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WESTRAIL Track Structures Section Draft Report TS 403.1/30

RAILWAYS OF AUSTRALIA Vehicle/Track Studies: Study No 2.

VOLUME TWO: DRAFT TECHNICAL REPORT

Section 2: Test Section Performance

December, 1993

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2.1 SUMMARY OF TRACK GEOMETRICAL PERFORMANCE

2.1.1 Track Geometry Data

Unfortunately the instrumentation used to record track geometry, located in WESTRAIL's Matissa PV 6 track recording car, became unusable in the early 1980's. Some early work was partially successful using hand digitisation techniques, see Section 4.3 of WESTRAIL report TS 403.1/20, Makin 1988. Subsequent reliability tests, however, highlighted other deficiencies causing variation in track geometry that appeared to depend significantly on the car's direction of travel and the ambient temperature at the time. As a result of this, the decision was made to continue with Study No 2 without PV 6 track geometry information.

In December 1992, Australian National's EM 80 track recording vehicle became available and a full east to west recording run was made on the Perth to Kalgoorlie Standard Gauge line. This was the first of numerous recordings to be subsequently made by AN for WESTRAIL. Appendix 8 provides listings and graphs of the December 1992 results for the following track quality indicators in the Test Sections.

1. Gauge (negative magnitudes are tight).
2. Line Left (alignment of the UP rail).
3. Line Right (alignment of the DOWN rail).
4. Top Left (UP rail dip).
5. Top Right (DOWN rail dip).
6. Cross Level (the difference between Top Right and Top Left).

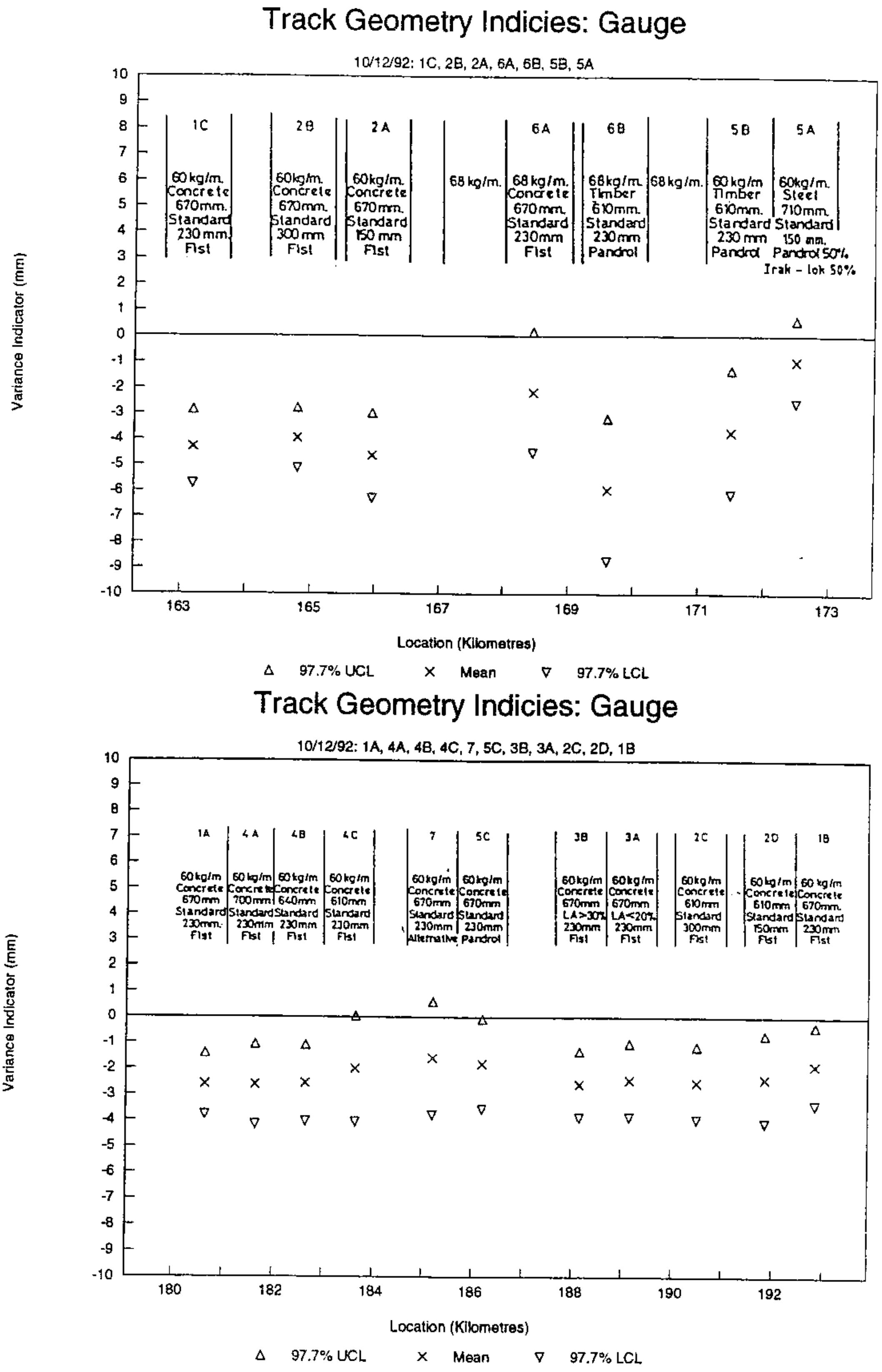
In each case, quality indicators are an accumulative standard deviation of the data at 500 mm spacing in the central 500 metres of each Test Section. This provides a deterioration or departure from design indicator.

With the gauge quality indicator for example, see Figures 2.1.1(i)&(ii) (which are duplicated in Appendix Figures A8.1(i)&(ii)) the higher the magnitude, the greater the departure from nominal gauge (negative magnitudes are tight) on the date the recording run was made.

2.1.2 Track Maintenance Requirements

Since early 1980, records have been maintained for direct expenditure against all track maintenance work that was conducted on each Test Section over the period, see Figures 2.1.2(i)&(ii). The relevant data is listed in Appendix 3. Expenditure associated with maintenance administration and other associated overhead costs have not been collected.

