AS 1085.14:2019

Railway track material Part 14: Prestressed concrete sleepers

RAIL INDUSTRY SAFETY AND STANDARDS BOARD

Infrastructure Standard

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AS 1085.14:2019 **Railway track material Part 14: Prestressed concrete sleepers**

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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.

Paul Daly
Chief Executive Officer
Rail Industry Safety and Standards Board

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Contents

Appendix Contents

1 Introduction

1.1 Purpose

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This Standard does not cover the use of materials complying with superseded editions of the AS 1085 series or the use of existing or re-used materials.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

1.2 Scope

This Standard specifies the performance requirements and gives design and testing methods for new prestressed concrete sleepers for use in railway track with continuously welded rail. It provides methods for determining loads on sleepers and refers to AS 1085.19 for requirements for resilient fastening systems.

This Standard does not cover the following:

(a) Design of post-tensioned concrete sleepers.

(b) Design of duo block concrete sleepers.

(c) Sleepers for use interspersed with other types of sleeper (e.g. timber or steel).

(d) Techniques and equipment for the manufacture of concrete sleepers.

This Standard is based on knowledge and experience of the following conditions of use:

(a) Train speeds less than 200 km/h.

(b) Sleeper spacing in the range 500 mm to 750 mm.

(c) Axle loads less than 50 tonnes.

Where parameters outside these limits are encountered, the general principles given in this Standard may be applied. However, the criteria in the Standard may not be sufficient and consideration should be taken of the intended conditions of use and the factors and methods used for design adjusted accordingly.

Additional requirements for the design and manufacture of special sleepers and fastenings are given in Appendix C.

NOTES:

1. Guidance to purchasers on information needing to be supplied at the time of calling for tenders or quotations and testing of new products is given in Appendix A.
2. Information on the means for determining compliance with this Standard is given in Appendix B.
3. Information on dynamic effects is given in Appendix D.

The scope of this Standard has been broadened to cover track situations other than main line track. The changes to the determination of loads by using alternative k_s values may include the use of the Eisenmann loading distribution method or other appropriate methods, which allows a wider range of speeds and track conditions to be taken into account.

1.3 Compliance

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

(a) Requirements.

(b) 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 cannot be applied or other controls are appropriate / 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.

1.4 Referenced documents

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:

(a) AS 1012 Methods of testing concrete

(b) AS 1012.11 Determination of the modulus of rupture

(c) AS 1085 Railway track material

(d) AS 1085.1 Steel rails

(e) AS 1085.19 Resilient fastening assemblies

(f) AS 1199 Sampling procedures for inspection by attributes

(g) AS 1199.0 Introduction to the ISO 2859 attribute sampling system

(h) AS 1199.1 Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection

(i) AS 1379 Specification and supply of concrete

(j) AS 1478 Chemical admixtures for concrete, mortar and grout

(k) AS 1478.1 Admixtures for concrete

(l) AS 2758 Aggregates and rock for engineering purposes

(m) AS 2758.1 Concrete aggregates

(n) AS 2758.7 Railway ballast

(o) AS/NZS 3582 Supplementary cementitious materials for use with portland and blended cement

(p) AS/NZS 3582.1 Fly ash

(q) AS/NZS 3582.2 Slag—Ground granulated iron blast-furnace

(r) AS/NZS 3582.3 Amorphous silica

(s) AS 3600 Concrete structures

(t) AS 3610 Formwork for concrete

(u) AS 3610.1 Documentation and surface finish

(v) AS 3972 General purpose and blended cements

(w) AS/NZS 4672 Steel prestressing materials

(x) AS/NZS 4672.1 General requirements

(y) AS/NZS 4672.2 Testing requirements

(z) SA HB 18.28 Conformity assessment—Guidance on a model third-party certification system for products

(aa) SA HB 79 Alkali aggregate reaction—Guidelines on minimising the risk of damage to concrete structures in Australia

(bb) AS/NZS ISO 9001 Quality management systems

(cc) AS/NZS ISO 9004 Managing for the sustained success of an organization—A quality management approach

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

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

NOTE: See Appendix D for additional referenced documents.

1.5 Definitions

Bearer: A transverse concrete unit supporting rails.

Bed of sleepers: All the sleepers that are stressed and cast together in the one concreting operation, and then cured in the same batch.

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

Construction joints: A joint, including a joint between precast segments, that is located in a part of a structure for convenience of construction and made so that the load carrying capacity and serviceability of the structure will be unimpaired by the inclusion of the joint.

Fastening: Component or group of components of a sleeper system that fastens the rail to the sleeper.

Gauge corner: Transition surface separating the rail running surface from the rail side.

Gauge point: The point on the gauge side of the rail head 16 mm beneath the top surface, at the centre- line of the rail at which track gauge is measured.

NOTE: Refer to Appendix D in AS 1085.1 for rail profiles which show the gauge point of the rails.

Insert: One or more of the fastening components that is cast into the sleeper at the time of manufacture.

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.

Line of sleepers: All the sleepers in a bed that share the same prestressing tendons.

Negative bending: Bending of a sleeper by application of a load that produces tension in the top surface of the sleeper.

Positive bending: Bending of a sleeper by application of a load that produces tension in the bottom surface of the sleeper.

Prestressed concrete sleeper: A sleeper utilizing concrete and prestressing tendons to resist flexure.

Prestressing tendon: A strand or wire within the sleeper that, under tension, compresses the concrete.

Proof testing (control testing): Testing of samples taken from routine production.

Rail pad: A part of the fastening that fits between the rail and the sleeper and acts to absorb impact, isolate electrically or protect components against abrasion.

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

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

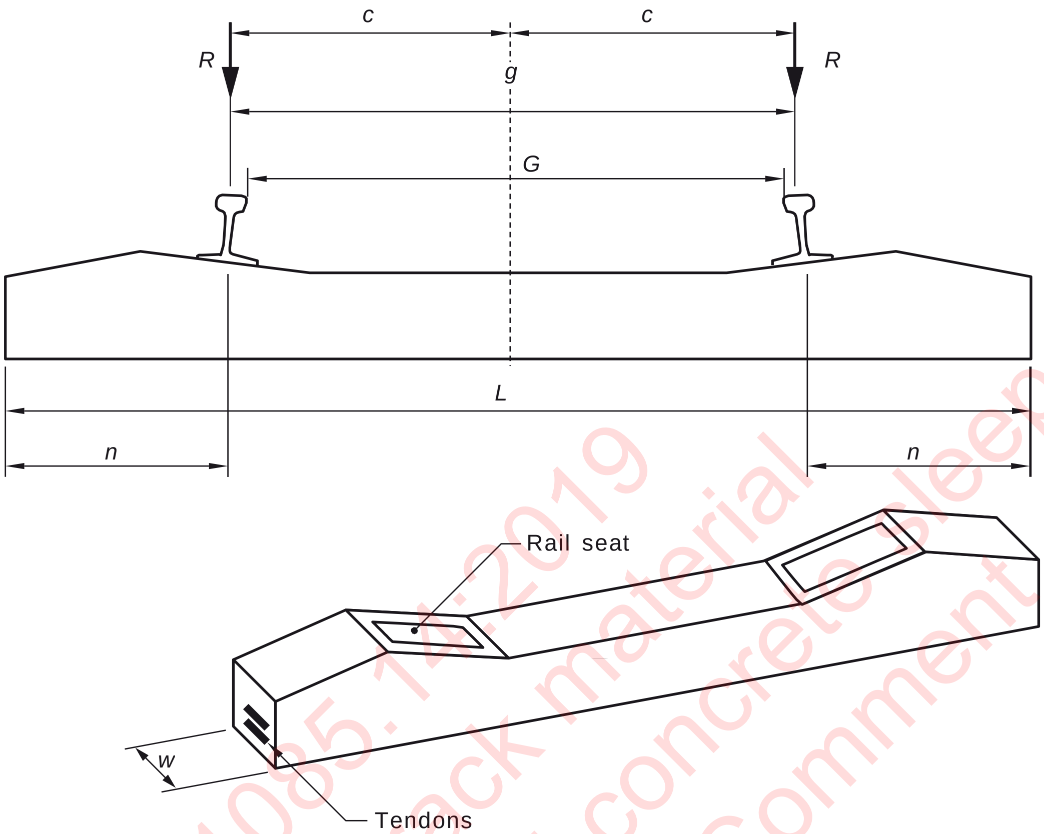
Soffit: Underside of the sleeper.

Structural cracking: In sleeper tests, hair-line cracking that originates at the tension face of the concrete sleeper, that extends up both sides of the sleeper to the nearest outside edge of the reinforcement or tendon, and that can be visually detected using an illuminated 5x magnifying glass with no other visual assistance from chemical or other methods.

Track gauge (G): Distance between the gauge points of the rails.

Type testing: Testing of samples from initial production to establish the performance of the specific design and the manufacturing methods.

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.



NOTE: The definitions of symbols in this Figure are given in Section 1.6.

FIGURE 1 SCHEMATIC REPRESENTATION OF SLEEPER SHOWING PRINCIPAL DIMENSIONS

1.6 Notation

Except where specifically noted, this Standard uses the SI units of kilograms, metres, seconds, pascals, newtons, hertz and tonnes (kg, m, s, Pa, N, Hz, t). For the purposes of this Standard, the term 'tonnage' indicates metric tonnes and not tons ('short' or 'long').

For the purposes of this Standard, the following notation applies:

At	=	transformed area of nominal section being tested, in millimetres squared
a	=	length of pressure distribution (ballast support) beneath each rail seat, in metres
$CBM(max.)$	=	maximum sleeper bending moment coefficient, in metres
$CBM(O)$	=	bending moment coefficient at the sleeper midpoint, in metres
$CBM(n)$	=	bending moment coefficient at the field side adjacent to the rail foot
$CBM(x)$	=	sleeper bending moment coefficient covering the region to the field side of the rail seat, in metres
c	=	dimension of sleeper from the centre-line of the rail seat to the centre of the sleeper, in metres (see Figure 1)
DF	=	load distribution factor, in percent
d	=	depth of wheel flat (see Appendix D Section D5)
drs	=	distance from the rail restraining face of the outside shoulder to the rail seat centre-line, in metres

E	=	Young's modulus of rail steel, in megapascals
E_s	=	Young's modulus of sleeper material, in megapascals
e	=	eccentricity of the centroid of prestress at the section being tested, in millimetres (see Section 3.4)
F_p	=	insert pull-out test load (specified value), in kilonewtons
$f_c{}'$	=	the characteristic 28-day compressive strength of concrete specified by the design, in megapascals
f_{cp}	=	the minimum compressive strength of concrete specified by the design at transfer, in megapascals
f_p	=	the tensile strength of the prestressing steel, in megapascals
$f_t{}'$	=	flexural tensile strength of the concrete in the extreme fibre at testing, in megapascals
G	=	track gauge, in millimetres
g	=	distance between rail centres measured at the top of the rail, in metres (see Figure 1)
g_{sh}	=	distance between the rail restraining faces of the outside shoulders of the assembly, in metres
g_1	=	distance between rail centres for larger dimension of dual gauge measured at the top of the rail, in metres (see Figure C1)
g_2	=	distance between rail centres for smaller dimension of dual gauge measured at the top of the rail, in metres
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	=	a value used to calculate bending (used in the empirical method), see Section 5.2 and Appendix C Section C4
k_s	=	service factor
L	=	length of the sleeper at the base
L_w	=	length of wheel flat (see Appendix D Section D5)
l	=	sleeper length at centre-line, in metres
M_d	=	design sleeper bending moment, in kilonewton metres
M_{C+}	=	design positive bending moment at the mid-span (centre) of the sleeper, in kilonewton metres
M_{C-}	=	design negative bending moment at the mid-span (centre) of the sleeper, in kilonewton metres
M_{R+}	=	design positive moment at the rail seat, in kilonewton metres
M_{R-}	=	design negative moment at the rail seat, in kilonewton metres
M^{cr}	=	cracking moment (calculated) at the section being tested, in kilonewton metres
$M^{cr}{}_{C+}$	=	positive cracking moment (calculated) at the mid-span (centre) of the sleeper, in kilonewton metres
$M^{cr}{}_{C-}$	=	negative cracking moment (calculated) at the mid-span (centre) of the sleeper, in kilonewton metres
$M^{cr}{}_{R+}$	=	positive cracking moment (calculated) at the rail seat, in kilonewton metres
$M^{cr}{}_{R-}$	=	negative cracking moment (calculated) at the rail seat, in kilonewton metres

n	=	dimension from end (on centre-line of bottom edge of end) to the centre-line of rail seat, in metres
P	=	calculated pre-stress force at the time of test, in newtons
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
P_3	=	test load required to produce the required negative centre moment (centre negative bending moment test), in kilonewtons
P_4	=	test load required to produce the required positive centre moment (centre positive bending moment test), in kilonewtons
P_{dV}	=	vertical design wheel load, in kilonewtons
P_{ab}	=	design sleeper to ballast bearing pressure, in kilopascals
Q	=	maximum static wheel load, in kilonewtons
R	=	design rail seat load, in kilonewtons
R_V	=	vertical design rail seat load, in kilonewtons
r	=	wheel radius (see Appendix D Section D5)
s	=	sleeper spacing, in metres
T	=	test torque for insert torque test, in newton metres
t_c	=	confidence limit (see Section 4.3.5)
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	=	maximum load per unit length of sleeper, in kilonewtons per metre (see Appendix C Section C1)
W_1	=	maximum load per unit length of sleeper for wider gauge of dual gauge, in kilonewtons per metre
W_2	=	maximum load per unit length of sleeper for narrower gauge of dual gauge, in kilonewtons per metre
w	=	average width of sleeper soffit supported by ballast, in millimetres
x	=	distance from the sleeper end, in metres
x_I	=	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 ‘xl’ from the point under consideration, in metres
$y_{max.}$	=	maximum sleeper deflection (assumed to occur immediately beneath the rail seat), in millimetres
Z	=	the transformed section modulus of the nominal uncracked section referred to the extreme fibre at which cracking occurs, in millimetres to the third power
β	=	track stiffness parameter calculated from the EI of the rail, in metres to the minus one, as follows (note this is different to ‘□’ which is used in the structural analysis Section): $\left(\frac{U}{4EI_x}\right)^{0.25} \times 10^{-}$

