

# DESIGN REQUIREMENTS FOR STREET TRACK



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## Introduction

This guidance is issued by the Office of Rail Regulation. Following the guidance is not compulsory and you are free to take other action. If you do follow the guidance you will normally be doing enough to comply with the law. Railway inspectors seek to secure compliance with the law and may refer to this guidance as illustrating good practice.



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At the request of HM Railway Inspectorate and with the assistance of the members of -

- The Light Rail Engineer's Group
- The ORR Tramway Standards Group
- HM Railway Inspectorate.

# Design requirements for street track

## Requirements

1. The primary requirements for any design of tramway track which will be used in the street<sup>1</sup> are:
  - a. **suitable load bearing foundations**  
the foundation provided to support the rails should be of a load bearing strength that is sufficient to support both the foreseeable tram and traffic loadings without distress;
  - b. **adequate rail support**  
the rails are adequately supported to allow operation of both trams and foreseeable maintenance vehicles without distress to their foundation or to the surrounding materials;
  - c. **prevention of gauge movements**  
the rails are held to gauge by positive means, sufficient to resist the lateral forces exerted by the wheelsets, by the motion of the vehicle and other highway vehicles;
  - d. **suitable rail fixings**  
anchored securely to the underlying foundation such as to be able to resist any lateral and/or vertical movements induced in the rails as a result of thermal expansion and contraction.

## Considerations

2. There are a number of further requirements, principally in regard to the future maintainability of both the track and the street, which also need to be observed, namely:
  - e. **rail maintenance**  
any coatings applied to the rails in order to limit the propagation of stray currents should be consistent with the long term maintenance requirements of the operator and the types of equipment likely to be available to them when there is a need to access and expose the full depth of the rails in order to effect repairs or electrical connections;
  - f. **ducts**  
where the tramway's cable ducts are constructed alongside the track foundation, a break joint should be provided so as to permit the latter to be excavated with minimal risk of consequential damage to either the ducts or the material in which they are encased. Additionally, where practicable, the cable ducts should be laterally separated from the track slab, particularly through curves and switch & crossing work, so as to allow for subsequent flexibility in the track alignment when renewal works take place. Undertrack crossings should be as near to 90° to the track as is practicable and protected so that the risk of damage when excavation of the track slab is taking place is minimised;
  - g. **under track excavation**  
it should be possible to excavate trenches of moderate width across the width of the trackform without disturbance to the alignment of the rails. Depending upon the rail section chosen, trenches of around 1m in width can normally be spanned by the rails without any additional support;
  - h. **track renewals**  
following works to renew the rails, or alter the alignment or track layout, the track should be capable of operation, under speed restriction if necessary, as soon as is practical, consistent with the needs of restoring the service as soon as possible. A normal expectation is that the track should be usable with the rails supported on temporary blocks or packing pending reinstatement of the underlying foundation layer;

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<sup>1</sup> Within this document "street" is used as a generic term to describe any road, highway, carriageway or pedestrian area, including grassed track in such environments, where it is necessary to construct track such that the rails are nominally level with the surfacing.

- i. **adjacent road level**  
the road surfacing adjacent to the rails to be capable of being adjusted post installation in order to ensure that the effects of rail wear and road surfacing settlement can be compensated such that the road surface can be maintained nominally level with the rail to within the accepted standards (see below);
- j. **street track surface**  
the materials used to build up the level between and around the rails to restore the ground or street surface should be capable of ready removal and replacement by alternative materials and finishes should the need arise for future aesthetic or highway reasons;
- k. **current return capacity**  
that the rail cross-section<sup>2</sup> should be as large as practicable so that, in combination with the use of cross-bonding cables and/or parallel return cables, the electrical impedance of the traction return path is minimised, thereby minimising the return voltage drop to the traction substations. This will increase the overall energy efficiency of the system, reduce the risk of electric shock from the system and/or reduce the number of substations that are required;
- l. **rail renewal**  
the rails should be capable of being electrically welded in order to enable –
- the effects of side and/or head wear to be made good with the rail in-situ,
  - new rails to be inserted<sup>3</sup>,
- without special requirements as to pre-heating and without causing distress to any components of the track system which are in contact with the rails;
- m. **duct and equipment access**  
access manholes to the tramway's cable ducts and other trackside equipment should be positioned such that they can be accessed without significant interruption to either tram or road traffic, or undue risk to staff working in such manholes;
- n. **rail joint levels**  
where it is necessary to join new rails to existing rails that have side and/or head wear, it is readily possible to lift and/or slew the existing rails so as to allow the contact faces across the joint to be made level<sup>4</sup>;
- o. **expansion joints**  
traditional practice in the UK has been for fully embedded grooved rail to be continuously welded and installed without provision for expansion, based upon the relatively limited variation that occurs in the ground temperature and the limited exposure of the rail itself to solar heating. Where it is considered that the provision of an expansion joint would be of benefit in limiting stresses in the rail and/or the rail fastenings, it should be such as to comply with (p) below;
- p. **rail joints**  
where rails have to be joined mechanically, the minimum standard is a six-bolt fishplate, preferably secured by Huck Bolts (or similar) and with the rail ends butted tightly together. Where relative movement of the two rails is necessary, it is desirable that the joint is scarfed, ie overlapped, in order to lessen the deleterious effects of impact as the tram wheels cross the joint. In all cases, it must be possible to obtain ready access to the fishplates in order that the joint can be maintained;
- q. **rail transition**  
where it is necessary to change rail sections, particularly between Vignole and Grooved rails, purpose made transition rails should be provided. These should always be located on straight track, if necessary on the approach side of any curve, so that the tram wheels can be properly centred in the gauge and impacts between them and the flared entry to the groove avoided. If this

