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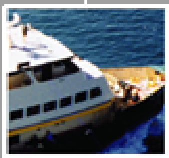


RAIL SAFETY INVESTIGATION REPORT

Steel Sleeper Introduction on NSW Class 1 Main Line Track.

1996 - 2004



OTSI File Ref: 02619

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STEEL SLEEPER INTRODUCTION ON NSW CLASS 1 MAIN LINE TRACK.

1996 - 2004

OTSI File Ref: 02619 **31 August 2005**	**Office of Transport Safety Investigations** **Level 22, 201 Elizabeth Street** **Sydney NSW 2000**

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Glossary of Terms

ARTC	The Australian Rail Track Corporation Ltd, from 1 September 2004 the Infrastructure maintainer for the NSW country rail network.
Ballast	Ballast is the selected crushed granular material placed at the top layer of the substructure on which the sleepers are laid. It is provided to support the sleeper and to transfer load between the sleeper and formation. Ballast also allows water to drain thereby keeping water away from the rails and sleepers.
Class 1 line	Refers to track with a 53kg or 60kg rail.
Clumping	The installation of multiple sleepers side by side.
Crib	Denotes the space between two adjacent sleepers. This space contains ballast.
High volume and high tonnage line	Refers to rail traffic above 6 million gross tonnes per annum and axle load above 22 tonnes.
In-face	Sleepers of the same type placed in a continuous row, also referred to as *on-face.*
ITSRR	Independent Transport Safety and Reliability Regulator – The NSW Government Rail Regulator from 1 January 2004.
MGT	Million Gross Tonnes
PRS	Partial Re-Sleepering – only replacing some sleepers, not installing in-face.
Pod	The space under a steel sleeper. The trough or void.
Pumping	Sleeper action where the sleeper moves vertically up and down as rail traffic passes over the sleeper. This movement often results in the degradation and contamination of the ballast structure.
RAC	Rail Access Corporation - NSW rail organisation July 1996 to January 2001.
RIC	Rail Infrastructure Corporation - NSW rail organisation January 2001 to present.
Rounding	The smoothing of the edges of ballast due to pumping of sleeper causing ballast to rub together; also known as marbleising.
RSA	Rail Services Australia - NSW rail organisation July 1997 to January 2001.

Sleeper	Sleepers are support members that are part of the structure of railway permanent way. They are embedded into the ballast and support the rails above. They tie the rails together maintaining gauge and rail position and resisting lateral and longitudinal movement of the rail system.
SMS	Safety Management System.
Tamping	The process by which ballast is packed in and around the sleepers of a track. In the case of tamping steel sleepers the ballast is squeezed to lift it into the pod.
Tie	Also referred to as a sleeper.
TSB	Transport Safety Bureau - The NSW Government Rail Regulator until January 1 2004.
Waiver	An approval given to a process or item which was formerly not recommended within a standard; it may be conditional in terms of time or scope.
WOLO	Temporary speed restrictions applied during hot weather.

EXECUTIVE SUMMARY

Commissioning of Investigation

1. When the Office of Transport Safety Investigations (OTSI) was established in January 2004, it took over an investigation into a derailment at Rocky Ponds in November 2002 which had been caused by track misalignment. Amongst the outcomes of this investigation, it was recommended that a systemic investigation be conducted into the introduction and performance of steel sleepers in the NSW Rail Network. Accordingly, OTSI initiated a systemic investigation into the installation of steel sleepers on Class 1 Main Line track, the results of which are contained in this report.

Background

2. The basic railway track structure consists of a number of components. These basic components are the ballast, sleepers, fasteners and rail. Sleepers are support members that are part of the railway track structure. They are embedded into the ballast and support the rails above. Sleepers tie the rails together maintaining track gauge (distance between the right and left hand rails) and the rail position. Sleepers also resist lateral and longitudinal movement of the rail system. The traditional material for sleepers in NSW railways since railway construction commenced in the 19th Century has been hardwood timber. The abundance of timber and the relatively low traffic volumes meant that timber was the material of choice for over a century.

3. The initial impetus to make a change from the traditionally-used timber sleepers was the impending supply problem with NSW hardwood timber. This prospective timber sleeper shortage was the subject of Ministerial-level consideration in 1993. Following this, a number of studies into alternative sleeper strategies were initiated in the early 1990s by Freight Rail which had responsibility for the upkeep of the railway infrastructure in regional NSW.

4. The results of these studies led to the identification of alternative sleeper materials, namely concrete and steel. Concrete sleepers were seen to have a clear benefit for lines having high tonnage and high volume traffic[1]. Steel sleepers were seen to have more advantages for low to medium traffic lines such as the regional lines.[2]

5. The preferred option of using concrete sleepers for the Main South[3] line was initiated in 1992. However, the lack of funding to implement this strategy ahead of timber sleeper deterioration meant that an alternative strategy was required. There were concerns that if the condition of the track was allowed to

[1] High axle load (>22 tonne) and high traffic volume (>6 MGT).

[2] Prior to ARTC's lease of the interstate network in September 2004, regional lines in NSW were rail lines classified as Class 2-5 and ranged from lower volume freight and passenger lines to grain lines.

[3] Main South – this track forms part of the line which connects Sydney to Melbourne – starting on the outskirts of Sydney at Glenlee and stretching to Albury on the NSW Victorian border.

deteriorate, then this may contribute to adverse consequences such as a derailment. The alternative strategy was to use steel sleepers on a temporary basis to meet the sleeper replacement requirements, until the concrete re-sleepering program progressed through the Main South. There were economic advantages to this strategy, with the major benefit being the ability to re-use these steel sleepers on regional lines. Shortly following the introduction of steel sleepers on the Class 1 Main South, a delay was experienced with the concrete re-sleepering program. This delay was anticipated to last only for two years. Eventually, all of the steel sleepers installed on the Main South were to be re-located to the regional lines once the concrete re-sleepering program recommenced. These regional lines were also in need of ongoing sleeper supply. Technical approval had already been granted for use of steel sleepers on the regional lines.

6. The program of installing concrete sleepers on the Main South began in 1992 and consisted of replacing existing timber sleepers with heavy duty concrete sleepers. This concrete sleeper installation was done in-face.[4] The program was suspended in 1998 due to budgetary constraints. Further developments in the technology of concrete sleepers have since seen the introduction of low profile concrete sleepers in Partial Re-Sleepering (PRS) programs. At the time of the decision to use steel sleepers, the supplier of concrete sleepers had not yet developed a low profile concrete sleeper.

Steel Sleeper Implementation

7. Steel sleepers were introduced in 1996 on the Class 1 track on the Main Western line between Bathurst and Dubbo. The introduction of steel sleepers on this line was consistent with the State Rail Authority (SRA) re-sleepering strategy of 1994 and occurred in accordance with the manufacturer's installation requirements. However, a technical standard was not approved in 1996 to allow for steel sleepers on Class 1 Main lines.

8. In 1997, steel sleepers were introduced on the Main South line between Junee and Albury. In the first year of their introduction on the Main South line, approximately 45,000 steel sleepers were installed. These steel sleepers were interspersed in a random pattern between timber sleepers. The purpose of their installation was to replace life-expired timber sleepers. The installation of these sleepers was not consistent with SRA's re-sleepering strategy of 1996 and was not carried out in accordance with the manufacturer's installation guidelines, nor with an applicable technical standards approval.

9. Various trials preceded steel sleeper introduction on lower class Western and Southern tracks with favourable outcomes. The decision to recommend the use of steel sleepers for Class 1 Partial Re-Sleepering (PRS) programs was made at senior management level in the then separate NSW rail organisations: Rail Access Corporation (RAC) and Rail Services Australia

[4] The term *in-face* refers to the practice of installing the same sleeper type continuously rather than interspersed with other sleepers in between.

(RSA). This decision was made without the endorsement of either the RAC or RSA Standards Groups and in contradiction of the manufacturer's original installation recommendations that were ultimately ratified by the Rail Infrastructure Corporation (RIC) within their installation standard of 1999.

Findings

10. Track geometry problems arose in some areas of the Main South line where steel sleepers were installed. The installation practices in these areas were found to be deficient in the tamping and ballasting requirements. Steel sleepers need to have correct installation as they do not perform as well as timber sleepers in situations where the track infrastructure (ballast and adjacent timber sleeper condition, ballast formation and track geometry) is poor. The insertion of the ballast into the underside of the steel sleeper is essential to the integrity of the structural stability of the steel sleeper. Where the correct insertion and tamping of ballast is not achieved, steel sleeper stability is compromised.

11. Discussions between management and technical standards groups regarding the installation of steel sleepers occurred from the beginning of their installation. With the introduction of steel sleepers on Class 1 Main line track, concerns were raised about the fatigue loading strength of the sleeper;[5] the interspersal patterns; their affect on track stiffness and track geometry problems. The standards group was not prepared to issue a waiver for the introduction on Class 1 lines, but were prepared to endorse the re-sleepering introduction as a trial. The technical standards group eventually issued a waiver in March 1999 allowing for installation of steel sleepers on Class 1 Main line track. This standards waiver also recommended improved installation standards. A Civil Engineering Standard relating to steel sleeper usage and installation was ultimately issued by RAC in 1999.

12. Had a more thorough trialling and evaluation process been undertaken in the context of the adopted process on the Main South, it would have been possible to mitigate the concerns of fatigue loading strength of the sleeper, the interspersal patterns, their affect on track stiffness and track geometry problems. These concerns should have been addressed prior to embarking on full scale implementation. While it is acknowledged that experience in the use of steel sleepers was gained on Class 2-4 lines and the Main West Class 1 line, formal approval was not granted for installation on Class 1 Main line track prior to the installation of steel sleepers.

13. Management responsibility for the majority of NSW Class 1 Main line track has been assumed by the Australian Rail Track Corporation (ARTC) under a 60 year lease arrangement with the NSW Government. This lease arrangement became operational on 5 September 2004. A number of Class 1 and 2 Main lines remain part of the Country Regional Network which is owned by the Rail Infrastructure Corporation (RIC) on behalf of the NSW Government. These

[5] Letter from RSA standards to RAC standards dated 5 August 1997.

Country Regional Network lines are maintained under contract by ARTC on behalf of RIC. While RIC intends to continue using steel sleepers, ARTC has expressed its intention to remove those steel sleepers currently installed in their leased Class 1 Main line track and install timber sleepers or heavy duty concrete sleepers where possible.

Recommendations

14. In response to those issues identified by the investigation that require further safety improvement, it is recommended that the specified responsible entity undertake the following remedial safety action:

Rail Infrastructure Corporation & Australian Rail Track Corporation

a) Inspect all steel sleepers installed on Class 1 Main line track to ensure the current installation meets the approved technical performance standards.

b) Ensure future steel sleepers are installed according to approved technical performance standards and procedures.

c) Provide adequate training to Installers and Maintainers relating to the installation and maintenance of steel sleepers.

d) Ensure that any proposed change to Class 1 Main line track, similar to that of the steel sleeper change, be made following rigorous testing and trials conducted by the relevant technical authority.

e) Institute a track infrastructure installation and maintenance policy that requires the installers of new components to comply with an engineering-type testing acceptance process. This process should ultimately underpin the configuration change approval provided by a relevant technical authority. The process should also identify the requirement to obtain the necessary theoretical design analysis to support the configuration change approval.

f) Further develop and specify a steel sleeper installation procedure that guides the installer in the recommended practices for installing steel sleepers. Such a procedure should recommend the various spot tamping, resurfacing and ballasting processes required. Quality control requirements should also be specified for the installation process. Such controls should ensure sleeper installation performance standards and procedures are met.

g) Ensure field inspection guidance is provided to Maintainers that would assist with steel sleeper maintenance tasks and the identification of potential problems associated with steel sleepers. Such inspection guidance should include corrective measures required to rectify identified defects. The provision of this guidance could be incorporated within existing field inspection guides.

h) Ensure that there is adequate contractor control over both internal and external suppliers of civil infrastructure services (e.g., PRS programs, in-face sleepering programs, rail renewal, etc.). Such controls should include appropriate standard references, work scope instructions, quality assurance checks and final work certifications.

Independent Transport Safety and Reliability Regulator

i) Conduct a Class 1 Main line steel sleeper audit program in order to satisfy itself as to the Maintainer's ability to meet the installation performance standard. This program should assess compliance relating to current steel sleeper performance standards.

j) Review the adequacy of Infrastructure Maintainers' contract controls, covering both internal and external suppliers of civil infrastructure services (e.g., PRS programs, in-face sleepering programs, rail renewal, etc.). Such controls could include appropriate standard references, quality assurance checks, final work certifications and applicable work scope instructions.

k) Review the adequacy of Infrastructure Maintainers' configuration management procedures to gauge how effective their system is in requiring configuration changes to have engineering approval, stakeholder consultation and Rail Regulator advice. Bring any identified deficiencies to the attention of the Infrastructure Maintainer for rectification.

l) Review the ITSRR guidelines for changing Safety Management Systems to ensure there is sufficient guidance provided to Infrastructure Maintainers in classifying those changes that require notification to the Rail Regulator. Such guidance could take the form of a configuration-type listing that identifies applicable reporting requirements.

Observations for Industry

m) Major infrastructure configuration changes, whether grouped under Major Periodic Maintenance or Capital Works projects, should contemplate life-cycle maintenance costs. Consideration should be given to determine if the configuration change can be sustained into the future and should be based on those costs derived from approved technical standards and procedures.

PART 1 INTRODUCTION

Appointment

1.1	Period of review:	1996-2004.
1.2	Location:	Class 1 Main line track in NSW where steel sleepers are installed. (Main South and Western lines).
1.3	Details of Incident:	Review and assess the process by which steel sleepers were approved for implementation on Class 1 Main line track.
1.4	Type of Inquiry:	Section 67 *Rail Safety Act* Investigation

Terms of Reference

1.5 The Chief Investigator of the Office of Transport Safety Investigation has authorised the investigation and publication of this report pursuant to the provisions of sections 67 and 68 of the Rail Safety Act 2002 NSW.

1.6 The following Terms of Reference relating to RIC required the Investigation to:

a) Review and assess the process by which steel sleepers were approved for implementation on Class 1 Main line track.

b) Consider how RIC evaluated the acceptability of steel sleepers at the concept, approval, implementation and condition monitoring stages of the steel sleeper introduction. Applicable technical standards, technical assessments against these standards, engineering authority approval, installation performance criteria and condition monitoring issues are to be reviewed by the Investigation.

c) Assess RIC's current configuration management approval process with the view of determining how the configuration change from wooden to steel sleepers would have been processed under this approval system. Any variances of the steel sleeper approval against the current configuration control approval process should define, as a minimum, preliminary safety recommendations.

d) Assess if the introduction of steel sleepers has increased the likelihood of track structure failures to any significant extent.

1.7 The following Terms of Reference relating to the former Transport Safety Bureau of the NSW Department of Transport (TSB) required the Investigation to:

a) Assess the Transport Safety Bureau's role in the acceptance of steel sleepers on Class 1 Main line track.

b) Assess how the Transport Safety Bureau managed configuration changes at the time of steel sleepers being introduced on Class 1 Main line track.

1.8 The following Terms of Reference relating to the Australian Rail Track Corporation (ARTC) required the Investigation to:

a) Determine the current and long term maintenance strategy that ARTC intend to employ with respect to steel sleepers on Class 1 Main Line track.

b) Assess ARTC's current configuration management approval process with the view of determining how like configuration changes are managed.

Conduct

1.9 The Investigation has been conducted in accordance with the principles of Australian Standard AS 5022:2001, Guidelines for Railway Safety Investigations The objective of the Investigation is to conduct a broad examination of the introduction, utilisation and maintenance of steel sleepers in the NSW rail network in order to ensure that network safety has nor been compromised.

1.10 It is not the intention of the investigation to imply or attribute blame or determine liability. However, sufficient factual information is included to support the analysis and conclusions. Some information may reflect on the performance of individuals and organisations, and how their actions have contributed to the outcomes of the matter under investigation.