Figures 2.1.2(i)&(ii) provide total and specific track geometry cumulative maintenance expenditure for the Test Sections up to December, 1992. It appears that more work has been done in the West Cunderdin sections, particularly Sections 5A and 5B, (Figure 2.1.2(i): 163 to 173 Km) compared to the East Cunderdin sections (Figure 2.1.2(ii): 180 to 193 Km). Costs associated with travelling or waiting time are not included.



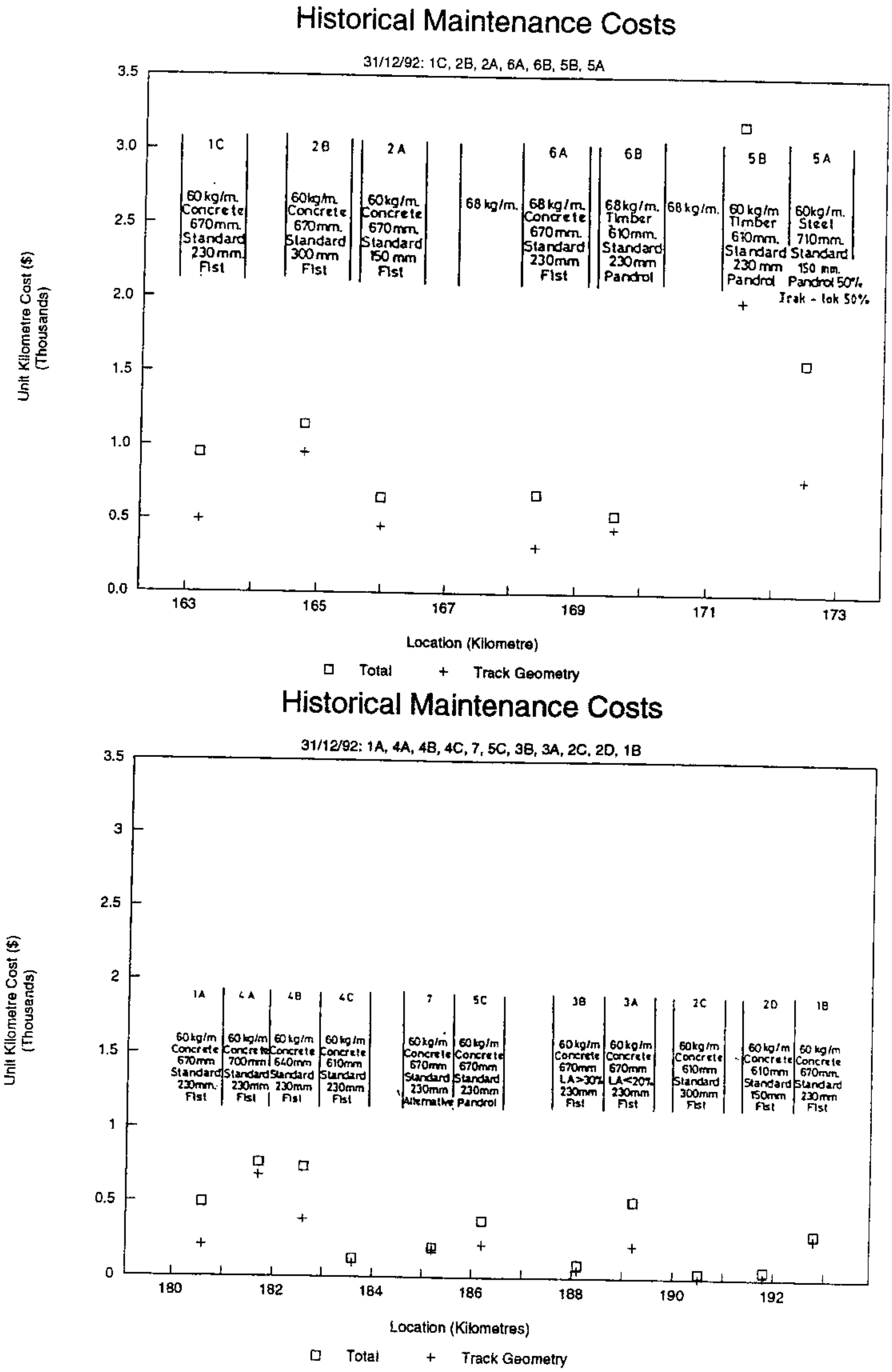
Track Geometry Indicies: Gauge

10/12/92: 1C, 2B, 2A, 6A, 6B, 5B, 5A

Track Geometry Indicies: Gauge

10/12/92: 1A, 4A, 4B, 4C, 7, 5C, 3B, 3A, 2C, 2D, 1B

Figures 2.1.1(i)&(ii)
Gauge variance: 500 metre mid Test Section averages: DECEMBER 1992.



Historical Maintenance Costs

31/12/92: 1C, 2B, 2A, 6A, 6B, 5B, 5A

Historical Maintenance Costs

31/12/92: 1A, 4A, 4B, 4C, 7, 5C, 3B, 3A, 2C, 2D, 1B

Figures 2.1.2(i)&(ii)
Maintenance Costs Up to 31 December 1992 (1992 Dollars)

2.1.3 Discussion on Observations

2.1.3.1 Track Geometry

Several reports not part of Study No 2, (for example; Szito 1992) have been prepared addressing the cracking performance of standard SF-1 concrete sleepers used on the Kwinana to Koolyanobbing standard gauge line upgrade. Similar sleeper behaviour was noted for the SF-1 sleepers in the Test Sections.

By December 1992, physical inspections confirmed that West Cunderdin Test Sections 1C(standard), 2B(ballast depth 300 mm) and 2A(ballast depth 150 mm) contained a greater portion of cracked sleepers. The average was 80% cracked, when compared to East sections 1A(standard), 4A(sleeper spacing 700 mm), 4B(sleeper spacing 640 mm) and 4C(sleeper spacing 610 mm), where the average was less than 20%. There appears to be a definite tightening of gauge, from less than 3 mm to more than 4 mm, accompanying more cracked sleepers. However, for a rigourous statistical confirmation more data is needed.

It has been separately observed that concrete sleepers exhibit weather shrinkage. The test track was also constructed with approximately 3mm tight gauge, see WESTRAIL report TS 403.1/1, Duncan 1984, This is reflected in Figures 2.1.1(i)&(ii). The tightening of gauge in the timber Sections 6B and 5B is apparent and not typical of timber sleepered track.

