THE MELBOURNE TRAMWAY SYSTEM—SOME REFLECTIONS

BY F. DUDLEY SNELL

READ TO THE HONG KONG SECTION IN 1986

At the outset I should set the record straight. I am not a Perway Engineer or even a Civil Engineer. I am, by profession, an Electrical Engineer although I have spent so long in the role of a transport administrator that some of my comments on electrical engineering are suspect.

I joined the Tramways Board in Melbourne in 1953—for a short term to broaden my electrical engineering experience—as the engineer in charge of the electrical overhead and feeder cable section and retired last year to move into the position of Project Manager for the Leighton M.T.A. Consortium on the Tuen Mun Project.

I became rather suspicious of Perway Engineers very early in my career with the Tramways Board because I was accused of causing a tram to derail because the trolley pole had dewired as the tram was using a crossover. The particular vehicle was of a type known as "Maximum Traction." They had four axles with only 2 axles driven and—as I learned later—they were prone to derailment.

With this background you will appreciate that anything that I say about track design must be treated with caution. I do not propose to become involved in detailed Civil Engineering discussions. I am indebted to Rob Vaneslow's paper to the Third International Rail Sleeper Conference in 1979 for much of the details. Rob was a Civil Project Engineer with the Board for some years. I must also be careful to point out that errors in this paper are mine—not his.

The Tramways Board always had a strong bias towards Civil Engineering in its senior management and most of its Chief Engineers in its 64 years history were Civil Engineers. In fact my predecessor and I were the only two from other engineering disciplines.

One of the major reasons why Melbourne retained its trams when most cities in the world were scrapping theirs was that the tracks were maintained to a standard at least equal to the adjoining road surface—and frequently better—so that the standard excuse of interfering with the smooth running of the motor car was not available.

There were—of course—other reasons for the retention of trams in Melbourne but that is the most appropriate one for this audience.

I assume that at least some of you will not have an appreciation of the size or the background of the tramway system in Melbourne and, at the risk of boring any Melbournians, a short history of the system may help to provide a background to the Perway story.

The present tramway system in Melbourne has some 233km of double track and is currently being extended to the north from East Preston towards Bundoora. A recent decision will result in the conversion of suburban railway lines to St. Kilda and Port Melbourne to a light railway extension of the tramway system.

The first organised street public transport system in Melbourne commenced in 1869 when a horse bus began to operate from the eastern end of the city—opposite where Parliament House now stands—to the inner suburb of Fitzroy. It may be considered to be typical of Australia that there was a hotel at each of the termini. As early as 1860 there were unsuccessful attempts to obtain approval to introduce horse trams. To place these

