AS 1085.22:2019

Railway track materials: Alternative material sleepers

RAIL INDUSTRY SAFETY AND STANDARDS BOARD

Infrastructure Standard

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RISSB RAIL INDUSTRY SAFETY AND STANDARDS BOARD

This Australian Standard® AS 1085.22 Railway track materials: Alternative material sleepers was prepared by a Rail Industry Safety and Standards Board (RISSB) Development Group consisting of representatives from the following organisations:

TBC

The Standard was approved by the Development Group and the Infrastructure Standing Committee in Select SC approval date. On Select Board approval date the RISSB Board approved the Standard for release.

This standard was issued for public consultation and was subject to a stakeholder workshop. It was also independently validated before being approved.

Development of the Standard was undertaken in accordance with RISSB's accredited process. As part of the approval process, the Standing Committee verified that proper process was followed in developing the Standard

RISSB wishes to acknowledge the positive contribution of subject matter experts in the development of this Standard. Their efforts ranged from membership of the Development Group through to individuals providing comment on a draft of the Standard during the open review.

I commend this Standard to the Australasian rail industry as it represents industry good practice and has been developed through a rigorous process.

Deb Spring
Exec. Chair / CEO
Rail Industry Safety and Standards Board

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This Standard was prepared by the Rail Industry Safety and Standards Board (RISSB) Development Group AS 1085.22 Railway track materials: Alternative material sleepers. Membership of this Development Group consisted of representatives from the organisations listed on the inside cover of this document.

Objective

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 alternative material sleepers for use in railway track.

This Standard does not cover the use of materials complying with superseded editions of the AS 1085 series or the use of existing or re-used products. Users should satisfy themselves that such materials are satisfactory for the application intended.

This Standard is Part 22 of the AS 1085 (Railway track material) series.

Compliance

There are two types of control contained within Australian Standards developed by RISSB:

1. Requirements.
2. Recommendations.

Requirements – it is mandatory to follow all requirements to claim full compliance with the Standard. Requirements are identified within the text by the term ‘shall’.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred. Recommendations are identified within the text by the term ‘should’.

Recommendations recognise that there could be limitations to the universal application of the control, i.e. the identified control is not able to be applied or other controls are more appropriate or better.

For compliance purposes, where a recommended control is not applied as written in the standard it could be incumbent on the adopter of the standard to demonstrate their actual method of controlling the risk as part of their WHS or Rail Safety National Law obligations. Similarly, it could also be incumbent on an adopter of the standard to demonstrate their method of controlling the risk to contracting entities, or interfacing organisations where the risk may be shared.

Controls in RISSB standards address known railway hazards are addressed in Appendix N.

Contents

Appendix Contents

1 Scope and general

1.1 Scope

This Standard specifies performance requirements for sleepers made from non-traditional materials, and the associated test methods to establish conformity.

The sleepers are for use in railway applications with continuously welded rail or jointed rail, and supported by ballast.

This Standard does not:

(a) include the design of bridge transoms,

(b) specify manufacturing process, given the diverse and uncertain nature of the materials used.

NOTE: Refer to AS 1085.14, AS 1085.17 and AS 3818.2 for sleepers made from traditional railway track materials such as prestressed concrete, steel and timber respectively.

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document:

- AS 1085.19 Railway track materials, Part 19: Resilient fastening assemblies.
- ISO 12856-1 Plastics — Plastic railway sleepers for railway applications (railroad ties).

NOTE: Documents for informative purposes are listed in a Bibliography at the back of the Standard.

1.3 Definitions

For the purposes of this document, the terms and definitions given in RISSB Glossary: https://www.rissb.com.au/products/glossary/ and the following apply:

(a) ***alternative material sleepers***

sleepers manufactured with non-traditional materials

(b) ***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

(c) ***negative bending***

bending of a sleeper by application of a load that produces tension in the top surface of the sleeper

(d) ***positive bending***

bending of a sleeper by application of a load that produces tension in the bottom surface of the sleeper

(e) ***proof testing (control testing)***

testing of samples taken from routine production.

(f) ***rail pad***

a part of the fastening system placed between the rail and the sleeper which absorbs impact, isolates electrically and protects components against abrasion

(g) ***rail seat***

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

(h) ***type testing***

testing of samples from initial production to establish the performance of the specific design and the manufacturing methods

(i) ***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

1.4 Notation

The symbols used in this Standard, including their definitions are listed below:

c = dimension of sleeper from the centreline of the rail seat to the centre of the sleeper, in metres.

DF = load distribution factor, in percent

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

Es = Young's modulus of sleeper material, in megapascals

$F_{c,m}$ = assembly clamping force (measured value) in kilonewtons

F_p = insert pull-out test load (specified value), in kilonewtons

G = track gauge, in millimetres

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

g_{sh} = distance between the rail restraining faces of the outside shoulders of the assembly, in metres

h =height from which to drop hammer mass for sleeper impact test, in millimetres

I_s = second moment of area for the sleeper section, in millimetres to the fourth power

I_x = rail second moment area about the horizontal neutral axis, in millimetres of the power of four

k_d =dynamic factor

k_s = service factor

L_t =lateral component of the test load, in kilonewtons

M_d = design sleeper bending moment, in kilonewton metres

m_f = weight of unsupported loading frame bearing on the sleeper

m_s = weight of unsupported sleeper (or part of sleeper) and fastening components

n = dimension from end (on centreline of bottom edge of end) to the centre-line of rail seat, in metres

P = load measured during the uplift test

P_0 = clamping force

P_1 = test load required to produce the required rail seat negative moment (rail seat vertical load test), in kilonewtons

P_2 = test load required to produce the required rail seat positive moment (rail seat vertical load test), in kilonewtons

$P6$ = assembly clamping force (measured value) in kilonewtons as determined in Appendix K

P_{dV} = vertical design wheel load, in kilonewtons

P_{ab} = design sleeper to ballast bearing pressure, in kilopascals

P_{imp} = impact load to be applied for sleeper impact test in kilonewtons

P_{RSL+} = applied vertical load to achieve rail seat positive design bending moment in kilonewtons

P_s = load at which shims may be removed during uplift test

Q = maximum static wheel load, in kilonewtons

R = design rail seat load, in kilonewtons

R_V = vertical design rail seat load, in kilonewtons

R_{33} = corrected wet electrical impedance, in ohms

s = sleeper spacing, in metres

T = test torque for insert torque test, in newton metres

U = track modulus (k is used in some publications), in megapascals

U_S = sleeper support modulus, in megapascals

V_t = vertical component of the test load, in kilonewtons

V_Z = Voltage applied during impedance tests in Appendix H (defaults to 12 V 50Hz unless specified)

W = maximum load per unit length of sleeper, in kilonewtons per metre

w = average width of sleeper soffit supported by ballast, in millimetres

x = distance from the sleeper end, in metres

x_1 = 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’ from the point under consideration, in metres

$y_{max.}$ = maximum sleeper deflection (assumed to occur immediately beneath the rail seat), in millimetres

β = track stiffness parameter calculated from the $\boldsymbol{EI}$ of the rail, in metres to the minus one, as follows (note this is different to ‘λ’ which is used in the structural analysis Section):

$$\left(\frac{U}{4EI_x}\right)^{0.25} \times 10^3$$

λ = sleeper stiffness parameter calculated from the $\boldsymbol{EI}$ of the sleeper, in metres to the minus one, as follows:

$$\left(\frac{U_s}{4E_sI_s}\right) \times 10^3$$

σ_{cont} = contact pressure at the sleeper/ballast interface in kilopascals

2 Functional analysis

2.1 Purpose

Sleepers support track components (rails, fastenings and other track and signalling hardware) that are part of the structure of railway track. 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. They provide a platform for the fastening systems that hold the rails to the sleeper.

2.2 Action

In supporting and guiding railway vehicles, the track structure is required to resist repeated lateral, vertical and longitudinal forces. As elements of the track structure, individual sleepers receive loads from the rails or fastenings and in turn transmit loads to the ballast, formation and subgrade. Consequently, the design of a sleeper affects and is affected by characteristics of other components of the track structure.

Sleepers are subject to:

(a) loads imposed on the rails by the passage of rollingstock and during maintenance activities;

(b) loads generated by thermal effects on the rail and by ballast movement,

(c) impact; and

(d) fatigue, wear, damage and degradation of the steel components interfacing with the sleeper due to exposure to service environment including ultraviolet radiation, thermal cycles and moisture.

2.3 Fitness for purpose

The intended application for sleepers of any type may be 100 % replacement, spot insertion to replace defective sleepers, interspersed with traditional sleepers or some other combination.

There is a wide range of materials that may be used to manufacture alternative material sleepers including but not limited to recycled plastic, homogenous thermosetting polymers and fibre reinforced epoxies. These alternative material sleepers have different properties and characteristics to traditional sleepers of timber, concrete and steel. Rail infrastructure managers should familiarise themselves with these differences and assure themselves that the material and design of the sleeper is adequate and fit for purpose.

As an example, a new sleeper design may have a deeper section than concrete or timber to achieve the same stiffness and load capacity. When used on a face this increased depth may be critical in areas with tight clearances and require adjustments to track levels.

This extra depth is also a consideration for interspersed and spot renewals. Instead of the depth of ballast being uniform from one sleeper to the next the thicker sleepers have less ballast under them than those on either side. This variation can induce drainage problems and formation failures and reduce the effectiveness of mechanised resurfacing operations.

