For Rail Engineer

Embedded LR55 track

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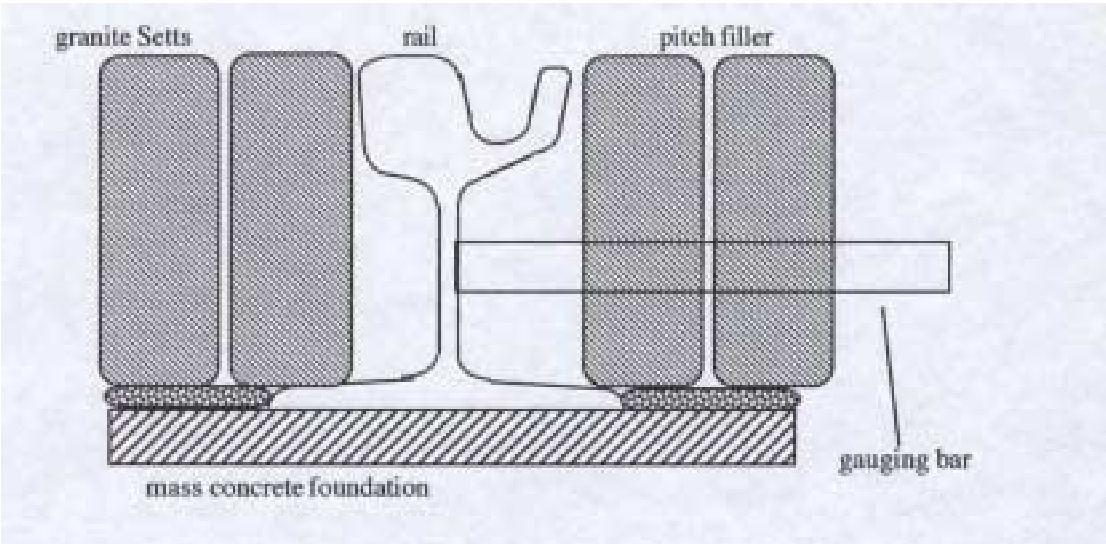
Introduction

An earlier article described the new P50T3 OHL system, which promises to make electrification more cost effective, and therefore open the opportunities for secondary rail lines to be electrified. This might become an important consideration as the price of oil continues to rise faster than inflation. The new OHL system can also be applied to reduce the cost of new light rail and tramway systems. In the UK no new system is being funded by the Government, due to poor value for money.

In terms of the infrastructure costs, the largest element is that for the tracks, especially if these are embedded in highway pavements, where there are issues of traffic management, under street utilities and access for frontages' premises. In over 100 years of street track installation, the technology has hardly changed being based on grooved Vignoles rails (Fig. 1) , even though the development of road pavements has been significant. Road pavements are now capable of carrying 80tonne goods vehicles at 80 mph. Tramway track design still seems to be based on the premise of 19th century dirt roads. The LR55 track is the first serious review of street track design for over 100 years and is the first to offer an integrated approach.

Fig. 1 Grooved Vignoles tramway track detail



Most city roads have flexible pavements, made up of layers of aggregate bound with tar, bitumen or asphalt. The uppermost (wearing course) layer is usually about 100mm thick and is the most dense with medium soft stone to provide high skid resistance over its design life. The high density is needed to support typically 10tonne axle loads and the abrasion of the tyres of heavy goods vehicles.

Under the wearing course is the main structural element of the pavement, the bearing course, which is usually about 300mm thick. This distributes the high stress loads from the wearing course. The bearing course is made up of larger aggregate in a less dense construction.

The final layer (the base course) is of variable thickness, between 200 - 400mm, depending on the strength of the ground on which it rests. The science of road construction is universally applied, and with the Californian Bearing Ratio (CBR), the design is well understood for robust flexible pavements, for given traffic flows, with known volumes of heavy axles for a predetermined life before fatigue replaces elastic with plastic behaviour.
In terms of new street tramways it makes sense therefore to work with the strength of existing road pavements, rather than destroy them, which is the approach of existing tramway track design and part of the reason for high track costs.

Under street utilities

Since the 19th century the space under city streets has been filled with utility plant; sewers, water pipes, electric cables, telecomms, gas pipes, fibre optic cables etc.. Utility companies require access to their plant for maintenance and repair, although designs are usually based on robust installations needing a minimum of access. There are however emergencies.

