Experiences after one year of RailPAVE and IVES in Australia

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Asphalt has been formally used as an integral pavement component of a non-ballasted rail track for the first time in Australia. Railpave Asphalt was incorporated into an engineered track system called IVES on a section of the track utilised for heavy haul rail transport in Branxton, New South Wales, Australia. IVES is an outcome of the latest development in non-ballasted track technology. It stands for Intelligent, Versatile, Efficient and Solid. These attributes are embodied in its integrated form which is based on an analysis that aims to optimise advantages and eliminates disadvantages in the various types of slab track systems that have been proven and honed in previous long term use. Another target is to achieve cost optimisation and make it more feasible for a wide range of applications, both: for known applications like high-speed tracks and also as a valued alternative technology to ballasted track in common lines with lower speeds. This could be achieved by applying a holistic approach during the selection and implementation of track components like Railpave asphalt and IVES sleepers, together with a range of modified work methods.

Railpave and IVES have been installed in ARTC's Hunter Valley Network with completion achieved in November 2017. During multiple shutdowns ranging between 58 hrs to 96 hrs a variety of components were installed to introduce a new track slab system. Railpave as part of the base layer and IVES as part of the track slab underwent extensive testing followed by a detailed approval process with ARTC.

For the Branxton project, the sophisticated track system is intended to provide the level of precision required to continuously and accurately weigh axle loads. The installation will also be instrumented to monitor rolling stock in transit and telegraph imminent maintenance needs earlier than current processes so that down time can be significantly reduced. Railpave asphalt was designed to meet the structural requirements of the track-bed and is positioned under the IVES concrete 'sleeper-slabs' to which rails are fastened. Axle loadings of 30 tonnes are applied and the system must provide an alternative to ballasted track that is much more durable and stable to facilitate accurate operation of the instrumentation. The project was delivered in stages so that works could be delivered within the nominated track shutdown periods. This made asphalt a more suitable construction material due to its early strength and accessibility almost immediately after placing and rolling.

One year after the completed installation the lessons learnt and experiences of constructing and monitoring a new track slab system in Australia will be discussed in this paper.

1 INTRODUCTION

Classic ballasted track has been the most common method of construction of railway tracks for almost 200 years. The reason for its success is simple; initially the main components for track construction (rails, sleepers, ballasted bed) were simple, readily available and relatively low priced. The laying technique needed to be uncomplicated to cover the huge demand for new track construction to be delivered with the support of many unskilled labourers in the early days. These factors drove this construction methodology which then developed efficiencies through some mechanised installation tools and techniques over time. Also, it has met and still meets the technical and operational requirements of the permanent way.

The post-war period saw the advancement of high speed trains and with this the demand on the railway superstructure increased significantly. The so called “floating support” of the ballasted superstructure had already reached its technical and economic limits in some areas. For this reason a variety of concepts for non-ballasted track designs with a fixed bearing have been recently developed. The preferred material for the track slab systems as they developed has been concrete (pre-cast elements or cast insitu). Other forms of ballastless track have been constructed with asphalt. In more recent times asphalt has been chosen as part of the structural support layer for track slab and ballasted systems due to expedience, and, cost effectiveness where ballast is a scarce resource. A bound sub-ballast layer can also reduce fouling and erosion thereby reducing maintenance and preserving natural resources. .

The Rhomberg Sersa Rail Group has many years of experience undertaking the conceptual, theoretical and practical installation and maintenance of different types of slab track. Based on this, the Rhomberg Sersa Rail Group has developed a new slab track system called **IVES** (**I**ntelligent, **V**ersatile, **E**fficient, **S**olid).

The development of the IVES slab track system was based on the knowledge and experience gained in the installation of track slab systems. These experiences include but are not limited to operating characteristics and installation methodologies of many ballastless superstructures. The objectives in the development of the new slab track system was to combine as many proven features as possible of existing systems while engineering out known problems and weaknesses of the other systems through elimination or improvement.

Support layer design plays an important role in successful performance of slab track system. In a merger of two technologies Boral recently developed Railpave asphalt to comply with the requirements of slab track systems.

The opportunity to use IVES and Railpave for the first time in Australia arose on a heavy-freight, mine haul-line under the supervision of ARTC in Branxton NSW in late 2017. The ambition was to provide a highly engineered track system to facilitate a weigh in motion system and rolling stock monitoring technology with minimum track downtime.

Figure 1: ARTC UP and DN lines at Branxton, NSW

The project was also an opportunity to offer proof of concept in the field that systems such as IVES and Railpave asphalt are very viable alternatives to network owners like ARTC and mine operators.

Figure 2: Non-ballasted track IVES

The central idea was to achieve technical and economic optimisation that not only reduces the cost of "usual" applications of slab track (high speed sections in highly developed countries) but also offers a much wider use of this technology as an alternative to the ballasted track by applying a holistic concept for the use of components, materials and work methods.

2 THE STRUCTURE OF IVES

The structure of a basic IVES track consists of a base layer, lateral pre-cast bearing elements and rail fastenings.