1.11 The Investigation provides factual information and an analysis of that information to establish findings and to determine appropriate recommendations.

Report Structure

1.12 This report is presented in five parts as identified in the contents page. Supplementary information to Parts 2 and 3 is provided in the Annexes and can be referenced following Part 5. A covering Executive Summary is also provided where a concise listing of the report's findings are contained together with a complete listing of the report's recommendations.

PART 2 FACTUAL INFORMATION

Rail Infrastructure Context

2.1 The introduction of steel sleepers in NSW Class 1 Main line track extended into two regions, Country South and West. Those lines where steel sleepers were installed included the line to Broken Hill (Main West), Wallerawang to Kandos, Orange to Dubbo and Glenlee to Albury (Main South). [See Figure 1]. Historically timber sleepers were used on these lines. However, since the start of the 1990s, timber sleepers have been progressively replaced with concrete sleepers, particularly on the Main South line. Since 1997, timber sleepers have been interspersed with steel sleepers and since 2001, with low profile concrete sleepers. Consequently, the track now consists of a mixture of concrete sleepers installed in-face and timber sleepers interspersed with both steel sleepers and low profile concrete sleepers.

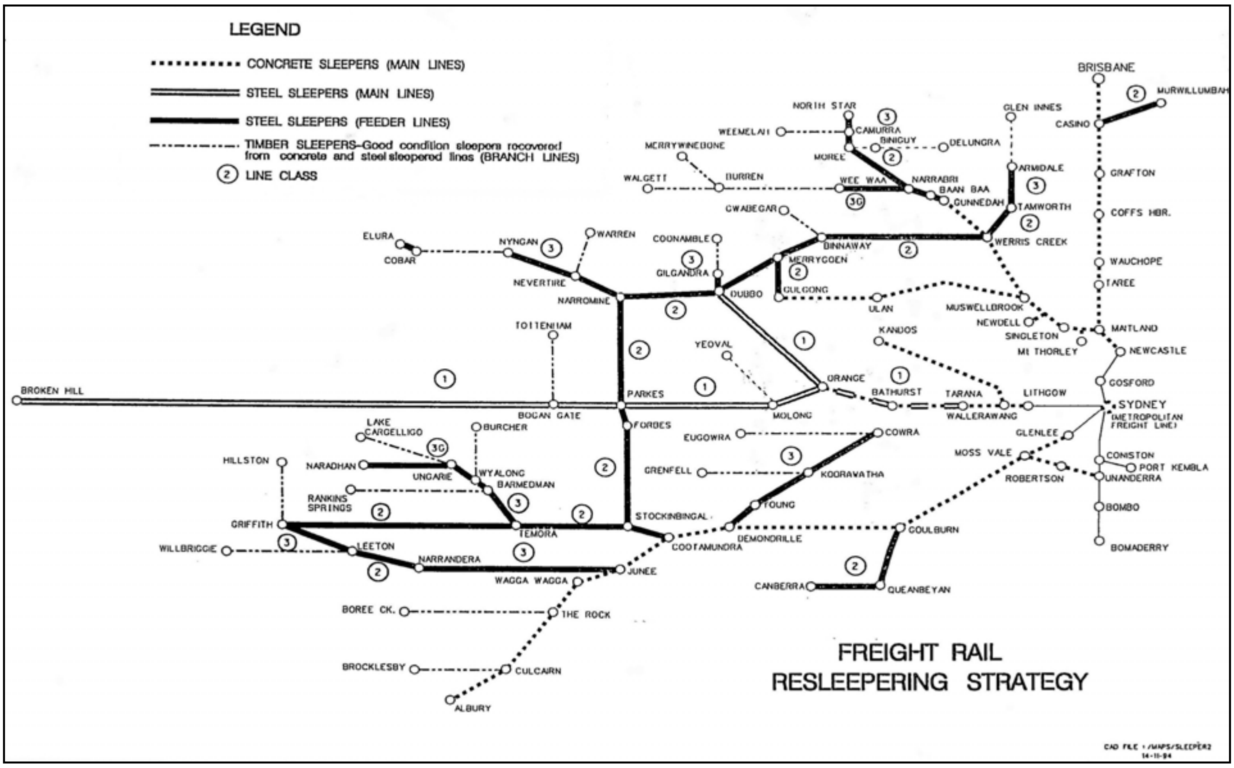

Figure 1 – 1994 Strategy for Country NSW Rail Network by Sleeper Type[6]

Organisation Structures

2.2 The Investigation identified a number of major organisational changes covering the period of the Investigation's review. From 1990 to June 1996, the responsibility for Class 1 Main line track standards and infrastructure maintenance rested with a business division of the State Rail Authority

[6] Freight Rail Infrastructure Assets Management Plan Version 3 June 1995.

(Freight Rail). During this period, the ultimate responsibility for approving infrastructure configuration changes and infrastructure standard changes resided with a chief infrastructure engineer position reporting to the CEO.

2.3 In July 1996, the State Rail Authority was broken up into four separate entities. These entities were the State Rail Authority, FreightCorp, Rail Access Corporation (RAC) and Rail Services Authority. One year later Rail Services Australia (RSA) was established from the Rail Services Authority. Following the changes in 1996, the responsibility for Class 1 Main line maintenance and standards rested with RAC. See Figure 2 depicting these organisational changes.

2.4 RAC was a small management body that contracted RSA to provide infrastructure maintenance services and infrastructure standards advice. Those Divisions within RAC that managed infrastructure maintenance consisted of an Asset Management Division and a Standards/Audit Division. These Divisions reported directly to the Chief Executive Officer (CEO) of RAC. The level at which decisions were made concerning infrastructure configuration changes, including those concerning sleepers, took place at the senior Asset Management Division level.

2.5 RSA provided infrastructure maintenance services through two groups. These groups consisted of Local Infrastructure Maintainers (Maintainers) who reported to Regional Maintenance Management and Regional Installers (Installers) who reported to a separate management structure. Both management structures reported independently to the CEO. The Installers carried out steel sleeper installation and the Maintainers carried out on-going maintenance of the steel sleepers. RSA also provided contracted technical standards advice to RAC's Standards/Audit Division.

2.6 In January 2001, Rail Infrastructure Corporation (RIC) was formed from Rail Access Corporation and Rail Services Australia.

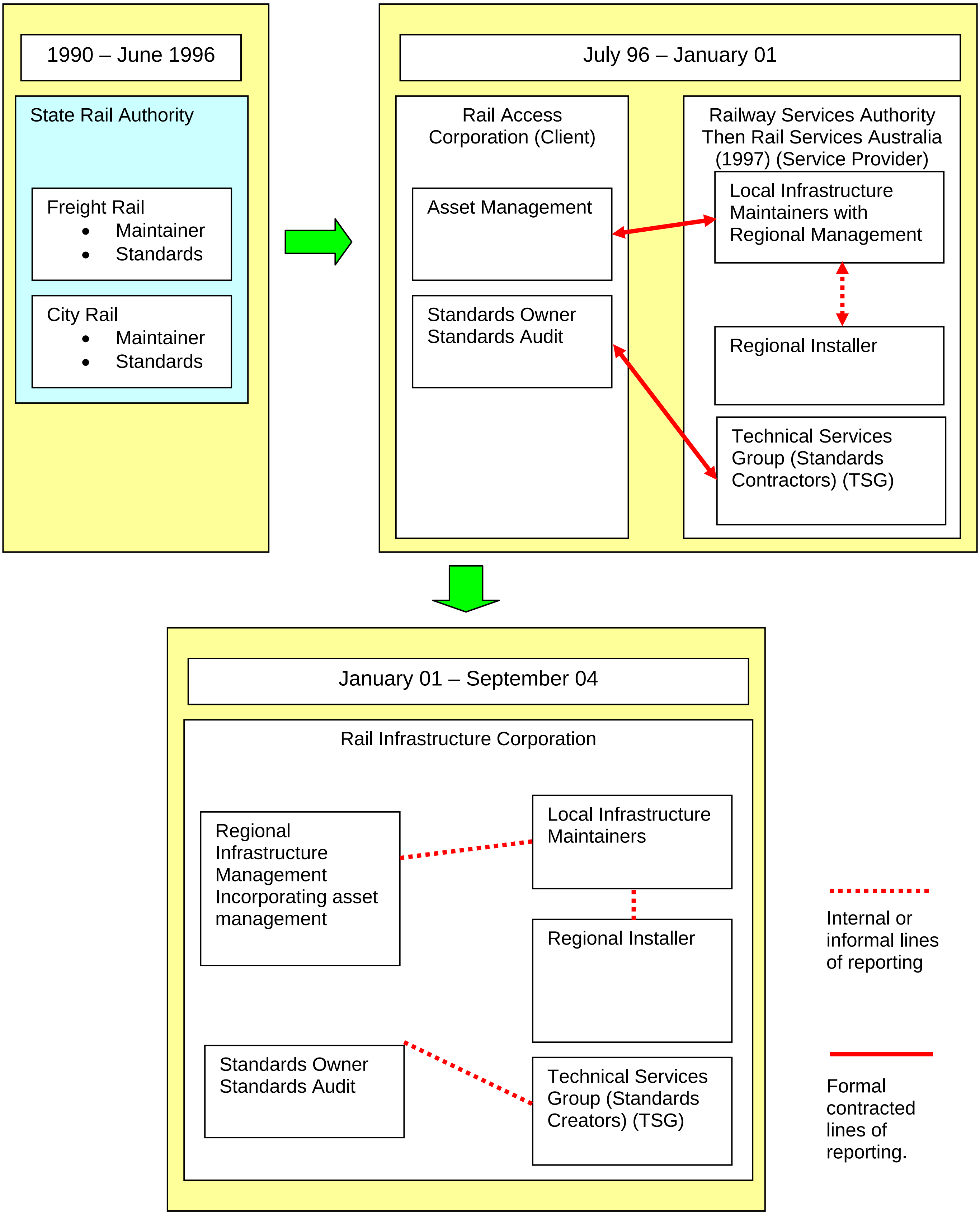

Figure 2 – Organisational Structures – 1990-2004

Research and Development preceding introduction

History of Steel Sleeper Use in NSW Railways

2.7 A number of steel sleeper trials had been conducted in NSW. Various steel sleepers types, fasteners and installation patterns of steel sleepers were employed within these trials. The basis of these trials resulted in the approval of steel sleepers for Class 2 – 5 lines. At the time of their installation in 1996, utilisation of steel sleepers for Class 1 lines had not been formally approved.

2.8 A trial was undertaken on Class 1 Main line track at Thornton in 1985. This trial did not prove successful. At that time, the trial did not recommend approval for the widespread use of steel sleepers. The type of steel sleeper used at Thornton was an earlier version of the steel sleepers used today. Refer to Annex A for further history of steel sleeper usage in NSW.

Interstate Experience in the Use of Steel Sleepers

2.9 The use of steel sleepers is widespread in all states of Australia. The Queensland and Western Australia experience has demonstrated favourable results for the installation of steel sleepers in 1 in 3 and 1 in 4 fixed patterns for low tonnage and low volume traffic lines. Queensland and Western Australia account for over 65% of the steel sleepers used within Australia. Steel sleepers have also proved successful for high axle loads when installed in an in-face pattern.[7] Refer to Annex B for further details on the experience gained interstate.

Overseas Performance Noted by NSW Rail

2.10 Reports from Canada in the early 1990's regarding steel sleepers indicated that they were experiencing problems with cracking in the rail seat area. These reports were noted by technical staff in NSW Rail. The technical problems in Canada were found to be related to the steel sleeper design. The steel sleeper design and failure mode was the same as that experienced in Thornton NSW. The steel sleepers used in NSW since 1994 have been of a modified design to address the previous failure mode experience. There were also positive reports of steel sleeper usage from Switzerland where the tonnages, speed and steel sleeper section are all similar to those prevailing in NSW rail environments.

[7] Cost Efficient Track by the Use of Steel Sleepers – Paper presented at Conference sponsored by Railway Engineering Rail Technical Society Australasia/Rail Track Association Australia – Wollongong November 2002

Viability Studies

2.11 In order to ascertain the viability or otherwise of alternative sleeper strategies, Freight Rail, a business division within State Rail, commissioned a number of studies into alternative sleeper types in the early 1990's. Three separate studies were conducted in 1994 and 1995. One economic study found that: *Steel PRS offers a higher economic return than steel on face, timber (including treated timber) PRS and concrete on face sleepering options on low axle load (less than or equal to 22t) and low trafficked (less than 6Mtpa) lines.*[8] These studies identified and promoted the use of concrete sleepers for lines that have a high proportion of curved track and also track with high tonnage and high volume traffic loads. The studies also identified the benefits of steel sleepers for low to medium tonnage and volume traffic lines. The Partial Re-Sleepering (PRS) cost comparison presented by one of these studies is shown in Table 1 below.

PRS	Timber H(+6MGT)	Timber L(-6MGT)	Steel (7.5mm)	Heavy Duty Concrete
Per unit	$29.50	$29.50	$40	Not suitable
Transport	$4	$4	$2.50	
Fastening (high load)	$43	$10	$13.70	
Ballast	$2	$2	$7	
Tamping	$2	$2	$6 -10	
Installation	$35	$35	$35	
Total Cost	**$115.50**	**$82.50**	**$104.20 - $108.20**	

Table 1 – Comparison of Partial Replacement Re-Sleepering Installation Costs 1994[9]

Decision

Impetus for Change

2.12 Supply issues surrounding the variable natural resource of timber had long been an area of concern for the continued widespread use of timber sleepers in the NSW Rail system. The problems of continued timber sleeper supply were raised in ministerial correspondence in 1993 between the Minister for Land and Water Conservation and the Minister for Transport. The correspondence identified that the major area of timber supply on the NSW North Coast had experienced a succession of operations through its forests over the past 100 years. These operations had ultimately removed much of

[8] Freight Rail Sleepers generic Economic Appraisal Final Report by Travers Morgan Pty Ltd – December 1994.
[9] Freight Rail Alternative Sleeper Type – Strategic Value Management Study by Value Systems Pty Ltd - 1994

the timber suitable for sleeper production, to the point where it was not possible to continue to meet the demands of State Rail.

2.13 A strategic study of sleeper supply commissioned by Freight Rail in 1994 also foreshadowed a number of problems with the future supply of timber sleepers. Projections described in this study, identified that there would be a drop in timber sleeper supply of 45% over the period of 1994 –1996. The reasons for the continued decline were that there was a decreasing supply of larger trees and durable species; a large reduction of registered timber cutters; increasingly stringent requirements under wildlife protection legislation to retain habitat trees and an increase in overall market demand for hardwood.

2.14 The concrete re-sleepering program on the Main South that was started in 1992 was stopped in 1998.[10] The decision to stop the program was communicated from RAC to RSA at the General Management level. This decision was influenced at the time by the need to reduce overall infrastructure costs. As a consequence, there was an increased demand for timber sleepers to cover the section of track planned for concrete re-sleepering. The concrete sleeper program stoppage further compounded the timber sleeper supply problem due to the loss of cascaded timber sleepers made available from the program (50,000 timber sleepers were expected to be made available from the in-face concrete renewal program). Coinciding with the increase in demand for timber sleepers was an increase in the per unit cost of timber sleepers.

2.15 The track condition at the time of steel sleeper introduction necessitated major infrastructure maintenance that would not tolerate deferment.

Decision to Change – Factors Identified at the Time of Steel Sleeper Introduction

2.16 The change from timber to steel sleepers on Class 1 Main lines proceeded because RAC Asset Management had the ability to make changes irrespective of the RAC/RSA engineering and Manufacturer's advice. The change was carried out under RAC's routine maintenance program, thereby not necessitating CEO management review and approval.

2.17 The decision to recommend and approve the use of steel sleepers was made by line managers within RAC and RSA. At the time this decision was taken, and subsequently, a number of facts were known by management:

a) The installation of steel sleepers on Class 1 Main lines in 1996, and later in 1997, contravened the sleeper standard at that time.
b) No immediate standards waivers were obtained to allow installation of steel sleepers on Class 1 Main lines.
c) There was an 18 month delay in obtaining this waiver from the standards group within RAC.

