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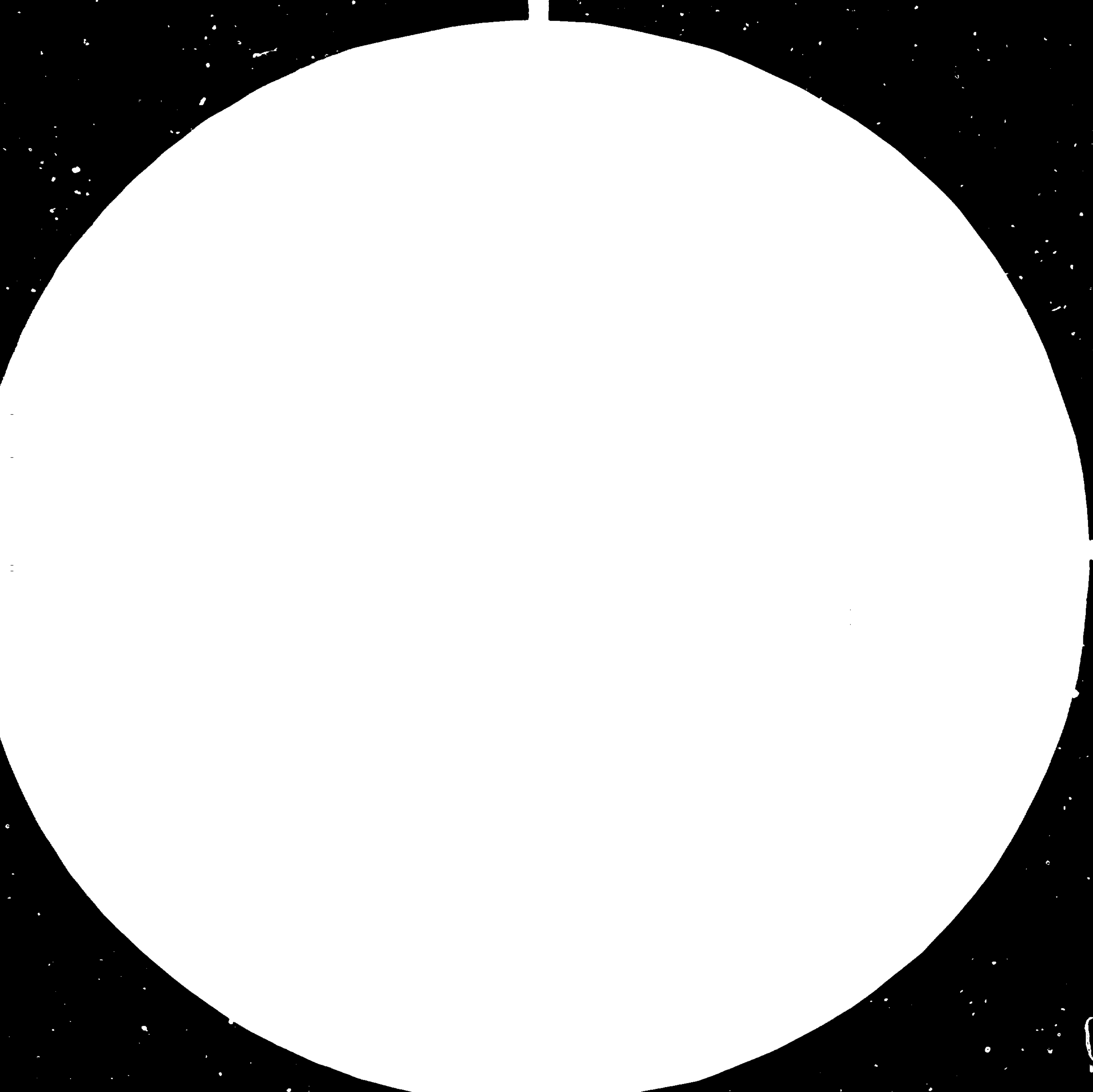

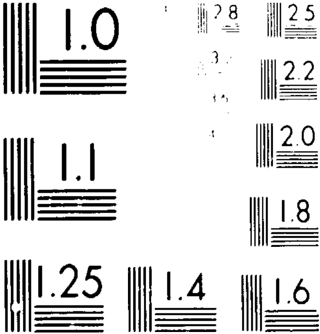
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PRECAST PRODUCTS - CONCRETE RAILWAY AND TRAMWAY SLEEPERS, TECHNOLOGY, MANUFACTURE AND USAGE: REVIEW OF CURRENT USAGE IN AUSTRALIA*

by

K.D. Campbell**

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** Cement and Concrete Association, Victoria.

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SYNOPSIS

The manufacture and use of tramway and railway sleepers is now a significant segment of the fixed rail industry. Tramway sleepers have been used in the Queensland cane fields for many years with over 1 million units in track. In 1970 the development of the concrete sleeper market commenced with the construction of the Pt. Augusta - Whyalla rail link using 125,000 concrete sleepers. The release of the Bureau of Transport Economics report on the Economic evaluation of timber and concrete sleepers for three railway lines in Central and South Australia showed by a life-cycle approach the benefits of a durable railway sleeper. This resulted in the establishment of the prestressed concrete railway sleeper industry in Australia.

Successful trials in heavy duty track resulted in the introduction into Hammersley Iron in the North West of West Australia. A large contract is underway for Westrail and small quantities of concrete sleepers have been used in Victoria, N.S.W. and Queensland railways. Recently a contract was let in N.S.W. for the use of concrete sleepers in a coal line and tender has been called for concrete sleepers in a main line track in N.S.W.

BACKGROUND

A small number of concrete sleepers were installed in tracks around Australia in the late 1940's and early 1950. They were placed in Suburban lines. The French duo block sleepers in Sydney and the German post-tensioned sleepers in Melbourne are still in track and performing well.

The first major test installation was at Wirrappa on the Commonwealth Railway line west of Pt. Augusta. This installation gave interesting results and provided basic data for future development.

All the proprietary designs were successful as concrete units. However, most of the fastenings have failed.

The fastenings used were mostly screwed, and preceeded the elastic fastenings available today.

There is, then a successful test installation of concrete sleepered track in Australia, which dates back 20 years and Australian National Railways state that these sleepers have received the barest of attention.

