (e) The place of manufacture.
- (f) Methods of manufacture sampling and testing.
- (g) Technical calculations.
- (h) Test results and reports.
- (i) Safety instructions including sleeper handling and installation and safe fastening installation procedures.

APPENDIX B  
MEANS FOR DEMONSTRATING COMPLIANCE WITH THIS STANDARD  
(Informative)

### **B1 SCOPE**

This Appendix sets out the following different means by which compliance with this Standard can be demonstrated by the manufacturer or supplier:

- (a) Evaluation by means of statistical sampling.
- (b) The use of a product certification scheme.
- (c) Assurance using the acceptability of the supplier's quality system.
- (d) Other such means proposed by the manufacturer or supplier and acceptable to the customer.

### **B2 STATISTICAL SAMPLING**

Statistical sampling is a procedure that enables decisions to be made about the quality of batches of items after inspecting or testing only a portion of those items. This procedure will only be valid if the sampling plan has been determined on a statistical basis and the following requirements are met:

- (a) The sample needs to be drawn randomly from a population of product of known history. The history needs to enable verification that the product was made from known materials at essentially the same time, by essentially the same processes and under essentially the same system of control.
- (b) For each different situation, a suitable sampling plan needs to be defined. A sampling plan for one manufacturer of given capability and product throughput may not be relevant to another manufacturer producing the same items.

In order for statistical sampling to be meaningful to the customer, the manufacturer or supplier needs to demonstrate how the above conditions have been satisfied. Sampling and the establishment of a sampling plan should be carried out in accordance with AS 1199, guidance to which is given in AS 1399.

### **B3 PRODUCT CERTIFICATION**

The purpose of product certification is to provide independent assurance of the claim by the manufacturer that products comply with the stated Standard.

The certification scheme should meet the criteria described in HB 18.28 in that, as well as full type testing from independently sampled production and subsequent verification of conformance, it requires the manufacturer to maintain effective quality planning to control production.

The certification scheme serves to indicate that the products consistently conform to the requirements of the Standard.

#### **B4 SUPPLIER'S QUALITY MANAGEMENT SYSTEM**

Where the manufacturer or supplier can demonstrate an audited and registered quality management system complying with the requirements of the appropriate or stipulated Australian or international Standard for a supplier's quality management system or systems, this may provide the necessary confidence that the specified requirements will be met. The quality assurance requirements need to be agreed between the customer and supplier and should include a quality or inspection and test plan to ensure product conformity.

Information on establishing a quality management system is set out in AS/NZS ISO 9001 and AS/NZS ISO 9004.

#### **B5 OTHER MEANS OF ASSESSMENT**

If the above methods are considered inappropriate, determination of compliance with the requirements of this Standard may be assessed from the results of testing coupled with the manufacturer's guarantee of product conformance.

Irrespective of acceptable quality levels (AQLs) or test frequencies, the responsibility remains with the manufacturer or supplier to supply products that conform to the full requirements of the Standard.

APPENDIX C  
SPECIAL SLEEPERS AND FASTENINGS  
(Informative)

## C1 GENERAL

Special sleepers and fastenings should conform to the requirements set out in Section 2 of this Standard and with the additional requirements given in this Appendix. Special sleeper types include the following:

- (a) Dual gauge sleepers.
- (b) Turnout bearers.
- (c) Sleepers with additional rails (other than dual gauge sleepers).

## C2 SPECIAL SLEEPER TYPES

### C2.1 Dual gauge sleepers

Dual gauge sleepers enable two separate groups of rolling stock, each with its own identifiable wheel gauge, to run on the same track. Each sleeper has fastenings to accommodate three rails (see Figure C1).

### C2.2 Turnout bearers

A turnout consists of a number of bearers of varying lengths. Rails are readily secured to the bearers at predetermined fastening locations to enable one track to be connected to an adjacent track.

Where parallel tracks are to be connected, a crossover consisting of two turnouts of the same orientation (either both left-handed or both right-handed) is used. A crossover may have discontinuous bearers midway along the connection or it may have bearers that are continuous through both parallel tracks.

A turnout normally has zero cant and typically consists of about 70 individual bearers each varying from its neighbouring bearers in length and in fastening locations. Transition sleepers with varying cants may be required to connect turnouts to canted track.