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<sup>2</sup> The ruling cross-section is that when the rail is fully worn.

<sup>3</sup> The process of replacing worn rail may require the rail being retained to be lifted in order that the running surfaces are maintained level whilst at the same time not causing the trackform to creep downwards into the street construction.

<sup>4</sup> Not being able to do this can cause significant difficulties in the renewal of, for example, turnouts that are incorporated into curved track, or can result in the progressive downward migration of the track as successive renewals take place at the same location.

cannot be guaranteed, even on straight track<sup>5</sup>, it may be necessary to insert a short length of renewable check rail on both sides of the track immediately ahead of the grooved rail transition, in order that they can take any impacts;

r. **groove transition**

changes from wide to narrow groove rail, eg on the departure side of curves, should also be aligned such that the tram wheels are not presented with a sudden change in lateral alignment. This applies particularly to the inner (or low) rail;

s. **electrical return path**

it must also be remembered that the track, specifically the rails, provide the electrical return circuit from the trams to the substations, and are therefore required to act as efficient electrical conductors in addition to their mechanical role. The standards which relate to this aspect of the track design are set out in the Design Requirements for Stray Current Management, covering the design of the power system as a whole and the measures pertinent to managing the generation of stray current.

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<sup>5</sup> Typically as a consequence of the use of bogies (or trucks) having independently rotating wheels, which cannot be regarded as having any self-steering properties.

## Features of UK second generation track designs

3. All of the second generation tramways built thus far in the UK and Ireland<sup>6</sup> are characterised by having track forms in which:

- the rails are encapsulated in an elastic polymer material, which serves as both an electrical insulator (against stray current) and a vibration isolator/damper (against noise and vibration);
- the rails are either held in place solely by virtue of the adhesive properties of the polymer or a combination of holding down bolts bearing on the pre-coated polymer jacket and in-situ cast concrete;
- the rails are mechanically independent of each other (i.e. there are no metal:metal connections between them, or between the metal and the concrete substrate that provide positive control of the gauge);
- the rails are supported on a reinforced concrete slab in which the reinforcement provides both structural integrity and is intended to act as a stray current mitigation measure.

Whilst each of the various designs could be said to have fulfilled the expectations of their designers and constructors, the same cannot always be said regarding those with the responsibility for their maintenance. The passage of time has revealed various shortcomings in relation to their performance and/or maintainability. This is necessarily more apparent with the longer established tramways.

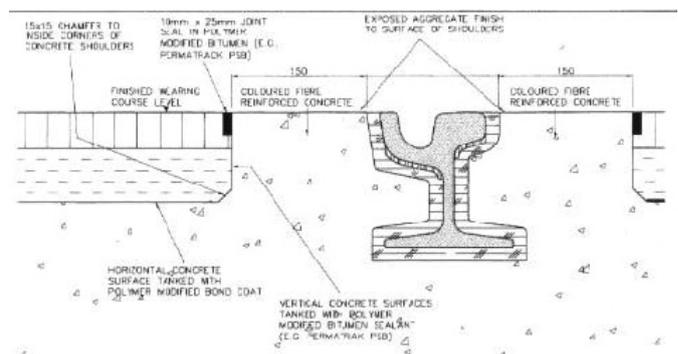
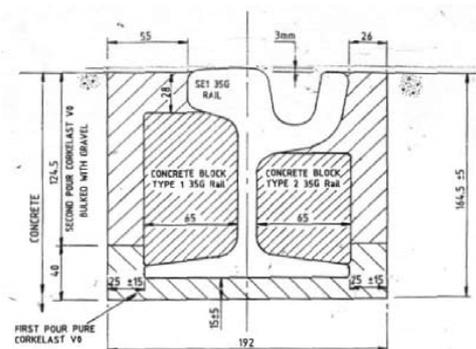
It also has to be remembered that the time pressures on the tramway operator to restore a section of track to operational use are considerably greater than those on the contractor, which factor has not always been properly considered in the overall track design.