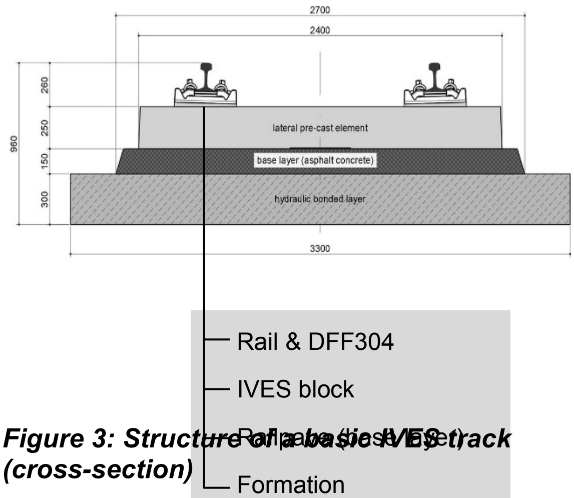

Figure 3: Structure of a basic IVES track (cross-section)

2.1 Base Layer

The base layer is laid on the substructure, such as a capping layer or tunnel floor. This base layer is usually made of a continuously built asphalt surface, like Railpave. In certain cases where the sub-structure has certain stability characteristics, the base layer can also consist of in situ concrete, provided corresponding installation methods are also available.

The advantage of applying a base layer, in comparison to some other slab track systems, is the removal of reliance of base layer production accuracy on the outcome of the geometry of the finished track. Asphalt also provides the expedience of not requiring extended curing periods and ability to rapidly access the Railpave platform to complete the rest of the track construction with minimum shutdown time. Although installed according to the bottom-up principle, latitude can be exercised with relatively large manufacturing tolerances for this layer. This type of base layer installation is the norm in the road construction methodology. In track construction, Railpave optimises asphalt mix for rail loading while taking into account any environmental conditions.

Figure 4: compaction of 2nd asphalt layer

Figure 5 completed 2nd asphalt layer with ballasted track adjacent

Figure 6: Condition of asphalt layer

2.2 Lateral Pre-Cast Bearing Elements

The lateral pre-cast elements are prefabricated, almost sleeper-like and pre-stressed or reinforced (depending on project requirements). Their main function is to bear the loads of the rail supporting points and to uniformly distribute the load forces onto the base layer.

The bottom of the lateral structural element is equipped with a soft compensating layer (geofabric material) which adjusts any unevenness of the base layer. Pockets for the anchoring of the rail fastenings are placed on the top side. These are large enough to allow for any adjustments in height and position of the rail fastenings.

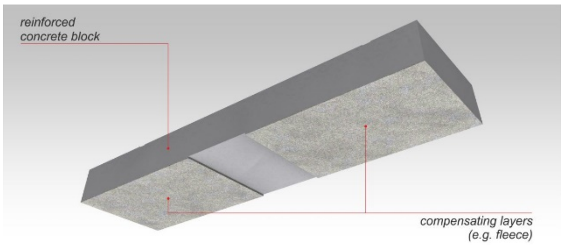

Figure 7: Structure of a lateral pre-cast element (bottom view)

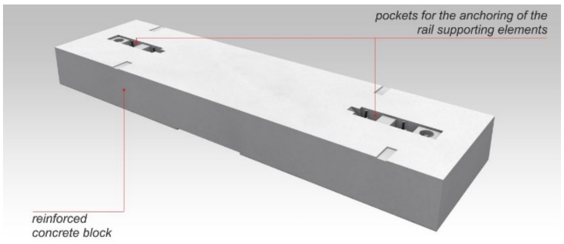

Figure 8: Structure of a lateral pre-cast element (top view)

The lateral pre-cast elements are typically arranged with gaps of 30 mm between them ensuring satisfactory cross drainage. The largely flat surface of the lateral structural elements when placed one after another creates the trafficable surface. This surface can be used by road bound vehicles during the installation stage.

Unlike the prefabricated elements of most other slab track types, the lateral pre-cast elements of IVES don't have to be made with high precision because their dimensional accuracy has no direct influence on the geometric quality of the final track. The result is that these pre-cast elements can be produced by any supplier, who has the ability to ensure the usual tolerances for manufacturing precast concrete elements (+/- 6 mm) together with an appropriate concrete quality / strength category. The compliance with extremely high accuracy requirements, which is typically reserved for highly qualified sleeper manufacturers, is no longer necessary.