2.4 Performance characteristics

In order to perform adequately in-service, the sleepers have various characteristics, including:

(a) maintain running rails at correct separation distance from each other;

(b) transfer load from rail to ballast;

(c) prevent rail rollout;

(d) electrically insulate one rail from the other;

(e) provide lateral stability;

(f) provide longitudinal stability;

(g) provide vertical stability;

(h) resist sudden brittle failure;

(i) resist abrasion under the rail seat;

(j) retain the rail in the correct position (with fasteners);

(k) provide adequate service life;

(l) present minimal risk to human health;

(m) provide compatibility with existing supply and logistics chain;

(n) present minimal risk of contamination to the environment over the entire life cycle, including disposal.

3 Design approach

3.1 Design Inputs

The rail infrastructure manager shall determine and provide to the designer required values for all inputs into the design process. These inputs shall include but are not limited to:

(a) expected life before replacement;

(b) intended use of the sleepers either as 100% replacement or interspersed with other sleeper types;

NOTE: The design of the sleeper shall also take into account the need for compatibility with existing sleepers and ballast depths when being used interspersed with existing sleepers

(c) maximum gradient;

(d) design curve radii including respective super elevation and speed envelopes for each curve;

(e) insulation requirements for and type of track signal circuits;

(f) voltage of traction supply if traffic is electrified;

(g) geographic and climatic extremes;

(h) environmental aggressiveness (e.g. presence of water or chlorides);

(i) maximum static axle load, in tonnes;

(j) the traffic mix as a combination of static wheel loads, in tonnes, and maximum train speeds, in kilometres per hour;

(k) centre of gravity of vehicle types above top of running rail;

(l) train consist configuration including axle loads and associated axle spacing, bogie spacing and inter car spacing;

(m) annual gross tonnes, in million gross tonnes per year;

(n) nominal track gauge, including tolerance;

NOTE: the coefficient of thermal expansion for some materials will influence gauge.

(o) rail size;

(p) nominal cant of rails;

(q) depth of ballast including shoulder profile;

(r) type and quality of ballast including maximum allowable bearing pressure;

(s) minimum distance required between sleepers to allow for mechanised track resurfacing;

(t) maximum allowable centre to centre spacing of sleepers for design load sharing purposes;

(u) critical dimensions of the sleeper and allowable tolerances;

(v) details of the fastening type;

(w) details of fastener insert to be used if any;

(x) axle load distribution factor or the equations to be used for calculating same;

(y) value of dynamic factor to be used for sleeper impact test, if required;

(z) any specific tests to determine material characteristics including but not limited to flammability, toxicity and combustibility;

(aa) voltage to be applied during impedance tests if other than 12 V 50Hz;

(bb) value of required wet electrical impedance;

(cc) makeup and configuration of the reference panel for test and comparison purposes.

3.2 Physical properties

In order to meet the characteristics listed in Section 0 the designer shall identify those physical properties which, either individually or collectively, contribute to meeting these performance requirements. These properties include but are not limited to:

(a) ability to maintain dimensional stability;

(b) resistance to permanent deformation under load;

(c) resistance to environmental factors;

(d) fastener pull-out resistance;

(e) fatigue strength;

(f) tensile strength;

(g) bending strength;

(h) mass;

(i) shear strength;

(j) electrical resistivity;

(k) ability to absorb energy from derailments and other impacts without suffering brittle failure;

(l) abrasion resistance of sleeper material;

(m) slip resistance for walking inspections;

(n) thermal stability;

(o) human and environmental toxicity;

(p) flammability, toxicity and combustibility;

(q) resistance to chemicals used for railway operation and maintenance including but not limited to as herbicides and pesticides, fuels, oils and lubricants, material from brake linings, and coal ash;

(r) compression strength;

(s) cross sectional area of sleeper in contact with ballast in horizontal plane at the bottom of the sleeper (footprint);

(t) cross sectional area of sleeper in contact with ballast in lateral direction;

(u) cross sectional area of sleeper in contact with ballast in longitudinal direction;

(v) expected time to failure compared to recommended inspection frequencies;

(w) frictional resistance on bottom, sides and ends of sleeper at sleeper / ballast interface.

3.3 Failure modes

Sleepers are to be designed so as to remain serviceable for the duration of their design life. The design shall address potential failures due to:

(a) structural fracture;

(b) material fatigue;

(c) permanent deformation;

(d) excessive deflection;

(e) buckling or surface wrinkling;

(f) local failure of adhesive or filler material;

(g) excessive rail seat abrasion;

(h) exposure to ultraviolet radiation;

(i) exposure to temperature extremes between - 20°C and 70 °C;

(j) exposure to biological agents and petrochemical substances used for railway operation and maintenance including but not limited to herbicides and pesticides, fuels, oils and lubricants, material from brake linings, and coal ash; and

(k) exposure to, and absorption of, water.

3.4 Structural analysis

The designer shall determine and agree on suitable methodology to use the design inputs listed above to calculate design load cases and constraints. The designer shall provide this methodology to the rail infrastructure manager for approval prior to manufacture.

Structural analysis for alternative sleeper materials shall include assessment of direct shear and inter-laminar shear (if applicable). The designer shall ensure shear strength is adequate to resist design loads.

The rail infrastructure manager may nominate the type of verification to be provided in the form of calculations or finite element analysis. The designer shall satisfy themselves and the rail infrastructure manager that the analysis is valid and accurate.

Some guidance on the use of beam on elastic foundation (BOEF) method is given in Appendix L.2.

4 Manufacture

Manufacturers shall demonstrate that manufacture process control and quality systems are adequate to meet purchaser requirements.

5 Testing

5.1 General

Where testing is required, it shall be carried out on sleeper assemblies or elements that have been produced using the processes, plant, and materials that the manufacturer uses or intends to use in mass production.

Sleepers shall be tested in accordance with Appendices A to K and configured for its intended used. This includes the use of spacers or other variations in configuration (e.g. multiple sets of holes).

Sleeper assembly tests shall be carried out using the rail profile (or part of the rail profile, as appropriate) and the rail fastening system that is intended to be used.

Testing facilities shall be appropriately qualified to carry out the required tests.

5.2 Inspection and test plan

An inspection and test plan (ITP) shall be created to record all inspection and testing requirements.

The ITP shall include values for the critical test inputs and pass criteria as given in Table 5.1 – Suite of Product Compliance tests.

5.3 Material compliance tests

5.3.1 General

The designer shall nominate material tests as per ISO12856-1.

5.3.2 Specific tests

Where required by the rail infrastructure manager, additional material characteristic tests such as flammability, toxicity and combustibility shall be carried out. Additional tests should be considered when sleepers are used in areas such as confined or restricted spaces, or stored in large quantities.

5.4 Product compliance tests

Product compliance tests shall be carried out as listed in Table 5.1 and those nominated in Section 5.3.

Table 5.1 –Suite of Product Compliance tests

Description	Test method	Critical test inputs	Pass criteria
Geometric conformance test	Appendix A	Key dimensions as per manufacturing drawings	As per Table 5.2 – Permissible tolerances
Track panel assembly test	Appendix B	All necessary components, tools and assembly instructions.	Correctly assembled and within tolerance.
Rail seat vertical load test	Appendix C	Magnitude of applied loads	Permanent deformation to be less than 0.5 mm after 3 min of unloading. No cracking or fracture of the specimen. No delamination, indentation or shear cracks developed.
Fastening assembly repeated load test	Appendix D	Magnitude of applied loads Number of load cycles	The system must be capable of successfully resisting the applied load No significant wear or abrasion should be apparent on the rail seat Movement of the rail foot in the direction of the lateral load application shall not be greater than 5 mm over the duration of the test
Rail seat durability test	Appendix E	Magnitude of applied loads Number of load cycles	Permanent deformation less than 2 mm. No cracking or fracture of the specimen.
Fastener insert pull-out test	Appendix F	Extraction force	No permanent deformation, local yielding or delamination.
Fastener insert torque test	Appendix G	Applied torque	No rotation of the insert or permanent deformation, yielding or delamination of the sleeper
Wet and dry impedance test	Appendix H	Voltage of applied electrical load	Impedance greater than nominated value
Lateral push test	Appendix I	Magnitude of applied loads	Deflection less than or equal to that experienced by the reference panel
Sleeper impact test	Appendix J	Magnitude of applied loads	A reduction of no more than 10% in the stiffness after 10 impact tests. No cracking.
Fastening assembly uplift test	Appendix K	Magnitude of applied loads	Deflection within required limits

5.5 Permissible tolerances

When designed in accordance with the methods provided in Section 3, the permissible tolerances outlined in Table 5.2 shall not be exceeded.

Table 5.2 – Permissible tolerances

Key dimensions and tolerances	
Dimension	Tolerance
Length	+/- 6 mm
Cross sectional dimensions	+/- 3 mm
Longitudinal Straightness (Bow/Spring)	+/- 5 mm
Concavity or convexity of rail seat in any direction	+/- 0.5 mm
Inward cant of the rail seats	+/- 1 in 250
Differential tilt of the rail seats in the direction of the rail	+/- 1 in 100
Rail seat centre-line to the rail restraining face of the fastening	+ 0.75 mm, - 0.25 mm
Deviation of the top surface from a horizontal plane (twist)	+/- 1 mm
Location of cast in shoulders and synthetic insert centre-lines measured from datum lines	+/- 1 mm
Rotation of each cast in shoulder in the plane of the rail seat relative to the design orientation	+/- 1 degree
Track gauge	+4 mm, -0 mm
Location of cast in shoulder clip hole (in three dimensions)	+/- 0.5 mm

5.6 Test loads

In conducting the tests specified in Table 5.1, the test loads shall be applied to values specified in Table 5.3.