## Systems with in-situ embedment

4. Descriptions and requirements for suitable load bearing foundations are as follows.

### a. Rail support

The earliest of the second generation tramways are characterised by the use of reinforced concrete track slab construction with the rails supported in a bed of polymer material, poured in place after the rails had been set to line and level. In each case, the rails are not mechanically fixed either to the slab or to each other.



The slab can be of either shallow or full depth construction, according to whether the concrete is carried to, and forms part of, the road surface (full depth) or is submerged by the street surfacing (shallow depth).

With shallow depth slabs, the rails are effectively bonded to the slab only around their foot, and in the absence of any mechanical fixings, have been found to roll laterally under tram loads, particularly in curves. This in turn leads to distress in the surrounding street surfacing, which lacks the strength required to resist these forces.

<sup>6</sup> Metrolink (Manchester), Supertram (Sheffield), Midland Metro, Tramlink (Croydon), NET (Nottingham) and LUAS (Dublin)



*Lateral roll of rails causes road surface damage*

*J Brown*

The lateral movement of the rail also leads to interference with the wheel: rail interface, to the extent that undesirable levels of flange front and back contact can be generated. Such a system fails to meet Requirement (b), and can be expected in addition to suffer higher levels of rail and wheel wear, as well as increased highway maintenance costs.

This situation does not arise to the same extent where a full depth slab is used, in that the greater strength of the concrete is better able to resist the lateral forces generated in the rail. However, the exposed edges of the concrete slab are liable to crumble under road traffic loads, leading to highway defects for which the tramway operator may be liable. Similar effects can occur with shallow depth slab construction at the interface between the embedment medium and the highway surfacing.

**b. Rail welding**

A common practice on tramways elsewhere in Europe is the longitudinal welding of the rail to make good the effects of wear to both the side and head. With the rail embedded in polymer, this is considerably more difficult due to the problems created by heat build-up, and if, as has commonly been the case, hardened or heat-treated rail has been used, the required preheating can be hard to achieve without causing the chemical decomposition of the polymer, with consequent health hazards to the welders. Without adequate temperature control, there is a high risk of initiating cracks in the rail, leading to breakage and, ultimately, premature renewal at considerably greater cost.

**c. Rail break repairs**

A further consequence of polymer embedment is that it becomes very difficult to gain access to the rail in the event that, for example, a crack requires repairing, or an electrical connection is required, or when a new section requires to be welded in. Generally, whilst the concrete can be broken out using common highway maintenance tools, cutting through the polymer requires an altogether different approach. So far, the only effective methods involve either the use of sharp tools to physically cut it, or the use of very high pressure water jetting.

Renewal generally requires the road surface to be saw cut on either side of the rail so that the rail can then be pulled out of the road. Depending upon how well the rail and concrete were cleaned prior to the embedment being poured in the first place, the bond between the two can be sufficient to cause small but significant quantities of concrete to be pulled away from the slab. Further, it is still necessary to excavate a significant size hole at each end of the section being renewed in order to allow the welds to be made to the existing rails.



*Welding a rail joint*

*M Howard*

A secondary problem is that the rail, with the polymer still attached, has a zero scrap value and can be difficult to dispose of.

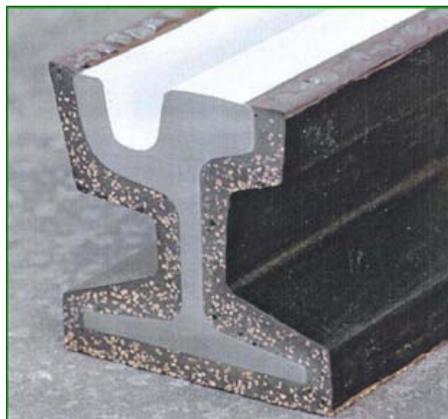
## Systems using pre-cast embedment

5. Descriptions and requirements for systems using pre-cast embedment are as follows.

d. **Pre-coated rail break welding**

As an alternative to the above, some systems have been constructed using rail to which the polymer jacket has been applied in a factory environment, so that the amount of in-situ work, which is always subject to weather conditions, is reduced to the on-site encapsulation of the rail ends where they have been welded together, and to switch and crossing work.

This technique also facilitates a much higher degree of control over the relative levels of the rail head and the surrounding street surface in that the usual method of installation is to set the rails to line and level on the previously cast concrete slab and then make up the surrounding street to the level of the rails. Crushed stone can be added to the top/exposed surface of the polymer to aid skid resistance.