### C2.3 Sleepers with additional rails

#### C2.3.1 *General*

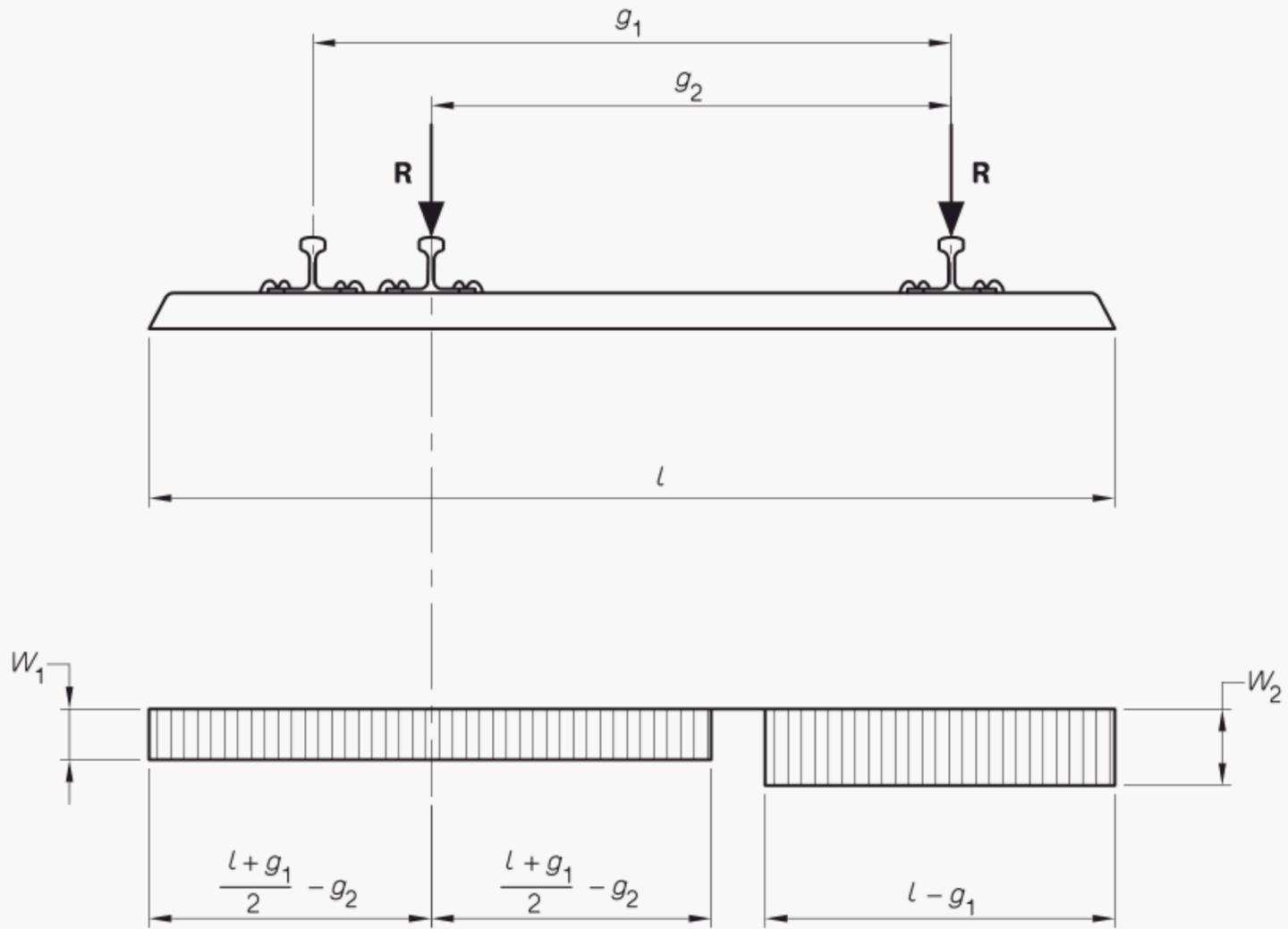
There are two types of sleepers that require additional rails that are not traversed by the wheels of railway vehicles. They are guardrail sleepers and splay rail sleepers.

#### C2.3.2 *Guardrail sleepers*

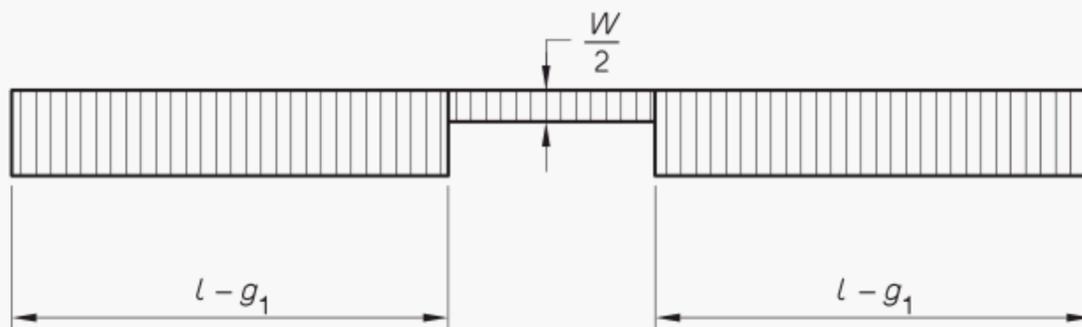
A guardrail sleeper has provision for fastening parallel rails in the centre of the sleeper (see Figure C2) in a manner so that derailed wheels are prevented from moving further than the edge of the fastened guardrail. This system may prevent or minimize damage to a bridge structure.

#### C2.3.3 *Splay rail sleepers*

A set of splay rail sleepers consists of a number of sleepers of variable lengths that facilitate connection of special rails to guide derailed wheels into the guardrails provided on sleepers. A typical layout of guardrail and splay rail sleepers is shown in Figure C3.