2.1.3.2 Track Maintenance

The actual on-rail instrumentation was located in the centre of each Test Section and prohibited through passage of working tampers and related track maintenance machinery. Sometimes work was conducted up to the monitoring point and machines disengaged to a point beyond before continuing. The records available reflected the maintenance work done for the bulk of each Test Section and not necessarily at the actual instrumentation point.

From Figures 2.1.2(i)&(ii), track geometry maintenance expenditure for the control Test Sections 1A and 1C were approximately 50% of the total expenditure reported. For most of the other sections, the proportion was above this.

In contrast with the concrete sleeper sections, track maintenance expenditure for the timber sleeper section, Test Section 5B with 60Kg rail, were excessive. As noted in Section 2.4.6, this was reflected in the greater level of structural deterioration of karri sleepers and track structure visually observed during physical inspections. Similar expenditure was not evident for the only other timber sleeper section, Test Section 6B with 68 Kg rail.

Track modulus evaluations, see Section 7, in Test Section 5B were less than most of the concrete sleepered sections. This reflected "softer" structure accompanied by greater structural deterioration and increased maintenance requirements.

2.2 SUMMARY OF BALLAST PERFORMANCE

2.2.1 General Considerations

In terms of track/rail structural requirements, the ballast layer performs various functions (Selig and Waters, 1992). The most important of these are:

(1) To resist vertical, lateral and longitudinal forces applied to the sleepers to retain the track in its required position.
(2) To provide some of the resiliency and energy absorption for the track.
(3) To provide large voids for storage of fouling material in the ballast.
(4) To facilitate track geometry maintenance operations by allowing the rearrangement of ballast material.
(5) To provide immediate drainage of water falling on to the track.
(6) To reduce the pressure from sleeper bearing area to acceptable levels for the underlying material.

A discussion on the current WESTRAIL ballast research work has been previously prepared (Duncan, 1982). Duncan provided a thorough introduction and assessment of the work done as part of ROA Study No 2 where alternate ballast types and depths have been introduced into the Test Sections.

Ballast depth (Standard Ballast Type):
Sections 2A and 2D: Ballast depth 150 mm.
Sections 2B and 2C: Ballast depth 300 mm.
For the remainder, the standard ballast depth is 230 mm.

Ballast type (Standard Ballast Depth):
Section 3A: New ballast from Hampton Quarry at Kalgoorlie, W.A. (with LAA < 20%).
Section 3B: New ballast from Meckering Quarry (with LAA > 30%).
For the remainder, the existing ballast was use with make-up ballast from Meckering.

The contact pressure distribution between the sleeper and the ballast is mainly dependant upon the degree of voiding in the ballast under the sleeper. Voiding is induced by traffic loading and results in gradual settlement and other changes in the structure of the ballast and subgrade. The difficulty in determining the in-track pressure distribution for a sleeper has been noted (for example, Jeffs & Tew, 1991;Volume 2 Section 3). In Study No 2, this task was attempted using specially developed analysis techniques, see Section 6.

2.2.2 In-Situ Ballast Density Measurements

In early 1982, an trial air permeability technique was introduced to measure the density of in-situ ballast without the need to remove sleepers or disturb ballast from the track structure, see WESTRAIL report TS 403.1/9, Duncan 1982. Unfortunately, the technique was still under development and the validation status of calibration curves used was never confirmed.

The effects of ambient wind and other geometrical considerations significantly limited confidence in ballast densities measured using air permeability techniques. Although there was little variation between Test Sections, measurements taken appeared to be significantly higher than the maximum obtained from separate laboratory density measurements, see WESTRAIL report TS 403.1/9, Duncan 1982. At the time it was suggested that significant ballast crushing might have occurred and a significant concentration of in-situ fines were present. The air system for ballast density measurement was not used again during the course of Study No 2.

2.2.3 Test Section Ballast Geotechnical Data.

As an integral part of assessing and monitoring the performance of ballast in each Test Section, three full sets of ballast samples were collected and analysed. On each occasion, ballast samples were collected from below the 45% loaded zone in previously undisturbed cribs without disturbing the track. The timing for sample collection was as follows:

(1) June 1982 (at approximately 20 MGT).
(2) February 1984 (at approximately 33 MGT).
(3) May 1987 (at approximately 56 MGT).

For each sample the following industry standard soils laboratory testing was performed:

(1) Ballast Particle Gradation.
(2) Crushing Value (ACV %).
(3) Cement Value (CV MPa: Test Sections 1C, 3A and 3B only).
(4) Toughness: Los Angeles Abrasion (LAA %).
(5) Hardness: Mill Abrasion (MA %).

Test on the 1982 samples were conducted by a different soils laboratory than the 1984 and 1987 samples.

2.2.4 Brief Descriptions of Geotechnical Tests

2.2.4.1 Particle Gradation.

Ballast particle size gradation involves washing and mechanical sieving procedures to develop a particle size/frequency distribution. Results presented on Appendix 9 include cumulative frequency distributions of WESTRAIL Grade A ballast.

2.2.4.2 Crushing Value.

The aggregate crushing value (ACV) gives a relative measure of the resistance of ballast material to crushing under a gradual applied load.

2.2.4.3 Cement Value

The cement value (CV) test measures the mechanical compressive strength of cemented ballast material. The testing process involves crushing, sieving, molding and mold strength testing. High cement values indicate ballast fines which bond strongly when cemented. Selig and Waters (1992) have suggest that specimen preparation methods do not simulate field conditions and cementation values, therefore, may not measure the actual tendency for cementation to be a problem in-situ.

2.2.4.4 Abrasion Tests.

The LAA test involves dry crushing processes that measure ballast material's relative toughness or the tendency to cause breakage. By contrast, the MA test involves wet crushing processes that measure relative particle hardness.

The MA wet crushing process produces finer material than LAA dry crushing. In recent work (Selig and Waters, 1992), it has been suggested that both tests are complementary and actually measure different rock characteristics. MA test measures the rock particle hardness and LAA testing measures rock particle strength or toughness. A combined Abrasion Number (AN) is suggested by Selig and Waters as an appropriate index for abrasion that has been adopted by some North American operators.

$$AN(\%) = LA(\%) + 5MA(\%)$$

2.2.5 Comparison of Geotechnical Results

The ballast in Test Section 3A was made from tougher material (sourced from Hampton Quarry at Kalgoorlie with LAA < 20%) than Meckering quarry material. This difference was consistent with the LAA test results in Appendix 9. With the combined Abrasion Number (AN) introduced in Section 2.2.3.4, the apparent abrasion was about 30% for Test Section 3A to nearly 60% for 3B. However, the corresponding hardness (MA index) results indicated little difference in particle hardness.