[10] Correspondence RSA to RAC Re: Main South Resleepering – April 1998

d) Recommendations derived from steel sleeper trials on Class 2 lines and the Class 1 Main Western line in 1996, in terms of installation patterns and procedures, were not followed in the initial introduction on the Main South line.
e) Similar recommendations from the Manufacturer were also not followed.
f) The Freight Rail sleeper strategy for use of steel sleepers did not extend to the Class 1 Main South.

Decision to change – Change Logic

2.18 The following information was used to support the decision to change from timber sleepers to steel sleepers on the Class 1 Main South line by Asset Management within RAC and RSA.

a) Strategy recommendations existed for steel sleepers to be used on the Main West Class 1 lines. [11]

b) The experience gained on the Main West Class 1 lines provided those responsible for the change with sufficient confidence to proceed with the change to steel sleepers on the Main South Class 1 line.

c) The decision to use steel sleepers on the Main South was not considered a material change from the use of steel sleepers on the Main West. The Main South axle loads and traffic volume were not significantly different to the Main West.

d) The selected installation pattern on the Main South sought to provide the maximum cost benefit. This pattern was a random interspersed pattern which replaced the poorest quality timber sleepers with steel sleepers. The rationale for using this pattern was based on causing less long term disturbance; effecting an immediate improvement in track structure and lengthening the life span of the remaining timber sleepers.

e) There was also the prospect of to reusing the steel sleepers on Class 2 - 4 lines following the recommencement of the Main South concrete sleepering program. The ability to cascade steel sleepers to other lines without the need to rebore new rail fastener holes, as in the case with timber sleepers, was also seen as a major benefit.

Configuration Management

2.19 The process for obtaining approval for a new configuration item, such as the installation of steel sleepers, has changed over time. Prior to 1996, within Freight Rail, the process to obtain an approval for new configuration items such as steel sleepers, would have required the following:

[11] Freight Rail Alternative Sleeper Type – Strategic Value Management Study by Value Systems Pty Ltd - 1994

a) Engineering trials to assess suitability.

b) Engineering standards approval by the relevant standards engineer.

c) A Submission for Approval to expend funds (Capital Works) with applicable justifications from the relevant standards manager, chief infrastructure engineer, Group General Manager and Chief Executive Officer.

2.20 Within the rail industry today the management of new engineering components and systems will often require a technical and organisational review that incorporates appropriate configuration control (evaluation, coordination, approval, and implementation of changes). This type of process (configuration management) was introduced within Rail Infrastructure Corporation (RIC) in 2001.

2.21 Prior to introduction of steel sleepers on the Main South line, no such configuration management practices were in place, and consequently, no successful engineering trials had been conducted on Class 1 Main lines to support the sleeper installation process and pattern configuration on the Main South.

2.22 The Asset Management approach at the time of installation was to proceed with the installation unless there was engineering proof that steel sleepers were unsafe. The approach was also based on life cycle costs and available funding, with the choice of installing either steel, concrete or timber sleepers.

2.23 A Configuration Management approval system was not in place at the organisational level to control sleeper-type installation decisions, nor was there an approval system in place similar to that which existed within Freight Rail prior to 1996. Finally, there was no formal process to inform and involve the NSW Rail Regulator in configuration changes.

Safety Regulation

2.24 The previous NSW Rail Safety Regulator, the Transport Safety Bureau (TSB), was not advised of the change to steel sleepers and generally lacked visibility of configuration changes to the infrastructure at the time of their introduction.

2.25 RIC introduced configuration change notification procedures within their Configuration Control Manual in March 2003. The introduction of these procedures came in response to TSB's Change Notification requirements. These procedures required RIC to classify configuration changes according to an indicative configuration type list. If the change to steel sleepers had been considered in March 2003, RIC would have been required to notify the Rail Regulator on completion of the change. Such a change in configuration would not have required RIC to advise the TSB at the configuration change planning stage or prior to the configuration change introduction.

2.26 Current Rail Safety legislation requires Operators to identify the scope and limits of the activities for which accreditation is sought and granted.[12] This information must be detailed in a documented Safety Management System (SMS). More recently the Independent Transport Safety and Reliability Regulator (ITSRR) has introduced requirements within each Operator's accreditation, requiring an Operator to seek approval of the ITSRR before any changes are made to the SMS.[13] The ITSRR has further produced guidelines to cover how an Operator is to advise the Rail Regulator when changing an Accredited SMS. The Guidelines provide for three levels of notification requirements:

i) a change requiring prior application for approval;

ii) a change requiring notification prior to implementation, and

iii) a change requiring notification after implementation.

2.27 The Rail Regulator requires that accredited organisations employ a risk management methodology to initially determine the significance of the change and the notification requirements to the Regulator.

Implementation

Initial Installation Location

2.28 The installation of steel sleepers occurred on the Class 1 Main West line between Bathurst and Dubbo in September 1996. A number of concerns were raised within RSA's Engineering Standards Group following this introduction. These concerns included the steel sleeper section size and its corresponding steel sleeper fatigue strength; the comparable lateral stability between timber and steel sleepers; the vertical stiffness relating to the spacing and installation procedures, and ongoing maintenance.

2.29 Steel sleepers were installed on the Main South in 1997 between Albury and Junee. Approximately 45,000 sleepers were installed using a random interspersed pattern at an average rate of 1 in 6 steel sleepers.

Installation Standard

2.30 The installation of steel sleepers on Class 1 Main line track within NSW was outside the engineering standards operating at the time. While there existed a strategy approved at the Group General Manager Freight Rail[14] level to consider using steel sleepers on Class 1 Main lines, there had not been a formal process initiated to amend the standard to include steel sleepers.

[12] NSW Rail Safety Act 2002.
[13] ITSRR Guidelines for Changing an Accredited Safety Management System 2004.
[14] Submission for Board Approval – Freight Rail Steel Resleepering Strategy- December 1994

2.31 In December 1998, a RAC Safety Audit Group's report identified that the installation of steel sleepers on the Main South Class 1 line contravened the RAC Civil Infrastructure standard *C1610 Engineering & Operational System Safety Standards*. At the same time, the installation also noted to have contravened the Manufacturer's installation guidelines in relation to steel sleeper installation pattern and tamping procedures.

Waivers

2.32 As a consequence of the RAC Safety Audit report, the RAC Standards Group recognised the requirement for the introduction of steel sleepers on Class 1 Main lines to be reviewed. RAC's Standards Group was not willing initially to accept the introduction of steel sleepers in Class 1 Main lines without appropriate testing and input from the Manufacturer. Ultimately, it was recognised from RAC's Asset Management group that a waiver would be required from RAC's Standard Group.

2.33 A standards waiver W.RAC.028 Steel Sleepers in Class 1 Main lines was issued on 8th February 1999 by the RAC Standards Manager. This stated that steel sleepers type M7.5 (non-insulated) and M8.5 (insulated) may be installed in Class 1 Main line tracks subject to conditions set out in the waiver. These conditions included sleeper patterns, tamping requirements, ballast profile, inspection and monitoring.

Control over Installation

2.34 Controls over the identification of timber sleeper removal were found to be inadequate. This lack of control led to the track having more steel sleepers installed than required and in some cases in an undesirable pattern. This practice was noted to have impacted on the track stability.

Installation Process

2.35 Steel sleepers were initially installed on the Main West line (1996) using a similar installation procedure to that recommended by the current standard. This involved the section of track being examined, with the timber sleepers to be removed being selected and marked. The marking was to a strict pattern of installation. The marked timber sleepers were then removed from the track. A linear scarifier then removed excess ballast from the sleeper position. [See Figures 3 & 4 depicting linear scarifiers removing ballast in preparation for sleeper insertion (in this case, low profile concrete sleepers)]. The next step in the installation process consisted of ballast tamping.

Figure 3 – Installation of low profile concrete sleepers in a production line (scarifier machines in foreground)

Figure 4 – Linear Scarifier (scarifying to install low profile concrete sleepers)

2.36 The tamping process carried out initially on the Main West is outlined below:

a) Install sleeper including spot tamping to hold sleepers so they can be clipped up to fasten with the rail. This tamping provides an initial level of ballast depth and compaction within the sleeper pod.

b) Ballast and regulate to ensure ballast is available to fill the sleeper pod.

c) Tamp, line and level all track with two insertions of tynes at steel sleepers.

d) Regulate again.

e) Tamp, line and level again if further track geometry correction is required or steel sleeper pods are not yet full.

f) Optional final squeeze of steel sleepers only with a 5mm nominal lift.

g) Ballast regulate and broom to give correct ballast profile.

2.37 When steel sleepers were first installed on the Main West (post 1996) and the Main South (early 1997), the tamping process was modified and involved the following reduced number of steps:

a) Install sleeper, including spot tamping to hold sleepers so they can be clipped up. This tamping provides an initial level of ballast depth and compaction within the sleeper pod. [See Figures 5 & 6 depicting a spot tamper].

b) Ballast and regulate. Ballasting was conducted using a hi-rail tipper or front end loader. [See Figure 7 depicting a Regulator].

Figure 5 – Spot Tamping operation- front view

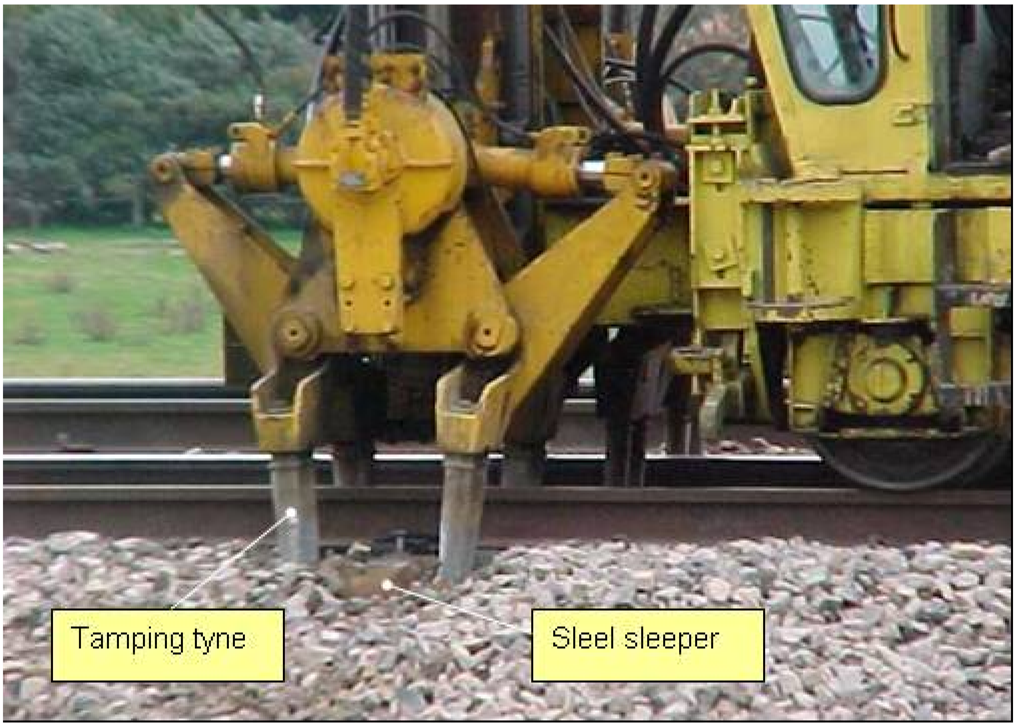

Figure 6 – Spot Tamping operation – side view

Figure 7 – Ballast Regulator

2.38 The tamping of newly installed steel sleepers needs to be carried out correctly in order to avoid introducing risks that are generated when the process is not undertaken correctly. Unlike other sleeper types, steel sleepers depend on the ballast for their structural integrity. If the ballast is not tamped correctly, then the result can lead to an inadequately filled pod or an unevenly filled pod. The tamping process that was initially carried out on the Main South was likely to cause the pod to be unevenly filled with ballast, as the ballast was being predominately lifted directly under the tamping tynes. [See Figure 8 depicting unevenly filled ballast within the sleeper pod]. This may give the false impression that the pod was full when checks were done using the inspection holes. If a deficiency of ballast existed in the centre of the sleeper, then the level of the ballast in the pod may settle down over time.

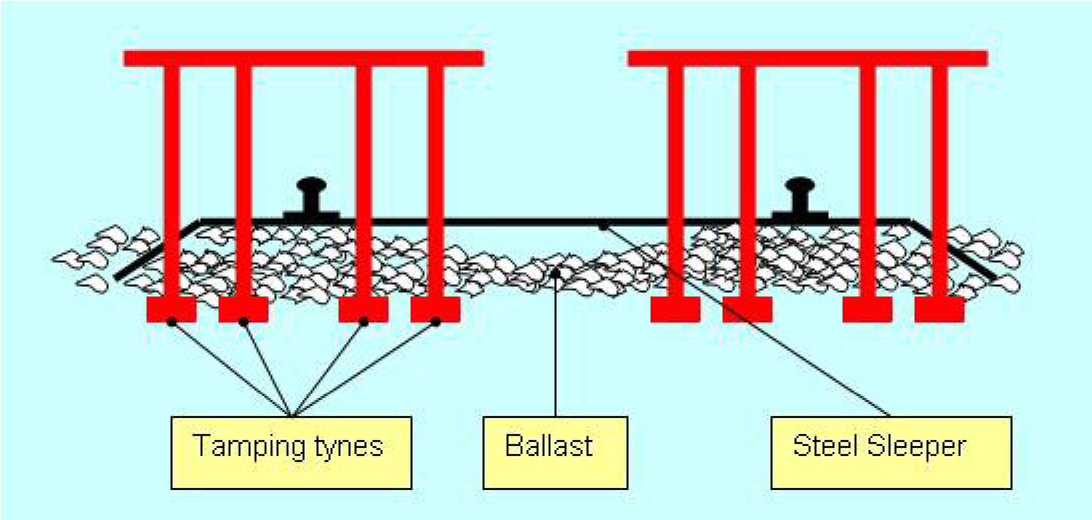

Figure 8 – Spot Tamping Operation – tendency to leave space in centre of pod.

Maintenance

2.39 Many of the requirements for successful maintenance of steel sleepered track are derived from of an understanding of the unique characteristics of steel sleepers. The steel sleepers used in NSW railways have a trough shaped cross section and have differing settlement characteristics from timber sleepers and concrete sleepers which are flat bottomed. Steel sleepers will tend to settle further under equivalent ballast and tamping conditions before supporting the same load as timber sleepers and concrete sleepers. This difference of settlement is important if the steel sleepers are interspersed and are not sharing the same amount of load as the adjacent timber sleepers. Excessive vertical track deflections and the loss of track geometry can occur where there are differences in sleeper load sharing.

2.40 There are two types of maintenance which support the rail system: preventative maintenance and corrective maintenance. A technical maintenance plan details the frequency of inspection for all inspection tasks. A track patrol is undertaken on lines carrying passenger services at least twice per week and a detailed walking examination every 3 months. This requirement also applies to freight-only lines carrying more than 10MGT. The frequency of inspections may increase with trigger events, such as during hot weather WOLO conditions.[15] The sleepers are subject to specific inspection every year in the case of timber sleepers, and every two years for concrete sleepers/ steel sleepers *in-face.*

[15] WOLO – Speed restrictions applied during hot weather –generally applied at and above 38°C.

2.41 The inspection of steel sleepers is facilitated by the provision of inspection holes 20mm in diameter, located on each side of the rail seat. This allows a visual or physical inspection of the ballast level inside the pod. [See Figure 9].

2.42 No standards or procedures could be sourced that provided guidance to Maintainers on the identification of track defects associated with steel sleepers.