Existing tramway tracks are usually installed with a foundation concrete slab typically 6000mm wide and 500mm deep (Fig 2), which intrudes into the space occupied by utilities. The slab also sterilises access to deeper plant. For this reason a significant part of track costs in the UK has been the relocation of utility plant, assuming that space can be found in parallel streets, and the reconnection of services. At a recent public inquiry into the Merseytram project, the promoter justified the high cost of utility relocation as it would mean that the tramway operations would not be disrupted by utility repairs or maintenance. If this is the justification for relocation, then promoters should pay 100% of the costs, rather than the present 92% ? The utilities would prefer to leave their working plant in situ, as long as they have access.

Fig. 2 Manchester, High Street

LR55 system

The LR55 embedded track system exploits the strength and durability of urban road pavements. The LR55 system has a shallow construction and maintains access to under street utility plant. The main element of the LR55 system is a top supported rail (Fig 3), which has a running surface and groove compatible with all existing rail and wheel profiles. Transition rails between LR55 and all existing rail profiles are available. (Fig. 4) The LR55 track can carry both light and heavy rail vehicles and has been tested up to 80tonne axle loads.

Fig. 3 Cross section of LR55 rail

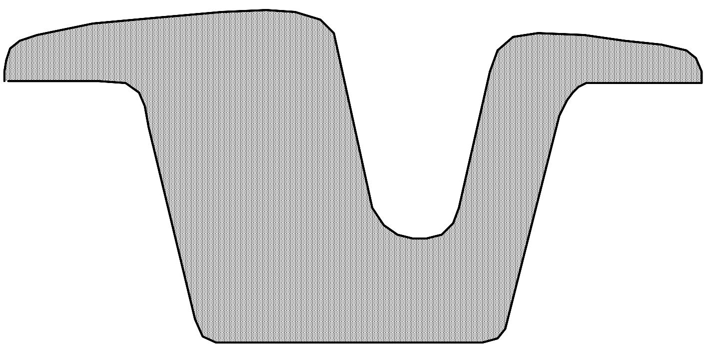
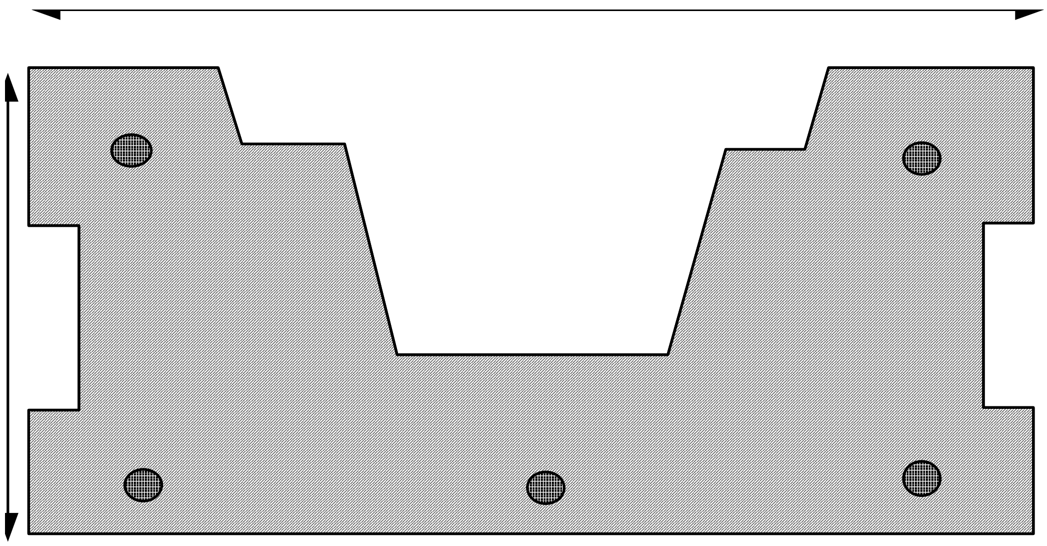


Fig. 4 Transition LR55-80lb

The wheel load is transferred by horizontal flanges at the upper surface. Typically the flange on the rail head side carries about 60% of the wheel load, while the flange on the groove side carries about 35%, and the rail base the remainder. The rail flanges rest on the top side of a pre cast foundation trough, which is 380mm wide and 180mm deep (Fig. 5). The foundation trough transmits the wheel load into the pavement bearing course at a lower pressure than would be experienced from a passing HGV tyre.

Fig. 5 Cross section of LR55 foundation trough with pre-stress tendons



The foundation trough sits on a compacted bedding layer about 20mm deep with a CBR of 10%. The trough is bound into the pavement by asphaltic sand or a similar compound. The LR55 rail is fixed into the trough with a polyurethane grout. This has both bonding and resilient qualities, which significantly reduces low frequency vibrations by about 30dB, and noise by 10dB. Because the LR55 rail is continuously supported, a smoother ride is provided for rail vehicles (and passengers), and the formation of rail head corrugations is significantly reduced.