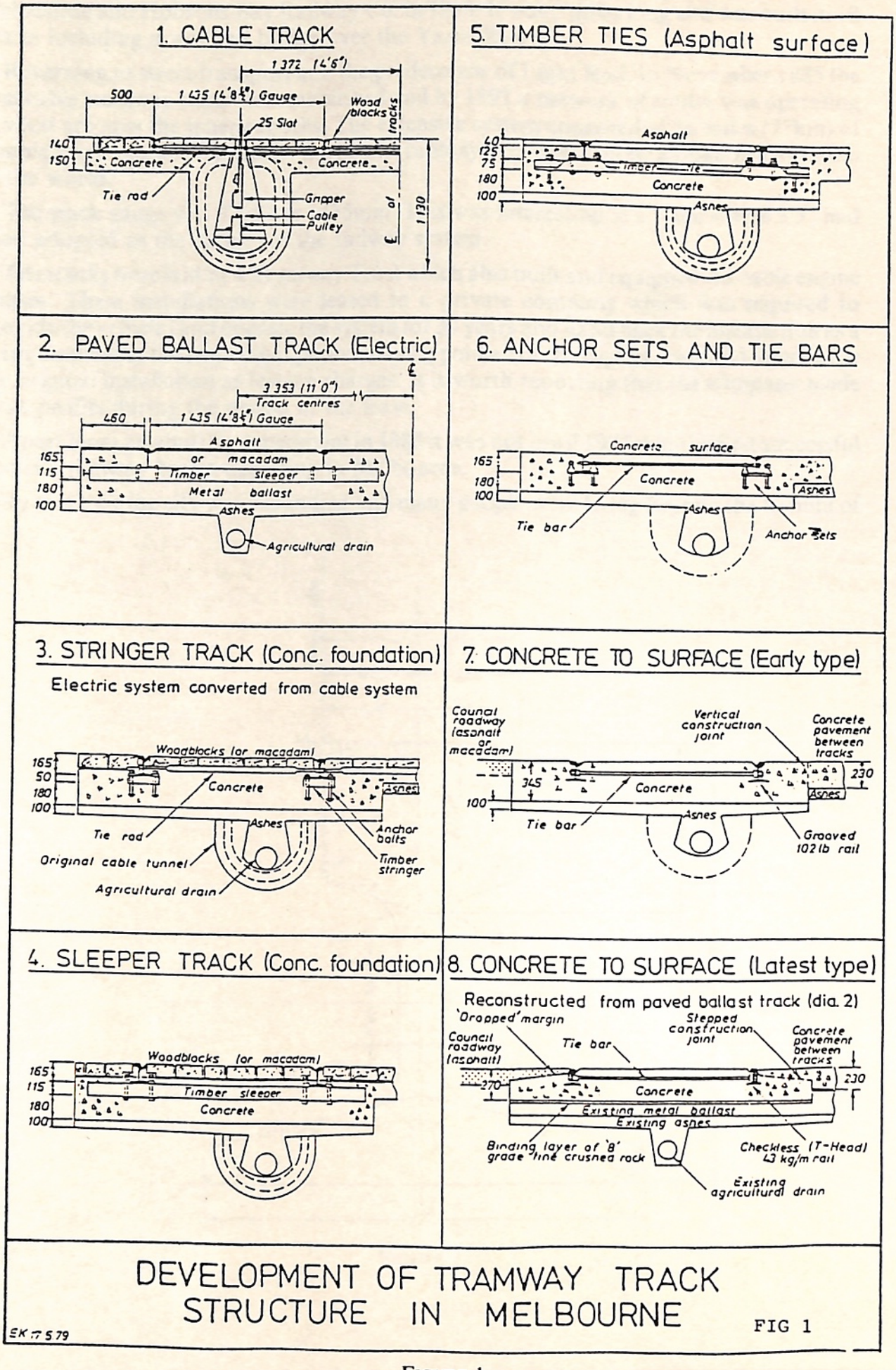

1. CABLE TRACK
1 372 (4'6")
500
1 435 (4'8½") Gauge
Wood blocks
tracks
25 Slot
140
150
Concrete
Concrete
Tie rod
Gripper
Cable Pulley
℄ of
1 130
2. PAVED BALLAST TRACK (Electric)
3 353 (11'0")
Track centres
460
1 435 (4'8½") Gauge
Asphalt
or macadam
165
115
180
100
Timber sleeper
Metal ballast
Ashes
Agricultural drain
3. STRINGER TRACK (Conc. foundation)
Electric system converted from cable system
Woodblocks (or macadam)
165
50
180
100
Concrete
Ashes
Ashes
Tie rod
Anchor bolts
Original cable tunnel
Timber stringer
Agricultural drain
4. SLEEPER TRACK (Conc. foundation)
Woodblocks (or macadam)
165
115
180
100
Timber sleeper
Concrete
5. TIMBER TIES (Asphalt surface)
Asphalt
40
125
75
180
100
Timber tie
Concrete
Ashes
6. ANCHOR SETS AND TIE BARS
Concrete surface
165
180
100
Concrete
Ashes
Ashes
Tie bar
Anchor sets
7. CONCRETE TO SURFACE (Early type)
Council roadway (asphalt or macadam)
Vertical construction joint
Concrete pavement between tracks
345
100
Concrete
230
Ashes
Ashes
Tie bar
Grooved 102 lb rail
8. CONCRETE TO SURFACE (Latest type)
Reconstructed from paved ballast track (dia. 2)
'Dropped' margin
Stepped construction joint
Council roadway (asphalt)
Tie bar
Concrete pavement between tracks
270
Concrete
230
Existing metal ballast
Existing ashes
Binding layer of '8' grade fine crushed rock
Checkless (T-Head) 43 kg/m rail
Existing agricultural drain
DEVELOPMENT OF TRAMWAY TRACK STRUCTURE IN MELBOURNE
FIG 1
EK 7 5 79

FIGURE 1

dates in perspective it must be recalled that the first settlement in Melbourne took place in 1834 and that it expanded rapidly as a result of the discovery of gold in 1851.