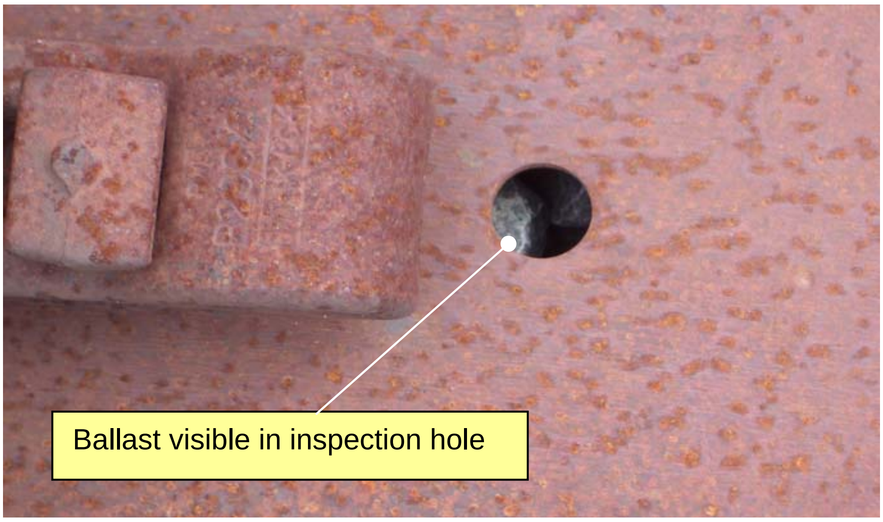

Figure 9 – Inspection hole in steel sleeper

Random Pattern Steel Sleeper Performance

2.43 Following the installation of steel sleepers on the Main South, a number of inspections were conducted. These included track condition inspections as well as the programmed track geometry inspections. The manufacturer was also regularly involved in the performance review of the steel sleeper installation.

2.44 Common findings of the performance review indicated that there was evidence of track pumping, as depicted in Figure 10, where the pumping resulted in the rounding of ballast.[16] Many of the steel sleepers inspected were also found to have loose ballast within the sleeper pod. Instances of the sleeper pods not being completely full were also identified in early inspections. Experience gained from the earlier installation of steel sleepers indicated that they performed poorly in foul ballast and mud, and that proper ballasting and tamping was essential to achieving the desired performance.

[16] "Pumping" denotes a sleeper that moves vertically up and down as rail traffic passes over the sleeper. This movement often results in the degradation and contamination of the ballast structure.

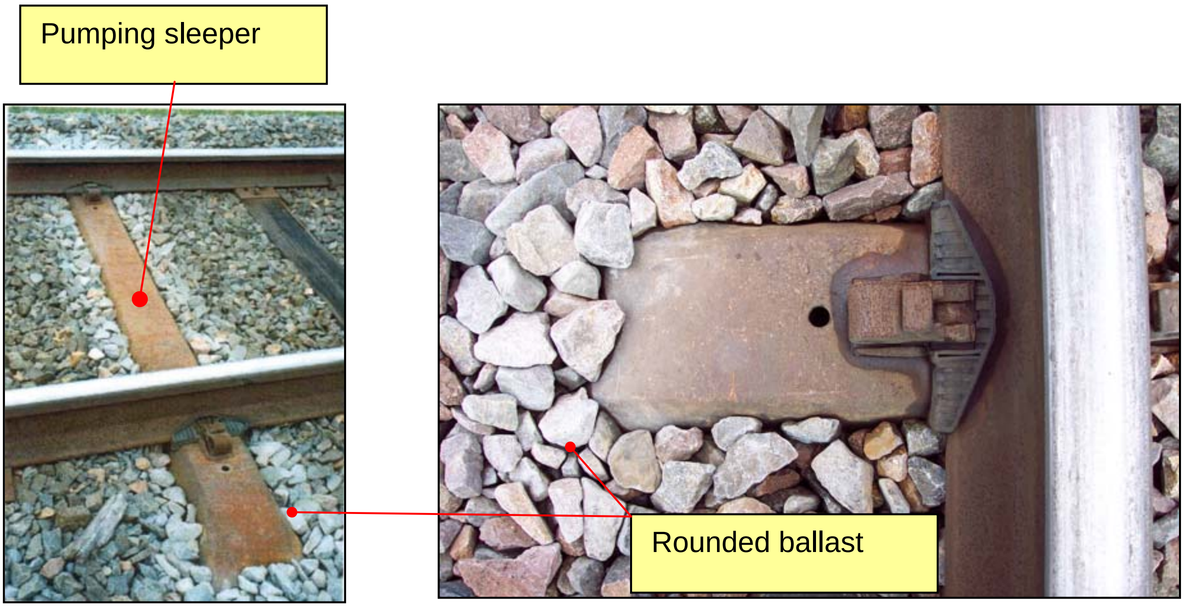

Figure 10 – Ballast rounding caused by steel sleepers pumping

2.45 During the early inspections on the Main South, the Manufacturer noted problems with sleeper stability that was indicative of inadequate tamping and ballasting. The inspections also identified that the steel sleeper pattern was random, with patterns ranging from 1 in 12 to clumps of 5. A summary of early inspection reports is attached at Annex E.

Incidents

2.46 A number of misalignments were reported in the Goulburn district in the summer of 1998-99. In many cases, the presence of floating and pumping steel sleepers was identified as the most likely cause.

Corrective Actions

2.47 The corrective actions taken to address the findings from incidents and inspections involved changes in training, organisational structure, tamping procedures, testing and standards.

2.48 Subsequent training has been provided to the Installers, emphasising the importance of correct tamping. The development of tamping training included a demonstration of how the sleeper pod was to be filled with ballast. This was achieved by cutting enlarged sleeper inspection holes to demonstrate how the ballast pod is filled during tamping.

Current Strategy

2.49 The responsibility for managing the major portion of NSW Class 1 Main line track has been accepted by ARTC under a 60-year lease arrangement with the NSW Government. This lease arrangement became operational on 5 September 2004 and primarily covers the interstate routes. A number of Class 1 and 2 Main lines remain part of the Country Regional Network which is owned by RIC on behalf of the NSW Government. These Country Regional Network lines are maintained under contract by ARTC on behalf of RIC. See Figure 11 depicting the Country Regional Network lines and those interstate routes currently leased by ARTC.

2.50 For those Country Regional Network lines (Class 1) owned by RIC, the use of low profile concrete sleepers is being considered but steel sleepers will remain an integral component of RIC's maintenance strategy for the Country Regional Network. Those Class 1 Main lines that form part of the Country Regional Network include Bowenfels to Dubbo, Orange to Parkes, Wallerawang to Kandos and The Gap to Narrabri. Installation and maintenance of steel sleepers on these lines will be carried out by ARTC in accordance with RIC maintenance standards.

2.51 The track configuration and maintenance approach taken by ARTC has been designated a "back to basics" approach. This approach is documented[17] in a paper entitled ARTC's "Railway Infrastructure Maintenance Strategy". In this paper, five main track areas are identified as needing to be managed in a systematic manner, rather than as individual components. The components of the system include: rail, fastenings, sleepers, ballast and formation. The paper emphasises the importance of these components being in harmony with each other and that strengthening one part of the system over the rest of the system is inefficient. The paper makes the point that a highly variable track modulus could result when mixing sleepers of variable strength and mass in interspersed patterns.

[17] ARTC's Railway Infrastructure Maintenance Strategy Presented to the conference on Railway Engineering Darwin 20-23 June 2003.

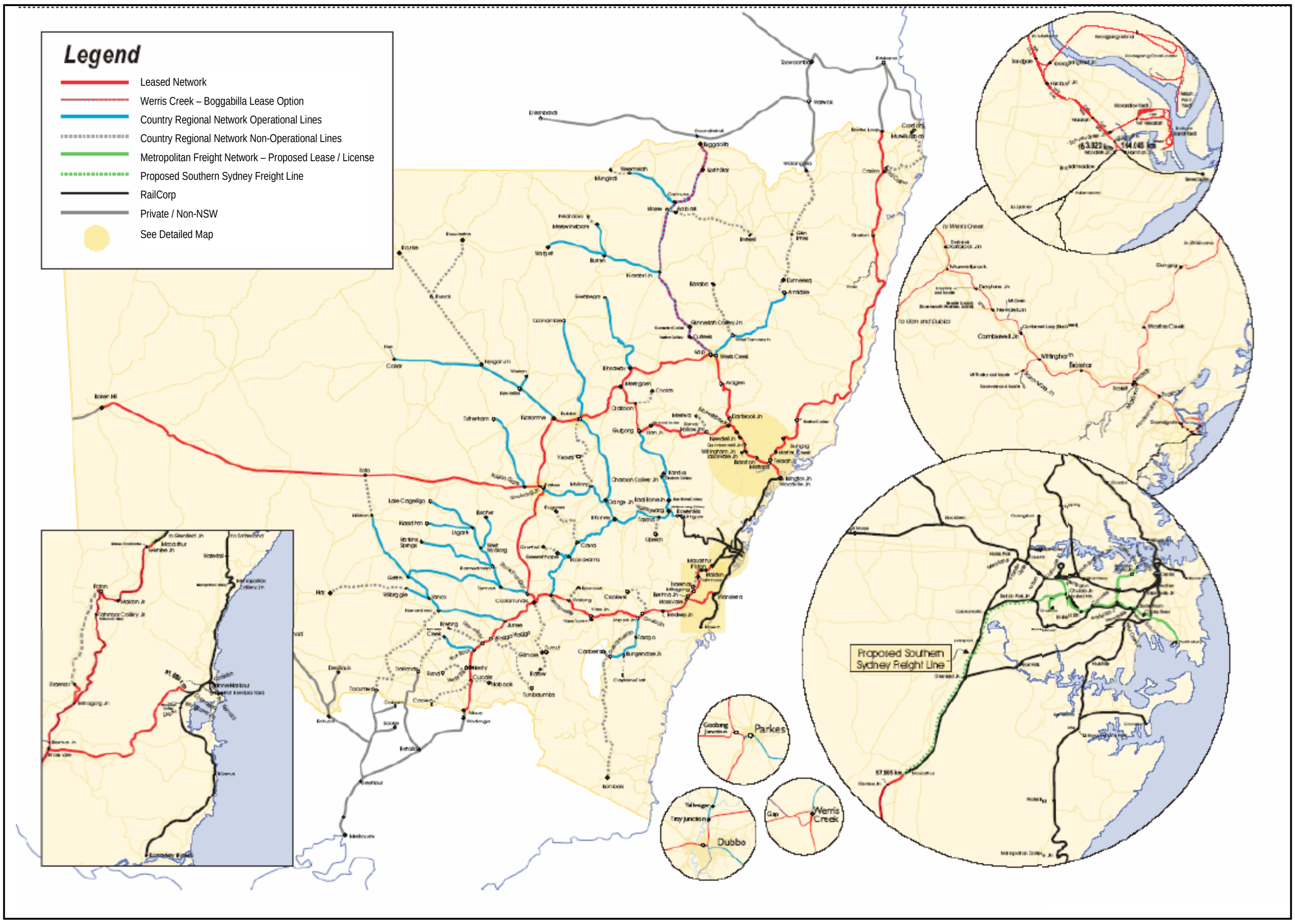

Figure 11 – NSW Rail Network Lease and Ownership Diagram

2.52 The operating parameters set down by ARTC do not include the installation of steel sleepers on Class 1 Main line track. ARTC has indicated its intention to remove those steel sleepers currently in Class 1 Main line track and install timber sleepers or heavy duty concrete sleepers where possible. These steel sleepers would be removed and sold or used on lower class lines. New steel sleepers installed on Class 2 - 4 track would be only be in-face or to a rigid pattern e.g. 1 in 4.

2.53 Heavy duty concrete sleepers would only be installed in-face and where they were commercially justified. The use of low profile concrete sleepers would not be considered for similar reasons to that of steel sleeper use.

2.54 ARTC has reissued RIC's steel sleeper usage and installation standard TS20 540 3 00 SP as TCS10. This standard requires steel sleepers to be installed in a pattern and prohibits clumping. ARTC has also undertaken a program to identify locations where steel sleepers have not been installed in accordance with the required standard. A significant number of non-compliant locations have been identified in the program. ARTC is progressively correcting any problems arising from poor steel sleeper installation that are detected from track inspections and track recordings. Where remedial work is undertaken to address steel sleeper performance problems, the work is done in accordance with their steel sleeper installation standard.

2.55 ARTC advised that any configuration change of the type experienced with steel sleepers would follow their Process Procedure.[18] This process involves ARTC's Engineering Services accepting or rejecting the change. Any change would be made according to existing standards. ARTC has structured the responsibility for maintenance procedures on a rail corridor basis, with local teams having responsibility for, and control of, their section. A compliance manager ensures the local team manager is following the standards. There is also a separate audit division reporting to a different general manager to whom the local teams report.

[18] ARTC Engineering and Infrastructure Process Procedure PP 122 – New Equipment & System Approval August 2004.

PART 3 ANALYSIS OF EVIDENCE

3.1 The following analysis has been derived from evidence documented in Part 2, Factual Information, and Annex A, the History of Steel Sleeper Use in NSW Railways.

The Decision and How it was Made

3.2 In 1996 the decision was made to install steel sleepers on the Main South line in a random installation pattern as a part of the Partial Re-Sleepering (PRS) program. This decision was made jointly at senior management level in the NSW railway organisations of Rail Access Corporation (RAC) and Rail Services Australia (RSA). The decision to continue with their installation was made against the advice of the Engineering Standards Group and in contradiction of the manufacturer's recommendation. The Engineering Standards and Manufacturer's advice recommended that a heavier sleeper section be used together with a different installation process. There was no corporate standard in place covering the installation within either organisation. There was also no track stiffness design verification conducted to provide an assurance that random steel sleepers would be compatible when interspersed with timber sleepers. A standards waiver was not issued before installation took place on Class 1 Main line track.

3.3 Discussions between those managers responsible for infrastructure maintenance and engineering standards occurred after the initial installation. There was a difference of opinion between the two groups regarding the installation of steel sleepers on Class 1 Main line track. The engineering standards group had concerns with the fatigue loading strength of the steel sleepers, the interspersal pattern and the effect they would have on the track stiffness and track geometry. The engineering standards group were not prepared to issue a waiver for the track standards but were prepared to endorse the steel sleeper installation as a trial. RAC Asset Management initially rejected the offer of a trial on the basis that more than 45,000 sleepers had already been installed on the Main South. Although some doubts were raised about the fatigue strength of steel sleepers, there have been no reports of their failure in this regard.

3.4 The stoppage[19] of the in-face heavy duty concrete sleeper installation on the Main South occurred after the installation of steel sleepers on Class 1 Main lines. If the concrete re-sleepering program had proceeded, then fewer steel sleepers would have been required. The duration in which the steel sleepers remained in the track would have also reduced.

[19] Correspondence RSA to RAC Re: Main South Resleepering – April 1998

Reasons Why This Decision Was Taken

3.5 The decision to introduce steel sleepers on Class 1 Main line track revolves around two key issues: the impending timber sleeper supply problem and the cost benefits to be gained from the use of steel sleepers. The forecast supply problem with timber sleepers initiated a number of studies into the alternatives regarding sleeper type and installation pattern. These studies identified savings associated with the use of steel sleepers and decisions were made based on these savings.

3.6 The ongoing costs associated with the tamping of steel sleepers is an area that appears to be deficient in the planning and the implementation strategy. The additional costs associated with the full tamping and ballasting procedure were not foreseen, based on the assumption that the modified tamping procedure would meet the performance standard without additional rework.

3.7 Cost savings were anticipated from the use of steel sleepers instead of timber sleepers in a PRS program. The option of using steel sleepers was made even more viable because of the ability to reuse the steel sleepers if they were later replaced by concrete sleepers under an in-face re-sleepering program. When installed in a random pattern instead of a fixed pattern, further savings were made by replacing the life-expired timber sleepers. This meant that the remaining timber sleepers would be in a better condition overall. The life expectancy of the remaining timber sleepers was also expected to increase as a result of the interspersed pattern.