*ALH6 polymer pre-coated SEI 41GP grooved rail NTC*

However, once installed, the same problems can exist in terms of the difficulty in accessing and welding the rail itself as with the in-situ embedded systems, for the same reasons. The extent to which this can be a problem will depend on the polymer used, the steel grade, particularly if significant preheating is required, and the ability to achieve adequate heat dissipation during welding processes.

## Generic problems with concrete slab construction

6. The generic problems associated with concrete slab construction are as follows.

e. **Road level**

Significant problems emerged early on with level differences between the rails and the adjacent concrete, sometimes well over the limits of what could be considered compliant with either the 1870 Tramways Act interpretation of “level” or the more recent redefinition that resulted from the legal case *Roe vs. Sheffield Supertram*, which had resulted primarily for the inherent differences in construction accuracy for the vertical alignment of the concrete work and the rails, and were blamed for a number of instances involving loss of control of road vehicles.



*Pre-coated rail installed on concrete slab*

*D Keay*

f. **Level resolution**

To a large extent, the pre-coated rail systems were designed to overcome this problem by ensuring that the rails could be laid first, and the street surfacing subsequently laid by reference to the rail level. However, the same principles can also be followed using traditional tramway track construction, so long as the surfacing is laid after the rails have been fixed, as was normal practice with traditional street track construction.

g. **Current track alteration practice**

It has also become practice in the UK to build the track on a reinforced concrete slab, with the concrete in at least some cases being of a high strength grade (at least C40) so that

(i) the slab can act as a bridge across trenches up to 2m in width, and

(b) the reinforcement can act as a collector mat for intercepting and redirecting stray currents from the traction return circuit.

As a consequence, it becomes much more difficult to either modify the track to accept tiebars or direct fixings to the slab, or to alter the alignment without first breaking out the slab entirely. That task is also made difficult by the high strength of the concrete employed and the amount of reinforcement present, and can thus represent a major cost and time element in any track renewal works, the latter giving rise to high risks of possession over-runs.

**h. Track replacement difficulties**

Rail replacement has exposed the difficulties of access through the track slab, in that although the rail can be released along its length by saw cutting the concrete, outside of the polymer, it is still necessary to excavate access holes around and below the rail at the cut ends, and to clean the remaining ends of polymer before welding.

## Generic problems with floating rail construction

7. The generic problems associated with floating rail construction are as follows.

**i. Polymer only supported rail allows too much movement**

Compared with traditional forms of tramway track construction, the extent to which the rails can move when they are supported solely in polymer, especially the softer grades, is liable to cause problems with track drains, as well as any other equipment, such as connection boxes and point mechanisms, that are attached to the rails, and non-welded rail joints.

The relative movements between the two are liable to result in failure and subsequent mechanical deterioration, whilst fishplated joints, particularly where only four bolts are used, are inadequately supported and once some wear has taken place on the fishing surfaces, will progressively deteriorate.

At the same time, where the rails have been embedded in polymer, even if only partly, it becomes next to impossible to undertake any basic maintenance work on the joint unless the polymer is removed first. Even then, unless attended to as soon as looseness has become visible, it is difficult to recover the situation as a result of the damage that has started to occur to the fishing surfaces of both the rail and the fishplate.

The failure of such joints in Switch & Crossing work is also liable to cause consequential damage to major components, such as the switch or crossing legs, which are then expensive to repair, given the complications introduced by any rail embedment.

Where switches are located in street areas where they are run across by other road traffic, particularly goods vehicles and buses, the mechanical security of the point mechanism is prejudiced as a result of the relative lack of support. The case containing the mechanism is usually supported on lugs welded to the rails, with the result its vertical movement under road traffic loads can be sufficient, over time to cause these lugs to break. Because they are contained within the embedment, they cannot be inspected without excavation, and first sign of breakage is when the whole mechanism case becomes loose in the road.

**j. In-situ adjustment**

Whenever it becomes necessary to replace sections of rail with new, it is essential to ensure that the head and gauge or keeper faces (as appropriate) are lined up across the joint. In the vertical direction, it is usual to lift the remaining old rail to meet the head of the new, whilst laterally it is necessary to slew the old rail. However, when the rail is encased in polymer and effectively bonded to and/or constrained by the surrounding concrete, there is very little latitude to do this without considerable additional excavation. Consequently, it becomes easier to set the new rail to line up with the old, with the effect that as the latter is then replaced, the vertical and horizontal alignment starts to drift, with potentially significant effects.

**k. Noise and vibration**

Once the rail is supported on elastic materials, eg polymer, it becomes a mass/spring system in own right. At the same time, it is usual, with modern trams, for the tyres to be resiliently mounted on the wheel centres, which are then resiliently coupled to the bogie frame and car body in turn.

The result, particularly if the support for the rail is relatively elastic, is that both the wheel rim and the rail can be set into oscillation as a result of either dynamic interaction or external inputs such

as a railhead discontinuity at a joint. This in turn becomes a generator of further excitation as well as noise and rail corrugation.