Also it should be recorded that the first heavy rail system in Victoria was built by the Melbourne and Hobsons Bay Railway Co. in 1853. It was 2 miles long and was built in 10 weeks including a wooden bridge over the Yarra River.

Returning to street transport and the predecessor of Light Rail. In November 1885 the first cable tramway route was established and by 1891 a network of routes was operating in what are now the inner suburbs. The extensive system consisted of 46 miles (77km) of double track and was reportedly the largest cable system operated by a single organisation in the world.

The track gauge was 4'8·5" or 1435mm. This was interesting in a State where 5'3" had been adopted as the gauge for the railway system.

The tracks were laid by a Tramway Trust which also built and equipped the cable engine houses. These installations were leased to a private company which was required to provide the vehicles and operate the system for 30 years and hand back the installation as a going concern at the end of that period, having paid all of the capital costs and interest for the original installation as leasing charges. It is worth reporting that the company made large profits during the period of the lease.

Apart from an abortive experiment in 1888 it was not until 1907 that the first successful electric tramway began operating in Melbourne.

By this time the city was expanding and many people were living beyond the termini of

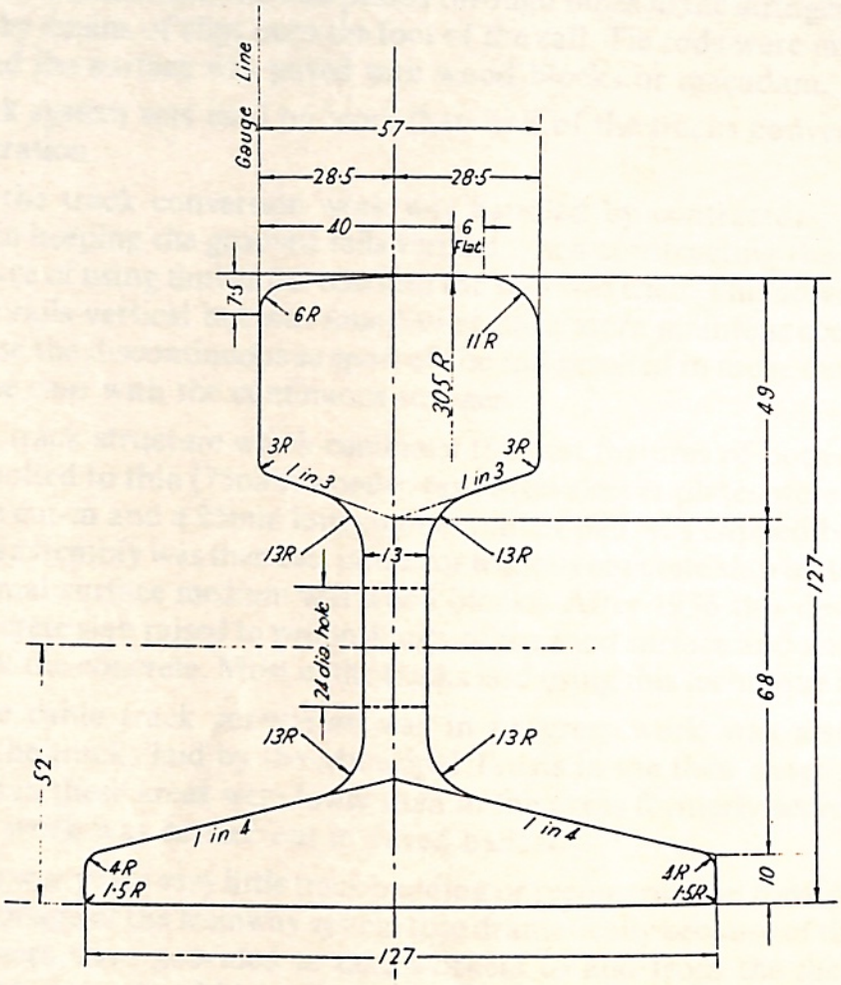


FIGURE 2

the cable tramway. All of the early electric tramways were built from the ends of the cable routes into the newer suburbs.

In 1919 the Tramways Board was formed to take over the cable tramways and all of the electric tramways—which had been built by municipal trusts—and integrate them into a single electric system.

Because of demands for extensions and the impact of the depression it was August 1940 before the last cable tramway was closed.