(a) Maximum positive rail seat moment



(a) Maximum negative rail seat moment

FIGURE C1 PRESSURE DISTRIBUTION FOR DUAL GAUGE SLEEPER

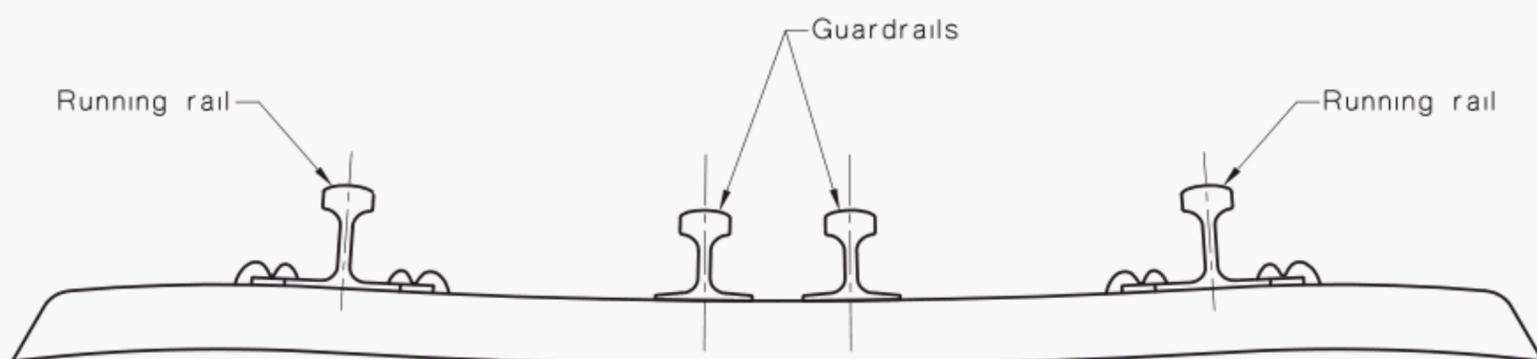


FIGURE C2 TYPICAL GUARDRAIL SLEEPER

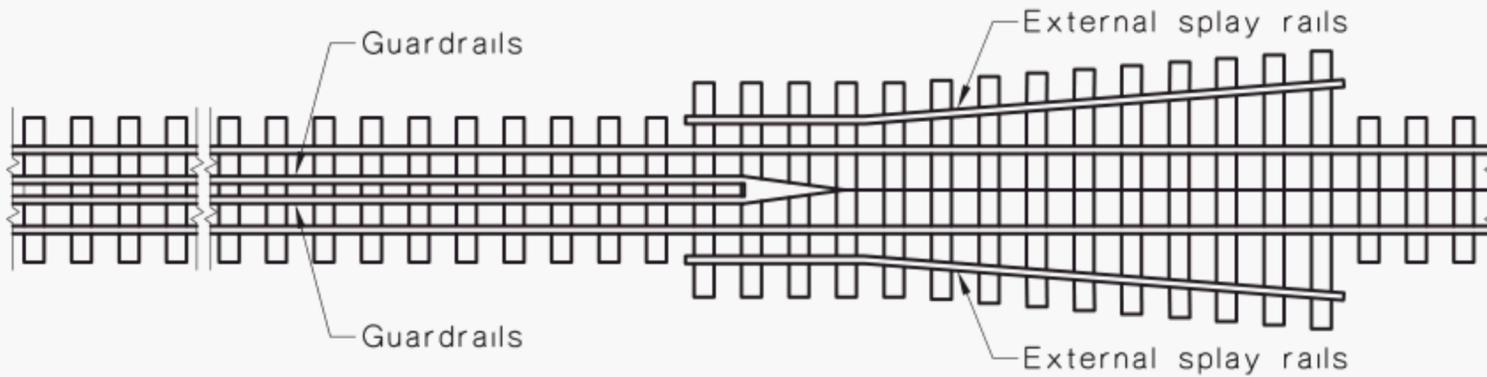


FIGURE C3 TYPICAL SPLAY RAILS AND GUARDRAILS

### C3 MANUFACTURING DETAILS

Because of the specialized nature of turnout bearers, splay rail sleepers and guardrail sleepers, the manufacturing procedure may be different from that for main line sleepers; however, it is common practice to modify main line sleepers to produce guardrail sleepers.

As each bearer or sleeper forms part of a set in turnouts or splay rail sets, it should be clearly branded to indicate its position and orientation in the set.

A trial assembly should be carried out on the first set of bearers or sleepers with the rails, plates and fastenings specified by the purchaser to ensure that all components fit together as intended and that basic track parameters such as gauge comply with the purchaser's requirements and the specified tolerances.

### C4 LOADINGS AND DESIGN

#### C4.1 Dual gauge sleepers

Examples of the load distributions for dual gauge sleepers are shown in Figure C1(a) and C1(b). These examples apply to dual gauge track with the narrower gauge greater than or equal to 1435 mm.

From the load distributions shown in Figure C1(a) and C1(b), the design moment equations for dual gauge with a narrower gauge of 1435 mm or greater are as follows:

$$M_{R+} = 0.25R ((l + g_1)/2 - g_2) \quad \dots \text{C4(1)}$$

$$M_{C-} = 0.5[Rg_1 - (Wg_1(l - g_1)) - W(2g_1 - l)^2 / 8] \quad \dots \text{C4(2)}$$

$$M_{C+} = 0.05R(l - g_2) \quad \dots \text{C4(3)}$$

where

$$W = 4R/(3l - 2g_1) \quad \dots \text{C4(4)}$$

For dual gauge track with a track gauge less than 1435 mm, allowance should be made for variations in the load distribution and design moment equations similar to those detailed for single gauge track in Clause 4.3.

#### C4.2 Turnouts and crossovers

A turnout bearer is a member of a complex grillage system in which rails are connected by elastic fastenings to bearers that are supported on a non-rigid foundation. This affects the loadings for such bearers.

NOTE: The following guidelines may be used for making an assessment of forces and moments where more detailed mathematical methods are not available:

- (a) *Distribution of axle load* The same method as used for standard sleepers may be adopted.

- (b) *Impact factor* In order to allow for quasistatic loading, the bearer should be designed as specified for standard sleepers.
- (c) *Centrifugal force* The effects of centrifugal force should be allowed for on the curved pair of rails.
- (d) *Other forces* Forces and moments from points motors and other equipment should be allowed for where appropriate.
- (e) *Load distribution* The method of distribution of the forces from rails and crossings should be specified by the purchaser.
- (f) *Support conditions* Generally, it may be assumed that the bearer will be supported over its whole length by tamped ballast. Exceptions may occur such as where a bearer extends beyond the ballast shoulder to carry points-operating equipment.

Moments and shears should be calculated assuming that the ballast and subgrade behave as an elastic foundation.

The foundation modulus may be calculated in accordance with the recommendations given in *A review of track design procedures*, Volumes 1 and 2, Australasian Railways Association, 1991.

In very poor ground or formation, consideration should be given to improving the subgrade in the area of the turnout to reduce the magnitude of the induced bending moments. Field testing is also used to confirm assumptions.