From observation, it is evident that the firmer the rail support, the less likely this is to occur. To an extent, some of this, particularly the higher frequencies, can be attenuated by means of dampers fitted to the wheel, or the wheel rim. However, the resonant modes are complex and cannot always be controlled in all respects.

## Solutions capable of meeting the requirements

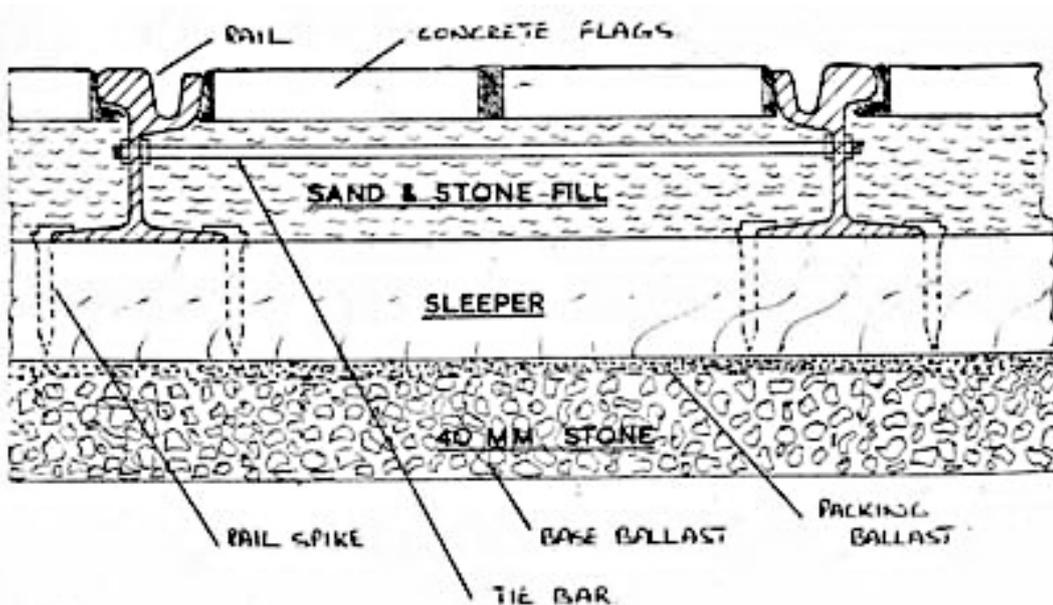
8. Producing a track form which will meet these requirements requires three fundamental elements in its design, namely:-

- a foundation layer, sufficient to transmit the loads imposed on the rails into the underlying substrate, ie the subsoil,
- rails, of sufficient weight to both support the trams and provide a sufficient return path for the electric traction current,
- means for maintaining the rails to the correct gauge and alignment under the vertical and horizontal loads imposed upon them.

### I. Foundation

As with the highway itself, some means is needed to spread the weight of the vehicle such that neither it nor the surface it is standing on will sink into the underlying ground. For railways, this was accomplished by supporting the rails on sleepers and ballast such that pressure exerted on the ground was low enough to be borne by the subgrade.

Similar techniques were adopted for the early street railways, but with the passage of time and heavier vehicles, were ultimately found wanting, with decay of the otherwise inaccessible sleepers being a significant factor. By the start of the electric tramway era, c.1890-1900, it had become more normal to set the rails directly on to a continuous concrete bed as a better means of support. The rails were held to gauge by steel tiebars, and anchored to the concrete, frequently by short lengths of old rail, laid transversely and secured tightly to the new running rails. The latter are necessary as a means of ensuring that the rails remain in place even under thermal stress, since they are neither pre-stressed (as in modern CWR practice) nor provided with expansion joints, it being normal to either weld or close joint the rail ends. The concrete foundation was simply laid up to the bottom of the rails, without any internal reinforcement.