The original cable tramway track was of relatively light weight construction with the rails laid on a 150mm thick continuous concrete slab. The rails were tied at frequent intervals to the slot beam by steel tie rods. Sleepers could not be used because of the need to maintain the 25mm gap for the grip to reach the cable. The surface was paved with 120mm deep red gum blocks.

Some of the early electric tram tracks installed by the Tramway Trust failed through faulty construction. They were laid on timber ties in ballast with a paved surface. A more permanent track design was sought for heavily used routes.

In 1925–26 during conversion of the cable tramway in St. Kilda Road an experimental track design based on the cable track was installed.

This track, known as "stringer track" consisted of a continuous concrete slab with longitudinal red-gum stringers about 60mm thick set into the slab beneath the foot of each rail. Anchor bolts cast into the slab passed through holes in the stringers and held the rail in position by means of clips onto the foot of the rail. Tie rods were installed at frequent intervals and the surface was paved with wood blocks or macadam.

This track system was used on more than half of the tracks converted from cable to electric operation.

Most of the track conversion work was handled by contractors. They experienced difficulties in keeping the grooved rails vertical when constructing the stringer track and the alternative of using timber ties cast into the slab was tried. This solved the problems of keeping the rails vertical but was found to require more maintenance than the stringer track because the discontinuous support of the rail resulted in more cut-in of the sleepers than was the case with the continuous stringer.

In 1927 a track structure which combined the best features of both designs was tried. Rails were bolted to thin (75mm) wooden ties. Steel sleeper plates were provided on each tie to reduce cut-in and a 25mm longitudinal timber pad was clipped beneath the foot of the rail. This assembly was then cast into a continuous concrete slab up the foot of the rails and the normal surface medium was wood blocks. After 1936 this design was modified with the concrete slab raised to within 40mm of the road surface and an asphalt sheet was laid on top of the concrete. Most of the tracks laid using this technique are still in service.

Whilst the cable track conversion was in progress work was also carried out on duplicating the tracks laid by the Municipal Trusts in the then outer suburbs. Because service levels in these areas were lower than in the areas formerly served by cable trams most of this work was carried out in paved ballast.

During the war years very little track building or reconstruction took place. During that time the patronage of the tramway system rose dramatically because of the lack of fuel and 24 hour services were provided to take workers to and from the factories. The peak patronage rose to some 354 million in 1945 i.e. almost 1 million passengers a day compared with some 450 000 passengers a day in 1984/85. Because of the quality of the tracks laid during the reconstruction they withstood the high level of service very well despite the low level of maintenance.

The immediate post war years were a time of uncertainty for public transport, the petrol rationing had eased, the first of the mass built Australian cars appeared in quantity on the market in 1948 and the cost of cars relative to income began to fall and, as building material became available the city expanded to the south and east away from the area served by trams.

In 1946 the Tramways Board began to accumulate material to convert the last remaining cable tram route (which had been operated by buses since 1940) but it had difficulty in persuading the Government to approve the borrowing of capital to finance the project.

Approval was finally given in 1953 and the work commenced in 1954. It was a courageous decision because most other cities in Australia—and for that matter most cities in the western world outside Germany and Switzerland—were tearing up their tram tracks. It was almost the last transport decision made by a Labour Government in Victoria for many years because the Government collapsed in 1954 as a result of internal disputes and did not govern again until 1982.

The track construction techniques used in that reconstruction of 18 kilometres of track were varied as the work progressed. The first section of some 1·6kms used timber ties with concrete to within 40mm of the road surface and an asphalt surface.

Then the asphalt surface was eliminated with the concrete brought right up to the street surface to increase the contact area between rail and concrete.

The timber ties were then eliminated leaving only steel tie bars and anchor bolts fastened to the rails with the rails buried in a continuous concrete slab to street surface.