3.8 The circumstances at the time dictated that cost savings were a priority for management. Control of allocating funds was in the hands of the senior managers at the head of each organisation. The decision was made at a level where the funds used were allocated from ongoing maintenance budgets. There were no formalised policies in place for configuration management at the time of introduction and therefore there was no requirement for the decision to be elevated to the General Management level for ratification. Even though there was opposition from the Engineering Standards Group, the decision-makers had sufficient confidence in the previous trials to support the installation of steel sleepers. Track stiffness testing in Northern NSW on lower class lines showed that PRS steel sleepers had good compatibility with timber sleepers, even though higher track stiffness could be achieved with steel when ballast was correctly chosen and effectively packed.[20] The Manufacturer was also engaged by the decision-makers to provide ongoing technical advice covering installation and maintenance.

3.9 The creation of RAC and RSA in 1996 made for an environment where changes to the infrastructure could be carried out under processes that differed from the previously vertically integrated State Rail. Changes to business processes could be made more readily in the newly formed

[20] Freight Rail Position Paper on Steel Sleepers and Fastenings Supply Aspects – June 1994

organisations, especially where there had been major organisational changes and loss of personnel.

How was Such a Decision Made in the Past?

3.10 The process of obtaining an approval to change track infrastructure prior to June 1996 varied to the process undertaken with the introduction of steel sleepers. Under Freight Rail, the process to obtain an approval for new configuration items, such as steel sleepers, would have required the following:

a) An engineering trial to assess the sleeper suitability, or sufficient technical trial information from a comparable interstate or oversees rail application.
b) A strategy endorsed at the Group General Management level covering the applicable change and planning issues associated with the change.
c) An engineering standards approval by the relevant standards engineer.
d) A Submission for Approval to expend funds (Capital Works) with applicable justifications from the relevant Standards Manager, Chief Infrastructure Engineer, Group General Manager and Chief Executive Officer.

3.11 This process, although not formally documented in the form of an infrastructure policy, is similar to the process in existence within RIC today. The process required product trials to be undertaken so that local knowledge of the changes could be assessed against local conditions. The requirement to seek an engineering standards approval for configuration changes created an engineering checking mechanism within the approval process. If the configuration change did not have an engineering approval, it would not be possible to amend the relevant standards and ultimately gain an approval to expend the funds necessary to purchase the configuration items. The process required long term planning and was rare to be progressed from start to finish in a short time-frame. Regional Infrastructure Management found it difficult to effect changes to the infrastructure without following the process.

3.12 By July 1996, the process of obtaining approval for the use of steel sleepers on Class 1 Main lines had progressed to a strategy approval for selected Class 1 Main lines only. This strategy was initially accepted at the Group General Manager Freight Rail level.

3.13 The Asset Management philosophy prevailing at the time of steel sleeper introduction, required RAC Engineering Standards to prove that steel sleepers represented an immediate safety concern if RAC Asset Management was to consider stopping the installation program.

How are Such Decisions Made Today?

3.14 RIC have in place today a configuration management system that requires applicable levels of engineering evaluation, coordination and approval in order to implement changes. Stakeholder review is also integral to the configuration change process of these organisations. The decision to introduce steel sleepers on Class 1 Main line track would have required consultation and approval under RIC's current configuration management processes. These processes require the approval of the relevant Standards Engineer and an endorsement of the relevant Standards General Manager. Configuration changes may be proposed by a number of stakeholders, such as infrastructure maintainers, but final approval of a change requires an appropriate standards approval.

3.15 OTSI notes that whilst a configuration management process is in place within RIC to manage civil infrastructure standards approval, this process does not cover a technical justification procedure to support the standards approval. Such a defined approval procedure would be of benefit in providing guidance to the standards engineer on how an appropriate technical approval is achieved, i.e., whether the approval requires type testing and/or design analysis review.

3.16 In contrast to the original RAC Asset Management philosophy, the configuration approval process employed within RIC today requires engineering approval to take place prior to the implementation of a change, such as installing steel sleepers.

Control Over the Decision's Implementation

3.17 A number of problems arose with the installation of steel sleepers in Class 1 Main lines. Contractor control issues, training, supervision deficiencies and conflicting organisational goals were identified as causes of concern. These problems had an impact on steel sleeper performance from the beginning of their installation on the Main South.

Contractor Control

3.18 The organisational framework under which the decision to implement steel sleepers was made affected four internal and external service relationships. These relationships are depicted in Figure 12. Formal service contracts existed between the Asset Management group within RAC and RSA. The RSA Maintainer managed the RSA Installer via internal scope of work orders and correspondence. The scope of works for steel sleeper installation was not covered under a formal internal service agreement. At the time of steel sleeper installation on the Main South, there was no corporate installation standard that existed within RSA or RAC defining the installation, and hence no such standard was included within the Installer and Maintainer workscope.

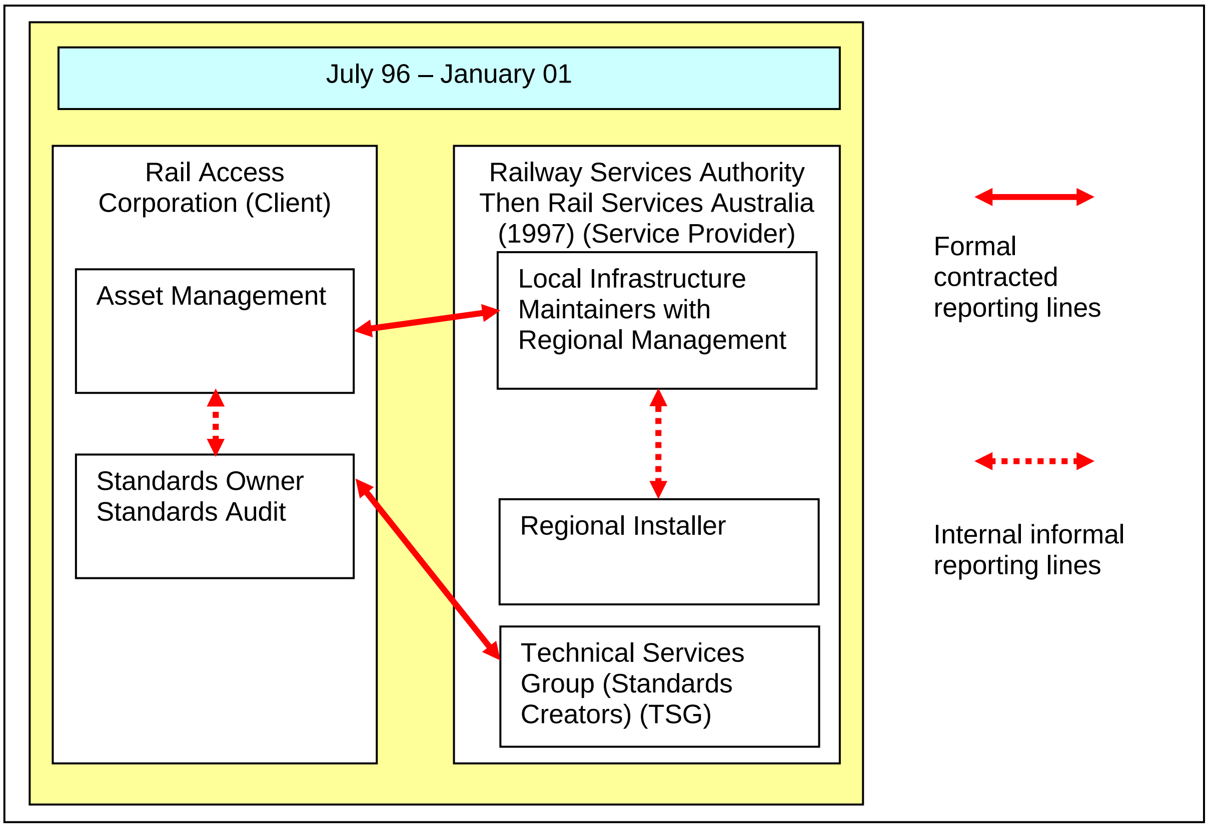

Figure 12 – Organisational Structure – 1996-2001

3.19 However, two RSA installation procedures did exist. These procedures varied in terms of the sleeper pattern and tamping processes. The Regional Maintenance Management's procedures required steel sleepers to be installed in a random pattern with spot tamping only, compared with the Installer's procedure of a fixed pattern with spot and in-face tamping at installation and again some 3-6 months following installation. Follow-up tamping was to be carried out at the discretion of the installer dependent on steel sleeper performance.

3.20 The measurement of steel sleeper performance was problematic due to the delay in identifying installation defects, where these defects could take up to 6 months before they became apparent.

3.21 A number of factors ultimately combined to impede the performance and assessment of steel sleepers on the Main South. These factors were predominately seen to be the inconsistent provision of training and the lack of corporate standards and corporate procedures. Corporate-approved standards and procedures were not in place until 1999, with corporate approval for training procedures taking until 2001 to formalise. These issues, together with the fact that no formal agreement existed between the Installer and the Maintainer, hindered the installation process from the outset.

Internal Rail Services Australia Conflict over the Installation Process

3.22 Experience gained from the Installers on the Class 1 Main West (pre-1996) and Class 2 - 4 lines, identified critical installation processes that needed to be followed. However, the Regional Maintainer decided to implement a modified installation process that had not been previously trialled. This modified process reduced the number of times a steel sleeper would be tamped. The Installer expressed concerns with the change in tamping processes. The modified installation process was ultimately followed as no production tampers were used on the Main South following the first 3 months of installation.

3.23 In 2003, further problems with steel sleeper ballast compaction and pumping were identified on the Main West and surrounding branch lines. The origin of these problems was believed to have been the result of excessive removal of ballast when scarifying the sleeper trough at installation, and a further change in the allocation of spot tamping resources. This change consisted of removing one of the two spot tampers allocated to the steel sleeper installation team.

3.24 The removal of one spot tamper from the installation team placed additional pressure on the remaining spot tamper to keep up with installation. OTSI was advised that if the remaining spot tamper could not maintain the required production rate, or if it was to fail, there existed the possibility of sleepers being installed manually without any tamping.

3.25 Once steel sleepers were installed under the revised installation processes, the track formation would initially appear as an acceptable track structure. As a consequence of removing the intermediate ballast regulation and the production tamping processes, and in conjunction with the loss of ballast from excessive sleeper trough scarification, a large number of steel sleepers were left with insufficient ballast depth within the pod. The performance of those steel sleepers that underwent the modified installation process was noted to have deteriorated at an increased rate. In order to rectify the ballast depth and compaction problem, additional ballasting, regulation and face tamping operations were required.

3.26 The removal of the second spot tamper in the modified installation procedure was reported to have been driven by the need to increase installation rates. As two spot tampers are specifiedin the recommended installation process, the removal of the second spot tamping operation released a spot tamper to carry out steel sleeper installation at another location. As a result of the lessons learnt from those problems identified in 2003, the approved steel sleeper installation procedures were restated and reinforced to the Installer through training, closer supervision and provision of additional tamping resources.

Organisational Goals

3.27 At the time of steel sleeper introduction, there was considerable focus on the minimisation of maintenance costs. This focus was a clear driver within RAC and RSA contracted arrangements. The Regional Maintenance Management communicated this driver to the Maintainer's field staff on a number of occasions, identifying the requirement to provide infrastructure that is "*fit for purpose at the lowest possible cost*". The maintenance agreement between RAC and RSA required the Maintainer to meet budget and workscope targets. Performance payments were available to the Maintainers should they identify cost savings.

3.28 The introduction of steel sleepers provided short and long term cost savings for RAC and RSA. Steel sleepers were a cheaper alternative to timber sleepers under a PRS program. In the longer term, if the steel sleepers were installed correctly, they had the potential to increase the lifespan of the remaining timber sleepers. Steel sleepers could also be reused on branch lines when the heavy duty concrete in-face re-sleepering program recommenced.

3.29 The focus on cost reduction that existed at the time of Class 1 Main line steel sleeper introduction could to have influenced the way in which the introduction was progressed without compliance with the historic engineering approval process. The focus on cost minimisation could have also influenced the decision to introduce a modified installation process with reduced procedures.

Regulator Consultation

3.30 At the time of steel sleeper introduction, there was no requirement for Infrastructure Maintainers to notify the TSB of configuration changes. The TSB became aware of the existence of steel sleepers on Class 1 Main lines in an audit of January 2001. By January 2001, there would have been in the order of 250,000 steel sleepers installed on the Main South. In January 2001, a standards approval existed for the installation of steel sleepers and as such was not identified by the TSB as a non-conforming item.

3.31 In 2000, the TSB introduced a configuration change notification requirement that is similar to the notification requirements specified within the ITSRR Safety Management System change notification procedure. As TSB's change notification requirements were not retrospective, there was also no requirement to notify them of the steel sleeper change at that point in time.

3.32 In 2002, the TSB became aware of track stability problems that could result from incorrectly installed and maintained steel sleepers. In particular the TSB held concerns regarding the "*loss of shoulder ballast at the sleeper ends*". Vertical pumping of steel sleepers was also identified as a concern to the TSB. Non-conformance notices were subsequently issued to RIC identifying these concerns.

3.33 The current change management procedure of ITSRR is intended to require infrastructure maintainers to advise changes similar to that of steel sleepers.

Of critical importance in the ITSRR's change management procedure is the requirement for an operator to conduct a rigorous risk assessment of proposed changes. The application of a risk assessment process to configuration changes will assist in drawing together key stakeholders such as technical experts, track maintainers and track installers. Configuration changes that are subsequently provided to the ITSRR for notification have the added benefit of ITSRR's review and applicable advice following the review.

3.34 At present RIC and ARTC have in place change management processes that require configuration changes to be assessed. In addition to these processes, the organisations have recently created an Engineering Standards Consultative Group that meets to review changes to standards. This consultative group will assist each organisation in gaining a professionally independent review of changes to standards.

Risk Management

3.35 At the time when steel sleepers were introduced on Class 1 Main lines, there were no formal risk management practices in place within RAC and RSA to evaluate such a change. The process of evaluating a change, using a qualitative risk assessment process, would have required the identification of a number of factors. Such factors would have included applicable standards, installation procedures, manufacturer's specifications and instructions, operating criteria and previous change experience.

3.36 Stakeholder consultation would then normally be undertaken to evaluate these factors and to provide an analysis of what could happen with the change and how it could happen. An analysis of the identified risks then follows to determine the likelihood and consequences of the risks. The analysed risks are then evaluated against an acceptable risk profile. Where risk levels are determined to be unacceptable the review and improvement of risk controls is required. Once adequate controls are determined to manage the level of risk, these controls are then implemented subject to a process of review and feedback into the assessment of risk:

3.37 Those risks that were identified by the relevant parties at the introduction of steel sleepers included concerns over the following.

a) The fatigue life of the sleepers applied to Class 1 Main lines.

b) The potential for a differential in track stiffness between timber sleepers and steel sleepers when interspersed in random patterns. Concerns were also raised over the effect of transitioning from random patterns to fixed patterns in a continuous section of track.

c) The correct method of installing steel sleepers to ensure track disturbance risks were minimised and that ballast depth and ballast compaction requirements were met.

d) The long term suitability of steel sleepers in maintaining their stability in a Class 1 Main line operating environment.

3.38 Problems with steel sleeper performance at a number of Class 1 Main line locations were identified as the introduction progressed. These problems were seen primarily to be the result of poor steel sleeper installation. Had a more thorough trialling and evaluation process been undertaken to assess the installation processes employed post-1996, it would have been possible to mitigate those risks identified prior to embarking on full scale implementation.

3.39 The formalised concept and use of the term risk management is gaining prominence in the NSW Rail Industry. This does not mean that it was not done under a different name in earlier times. Trialling and testing innovations before implementation has been a standard practice. The current standards relating to configuration change processes bear this out. The risk of installing steel sleepers was perceived to be mitigated by the experience of their use in previous trials and the experience of the rail staff managing the change. However, change of the magnitude embarked upon in 1997 is surprising considering the opposition raised at the time. The change was seen as a temporary measure by those engaged in the decision-making process.