Table 5.3 – Test loads

Description	Test Method	Load Definition
Rail seat vertical load test	Appendix C	$P_1 = \frac{2M_{RSL+}}{(0.330-0.075)}$ $P_2 = \frac{2M_{RSL+}}{(0.330-0.045)}$ $P_3 = 0.55R$
Fastening assembly repeated load test	Appendix D	$P_{max} = \frac{2M_d}{(0.350-0.075)}$
Rail seat durability test	Appendix E	P_{RSL+}
Fastening insert pull-out test	Appendix F	$F_P = 8.5\ kN\ (dog\ spikes)$ $F_P = 22.2\ kN\ (screw\ spikes)$
Fastener insert torque test	Appendix G	$T = 0.34\ kN$
Wet and dry insulation test	Appendix H	Voltage of 40 V ac
Sleeper impact test	Appendix J	$P_{imp} = Q\ DF\ k_d$

5.7 Type testing

A track assembly test shall be carried out as detailed in Appendix B and product compliance tests in Section 0. The tests shall be carried out when:

(a) a new design is submitted to the purchaser; or,

(b) a new manufacturing plant or process is adopted by the manufacturer before or during production;

(c) any change is made in the manufacture process with the potential to reduce or degrade sleeper performance.

Appendix A Geometric conformance test

Normative

A.1 Scope

This Appendix sets out the method of testing the geometric conformance of individual sleepers.

A.2 Apparatus

The following apparatus is required:

(a) Fully dimensioned manufacturing drawings showing key dimensions and tolerances.

(b) Suitable measuring instruments and equipment.

A.3 Procedure

The procedure shall be as follows:

(a) Identify key dimensions as required by the inspection and test plan.

(b) Measure and record these dimensions.

A.4 Report

The following shall be reported:

(a) Any dimensions that fail to comply with the design.

(b) The number of this Australian Standard®, i.e. AS 1085.22.

Appendix B Track panel assembly test

Normative

B.1 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 can also be evaluated using this test.

B.2 Apparatus

The following apparatus shall be used:

(a) 6 sleepers.

(b) 12 sets of rail fastening assemblies including pads.

(c) 2 rails, each 4 m long.

B.3 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 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.

NOTE: Rail of other than nominal dimensions may be used provided corrections are made to the measurements to account for the actual measured dimensions of that rail.

B.4 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 1085.22.

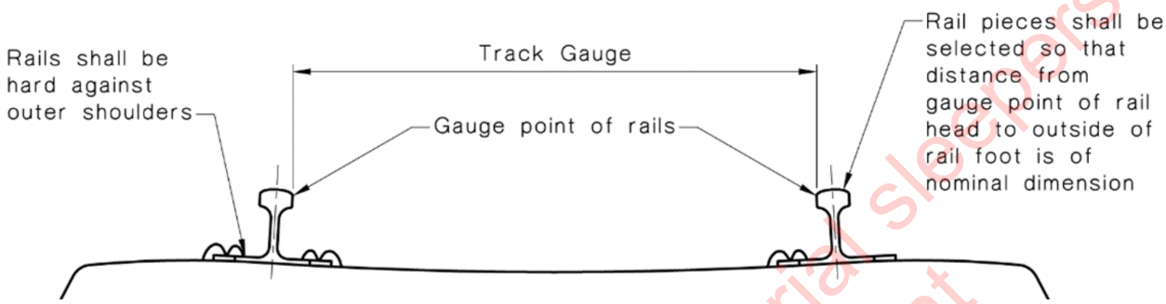


Figure B1 – Measurement of track gauge

Appendix C Rail seat vertical load test

Normative

C.1 Scope

This Appendix sets out the method of testing the rail seat for vertical loading under bending and shear.

If the cross section is consistent through the length of the sleeper, the procedure outlined in section C.3.2 is not required.

C.2 Apparatus

The test assemblies shown in Figures C1, C2 and C3 shall be used.

C.3 Procedure

C.3.1 Negative moment test

The procedure shall be as follows:

(a) Prepare sleepers as if they are being installed in track with all holes drilled.

(b) Support the sleeper as shown in Figure C1 for the negative moment test.

(c) Measure initial straightness of the sleeper.

(d) Apply load at a rate not greater than 25 kN/min until the test load P1 required to produce the proof rail seat negative moment is established.

(e) Maintain the test load (P1) for not less than 3 min.

(f) Inspect for permanent deformation or delamination

(g) Release the load.

(h) Record the residual deflection at mid span at 0 min, 3 min, 15 min, 30, min, 1 h after unloading to assess the response of the permanent deformation

C.3.2 Positive moment test

The procedure shall be as follows:

(a) Prepare sleepers as if they are being installed in track with all holes drilled.

(b) Support the sleeper as shown in Figure C2 for the positive moment test.

(c) Measure initial straightness of the sleeper.

(d) Apply load at a rate not greater than 25 kN/m until the test load P2 required to produce the proof rail seat positive moment is established.

(e) Maintain the test load (P2) for not less than 3 min.

(f) Inspect for permanent deformation or delamination

(g) Release the load.

(h) Record the residual deflection at mid span at 0 min, 3 min, 15 min, 30, min, 1 h after unloading to assess the response of the permanent deformation

C.3.3 Shear test

The procedure shall be as follows:

(a) Prepare sleepers as if they are being installed in track with all holes drilled.

(b) Support the sleeper as shown in Figure C3 for the asymmetrical beam shear test where d is the nominal depth of the sleepers and the test load (P3) passing though the drilled holes for the fasteners.

(c) Apply load at a rate not greater than 25 kN/m until the test load P3 required to produce the proof rail seat shear force is established.

(d) Maintain the test load (P3) for not less than 3 min.

(e) Inspect for delamination, delamination, indentation or shear cracking.

(f) Release the load.

C.4 Report

The following shall be reported:

(a) Any permanent deformation or delamination.