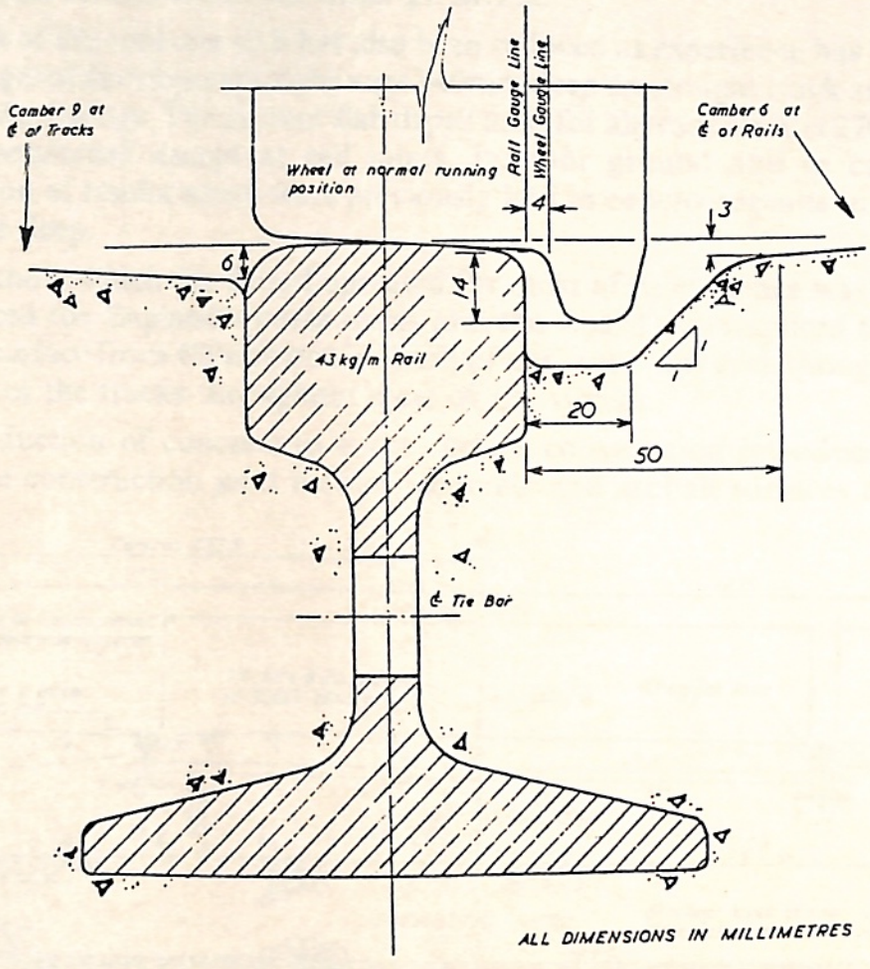


FIGURE 3

The final step eliminated the anchor bolts and relied completely on the concrete/rail bond to hold the rail in place. The rails are set on precast concrete blocks placed at about 3·5 metre centres and lifted by driving opposing hardwood wedges until the appropriate level is obtained and lined by wooden toms off the side of the excavation. This technique developed in 1954 is still the basic means of laying new tracks or reconstructing tracks in Melbourne.

During the 1954/56 conversion of the East Preston route as the track laying technique was being developed experiments were conducted to find an economical mix for the concrete being poured for the tracks.

In those days the Board mixed its own concrete in portable mixing plant which was towed along the road beside the track and the concrete was discharged directly into the excavation. The optimum mix was found to be 6·2 bags per cubic metre which yielded 7 day strengths of the order 24 to 28 M.P.a. (3500 to 4000 psi). This, I am told, is a relatively high result mainly because the on site mixing resulted in very low slumps.

Because of the high cost of labour for on site mixing the Board turned with some apprehension to plant mixed concrete delivered to site and over a period of years a satisfactory mix has been developed.

The most commonly used concrete mix now has a cement content of 315kg/cubic metre (6·8 bags/cubic metre). A minimum strength of 17·5 M.P.a. (about 2500 psi) is specified and the normal results are of the order 21 M.P.a.

The depth of the concrete slab has also been reduced as experience has been gained. In the early stages of development slabs were 340mm deep on straight track and 390mm deep at points and crossings. The current slab depth used for all trackwork is 270mm. The slabs are rarely reinforced except at rail joints, in poor ground and in cases where the reconstruction of tracks which were previously laid in concrete results in a new slab less than 150mm deep.

The Act under which the Board operated for most of its existence was based on early Acts produced for England's horse trams and the Board was required to maintain the entire road surface from 480mm outside each of the outer rails even though road vehicles had the use of the tracks throughout most of the system.

The introduction of concrete to street surface construction introduced the difficult problem of a construction joint between concrete and asphalt surfaces at the margin.