λ = sleeper stiffness parameter calculated from the EI of the sleeper, in metres to the minus one, as follows:

$$\left(\frac{U_s}{4E_sI_s}\right)^{0.25}\times10^3$$

σ_{cont} = contact pressure at the sleeper/ballast interface (see Clause 4.3.2), in kilopascals

2 Context of use

2.1 Function

Sleepers are support members 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 railways vehicles, the track structure should restrain 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 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;

(c) impact; and

(d) fatigue, wear, damage and corrosion.

Purpose and context of use defines the performance aims for the sleepers. The remaining Sections of the Standard set out how compliance with these performance aims can be achieved.

The critical outcome of sleeper design is the life to be expected in track (see Section 3.5). Expected life is not directly related to the expected load. For example, a single event such as a derailed rolling stock bogie can damage large numbers of sleepers. A serious wheel flat or wheel burn will reduce the sleeper life.

Cracking and significant damage to sleepers will not necessarily cause closure of the track or require that sleepers be replaced. A program is usually established for inspection and eventual replacement before deterioration reaches the unsafe operational limit.

3 Performance requirements and testing

3.1 General

This Section sets out the performance requirements for the sleeper and the tests and pass criteria to satisfy these requirements.

The performance of concrete sleepers in track depends on the condition of the rail and the joints provided, and on the rail fastening system, which comprises resilient fastenings, rail pads and insulators (see AS 1085.19). Accordingly, when considering their performance, the concrete sleeper and its fastening together with the rail and supporting ballast should be regarded as interdependent components of a system.

The analysis of requirements for such systems should necessarily involve not only the sleeper but all components of the track system, their interdependency and the conditions under which they should be applied. Thus, concrete sleeper track systems involve:

(a) rail, sleeper fastenings, ballast, formation and subgrade;

(b) design of each component, method of manufacture, installation and maintenance;

(c) direction, magnitude and frequency of traffic-imposed loads;

(d) effect of environmental factors such as temperature and weather;

(e) overall economics of installation and maintenance; and

(f) need to support and guide railway vehicles while restraining repeated lateral, vertical and longitudinal forces.

Item (c) will be influenced by the condition and interaction of both the track and the rolling stock.

3.2 Testing

3.2.1 General

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.

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

Testing facilities shall be appropriately qualified to carry out the required tests in accordance with the purchaser's requirements (see Appendix A Section A2(f)).

3.2.2 Type testing

The manufacturer shall carry out a track assembly test as detailed in Section 3.7.1 and type tests as detailed in Section 3.8.1 and (unless otherwise specified) on components that have been produced by the plant, materials and processes that the manufacturer intends to use in mass production when—

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

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

(c) the characteristic strength of the concrete or the prestressing is varied by the manufacturer.

3.2.3 Proof testing

Proof testing shall be carried out on a routine basis in accordance with Section 3.8.2.

3.3 Pre-stressed concrete sleeper design

3.3.1 Design principles

Sleepers shall be designed as fully prestressed sections.

The stresses shall be calculated from the design bending moments calculated in accordance with Section 4 using the design loads calculated in accordance with Section 4.

Where no other information is available, the value of R used for the calculations in Section 5 shall not be less than RV as determined in accordance with Section 4.

Loads and calculation methods given in this Standard are in permissible stress format and are not based on limit state principles. Alternative design techniques and materials may be used where the manufacturer can demonstrate compliance with the requirements of Sections 6 and 7 and other requirements, to the satisfaction of the purchaser.

NOTES:

1. The value of R used for design can be subject to other information requiring engineering judgement.
2. Background on design of sleepers can be found in Appendix N and on dynamics in Appendix D.

3.3.2 Shape and dimensions

The depth and width of the sleeper can vary throughout its length. The minimum length of the sleeper shall be determined by the bond development requirements of the prestressing tendons and the base width shall then be not less than that determined by the allowable bearing pressure.

The tolerances on sleeper manufacture shall be as given in Table 3.1. The manufacturer's tolerance of rail seat centre-line distance shall be consistent with track gauge tolerance as specified by the purchaser.

NOTE: See Appendix A for guidance on information to be provided by the purchaser.

3.3.3 Design ballast contact pressure

When designed in accordance with the service loads and track conditions specified using the methods given in Sections 4 and 5, the calculated ballast pressure shall not exceed 750 kPa for high-quality, abrasion-resistant ballast.

Where lower quality ballast materials than specified using AS 2758.7 are used, consideration shall be given to reducing the allowable ballast pressure.

Table 3.1
Permissible Tolerances

Dimension/Part/Condition	Tolerance
Length immediately after transfer	±6 mm
Cross-sectional dimensions	±3 mm
Location of centroid of tendons relative to the moulded surface of the sleeper	±3 mm
Location of individual tendons subject to complying with clear cover requirements	±5 mm
Longitudinal straightness	±6 mm
Concavity or convexity of rail seat in any direction	±0.5 mm
The 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 (tolerance on d_{rs})	+0.75, –0.25 mm
Distance between gauge restraining faces of the outside shoulder (tolerance on g_{sh})	+2.0, –1.0 mm

NOTES:

1. Track gauge and track gauge tolerance are to be specified by the purchaser (see Appendix A2(d)). A typical track gauge tolerance has a range of 6 mm, for example, +4, -2 mm.
2. Track gauge can be influenced by the sleeper tolerances, the fastening tolerances and the rail tolerances.

3.4 Sleeper integrity

3.4.1 General

The performance requirements for the integrity of the sleeper assembly shall be deemed to be met when Sections 3.4.2 to 3.4.5 are satisfied.

3.4.2 Sleeper materials

Materials shall conform to the requirements set out in Section 6.

3.4.3 Manufacture

Manufacture shall be carried out in accordance with Section 7.

3.4.4 Permissible stresses for design

When designed in accordance with the service loads and track conditions specified using the methods given in Sections 4 and 5, the calculated sleeper bending stresses in tension and compression shall not exceed the permissible stresses given in Table 3.2 for the cases described.

Consideration need not be given to checking sleeper sections for stresses other than flexural stresses (e.g. shear stresses), subject to the design complying with all other Sections of this Standard.

Table 3.2
Permissible Stresses

Material	Design situation	Type of stress	Permissible stress (MPa)
Concrete	Immediately after transfer and before deferred losses	Maximum compressive stress, where the distribution of stress is triangular or approximately triangular	$0.6\ f_{cp}$
	Immediately after transfer and before deferred losses	Maximum compressive stress, where the distribution of stress is uniform or approximately uniform	$0.5\ f_{cp}$
	Working conditions in track assumed by the designer after allowing for all losses of prestress	Maximum compressive stress	$0.45\ f'_c$
	Working conditions in track assumed by the designer after allowing for all losses of prestress	Maximum tension (flexure)	$0.4(f'_c)^{0.5}$
	Without any applied load, after all losses of prestress	Minimum compressive stress at any cross-section through the rail seat area	1.0
Prestressing tendons	Jacking stress after losses due to jack friction only, under the working conditions assumed by the designer	Maximum tensile stress	$0.8\ f_p$
	Initial stress immediately after transfer, under the working conditions assumed by the designer	Maximum tensile stress	$0.7\ f_p$

NOTES:

1. Where fp is the minimum of the range given in AS/NZS 4672 (series), as appropriate.
2. The loss of prestress shall be determined by the methods specified in AS 3600.

Where there is doubt on which category of distribution is appropriate, 0.55fcp is commonly adopted as the maximum permissible compressive stress at transfer.

The permissible concrete flexural tensile stress of $0.4\ (f')^{0.5}$ is based on the flexural tensile strength of $0.6\ (f')^{0.5}$ given in AS 3600.

3.4.5 Vertical load tests

When tested in accordance with Appendices E to I (rail seat vertical load test, rail seat repeated load test, development length test, centre negative bending moment test and centre positive bending moment test) using the loads given in Table 3.3, the sleeper shall not fail the pass criteria given in Table 3.3.

Table 3.3
Test Loads

Test method	Description	Load definition	Pass criteria
Appendix E	Rail seat negative bending	$P_1 = \dfrac{2M^{cr}_{R-}}{(0.33 - 0.075)}$	No structural cracking at P_1
Appendix E	Rail seat positive bending	$P_2 = \dfrac{2M^{cr}_{R+}}{(0.33 - 0.045)}$	No structural cracking at P_2
Appendix F	Rail seat repeated load (positive bending)	$P_2 = \dfrac{2M^{cr}_{R+}}{(0.33 - 0.045)}$	At the end of cyclic loading at $1.15P_2$— Support a static test load of $1.15P_2$ for at least 3 min without collapse Slippage of the tendon not exceeding 0.025 mm under $1.5P_2$ (development length test)
Appendix G	Development length	$P_2 = \dfrac{2M^{cr}_{R+}}{(0.33 - 0.045)}$	Slippage of the tendon (under $1.5P_2$) not exceeding 0.025 mm
Appendix H	Centre negative bending	$P_3 = \dfrac{2M^{cr}_{C-}}{(0.5g - 0.075)}$	No structural cracking at P_3
Appendix I	Centre positive bending	$P_4 = \dfrac{2M^{cr}_{C+}}{(0.5g - 0.075)}$	No structural cracking at P_4
Appendix J	Insert pull-out test	F_p = 60 kN	No yielding or cracking other than mortar cracking (see Section 3.6.3) Residual relative movement not
Appendix K	Insert torque test	T = 0.34 kNm	No rotation, cracking of the concrete or permanent deformation (see Section 3.6.4)

LEGEND:

$$M^{cr} = Z\left(f_t' + P/A_t\right) + e_p P$$

$$f_t' = 0.75\left(f_c'\right)^{0.5}$$

…3.4

NOTES:

1. Where agreed between the manufacturer and the purchaser, f_t' may be determined in accordance with AS 1012.11 for specimens cured in the same environment as the concrete sleepers.
2. Transformed section properties are used as this allows for the contribution of the prestressing steel to the stiffness of the uncracked section.
3. Prestress at the time of test may be calculated in accordance with AS 3600. If the sleeper is steam cured, then the basic relaxation of tendons as given in AS 3600 should be used.

The vertical load tests (Section 3.4.5) function as a compliance test of the sleeper. The loads are intended to create a bending moment that will just crack the sleeper. They are calculated from the flexural tensile strength of the concrete, f_t'.

The repeated load test bends the sleeper at just above the cracking moment.

The tendons should have sufficient reserve bond strength that they will not fail if the sleeper cracks. This is tested following the repeated load test.

3.5 Service life

3.5.1 General

The performance requirements for the expected service life of the sleeper assembly shall be deemed to be met when Sections 3.5.2 to 3.5.4 are satisfied.

NOTE: Sleepers designed to this Standard can be expected to have a life of 50 years; however, abrasion of the soffit particularly in poor ballast conditions will reduce that life. This should be taken into account when determining the bottom cover to the tendons.

3.5.2 Concrete durability

Materials shall conform with the requirements of Section 5 and concrete cover shall be in accordance with Section 3.5.3.