The number of this Australian Standard®, i.e. AS 1085.22

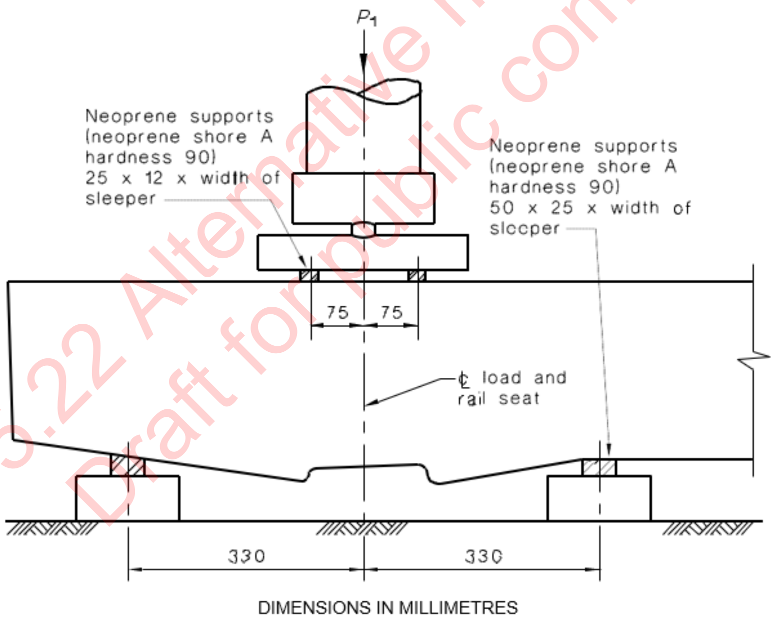


Figure C1 Apparatus for rail seat negative moment test

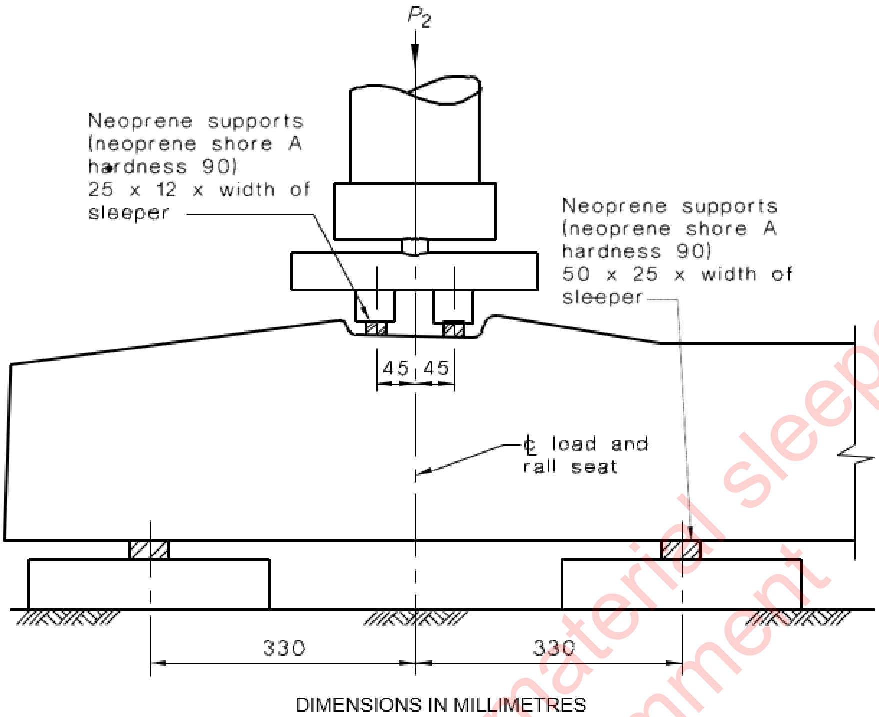


Figure C2 Apparatus for rail seat positive moment test

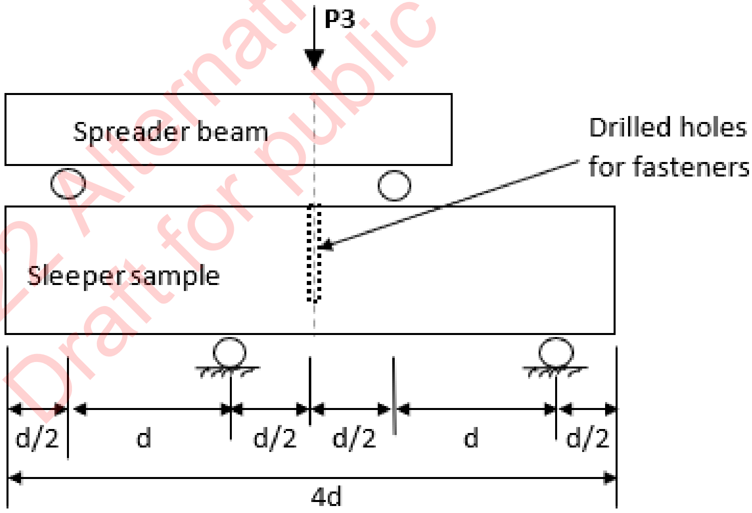


Figure C3 Apparatus for asymmetrical beam shear test

Appendix D Fastening assembly repeated load test

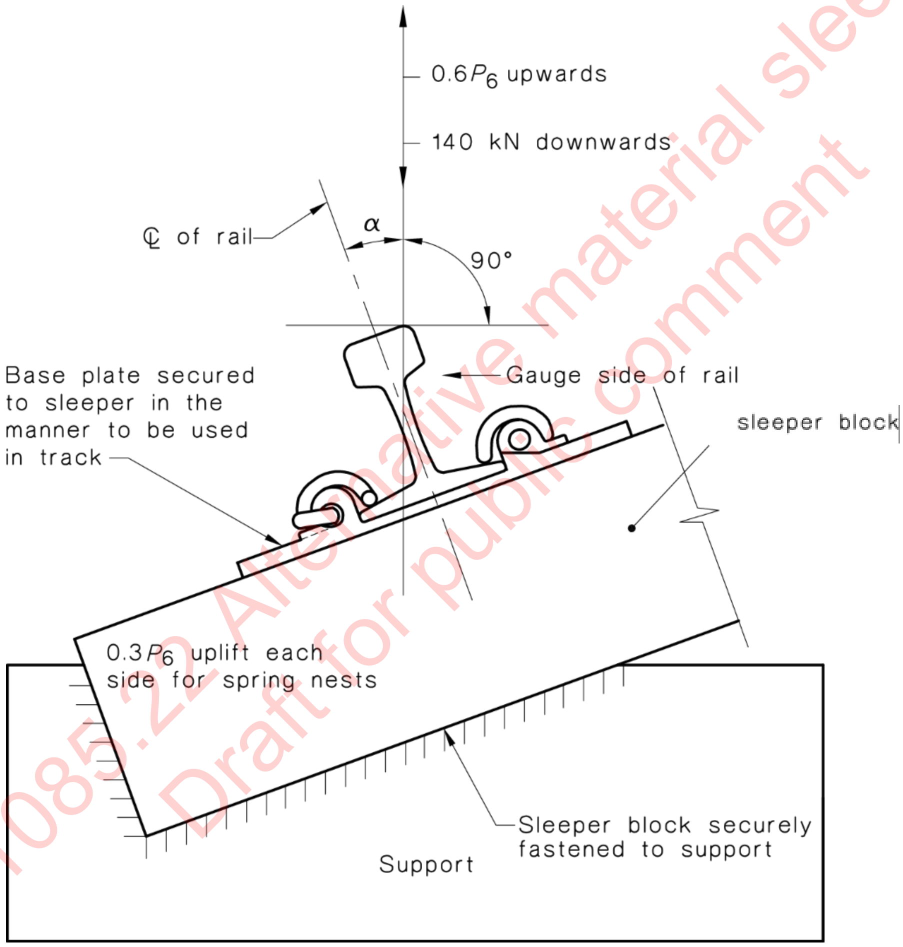
(Normative)

D.1 Scope

This Appendix gives methods for the repeated load testing of resilient fastening assemblies. For other types of fasteners refer to AS1085.17.

D.2 Apparatus

Test assembly using a suitable base that is as close as possible approximates the in-service use.



D1 Test assembly for timber sleeper

D.3 Procedure

The procedure shall be as follows:

(a) Remove all loose mill scale and foreign matter from the rail section to be tested.

(b) Establish the measured load ($F_{c,m}$) by performing the fastening assembly uplift test in accordance with Appendix K, Steps F3(a) to (e) only.

(c) Set up the test assembly as shown in Figure D1, using $\alpha = tan^{-1}(L_t \,/\, V_t)$

(d) Ensure that the rail is free to rotate under the applied loads.

(e) Ensure that the temperature in the elastomeric rail seat pads does not exceed 60°C (because the test generates heat in the elastomeric rail seat pads).

(f) Apply alternating load with an upward load of 0.6 $F_{c,m}$ and a downward load of $(L_t^2 - V_t^2)^{0\cdot5}$ kN at an angle of α degrees to the vertical axis of the rail at a rate in the range 3 Hz to 5 Hz for 3 million cycles.

Perform the fastening uplift test in Appendix K, Steps K3(a) to (e) only, to establish the residual clamping force of the resilient fastening assembly.

(g) Dismantle the fastening assembly and visually inspect the components for fracture, wear and permanent set. The security of any components cast into the base material shall also be recorded

NOTES:

1. One cycle consists of a downward and upward loading.
2. Where a spring is used to apply the upward load, care should be taken to ensure that the full downwards load is applied to the rail ($(L_t^2 - V_t^2)^{0\cdot5}$ kN + 0.6 $F_{c,m}$).

D.3.1 Report

The following shall be reported:

(a) Details of laboratory performing the test, date, and similar.

(b) Identification of all tested components (for example, the origin, name, code and description of the individual components of the fastening assembly, rail section used, and similar).

(c) Result of visual inspection after test including, as follows:

I. Rupture failure of any component of the fastening assembly.

II. Fatigue cracking or other failure of any component (e.g., rail insulation pads) and number of cycles when occurred.

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

(d) The residual clamping force of the fastening assembly.

(e) The number of this Australian Standard and identification of the test procedure used, i.e., AS 1085.22, Appendix D, Fastening repeated Load test.

Appendix E Rail seat durability test

Normative

E.1 Scope

This Appendix sets out the method of testing the rail seat durability.

E.2 Apparatus

The following apparatus shall be used:

(a) A sleeper segment, greater than 900 mm in length, containing rail and fastening system placed centrally.

(b) Test assembly shown in Figure E1.

E.3 Procedure

The procedure shall be as follows:

(a) Support the sleeper segment as shown in Figure E1.

(b) Using a straight edge and feeler gauge, measure the initial out of straightness of the sleeper segment at the sleeper centre;

(c) Apply a cyclic compressive load over the range 0.1 to 1.15 of P_{RSL+} for a period of 10,000 cycles at a frequency not exceeding 3 Hz

(d) Unload the sample for 60 min to allow the sample to recover.

(e) Repeat steps 3 and 4 until 1 million cycles are accumulated.

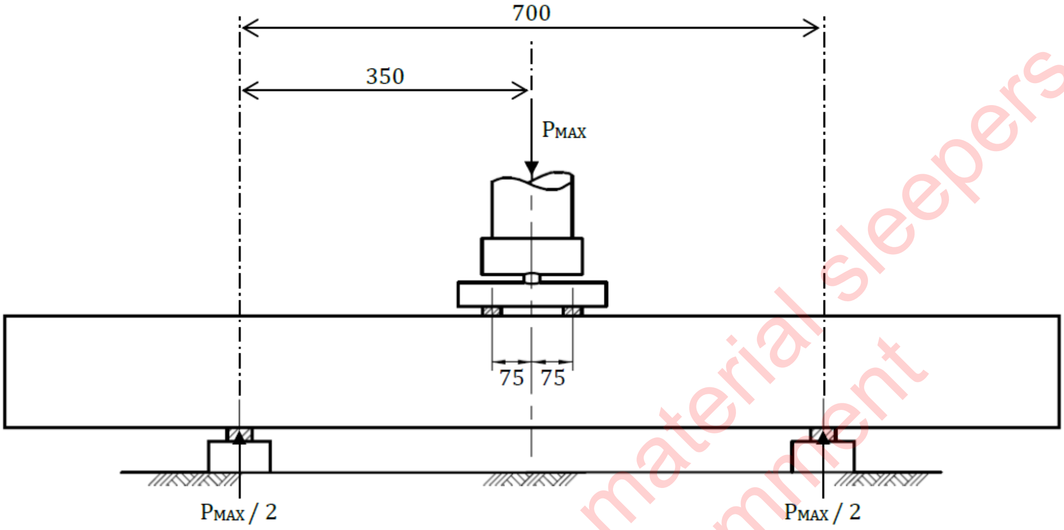
(f) Repeat straightness measurement to get final deflection.

E.4 Report

The following shall be reported:

(a) The ultimate load (if appropriate).

(b) The number of this Australian Standard®, i.e. AS 1085.22.



Dimensions in millimetres

Figure E1 Assembly requirements for bending moment capacity test

Appendix F Fastening insert pull-out test

Normative

F.1 Scope

This Appendix sets out the method of conducting the fastening insert pull-out test where inserts are used. For other types of fasteners refer to AS 1085.17.

F.2 Apparatus

The following apparatus is required: Test assembly as shown in Figure F1. Dial gauge.

F.3 Procedure

The procedure shall be as follows:

(a) Set up the test assembly.

(b) Install suitable dial gauge to monitor movement of the fastening relative to the sleeper.

(c) Apply the test load (F_p) (see Table 5.3 – Test loads).

(d) Maintain the load (F_p) for not less than 3 min.

(e) Release the load.

(f) Repeat Steps (c) to (e) inclusive 4 more times.

(g) Check the fastening and surrounding sleeper material for signs of yielding and cracking.