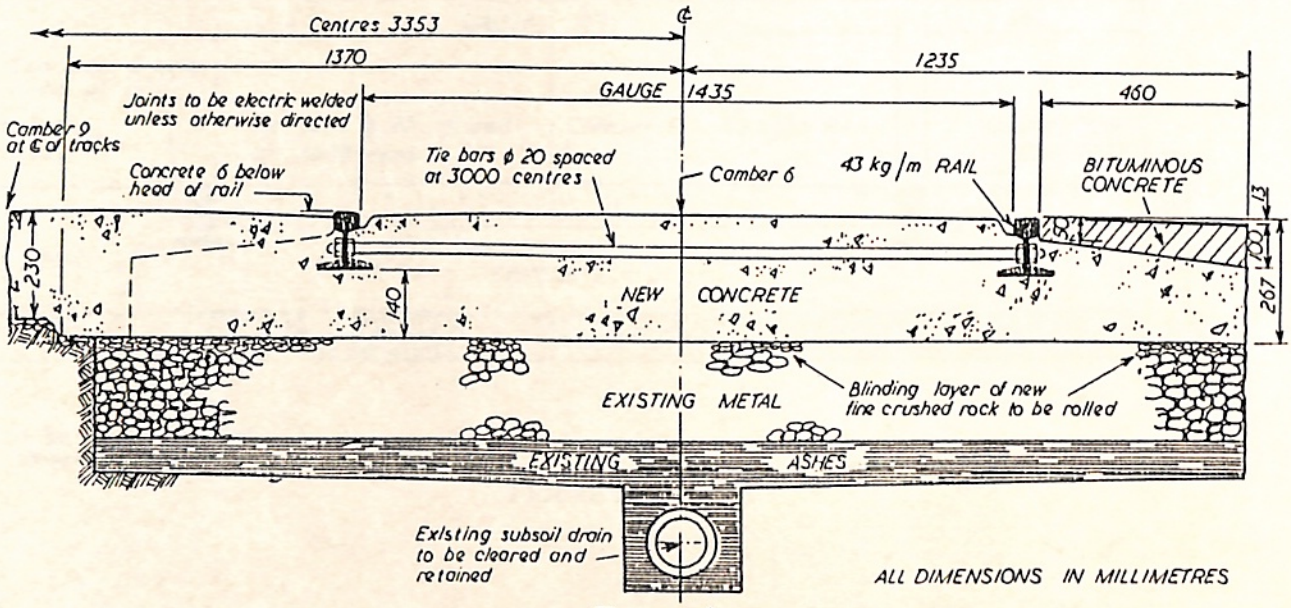


FIGURE 4

This problem was finally solved by stepping the concrete down by 50 to 100mm outside the two outer rails and placing asphalt sheet in this area. When tracks are being reconstructed the Road Authority frequently reconstructs the adjoining roadway and the final surface is generally made continuous between the outer rail and the kerb.

In reconstructing tracks by the concrete to street surface method, it is rarely possible to concrete both tracks at the same time and the need for a vertical construction joint between the tracks has been eliminated by the stepped down technique on the inner rail when pouring the first track.

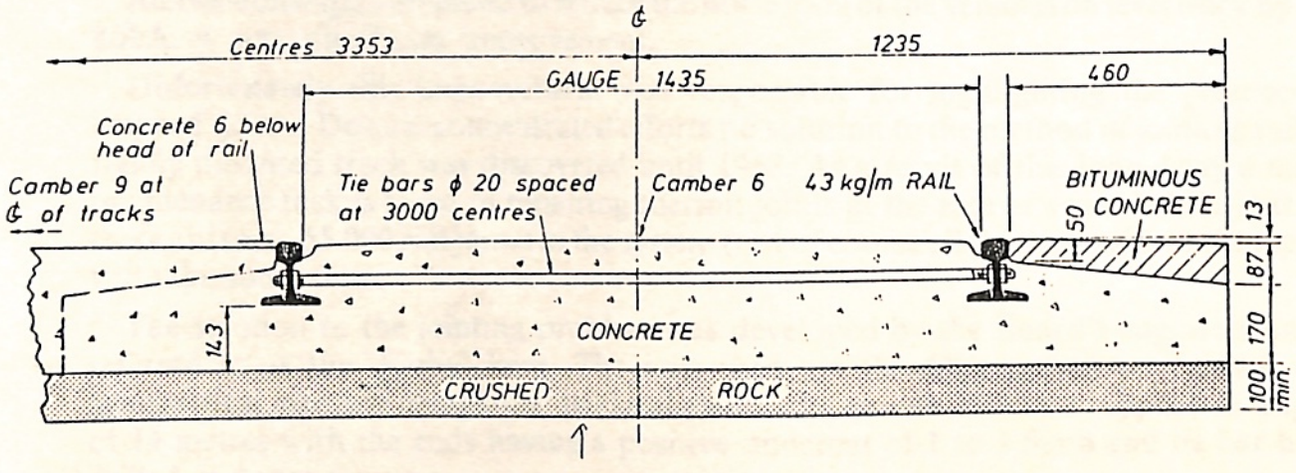
Rails have also changed over the years. The early electric tracks were constructed with 80lb/yard T-head rail with the groove formed by bolt-on flanges whilst others used a British Standard 90lb/yd tramway rail with the groove rolled as an integral part of the rail.