3.40 As with many decisions made under economic constraints, the change was a compromise solution. There were many benefits to be derived from the use of steel sleepers for PRS and there were also disadvantages. These disadvantages were evident at locations where installation of the steel sleepers did not occur according to the existing standard. Where steel sleepers were not installed to the existing specified standard, the infrastructure risk profile was increased.

3.41 The evaluation of whether the risk profile has increased to any significant extent as a result of the introduction of steel sleepers is a complex matter. The stability of all track configuration types is influenced by a number of factors. Such factors are primarily derived from the track structure configuration, condition and alignment. Rail adjustment, ballast condition, ballast depth, ballast profile, fastener type, fastener condition, sleeper type, sleeper condition, and maintenance intervention, etc., all contribute to the track structure stability. It should also be noted that some changes to the track infrastructure, such as steel sleepers, may improve one aspect of the track structure stability (e.g. improved gauge holding) but conversely may reduce another part of the track structure stability (e.g. lateral stability) if not carried out in accordance with approved practices.

3.42 A qualitative review of the risk of steel sleeper introduction has considered those risks identified in 3.37 and the additional risk of the introduction not following an acceptable configuration change process. OTSI considers that the risk profile would have increased at the time of the Class 1 Main line steel sleeper introduction based on these risks. OTSI also considers that the increased risk profile has subsequently reduced, in part as a result of the introduction of a corporate installation standard, further training development and the provision of more tamping resources to correct areas where installation problems have been identified.

PART 4- FINDINGS

4.1 The following findings have been identified from the factual information and analysis presented in Parts 2 and 3 respectively.

Class 1 Main line Steel Sleeper Approval and Implementation Process

Impetus for Change

4.2 Those factors that were present prior to the introduction of steel sleepers on Class 1 lines, and that generated a requirement to find an alternative sleeper from timber included the following:

a) An impending sleeper shortage was raised at Ministerial Level in 1993.

b) A reduction in the supply and quality of timber sleepers together with an increase in their cost. Timber sleeper supply rates, of the approved timber species, could not match demand requirements to replace life-expired sleepers.

c) The track condition at the time of steel sleeper introduction necessitated major infrastructure maintenance that would not tolerate deferment.

Logic Used to Support the Change to Steel Sleepers

4.3 The logic used to support the change from a continuous timber sleepered track to a combination of timber and steel sleepered track considered the following:

a) Recommendations existed for steel sleepers to be used on Class 1 Main line track (West).

b) Experience gained on the Main West Class 1 lines and Class 2 lines provided those responsible for the change with sufficient confidence to use steel sleepers on the Main South Class 1 line using a modified sleeper installation process.

c) The installation pattern selected provided minimal track disturbance and maximum cost benefit at installation.

d) Steel sleepers could be reused on Class 2 - 4 lines following the recommencement of the concrete re-sleepering program.

Organisational Factors Identified at the Time of Change

4.4 Those factors that were present at the time when steel sleepers were introduced included the following:

a) A Class 1 Main line trial at Thornton in 1985 was not successful due fatigue cracking of the sleeper near the rail fastener attachment point. (Note the sleeper / fastener arrangement of today's steel sleeper has improved upon the trial version).

b) RAC Asset Management had the ability to make changes irrespective of the RAC/RSA Engineering and Manufacturer's advice.

c) The Installation of steel sleepers on Class 1 Main line in 1996 (Main West) and later in 1997 (Main South) contravened the sleeper standard at that time. No immediate standards waivers were obtained to allow installation of steel sleepers on Class 1 Main lines. A waiver to the standard allowing for the change was ultimately obtained some 18 months following the introduction. This standards waiver contained a number of conditions relating to installation and inspection requirements.

d) Installation procedure and pattern recommendations gained from steel sleeper trials on the Main West Class 1 and Class 2 lines were not followed in the installation on the Main South.

e) No prior engineering trials were conducted on Class 1 Main lines covering the modified installation process and patterns employed on the Main South Class 1 line. There was also no track stiffness design verification conducted to provide an assurance that steel sleepers would be compatible when interspersed with timber sleepers.

f) Financial provision for the tamping of steel sleepers as they were installed on the Class 1 Main South was inadequate in the planning and the implementation stages. Based on the assumption that the modified tamping procedure would meet the required performance standard without additional rework, the additional tamping costs were unforecast.

g) The RAC Asset Management approach at the time of installation was to proceed with the installation unless there was engineering proof that steel sleepers were unsafe. The interstate, Main West Class 1 and Class 2 line experience was used to support the Asset Management decision to use steel sleepers.

Installation

4.5 Those factors that were identified as causes of concern during the installation of steel sleepers on Class 1 Main lines post 1996 included:

a) Controls over the identification of which timber sleepers were to be removed were inadequate in the initial stages of changeover. This lack of control led to the track having more steel sleepers installed than required and in some cases in an undesirable pattern. This practice was noted to have impacted adversely on the track stability.

b) The filling and compaction of steel sleeper ballast pods was not consistently achieved due to the problems associated with the revised installation process required by the Maintainer. The RSA Regional Maintenance Management's modified tamping procedure could not be consistently achieved by the Installers. The Installers previously employed an installation procedure that required additional steps. The reduced number of steps made it more difficult for the Installer to attain the required installation performance standard.

c) The inherent difficulties of identifying substandard installation immediately following the installation process meant that a measurement of quality could not be easily associated with the installation.

Corrective Actions Imposed by RAC/RSA and then RIC to Improve Steel Sleeper Performance

4.6 Those corrective actions that were taken by RAC/RSA and then subsequently RIC and ARTC to improve steel sleeper performance included the following:

a) Subsequent training has been provided to the Installers emphasising the importance of correct sleeper pattern marking and tamping (2004).

b) RIC has put in place configuration change standards requiring engineering review and approval of like changes prior to their implementation.

c) RIC is now requiring the installation of steel sleepers on the Country Regional Network Class 1 Main lines to be in strict accordance with their installation and usage standard.

d) ARTC is no longer installing steel sleepers on any of the defined interstate Class 1 Main line network and is presently using timber sleepers in the PRS program.

e) ARTC has issued its own steel sleeper installation standard requiring steel sleepers to be installed in a specified pattern.

f) ARTC is progressively correcting any problems arising from poor steel sleeper installation that are detected from track inspections and track recordings. Where remedial work is undertaken to address problems, the work is done in accordance with its steel sleeper installation standard.

Steel Sleeper Change Process Considered against the RIC Change Process

4.7 The configuration change from timber to steel sleepers would have required engineering standards approval prior to its full scale implementation. Despite the fact that steel sleepers were initially installed without the appropriate engineering approval, such approval was ultimately gained some 18 months following their introduction.

ARTC and RIC Current and Long Term Steel Sleeper Strategy

4.8 The operating parameters set down by ARTC indicate that steel sleepers would no longer be installed on Class 1 Main line track. ARTC has the intention to remove the steel sleepers currently in Class 1 Main line track and install timber sleepers or heavy duty concrete sleepers where possible. The steel sleepers would be removed and sold or used on low tonnage and low volume lines. The use of steel sleepers on Class 2 - 4 track would be only be in-face or to a rigid pattern e.g. 1 in 4.

4.9 Heavy duty concrete sleepers would only be installed in-face and where they were commercially justified. The use of low profile concrete sleepers on ARTC's Class 1 main lines would not be considered for similar reasons to that of steel sleeper use.

4.10 ARTC has reissued RIC's steel sleeper usage and installation standard. ARTC has also identified a significant number of locations where steel sleepers have not been installed in accordance with this standard. ARTC acknowledges that it will take some time to rectify the pattern of steel sleeper installation in accordance with the standard at these locations. Where remedial work is undertaken to address steel sleeper performance problems, the work will be done in accordance with the standard. Steel sleepers will remain in the ARTC leased network until ARTC has the required funds to progress their Class 1 Main line in-face concrete or timber sleeper strategy.

4.11 RIC has advised that they will continue to maintain steel sleepers within the track configuration for the Class 1 Country Regional Network lines. Any maintenance and recitification work required on these sleepers will be carried out in accordance with their applicable technical standard. RIC will also consider the long term use of low profile concrete sleepers on these lines.

ARTC Configuration Management Process

4.12 ARTC advised that any configuration change of the type experienced with steel sleepers would follow their Process Procedure. This process involves Engineering Services accepting or rejecting the change. Any change would be made according to existing standards.

Assessment of Risk Associated with Steel Sleepers

4.13 Steel sleepers have been found to provide acceptable performance on Class 1 Main line track if the installation and ongoing maintenance requirements are met. However, installation and ongoing maintenance efforts were noted to have varied throughout the 7 years in which steel sleepers have been installed on Class 1 Main line track. The variation in installation processes from those identified within the current performance standard has inevitably led to locations of substandard track. This has placed additional maintenance intervention requirements on the maintainer and often forced the maintainer to reconsolidate the steel sleepers with additional ballasting and tamping runs.

4.14 The installation process must also be carried out by experienced installers in a controlled and consistent manner. If the maintainer does not detect the presence of substandard steel sleeper installation, the risks associated with track geometry and track stability problems will increase over time. As identified above, the reliability of the maintainer to detect and control substandard sleepers needs to improve. If the maintainer cannot provide the required level of reliability to detect and rectify substandard installation, there is a real risk of steel sleepers on Class 1 Main line track becoming a serious problem.

The Transport Safety Bureau Exposure to the Steel Sleeper Change

4.15 The TSB was not advised of the change to steel sleepers on Class 1 Main line track and lacked visibility of configuration changes to the infrastructure at that time. At the time of the configuration change, the TSB had no formal requirement to be advised of such changes.

4.16 The ITSRR now has in place an accreditation requirement for operators to notify similar configuration changes prior to their implementation.

PART 5- RECOMMENDATIONS

5.1 In response to those issues identified by the investigation that require further safety improvement, it is recommended that the specified responsible entity undertake the following remedial safety action:

Rail Infrastructure Corporation & Australian Rail Track Corporation

5.2 Inspect all steel sleepers installed on Class 1 Main line track to ensure the current installation meets the approved technical performance standards.

5.3 Ensure future steel sleepers are installed according to approved technical performance standards and procedures.

5.4 Provide adequate training to Installers and Maintainers relating to the installation and maintenance of steel sleepers.

5.5 Ensure that any proposed change to the Class 1 Main line track, similar to that of the steel sleeper change, be made following rigorous testing and trials conducted by the relevant technical authority.

5.6 Institute a track infrastructure installation and maintenance policy that requires the installers of new components to comply with an engineering-type testing acceptance process. This process should ultimately underpin the configuration change approval provided by a relevant technical authority. The process should also identify the requirement to obtain the necessary theoretical design analysis to support the configuration change approval.

5.7 Further develop and specify a steel sleeper installation procedure that guides the installer in the recommended practices for installing steel sleepers. Such a procedure should recommend the various spot tamping, resurfacing and ballasting processes required. Quality control requirements should also be specified for the installation process. Such controls should ensure sleeper installation performance standards and procedures are met.

5.8 Ensure field inspection guidance is provided to Maintainers that would assist with steel sleeper maintenance tasks and the identification of potential problems associated with steel sleepers. Such inspection guidance should include corrective measures required to rectify identified defects. The provision of this guidance could be incorporated within existing field inspection guides.

5.9 Ensure that there is adequate contractor control over both internal and external suppliers of civil infrastructure services (e.g., PRS programs, in-face sleepering programs, rail renewal, etc.). Such controls should include appropriate standard references, work scope instructions, quality assurance checks and final work certifications.

Independent Transport Safety and Reliability Regulator

5.10 Conduct a Class 1 Main line steel sleeper audit program in order to satisfy itself as to the Maintainer's ability to meet the installation performance standard. This program should assess compliance relating to current steel sleeper performance standards.

5.11 Review the adequacy of Infrastructure Maintainer's contract controls, covering both internal and external suppliers of civil infrastructure services (e.g., PRS programs, in-face sleepering programs, rail renewal, etc.). Such controls could include appropriate standard references, quality assurance checks, final work certifications and applicable work scope instructions.

5.12 Review the adequacy of Infrastructure Maintainers configuration management procedures to gauge how effective their system is in requiring configuration changes to have engineering approval, stakeholder consultation and Rail Regulator advice. Bring any identified deficiencies to the attention of the Infrastructure Maintainer for rectification.

5.13 Review the ITSRR guidelines for changing Safety Management Systems to ensure there is sufficient guidance provided to Infrastructure Maintainers in classifying those changes that require notification to the Rail Regulator. Such guidance could take the form of a configuration-type listing that identifies applicable reporting requirements.

Observations for Industry

5.14 Major infrastructure configuration changes, whether grouped under Major Periodic Maintenance or Capital Works projects, should contemplate life-cycle maintenance costs. Consideration should be given to determine if the configuration change can be sustained into the future and should be based on those costs derived from approved technical standards and procedures.

ANNEXURES

Annex A - History of Steel Sleeper Use in NSW Railways

Parkes to Broken Hill

1.1 In the 1950s, steel sleepers were used on the line between Parkes and Broken Hill. The sleepers were supplied from England with 200,000 steel sleepers initially ordered. The contract was cancelled in 1954 when, by that time, over 178,000 steel sleepers had been installed. The line was 41kg/m line on sand ballast. The type of steel sleeper used was a British Standard shape sleeper. This sleeper was an earlier version of the steel sleepers used today. The sleepers were installed in in-face sections of track at three locations with the majority in the Parkes to Broken Hill line. The other locations were between Junee to Narrandera and Goulburn and Cooma. By 1971, those sleepers on the Broken Hill line were all removed and replaced with timber sleepers. The initial reason for removal was to prepare the track for the laying of a higher class of rail. The steel sleepers were plagued with maintenance problems associated with the resilient fastening used to connect the sleeper to the rail. The fastener wedges holding the lugs in place worked loose from vibration. There was also an accelerated loss of top and line in jointed track.[21]

Picton – Mittagong

1.2 In 1968, a trial 3.2 km section of the Picton to Mittagong loop line was laid with steel sleepers taken from the Parkes to Broken Hill line. Modified fasteners were used in this installation. The trial performed well and a further 6km was later laid on that line.

Thornton

1.3 A later sleeper trial took place at Thornton in the Newcastle area in 1985. The trial was on the Up Coal Class 1 line where heavy axle loadings occur. The type of steel sleeper used was an earlier version of the steel sleepers used today. In this instance, BHP developed a system of cold pressing a housing for the pandrol clip to seat into. The pandrol clips were driven into a raised section of the steel sleeper on either side of the rail. However, these sleepers retained excessive residual stress from the deformation required to form the pandrol housing. When the sleeper was subjected to high lateral forces, fatigue cracking of the sleeper pandrol housing occurred. It was found that after 2 or 3 years, very fine cracks around the pandrol housing developed. These sleepers were removed from service. In the subsequent redesign, BHP returned to a plain steel trough section sleeper with a hole on either side of the rail seat. This was used in conjunction with lock -in shoulders and a Track-lok resilient fastening to secure the rail to the sleeper.

[21] The term *Top and Line* refers to the overall performance of the track geometry with respect to vertical and horizontal movement.

Moree to Boggabilla.

1.4 Numerous types and installation patterns of steel sleepers were trialled on the Moree to Boggabilla line. One of the first trials occurred in the vicinity of Croppa Creek in the early 1980's. This followed improvements in the use of resilient fastenings and welded rail. This installation was part of an upgrade from Class 5 to Class 3. Reconditioned British Standard steel sleepers from the Parkes to Broken Hill line were used. About 95,000 sleepers were installed. They were trialled both in-face and in an interspersed pattern.