Ten years later ANR investigated more thoroughly the design and performance of concrete sleepers. It was the opinion of the Railway engineers that the British F.27 design with the Pandrol fastening was the most appropriate for their system.

The British sleeper is designed for a 25-ton axle load. The only area requiring deviation from the British Standard was the use of plastic spacers and rubber resilient pads under the rails as it was considered that these would not perform satisfactorily in the harsh, hot sunny climate on the ANR line.

The 1970 manufacture commenced on 125,000 Type CR1 sleepers for the Pt. Augusta/Whyalla Line. Neoprene/cork composition pads were adopted for rail seats in preference to the British system of natural rubber/cork pads. Since the line is not required to be insulated, steel spacers were used. This has the additional advantage of permitting rails to be changed from 40kg/m to 53kg/m at a later date.

The only basic difference between the British F.27 and C.R. 1 is the incorporation of Australian Standards in the Specifications.

British Rail have the following recommended sleeper spacings for main line tracks.

	High Speed or Heavy Duty Sleeper/km	Normal Traffic Sleepers/km
Straight	1530 to 1640	1420 to 1530
Curves over 1600m radius	1640	1530
Curves under 1600m radius	1750	1640

In Australia, Australian National Railways have adopted 1500 sleeper/km.

The introduction of concrete sleepers has eliminated the random decay and replacement of sleepers which, besides the physical task of renewal, requires a follow up surfacing to ensure a uniform support for the rail. The incidence of thermal buckling is reduced by an increase of 300% in sleeper weight, while reduced the ballast pressure results from a 25% increase in bearing area.

The concept of the concrete sleeper is that the unit is part of the complete track structure. The manufacturer is responsible for ensuring that the rail seat width, gauge and tension in the fastenings are all within the required tolerances. The contractor is considered as a manufacturer of sleepers, responsible for the quality of all materials, not simply as a manufacturer of prestressed concrete.

The greater depth of concrete sleepers has prevented insertion on a spot-renewal basis but the method adopted is that of face renewal. The equipment used for conventional timber renewal work is imminently suitable for handling of concrete sleepers thereby eliminating the need for investment in specialised equipment.

The only restriction on the use of prestressed concrete sleepers of the B.R.F. 27 type in the state rail system is the shortage of capital funds. It is the author's opinion that with funds available the State system would standardize on the prestressed concrete sleeper on 200mm of ballast with C.W.R. of 60kg. of mainline track.

It must be appreciated that the design of a prestressed concrete sleeper bedded on a elastic foundation of unknown properties is not a reliable procedure. Most of the concrete sleepers designed by theoretic assumptions have failed in practice.

The advantage of selecting a proven product and ensuring that it is installed in similar conditions is of the utmost importance.

ADVANTAGE OF CONCRETE SLEEPERS

The factors which merit consideration are:

* long life
* durability
* stability
* geometry
* sleeper spacing
* reduced on-track maintenance
* availability
* electrical insulation

Most of these factors have been covered extensively in the literature and are well known;

EXPECTED BENEFITS NOT INCLUDED IN ECONOMIC ANALYSIS

It is worthy of note that the following benefits are expected to be realised, but can not be quantified reliably and hence are not included in analysis. The calculated return on investment is thus considered to be quite conservative.

* investment allowance on capital items
* reduced wheel wear
* reduced rail wear
* the ability to incorporate rail renewal in

conjunction with concrete resleepering and relatively minimal additional cost

* the possibility of wider concrete sleeper spacing that present standards.
* lower derailment risk
* excess fastenings released from track
* line camp co-commitments
* decreased rail grindings
* elimination of cross-boring, adzing and regauging of track
* fuel saving

DESIGN PHILOSOPHY

There are two design philosophies for prestressed concrete sleepers. One results in a relatively flexible sleeper; the other in a much stiffer sleeper.

Possibly the best known of the flexible type is the current British Rail F27 concrete sleeper. This type of sleeper has been selected by the Australian National Railways for all its current projects, and is the preicipal sleeper now used by British Rail. The design does not allow for the full distribution of loading over the total length of the sleeper as it settles into the ballast under traffic and therefore results in a sleeper with a low mid sleeper moment of resistance. For this type of sleeper to function as it was designed a high level of maintenance may be required to ensure that sleeper support is restricted to an area under the rail and that centre bound track does not develop.

On British Rail with its intensive track mechanised maintenance programmes this type of sleeper is performing satisfactorily. Hammersley Iron also report excellent results from the flexible type sleeper. This author has inspected flexible type prestressed concrete monoblock sleepers in track in California which exhibited centre binding condition. There was no gauge widening, spalling of concrete or any noticeable deterioration of the concrete sleepers although cracking had been visible for over 12 years. There are no reported instances of failure of concrete sleepers, even with fouled ballast in the literature.

The stiffer sleepers, which take into account the high mid sleeper moment due to possible centre binding, is used by South African Railways, several European Railways, and is in accordance with the American Railway Engineering Association specification for concrete sleepers and fastenings.

This type of sleeper has been selected by West Rail.

These prestressed concrete sleepers are being used in the dual gauge track between Kwinana and Avon and also in the standard gauge track between Avon and Kooly robbing. Both sections of the track would be subject to freight and passenger trains and the following speeds and axle loadings are applicable:-

Standard Gauge - 25 tonne axles at 70 km/hr
20 tonne axles at 120 km/hr
23 tonne alxes at 120 km/hr (locomotives only)

Dual Gauge - Standard gauge loadings as above with the narrow gauge loading as follows :

20 tonne axles at 90 km/hr

The development of the use of the concrete sleepers industry in Australia has been assisted by:-

The shortage of durable hard wood sleepers of cross section size selected by the authority.

The introduction of elastic fastenings which resulted in reducing the cost differential between sleeper types.

The technical superiority of the concrete sleeper as part of the track structure due to its weight and area of face.

The shortage of track maintenance personel resulting in the move to mechanised maintenance.

PRESENT STATUS

Government Railways

A.N.R.

Complete Concrete Sleeper Track - new line.

Pt. Augusta to Whyalla

Tarcoola to Alice Springs 837km

Uncompleted Track - Track Renewal

Pt. Augusta to Kalgoolie 1770km

To Commence shortly

Adeliade - Crystal Brook 195km

These are standard gauge sleepers, using pandrol fastenings, cork/neoprone pads - similar British F27.