In 1927 the Melbourne and Adelaide tramways operators persuaded B.H.P. to consider the local production of tramway rails and a 120lb/yd grooved rail was produced. This became the standard Australian tramway rail and it was used in Melbourne until 1975.

This grooved rail required two rolling operations, one to form the basic rail and the second to form the groove, and the heated rail had to be returned to the front of the rolls for the second pass. With automation of rolling mills this became uneconomic and almost impossible and B.H.P. indicated that when their rolls wore out they would not be prepared to continue production.

Grooved rail was still available from Europe but the price was so much higher than the local product that other solutions were sought. The result was the design of a new T-head rail particularly suited to concrete to street surface construction. It is non-symmetrical having a deep head and weighing 43kg/metre and is rolled from medium manganese steel. This rail is still used in most trackwork in Melbourne. The groove is slip formed in the concrete next to the running edge of the rail in straight track and a steel guard plate is fixed to both rails in track on curves of less than 600 metres radius.

When you look back at 100 years of track construction changes are inevitable and this applies to jointing techniques as well as track construction and rails. The early jointing technique was the conventional one using a pair of fishplates bolted together through the web of the rail. This technique was acceptable with open ballast construction but proved troublesome in paved track because of the need to open the roadway to tighten fishplate bolts and other solutions were sought. They included seam welding of the fishplates to the rail. This was reasonably successful on standard paved ballast track with timber ties but



Joints to be electric welded unless otherwise directed

FIGURE 5

proved to be quite unsatisfactory for semi-rigid and rigid track because of rail web failures with cracks propagating from the fish bolt holes.

The introduction of thermit welding about 1930 appeared to provide a solution and in fact proved to be reasonably satisfactory on timber supported rails but unsatisfactory on rigid track. The difficulty was that although the hardness of the weld material could be matched closely to that of the parent rail the heat affected zone on each side of the weld metal was always of a different hardness. In rigid track this resulted in rail head batter and the eventual formation of a 'cupped' joint. To make matters worse these 'cupped' joints started to develop at the time that the Board was trying to reduce the noise created by its trams—partly because it was a problem and partly because of the anti-tram lobby which was still very strong.

The trams that were then being operated had mainly been built in the 1920's and even the trams which were built in the 1950's were still based on a 1935 design. They had solid wheels, straight spur gears, cast iron brake shoes, steel brake shoe keys, slack brake rigging and axle hung motors.

The problem was tackled on a number of faces during the 1950's and 1960's. There was no money to purchase new vehicles and even if there had been the necessary funds it is unlikely that anyone would have authorised expenditure on new vehicles at a time when most people were claiming that trams should be eliminated.

Resilient wheels were fitted to some of the vehicles built in 1954 to 1956 and had some effect in noise reduction but the effect was masked by other noise generators. Double helical gears and pinions were fitted to a series of trams and the use of these gears reduced noise generated by gear backlash.

The cast iron brake shoes were replaced by moulded non metallic shoes developed over a period of experiments between the Board's engineers and Ferodo. They reduced the ringing noise and also helped to produce more even braking which in turn reduced flats on the wheels. The steel pins which located the brake shoes in the hangers could then be heard and these were replaced with nylon keys.

The brake rigging slack was then a noticable source of noise and nylon bushes were fitted to all of the linkage with accurately machined case hardened pins transmitting the forces; and non metallic bearing plates between the rods and bogie frames.