(h) Check for any relative movement in the position of the fastening.

F.4 Report

The following shall be reported:

(a) Signs of yielding or cracking in the fastening or surrounding sleeper material.

(b) Relative movement in the position of the fastening.

(c) The number of this Australian Standard, i.e. AS 1085.22.

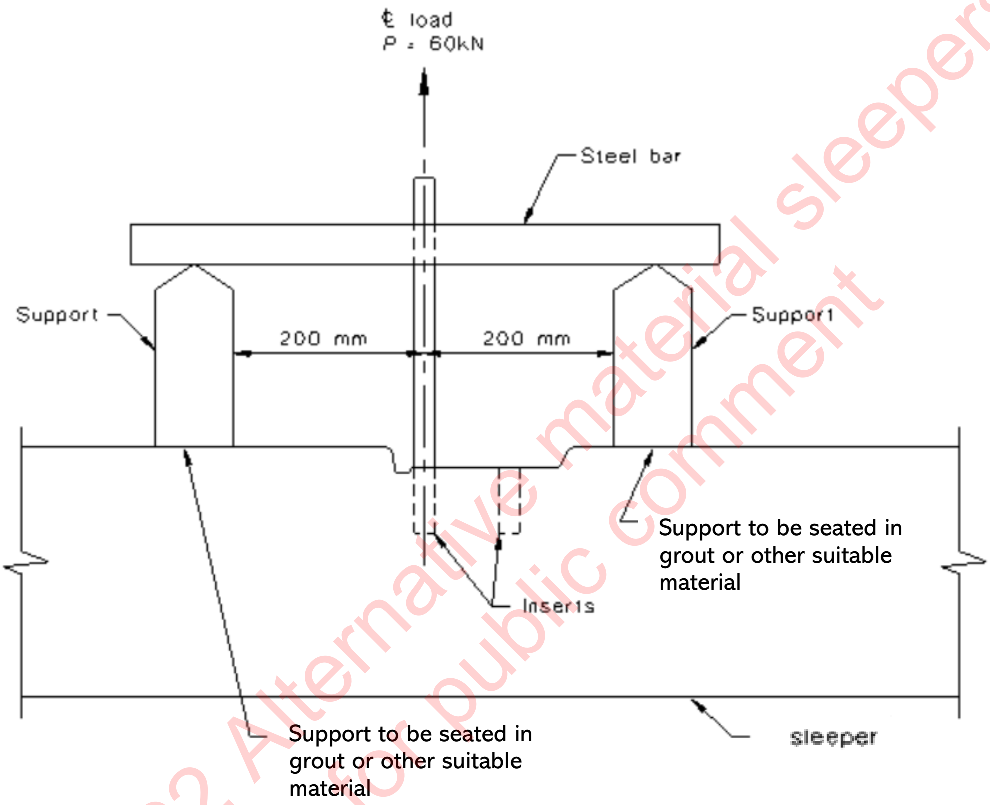


Figure F1 Apparatus for fastening insert pull-out test

Appendix G Fastening insert torque test

Normative

G.1 Scope

This Appendix sets out the method of conducting the fastening insert torque test.

NOTE: This test is performed on each insert following the successful completion of the fastening insert pull-out test.

G.2 Apparatus

The following apparatus shall be used:

(d) A calibrated torque wrench.

(a) Suitable attachment to the insert.

G.3 Procedure

The procedure shall be as follows:

(a) Following the successful completion of the fastening insert pull-out test (see Appendix E), apply the test torque (T) (see Table 5.3) about the vertical axis of the insert by means of a calibrated torque wrench and a suitable attachment to the insert.

(b) Maintain the torque for not less than 3 min.

(c) Check for insert rotation, delamination or any permanent deformation.

G.4 Report

The following shall be reported:

(a) Test torque (T) applied to the insert.

(b) Any delamination or permanent deformation.

(c) The number of this Standard, i.e. AS 1085.22.

Appendix H Sleeper assembly wet and dry impedance test

Normative

H.1 Scope

This Appendix sets out the methods of testing the sleeper, rail and fastening assembly for the dry electrical impedance, (Paragraph H2) and the wet electrical impedance (Paragraph H3).

The wet electrical impedance test (Paragraph C4) has been harmonized with prEN 13146-5.

H.2 Sleeper assembly dry impedance test

H.2.1 General

This Paragraph sets out the method of conducting the sleeper assembly dry electrical impedance test. The purpose is to establish the ability of the assembly (and the elements that provide electrical insulation) to resist the flow of electrical current.

H.2.2 Apparatus

The following apparatus shall be used:

(a) One test sleeper.

(b) Four complete fastenings with all components making up the assemblies as they will be used in track.

(c) Two short lengths of rail for which the sleeper and fastening assembly under test is designed. The rail shall be in a condition typical of new rail, smooth with no ribs or major signs of oxidation or any treatment of its foot. Clean the surface contact points of the rail if contaminated with rust, dirt or mill scale.

(d) Voltage supply in the range 10 V to 40 V a.c. at 50 Hz or 60 Hz (nominal frequency).

(e) A calibrated meter to measure impedance (or allow impedance to be calculated) with an accuracy of at least 95 percent.

(f) An appropriate bed on which to assemble the fastening (i.e., plastic base, steel base or timber.

H.2.3 Procedure

The procedure shall be as follows:

(a) Assemble all the components of the fastening and the rail on the appropriate base (i.e., plastic base, steel base or timber).

(b) If contaminated with rust, dirt or mill scale, clean the surface contact points of the rail and the base plate or similar part of the assembly to be connected to the voltage.

(c) Apply the voltage across the fastening assembly (from rail to insert, sleeper plate or steel base, as appropriate).

(d) Measure the impedance and record as the initial impedance.

(e) Continue to apply the voltage for 10 min except that where rubber pads are used to provide insulation, apply the voltage for 48 h.

(f) Measure the impedance at the end of the elapsed time and record as the final impedance.

H.2.4 Report

The following shall be reported:

(a) The voltage applied (e.g., 12 volts a.c.) and frequency.

(b) The initial and final impedances.

(c) The number of this Australian Standard and identification of the test procedure used, i.e., AS 1085.22, Appendix H, Sleeper assembly dry electrical impedance test.

H.3 Sleeper assembly wet electrical impedance test

H.3.1 General

This Paragraph sets out the method of conducting the sleeper assembly wet electrical impedance test. The purpose is to establish the ability of the assembly (and the elements that provide electrical insulation) to resist the flow of electrical current in wet conditions.

This Method has been harmonized with prEN 13146-5.

H.3.2 Principle

The electrical impedance between two short lengths of rail fastened to a sleeper is measured whilst the fastenings and the sleeper are sprayed with water at a controlled rate. Correction is made for the conductivity of the water to a reference value of 33 mS/m.

H.3.3 Apparatus

The following apparatus shall be used:

(a) One test sleeper.

(b) Four complete fastenings with all components making up the assemblies as they will be used in track.

(c) Two short lengths of rail for which the sleeper and fastening assembly under test is designed. The rail shall be in a condition typical of new rail, smooth with no ribs or major signs of oxidation or any treatment of its foot. Clean the surface contact points of the rail if contaminated with rust, dirt or mill scale.

(d) Voltage supply in the range 10 V to 40 V a.c. at 50 Hz or 60 Hz (nominal frequency).

(e) A calibrated meter to measure the applied electric voltage and the electrical impedance between the rails up to 100 kΩ with an accuracy of at least 95 percent. It shall have the capability to make a record of impedance against time.

(f) An appropriate bed on which to assemble the fastening (i.e., plastic base, steel base or timber

(g) A potable water supply at a pressure of 1 kN/m2, having known conductivity in the range 20 mS/m to 80 mS/m at a temperature in the range 10°C to 20°C.

(h) Spray equipment incorporating a frame that can be moved parallel to the rails, and four spray nozzles as shown in Figure H1. The nozzles shall have a diameter of 3.6 mm and a spray cone of 100° to 125°. The equipment shall include a means of controlling and measuring the flow of water to each nozzle.

(i) Blocks made of electrically insulating material not less than 50 mm thick capable of supporting the sleepers

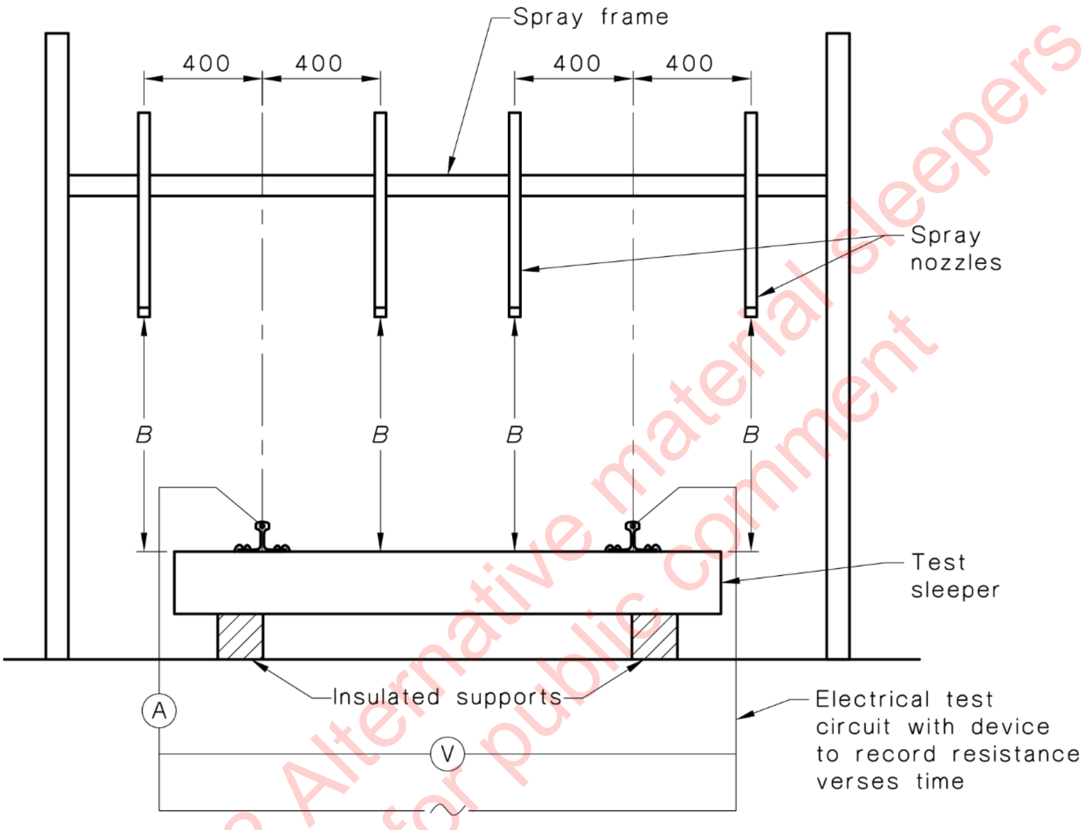


FIGURE H1 Test assembly for wet electrical impedance test

H.3.4 Procedure

The procedure shall be as follows:

(a) Carry out the test under cover and protected from rain and draughts in a room or enclosure that is ventilated and has an air temperature in the range 15°C to 30°C.

(b) Fix the rails to the sleeper with two fastening assemblies, using all the fastening components as intended for use in track.

(c) If contaminated with rust, dirt or mill scale, clean the surface contact points of the rail that will be connected to the voltage.

(d) Support the sleeper, which shall be surface dry, on two electrically insulating blocks not less than 50 mm thick (see Figure H1).

(e) Where the sleeper has not already been used for this test, before carrying out the test, perform the spraying procedure (Item (f)) and leave for the longer of 15 h or the time for the sleeper to become surface dry.

(f) Set up the measuring instruments and connect to the electrical supply (see Figure H1).

(g) Move the spray equipment over the sleeper and spray with water at a rate of 8 L/min from each nozzle for 2 min.

(h) Record the electrical impedance during spraying and for not less than 10 min after spraying has ceased.

H.3.5 Calculation

Perform the calculations as follows:

(a) Determine the measured minimum impedance (Rc) from the time impedance plot for each test.

(b) Calculate the corrected wet electrical impedance, in ohms, as follows:

$$R_{33} = k_c R_c$$

$$= 0.03\,C\,R_C$$

H.3.6 Test report

The following shall be reported:

(a) Details of laboratory performing the test, date, and similar.

(b) Identification of all tested components (for example the origin, name, code and description of the individual components of the fastening assembly, rail section used, sleeper and similar).

(c) The voltage applied (e.g., 12 volts a.c.) and the frequency.

(d) Conductivity of the water used (C).

(e) Individual and mean values of corrected wet electrical impedance (R_{33}).

(f) The number of this Australian Standard and identification of the test procedure used, i.e. AS 1085.22, Appendix H, Sleeper assembly wet electrical impedance test.

Appendix I Lateral push test

Normative

I.1 Scope

This Appendix sets out the method of conducting the lateral push test.

I.2 Apparatus

The following apparatus is required:

(a) Three 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.

I.3 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.

I.4 Report

The following shall be reported:

(a) For both the 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 1085.22.

Appendix J Sleeper impact test

Normative

J.1 Scope:

This Appendix sets out the method for impact test to assess the capacity of sleeper to resist derailment impact forces.

J.2 Apparatus:

The test assembly as shown in the Figure I.1 is required. The rail should be firmly attached to the sleeper using the appropriate fastening system and at a distance between rail centres of *g*. A 3-girder set-up is required to induce positive bending at rail seat and negative bending at midspan during the impact force.

J.3 Procedure:

The procedure shall be as follows:

(a) Drop a hammer mass of approximately 270 kg from height h to create the desired impact force P_{imp} on the rail seat. The below table is provided for reference for the desired impact force on each rail seat and the height. Values may be interpolated between shown data points.

P_{imp} (kN)	h (mm)
60	50
130	150
200	300
240	450
290	600
320	750
340	900

(b) Measure the displacement at rail-seat location.

(c) Observe any failure in the sleeper at the rail seat and midspan.

(d) Repeat the impact load test 10 times.

(e) Record any failure in the sleeper.

J.4 Report:

Report the following:

(a) Plot of the stiffness (impact force/rail-seat deflection) of the sleeper for each impact.

(b) Failure in the sleepers if any.

(c) Number of impact if sleeper failure occurs within the 10 impacts.

(d) The number of this Australian standard, i.e. AS 1085.22.

J.5 Acceptance criteria:

A reduction of not more than 10 % in the stiffness after 10 impact tests. Only recess should be formed but no crack should be formed on the surface of the sleepers.

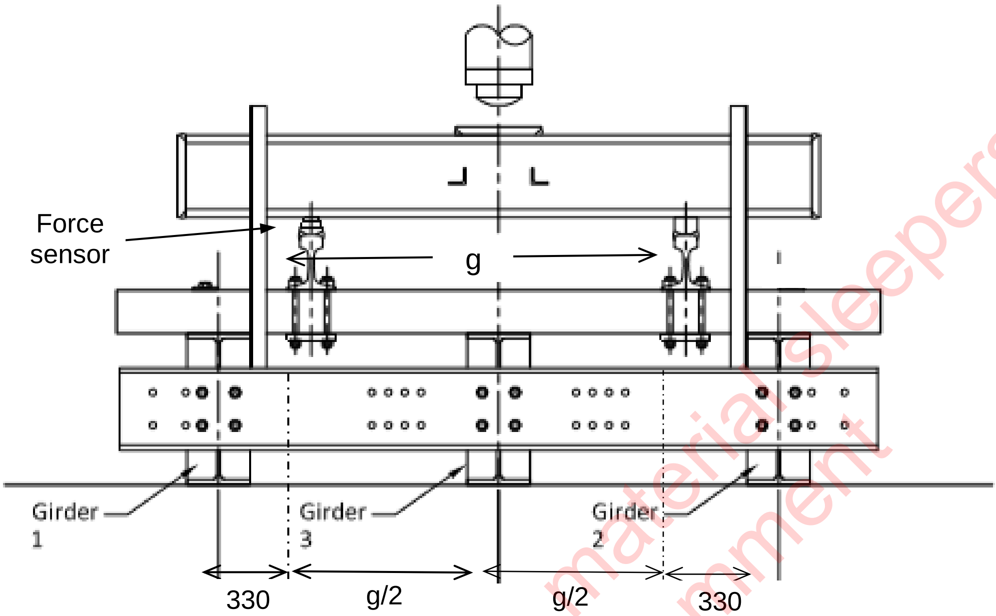


Figure I.1 Set-up for impact tests of sleepers (dimension in millimetres)

Appendix K Fastening assembly uplift test

K.1 Scope

This Appendix sets out the method of testing the fastening assembly for an uplift load.

This Method has been harmonized with prEN 13146-7.

K.2 Apparatus

The following apparatus is required:

(a) A piece of the specified rail section, at least 450 mm long.

(b) Rail-fastening assembly, including pads and spacers if required.

(c) Instruments that measure the vertical displacement of the rail support (sleeper or test block) relative to the rail. They shall be capable of recording load/displacement curves, and shall be located one each side of the rail on the sleeper (or test block) on the longitudinal centre-line of the sleeper.

(d) Two 0.25 mm thick feeler gauges.

(e) Test assembly (with the sleeper suspended under the supported rail) as shown in Figure K1.

NOTE: An alternative test assembly where the force is transmitted upwards to the rail rather than downwards to the support structure may be used subject to agreement by the manufacturer and purchaser. The calculations would have to be adjusted to allow for the weight of the rail rather than the support structure and frame (see Paragraph K3, Steps (b), (c)(iv), (c)(vi) and (d)(v)).

K.3 Procedure

The procedure shall be as follows:

(a) Secure the piece of rail section to the support base using a complete rail-fastening assembly (including pads if required), clips and associated hardware as shown in the test assembly.

(b) Determine the weight of the unsupported support structure including the sleeper or part of sleeper and fastening components (m_s) and of the loading frame bearing on the sleeper or test block (m_f).

(c) Where a resilient rail pad is part of the assembly, as follows:

I. With no load applied, set the displacement measuring instruments to zero ($d = 0$).

II. Apply an increasing load through the loading frame until the pad can just be removed.

III. Remove the pad and record the load as P.

NOTE: If a rail pad that is shaped to provide positive location in the assembly is used, the edges of the pad can be cut off before assembly of the test apparatus to simplify removal of the pad as described in Step (iii). The portion of the pad under the rail should not be cut.

IV. Decrease the load until $P + 0.0098\,(m_s + m_f) \leq 2$ kN is reached or the rail comes into contact with the sleeper (or test block) if that occurs at a greater load.

V. Record the displacement.

VI. Increase the load at a rate not exceeding 10 kN per min whilst recording the displacement.

VII. Continue until $P + 0.0098(m_s + m_f) = 1.1P_0$ is reached, where P_0 is the load at which *d* = 0 with no pad in place.

VIII. From the load/displacement curve generated by the instrument described in K.2 (c) read off the value of P_0, which is taken as the clamping force.

IX. Repeat the procedure two more times and calculate the mean measured clamping force ($F_{c,m}$).

(d) Where a non-resilient rail pad or no rail pad is used, as follows:

I. Apply an increasing load P until there is clear space under the rail, sufficient to allow insertion of steel shims under the rail.