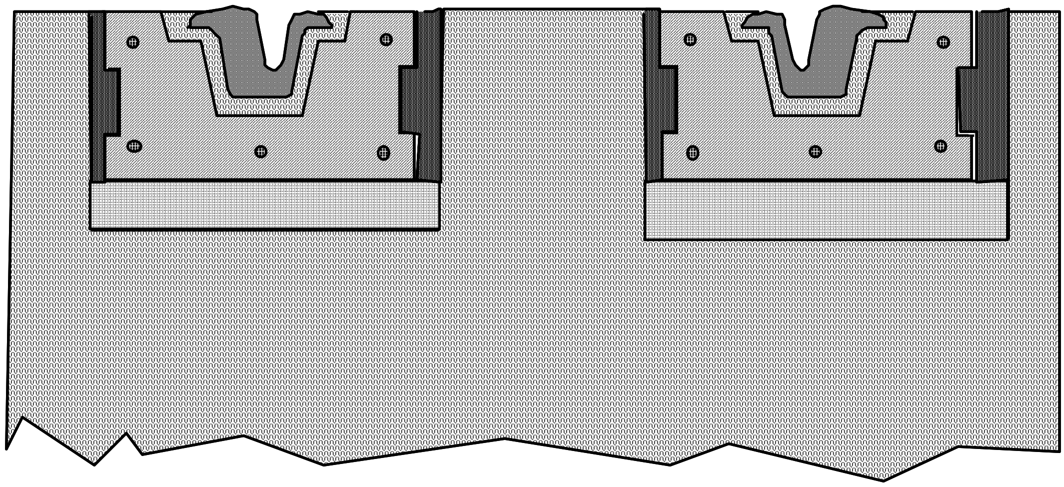
LR55 installation

A trial section of LR55 was installed in March 1996 in the South Yorkshire Supertramway, where it remains without having had any maintenance subsequently. It replaced conventional 80lb rails,(Fig. 6) which failed within a year of installation. For LR55 installation the first stage is a survey of the highway pavements to ensure that there are no failures, either from subsidence or fatigue where the elastic limit has been exceeded. In this case a conventional pavement repair, which can be undertaken by many road builders at competitive costs. The next stage is to determine in what order to install the rails. Track can be installed one rail at a time, with the first rail used as a datum. This means that traffic management problems are reduced, and access for frontages is easier to maintain.

Fig.6 LR55 installation on South Yorkshire Supertramway

A single pass excavator creates a trench 400mm wide and 200mm deep. Pre cast concrete foundation troughs in 6m lengths for straight tracks, are laid directly onto a bedding layer compacted to line and level. The troughs are initially linked together by ‘hairpins’ between adjacent ends. The troughs are then sealed into the pavement, although their mass (300kg) means that they become an important part of the road structure. The LR55 rail, welded into long strings, is laid in the trough, either using wedges of pre-cured PU grout, or clamp stands, to achieve line and level. With the achievement of line and level as a two stage process, much higher precision ought to be achieved than with sleepered track. The final bonding grout is then injected under the rail to ensure full adhesion between the rail and trough, and between troughs. The exposed surface of the PU grout can be sprinkled with an aggregate to improve skid resistance for road vehicles using the same alignment.

Fig. 7 LR55 installed in highway pavement



Troughs are laid in advance of the rails and temporarily plated over until the rails are ready to install. By this means a complete installation of four rails for a double track can be completed at the rate of about 400m or more per week. By the use of several track installation teams a 20km route can be completed in less than 6 months, if there are no road traffic management issues.

Only those utilities physically in or across the installation trenches need to be relocated. Usually this normally only means magnetic loop detectors for traffic signals, and with radar detectors do not need replacing. Other utilities are usually 400mm or deeper, and access to them is possible between rails. The track is self supporting over trenches 1m wide, allowing utility companies to lay new plant across tracks without disrupting services. It may also be possible with the co-operation of the utilities to lay empty ducts across the street when tracks are being installed, so that for any future work, cables, pipes etc. can be pulled through without having to disturb the tracks.

Testing the LR55

The long running field test since 1996 in Sheffield is more than ample evidence of the robustness and durability of the LR55 system. Prior to that there was a battery of laboratory and field testing. This included the cyclic loading under water with a replicated 200million main line axles loads (25tonnes) (Fig.8). This is about 30 years of a high frequency service, without debonding or failure. Static tests over 1m wide voids with 80 tonne axle loads caused the concrete troughs to fail in tension whilst the bonding remained intact. A pull out test demonstrated that the bonding is several orders of magnitude stronger than forces due to thermal expansion. A 29kN force on a 1 metre sample was required to fail the trough in tension.