4.17 In 1987, further installation and testing of steel sleepers continued on this line and a further 50,000 steel sleepers were installed. Instead of the reused British Standard sleepers, these steel sleepers were 7mm thick and were manufactured by Titan Engineering, Port Kembla. For comparison, another 3,000 steel sleepers from Omark (now Trak-lok), made in Whyalla, were installed. Various patterns in-face and interspersed with timber and different tamping methods were employed. A report and general conclusions were made following this trial. The conclusions from this trial reported that:

a) Steel sleepers as trialled were suitable for PRS for Class 2 or 3 track with rails 41/kg/m or greater.

b) Minimum of 1 in 4 pattern should be used for best ride quality.

c) A minimum ballast depth of 200 mm was required, and

d) There were benefits of welded rail on steel sleepers with resilient fastenings.[22]

Dubbo – Merrygoen

4.18 Between 1994 -1996, approximately 100,000 steel sleepers were installed on the Class 2 Main Line from Gulgong to Merrygoen and from Dubbo to Narromine. A variety of tamping methods was evaluated as well as a vaiety of tie patterns. The trial was successful and the installation methods were studied by the installers of steel sleepers in the Main West and Main South.

Stockingbingal to Griffith

4.19 In 1996, Country South introduced steel sleepers on Class 2 track. They were first put in the Stockingbingal to Griffith line at an average random pattern of 1 in 7. The random pattern installation method was used to overcome the necessity of taking out good timber sleepers employed with the fixed pattern method. Again, this trial was successful for the Class 2 track and was immediately followed by the installation of steel sleepers in the Main South line.

[22] Report entitled *Background Info –Steel* included in Appendix 4 of Freight Rail Alternative Sleeper type – Strategic Value Management Study 18th April 1994

Annex B – Interstate Experience of Steel Sleeper Use in Australian Railways

Queensland

4.20 On the narrow gauge Queensland Rail lines, there is widespread use of steel sleepers. Most of the steel sleepers date from the late 1970s with the majority supplied after 1990. The lack of adequate quality timber sleepers, increasing cost of timber sleepers and increasing requirements for coal track infrastructure were reasons stated for the development of new sleeper strategies. These strategies saw the use of steel sleepers in areas of lighter axle loads and light traffic lines; concrete sleepers in areas of high freight traffic and high speed passenger lines, and timber sleepers in areas of non-commercial freight and light traffic.

4.21 In terms of total number of sleepers, steel sleepers comprise approximately 17%, concrete sleepers 30% and the remaining 53% are timber sleepers. Steel sleepers were installed in a fixed pattern of 1 in 4 and 1 in 3 around Rockhampton. Steel sleepers have also been installed in the Brisbane suburban area and outside of Brisbane, on the Mt Isa to Hughenden line.

4.22 There is also historical use of steel sleepers on the Normanton to Croydon line. Approximately 250,000 steel sleepers were installed in the1890's and are still in use today on a tourist line.

Tasmania

4.23 The total track length in Tasmania is approximately 800 km and has large sections of curved and steep gradient track. Since 1986, there has been a strategy of introducing steel sleepers with steel sleepers now comprising approximately 65% of track. The majority of these sleepers are installed in-face. Initially, Tasrail used a random pattern but this was found to be unsuccessful regarding track geometry and now in-face installation is the accepted practice.

Western Australia

4.24 In 1978, steel sleepers were installed in-face in a test track at Cunderdin and remain in service. Westrail installed steel sleepers to a pattern in 1987; most of the narrow gauge tracks use a 1 in 4 pattern interspersed amongst existing timber sleepers. This installation has resulted in reducing the incidence of track buckles and has proved successful. In the standard gauge branch lines from Kalgoorlie to Lenora, there are sections of 1 in 4 pattern, and from Kalgoorlie to Esperance there are sections of 1 in 2 pattern steel sleepers. It was reported that recently, the Western Australian Government had legislated cessation of the use of timber as a sleeper material.

South Australia

4.25 In South Australia, two main railways have invested significantly in steel sleepers: the Adelaide suburban network and the Eyre Peninsular. The Adelaide suburban rail system of today comprises five rail lines which total over 120 kilometres of track. Adelaide has the following approximate percentages of sleepers in the system: Steel sleepers 40%, concrete sleepers 20% and timber sleepers 40%. The steel sleepers were initially installed in a random pattern but this was found to be unsuccessful. This pattern was changed to a strict use of 1 in 4 pattern and some areas are also installed in-face.

4.26

4.27 The Eyre Peninsula in regional South Australia has a history of transporting grain to Port Lincoln. In an average year, more than 1.2 million tonnes of grain is moved into the grain terminal facilities for export to domestic and foreign markets. In 2003, the railway line between Cummins and Port Lincoln was upgraded with the replacement of 15,000 wooden sleepers with new steel sleepers, as well as the introduction of continuous welded rails.

Annex C – Sleeper Installation Patterns and Material Types

Interspersed Patterns

1.1 There are a variety of ways that sleepers can be installed and a variety of sleeper material that can be used. Generally when the track is first laid, the same sleeper type is used. Traditional timber sleepered track can have its life extended by replacing the timber sleepers in the poorest condition with new timber sleepers. This method reduces the variation in track geometry found with differing types of sleepers laid in proximity. When the same type of sleeper material is used consecutively the term *in-face* is used. The method of replacing some sleepers is known as Partial Replacement Sleepering (PRS). The pattern of sleepers to be installed depends on the following:

a) The number of sleepers needing replacing.

b) Route Class & Gross tonnage of rail traffic.

c) Timber quality.

d) Radius of curve.

e) Number of years planned to cycle the pattern to reach 100% of the same material.

1.2 OTSI noted the manufacturer's guidelines for use of steel sleepers. Successful in-track performance of steel sleepers depends not only on the selection of suitable sleeper configuration, but also on the method of installation and tamping used. This is especially true when interspersing with timber sleepers.[23] If sleepers are used in an interspersed pattern, a disproportionate amount of the load may be taken by a particular sleeper and early in-service failure may result.[24] It is highly desirable that steel sleepers are installed to a consistent tie pattern if they are to perform satisfactorily in service. The degree of criticality of this factor will depend on the track curvature, the operational loading and the condition of the adjacent timber sleepers.[25]

Fixed pattern

1.3 This pattern refers to the replacement of sleepers in a set pattern. The most common patterns used are 1 in 2, 1 in 3, 1 in 4 and 1 in 8. See Figure 13.

[23] *TRAK-LOK* steel sleepers – A Description for Guidelines and Use August 2002
[24] AS1085.17 – 2003 Railway Track Material Part 17 Steel Sleepers
[25] Steel Sleepers - Usage and Installation Standards -RAC March 1999

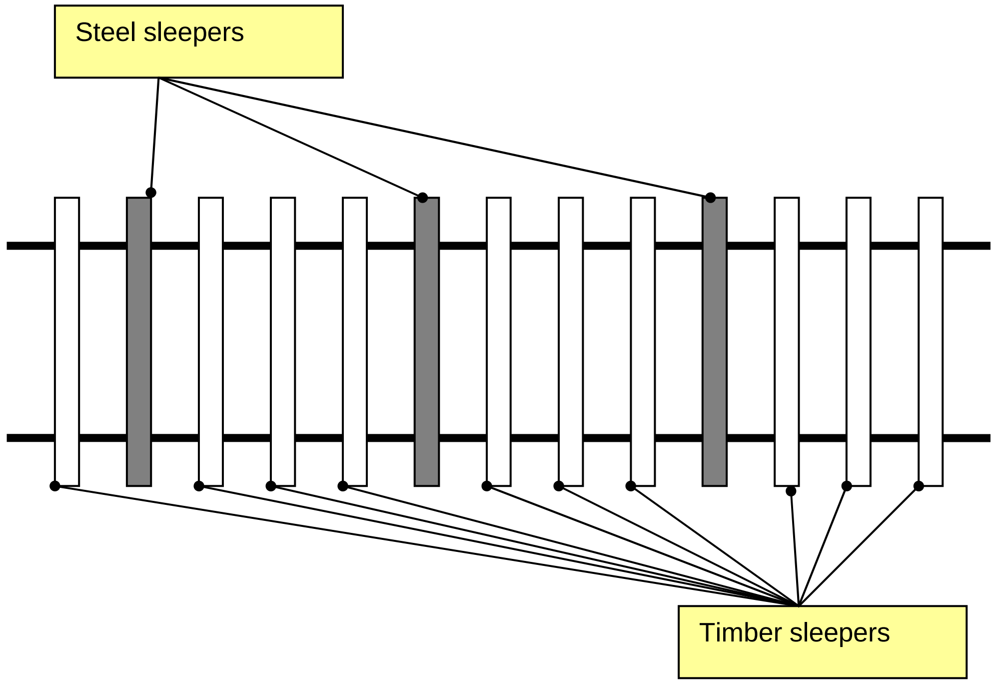

Figure 13 – Fixed pattern sleeper interspersal 1:4

Random pattern

1.4 This pattern refers to the replacement of sleepers in a pattern left to the discretion of the installer. This may result in a number of steel sleepers placed consecutively or with numerous timber sleepers in between. Experience from early trials has shown that interspersal using a purely random pattern results in poor track geometry. See Figure 14.

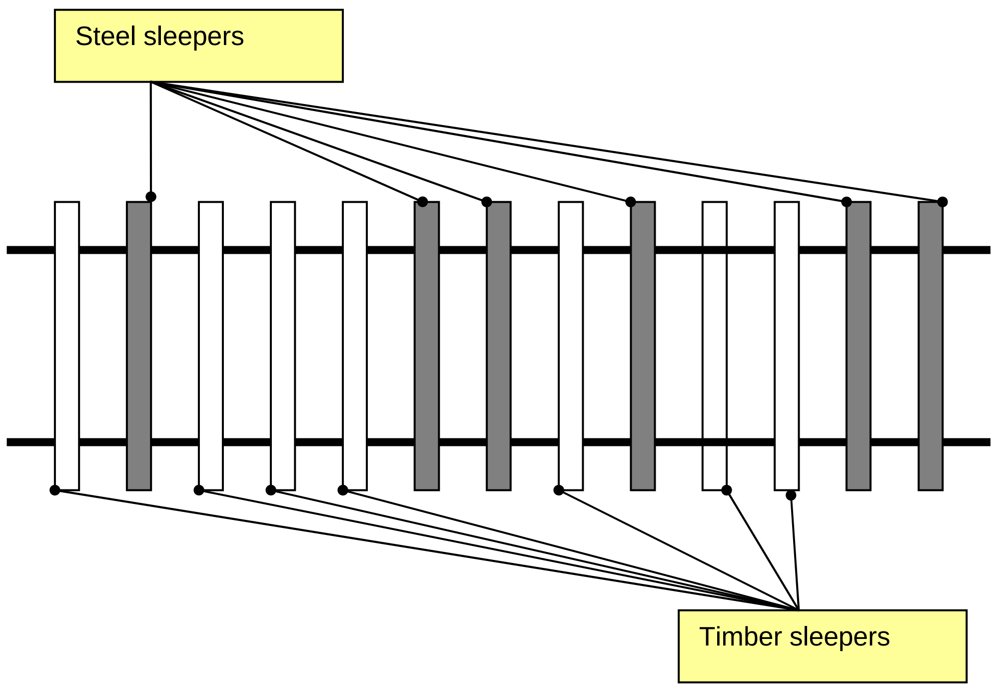

Figure 14 – Random pattern sleeper interspersal

Clumping

1.5 Clumping is where there are two or more adjacent steel sleepers within an area of tie pattern 1 in 2 or greater. This configuration is usually not recommended as it increases the variation in line performance and increases the likelihood of the line experiencing top defects/deviations.

Curves

1.6 Curves present areas where special care is required regarding sleeper installation. A steel sleepered track radius of 400m or sharper may be subject to lateral stability problems; as such, concrete sleepers are preferable.[26]

1.7 The current standard for sleeper marking state the following:
a) for curves less than 300m radius steel "*in-face"* or timber
b) for curves between 300 and 600m fixed 1 in 4 pattern
c) for curves greater than 600m nominal pattern 1 in 6 or 1 in 8.[27]

Heavy Duty concrete sleepers

1.8 The heavier weight of the concrete sleeper and the greater contact area of its base and sides with the ballast provides for significantly better stability than timber.[28]

Low Profile concrete sleepers

1.9 The lighter, low profile, pre-stressed concrete sleeper is specifically designed to be interspersed with timber sleepers in exsisting timber tracks.[29] The intention originally was for this type of sleeper to be used as a replacement for timber on selected Class 1 Main lines and some suburban lines. See Figure 15.

[26] Steel Sleepers - Usage and Installation Standards -RAC March 1999
[27] Sleeper Marking Standard
[28] Performance of Interspersed Steel Sleepers on Main South line between Macarthur and Albury -Fluor report Sept 2001
[29] Rocla Pty Ltd – Product Information for Rocla Pipeline Products - concrete sleepers 2004

Figure 15 – Low profile concrete sleeper

Annex D – Steel Sleeper Design and Performance Characteristics

1.1 The steel sleepers used in NSW are a propriety product manufactured originally by BHP. Steel sleepers were developed following a research program in 1978 which assessed the applicability of steel sleepers to the Australian market.[30] The current steel sleeper used in NSW railways is supplied by OneSteel which is an operating business unit of OneSteel Manufacturing Pty Ltd. This company currently supplies approximately 500,000 steel sleepers per year to the Australian market.[31]

1.2 These steel sleepers are manufactured from either "M" or "W" rolled sections at the Whyalla Steelworks in South Australia. Various thicknesses are available from 6.5mm to 14mm. The material used for steel sleepers is a mild steel grade with 95% characteristic yield strength of at least 250MPa. The sleepers are pressed so they have a hollow trough underside and ends which are spaded. This allows ballast to be effectively retained in the sleeper trough. The end spade is formed at an angle of 25°giving both high lateral holding in the track and the ability to stack for easy handling and transport. See Figure 16.

Figure 16 – Stacked Steel Sleeper

1.3 The bottom edge of the end spade is formed to a position level with the nominal underside of the sleeper allowing easy installation in existing track.

[30] Steel sleeper development brochure – BHP Institute Railway Technology
[31] *TRAK-LOK* steel sleepers – A description for Guidelines and Use August 2002

1.4 On Class 1 track in NSW, Type 1 Steel Sleepers are required to have the following specifications: Length 2500mm, Width (at base) 250 mm to 260 mm, Width (at seat) 150 mm to 160 mm, Depth 95 mm to 100 mm, Thickness (at shoulder) 7.5 mm to 10 mm.[32] See Figure 17.