All these changes combined to reduce the noise level of the vehicles on level track by 7 to 8dbA. A very significant improvement.

Unfortunately this improvement was responsible for highlighting the presence of 'cupped' joints. Despite concentrated efforts no solution to the method of jointing rails in rigidly mounted track was discovered until 1968. As a result of this long delay a major maintenance task is faced in repairing thermit joints at the rate of some 3000 a year. As there are some 65 000 rail joints in the system (not of course all thermit welded) the repairs will take some time.

The solution to the jointing problem was developed by the Board's engineers and is referred to as the 'Kirby' joint. The rails used are the 43kg per metre T head, non symmetrical medium manganese steel rail mentioned earlier. They are supplied in lengths of 14 metres with the ends having a positive undercut of 1 to 1·5mm and tie bar holes drilled at 3 metre centres.

The rails are lifted onto supporting blocks by crane and 20mm tie bars threaded at each end are inserted to join each pair of rails. The nuts are tightened against each side of the rail web to hold the rails accurately to gauge and they are aligned horizontally from offset pegs at 10 metre centres.

The vertical alignment through each joint is achieved by thin opposing hardwood wedges beneath each foot of the rail at each supporting block. The mating ends of the rail are then drawn together by means of hydraulic pullers and once the gap is closed the rails are held in position by means of a large double U clamp.

A 12mm mild steel sole plate 230 × 200mm is wedged up under the joint and fillet welded along both sides of the rail foot. A 12mm strip 250mm long and 25mm wide is welded on top of the foot on each side of the rail. A length of reinforcing rod is tack welded to the inside of the rails at each joint. It is shaped so that it stands about 100mm clear of the rail. When the track is concreted in this bar helps to support the joint.

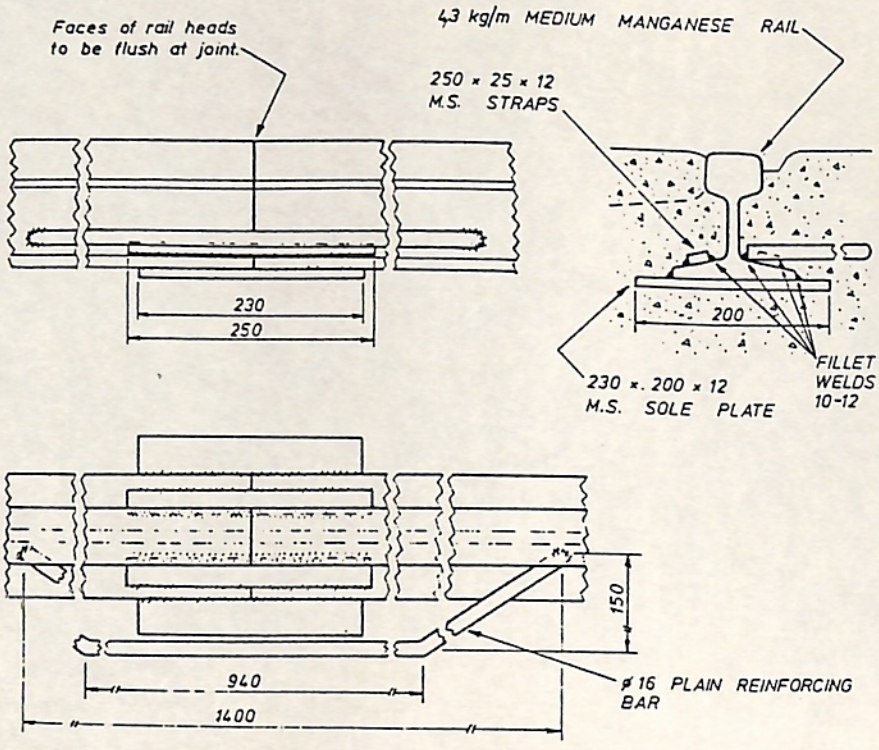


FIGURE 6

This technique has proved to be very successful. There have been very few failures in service over the last 8 years. The rail head generally flows to fill the minor gap and it is very difficult to detect the location of the joint.

To end on the note on which I started perhaps Electrical Engineers are of some use to Civil Engineers after all. The Kirby joint concept was proposed by the then Chief Engineer Frank Kirby and he was an Electrical Engineer.