*Tie bar arrangement of rails as used on the Blackpool tramway*



*An example of traditional track construction in Graz in 2004*

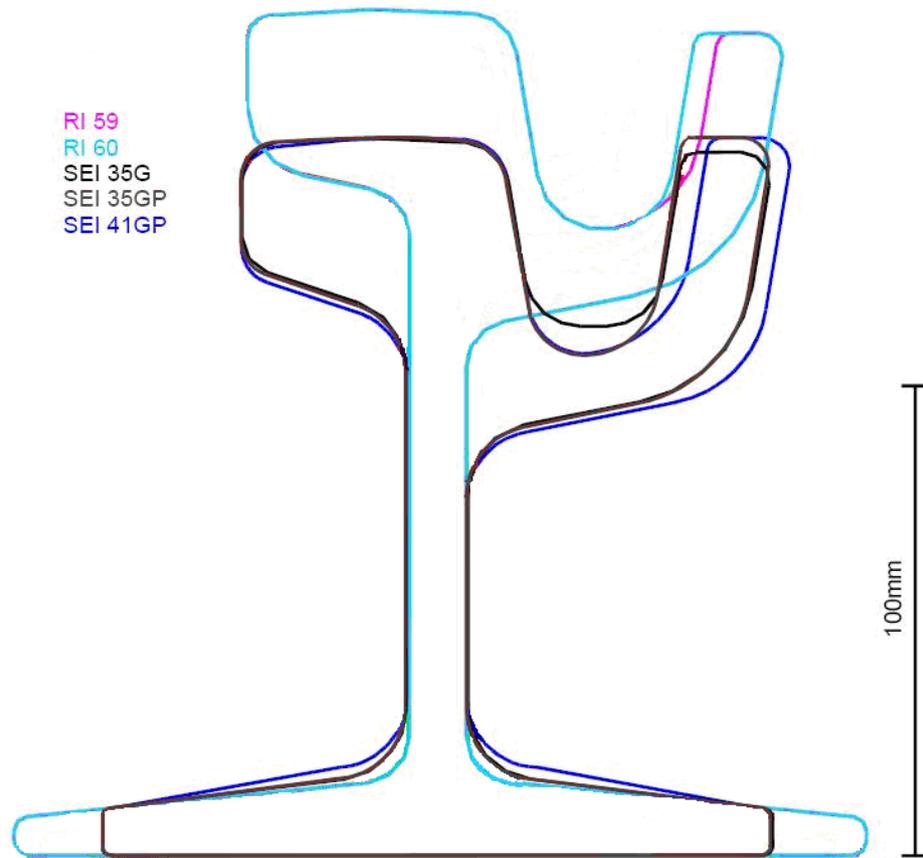
This method for laying street tramway track is still in widespread use across Europe and has changed little other than by way of the insertion of resilient elements between the rail and the concrete, and the introduction of precast concrete sleepers which are then cast into the slab. In some instances, a single layer of reinforcement is used, but only as an anti-cracking measure in the same manner as for concrete highway construction.

There are also a number of systems that were developed in the latter part of the 20<sup>th</sup> century, principally in Eastern Europe, where the trackbed is formed of precast concrete slabs which are laid on to a prepared subgrade, with the rails then inserted into slots cast in the top surface and retained by rubber strips. These systems are not suited to other than plain track, and require an accurately laid sub-base to support the slabs, as there is no scope for subsequent adjustment.

**m. Rail weight**

Although not essential, it has long been established practice in Europe and elsewhere for tramway track to be laid using grooved rail. There are a number of different sections available, largely as a result of historical and national differences however, consistent with [Requirement \(k\)](#) above, it is preferable to adopt as large a section as is practicable. It is also preferable from a maintenance viewpoint to adopt a section which is in large scale use, and thus readily available from the rolling mills.

As one example, the German Ri60N section fulfils these requirements, with the complementary Ri59N section (having a wider groove) for use on curves of less than 100m radius.



**Grooved rail profiles**

n. **Gauge and alignment**

Where the rails are laid on a plain concrete slab, as per traditional methods, it is necessary to provide some means whereby they are

- (a) held to the required gauge and
- (b) tied so as to resist the overturning forces induced by the action of the wheelsets on curves<sup>7</sup>.

The traditional, and still current, method is to use steel tiebars, usually fabricated from flat or round bar construction and bolted to the rail webs at suitable intervals, typically every 2m on straight track, 1.5m or less on curves of less than 150m radius.