II. Insert four steel shims (or feeler gauges), one at each corner of the bearing area of the rail foot.

III. Reduce the load to zero.

IV. Reapply an increasing load until a value is reached (Ps) at which it is just possible to remove all the shims by hand.

V. Calculate the value of $P_s + 0.0098\ (m_s + m_f)$. Record the value as P_0, which is taken as the clamping force.

VI. Repeat the procedure two more times and calculate the mean measured clamping force ($F_{c,m}$).

(e) Release the load completely.

(f) Apply a load of 1.5 $F_{c,m}$, but not exceeding 45 kN.

(g) Release the load completely.

K.4 Report

The following shall be reported:

(a) The mean measured clamping force ($F_{c,m}$).

(b) Fracture of any component of the fastening system.

(c) Load at which the rail lifts off the rail seat, the unsupported support structure weight and the frame weight.

(d) The number of this Australian Standard, i.e., AS 1085.22.

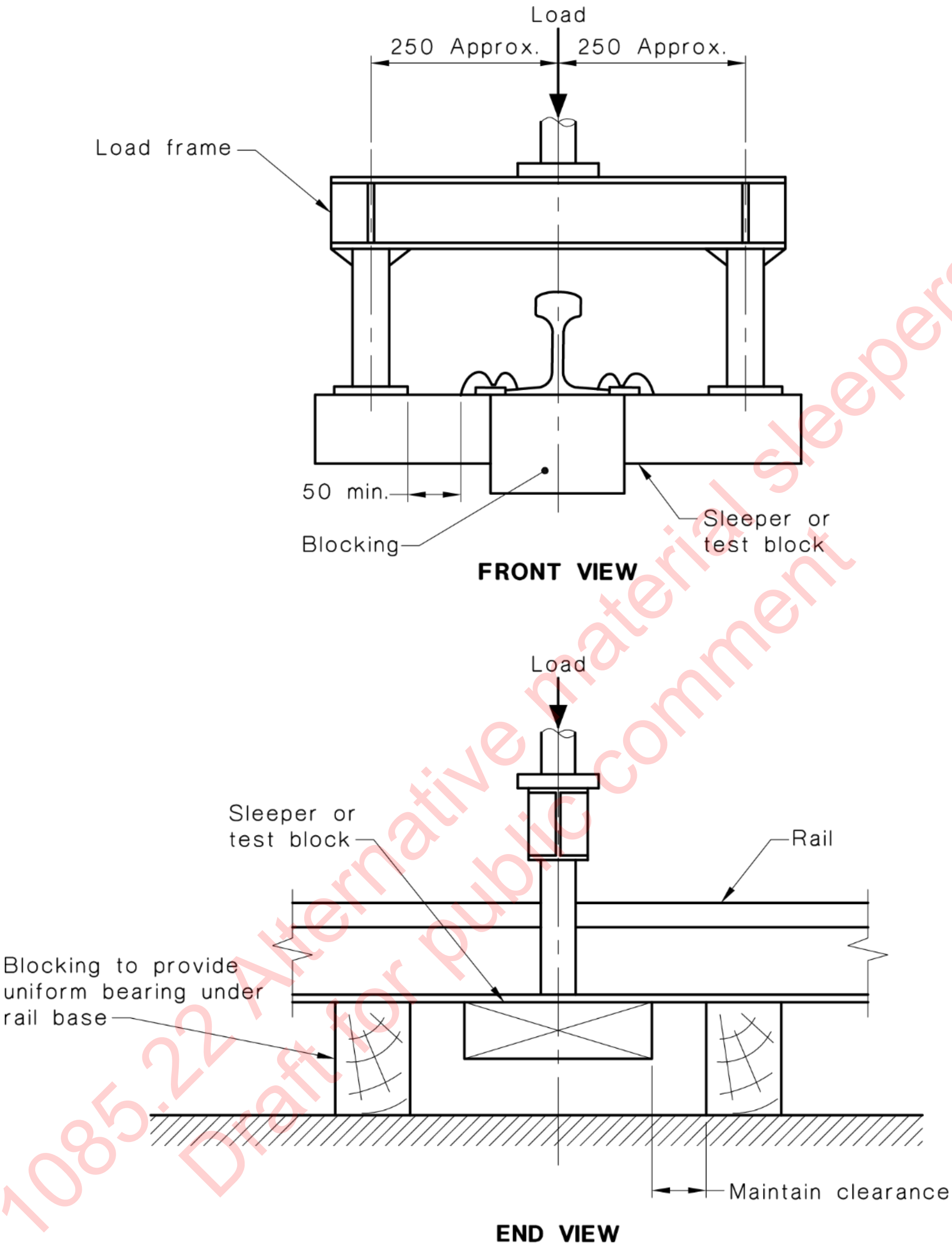


Figure K1 – Test assembly for fastening uplift test

Appendix L Guidance on structural analysis

Informative

L.1 General discussion of design

L.1.1 General

This Appendix provides a general discussion of the design of sleepers. It covers the influence on design of shape, spacing, track modulus, ballast and subgrade, curvature, quality of track and vehicles, load distribution, lateral and longitudinal loads and similar.

L.1.2 Spacing

The spacing of sleepers affects rail flexure stress, compressive stress on ballast and roadbed, and the flexure stress generated in the sleepers themselves. For a given set of dimensions and wheel loads, the consequences of increasing sleeper spacing are higher rail bending moments and increased stresses within the individual sleepers.

Where characteristics of sleeper, ballast and subgrade are constant, wider sleeper spacings bring about larger track depression per unit of wheel load, i.e. a lowered track modulus. Conversely, reduction of sleeper spacing lowers unit stress and increases track modulus.

L.1.3 Shape and dimensions

Use of longer, wider, or stiffer sleepers that increase the sleeper-to-ballast bearing area has many of the same effects as reducing sleeper spacing. There are, however, limits beyond which an increase in sleeper size is ineffectual in reducing track stress and increasing track modulus. There is also a point beyond which lengthening sleepers will fail to reduce significantly the unit bearing load. In addition, required right-of-way clearances and machinery limitations restrict sleeper length.

Widening sleepers introduces similar benefits to those resulting from increases in sleeper length but widening sleepers beyond an optimum point is ineffective. The optimum point is one beyond which the ballast can no longer be fully compacted.

L.1.4 Load distribution

It is assumed that wheel loads applied to the rail will be distributed through the rail to several sleepers. This distribution of loads has been confirmed in field investigations. The distribution of load is dependent upon sleeper and axle spacing, ballast and subgrade reaction, and rail rigidity. The percentage of wheel-to-rail load carried by an individual sleeper varies from one location to another and typical values range from 45% to 60%. For the sake of simplification, the distribution factors are often shown only as a function of sleeper spacing. The values chosen are intended to offset variations resulting from other influences. While rail stiffness does influence these percentages, its effect is small compared to other factors.

L.1.5 Service Factor k_S

L.1.5.1 General

The service factor (k_S) enables adjustment of the design loading by the purchaser to allow for the uncertainty of the loading and future use of the track.

This factor covers the uncertainties related to the selection of the design axle load and its transfer onto the rail seat of the sleeper. It should include consideration of risk, economics and possible future use of the track (higher axle loads and increased speeds or gross tonnage). Track importance may also affect some of these uncertainties.

The service factor is fundamentally the impact factor with a safety factor applied. The impact factor can be further adjusted taking growth and / or overload factors into consideration.

$$(Impact\ factor + growth\ factor + overload\ factor)\ x\ safety\ factor$$

L.1.5.2 Impact factor

The impact factor allows for the increase of wheel static wheel load (Q) due to dynamic effects in the vehicle / track system. The impact factor can be calculated using any one of a number of traditional methods (i.e. Eisenmann, ORE, AREMA etc.), utilizing the specific input values for the network under consideration. Typically, these values will take into account some or all of the following:

(a) design speed,

(b) track condition,

(c) vehicle characteristics,

(d) wheel condition, and

(e) network variability.

In most cases, the impact factor will range in value from 1.40 to 1.70.

Note: These values do not take into account the impact forces from dipped welds or wheel flats.

L.1.5.3 Growth factor

As sleeper design life can be as much as 50 years, it is important to be able to take into consideration future growth within the considered network. If growth is well understood, it should be included directly into the Impact Factor calculations above. However, if there is uncertainty, a Growth Factor in the range of 0.1 to 0.3 may be added to the Impact Factor.

L.1.5.4 Overload factor

The Overload Factor allows for variability in loading or load distribution within vehicles which may cause an actual axle load to exceed the nominal axle load calculated from the gross mass. Where used, an Overload Factor should represent the overload limits permitted by the Rail Infrastructure Manager and/or the observed distribution of vehicle loadings. An Overload Factor would not typically exceed 0.1.

L.1.5.5 Safety factor

A safety factor between 1.25 and 1.5 may be used, which should consider the proposed application for the sleepers.

L.1.6 Ballast and ballast pressure

In addition to sleeper size and spacing, ballast depth and subgrade modulus are also significant in the manner in which a particular track design restrains vertical loading. Increasing ballast depth tends to spread individual sleeper loads over a wider area of subgrade, thereby reducing the unit subgrade load and consequent track depression. Thus the effect of increased ballast depth may be similar, within limits, to that of reduced sleeper spacing. Stiffer subgrades do not require as low a ballast pressure as more flexible subgrades. Consequently, stiffer subgrades are better able to tolerate wider sleeper spacings, smaller sleepers, shallower ballast depths, or all three, without failure or excessive track depression.

L.1.7 Lateral loads

Lateral forces are generated at the interface between rails and the wheels of railway vehicles in order to steer those vehicles along the track. The greatest lateral forces are usually generated in curves when, for example, the curve is too severe for the wheelset to orient itself radially and steer on the conicity of the two wheels; under these conditions the wheelset develops an angle of attack to the track and lateral forces are generated accordingly. If the curve is sufficiently severe, there may be contact between the wheel flange and the rail, in which case lateral forces are extremely high.