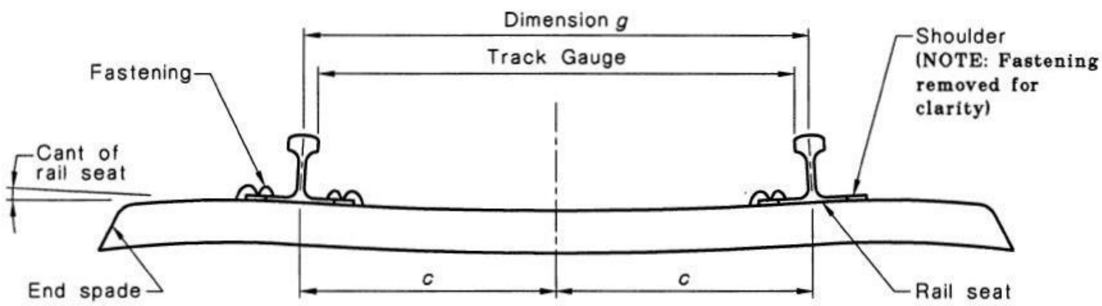

Figure 17 – Steel Sleeper Elevation

1.5 The steel sleepers that have been installed on the Main South are the M8.5 section as depicted in Figure 18.

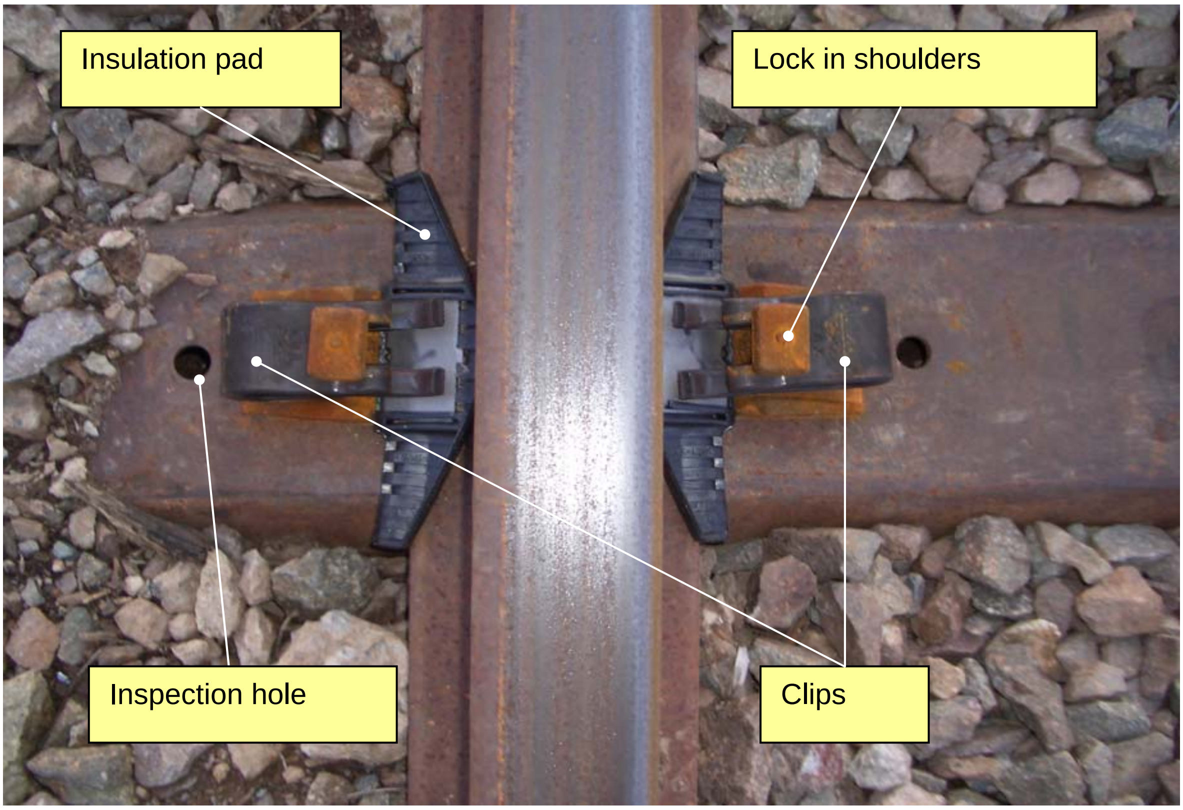

Figure 18 – Steel Sleeper Components

[32] RIC Steel Sleeper Specification C3110 April 2003

1.6 Steel sleepers have the following characteristics.

a) Lightweight design.

b) Easy manual and mechanical handling.

c) Stackable.

d) Environment benefits in reducing the use of hardwood resources.

e) Ability to be reused in other lines.

f) At end of their lifecycle may be recycled.

g) Capable of being repaired, that is, re-pressed.

h) Unaffected by insect attack.

i) Resistant to fungus growth.

j) Non-flammable.

k) Long service life – minimum of 50 years.

l) Functionally dependent on track ballast.

m) Susceptible to corrosion in certain environments.

n) Increased rounding of ballast due to increased deflection and vibration.

o) Different installation and maintenance requirements from other sleeper types.

p) Ballast does not grip the steel sleeper in the positive manner that occurs with timber.[33]

q) When properly consolidated, steel sleepers have a high lateral resistance to movement due to the action of the ballast within the sleeper pod and the spade sleeper ends.

1.7 Because the functionality of steel sleepers is dependent on their maintaining a stable bond with the track ballast, they should not be used in situations where this bond is likely to be compromised; where the ballast formation is poor and where deflection under load is high; at locations where track dynamic forces are high, such as joints, or where the inherent rail surface condition is poor.[34]

1.8 Steel sleepers behave differently to conventional track sleepers, mainly because they are relatively light in comparison to their rigidity. They rely on the ballast to provide support and to add to their effective mass.

1.9 One of the features of steel sleepers, as compared with timber sleepers, is the reduction in the coefficient of friction between the ballast and the sleeper itself. This is greatly enhanced with timber sleepers as sharp ballast edges penetrate the surface of the sleeper. Steel sleepers do not have this advantage. Ballast deterioration can result around steel sleepers when they are not correctly tamped and consolidated. A steel sleeper that has not been correctly tamped

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[33] Adequate ballast angularity is required in order for the ballast to lock in together and maintain acceptable ballast compaction. It is also required in order for the ballast to lock into the timber sleeper surface. Ballast stability effectively reduces as ballast angularity reduces.

[34] RIC Steel Sleepers –Usage and Installation Standards v1.1 Mar 2004 p11

and consolidated may eventually pump (move up and down when subject to a train's wheel load). The deterioration of ballast is often referred to as the rounding of ballast where the gradual rounding of ballast occurs producing a whitening of ballast around the steel sleeper. [See Figure 19]. Steel sleepers are designed to capture and retain the ballast that is moved into the pod in the underside of the sleeper, however if the ballast is rounded, then the lateral stability of the sleeper is greatly reduced. Inspection holes are provided adjacent to the inside of the rail to check that the ballast has been introduced fully into the pod and is firmly packed.

1.10 It should also be acknowledged that in many instances, the use of steel sleepers has improved the gauge holding ability of the track due largely to the lack of deterioration of the sleeper and the improvements made with the resilient fastening system. However, this advantage may be off-set by the loss of top and line that accompanies variations in sleeper materials, fastening systems and the subsequent effect on ballast. Poor quality timber sleepers and their fastenings, in proximity to steel sleepers, may also be seen to have a negative effect on the performance of steel sleepers.

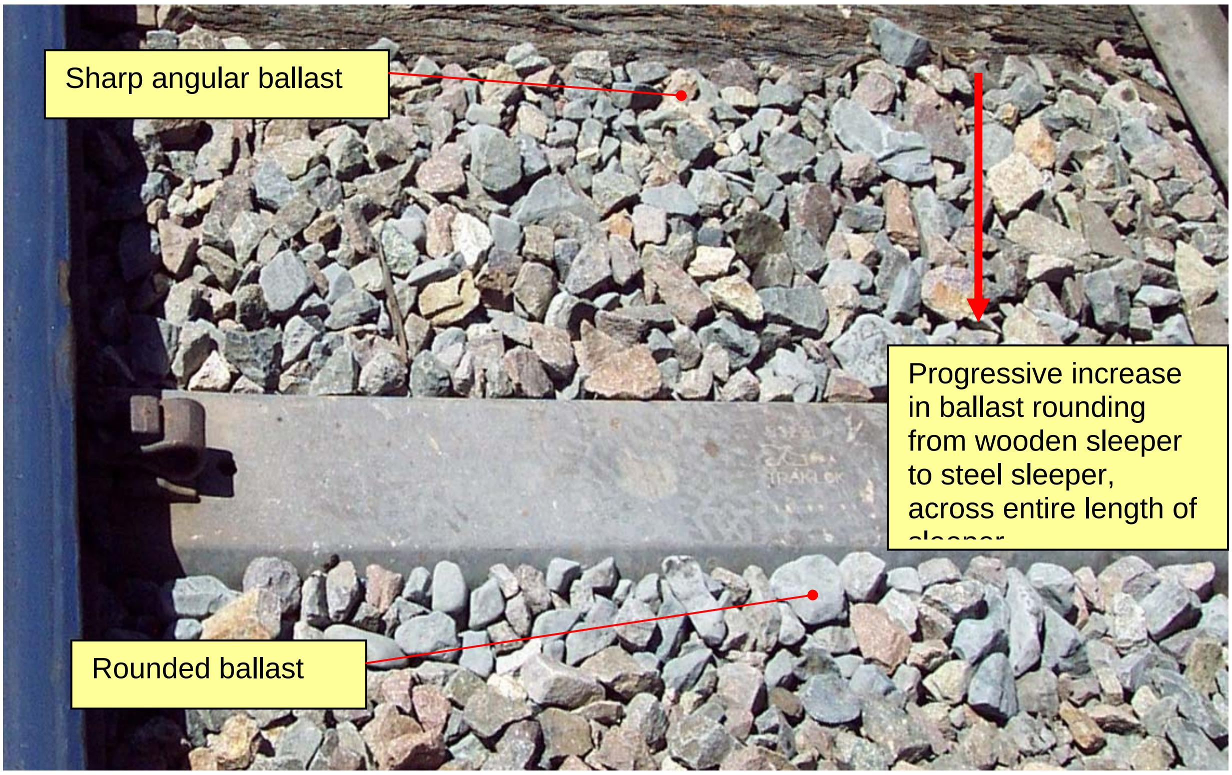

Figure 19 – Rounded Ballast

Annex E – Steel Sleeper Performance Reports

1.1 The following reports provide an indicative measurement of steel sleeper performance on their introduction.

1.2 *BHP Report on Track Inspection of steel sleepers between Albury and Junee, 8th December 1997*. The following observations were made. The average sleeper pattern was approximately 1 in 6 with the variation in pattern between 1 in 2 and 1 in 10, with occasional higher patterns. Grouping of multiple sleepers together was observed but not common. There was evidence of track pumping and in many of the steel sleepers inspected, the ballast in the troughs was loose and not completely full.[35] The conclusion of this report indicated that the track was generally in good condition despite the looseness of the ballast within the steel sleepers. The report stated that opportunities existed for the improvement of the tamping procedures.

1.3 *BHP Report on Customer Visit and Track Inspection to South West Region RSA, 25th to 30th October 1998 by BHP. This visit included both meetings and inspection of track.* It was documented that concern was raised by the local Regional Engineer about the stability of the track between Picton and Goulburn. A track misalignment had recently occurred and white ballast was occurring in a high proportion of the steel sleepers.[36] This was responded to with the statement that poor conditions had existed in this area previously and that steel sleepers were performing to a quite reasonable level of expectation. It was also noted that the tamping of steel sleepers was problematic and that tamping procedures had not been developed or standardised to give optimum performance. In the area of Junee to Albury, it was reported that the track was generally performing well. Among the recommendations was that a workshop to discuss all aspects of the set-up and tamping of steel sleepers should be conducted.

1.4 *RSA Notes on Track Inspection between Picton and Moss Vale, 26th November 1998*. The following aspects of the track condition were observed: poor dogged timber moved up and down but did not take the rail; steel sleepers moved up and down; vibration of the steel sleepers caused looseness at the sleeper ends and the ballast under the sleeper; the ballast was deficient around many of the sleepers; the pattern of placement of steel sleepers was completely erratic, some 1 in 12 and some 5 together; the worst alignment/top was with steel sleepers clumped together; curve creep was noticeable, and there was centre binding with timber sleepers which was especially bad for steel sleepers. The assessment noted that the poor condition of adjoining timber sleepers meant that the steel sleepers were taking more of the load; that the fatigue performance of steel sleepers was unclear, and that steel sleepers among poor timber sleepers was likely to cause less stable track than timber sleepered track.

[35] "Pumping" denotes a sleeper that moves vertically up and down as rail traffic passes over the sleeper. This movement often results in the degradation and contamination of the ballast structure.
[36] Indicative of track pumping and rounding of ballast – leading to track instability.

1.5 *BHP Report on Track Inspection between Picton and Moss Vale, 26th November 1998*. This area of track was identified as an area of concern in the previous report. This inspection also included numerous representatives and managers from both RSA and RAC. The report stated that concrete re-sleepering was the preferred option if funding was available and that the insertion pattern of steel sleepers needed careful consideration.

1.6 *RAC Rail Safety Management Surveillance Report, 1st December 1998.* This audit was for the Up and Down lines between Glenlee and Marulan. A number of major concerns were identified as a result of this audit. They were that the volume of defects and the rate of removal were not being adequately managed; the Civil Standards relating to the type and application of steel sleepers were not in place and could lead to an unacceptably high risk situation, and the Maintainers current asset management practices were not being adequately monitored and reported to RAC's Asset Manager. In particular, the report mentioned that the installation of steel sleepers in the area did not comply with RAC guidelines or BHP guidelines. The type of steel sleeper (8.5mm) was lighter than the size recommended for the tonnage and life-cycle required. The steel sleepers were inserted in a very random pattern and on curves less than 500 m radius.

1.7 *RAC Report on the use of steel sleepers on Class 1 lines, 15th December 1998*. This report covered developments in the assessment and approval of steel sleepers on Class 1 lines. Among its conclusions was that where steel sleepers had been installed to a strict pattern and with full tamping, the track was performing well. At some locations they were not performing well particularly in the north end of the Main South where there are sharp curves and high tonnages. The report stated that some of the steel sleepers had not stabilised and poor alignment would result in accelerated degradation of track components. The Junee to Albury area was performing well but there were potential longer term issues from the use of an inconsistent pattern. It appeared that the life-cycle maintenance costs and risks had not been adequately factored into the determination of the proposed strategy for steel sleepers on the Main South.

1.8 *BHP Notes on RAC workshop, 23rd February 1999.* In these notes it was stated that reasonable track performance was reported in the section Junee to Albury where steel sleepers were installed in 1997. However, poor track performance was reported at locations in the section between Picton and Gunning which was installed in 1998.

1.9 *BHP report on visit to RAC NSW, 4th April 2000.* This report included a comment that RAC was not sure if it wase satisfied with the performance of steel sleepers in Class 1 track and there were mixed views on whether the installation of steel sleepers had improved or worsened the track performance. In summary, it was stated that the level of track performance achieved was directly proportional to the condition of the remaining timber sleepers.

1.10 *BHP Report on visit to Rail Services Australia South West Region, 22nd February 2001.* Comment was made in this report on the difference of opinion regarding the installation pattern of steel sleepers. The manager of Infrastructure South West in RSA was quoted about the restrictions placed on the usage of steel sleepers and that to obtain maximum economic benefit they needed to be installed on a random basis, regardless of track classification. The report also stated that problems reported with steel sleepers were not associated with the choice of steel sleepers, but were caused by existing track condition factors or inadequate sleeper installation. The issue of random versus pattern interspersal was discussed and the comment was made that either strategy could be used after due consideration of all requirements. It concluded with a statement that the OneSteel Trak-Lok Product Warranty was not invalidated by any particular re-sleepering practice.

1.11 *Fluor Report on the Performance of Interspersed steel sleepers on the Main South line between Macarthur and Albury, September 2001.* This report was written by Flour Australia which was commissioned by RIC to undertake an independent assessment of the performance of the track where steel sleepers were inserted. The summary of the findings was that there were many good areas of track, as well as many areas where the standard was poor. It stated that the poor quality could not be attributed to the existence of steel sleepers in the track. It was primarily as a result of heavily fouled ballast. There were many areas where track surface around steel sleepers needed improvement, where the ballast was not filling the pod of the sleeper. It recommended that minimal lift resurfacing should be undertaken through all areas where there was evidence of pumping of steel sleepers.

1.12 *BHP Report on Track Inspection of the Boree Creek, Griffith, Temora and Wagga Wagga Albury lines, 9th May 2002.* Observation on Installation procedures on the Main South included that the installation procedure was proceeding well and that inspections revealed that in the section between Albury and Yerong Creek, there was a high proportion of steel sleepers in track and that the grouping of two steel sleepers together was very common, while the grouping of three sleepers was quite common. It also stated that these groupings did not seem to affect the performance of the track.

1.13 *BHP Report on visit to RIC South West Region,17th December 2002.* The report stated that the section of the Main South between Wagga Wagga and Albury appears to be performing well, following the second pass of steel sleepers and in-face tamping.

1.14 *RIC Test Report on Dynamic Track Gauge Measurement low profile concrete Re-sleepering, 23rd September 2003.* This engineering investigation was commissioned to carry out dynamic track gauge measurements under the passage of several trains before and after low profile concrete sleepers were installed on the Down Main South Line. The track at the measurement site was timber sleepers with steel sleepers spaced one in every four timber sleepers. In part, the summary found that after low profile concrete sleepers were installed, they were relieving the load on steel sleepers by around 30-70%.