- (g) *Shear forces and bending moments* The values obtained from the above assumptions should be used to produce design bending moments and shear force envelopes for the bearer; however, in some cases this analysis may yield small values of negative (hogging) bending moment.

#### **C4.3 Sleepers with additional rails (other than dual gauge sleepers)**

Guardrail sleepers and splay rail sleepers are both likely to suffer impact from the wheels of derailed vehicles.

Forces arising from this impact are very difficult to quantify. It is suggested that sleepers be designed for loads from derailed wheels equivalent to at least twice the static wheel load, but designers may use their own judgement in this matter.

Sleepers with additional rails should be designed on the same basis as the turnout sleepers but with allowance for forces from derailed vehicles also acting on the guardrails and splay rails. Ballast under these sleepers should be assumed to be uniformly tamped and the design sleeper moments calculated accordingly.

### **C5 FASTENINGS**

Fastenings discussed in this Appendix include elastic resilient fastenings as well as cast iron or formed steel hook-in shoulders or bolts to secure plates.

Where plates are specified to hold the rails, the methods of attaching plates to sleepers and rails to plates should be specified.

Insulation, where required should conform to the requirements of Section 2 of this Standard.

Plates may be secured by two or four bolt systems. Bolts pass through the top of the sleeper and engage nuts welded underneath.

### **C6 TESTING**

#### **C6.1 General**

Testing should be carried out in accordance with the provisions of Section 2.

### **C6.2 Additional fastening tests**

In addition to fastening types covered in Section 3 of this Standard, sleepers covered by this Appendix may have fastenings of the types described in Paragraph C5.

Additional tests may be required by the purchaser (see also AS 1085.19).

NOTE: Evidence of adequate performance may be negotiated between the supplier and the purchaser.

APPENDIX D  
SLEEPER SHAPE  
(Normative)

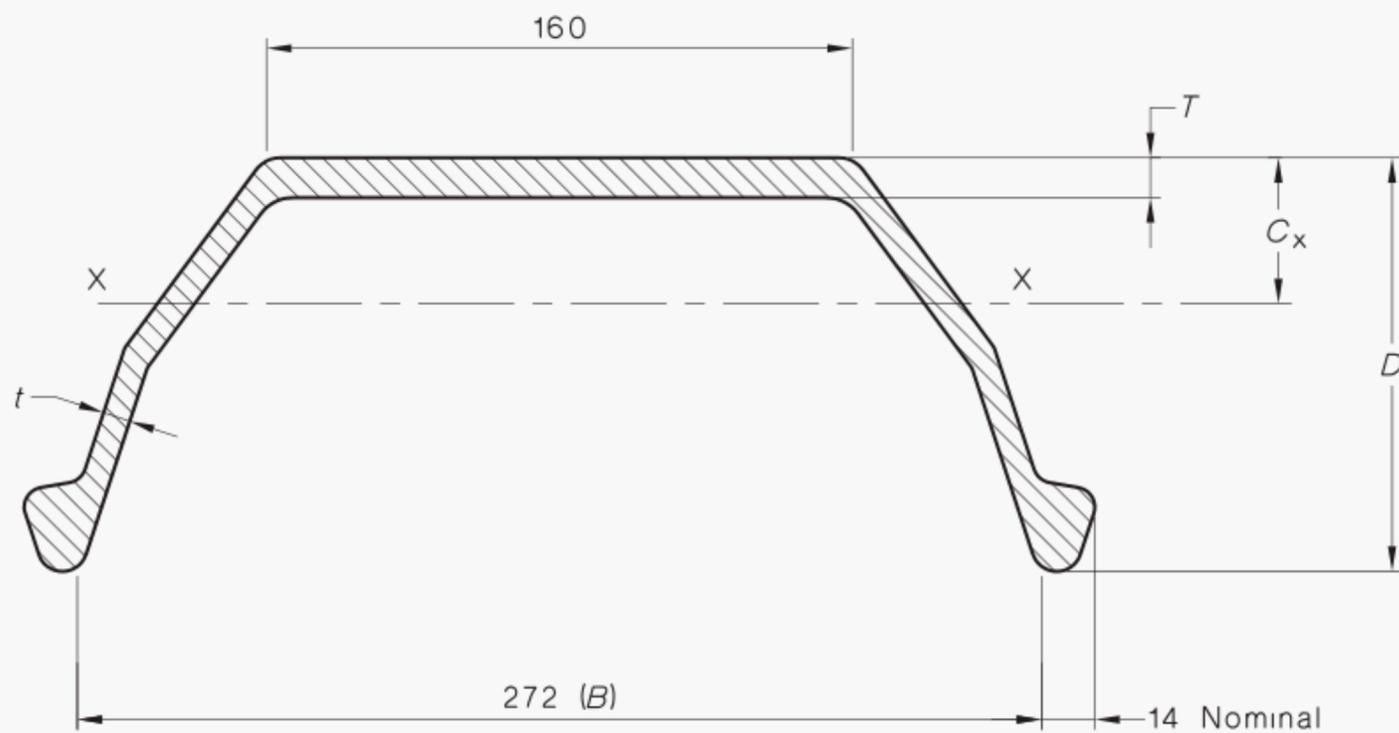
**D1 GENERAL**

This Appendix sets out requirements for sleeper cross-sections in Figures D1 and D2, end details in Paragraph D2 and tolerances in Table D1 and Figure D3.