3.5.3 Clear tendon cover

The minimum clear concrete cover to tendons generally shall be 25 mm with the exception that the tendon can be exposed at the end faces. However, minimum cover to soffit of the sleeper shall be 35 mm.

The minimum clear tendon cover to an insert hole or fitting shall be 12 mm. Dissimilar metals shall not be in contact with any steel tendon.

3.5.4 Rail seat repeated load test

When tested in accordance with Appendix F with test load as given in Table 3.3, the sleeper shall not fail the pass criteria given in Table 3.3.

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.

3.6 Rail restraint and support

3.6.1 General

The requirements for rail restraint and support shall be deemed to be met when Sections 3.6.2 to 3.6.4 are satisfied.

3.6.2 Rail fastening systems

The fastening system shall be in accordance with AS 1085.19.

Where cast-in components are used, they shall be designed for the full life of the sleeper. The cast-in component shall be set in the concrete to a level below that of the top tendons.

NOTE: Alternative arrangements of cast-in components may be considered if their suitability is proven.

Abrasion-resistant pads or abrasion-vibration and impact reducing pads shall be used between the rail and concrete sleepers to minimize the possibility of abrasive action in the rail-bearing area of the sleepers.

NOTE: The rail pads are integral components of the concrete sleeper system. The degree of softness or hardness of the rail pads should be considered individually for each installation.

Factors such as wheel loads, speed of traffic, grade and degree of curvature should be considered.

3.6.3 Fastening insert pull-out test

When tested in accordance with Appendix J using the load Fp given in Table 3.3, the fastening and the surrounding concrete shall not show signs of yielding or cracking other than mortar cracking. Mortar cracking usually consists of surface hairline cracks in the hardened mortar paste of the concrete and is just visible to the unaided eye (see Note 1). Residual relative movement in the position of the fastening shall not exceed 0.2 mm relative to the rail seat (see Note 3).

NOTES:

1. Under the rail seat surface, surface craze cracks (usually of regular patterns) and hairline cracks (crack just visible to the unaided eyes) can become apparent on the concrete sleeper. This should not be confused with cracks formed by the generation of the conical tensile failure of the concrete.
2. Mortar cracking of concrete can form around inserts in the sleepers. The shape, material of the insert and characteristics of the concrete are the contributing factors. These are hairline cracks usually less than 0.1 mm and of short length. The cracks appear in the area surrounding the insert.
3. Evidence of adequate performance may be negotiated between the supplier and the purchaser.

3.6.4 Fastening insert torque test

This test shall be performed on inserts that have metal components protruding from the top of the sleeper to which a resilient fastening is attached. These inserts also act as the shoulder that restrains the rail and its pad from lateral or skewing movement.

When tested in accordance with Appendix K, the insert shall resist the test torque T given in Table 3.3 without rotation, cracking of the concrete or permanent deformation.

3.7 Track systems compatibility

3.7.1 Gauge

When tested by the track panel assembly test in accordance with Appendix L, sleeper assemblies shall maintain the track gauge within the tolerances specified by the purchaser (see Appendix A).

3.7.2 Signalling

When tested by the electrical short test in accordance with Appendix M, the impedance shall be greater than 30 ^ at 24 h after removal from the moulds. If less than 30 ^ is measured a further test shall be undertaken after 28 days and shall achieve an impedance of greater than 200 ^.

3.8 Sleepers testing

3.8.1 Type tests

3.8.1.1 Selection and marking

From the first bed of sleepers, two sleepers shall be selected for testing and shall be marked with numbers ‘1’, and ‘2’ respectively and sleeper 1 rail seats marked ‘A’ and ‘B’. Tests shall be carried out on sleepers in which the concrete has attained the required 28 days compressive strength. All sleepers tested shall be not more than 42 days old.

3.8.1.2 Sleeper 1

Sleeper 1 shall have the following type tests carried out on it in the following sequence:

(a) Rail seat vertical load tests (on seat A) in accordance with Appendix E.

(b) Rail seat vertical load tests (on seat B) in accordance with Appendix E.

(c) Rail seat repeated load test (on seat A) in accordance with Appendix F, including the development length test with a load of 1.5P2 in accordance with Appendix G but excluding the ultimate load part of the test.

(d) Centre negative bending moment tests in accordance with Appendix H.

(e) Centre positive bending moment tests in accordance with Appendix I.

(f) Rail seat repeated load test (on seat B) in accordance with Appendix F.

3.8.1.3 Sleeper 2

Sleeper 2 shall have the following tests carried out on it in the following sequence:

(a) Cast-in fastening component tests in accordance with Appendices J and K.

(b) Rail seat vertical load test followed by development length and ultimate load test on a rail seat in accordance with Appendices E and G.

3.8.2 Proof tests

The manufacturer shall carry out the following routine proof tests:

(a) Dimensional checks as follows:

i. Sleeper dimensions.

ii. Tendon location.

iii. Rail seat to rail seat.

iv. Fastening insert locations.

(b) Rail seat vertical load test between 7 and 30 days after casting in accordance with Appendix I performing the positive moment test only.

(c) Development length and ultimate load test between 7 and 30 days after casting in accordance with Appendix G.

(d) Electrical short test in accordance with Appendix M.

3.9 Marking

All markings shall be located so that they can be readily seen when the sleeper is installed.

Each sleeper shall be marked, by raised or indented letters of not less than 12 mm high, and at least 3 mm raised or indented (ensuring cover to reinforcement is not reduced below the minimum specified) with the following information:

(a) Mark required by the purchaser.

(b) Mark of manufacturer.

(c) Year of manufacture.

(d) Sleeper identification marks as required (including indication of the mould).

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.

3.10 Handling

3.10.1 Storage

The manufacturer shall provide a hard standing area for storing sleepers. The storage area shall be capable of sustaining the loading imposed by sleeper stack.

3.10.2 Stacking of sleepers

The finished sleepers shall be handled and stacked in such a manner that there shall be no damage to the sleepers. Sleepers shall be stacked on timber with timber packing between layers in such a manner that unacceptable stresses will not be induced in the sleepers.

NOTE: The recommended stacking method is to place timber packing on rail seats. The packing should be of sufficient height to maintain vertical clearance between layers and to allow forklift truck tines to enter and withdraw, and of sufficient width to prevent damage to rail pads if pre- installed on the sleepers.

4 Loads for design

4.1 General

For the design of the sleeper, loads on the rail seat of the sleeper shall be determined.

Where available, field measurements shall be used for determining loads to be used for testing and analysis. If field measurements are not available, Sections 4.2 to 4.4 below set out theoretical means for calculating vertical loads.

For the calculation method, the static wheel load (Q) is factored and applied at the top of the rail as the design vertical wheel load (PdV). This load is then distributed to the rail seat according to the behaviour of the rail, sleeper and ballast system as the vertical rail seat load (RV). Once determined, the load is used for calculation of sleeper stresses at working load.

4.2 Track conditions and dynamics

The factors used in this Section to modify the static wheel load are intended to cover all the possible effects on loading as they occur at the rail seat. These include the effects of the motion of railway vehicles, their springing, possible variation in vehicle weight, track geometry (curves) and geometrical roughness, low frequency resonances in the vehicle and rail interaction, high frequency dynamics, impact due to irregularities in the rail surface (joints and similar) and impact due to wheel irregularities.

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.
3. For information about dynamic effects on wheel loads and sleepers, see Appendix D.

Track that is constructed using concrete sleepers and fastener components meeting the requirements of this Standard is expected to give satisfactory performance under the nominated axle loads, providing that an acceptable level of maintenance is carried out.

The selection of an appropriate design load is critical and should be based on the actual track conditions and projected use of the track.

Many Australian tracks carry a mix of passenger and freight. Rolling stock axle loads are usually near the track load limit and, therefore, the average load for freight is close to the maximum permissible load. For mixed traffic or purely passenger trains, loads tend to be distributed more widely with the mean being somewhat below the track permissible load.

Appendix A lists the information to be supplied by the purchaser in order to enable the design load to be determined.

For the reasons discussed in Appendix D, the factors in this Standard covering the dynamic effect of loads will not guarantee satisfactory life of the sleeper where there are appreciable defects such as wheel burns, corrugations and wheel flats. In such circumstances, design of the sleeper and fastening assembly should be undertaken on the basis of high frequency forces that have been measured in the field for traffic and rail head conditions similar to those for which the system is to be designed.

4.3 Vertical design wheel load

4.3.1 General

The vertical design wheel load (PdV) shall be calculated as follows:

$$P_{dV} = ks\,Q \quad \text{. . . 4.3}$$

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

4.3.2 Service factor (ks)

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

The service factor (ks) 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 can also affect some of these uncertainties.

NOTES:

1. The default condition represents well maintained wheels and suspension systems.
2. The amount of unsprung mass might also be considered as part of this factor.

4.4 Vertical design rail seat load

4.4.1 General

The vertical design rail seat load (RV) shall be calculated by the methods given in Section 4.4.2 or 4.4.3.

Design of the sleeper by distribution of the load to the centroid of the sleeper is not permitted.

NOTE: Methods of calculation, other than those given in Section 4.4, which give equal or better estimation, may be used where agreed between the purchaser and supplier.

4.4.2 Vertical design rail seat load using the load distribution factor (DF)

The vertical design rail seat load (RV) shall be calculated as follows:

$$R_V = \frac{P_{dV}\,DF}{100} \quad \text{...4.4(1)}$$

DF is given in Figure 3.1.

Unless otherwise agreed, for a given sleeper spacing, the actual proportion of the vertical axle load taken by an individual sleeper shall be obtained from Figure 3.1. The distribution factors (DF) adopted in Figure 3.1 are based on rails equal to or heavier than 47 kg/m.

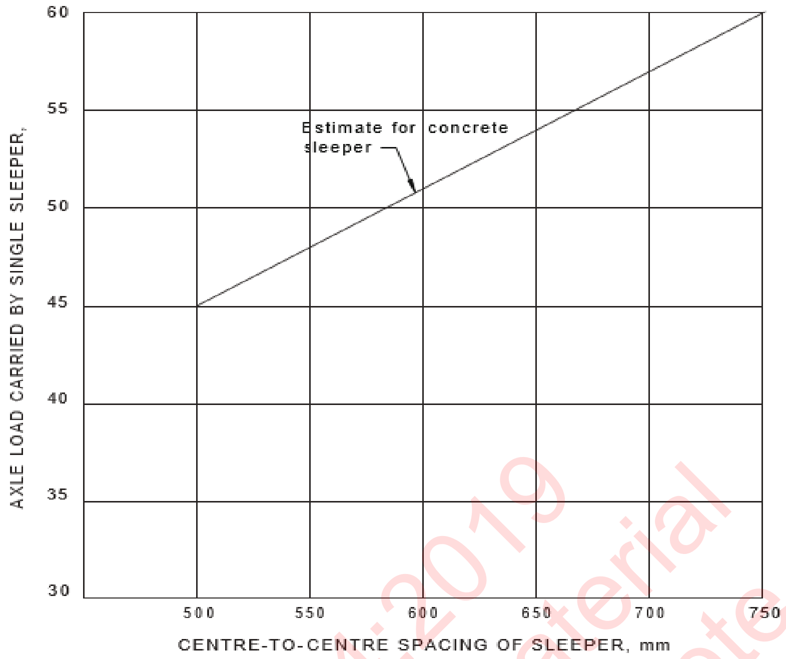


FIGURE 3.1 AXLE LOAD DISTRIBUTION FACTOR (DF)

4.4.3 BOEF method

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:

$$R_V = (U y_{max.}) s$$

and

…4.4(2)

$$y_{max.} = \sum_{i=1}^{n} y_i$$

…4.4(3)

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

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

…4.4(4)

Where Pav as calculated in Section 4.3

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) can 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.

5 Structural analysis

5.1 General

This Section specifies the method for determining the bending stress, sleeper bending moment (Md) 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 Section 5.2 or the method based on BOEF theory in Section 5.3.

Where no other information is available, the value of R used for the calculations in Section 5 shall not be less than RV as determined in accordance with Section 4.

NOTES:

1. Other methods of analysis may be used where agreed between the purchaser and the supplier.
2. The value of R used for design can be subject to other information requiring engineering judgement.
3. For guidance on Section 5 refer to Appendix N, Commentary to structural analysis.

5.2 Empirical method

5.2.1 Ballast and ballast pressure

The design sleeper to ballast bearing pressure (pab) shall be determined from loading conditions similar to those for the design positive bending moment at the rail seat. This bearing pressure is based on a uniform pressure distribution beneath each rail seat and is calculated using the appropriate equation from Table 5.1.

The equations given in Table 5.1 are derived from simple statics and can be readily verified.