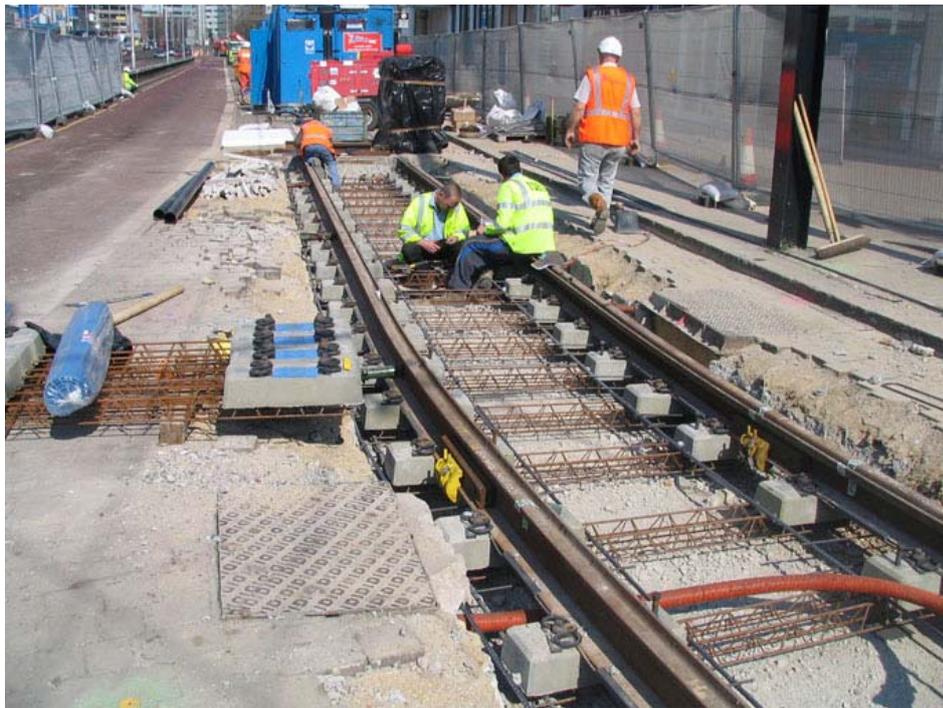
This method also has the advantage, useful during maintenance activities, that the track can remain safely usable, albeit under restriction, even without the underlying concrete in place, with the rails simply supported on packing blocks.

A modern alternative, adapted from the methods used to construct the slab tracks used for high speed railway lines, is to attach the rails to precast concrete sleepers, or sleeper blocks, which after being lined and levelled are then embedded in the mass concrete foundation slab. To facilitate this, these sleepers are only partially cast so that their internal reinforcement cage is exposed and becomes embedded in the slab. Such systems have the benefit of positively holding the rails to gauge and restraining them against twisting under wheel steering forces on curves. Gauge tiebars are not required, the function being provided by the sleepers, and replacement is considerably simplified by comparison with the polymer embedded track systems, rails can be readily unclipped from the sleepers to facilitate replacement.

<sup>7</sup> On typical street tramway curves of <50m radius, these can be very considerable, in the order of 30-40kN.



*Twinblock concrete sleepers for street track in Grenoble E Hollis*



*Rheda City precast sleepers in use on a renewal in Croydon*

*J Snowden*

Irrespective of the method used, it is beneficial to place a layer of resilient material between the rail foot and the concrete in order to provide some cushioning against vibration transmission and to avoid the fretting action between the rail and the concrete which would otherwise occur under repeated loading.



***New track in The Hague, showing (nearest) expanding foam injected into the gap between the rail and the concrete.***

o. **Rail hardness**

Rails are available in both normal (700 / R200 grade) and heat-treated (900 / R260\*\* grade<sup>8</sup>) or alloy steels (typically 1100 / R340\*\* grade), the latter intended to provide greater wear resistance and thus longer life. Whilst there are some attractions to using harder rails on curves that are expected to receive heavy wear, their life is still significantly less than the same rails on plain track.

As an alternative to the considerable cost of replacing such rails, it has become a common practice to rebuild the side and/or head wear by welding. Whilst readily practicable on normal R200 grade rail, careful control of the welding process is required for the harder rails if the risk of cracking is to be avoided. This requires either preheating or very careful control of the welding process, usually by automated techniques, to ensure that cracks do not develop in the heat affected zones behind the welds and subsequently propagate through the rail section. It should be borne in mind that, because the rail is fully embedded, it is not always possible to monitor the progress of any crack beneath the visible surface of the rail head.

It must also be borne in mind that excessive rises in the rail temperature can exceed the safe limits for the polymer, causing both degeneration and exposing workers to hazardous fumes and fire risk.

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<sup>8</sup> BS EN 14811 lists steel grades as both Rxxx & RxxxGHT, the latter designating heat treated steels.



***Welded repair to keeper flange - Fleetwood***

For this reason it is the practice of some of the well-established European systems that normal (700 / R200) grade rail is used in the high wear areas, if not throughout the system. Once the initial wear has taken place, it is made good by welding using hard wearing materials, thus obtaining the wear characteristics of the higher grade steels but retaining the advantages of the weldability of the normal rail.

As these wear, the hard facings can be renewed several times before wholesale renewal of the rail becomes necessary. As a rule, the costs of replacement normally outweigh the costs of repair by welding many times over, reducing the life cycle cost.

p. **Wheel hardness versus rail hardness**

Consideration must also be given to the relative hardnesses of both the rail and the vehicle tyres, particularly in areas where sliding (as against rolling) action takes place. This normally occurs in the curves, and experience has been that there should be a distinct difference between the hardness of the two components; empirical evidence would indicate that where the rail and tyre are of comparable hardness significant roughening of the surfaces can occur, resulting in an increased risk of derailment, as well as higher wear.

q. **Surface reinstatement**

The level of any surfacing adjacent to the rail head should be such that the tram wheels, particularly in a fully worn condition, do not run on the surfacing such as to cause damage, as well as unnecessary noise and vibration. Where possible, the surfacing should be kept below the top of the rail head, subject to any limitations as regards the safety of other road users and/or pedestrians.