Fig. 8 Pressure into road pavement with distance from 25tonne axle

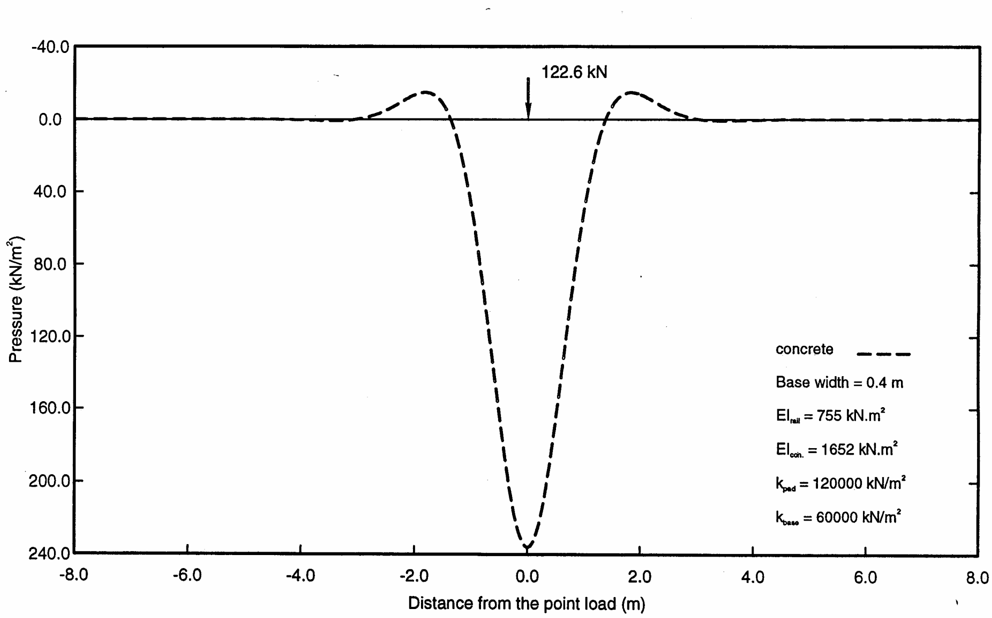


Fig. (1): Pressure distribution on the base of the track due to single wheel of 122.6 kN.

A length of LR55 track was laid in the throat of Rotherham Bus Station (Fig.9), where over 2 years, 2.5million bus axles passed, crossed and turned, representing about 30 years in a typical main city street. The final test was the length laid in the South Yorkshire Supertramway to replace a failed 80lb section. In spite of carrying 100HGV and about 400 LRVs per day, the wear rate suggests that it will have at least a 30year life. (Fig.10)

Fig.9 LR55 installed in throat of Rotherham Bus Station

Fig. 10 HGV crosses LR55 installation

Other Applications

The LR55 has been designed to support heavy rail axle loadings, and tested up to 80tonne axles without failure. Whilst the LR55 is presently more expensive than UI60 on concrete sleepers, for special applications LR55 offers considerable advantages, including cost savings. The most important of these is being able to increase tunnel loading gauge without having to excavate the invert. For traditional masonry arch tunnels, LR55 can increase loading gauge headroom by at least 300mm. This is achieved by the removal of the ballast down to the invert, the laying of a type one highway bed, at least 50mm thick. On this the LR55 troughs are laid to gauge, using stainless steel gauge bars. The rails are then bonded into the troughs. Finally ballast is added to rail level between the troughs, which locates the track in the tunnel. Most of these processes can be undertaken by competent road contractors.

Increasing the loading gauge will allow both OHL electrification and the carriage of supercube 10ft 6in high maritime containers. It would also allow double deck passenger trains, as a low cost way to increase line capacity. Tube tunnels constrained by their diameter can also benefit from LR55 enlarging the loading gauge, allowing both higher and wider trains. In both cases the LR55 will leave a level tunnel floor allowing road vehicles to be used for maintenance, reducing costs and simplifying procedures. Emergency evacuation will be faster and safer, as ambulances are able to drive in and passengers walk out safely.