The noted differences in abrasive characteristics between the two ballast types was also contrasted with cementation value results. In this case, the severe abrasive characteristics for 3A ballast were accompanied by higher strength cementation (above 2MPa). The Meckering ballast (Test Section 3B) appeared to offer a comprimise with both reasonable abrasive character and reduced cementation strength. It has been argued (Selig and Waters, 1992) that cementation test methods do not simulate field conditions and cementation values, may not measure the actual tendency for cementation to be a problem in-situ.

The standard ballast depth was 230 mm. In contrast, Test Sections 2A & 2D were shallow ballasted (depth 150 mm) and 2B & 2C were deeper (ballast depth 300 mm). From Appendix 9 results, no difference in ballast characteristics appeared to correlate with this depth variation.

Ballast Comparison: Cementation and Abrasion.
Section: 1B Made-up LAA > 30%. 3A LAA < 20%. 3B LAA > 30%

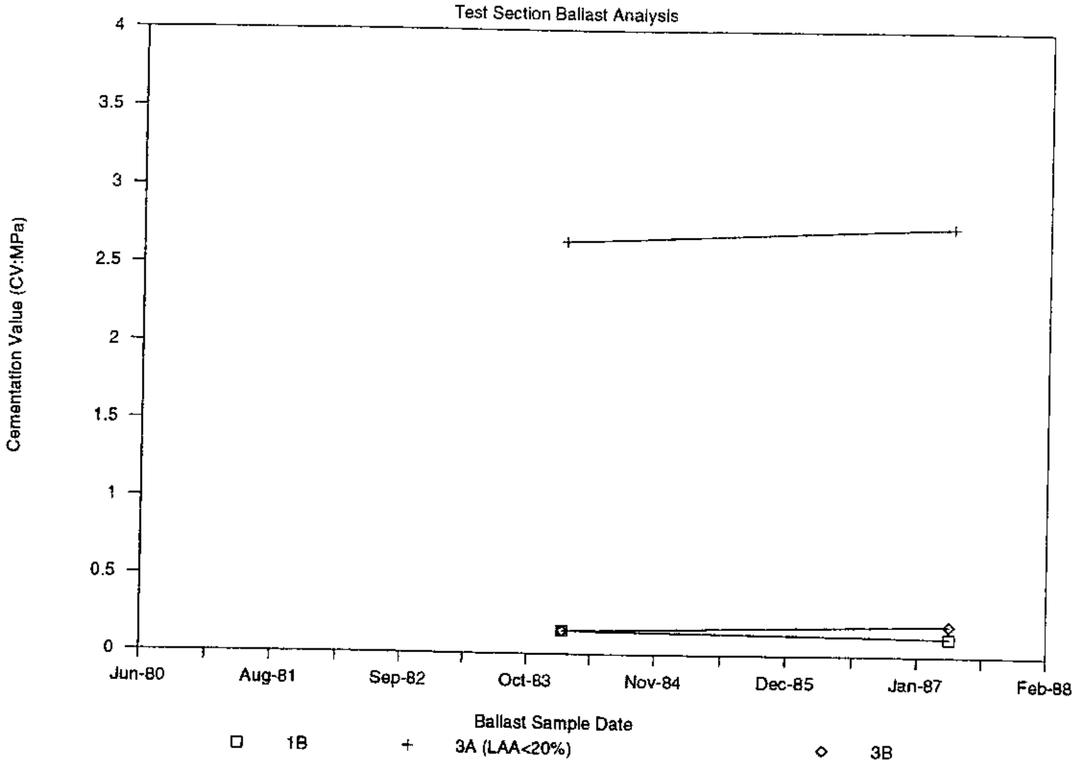


Figure 2.2.4(i): Cementation (CV Index)

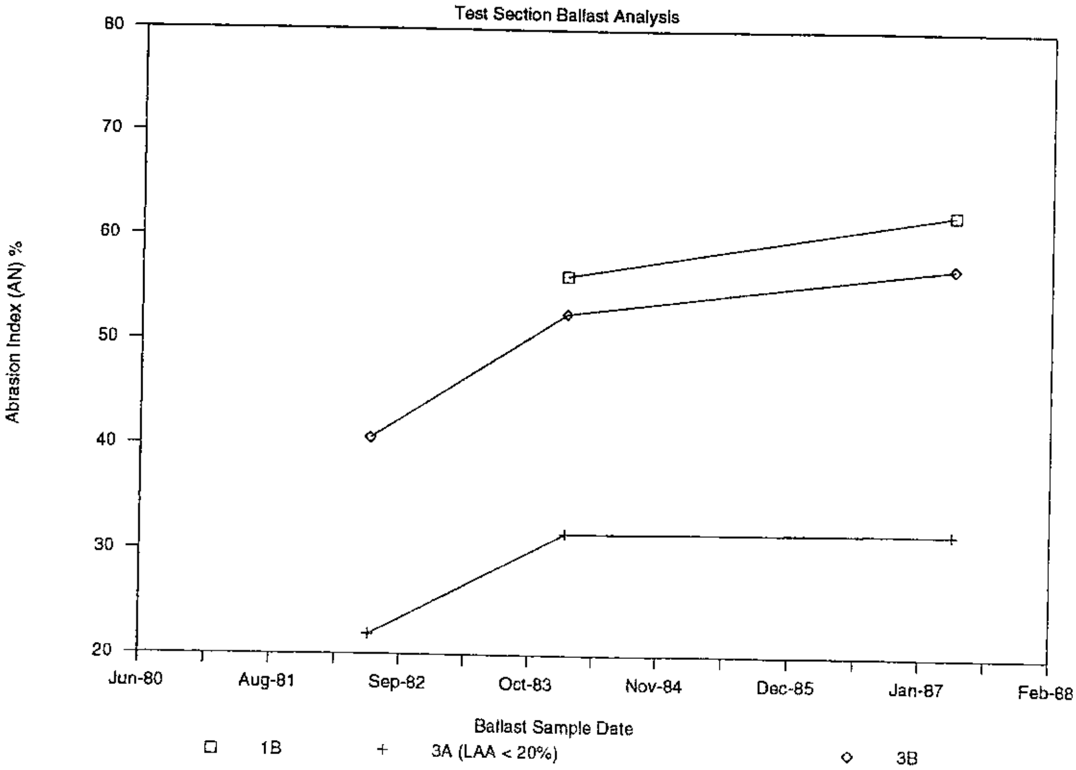


Figure 2.2.4(ii): Abrasion (AN Index)