**D2 END DETAILS**

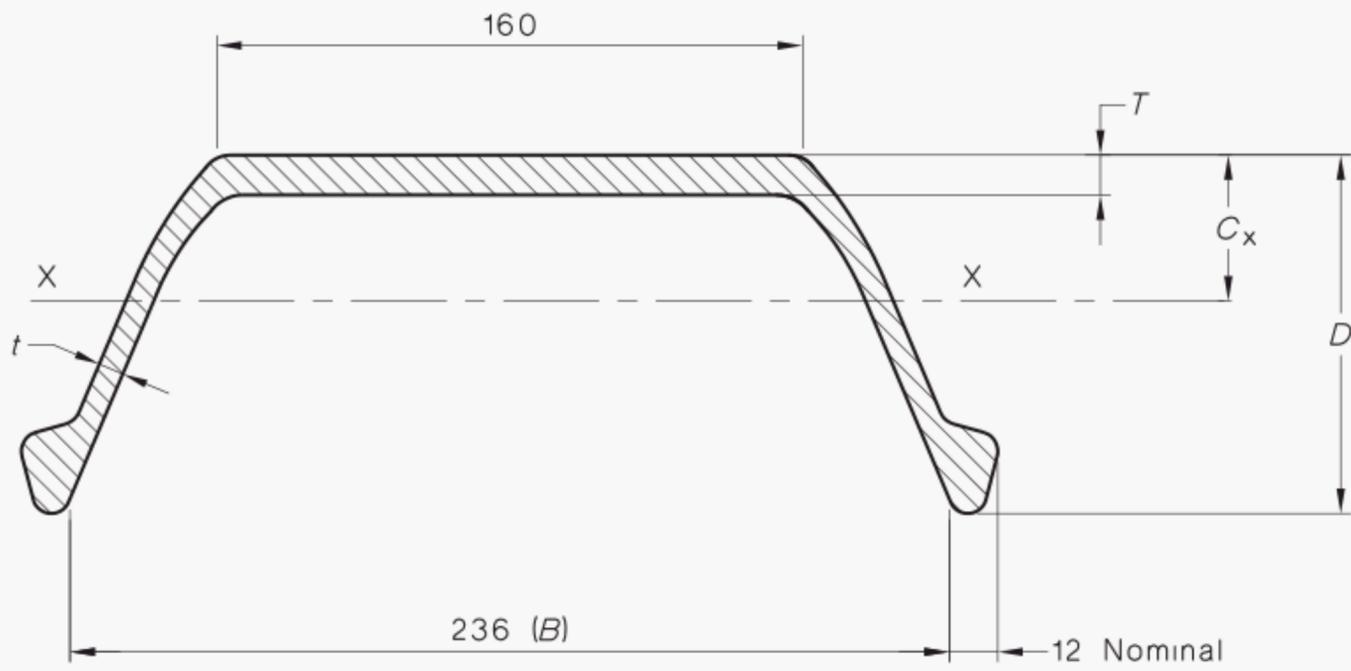
Ends shall be folded down (spaded) to a depth not less than the depth of the sleeper. Each spade angle along the sleeper centre-line shall be not greater than 30 degrees from the vertical.

NOTE: End spading details will typically govern the lateral stability performance of the sleeper and effect ballast containment and vibration performance.



Heavy duty designation	Nominal mass per unit length	Nominal area of cross-section	Nominal thickness		Nominal depth	Nominal geometric properties of section		
			$T$	$t$		$D$	$I_{s(new)}$	$Z_{toe}$
mm	kg/m	mm <sup>2</sup>	mm	mm	mm	10 <sup>6</sup> mm <sup>4</sup>	10 <sup>3</sup> mm <sup>3</sup>	mm
W9	28.1	2581	9.0	6.0	117	5.68	74.14	40.33
W10	30.5	3884	10.0	6.3	118	6.12	78.52	40.10
W12	35.3	4490	12.0	7.0	120	6.98	87.27	39.96
W14	40.0	5098	14.0	7.7	122	7.86	95.99	40.12

FIGURE D1 HEAVY DUTY STEEL SLEEPER DETAILS



General duty designation	Nominal mass per unit length	Nominal area of cross-section	Nominal thickness		Nominal depth	Nominal geometric properties of section		
			$T$	$t$		$D$	$I_{s(new)}$	$Z_{toe}$
mm	kg/m	mm <sup>2</sup>	mm	mm	mm	10 <sup>6</sup> mm <sup>4</sup>	10 <sup>3</sup> mm <sup>3</sup>	mm
M6.5	19.5	2478	6.7	5.1	97.2	2.73	41.88	32.06
M7.5	21.1	2687	7.5	5.4	98.0	2.94	44.40	31.71
M8.5	23.1	2948	8.5	5.7	99.0	3.22	47.61	31.43
M10	26.2	3341	10.0	6.2	100.5	3.64	52.56	31.26

FIGURE D2 GENERAL DUTY STEEL SLEEPER DETAILS

**TABLE D1**  
**PERMISSIBLE TOLERANCES FOR SLEEPERS**

Characteristic	Tolerance
(a) Overall length of sleeper	$\pm 10$ mm
(b) Individual cross-sectional dimensions of sleepers other than those specified in Items (c), (d) and (e)	$\pm 3$ mm
(c) Internal width of sleeper at the section toe, <i>B</i>	$\pm 5$ mm
(d) Overall depth of sleeper section, <i>D</i>	$\pm 2$ mm
(e) Thickness of the sleeper top, <i>T</i>	$+0.5$ mm, $-0.3$ mm
(f) Inward cant of rail seats: (i) hot-pressed (ii) cold-pressed	$\pm 0.5^\circ$ $\pm 0.2^\circ$
(g) Rail seat flatness* (no convexity allowed)  Note: Where this tolerance is not met by special sleepers such as turnout and splay bearers (see Appendix C), the flatness may be agreed with the purchaser.	0.0 to 1.0 mm
(h) Differential tilt angle of rail seats in the direction of rail	$\pm 0.6^\circ$
(i) Track gauge, measured between gauge points of rails with the rail placed hard against the outer shoulder (see Figure D3)	$\pm 2$ mm
(j) Distance between inside walls of inner and outer shoulders of each rail measured 2 mm above the rail seat	$+1.0$ mm, $-0.0$ mm
(k) Inside walls of inner and outer housings of each rail seat to be parallel to longitudinal axis of each rail	$\pm 0.2^\circ$
(l) Sleeper longitudinal straightness (over the nominally straight portion in plan view)	6 mm/m
(m) Distance between outer edges of external fixing holes	$\pm 1$ mm
(n) Distance between outer edges of fixing holes of the same rail seat	$\pm 0.5$ mm

\* Flatness tolerance shall be measured in accordance with AS/NZS 1100.101.