N.S.W.

Completed - 5,000 prestressed concrete sleepers in track for test purposes.

Uncompleted - Tenders have recently been called for 150,000 p.s. sleepers for the Illawarra line.

To investigate the different types of fastenings systems available for cost, tolerances and life, a four year guarantee on workmanship and materials is specified.

The N.S.W. State Rail Authority are considering other track renewals requiring approximately 1,000,000 prestressed concrete sleepers.

WEST RAIL

Uncompleted - Kwinana - Koolyanobbling 595km
about 300km completed to date

Cost studies concurred with the independent studies carried out by the Bureau of Transport Economics and assessments by the Department of Transport, that concrete rail sleepers, whilst initially high in supply cost, were cheaper in service.

Having determined technical requirements for both timber and concrete sleepers, and the fastening system alternatives, tenders were called internationally to assess the economic merit of each. The choices were:

* preserved hardwood sleepers of 230mm x 150mm section fitted with baseplates, Pandrol clips and lockspikes;

* concrete sleepers, to similar dimensions supplied with cast-in shoulders, insulators and Pandrol clips;

* concrete sleepers with cast-in tubing and supplied with ferrules, Fist fastenings and insulators.

Tenders showed that the concrete sleeper and fastening assembly was in terms of first cost cheaper than the preserved hardwood sleeper with its fastening system. Additionally, concrete-sleeper track has been assessed to be significantly cheaper to maintain than timber-sleeper construction.

The tenders also revealed that the Fist BTR sleeper/fastening assembly was lower priced than the Pandrol assembly.

Contracts were awarded to Rail Track Fasteners (Fist BTR) for 75 per cent of the fastenings required, and to Pandrol Australia for the remainder. The Pandrol clip was ordered for use on the more heavily curved section in the Avon valley and the dual gauge sleepers.

A 1.25km trial section of dual-gauge track with concrete sleepers has been placed in service to evaluate performance, as this type of sleeper has not been used anywhere else in the world to our knowledge.

VIC RAIL

Completed - 20,000 prestressed concrete sleepers in suburban lines.

Uncompleted - 16,000 p.c. sleepers being installed on Geelong - Melbourne duplication Broad gauge sleeper, F27 design with pandrol fastenings.

Vic Rail has reported the concrete sleepered track to this standard is lower first cost than comparable timber sleepered track with pandrol plates.

Completed - Approximately 5,000 double sleepers with pandrol plates fixed by epoxy grout for the Melbourne Underground Loop Authority.

HAMMERSLEY IRON

This iron ore railline carried a Standard axle load of 30 tonne over 388km track with about 50 million gross tonnes/annum.

The tests on concrete sleepers after 225 MGT showed:-

Track maintenenance savings of 30% with improved track stability and increase in component life, including rail.

Sleeper spacing increased to 600mm from 495mm for timber sleepers.

Life of concrete sleepers estimated to be 30 years against 7 - 10 years for hardwood sleepers.

Due to the greater mass and surface area of the concrete sleepers there is a greater resistance against buckling and creep of the rail. Temperature range is 0 - 50°C on the Hammersley line.

Concrete sleepers are 100% Australian made so supply can be controlled whilst timber sleepers are imported from Malaysia.

Hammersley Iron are at the present installing 600,000 p.s.c. sleepers which they claim will replace their present perpetual resleepering operation to only a rail life criteria.

CANE RAILWAY TRACK - TRAMWAY - QUEENSLAND

In the far north of the growing area where rainfalls often exceed 4,500 millimetres per year, adequate drainage is often difficult to provide and the track, which is generally laid on uncompacted natural earth formations, is often water logged for weeks at a time during the off season period. The rapid deterioration of timber sleepers under these conditions resulted in an expected sleeper life of eight to ten years or less and led to the development of prestressed concrete sleepers. This type of sleeper, together with the three types of elastic rail to sleeper fastenings developed for them, are now almost exclusively used in the wet northern area of the industry (equivalent to about 40 per cent of the total track).

Prestressed concrete sleepers are generally 1,200 millimetres long and 100 millimetres deep. Their gross section tapers from 180 millimetres at the bottom to 130 millimetres at the top. Six square holes (three per rail) are precast in such a way that 20 to 22kg/m or 30kg/m rail size can be used. Four galvanised spikes per sleeper are used.

There are clear indications that sleeper sizes and formations are barely adequate for existing loads and speeds.

M.U.R.L.A.

The Melbourne Underground Rail Loop Authority tested two types of sleepers bedded on neoprone pads on a concrete base.

The Toronto type double sleepers were selected throughout the circular tunnels and under city streets adjacent to city properties and the STEFEF sleepers under Treasury Gardens for future tests.

The floating slab track support system, such as the double sleeper system was selected as it reduced in the building adjacent to the tunnels the noise caused by the ground transmitted vibrations.

MANUFACTURE

All the prestressed concrete sleeper manufacturers in Australia are using the long line system with gang moulds. These plants have high productivity and are far more efficient that European manufacurers. Only in recent constrcted plants in Canada and U.S.A. using the long line system are there low labor contents in the production of sleepers.

The only sleeper plant in Australian in an enclosed factory is at Meckering, W.A. supplying the West Rail project.

INSTALLATION

There are a number of methods of handling sleepers regardless of weight.

1. Manual

   This test track in N.S.W. was laid manually. Four men per sleeper with cradles hooked through the pandrol shoulders.

2. Gantries

   The Tarcoola Alic Springs line was laid by gantries.

3. Belt Conveyor

   West Rail and Hammersley Iron are placing their sleepers by belt conveyor system called Canron P811.

4. Cranes

   Mobile cranes are used by Vic Rail for placing sleepers individually in both new track and resleepering

TEST REQUIREMENTS

The following test requirements are specified by West Rail.

Two main tests are required of the sleepers to show that they will conform to the design requirements. They are:

* A bending test of both positive Rail Seat and Negative Centre Section, where a force calculated to produce a concrete tensile stress of 0.8 F'c MPa in the bottom or top faces of the sleeper respectively, is applied as shown in Appendix 6 and held for 10 seconds. If a crack does not appear the sleeper passes the test.