2.3 FORMATION PENETRATION CHARACTERISTICS

Under dry summer conditions of late February 1993, a dynamic cone penetrometer was used in an attempt to investigate Test Section formation strength. The rate of penetration was measured as the number of blows required for the standard 9kg weight falling a preset distance to advance a 20 mm diameter cone 50 mm into the formation. For each Test Section, tests were carried out in sleeper cribs adjacent to the track force monitoring instrumentation usually down to about 350 mm below the top of formation. Unfortunately, no formation penetration measurements were made at any earlier stage of Study No 2.

Results from this exercise are provided in Appendix 10. For each plot, the Top of Rail (TOR) was taken as the upper depth reference. The top of formation to top of rail distance (nominated Design Ballast Height, DBH) will depend on the structural parameters of each particular section. Based on historical Test Section structural design information, it is understood that the present track was built on the original formation. Appendix 10 results indicate an easing of formation penetrate as formation depth increases.

There were significant differences in penetration characteristics for the Test Sections. For most, results indicated hard layering, i.e. the more blows per 50 mm penetration, at the ballast/formation interface. To a varying degree, this confirmed the presence of formation/ballast interaction mechanisms like compression, ballast breakdown, ballast settlement or formation mechanical compression. Section 1A(standard), for example had a particularly hard top of formation layer whereas for sections 1B(standard) and 4A(sleeper spacing 700 mm) it appeared to be less detectable.

The last track force data acquisition was conducted in August 1985, this was 7 years distant. From Appendix 10, Test Sections 1A(standard) and 1B(standard) for example, there were noted differences in below ballast penetration characteristics. However, such differences did not appear as significant track modulus evaluation differences from data collected in 1985 and earlier, see Section 7. A current set of track force measurements would be needed to quantify relationships between below ballast penetration characteristics and in-situ vertical load/track deflection behaviour.

2.4 SUMMARY OF TEST SECTION INSPECTIONS

A total of 18 general walking inspections of Test Sections were conducted from early 1980 through to late 1992. Individual reports were prepared for each inspection and inspection dates are listed in Appendix 2. In addition, several specific inspections looking at the performance of wooden sleepers for example, were conducted during this period. For identification purposes, in each Test Section all sleepers were numbered beginning at the western end.

Several reports not part of Study No 2, (for example; Szito 1992) have been prepared addressing the cracking performance of SF-1 concrete sleepers used on the Kwina-na-Koolyanobbing standard gauge line upgrade. Similar performance has been noted for the SF-1 sleepers in the Test Sections. The problems have been identified as the result of material selection for sleeper manufacture that were not specific to the Test Sections. Walking inspections have visually confirmed:

(1) distinct colouration differences for sleepers more prone to cracking. More pink colouring (as compared to grayer) is more evident for cracked sleepers.

(2) Batches marked 1978 are more prone to cracking than 1979 marked batches.

Where surface cracks are evident on SF-1 sleepers, cracking appears to initially propagate longitudinally (perpendicular to the rail) from the sleeper ends. Cracks then extend towards the rail seat. Cracking in the gauge portion generally appears later in the life of the sleeper. Longitudinal cracking also propagates on the sides of SF-1 sleepers, initiating from the FIST fastening tube.

To investigate and report on sleeper performance, specific sleepers in each Test Section were identified and marked as Crack Measurement Sleepers. This enabled specific crack length measurements to be progressively made and monitored. Ballast was removed from the two adjacent cribs as part of this investigation process.

A historical summary and performance comparison is hereby provided for each Test Section according to track structure generic groupings. No reference is made where no abnormalities were apparent. In each case, cumulative months since installation and gross tonnages are specified.

2.4.1 Control Group: 1A, 1B, 1C (60 Kg rail) & 6B (68Kg rail).

2.4.1.1 Inspection #8: September/October 1985 (75 Months & 43 MGT)

Formation failure in Section 1B necessitated ballast make up and geometry corrective maintenance towards the eastern end of the Test Section.

2.4.1.2 Inspection #10: October/November 1986 (90 Months & 50 MGT)

Following removal of ballast from adjacent cribs of specific crack monitoring sleepers, in all Test Sections progressive horizontal cracking was observed to initiate from the FIST fastening tube. On previous inspections, sleepers were not thoroughly examined.

2.4.1.3 Inspection #15: May 1989 (123 Months & 71 MGT)

Cracking became apparent in the gauge section of most badly cracked sleepers.

2.4.2 Alternate Ballast Depth: 2A, 2B, 2C & 2D (SF-1 Sleepers).

2.4.2.1 Inspection #1: November 1980 (12 Months & 6 MGT)

In Section 2A, one sleeper was identified as having longitudinal cracks (parallel with the rail) in the gauge portion of the sleeper, not typical of the later observed cracking patterns for SF-1 sleepers.

2.4.2.2 Inspection #4: March 1983 (43 Months & 27 MGT)

In Sections 2C and 2D, track maintenance machinery reported to have damaged the fastenings of 34 sleepers since the last inspection.

2.4.3 Alternate Ballast Grade: 3A & 3B (SF-1 Sleepers).

2.4.3.1 Inspection #5: November 1983 (52 Months & 31 MGT)

In Section 3B, a 13 rail pads were reported to have moved. This was a greater proportion than Section 3A or the standard control Test Sections. This did not appear to have resulted from track machinery as no prior maintenance operations were reported in either 3A and 3B.

2.4.3.2 Inspection #11: April 1987 (96 Months & 54 MGT)

In Sections 3A and 3B, Cobbler Pool ballast was reported to have been dumped on the shoulder along most of the Test Section. This occurred in error during routine maintenance operations. The foreign ballast was later removed, no tamping was done, minimum contamination occurred and maintenance costs for 3A were accordingly inflated.