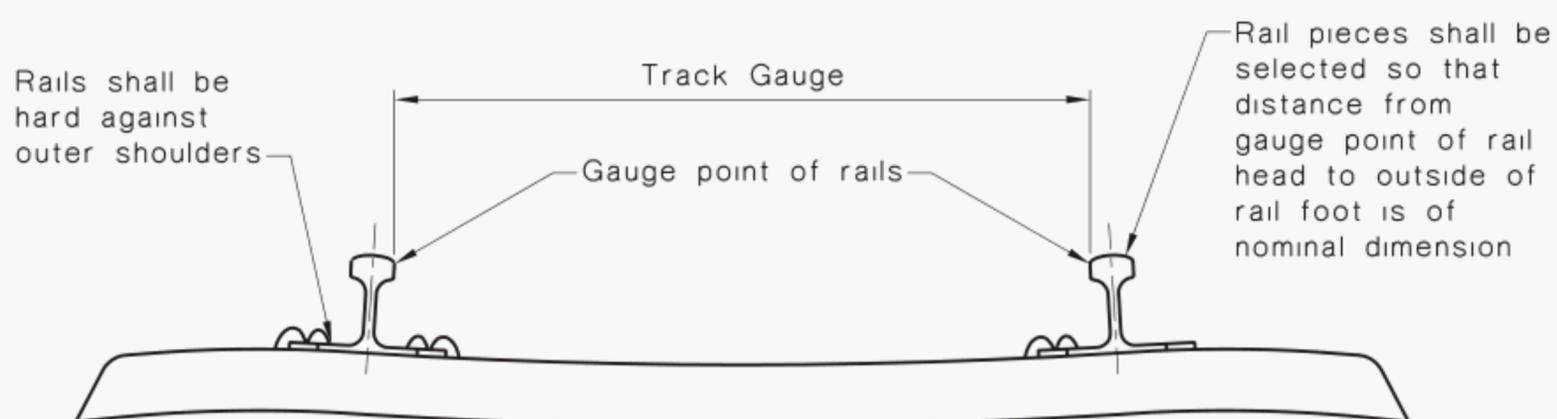


FIGURE D3 MEASUREMENT OF TRACK GAUGE

APPENDIX E  
TRACK PANEL ASSEMBLY TEST  
(Normative)

**E1 SCOPE**

This Appendix sets out the method of testing six assembled sleepers and their components by assembling them together with rails to ensure that basic track parameters such as track gauge are met. Assembly procedures may also be evaluated using this test.

**E2 APPARATUS**

The following apparatus is required:

- (a) 6 steel sleepers.
- (b) 12 sets of rail fastening assemblies including pads.
- (c) 2 rails, each 4 m long.

**E3 PROCEDURE**

The procedure shall be as follows:

- (a) Assemble a track panel consisting of two rails of the appropriate rail profile and of suitable length and six sleepers with the fastening assemblies and any other components to be supplied. All components used to assemble the track panel shall be shown to be of nominal dimensions except the sleepers being tested.
- (b) Check the assembly to ensure that all components of the assembly fit together as intended and that basic track parameters such as track gauge are met.
- (c) Compare the assembled track panel against the design and ensure that the requirements of the purchaser are met.
- (d) Measure the track gauge achieved by the rail (see Figure D3).

**E4 REPORT**

The following shall be reported:

- (a) Any parameters that fail to comply with the design.
- (b) The measured track gauge.
- (c) The number of this Australian Standard, i.e., AS 1085.17.

APPENDIX F  
RAIL SEAT ASSEMBLY REPEATED LOAD TEST  
(Normative)

**F1 SCOPE**

This Appendix sets out the method of conducting the rail seat assembly repeated load test.

**F2 APPARATUS**

The following apparatus is required:

- (a) A length of the specified rail section (for lateral-to-vertical force ratios above 0.6, part or all of the rail head and part of the web may require removal to prevent rail rollover).
- (b) A segment of the sleeper including a rail seat with dimensions as shown in Figure F1.
- (c) A set of the appropriate rail fastening components including shoulders, clips, insulation and spacers as required.
- (d) Crack detection kit.
- (e) Wire brush.
- (f) Test rig as shown in Figure F2.

**F3 PROCEDURE**

The procedure shall be as follows:

- (a) Wire brush the piece of rail section and sleeper to remove all loose millscale and foreign matter.
- (b) Inspect the sleeper to ensure that it is free of any original cracking by checking the sleeper, its shoulder and rail seat regions for cracking by using suitable crack detection techniques, such as dye penetrant or magnetic particle techniques in accordance with AS 1171.
- (c) Assemble all new components.
- (d) Set up the test assembly in the test rig.
- (e) Apply a cyclic downward load over a range equal to the resultant of the specified lateral and vertical loads. No uplift loading is required.
- (f) Load the sleeper for a minimum *total* of three million cycles (3 000 000) at a maximum frequency of 10 Hz.  
NOTE: One cycle consists of a downward and upward loading.
- (g) Carry out periodic inspection of the sleeper every 500 000 cycles as specified in Step (b).
- (h) Examine fastening components including pads for cracking and other damage.

**F4 REPORT**

The following shall be reported:

- (a) Identification of the sleeper and its components (e.g., fastening and hole spacing where applicable).