* Dynamic testing of rail seat repeated load test. The sleeper is set up in the dynamic test machine load frame and a load applied to induce a crack in the bottom of the sleeper to at least the height of the bottom reinforcement. The sleeper is then set up as shown in Appendix and 3 million repeated loading cycles of varying uniformity from 3kNm to 28.97kNm or 1.1 times the theoretical cracking moment of 26.38kNm. If after testing the sleeper can withstand a rail seat load equivalent to 28.97kNm bending moment without the crack propogating, the sleeper has passed the test.

Other tests required are:

* Fastening Pullout. An upward load of 30Kn is applied to the fastening as a check for bond.

* Electrical Impedence. Two short sections of rail are assembled with appropriate fastenings and insulator pads. The complete asembly is then immersed in water for six hours. Immediately after removal from the water an A.C. 12 molt 50 Hertz potential is applied across the rails for 30 minutes. The current flow in amperes is measured and the Ohmic impedence is determined.

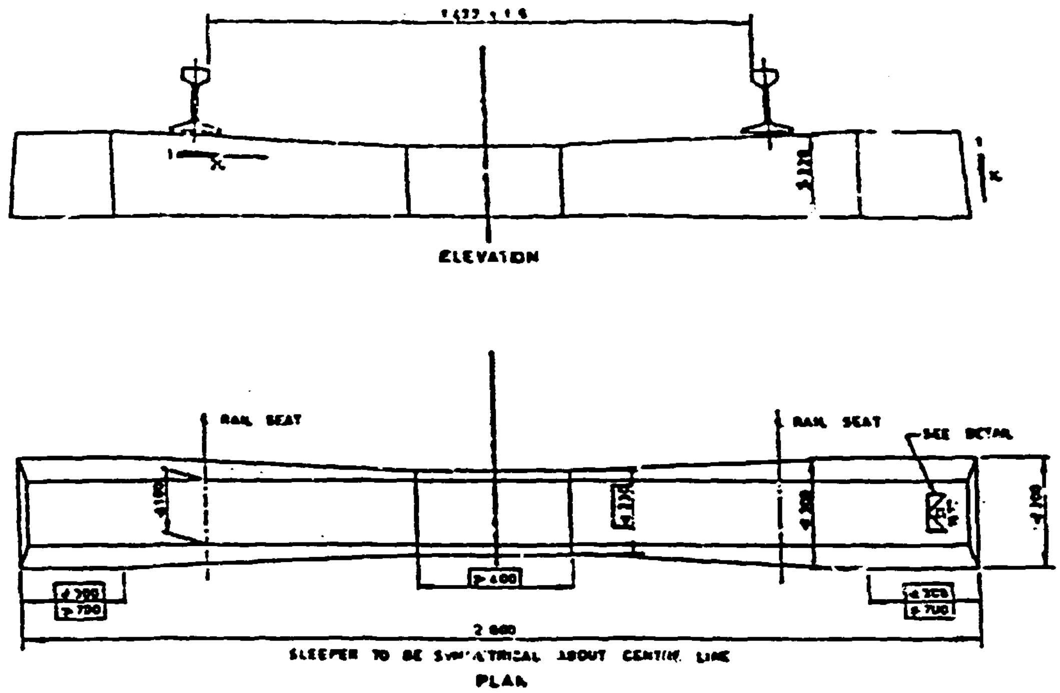
* Bond Development and Ultimate Load. A load to induce a moment of 39.3kNm is applied to a sleeper set up as in Appendix and wire slippage is measured. The sleeper is then tested until ultimate failure occurs and the maximum moment recorded.