Fig. 11 Arch tunnel loading gauge enhancement with LR55

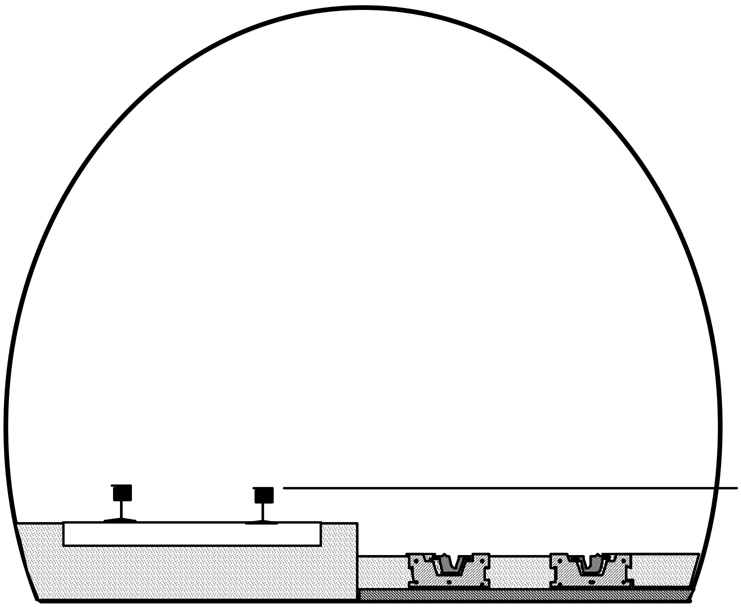
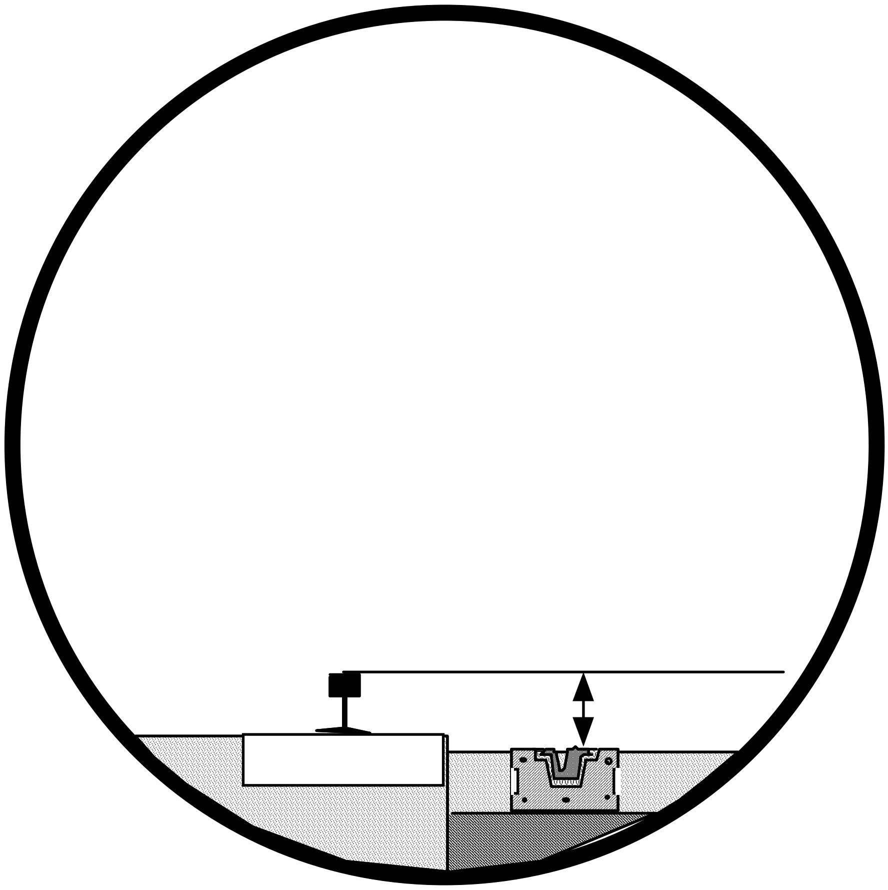


Fig.12 Tube tunnel loading gauge enhancement



LR55 can also be used for large areas shared between road and rail vehicles like docksides, road/rail freight interchanges, where the shallow depth of the LR55 is compatible with a concrete pavement suitable for heavy goods vehicles.

Conclusion

The LR55 track has been comprehensively tested, offers affordable and less disruptive tramway tracks for crowded city streets. LR55 offers an economic and rapid method to increase tunnel loading gauge without the need for structural rebuilding. The LR55 track will carry all existing rail wheel profiles and axle loads, and can carry the heaviest road vehicle axles, which do most damage to city streets. It represents a radical departure from the Vignoles rail which has formed the majority of tracks for the last 100 years, and works with the strength and structure of highway pavements, being the first integrated embedded track design.