The pressure distributions upon which they are based are simplified but are conservative versions of actual distributions measured. The maximum positive moment under the rail seat occurs when the track is freshly tamped and there is little or no contact between the ballast and centre portion of the sleeper. Over a period of time the ballast will gradually compact, allowing the centre portion of the sleepers to resist some of the applied load.

5.2.2 Design moments

5.2.2.1 General

The loads applied through the rail, combined with the ballast support reactions at the base of the sleeper, produce flexural stresses in the sleeper. Unless otherwise specified, the design moments shall be determined in accordance with Sections 5.2.2.2 to 5.2.2.5.

NOTE: The rail seat positive bending moment and the centre negative bending moment usually govern the design of the sleeper.

5.2.2.2 Rail seat positive design bending moment

The maximum positive bending moment shall be taken to occur at the rail seat producing compressive stress at the top and tensile stress at the underside of the sleeper. The value of this moment, the design rail seat positive bending moment (MR+), is based on a uniform ballast support beneath each rail seat as shown in Figure 4.1(a).

The length of the ballast support and rail seat positive design bending moment shall be calculated from the appropriate equation in Table 5.1 according to track gauge.

5.2.2.3 Rail seat negative design bending moment

The design rail seat negative bending moment (MR-) shall be not less than 67 percent of the rail seat positive design bending moment as given in Table 5.1.

5.2.2.4 Centre positive design bending moment

The maximum positive bending moment of the sleeper shall be based on a pressure distribution beneath each rail seat, similar to that shown in Figure 4.1(a). The length of the ballast pressure distribution beneath each rail seat and the design centre positive bending moment (MC+) shall be calculated from the appropriate equation given in Table 5.1.

5.2.2.5 Centre negative design bending moment

The maximum negative bending moment shall be taken to occur at the centre of the sleeper, producing tensile stress at the top and compressive stress at the underside of the sleeper.

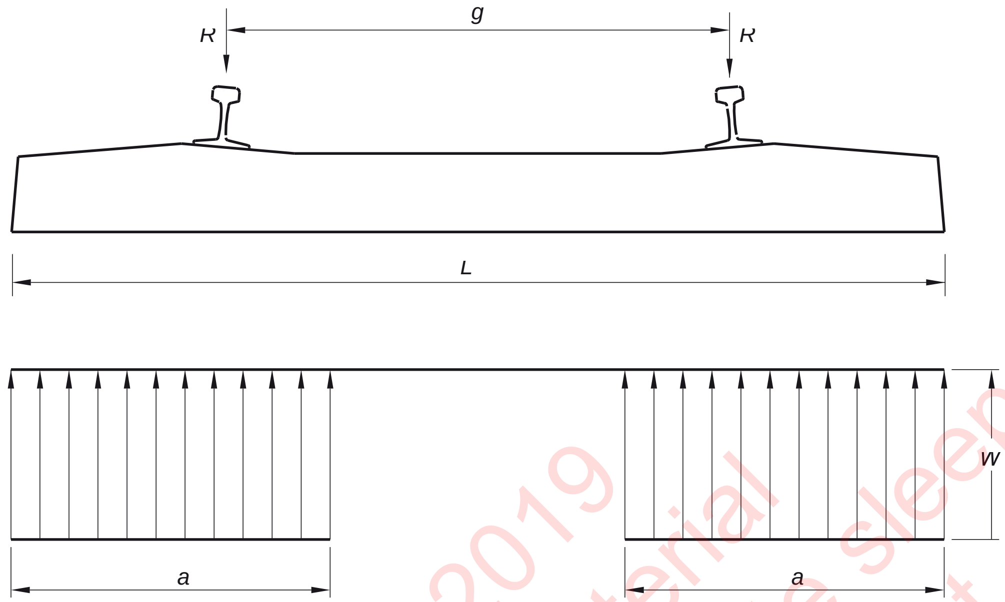
The design centre negative bending moment (MC-) shall be calculated from the appropriate equation given in Table 5.1.

TABLE 5.1
DESIGN PRESSURES AND MOMENTS—EMPIRICAL METHOD

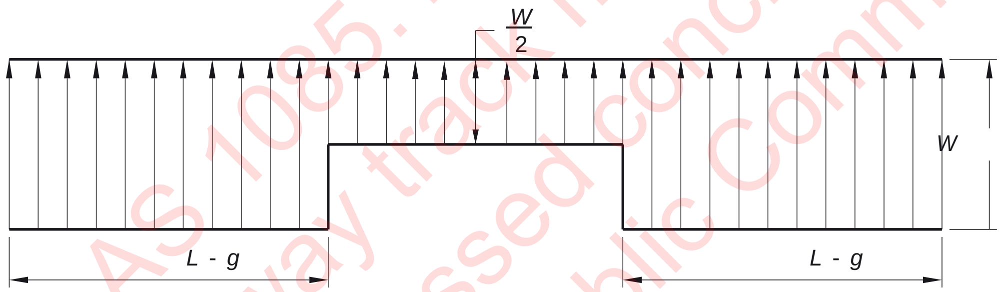
Distance between rail centres (g) m	Length of ballast support beneath each rail seat (a) m	Design values (see Note 1) kPa or kNm		
$g > 1.5$ m (standard and broad gauge)	$a = L - g$	1 Design ballast pressure (p_{ab})		$p_{ab} = \frac{R}{(w(L-g))}$
		2 Design positive bending moment at rail seat (M_{R+})		$M_{R+} = \frac{R(L-g)}{8}$
		3 Design negative bending moment at rail seat (M_{R-})		$M_{R-} = 0.67\ M_{R+}$
	$a = 0.9\ (L - g)$	4 Design positive bending moment at the centre (M_{C+})		$M_{C+} = 0.05R\ (L - g)$
		5 Design negative bending moment at the centre (M_{C-})	For Standard gauge: (see Note 2)	$M_{C-} = \frac{R(2g-L)}{4}$
			For Broad gauge: (1600 mm or greater, see Note 3)	$M_{C-} = 0.5\left[Rg - (kg(L-g)) - \frac{k(2g-L)^2}{8}\right]$ where $k = \frac{4R}{(3L-2g)}$
$1.5\text{ m} \geq g > 1.0$ m (narrow gauge)	$a = 0.8\ (L - g)$	6 Design ballast pressure (p_{ab})		$p_{ab} = \frac{R}{(0.8w(L-g))}$
		7 Design positive bending moment at rail seat (M_{R+})		$M_{R+} = \frac{R(L-g)}{6.4}$
		8 Design negative bending moment at rail seat (M_{R-})		$M_{R-} = 0.67\ M_{R+}$
		9 Design positive bending moment at the centre (M_{C+})		$M_{C+} = 0.10R\ (L - g)$
		10 Design negative bending moment at the centre (M_{C-})		M_{C-} = as spec by purchaser $\geq 0.67\ M_{C+}$ (see Note 4)

NOTES:

1. Calculation of the maximum rail seat positive bending moment can be varied by allowing uniform distribution of the applied load over the foot of the rail and taking moments at the outside edge of the rail foot.
2. Ballast support is assumed to be uniform.
3. Ballast support is assumed to be as shown in Figure 4.1(b).
4. The purchaser should consider the support conditions in determining the value of MC-. An increased value can provide some measure of confidence in situations where centre binding might occur.



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



(b)) Pressure distribution for maximum centre moment (negative) for track gauge of1600 mm and greater

FIGURE 4.1 PRESSURE DISTRIBUTION

5.3 Beam on elastic foundation (BEOF) method

5.3.1 General

The calculations in this Section 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 4.2 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).

This method has been introduced as an alternative to the empirical method. Further sophistication may be developed with the increasing use of finite element methods.

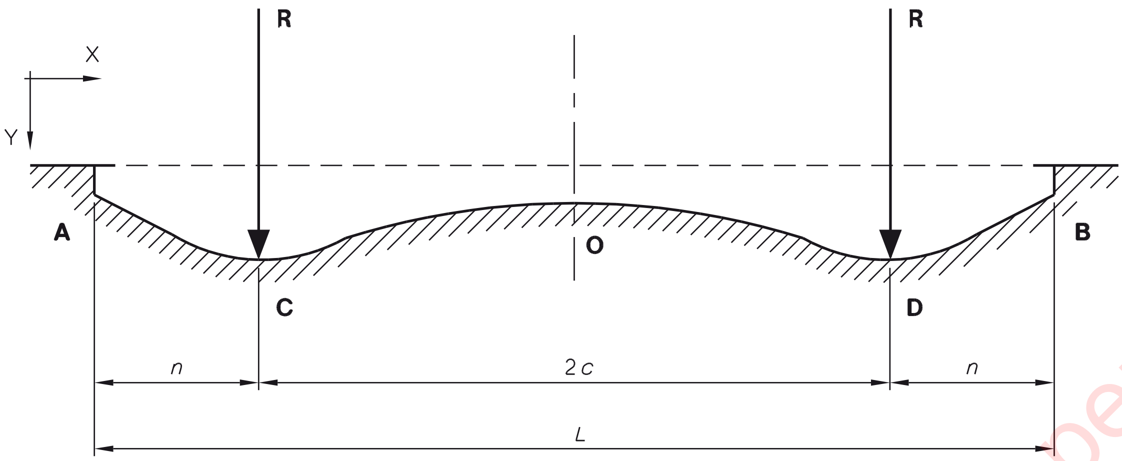


FIGURE 4.2 BOEF FORMULATION FOR SLEEPER MOMENTS AND DEFLECTION CALCULATIONS

5.3.2 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:

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

…5.3(1)

It is noted that, in general, the sleeper support modulus is approximately half the track modulus. More accurate values may be computed by equating the track deflection defined in Section 4.4.3 and the sleeper deflection at the rail seat given in Section 5.3.3.

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

5.3.3 Sleeper stiffness and deflection

The sleeper stiffness can be computed by solving the following equation iteratively, equating the maximum sleeper deflection to the maximum track deflection as given by Equation 3.4(4):

$$\begin{aligned} y_{max.} = \frac{R\lambda}{2U}\frac{1}{\sinh\lambda l+\sin\lambda l}\Big[&2\cosh^2\lambda n\left(\cos 2\lambda c+\cosh\lambda l\right) \\ &+2\cos^2\lambda n\left(\cosh 2\lambda c+\cos\lambda l\right)+\sinh 2\lambda n\left(\sin 2\lambda c-\sinh\lambda l\right) \\ &-\sin 2\lambda n\left(\sinh 2\lambda c-\sin\lambda l\right)\Big] \end{aligned}$$

…5.3(2)

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

5.3.4 Bending moment

Using the BOEF analysis the design moment (Md) can be calculated from the following equation:

$$M_d \qquad = \quad RC_{BM(max.)}$$

…5.3(3)

Two equations are utilized in the derivation of the sleeper bending moment coefficients (CBM). One covers the region to the field side of the load source (region A to C in Figure 4.2) and is used to determine the moment coefficient adjacent to the rail foot (CBM(n)). The second covers the midpoint of the sleeper (location O) and is used to determine the bending moment at the sleeper centre (CBM(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 CBM (max.) for use in calculating Md is the larger of CBM(O) and CBM(n) shall be calculated as follows:

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

$$\begin{aligned} C_{BM(x)} = \frac{1}{2\lambda}\frac{1}{\sinh\lambda L+\sin\lambda L}&\{2\sinh\lambda x\sin\lambda x|\cosh\lambda n\cos\lambda(L-n) \\ &+\cosh\lambda(L-n)\cos\lambda n]+(\cosh\lambda x\sin\lambda x \\ &-\sinh\lambda x\cos\lambda x)[\cosh\lambda n\sin\lambda(L-n)-\sinh\lambda n\cos\lambda(L-n) \\ &+\cosh\lambda(\mathrm{L-n})\sinh\lambda(L-n)\cos\lambda n]\} \end{aligned}$$

…5.3(4)

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

$$\begin{aligned} C_{BM(O)} = \frac{1}{\quad}\frac{1}{\sinh\lambda L+\sin\lambda L}&\ \ldots \sinh \ldots \sin \ldots \sin \ldots \\ &+\sin\lambda c[\sinh\lambda c+\sinh\lambda(L-c)] \\ &+\cosh\lambda c\cos\lambda(L-c)-\cos\lambda c\cosh\lambda(L-c)\} \end{aligned}$$

…5.3(5)

6 Materials

6.1 Cement

Unless otherwise specified, cement used shall comply with the requirements of AS 3972 for one of the following:

(a) Type GP—general purpose portland cement.

(b) Type GB—general purpose blended cement.

(c) Type HE—high early strength cement.

(d) Type SL—shrinkage limited cement.