SUMMARY OF PSC MONOBLOCK SLEEPER TENDERS

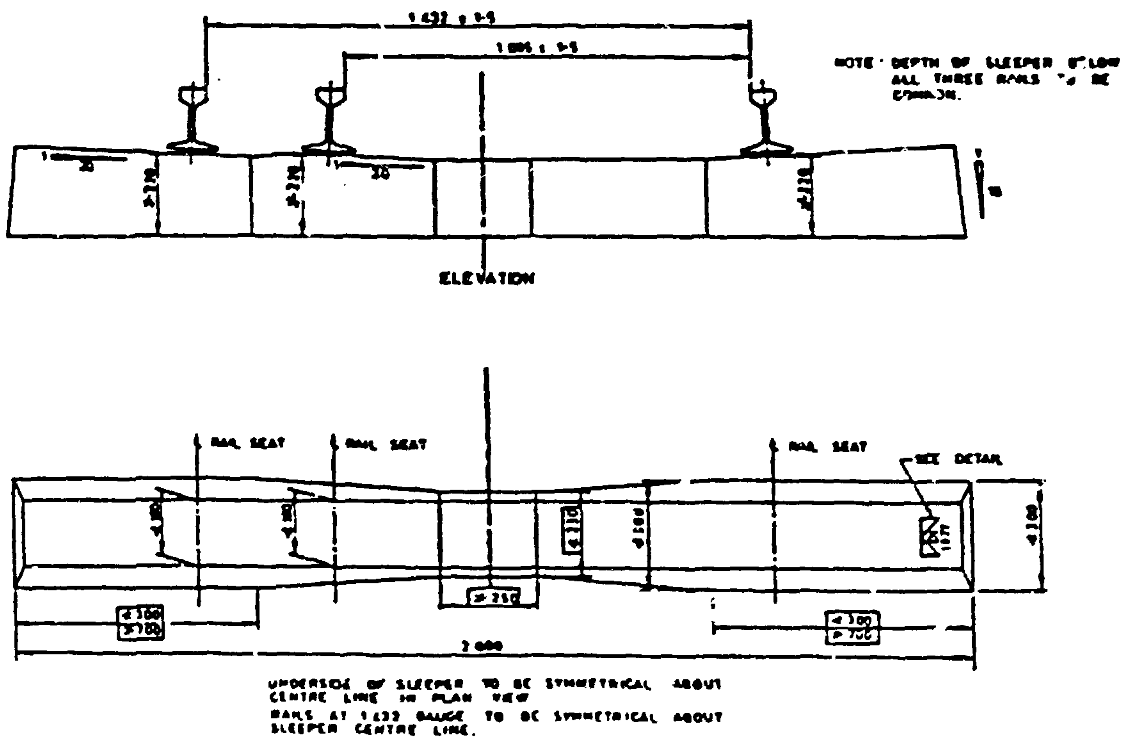
IN AUSTRALIA SINCE 1970

DATE	AUTHORITY/JOB	QUANTITY	R & M
Sept 1970	Commonwealth Railways	125,000	
May 1972	Commonwealth Railways	200,000	
June 1973	Commonwealth Railways	200,000	Recall
1972	Hammersley Iron	950	
1972	Mt. Newman Mining	3,000	Test Installation
July 1974	Commonwealth Railways	500,000	
1974	Victorian Railways	25,000	Broad Gauge
June 1975	Port Waratah Coal Loader	12,500	Single Rail Sleepers
July 1975	Commonwealth Railways	300,000	
Jan 1976	A.N.R.	600,000	
Mar 1977	Hammersley Iron	20,000	
May 1977	A.N.R.	240,000	
Dec 1977	A.N.R.	180,000	
June 1977	Westrail	960,000	St. & Dual Gauge
Dec 1977	Hammersley Iron	200	Track Circuit Sleepers
May 1978	Victorian Railways	3,000	
Sept 1978	M.U.R.L.A.	2,800	Special Double Sleepers
Sept 1978	Hammersley Iron	600,000	
Nov 1978	A.N.R.	450,000	
Jan 1978	A.N.R.	150,000	
Jan 1978	Mt Isa Mines	1,500	1067 Gauge Mine Sleepers
Mar 1979	Q.G.R.	5,000	1067 Gauge Mainline Sleepe
May 1979	Snowy Mountains Authority	420	Std. Gauge Track
May 1980	A.N.R.	800,000	
1980	Vic Rail/Geelong	16,500	
Feb 1981	White Industries/Ulan - Sand Hollow	250,000	
May 1980	N.S.W. S.R.A.	150,000	