Depending upon whether the finished track is in the carriageway (shared) or segregated, the surface between and outside of the rails is built up using a combination of mass concrete and normal bituminous street surfacing materials, sand- or stone-bedded blockwork, crushed stone or, if appropriate, earth and grass.

Whichever method is chosen, it is necessary to consider how it will be maintained in the future, both from the point of view of reinstatement following maintenance and the issues of controlling the height of the rail head relative to the road surface. Experience with bituminous materials has shown that these can be difficult to lay accurately and with the proper consolidation over relatively narrow widths, such as alongside the outside of the rails and in turnouts.

Further, such materials are by their nature susceptible to flow under repeated loadings by road vehicles following the same track. This can result in the tram rail becoming significantly proud of the adjacent surfacing and vice versa. Buses present special difficulties in this regard as a result of weight and suspension characteristics, particularly where they routinely wait in shared tram and bus lanes, such as at traffic signals and stops.

Alternatively, there are foreseeable advantages to reinstating the road surface around the rails using concrete blocks<sup>9</sup>, in that these can relatively easily be adjusted to be level with the rails when laid and subsequently as the rails wear. It is a technique used on various tramways in Europe with no apparent problems, with slabs typically ranging from 400mm square to the full width of the “four-foot” and 2-2.5m in length. The technique is essentially only a modern day equivalent of the granite and/or wooden setts used on the first generation tramways.



***An example of street surface reinstatement using concrete blocks, with hot poured sealant between blocks and rail***

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<sup>9</sup> Not to be confused with the small concrete paving bricks used in, typically, pedestrian and non-trafficked areas.



***Rail concreted in place***

***M Howard***

A third option, subject to the approval of the street authority, is to surface using concrete. This should, as with any concrete used to infill between the top of the slab and any bituminous surfacing, be of a lower strength such that it can easily be excavated as and when it is necessary to access the rails and their fixings. This does, however, carry the disadvantage that the edges of the concrete next to the rail edge sealant are liable to crumble over time.

For track which is not shared with road vehicles, the space in between the rails, and between the rails and the edges of the track can be infilled with a variety of materials, ranging from crushed stone to earth sown with grass, or compacted sand on which concrete or stone blockwork is set. Where the infill material is porous, appropriate and adequate drainage should be provided to the section between the rails, or between tracks, by the inclusion of drains in the foundation slab at the time of construction.



***Street and segregated track in Montpellier***

***E Hollis***

r. **Drainage**

In addition to any provision made for the drainage of surface water from the street as a whole, arrangements should also be made to drain water from the rail grooves at appropriate intervals and/or locations. These should be on straight track as far as is possible and should not, unless there is no other option, be located in curves of less than 50m radius. The drainage slots should be of sufficient size not to become easily blocked by street detritus and/or sand dropped by trams, and should be formed by machining, with generous radii at the corners in order to avoid stress concentrations under lateral loadings.



*An example of traditional drain boxes for grooved rail prior to concreting in. J Snowdon*

Examples of typical detritus that will end up in rail drainage slots include -

- food remains from fast food outlets, typically packaging and chicken bones
- disposable pens, of the sort found in catalogue stores and betting shops
- coffee stirrers
- plastic drinks bottles and cans, which lodge in the groove and become crushed

all of which may not necessarily block the drain slot by themselves, but which, once lodged, then provide sufficient obstruction for other detritus, including tram sand, to collect and ultimately block the slot.

It is also common practice on established tramways to install a continuous drain along the centre line of each track, into which both the rails, the top of the track slab, if covered by a porous material eg grass or stone, and point mechanism boxes can drain. This is in turn drained to the highway drainage system at suitable intervals, thereby minimising the number of under-rail pipe connections needed. It also facilitates the use of transverse drainage gulleys between the rails in order to drain that part of the highway, which can otherwise tend to act as a wide channel.



***Transverse drain in Montpellier E Hollis***

Drainage water should be led into purpose made drain boxes bolted to the rail web before being conducted into the street drainage system. The size, number and capacity of the drainage boxes at any location should be sufficient to ensure effective drainage under all reasonable conditions of rainfall and maintenance.

These boxes should incorporate a silt trap, sufficient to allow for both normal detritus and the additional sand which may be dropped by the trams, as well as facilities for rodding and/or flushing through the drainage connections leading from them. Connections to the street drainage system should be of adequate size, having regard to the fact that the rail grooves often act as drainage channels for a significantly greater area than the street in the immediate vicinity.