6.2 Supplementary cementitious materials

6.2.1 Fly ash

Fly ash, if used, shall comply with the requirements of AS 3582.1. In addition, fly ash that contains carbon in such quantities that the electrical impedance requirements of Section 3.7.2 cannot be met shall not be used.

6.2.2 Slag

Ground granulated iron blast-furnace slag, if used, shall comply with the requirements of AS 3582.2.

6.2.3 Silica fume

Silica fume, if used, shall comply with the requirements of AS/NZS 3582.3.

6.3 Aggregates

6.3.1 General

Aggregates shall comply with AS 2758.1 and any additional requirements that should to be separately specified, in accordance with AS 2758.1, for a particular project or member.

6.3.2 Durability

Coarse aggregates shall comply with the requirements of AS 2578.1.

NOTE: AS 2758.1 includes a number of alternatives such that it cannot be used without qualification as a specification for contract purposes. Options appropriate to the available raw materials and intended use are to be specified by the purchaser. See Table 3.1, Note.

6.4 Water

Water used shall comply with the requirements of AS 1379.

6.5 Admixtures

6.5.1 Chemical admixtures

Chemical admixtures shall comply with AS 1478.1. Admixtures that are not compatible with each other shall not be used in the same volume of mixed concrete. Admixtures that delay the set shall not be used.

6.5.2 Chlorides

Calcium chloride or other chlorides shall not be used as either an admixture or a constituent of any admixture. An admixture is defined as ‘chloride free’ in accordance with the definition in AS 1478.1.

6.6 Prestressing tendons

6.6.1 Wire tendons

Wire tendons shall be stress-relieved indented wires not larger than 8 mm nominal diameter conforming to AS/NZS 4672 (series) unless otherwise approved by the purchaser. If chevron patterned indented wire is used, the indentations shall conform to the values for 5 mm nominal wire diameter.

Each line of sleepers shall contain no more than one wire joined by mechanical means.

6.6.2 Strand tendons

Strand tendons shall be stress-relieved 7-wire strand not larger than 10 mm diameter and conforming to AS/NZS 4672 (series).

Owing to the difficulty in achieving bond strength with plain bar, this Standard specifies indented wire or crimped wire. As an example of the bond afforded by indented wire, 5.03 mm chevron-patterned wire attains a transmission length of at least 300 mm. As the distance between the centre-line of the rail seat and the end of the sleeper is approximately 500 mm, bond failure is rare and is controlled by the routine load tests specified in Section 3.4.5.

Some manufacturers supply wire that is indented and crimped. These wires are most suitable where transmission length is critical.

Because of the small size and evenly scattered distribution of wires, tensions due to bursting and spalling forces are minimal and non-prestressed reinforcement is not generally required. However, in some circumstances transverse reinforcement can be necessary.

6.6.3 Alkali aggregate reactivity

For the purpose of this Standard, aggregates shall comply with the requirements of AS 2758.1 for alkali aggregate reaction.

If aggregates are found to be potentially reactive appropriate strategies shall be adopted to minimize the risk of damage due to alkali aggregate reaction.

NOTE: Guidance on the appropriate strategies can be found in HB 79, prepared by the National Working Group on AAR and jointly published by the Cement and Concrete Association of Australia and Standards Australia.

6.7 Concrete

6.7.1 General

Concrete shall be manufactured in accordance with AS 1379.

6.7.2 Characteristic compressive strength

The characteristic compressive strength (f_c') shall be not less than 50 MPa.

6.7.3 Minimum compressive strength

The compressive strength at transfer (f_{cp}) shall be not less than 30 MPa.

6.7.4 Saturated surface-dry density of the concrete

The saturated, surface-dry density of the concrete shall be in the range of 1800 kg/m3 to 2600 kg/m3.

6.7.5 Total chloride content

For total chloride ion content in concrete mix, the limits shall be as specified in AS 3600.

7 Manufacture of Sleepers

7.1 General

The manufacture of prestressed concrete sleepers shall comply with AS 3600, unless there is conflict with this Section, in which case the requirements of this Section shall take precedence.

7.2 Moulds

7.2.1 Specifications

The sleeper moulds shall be designed and constructed to ensure that sleepers are manufactured to the dimensions and within tolerances (see Section 2).

Provision shall be made for the accurate location and firm support of the cast-in components of the fastening system during the placement and vibration of the concrete.

Mortar leakage shall be controlled and shall not hinder the assembly of the fastening system of the completed sleeper.

7.2.2 Mould surfaces

Mould surfaces in contact with concrete shall have all bolt and rivet heads countersunk and all welds ground back to the correct dimensions.

The interior surface of the moulds shall be treated with a release agent to ensure non- adhesion of the concrete. Moulds shall be treated before placing tendons and cast-in fastening components.

7.3 Workmanship and finishes

The sleepers when removed from the moulds shall be free from cracks, chipped edges, honeycombing and surface defects, which lead to inadequate cover (see Section 3.5.3). The surface finishes shall be as follows:

(a) Rail seat surface shall be Class 1 finish as specified in AS 3610.1.

(b) Other surfaces shall be Class 3 finish as specified in AS 3610.1.

(c) Soffit surface shall be rough screed finish to achieve—

  i. cover from the surface to the tendons and embedded items; and

  ii. a uniform surface texture such that both projections from the indentations into soffit shall not exceed 5 mm from the general level of the surface.

7.4 Bonding of tendons

Any substance that impairs the bonding of the tendons to the concrete shall be removed from the tendons before and after they are placed in the moulds. The tendons shall be maintained in a clean condition until embedded in the concrete.

7.5 Concreting

7.5.1 Concrete consistency

Prior to production, optimum consistency and target water/cement ratio of the concrete shall be established and records of water cement ratio shall be available. The tolerance of water/cement ratio shall be 0.03.

7.5.2 Construction joints

Construction joints shall not be permitted in the casting of sleepers.

7.5.3 Curing

7.5.3.1 General

Curing of the concrete shall start immediately after finishing and shall be carried out continuously so that the design and performance requirements for strength and durability will be met.

Where low-pressure steam is curing is used it shall comply with requirements of Section 7.5.3.2.

7.5.3.2 Low-pressure steam curing

Low-pressure steam curing shall comply with the following requirements:

(a) Humidity The relative humidity of the curing atmosphere shall be not less than 95 percent during a curing cycle.

(b) Maximum concrete temperature When measured by a thermocouple placed centrally in the concrete sleeper below a rail seat, the temperature within the sleeper shall not exceed 70°C at any time during the curing process.

(c) Maximum rate of temperature rise When measured as in Item (b), the rate of temperature rise within the sleeper shall not exceed 24°C per hour at any time during the curing cycle.

(d) Maximum rate of temperature fall The concrete shall cool at a relatively uniform rate, and when measured at the centre and within 10 mm of the surface of the sleeper the difference in concrete temperature shall not exceed 15°C during any part of the cooling phase.

NOTES:

The time between the completion of casting and the full application of steam to the curing environment (‘delay period’) is dependent on the following:

1. Cement characteristics.
2. Initial temperature of the mix.
3. Water content of the mix.
4. Rate of temperature change during the delay period.
5. Proposed rate of concrete temperature rise.
    a. If the temperature within the sleeper exceeds 70°C, there is potential for delayed ettringite formation.
    b. In practice, curing cycles are controlled by adjusting the curing atmosphere temperature profile once the correlation between concrete temperature profile and curing atmosphere profile has been established for the particular manufacturing centre and mix design.

7.6 Transfer of prestress to sleepers

7.6.1 Releasing the tendons

Prestress shall be transferred to the sleepers in such a manner that the stress is transferred gradually and without interruptions.

Shock release of tendons shall not be permitted.

7.6.2 Cutting of tendons where required

After the prestress has been transferred to the sleepers, the tendons and individual sleepers shall be severed, working along the line or bed from the end points of release. All tendons shall be cut and trimmed mechanically, without damaging the concrete.

The cut ends of the tendon shall not protrude more than 5 mm beyond the surrounding face of concrete.

Appendix A Information to be provided

A.1 General

This Appendix contains guidance on the information on fastening systems that should be provided by the purchaser and supplier.

A.2 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 1085.14.

(b) General information, as follows:

   i. Name of railway system.

   ii. Section or sections of track where sleepers are to be installed.

   iii. Expected life before replacement.

   iv. The value of service factor (ks).

   v. Alternatively, if the Eisenmann loading distribution is proposed to determine the service factor (ks) then the values of the track condition factor, velocity dependent factor and the confidence limits.

   vi. Maximum gradient.

   vii. Design curve radii including respective super elevation and speed envelopes for each curve.

   viii. Insulation requirements for and type of track signal circuits.

   ix. Voltage of traction supply if traffic is electrified.

   x. Geographic and climatic extremes.

   xi. Environmental aggressiveness (e.g. presence of water or chlorides).

(c) Traffic information, as follows:

   i. Maximum static axle load, in tonnes.

   ii. The traffic mix as a combination of static wheel loads, in tonnes, and maximum train speeds, in kilometres per hour.

   iii. Centre of gravity of vehicle types above top of running rail.

   iv. Train Consist configuration including axle loads and associated axle spacing, bogie spacing and inter car spacing.

   v. Annual Gross Tonnes, in million gross tonnes per year.

(d) Track information, as follows:

   i. Nominal track gauge, including tolerance.

   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. Any special installation requirements (if relevant).

(e) Sleeper assembly design information, as follows:

   i. Sleeper spacing.

ii. Minimum length of sleeper and any additional limits on cross-sectional dimensions.
iii. Details of the fastening type.
iv. Acceptable type of types of pads and any attenuation requirements.

(f) Testing facilities, as follows:
i. Qualification and level of independence of the facility carrying out type testing.
ii. Qualification and level of independence of the facility carrying out proof testing.

(g) Packaging information, as follows:
i. Rail wagon loading details.
ii. Associated fastenings packaging requirements.

(h) Additional information Any special or supplementary requirements or exceptions to the requirements of this Standard.

NOTE: 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.

A.3 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.
(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) Fastening details.
(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 Product conformity

B.1 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.

B.2 Statistical sampling

Statistical sampling is a procedure which 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 or given capability and product throughput cannot be relevant to another manufacturer producing the same items.

(c) 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 1199.1, guidance to which is given in AS 1199.0.

B.3 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.

B.4 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 can provide the necessary confidence that the specified requirements will be met. The quality assurance requirements should 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.

Appendix C Special sleepers and fastenings

C.1 General

Special sleepers and fastenings shall conform to the requirements set out elsewhere in this Standard and with the additional requirements given in this Appendix. Special sleeper types include the following:

(a) Turnout bearers.

(b) Sleepers with additional rails (other than dual gauge sleepers).

(c) Dual gauge sleepers.

C.2 Special sleeper types

C.2.1 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).

C.2.2 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 bearer set 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 can be required to connect turnouts to canted track.

C.2.3 Sleepers with additional rails

C.2.3.1 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.

C.2.3.2 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 can prevent or minimize damage to a bridge structure.

C.2.3.3 Splay rail sleepers

A set of splay rail sleepers consists of a number of sleepers of variable lengths, which 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.