2.4.4 Alternate Sleeper Spacing: 4A, 4B & 4C (SF-1 Sleepers).

2.4.4.1 Inspection #4: March 1983 (43 Months & 27 MGT)

In Section 4C, a 11 rail pads were reported to have moved. This was a greater proportion than Sections 4A or 4B. This did not appear to have resulted from track machinery as no prior maintenance operations were reported for Test Section 4C.

2.4.5 Steel Sleepers: Section 5A.

2.4.5.1 Inspection #1: November 1980 (12 Months & 6 MGT)

In Section 5A, dirty ballast was reported.

2.4.5.2 Special Inspection of Section 5A: August 1984 (61 Months & 36 MGT)

In August 1984 a special inspection of Section 5A was conducted to survey the cracking damage noted to the pads used with both Pandrol and Trak-Lok fastenings, see Appendix A7.3. Trak-Lok pads appeared to be predominantly cracking horizontally where as the Pandrol pads appeared to be cracking vertically at the rail seat hinge line.

2.4.5.3 Inspection #8: September/October 1985 (75 Months & 43 MGT)

In Section 5A, 12 pads were renewed, 6 Pandrol and 6 Trak-Lok. To date Section 5A, 16 steel sleepers had been noted to be skewed (no longer perpendicular to the rail). All occurrences likely to have resulted from track maintenance machinery activity during the 1984/85 period.

2.4.5.4 Inspection #11: April 1987 (96 Months & 54 MGT)

In Section 5A, 20 pads were replaced by a new type, 10 Pandrol and 10 Trak-Lok.

2.4.5.5 Inspection #18: December 1992 (171 Months & 103 MGT)

By December 1992, a total of 9 Trak-Lok clips (out of 1400) and no Pandrol clips (out of 1400) were noted to be dislodged in Section 5A. The new type of pad installed in April 1987 had not developed visible cracks at the hinge.

2.4.6 Timber Sleeper Group: Sections 5B & 6B.

2.4.6.1 Inspection #1: November 1980 (12 Months & 6 MGT)

In Section 5B, track reported to crunch under foot on the shoulders of some sleepers. This observation was noted on all inspections.

2.4.6.2 Inspection #5: November 1983 (52 Months & 31 MGT)

The timber sleepers in Sections 5B and 6B were subject to a detailed inspection and report (Duncan 1983), see Appendix A7.1 The sleepers were performing no worse than other treated karri sleeper in service elsewhere.

Five Pandrol clips from Section 5B, were forwarded to Pandrol for testing, see Appendix A7.2. No specific causes of observed clip dislodging were found.

2.4.6.3 Inspection #7: December 1984 (66 Months & 38 MGT)

In Sections 5B and 6B exposed treated timber surfaces were beginning to look like untreated timber, the treatment was still obvious for ballast covered surfaces. This was also noted in future inspections and appeared to be much worse in Section 5B.

2.4.6.4 Inspection #18: December 1992 (171 Months & 103 MGT)

By December 1992, approximately 220 (out of 1627) timber sleepers were noted to be splitting or rotting in Section 5B.

2.4.7 CR-2 Sleepers: Section 5C.

2.4.7.1 Inspection #1: November 1980 (12 Months & 6 MGT)

On the first inspection in Section 5C, the CR-2 sleepers were reported be have begun to develop cracks.

2.4.7.2 Inspection #3: November 1980 (34 Months & 21 MGT)

In Section 5C, 9 individual CR-2 sleepers were identified and recorded as reference sleepers so as to monitor the progress of the observed cracking.

2.4.7.3 Special Inspection of Section 5C: January 1984 (54 Months & 32 MGT)

In January 1984 a special inspection of Section 5C was conducted to survey cracked CR-2 sleepers. Twelve pads were replaced with a more compressible type. The pads removed were forwarded to Australian National. In subsequent inspections, no difference in sleeper performance was reported with the new pads.

2.4.7.4 Inspection #10: November 1986 (90 Months & 50 MGT)

In Section 5C, the pads replaced at the time of Inspection # 8 now indicated the same signs of cracking as the originals.

2.4.7.5 Inspection #11: April 1987 (96 Months & 54 MGT)

A summary report was prepared detailing performance up to April 1987 of the Section 5C CR-2 sleeper (Inspection #1 through to Inspection #11), see WESTRAIL report TS 403.1/17, Page 1987. During this period the following cracking performance statistics had been recorded.