- (b) Loading and lateral-to-vertical force ratio used for the test.
- (c) Fatigue cracking or other failure of any component (e.g. rail insulation pads) and when occurred.

NOTE: Undue wear of the insulation pad can result in loosening of the fastening due to changes in the operating range.

- (d) Any additional information as required by the purchaser.
- (e) The apparatus used.
- (f) The name of the operator.
- (g) The number of cycles at which failure occurred.
- (h) The number of this Australian Standard, i.e., AS 1085.17.

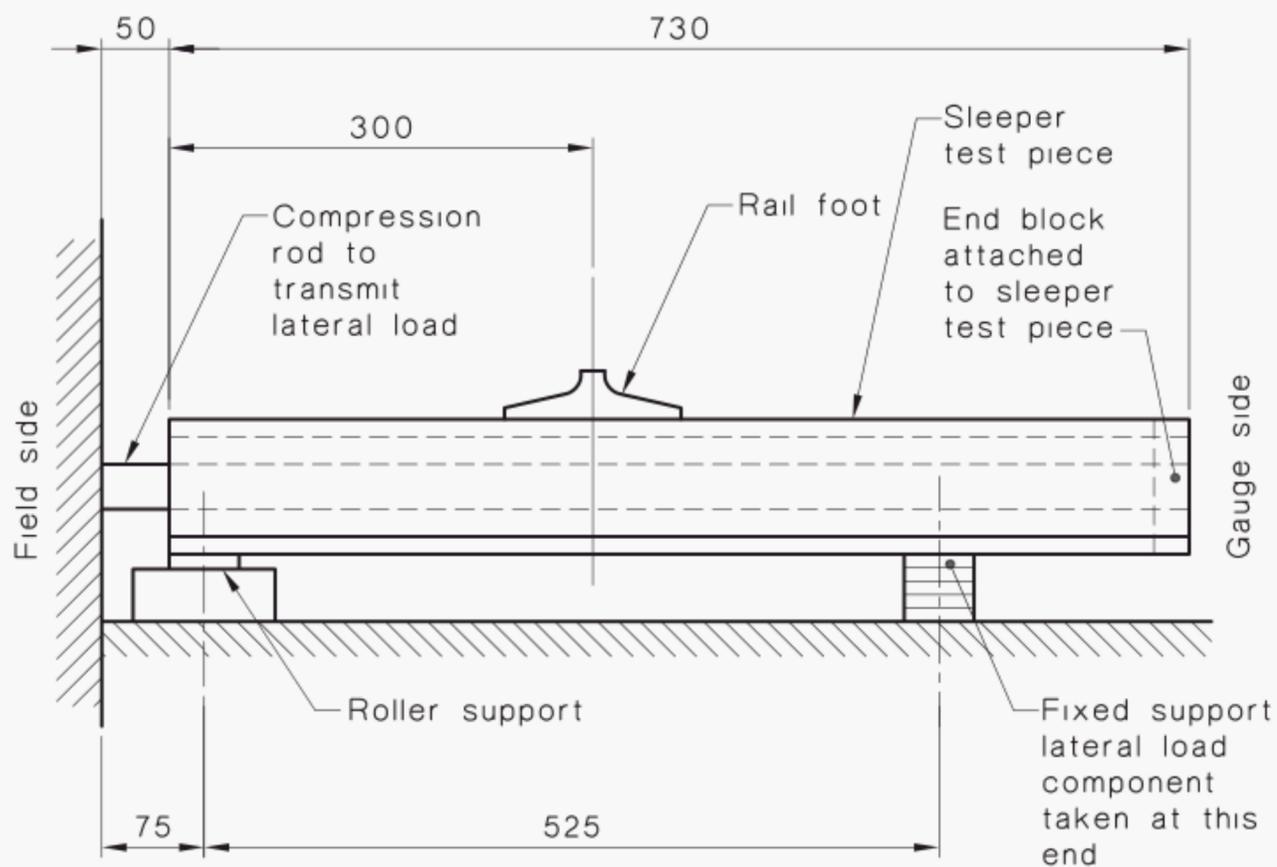


FIGURE F1 RAIL SEAT REPEATED LOAD TEST SLEEPER TEST PIECE SET-UP

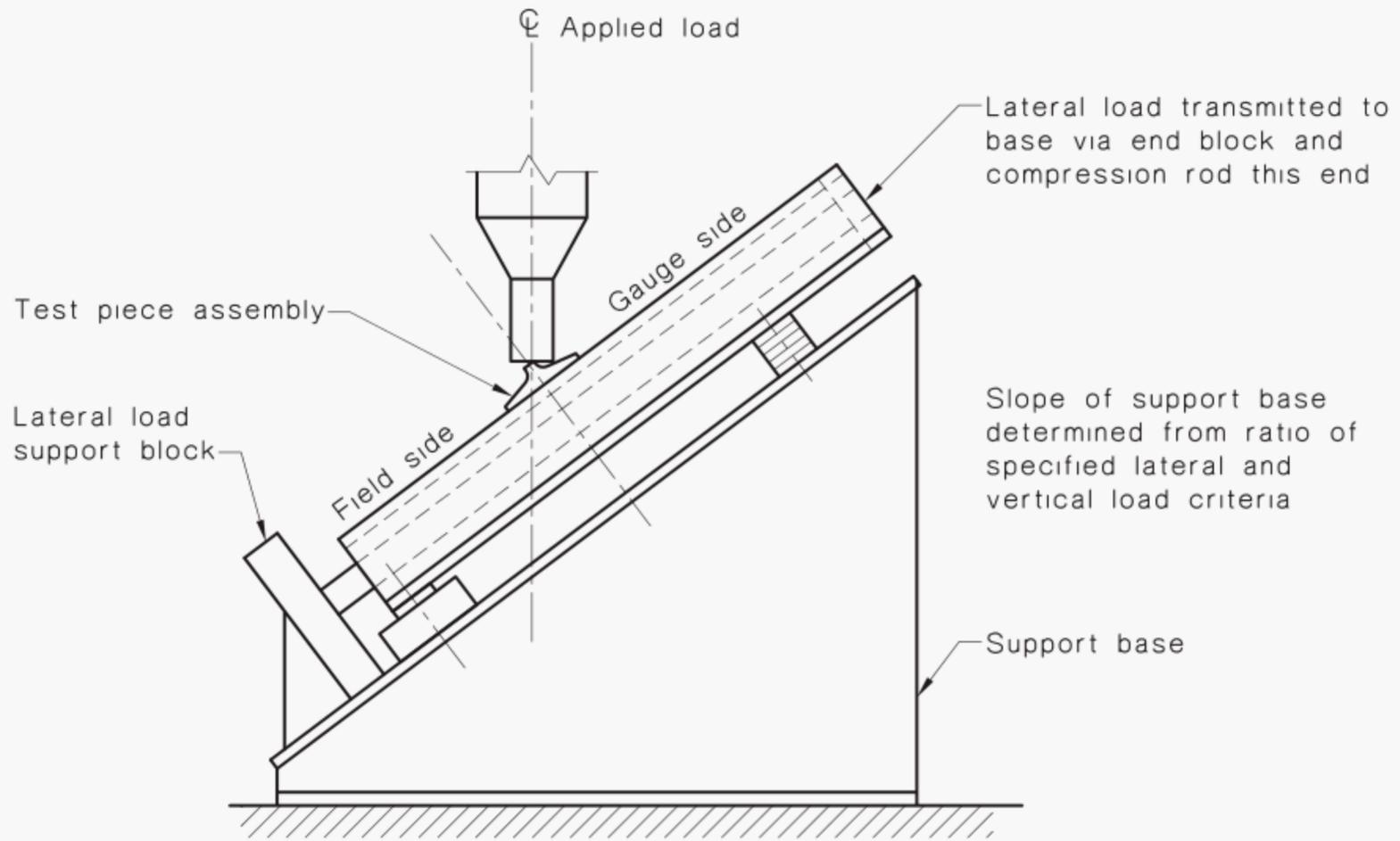


FIGURE F2 RAIL SEAT REPEATED LOAD TEST RIG ASSEMBLY

APPENDIX G  
LATERAL STABILITY TEST  
(Normative)

**G1 SCOPE**

This Appendix sets out a method for determining the lateral track stability of a steel sleeper panel in ballast.

**G2 APPARATUS**

The following apparatus is required:

- (a) Three steel sleepers.
- (b) Six sets of rail-fastening assemblies including pads if required.
- (c) Ballast bed (with ballast generally in accordance with AS 2758.7).
- (d) Two lengths of rail, 1.5 m long each.
- (e) Three reference sleepers, including fasteners to be used for comparison.

NOTE: The reference sleepers should have a known satisfactory performance in track. They are tested in the same rig for comparative purposes. A sleeper type that the purchaser has already installed, and is therefore familiar with, may be appropriate.

- (f) A displacement transducer.

**G3 PROCEDURE**

The procedure shall be as follows:

- (a) Form the panel comprising sleepers, rails and fasteners in the ballast bed such that a quasi-static vertical loading and lateral loading can be applied to the system through the rail.
- (b) Apply a cyclic vertical loading at a suitable load to provide consolidation of the sleeper panel in the ballast. The loading shall be applied over the length of each rail.