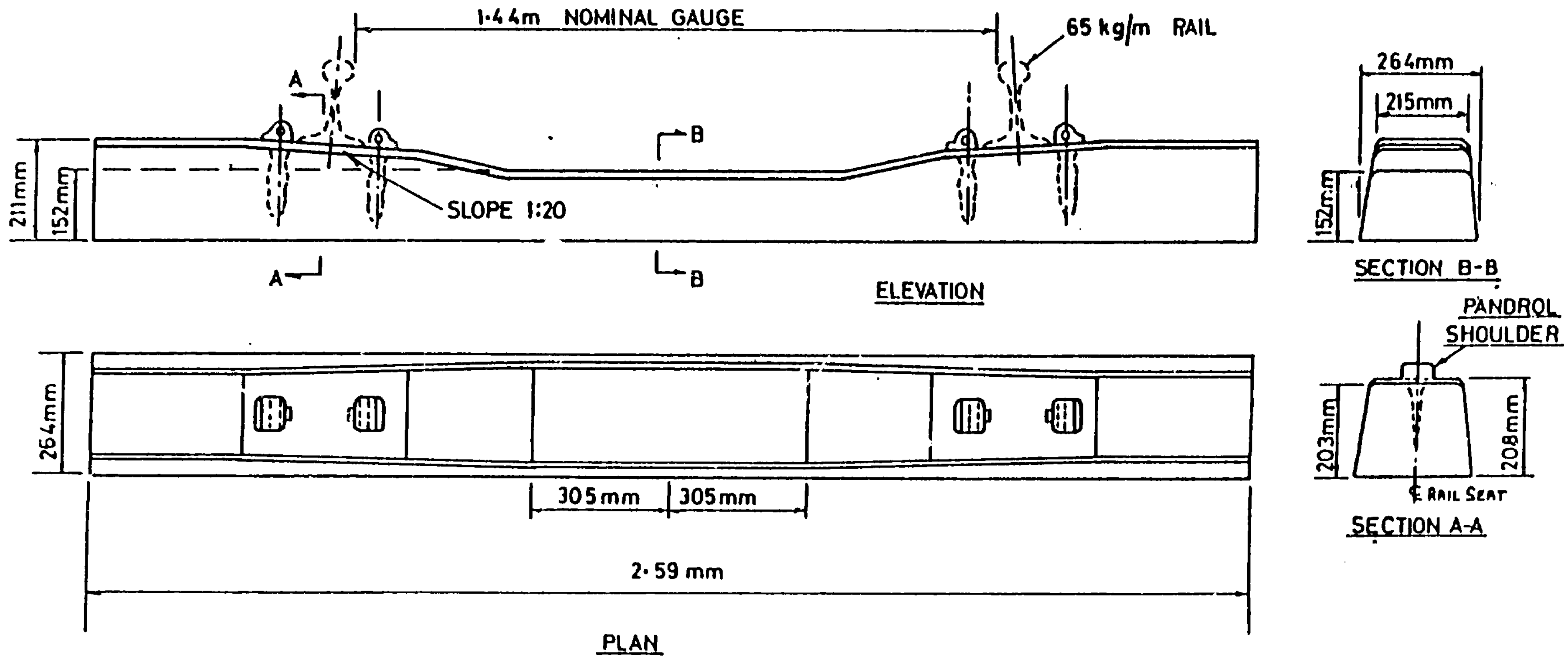
FIGURE 1
WEST RAIL



STANDARD GAUGE SLEEPER

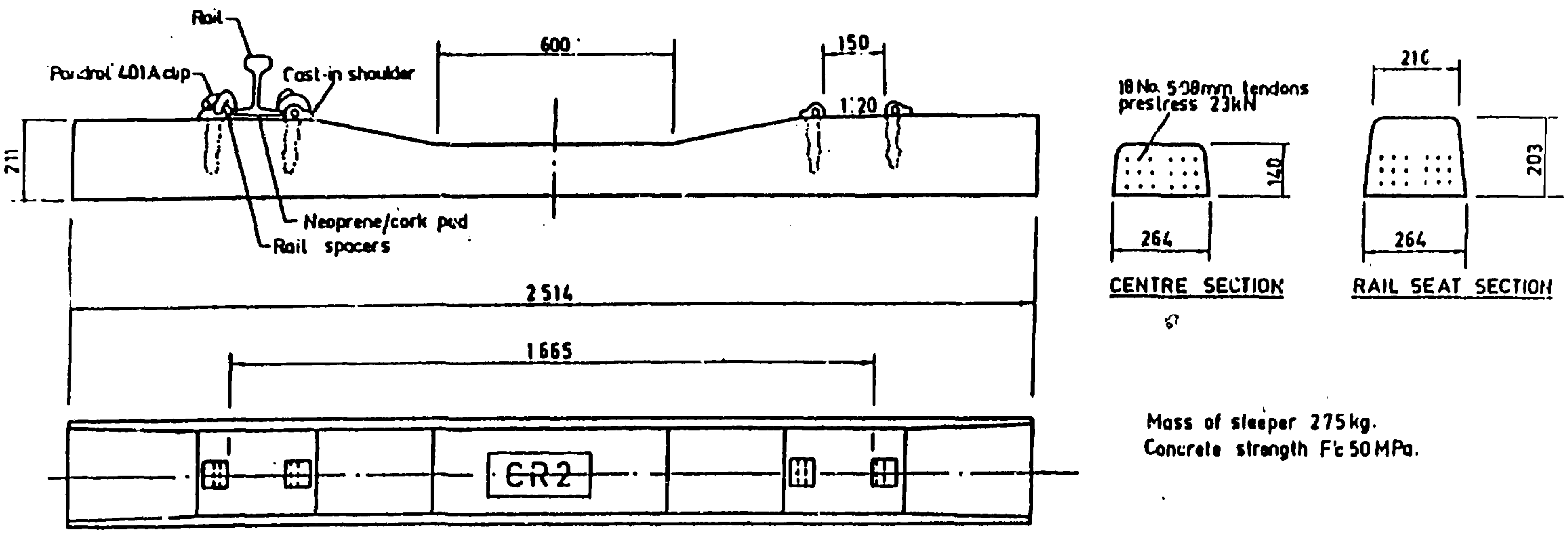


DUAL GAUGE SLEEPER



APPENDIX. 2.

FIGURE 2 HAMMERSLEY IRON

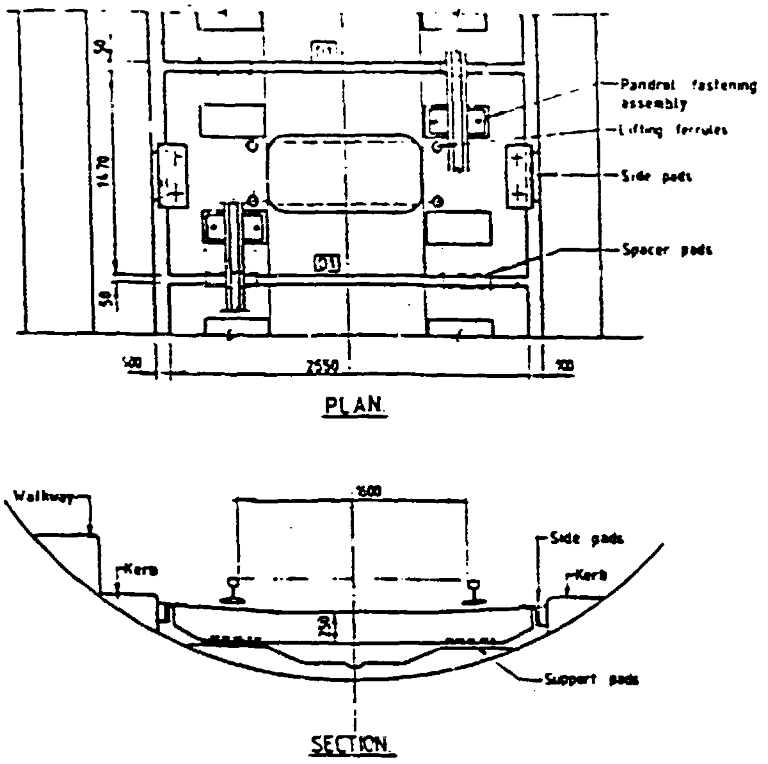


Mass of sleeper 275 kg.
Concrete strength F'c 50 MPa.

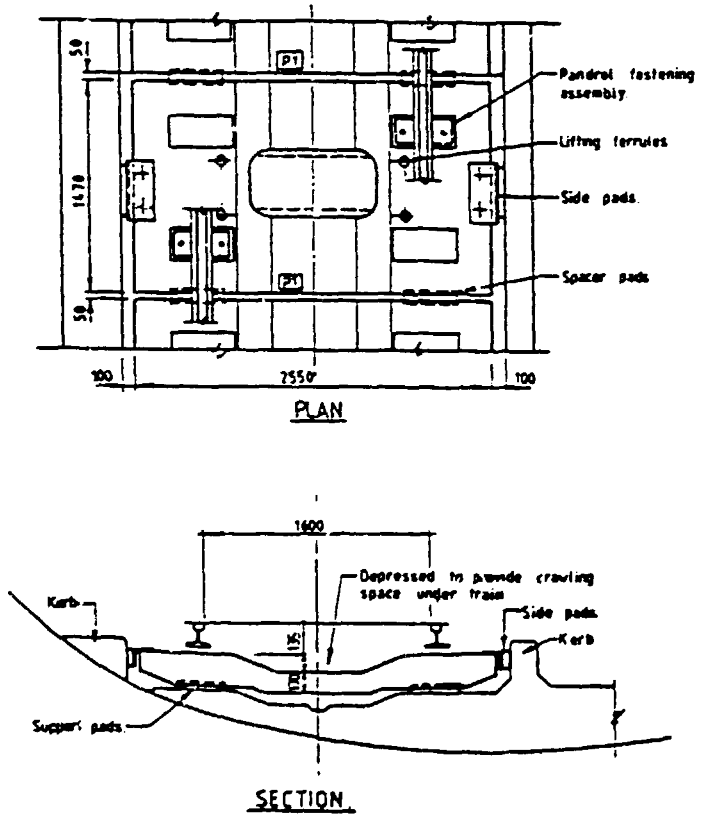
DETAILS OF CR2 SLEEPER

FIGURE 4

M.U.R.L.A.