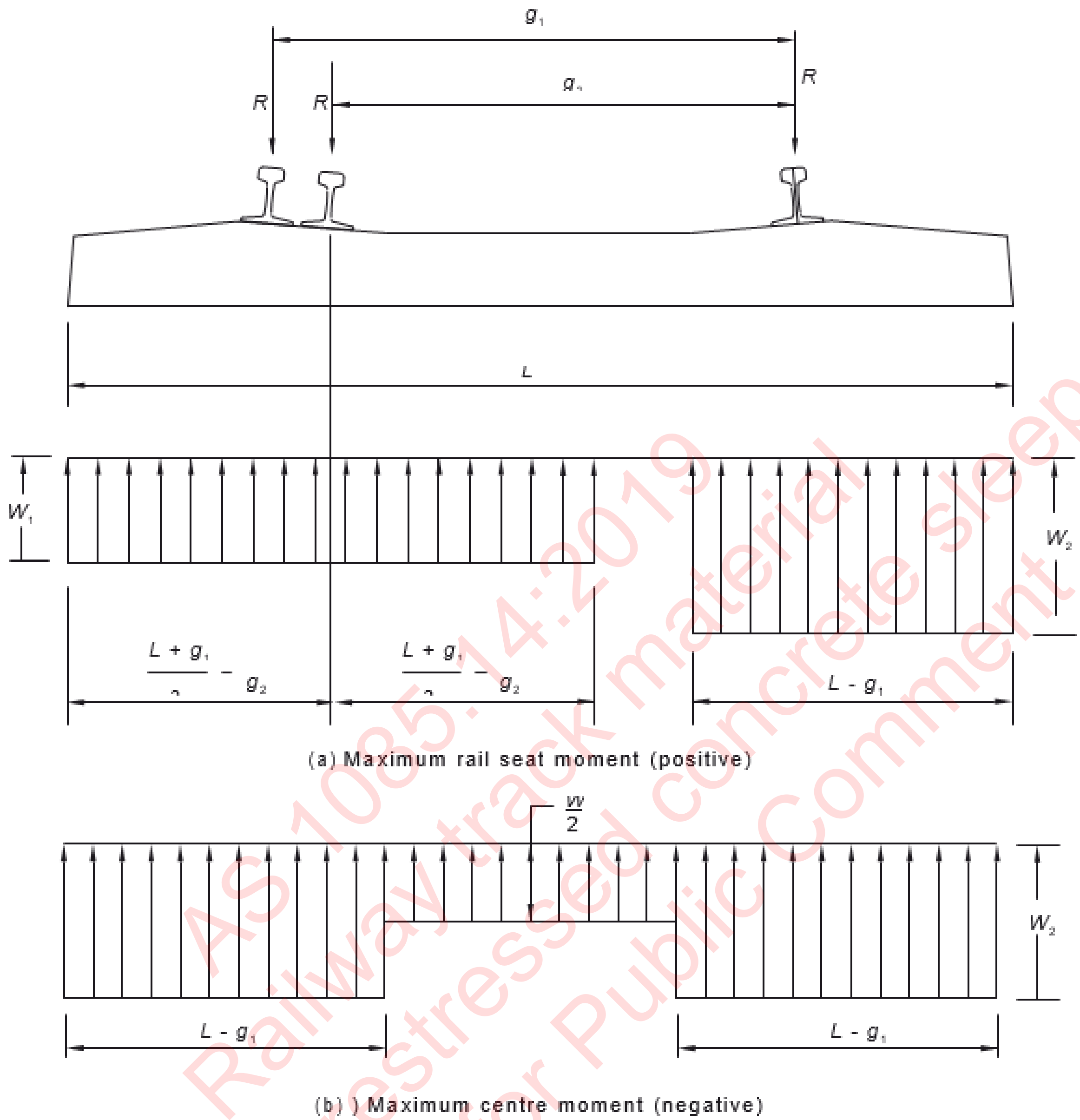


FIGURE C1 PRESSURE DISTRIBUTION FOR DUAL GAUGE SLEEPER

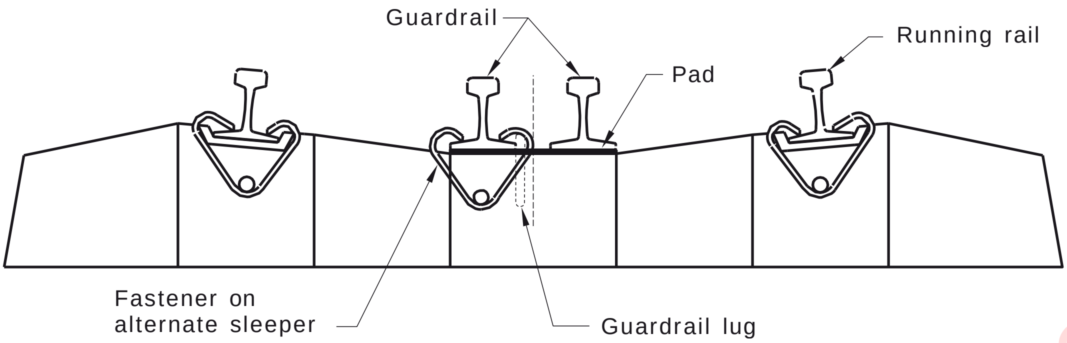


FIGURE C2 TYPICAL GUARDRAIL SLEEPER

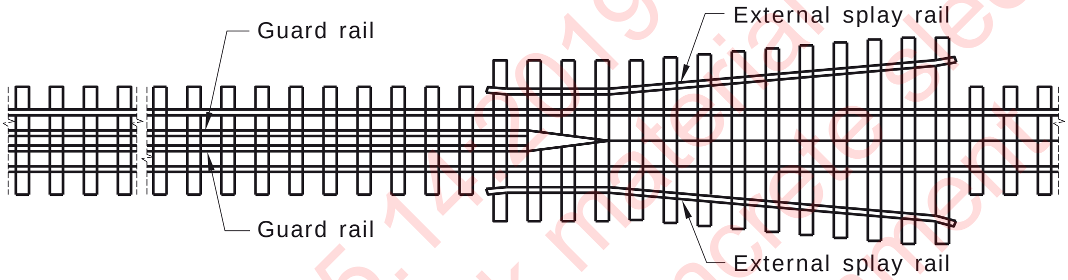


FIGURE C3 TYPICAL SPLAY RAILS AND GUARDRAILS

C.3 Manufacturing details

Because of the specialized nature of turnout bearers, splay rail sleepers and guardrail sleepers, the manufacturing procedure can be different from that for main line sleepers. However, it is common practice to cast prestressed concrete guardrail sleepers as part of the operation to produce main line sleepers, as the dimensions are usually similar.

For the varying lengths and fastening locations of turnout bearers and splay rail sleepers, a special bed is used, which is one sleeper wide. Typically, the bed will be about 50 m in length and able to accommodate moulds of differing length. It will incorporate one common pattern of prestressing tendons that are stressed by a common jack.

As each bearer or sleeper forms a part of a set-in turnouts or splay rail sets, it shall be clearly branded to indicate its position and orientation in the set. Where plates are used as part of the mould to form indented marking in the concrete, particular attention shall be given to prevent restraint type cracking due to shrinkage, particularly in the longer members.

There shall be sufficient bond development of the tendons in a relatively short length from the end of the sleeper. Bond development is characterized by sufficient compaction of the concrete, surface shape and condition of the tendon.

The ends of bearers or sleepers shall be sawn and shall be in accordance with Section 7.6.2.

A trial assembly shall be carried out on the first set of bearers or sleepers cast, with the rails, plates and fastenings specified by the purchaser to verify compliance with the specified tolerances. Moulds shall be adjusted as required and subsequent casts measured until the sleepers are within the tolerances.

C.4 Loadings and design

C.4.1 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 track gauge greater than or equal to 1435 mm.

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

$$M_{R+} = 0.25R\left[\frac{(L+g_1)}{2} - g_2\right] \qquad \text{. . . C4(1)}$$

$$M_{C-} = 0.5\left[Rg_1 - [kg_1(L-g_1)] - \frac{k(g_1^2 - L^2)}{8}\right] \qquad \text{. . . C4(2)}$$

$$M_{C+} = 0.05R(L-g_2) \qquad \text{. . . C4(3)}$$

where

$$k = \frac{4R}{(3L - 2g_1)} \qquad \text{. . . C4(4)}$$

For dual gauge track with a narrower 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 Section 5.2.

Alternatively, the BOEF method used in Section 5.3 may be used taking into account the dual nature of the track.

C.4.2 Turnouts and crossovers

A turnout bearer is a member of a complex grillage system in which rails are connected by resilient 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:

Distribution of axle load: The same method as used for standard sleepers may be adopted.

Impact factor: In order to allow for dynamic loading, the bearer should be designed for loads similar to those given for standard sleepers (see also Appendix D).

Centrifugal force: The effects of centrifugal force should be allowed for on the curved pair of rails.

Other forces: Forces and moments from points motors and other equipment should be allowed for where appropriate.

Load distribution: The method of distribution of the forces from rails and crossings to the rail seats should be specified by the purchaser.

Support conditions: Generally, it can be assumed that the bearer will be supported over its whole length by tamped ballast. Exceptions can 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.

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 can yield small values of negative (hogging) bending moment.

It is essential that adequate negative bending capacity be built into prestressed concrete bearers to cope with dynamic rebound effects, handling stresses and a degree of centre binding.

For prestressed concrete bearers, it is recommended that a value of negative bending moment be assumed that is at least two-thirds of the bearer's calculated maximum positive bending moment. The bearers should be designed to have this capacity at all sections outside the transmission zones.

Prestressed concrete end zone stresses Consideration should be given to bursting stresses induced at the bearer ends by the tendons. Transverse reinforcement should be provided where required. Where substantial bending moments can occur at the end portions of bearers, bond stresses in tendons should be limited to prevent slip under the design moment.

C.4.3 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 judgment 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.

It has been reported that the provision of transverse reinforcement reduces damage to prestressed concrete sleepers due to impact from derailed wheels. It may not be economically feasible to incorporate this in guardrail sleepers that are produced as part of a long-line process; however, sets of splay rail sleepers are produced individually and transverse reinforcement can be more readily incorporated.

C.5 Fastenings

Fastenings discussed in this Appendix include elastic resilient fastenings of a type already described in Section 6 as well as cast-in nylon, high-density polyethylene or galvanized steel inserts, sleeves or bolts.

Fastenings cast integrally with the sleepers shall be positioned within the specified tolerances at the locations shown.

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

Insulation, where required, shall conform to the requirements of AS 1085.19.

Plates may be secured by two or four bolt systems. Allowance shall be made by the designer to accommodate both fasteners and prestressing tendons, while still providing adequate cover to the tendons (see Section 3.5.3).

Nylon or high-density polyethylene inserts shall be threaded internally and externally so as to be replaceable (see AS 1085.19). The internal threading shall be designed to accept the diameter of coach screw or bolts specified. A locking device can be required to retain the coach screws in position.

C.6 Testing

C.6.1 General

Testing shall be carried out in accordance with the provisions of Section 3, except that the location of the maximum design bending moment should not coincide with the rail seat centre-line. In this event, the tests specified in Section 2 of this Standard to be carried out at the rail seat shall be carried out at those cross-sections nearest the ends of the sleeper that are designed to carry the maximum bending moment.

The purchaser may specify additional testing at the rail seat centre-line, to determine that adequate tensile strength and bond capacity exists there as well.

C.6.2 Additional fastening tests

In addition to fastening types covered in Section 3 of this Standard, sleepers covered by this Appendix can have the following types of cast-in components:

(a) Metal holding-down bolts with the threaded portion protruding above the top surface of the sleeper, which accept a plate to which a resilient fastening system is attached.

(b) Inserts of metal, vegetable fibre, polymer, or a composite of these, which receive bolts that hold down a plate to which a resilient fastening system is attached.

The fastening insert pull-out test (see Section 3.6.3) shall be performed on sleepers incorporating either type of fastening.

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

Where fastenings use inserts of the type specified in Appendix C Section C6.2(b), they shall be tested in accordance with the assembly lateral repeated load test described in AS 1085.19.

Appendix D Dynamic effects

D.1 Introduction

This Appendix provides some background information on the nature and effects of track loads on concrete sleepers to help the user of this Standard when dealing with this aspect of concrete sleeper design.

D.2 Track loads

While track loads originate from the rolling stock running on the track, the loads experienced by the sleeper are quite complex. The loads on the sleeper can occur with a very wide range of frequencies and effects. The loads from individual axles have frequencies of a few cycles per second (Hz) but the size of these loads depends on the rolling stock response to track geometry and support conditions. Track geometry here includes the design geometry (e.g. curvature, superelevation) and also the incidental geometry, i.e. track roughness. Loads with high frequencies occur as a result of irregular rail and wheel surface condition. Typical irregularities are rail corrugations, wheel flats, wheel burns, rail joints and welds. At higher frequencies the mass of a typical concrete sleeper becomes increasingly important and should also consider the sleeper as a dynamic component which has both mass and stiffness. Because of its distributed mass and stiffness, the sleeper resonates at a series of frequencies, the most significant for typical sleepers being around 200 Hz and 650 Hz.

D.3 Types of loads

The loads which arise from corrugations are essentially periodic, whereas the other types of irregularity give rise to impact loads. Both types of loading have been examined (Appendix D Refs (a) to (f)) where it is shown that the amplitudes of force depend not only upon the characteristics of the vehicle and of the track but also upon the shape. The amplitude of force on the rail arising from a typical dipped joint increase almost linearly with the product of train speed and the included angle of the dip, whereas the amplitude of force arising from a wheelflat increases with increasing severity of the flat but is not proportional to vehicle speed.

The forces impacting on the rail at the dip were called P1 and P2. P1 represented high force of very short duration while P2 a lower force with a much longer duration. These forces account for the impact arising from a discrete irregularity (Appendix D Ref. (e)).

The terms P1 and P2 are now generally associated with forces in certain frequency domain, e.g. P2 for the range 30 to 100 Hz and P1 for 100 Hz and above.

NOTE: These forces are not related to P1 and P2 forces used for the sleeper testing referred to in Section 2.