Railway track is flexible and moves under these lateral forces. In order to avoid derailment of the vehicle it is essential that lateral movement be limited. It is also necessary to restrain the lateral forces that arise from thermal expansion of a rail that is not straight; buckling can arise if restraint is inadequate. A lateral load applied at the railhead gives rise to both torsion and flexure of the rail, as a result of which the reaction is distributed over several sleepers. Movement of the rail can be reduced by using a heavier rail section which distributes the reaction over more sleepers. Its movement is further reduced if the individual fastening system is stiffer or if there are more sleepers and fastenings per unit length of track. If the fastening system is rigid, lateral movement arises largely from flexure and torsion of the rail itself.

The couple and lateral force transmitted to the rail seat tend to bend the sleeper and move it laterally in the ballast. Sleeper bending is reduced with a stiffer sleeper while its resistance to lateral movement in the ballast is influenced by, for example, the effective end area of the sleeper, friction on its underside, and the depth and width of ballast shoulders.

The magnitude of lateral loads which need to be restrained depends not only on the dimensions, configuration, weight, speed and tracking characteristics of the equipment, but also on the geometric characteristics of the track structure. Both the gross geometry – whether the track is straight, curved or sharply curved – and the detailed geometry – the irregularities and small deviations from design – influence the magnitude of lateral load.

L.1.8 Longitudinal loads

The longitudinal load developed by the combination of traffic and thermal stress in continuous welded rail, is transferred by the fastenings to the sleepers and ultimately restrained by ballast. Consequently, the longitudinal bearing area (side area) of sleepers per unit of track length, friction between the bottoms of sleepers and ballast, and physical properties of ballast ultimately determine the track resistance to longitudinal movement.

Resistance to rail movement with respect to sleepers is determined by the characteristics of fasteners. While total restraint of longitudinal rail movement is generally desirable, there are situations where such restraint is impractical or undesirable. In conventional track construction, the limiting factor in longitudinal restraint is most often ballast resistance. Most recognized fastener suppliers have fasteners that have creep-resistant properties equivalent to the load and movement specified.

L.2 Beam on elastic foundation (BOEF) method

L.2.1 General

The calculations in this Clause give sleeper bending moment coefficients and sleeper deflections for determining bending moments and sleeper to ballast contract pressure. They are based on the BOEF theory. Figure J.1 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).

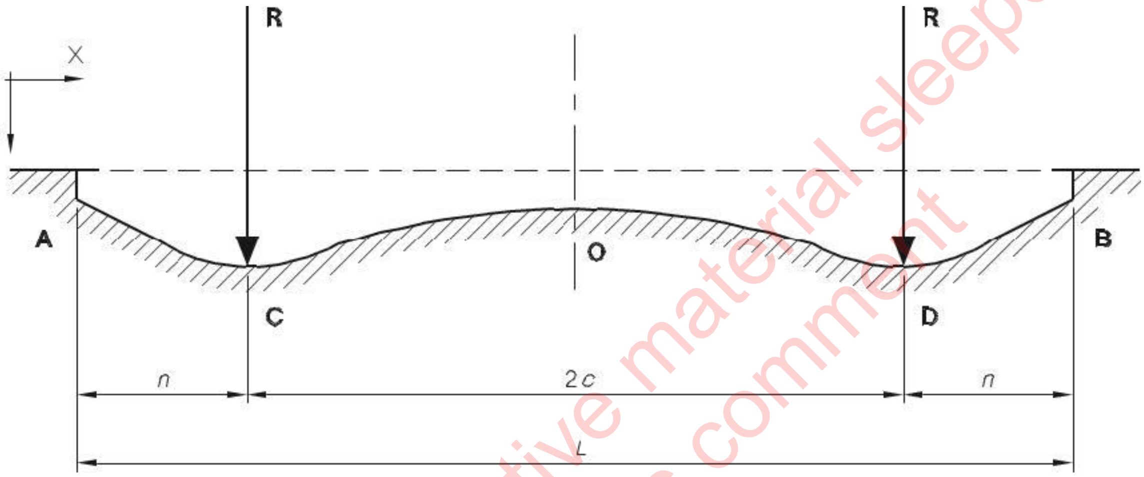


Figure J.1 BOEF formulation for sleeper moments and deflections calculations

L.2.2 Vertical design wheel load

L.2.2.1 General

The vertical design wheel load (P_{dV}) shall be calculated as follows:

Equation J-1

$$P_{dV} = k_s Q$$

Where Q equals the maximum static wheel load, in kilonewtons.

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

L.2.3 Service factor k_s

The purchaser may specify a service factor value calculated using the Eisenmann loading distribution method or other appropriate methods, which allows a wider range of speeds and track conditions to be considered.

Where in-field measurements are not available or the purchaser has not specified a value, the service factor k_s shall default to a value of 2.5.

NOTES:

1. Further guidance on determining k_s is contained in Appendix L.1.5.
2. The default condition represents well maintained wheels and suspension systems.
3. The amount of unsprung mass might also be considered as part of this factor.
4. Eisenmann and other loading distribution methods are discussed in Australasian Railways Association *Review of Track Design Procedures*. Volumes 1 and 2, 1991. (ISBN 0 909582 01 7)

L.2.4 Vertical design rail seat load

L.2.4.1 General

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:

Equation J-2

$$R_V = (Uy_{max.})s$$

and

Equation J-3

$$y_{max.} = \sum_{i=l}^{n} y_i$$

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

Equation J-4

$$y_i = \left(\frac{P_{dV}\beta}{2U}\right) e^{-Bx^1}(cos\,\beta x_1 + sin\,\beta x_1)$$

Where

P_{dV} as calculated in Equation J-1

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

NOTES:

1. As the track modulus increases, the percentage of wheel load distributed to the sleeper increases for a particular sleeper spacing.
2. The track modulus should be chosen to suit the application in which the sleepers are to be used.
3. The purchaser should specify train configuration for the BOEF method.
4. As rail size decreases, the percentage of wheel load distributed to the sleeper increases for a particular sleeping spacing.

L.2.4.2 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:

Equation J-5

$$\sigma_{cont} = \frac{U_s\, y_{max}\, 10^3}{w}$$

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 3.4.3 and the sleeper deflection at the rail seat given in Clause 4.3.3.

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

L.2.4.3 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 as given by Equation J-4:

Equation J-6

$$y_{max} = \frac{R\lambda}{2U}\frac{1}{\sinh\lambda l + \sin\lambda l}[2\cosh^2\lambda n\,(\cos 2\lambda c + \cosh\lambda l) + 2\cos^2\lambda n\,(\cosh 2\lambda c + \cos\lambda l) + \sinh 2\lambda n\,(\sin 2\lambda c - \sinh\lambda l) - \sin 2\lambda n\,(\sinh 2\lambda c - \sin\lambda l)]$$

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

L.2.5 Bending moment

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

Equation J-7

$$M_d = RC_{BM(max.)}$$

Two equations are utilized in the derivation of the sleeper bending moment coefficients (C_{BM}). One covers the region to the field side of the load source (region A to C in Figure), and is used to determine the moment coefficient adjacent to the rail foot ($C_{BM(n)}$). The second covers the midpoint of the sleeper (location O) and is used to determine the bending moment at the sleeper centre ($C_{BM(O)}$).

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 ($C_{BM(max.)}$) for use in calculating M_d is the larger of $C_{BM(O)}$ and $C_{BM(n)}$ shall be calculated as follows:

(a) Bending moment along portion A to C (x varies from 0 to n):

Equation J-8

$$C_{BM(x)} = \frac{1}{2\lambda}\frac{1}{sinh\,\lambda l + sin\,\lambda\,l}\{2\,sinh\,\lambda x\,sin\,\lambda x\;\;[cosh\,\lambda n\,cos\,\lambda\,(L-n) + cosh\,\lambda(L-n)\,cos\,\lambda n]\;\;+(cosh\,\lambda x\,sin\,\lambda x - sinh\,\lambda x\,cos\,\lambda x)[cosh\,\lambda n\,sin\,\lambda(L-n) - sinh\,\lambda n\,cos\,\lambda\,(L-n) + cosh\,\lambda\,(L-n) sing\,\lambda\,(L-n)\,cos\,\lambda n]\}$$

(b) Bending moment at sleeper centre ($x = L\,/\,2$):

Equation J-9

$$C_{BM(O)} = \frac{1}{2\lambda}\frac{1}{sinh\,\lambda l + sin\,\lambda\,l}\{sinh\,\lambda c\;[sin\,\lambda(L-c)] + sin\;\;\lambda c[sinh\,\lambda c\;+sinh\,\lambda\,(L-c)] + cosh\,\lambda c\;cos\;\;\lambda(L-c) - cos\;\;\lambda c\;cosh\;\;\lambda(L-c)$$

Appendix M Bibliography

The following referenced documents are used by this Standard for information only:

(a) AS 1085.14 Railway track materials, Part 14: Prestressed concrete sleepers.

(b) AS 1085.17 Railway track materials, Part 17: Resilient fastening assemblies.

(c) AS 3818.2 Timber - Heavy structural products, Part 2: Visually graded - Railway track timbers.

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

(e) Australasian Railways Association *Review of Track Design Procedures*. Volumes 1 and 2, 1991. (ISBN 0 909582 01 7)

Appendix N Hazard register

Hazard number	Hazard
6.8.1.9	Poor specifications, manufacture and QA (Quality Assurance) of material
6.9.1.36	Poor design and manufacture
6.14	Derailment
6.15	Track failure
6.20	Breathing in hazardous substances
6.28	Track and civil infrastructure design failure

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