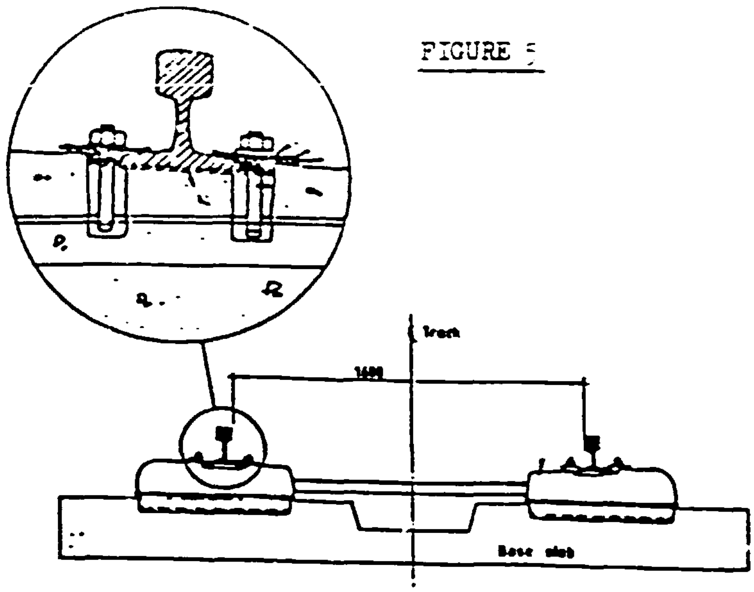


TYPE 'D' DOUBLE SLEEPERS FOR RUNNING TUNNELS.

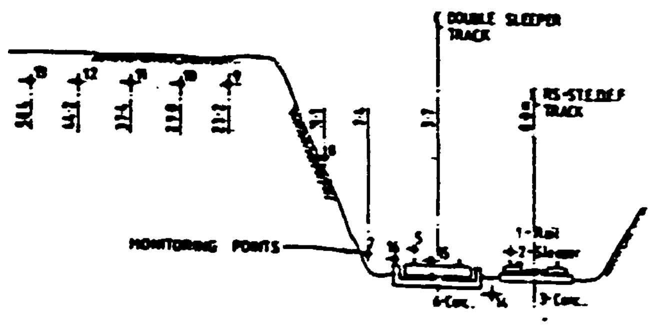


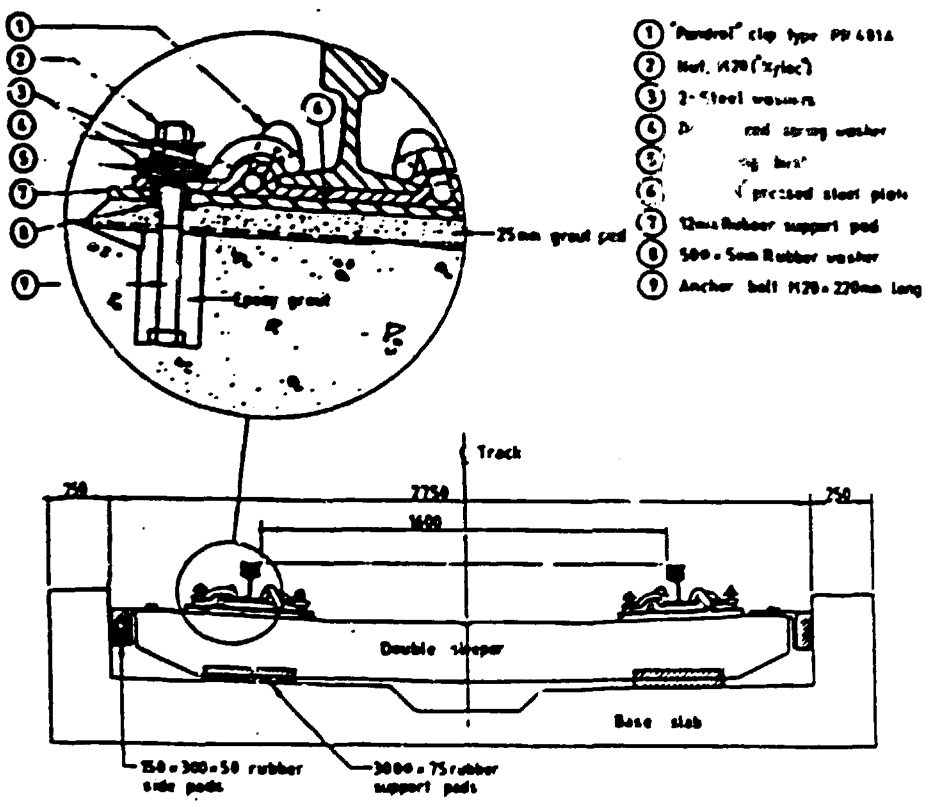
TYPE 'P' DOUBLE SLEEPERS FOR PLATFORM TUNNELS.

FIGURE 5



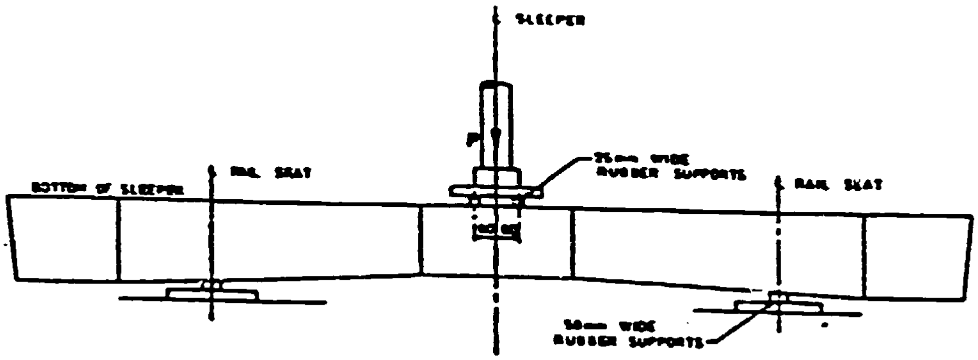
STEDEF TEST TRACK - SECTION.





DOUBLE SLEEPER TEST TRACK - SECTION.