The P2 forces arises from bouncing of the vehicle's unsprung mass on the overall elasticity of the track and occurs at sufficiently low frequency as to be regarded as quasi-static. The force will increase when there are:

(a) increases in the effective unsprung mass of the vehicle;
(b) increases in the track stiffness; and
(c) decreases in the track damping.

The effect of P1 type loads depends on input frequencies due to wheel/rail contact conditions and the extent to which the track and its components will respond in resonance.

This is an area of considerable interest to researchers. Modes of response differ with the frequency involved. At around 150 Hz resonance occurs with the whole track bouncing on the ballast stiffness. At about 500 Hz, there is anti-resonance where sleepers vibrate on the ballast and pad stiffness, and at about 1000 Hz there is resonance at which the rail bounces on the pad stiffness (in anti-phase with the sleeper) (Appendix D Ref. (g)).

Amplitude of the P1 force as high as 400 kN have been measured in track (Appendix D Refs (a) and (b)). This force is associated with resonance of the sleeper at about 200 Hz. More recent work than that of Jenkins and Stephenson (Appendix D Ref. (a)) suggests that typically there exists another component of the impact force associated with the sleeper resonance of 650 Hz. Because the sleeper resonates, amplitudes of dynamic strain can be very much larger than would exist if the same force were applied to the track quasi-statically. Because concrete has little inherent damping, amplitudes of vibration at resonance can be very large. It has been recognized that premature cracking of concrete sleepers on Amtrak, British Rail and other systems has arisen because sleeper resonances have been excited.

Therefore, if there is severe dynamic loading of the track at high frequencies, this should be considered in the sleeper design.

D.4 Fatigue life

Failure of materials such as steel under fatigue loading is well established, but there has been relatively little work on fatigue loading of prestressed concrete. Present knowledge indicates that the design life will be obtained provided that the resultant strain in the concrete from precompression, static and dynamic loading is not tensile.

D.5 Rail head and wheel irregularities

For a prescribed amplitude of rail head irregularity, whether it be periodic or discrete, the dynamic force between wheel and rail and the dynamic sleeper strains depend most significantly upon the rail pad which has been placed between the rail and sleeper, the sleeper design and the ballast (in particular, how well the ballast damps vibration of the sleeper) (Appendix D Refs (c) to (e)). It is therefore desirable to consider these components together as a dynamic system in their design to withstand high frequency dynamic loading. Specification of their performance should be considered similarly.

A specification could, for example, be based upon the loading resulting from a wheel flat (examples of which exist on all railways) of specified size. Clayton, Cope and Frederick (Appendix D Ref. (h)) have suggested that a realistic target for conventional inspection techniques is that flats of 75 mm length be detected. Such a flat would be about 0.7 mm deep since length (LW), depth (d) and wheel radius (r) for a worn flat are related approximately by the formula d = LW2/16r.

The specification could demand that the resultant strain in the sleeper from dynamic plus static loading under the prescribed wheel flat, axle load and vehicle speed, be a prescribed fraction of the cracking strain found from a three-point bending test. It would then be as open to suppliers to obtain the required performance by using stiff and relatively inexpensive rail pads with substantial sleepers or by using less substantial sleepers with more resilience and more expensive rail pads that attenuate dynamic loads.

D.6 Alternative specification

An alternative specification of dynamic performance could be based upon testing of the combination of fastening system and sleeper in track in the railway's own operating conditions. Such a specification would be particularly desirable in view of data which have been found by Grassie (Appendix D Ref. (i)) from tests in track with a wide variety of operating conditions, wheel and rail defects. These tests indicate in particular that the ability of rail pads to attenuate dynamic strains in concrete sleepers depends on the type of defect. An appropriate test, which is discussed by Grassie (Appendix D Ref. (h)), would involve the attachment of strain gauges to one or more sleepers in track, and subsequent measurement of strains under either service traffic or a test train.

D.7 Testing apparatus

Although it would be desirable for any specification to be associated with a test in controlled laboratory conditions of the performance of the dynamic systems, at present there is no laboratory apparatus that adequately represents railway track and service conditions.

AS 1085.19 provides a test method for assessing pad attenuation by comparison with a reference pad assumed to have no attenuation of impact loads. This test might be applied to study dynamics in a laboratory situation using strain gauges at critical points such as the rail seat and sleeper centre. Background to this test can be found in Dean and Harrison (Appendix D Ref. (j)), Grassie and Cox (Appendix D Ref. 5) and Cox, Grassie, Leeves and Rhodes (Appendix D Ref. (k)).

While this test can be used to rank the dynamic performance of rail pads, its ability to give a quantitative assessment of the attenuation of particular cycles of dynamic strain in service conditions is limited. Accordingly, it is recommended at present that tests may be carried out in track under the railway's own operating conditions if more quantitative data for sleeper design are required.

The attenuation is applicable to the dynamic load component only and does not reduce the static effects on the sleeper. With high values of static axle load, the attenuation capacity of the pad can be reduced because static compression of the pad could reduce its response to dynamic effects.

The attenuation is applicable to the dynamic load component only and does not reduce the static effects on the sleeper. With high values of static axle load, the attenuation capacity of the pad can be reduced because static compression of the pad could reduce its response to dynamic effects.

D.8 References

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Appendix E Rail set vertical load test

E.1 Scope

This Appendix sets out the method of testing the rail seat for vertical loading.

E.2 Apparatus

The test assemblies shown in Figure E1 and Figure E2 are required.

E.3 Procedure

E.3.1 Negative moment test

The procedure shall be as follows:

(a) Support the sleeper as shown in Figure E1 for the negative moment test.

(b) 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 (see Section 3.4.5) is established.

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

(d) Inspect for structural cracking.

(e) Release the load.

E.3.2 Positive moment test

The procedure shall be as follows:

(a) Support the sleeper as shown in Figure E2 for the positive moment test.

(b) Apply load at a rate not greater than 25 kN/min until the test load P2 required to produce the proof rail seat positive moment (see Section 3.4.5) is established.

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

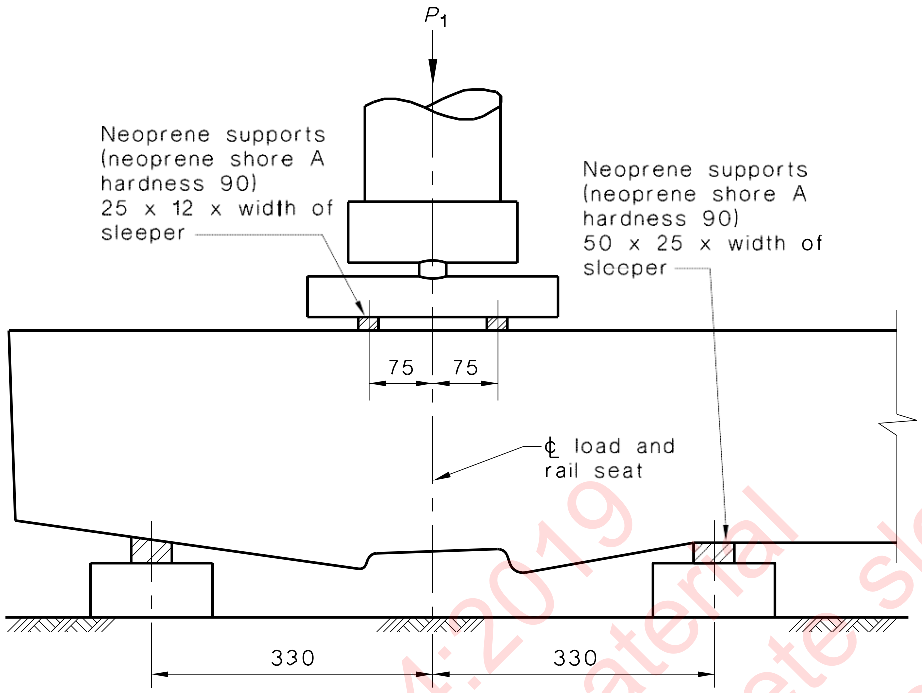
(d) During the 3 min period, visually inspect for structural cracking. A 5x magnifying glass may be used with no other visual assistance from chemical or other methods.

E.4 Report

The following shall be reported:

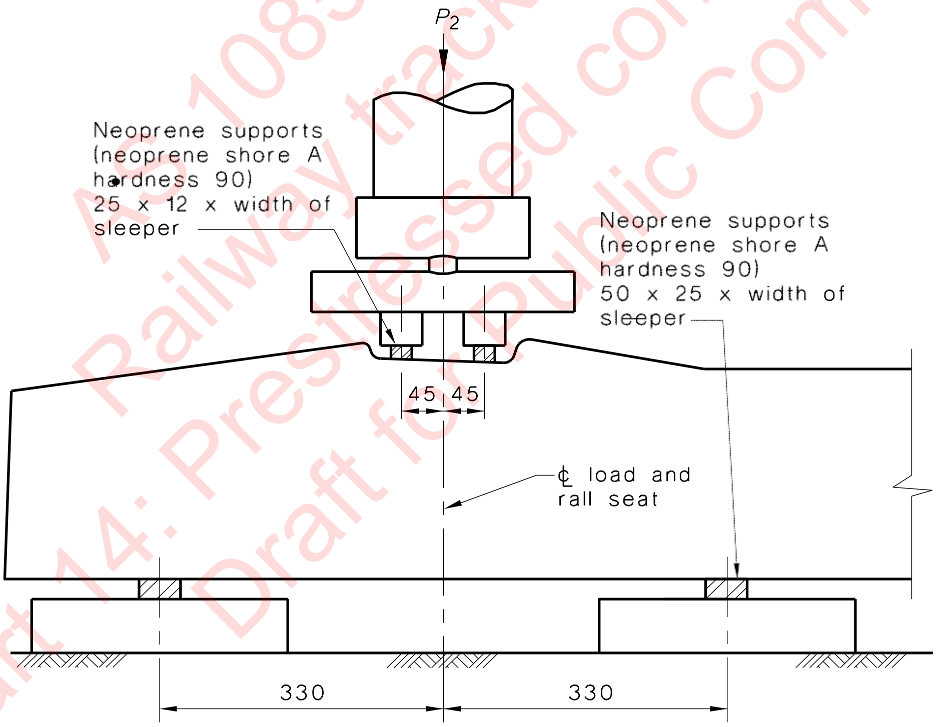
(a) Any structural cracking that occurs.

(b) The number of this Australian Standard, i.e. AS 1085.14.



DIMENSIONS IN MILLIMETRES

FIGURE E1 RAIL SEAT—NEGATIVE MOMENT TEST



DIMENSIONS IN MILLIMETRES

FIGURE E2 RAIL SEAT—POSITIVE MOMENT TEST, REPEATED LOAD TEST, BOND DEVELOPMENT AND ULTIMATE LOAD TEST

Appendix F Rail set repeated load test

F.1 Scope

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

F.2 Apparatus

The test assembly as shown in Figure E2 of Appendix E is required.

F.3 Procedure

The procedure shall be as follows:

(a) Following the vertical load test for the rail seat positive moment, apply load at a maximum rate of 25 kN/min until structural cracking occurs (that is, the sleeper cracks from the bottom surface up to the lower layer of prestressing tendons). A 5x magnifying glass may be used to inspect for structural cracking with no other visual assistance from chemical or other methods.

(b) Record the load at which this cracking occurs.

(c) Release the load.

(d) Apply a repeated load for 3 million cycles with the load varying uniformly from 15 kN to the test value of 1.15 P2 with each cycle.

(e) Ensure that the repeated loading does not exceed 600 cycles per minute.

(f) After 3 million cycles, apply the static test load of 1.15 P2 for at least 3 min.

(g) Record any failure to support the static test load.

(h) Perform the development length test (see Appendix G) with the test load of 1.5 P2, without performing the ultimate load part of the test.

(i) Record the tendon slippage (see Appendix G).

F.4 Report

Report the following:

(a) The value of the load at which the cracking occurs.

(b) Whether the sleeper failed to support the static test load for 3 min.

(c) The amount of tendon slippage based on the development length test.

(d) The number of this Australian Standard, i.e. AS 1085.14.

Appendix G Development length and ultimate load test

G.1 Scope

This Appendix sets out methods for conducting the bond development and ultimate load tests for the sleeper.

G.2 Apparatus

The following apparatus is required:

(a) The test assembly as shown in Figure E2 of Appendix E is required.

(b) Two extensometers reading to 0.001 mm.

G.3 Procedure

G.3.1 Bond development length

The procedure shall be as follows:

(a) Support the sleeper in the test assembly.

(b) Attach extensometers to the ends of at least two tendons. The tendons gauged shall be in the bottom layer of the tendons.

(c) Apply the load at a uniform rate not greater than 25 kN/min until the total test load of 1.5 P2 is applied.