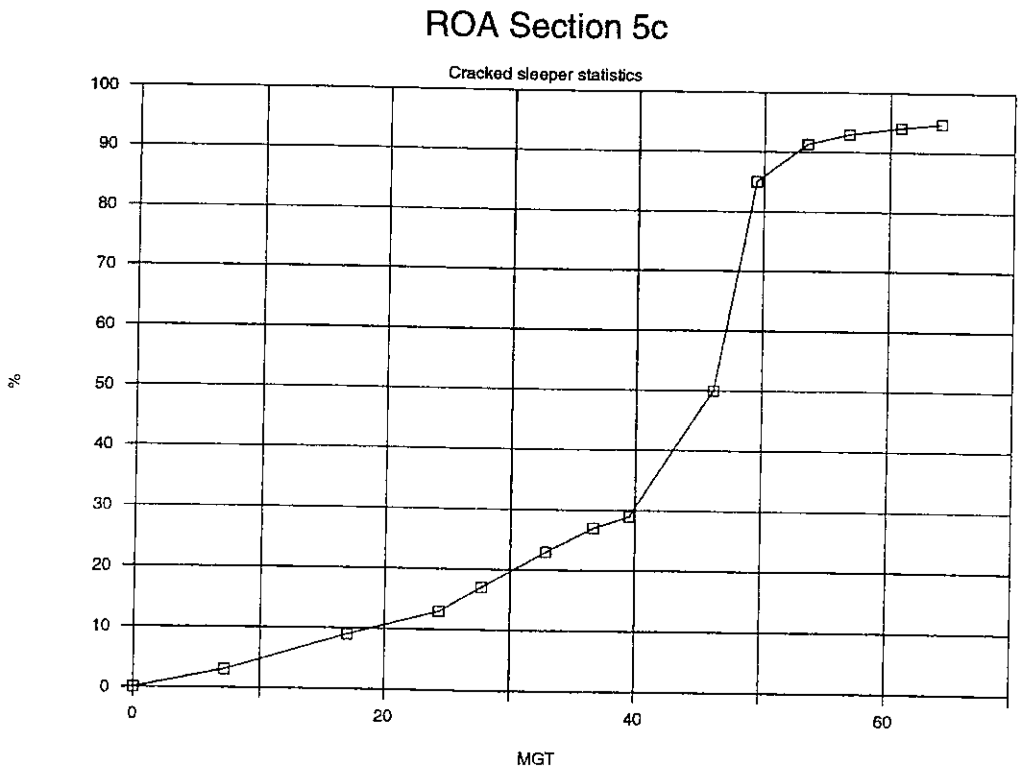


Figure 2.4.7.5
Test Section 5C: CR-2 Sleeper Cracking v Load Statistics

Following a request from Australian National, 10 CR-2 sleepers were removed from Section 5C and dispatched to AN for analysis. The new CR-3 type sleepers was installed as the replacement. In subsequent inspections, no cracking of the new CR-3 sleepers was observed.

2.4.7.6 Inspection #14: November 1988 (117 Months & 66 MGT)

A further 9 CR-2 sleepers were removed and replaced by CR-3 sleepers in Section 5C. No cracking of CR-3 sleepers had been observed to date.

2.4.8 Alternate Fastenings Group: Section 7

Section 7A: Hambo Fastening
Section 7B: Sidewinder 2 Fastening
Section 7C: Sidewinder 1 Fastening
Section 7D: Vossloh Fastening
Section 7E: Springlock Fastening

2.4.8.1 Inspection #7: December 1984 (66 Months & 38 MGT)

A summary report was prepared detailing performance up to December 1984 on the Springlock fastening system (Inspection #1 through to Inspection #7), see WESTRAIL report TS 403.1/14, O'Rourke 1985. Difficulties with broken or dislodged heel blocks, leak springs, hoops and hoop insulators had been experienced. By early 1985 all heel blocks had been replaced.

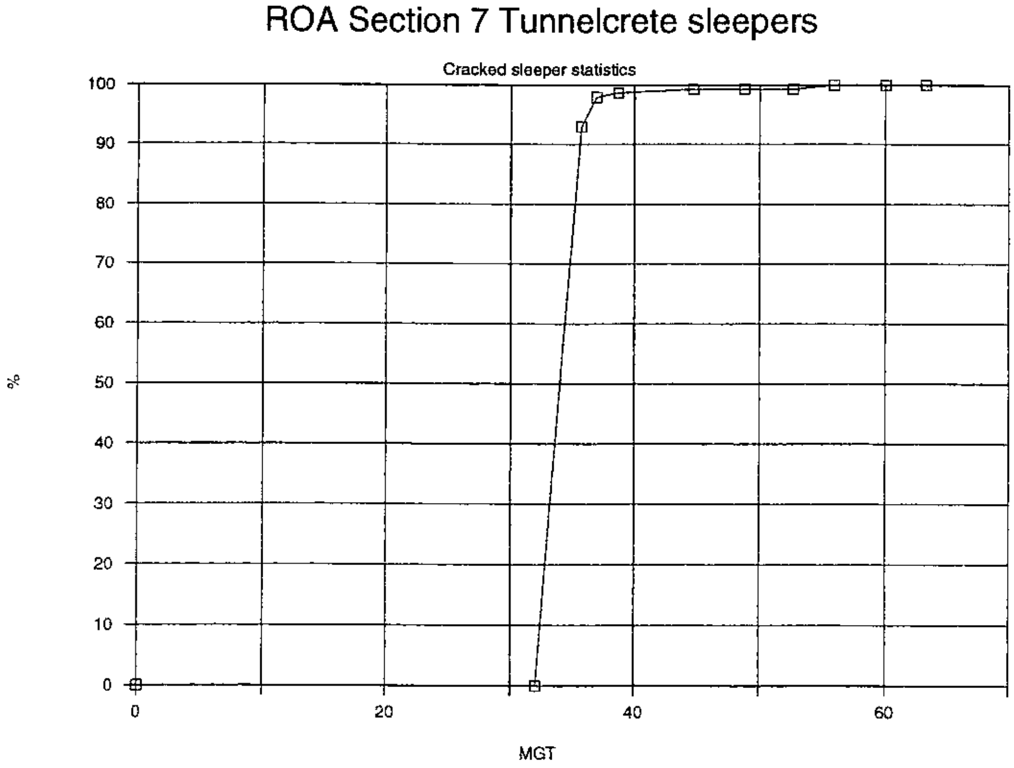


Figure 2.4.8.2
Test Section 7: Tunnelcrete Sleeper Cracking v Load Statistics

2.4.8.2 Inspection #9: April 1986 (83 Months & 47 MGT)

A summary report was prepared detailing performance up to April 1986 of the Vossloh fastening system (Inspection #1 through to Inspection #9), see WESTRAIL report TS 403.1/15, Page 1986. All of the Tunnelcrete sleepers had developed cracks which were still propagating. Most appeared to generate from the fastening bolt hole laterally (perpendicular to the rail) into the gauge and field portions of each sleeper. During this period the following cracking performance statistics had been recorded.

2.4.8.3 Inspection #10: November 1986 (90 Months & 50 MGT)

A summary report was prepared detailing performance up to October 1986 on the Springlock fastening system (to Inspection #10), see WESTRAIL report TS 403.1/16, Page 1987. It was concluded that this particular fastener was unsatisfactory. Following which, the Springlock fastening subsection was formally abandoned from Study No 2.

2.4.8.4 Inspection #12: October 1987 (103 Months & 58 MGT)

A summary report was prepared detailing performance up to October 1987 of the Hambo fastening system (Inspection #1 through to Inspection #12), see WESTRAIL report TS 403.1/21, Makin 1988. During this period a significant portion of the Swedish Rail System (SRS) sleeper has developed cracks. Clip and insulator skewing, damaging and dislodging were also common occurrences. During this period the cracking performance statistics of Figure 2.4.8.4 had been recorded.

Since Inspection #1, 21 Vossloh fastening insulator pads (out of 568) had become dislodged or skewed.

2.4.8.5 Inspection #16: November 1990 (143 Months & 84 MGT)

All SRS sleepers (Hambo fastening) were reported to have become crack.