- (c) Following consolidation of the sleeper panel, form a ballast shoulder, not exceeding 300 mm, level with the sleeper. Apply a lateral load by means of two chains fastened to the web at each end of one of the rails. Measure lateral deflection of the panel on the adjacent rail by means of a displacement transducer mounted from a fixed reference to the rail head.
- (d) Perform a lateral resistance test by increasing the load until there is lateral failure. The load-deflection curve for the panel shall be recorded on an X-Y recorder.
- (e) Repeat Steps (a) to (d) on the panel of reference sleepers.

**G4 REPORT**

The following shall be reported:

- (a) For both the steel sleeper panel being tested and the reference panel, the lateral location when the test load reaches—
  - (i) 25% of the maximum load;
  - (ii) 50% of the maximum load;
  - (iii) 75% of the maximum load;
  - (iv) 90% of the maximum load; and
  - (v) the maximum load.
- (b) The number of this Australian Standard, i.e., AS 1085.17.

## APPENDIX H SLEEPER SPACING

(Informative)

This Appendix gives a method for determining the sleeper spacing beyond which bending capacity is exceeded.

The maximum sleeper spacing (based on sleeper bending) may be calculated by an iterative process using the following equation:

$$s = \frac{2\sigma_{\text{all}} Z_{\text{toe}} 10^{-6}}{F_1 P_{\text{dV}} \beta C_{\text{BM(max.)}}} \quad \dots \text{H1}$$

where

- $s$  = sleeper spacing, in metres
- $\sigma_{\text{all}}$  = allowable sleeper bending stress, in megapascals
- $F_1$  = factor applied to the rail seat load to incorporate the effects of the interaction of adjacent wheels to the design wheel load
- $P_{\text{dV}}$  = quasi-static vertical wheel load, in kilonewtons
- $\beta$  = track stiffness parameter, in metres<sup>-1</sup>
- $C_{\text{BM(max.)}}$  = maximum sleeper bending moment coefficient, in metres

This relationship, based on the BOEF theory and equations described in Clause 5.5.4, is derived by equating the design bending stress to the allowable stress in tension and compression. Where alternative formulations are used, the above equation has to be duly modified.

NOTE: Sleeper spacing will have a major effect on the fatigue performance of the sleeper.

NOTES

## NOTES

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