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

(e) Record the deformation of the tendon as measured by the extensometer.

(f) If structural cracking has not occurred increase the load until structural cracking has occurred. A 5x magnifying glass may be used to inspect for structural cracking with no other visual assistance from chemical or other methods.

(g) Maintain the load (at structural cracking) for 3 min and record the deformation of the tendon.

G.3.2 Ultimate load

When the sleeper is not to be used for further testing (see Appendix F and Section 3.8.1.2(f)), the following procedure shall be performed:

(a) Remove the extensometer.

(b) Increase the load until ultimate failure occurs.

(c) Record the ultimate load.

G.4 Report

The following shall be reported:

(a) The load at structural cracking (if above 1.5 P2).

(b) The deformation of the tendon, in millimetres, at the load of 1.5 P2 and if relevant at structural cracking.

(c) The ultimate load (if appropriate).

(d) The number of this Australian Standard, i.e. AS 1085.14.

Appendix H Centre negative bending moment test

H.1 Scope

This Appendix sets out the method of conducting the centre negative bending moment test for the sleeper.

H.2 Apparatus

The test assembly as shown in Figure H1 is required.

H.3 Procedure

The procedure shall be as follows:

(a) Apply load at a rate not greater than 25 kN/min until the test load P3 required to produce the specified negative centre bending moment (see Section 3.4.5) is obtained.

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

(c) During the 3 min period, visually inspect for structural cracking. A 5x magnifying glass may be used with no other visual assistance from chemical or other methods.

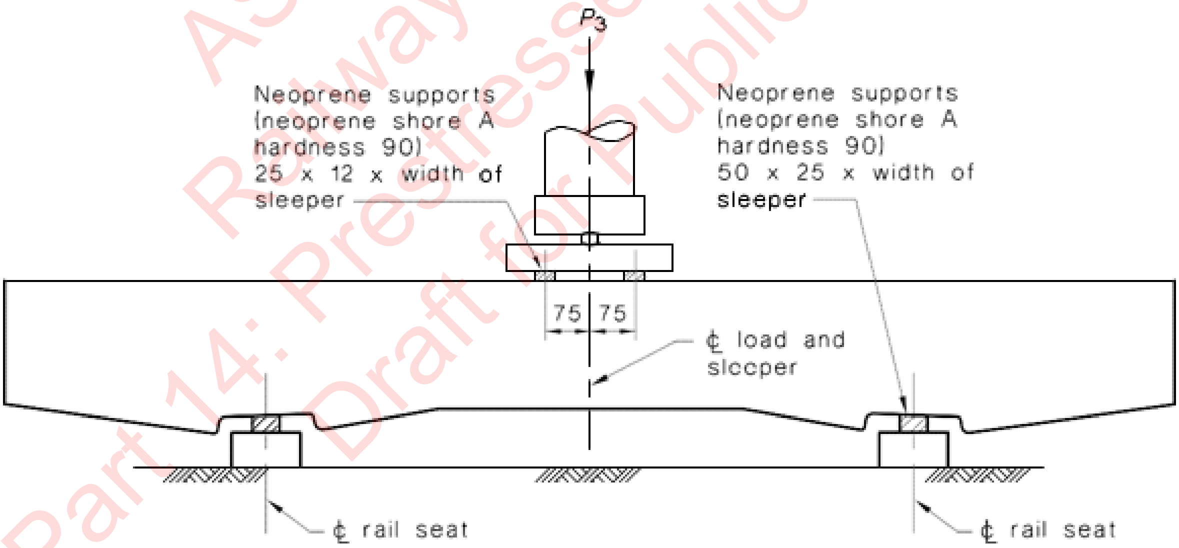
(d) Release the load.

H.4 Report

The following shall be reported:

(a) Any structural cracking in the sleeper.

(b) The number of this Australian Standard, i.e. AS 1085.14.



DIMENSIONS IN MILLIMETRES

FIGURE H1 CENTRE—NEGATIVE MOMENT TEST

Appendix I Centre positive bending moment test

I.1 Scope

This Appendix sets out the method of conducting the centre positive bending moment test for the sleeper.

I.2 Apparatus

The test assembly shown in Figure I1 is required.

I.3 Procedure

The procedure shall be as follows:

(a) Apply load at a rate not greater than 25 kN/min until the test load P4 required to produce the specified positive centre proof moment (see Section 3.4.5) is obtained.

(b) Maintain the load (P4) for not less than 3 min.

(c) During the 3 min period, visually inspect for structural cracking. A 5x magnifying glass may be used with no other visual assistance from chemical or other methods.

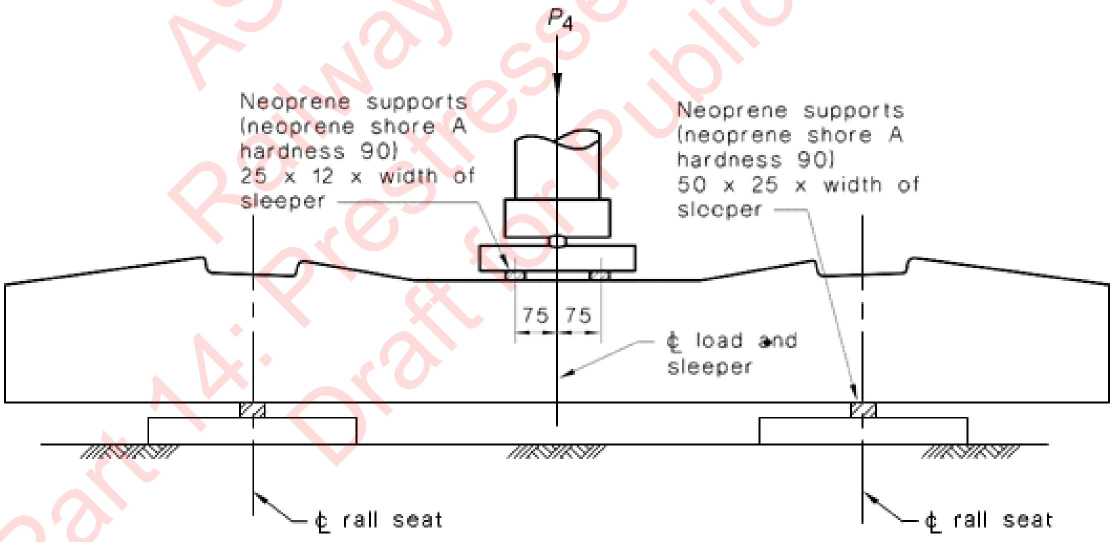
(d) Release the load.

I.4 Report

The following shall be reported:

(a) Any structural cracking in the sleeper.

(b) The number of this Standard, i.e. AS 1085.14.



DIMENSIONS IN MILLIMETRES

FIGURE I1 CENTRE—POSITIVE MOMENT TEST

Appendix J Fastening insert pull-out test

J.1 Scope

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

J.2 Apparatus

The following apparatus is required:

(a) Test assembly as shown in Figure J1.

(b) Dial gauge.

J.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 (Fp) (see Section 3.4.5).

(d) Maintain the load (Fp) 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 concrete for signs of yielding and cracking.

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

J.4 Report

The following shall be reported:

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

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

(c) The number of this Australian Standard, i.e. AS 1085.14.

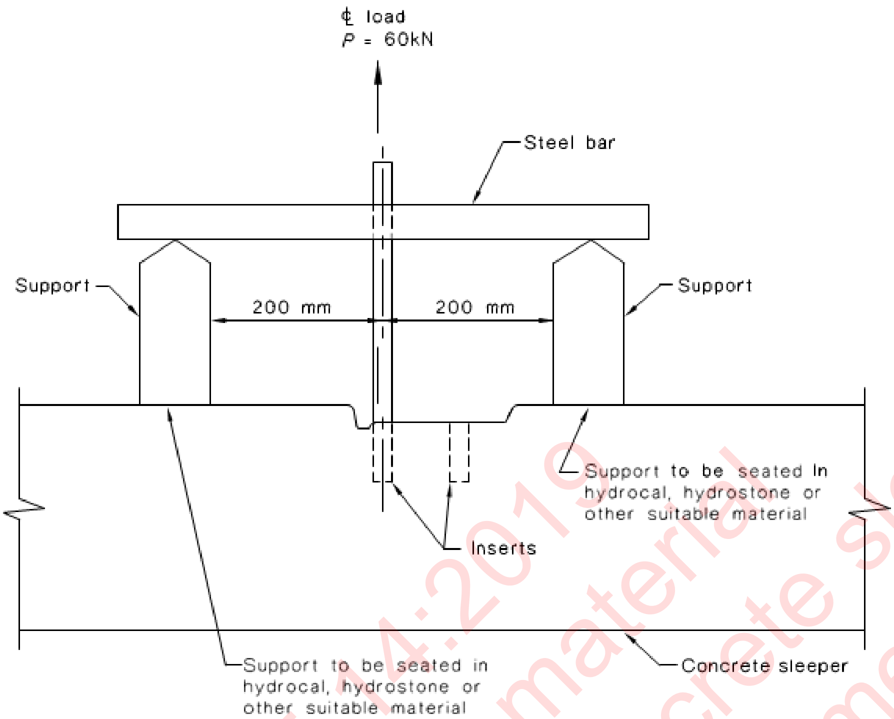


FIGURE J1 FASTENING INSERT PULL-OUT TEST

Appendix K Fastening insert torque test

K.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.

K.2 Apparatus

The following apparatus is required:

(a) A calibrated torque wrench.

(b) Suitable attachment to the insert.

K.3 Procedure

The procedure shall be as follows:

(a) Following the successful completion of the fastening insert pull-out test (see Appendix J), apply the test torque (T) (see Section 3.4.5) 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, cracking of the concrete, or any permanent deformation.

K.4 Report

The following shall be reported:

(a) Insert rotation.

(b) Cracking of the concrete.

(c) Any permanent deformation.

(d) The number of this Standard, i.e. AS 1085.14.

Appendix L Track panel assembly test

L.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 may also be evaluated using this test.

L.2 Apparatus

The following apparatus is required:

(a) 6 sleepers.

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

(c) 2 rails, each 4 m long.

L.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 shown to be of nominal dimensions except the sleepers being tested.

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) 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) Ensure the rails are in the centre of the rail seat, unless otherwise agreed with the Purchaser.

(e) Measure the track gauge achieved by the rail.

L.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 1085.14.

Appendix M Electrical short test

M.1 Scope

This Appendix sets out the method of conducting the electrical short test. The impedance of the sleeper between rail seat inserts is determined to check for electrical short between the rail seats.

M.2 Apparatus

The following apparatus is required:

(a) One prestressed concrete sleeper.

(b) 12 V dc. or 12 V ac. (50 Hz) voltage source.

(c) Two calibrated meters to measure impedance with an accuracy of better than 95 percent.

M.3 Procedure

The procedure shall be as follows:

(a) Perform the initial test when the sleeper has been removed from the mould for no longer than 24 hours or, alternatively, at 28 days if required.

(b) The two inserts of each rail seat shall be connected together electrically using a source of 12 V.

M.4 Report

The following shall be reported:

(a) Impedance at 24 h or impedance at 28 days, as applicable.

(b) The number of this Australian Standard, i.e. AS 1085.14

Appendix N Guidance on structural analysis

N.1 General discussion of design

N.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.

N.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.

N.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.

N.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. A conservative estimate of the distribution is given in Figure 3.1. For the sake of simplification, the distribution factors are 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.

The flexure stress generated in rail under load is a function of applied bending moment and the section modulus of the rail. Rail bending moment is determined by wheel load, axle spacing and track modulus. Most modern rail sections are capable of bearing current wheel loads on sleeper spacings up to 750 mm with normal ballast support without distress. The distribution factors given in Figure 3.1 are used only for rails heavier than 47 kg/m. For lighter sections it is recommended that the designer carry out an independent analysis to compute the real bending stresses, distribution factors and other factors.

N.1.5 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 can 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.

N.1.6 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 can 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 should 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.

N.1.7 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.

N.1.8 Shear stresses

Past practice has indicated that a design based on proportioning the sleeper for flexural strength only is adequate, subject to complying with the dimensional requirements of Section 3.3.2.

N.2 Interspersed sleeper types

This Standard does not cover interspersed concrete sleepers, nevertheless prestressed concrete sleepers are sometimes used interspersed with other sleeper types. Assessment of the design load can require additional considerations such as the condition of the other sleepers and the resultant possibility of more loads being attracted by the concrete sleepers.

The following additional investigation can be necessary:

(a) In track testing.

(b) Finite element analysis.

(c) Control trials.

(d) Condition and depth of the ballast.

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