Since Inspection #1, 20 Sidewinder 1 clips (out of 588) and 12 Sidewinder 2 clips (out of 600) had been observed to had become dislodged or skewed.

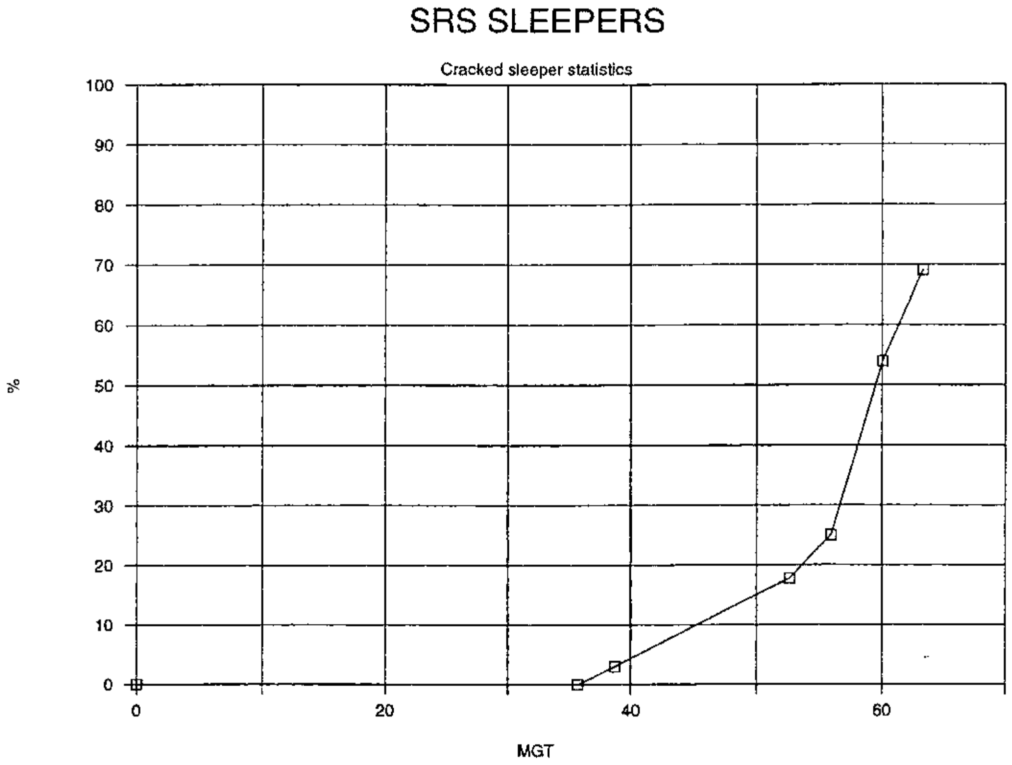


Figure 2.4.8.4
Test Section 7: SRS Sleeper Cracking v Load Statistics

2.4.9 Rail Asymmetry and Straightness: Section 8.

In early 1984, this Test Section developed a bog hole and was formally abandoned from Study No 2.

2.5 CONCLUSIONS ON TEST SECTION PERFORMANCE

2.5.1 Track Geometry

Reliability testing of track geometry data from WESTRAIL's Matissa PV 6 track recording car indicated the data to be unsatisfactory. The decision was made to continue Study No 2 without PV 6 historical track geometry data.

In December 1992 a different vehicle was used and the concrete sleepered test track generally exhibited tight gauge.

The tightening of gauge in the timber Sections 6B and 5B was apparent and not typical of timber sleepered track.

There appeared to be a definite tightening of gauge accompanying greater portions of in-situ cracked sleepers.

2.5.2 Maintenance

For Test Sections 1A and 1C, maintenance expenditure was about 50% of the total section requirement. For the majority of the other sections, this proportion was greater.

There was excessive maintenance expenditure associated with the timber sleepered Test Section 5B. In 5B there was greater levels of visual deterioration of karri sleepers and track structure observed during physical inspections.

Track modulus evaluations in timber sleepered Test Sections were less than most of the concrete sleepered sections. This reflected a "softer" overall track structure to accompany the greater degree of visual deterioration.

2.5.3 Ballast

The wind and other effects limited confidence in in-situ ballast density measurements made using the air permeability techniques. Measurements appeared to be significantly higher than the maximum obtained from laboratory density measurements on WESTRAIL standard Grade A ballast.

The ballast in Test Section 3A was sourced with LAA < 20%. In 3B Meckering LAA > 30% ballast was used. With the combined Abrasion Number (AN) the apparent abrasion was about 30% for Test Section 3A to nearly 60% for 3B.

The Meckering ballast (Test Section 3B) appeared to offer a comprimise with both reasonable abrasive character and reduced cementation strength.

The standard ballast depth was 230 mm. Test Sections 2A & 2D were shallow ballasted (depth 150 mm) and 2B & 2C were deeper (ballast depth 300 mm). No difference in ballast characteristics appeared to correlate with this depth variation.

2.5.4 Sleepers

Sleeper cracking performance of the standard SF-1 concrete sleeper used on the Kwinana to Koolyanobbing line have been the subject of a separate study. The problems were not specific to the Test Sections and were the result of material selection during manufacture.

Where surface cracks were evident, cracking appeared to initially propagate longitudinally (perpendicular to the rail) from the sleeper ends. Cracks then extended towards the rail seat. Cracking in the gauge portion generally appeared later in the life of the sleeper. Longitudinal cracking also propagated on the sides of SF-1 sleepers, initiating from the FIST fastening tube.

Walking inspections have visually confirmed that distinct colouration differences for sleepers more prone to cracking as were batches marked as 1978 manufacture.

2.5.5 Formation

High track quality,.especially near to the instrumented Test Sections, was the result of well bedded foundations, high standard of construction and lower than anticipated gross tonnages.

High axle load iron ore trains ceased running on the track in mid-1983, resulting in reduced overall tonnages and reduced average axle loads, with subsequent reduced track structural and geometrical deterioration.

There were significant differences in formation penetration resistance characteristics. For most sections, results indicated hard layering at the ballast/formation interface and the presence of formation/ballast interaction mechanisms like compression, ballast breakdown, ballast settlement or formation mechanical compression.

More data is necessary to confirm relationships between below ballast penetration characteristics and in-situ vertical load/deflection behaviour.