FIGURE 6

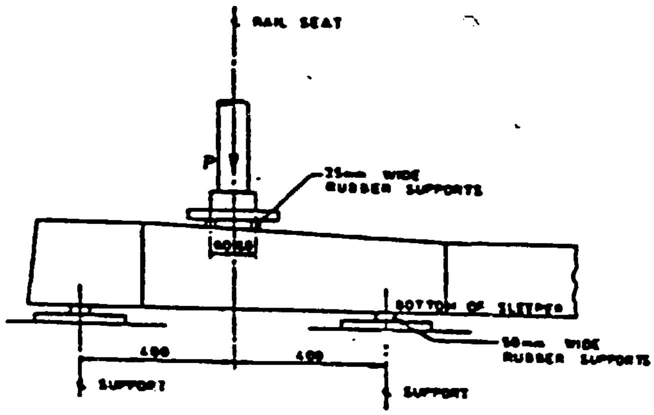


THE FOLLOWING FORMULA SHALL BE USED TO DETERMINE THE VALUE OF P =

$$P = \frac{M}{0 \cdot 35} \text{ (KILONEWTONS)}$$

WHERE M = SLEEPER CENTRE NEGATIVE BENDING MOMENT (KILONEWTON METRES) WITH A TENSILE STRESS IN CONCRETE OF 6·2 MEGAPASCALS.

NEGATIVE SLEEPER CENTRE MOMENT TEST



THE FOLLOWING FORMULA SHALL BE USED TO DETERMINE THE VALUE P =

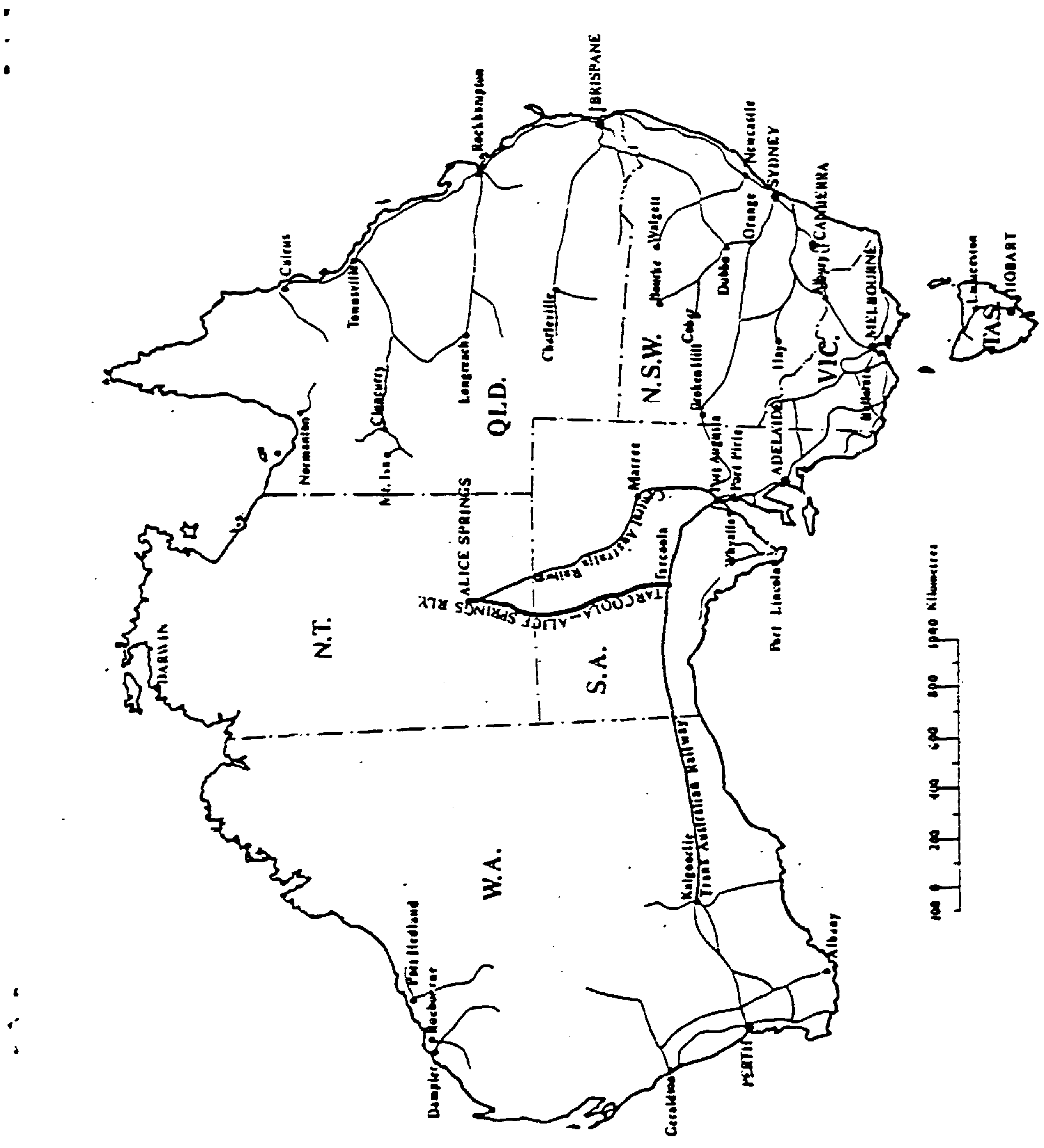
$$P = \frac{M}{0 \cdot 17} \text{ (KILONEWTONS)}$$

WHERE M = RAIL SEAT POSITIVE BENDING MOMENT (KILONEWTON METRES) WITH A TENSILE STRESS IN CONCRETE OF 6·2 MEGAPASCALS.

POSITIVE RAIL SEAT MOMENT TEST

SLEEPER TEST ARRANGEMENTS

FIGURE 7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VIC.
TAS.
ALICE SPRINGS
TARCOOLA–ALICE SPRINGS RLY
Central Australia Railway
Tarcoola
Marree
Port Augusta
Port Pirie
ADELAIDE
Whyalla
Port Lincoln
Broken Hill
Cobar
Bourke
Walgett
Dubbo
Orange
Newcastle
SYDNEY
CANBERRA
Albury
MELBOURNE
Ballarat
Hay
Launceston
HOBART
BRISBANE
Rockhampton
Cairns
Townsville
Longreach
Charleville
Cloncurry
Mt. Isa
Normanton
Kalgoorlie
Trans Australian Railway
Port Hedland
Roebourne
Dampier
Geraldton
PERTH
Albany
0 200 400 600 800 1000 Kilometres

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