2.3 Rail Fastenings

The rail fastenings correspond largely in their properties to current so-called direct fastenings. They will be precisely aligned within the lateral pre-cast elements of IVES according to the top-down principle and then cast in using a high strength grout material. The rail fastenings anchor into the prepared pockets of the (roughly aligned) lateral pre-cast elements. A single rail fastening, manufactured by Vossloh Fastenings, consists of:

- 2 plastic dowels
- 2 dowel screws with washers
- 1 base plate with grout channels
- 1 elastic pad
- 1 base plate
- 1 rail pad
- 2 angled guide plates
- 2 tension clamps
- optionally 1 or more height adjustment plates

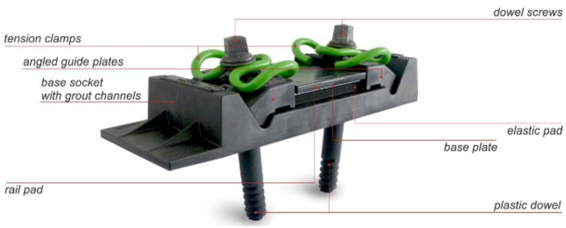

Figure 9: Structure of the rail fastening system DFF304 by Vossloh

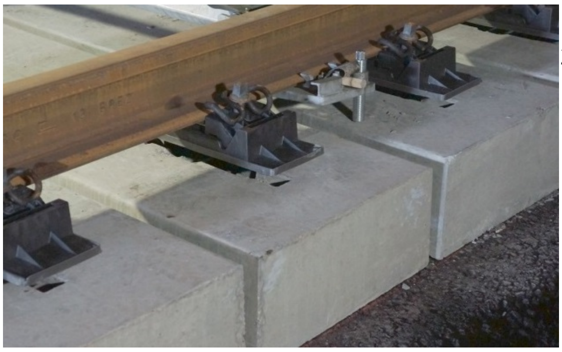

Figure 10: Rail fastenings on the pre-cast elements (before grouting)

The main feature of the rail fastening system is the base plate. In the base plate integrated special opening channels ensure a simple, clean, fast and reliable grouting of the rail fastenings even in extremely super-elevated track sections.

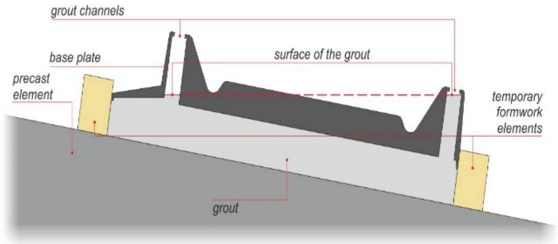

Figure 11: Design of filling device within the base plate

The plastic dowels used include dowel screws and pockets for the anchoring of the rail fastenings, and are the result of a thorough development process. The main weakness of most slab track systems with grouted in-situ rail fastenings is the anchoring quality of dowels in the slab track (if pull-out strength is too low). The slab track system IVES achieves greater pull-out strengths compared even to some standard concrete sleepers. In contrast to existing slab track systems, these high pull-out values are reliable and especially easy to deliver on site.

This rail fastening system was designed specifically for the IVES slab track system. During development all characteristics of classical direct fastenings were considered, analysed and ultimately replicated, so the rail fastenings can also be used as adequate single supporting points / direct fastenings.

The other parts of the rail fastening system (elastic pad, base plate, rail pad, angled guided plates and tension clamps) are established elements of the existing Vossloh 304 rail fastening system.

2.4 Grouting of the Rail Fastenings

The rail fastenings are cast in using grout at the end of the construction process, immediately after the exact track geometry is established. Typically a high-quality, high-strength cementitious grout is used. This application is done with ease and will reach its full nominal strength within 48 hours. This allows, unlike many other slab track systems, the first full loading of the track at a very early and clearly defined time. A project specific grout mix can be specified to reduce curing times if required.

3 RAILPAVE DESIGN

The base layer of the IVES system at Branxton is composed of Railpave Asphalt which has attributes optimised for the conditions.

Asphalt has been used as a structural element of the rail-bed in several countries. It must be designed to achieve a durable, moisture resistant layer that is workable and easy to compact so that accurate control of finish level of the track is possible. The asphalt must not lose shape during years in service because this can increase track maintenance costs.

A mix was designed using local New South Wales aggregates and specialised binder. Mineral constituents like aggregates and filler were, as a minimum, required to have properties conforming to the local road authority specification. Consideration had to be given to balancing the choice of the maximum aggregate size, mineral constituent grading and bituminous binder content to optimise performance. Asphalt mix performance was required to exceed minimum thresholds for rutting, stiffness, moisture susceptibility and flexural fatigue life (cyclical bending) to qualify for the Branxton rail project. Special attention was paid to the temperature regime at which performance values were assessed because of the consistent high ambient temperatures between 30C and 40C during summer which can result in track-bed temperatures greater than 50C. Additional specialised performance tests to simulate rail loading have been carried out to prove the suitability of the mix once in service.

Mix design needs to accommodate the coring of dowel holes in the final (third) asphalt layer within 4 hours of placement so that completion deadlines can be met.

3.1 Railpave Asphalt Development

To simulate static loading of stationary railcars in stockyards over extended periods of time or the impact of rolling stock dynamic loads on asphalt, a constant static load test was adopted. Existing methods of measuring deformation in asphalt mixes for road applications are unable to apply sufficiently high loads to simulate the typical rail axle loads of 30 tonne experienced on the Branxton line. Therefore the Rail Asphalt Load Simulation Test was used to apply a load of 22.5 kN so that asphalt performance under these rail loading conditions could be assessed.

The load was applied for a period of 48 hours and the extent of permanent deformation was measured at each point in a grid. Deformation of less than 5 mm was considered acceptable for Railpave.

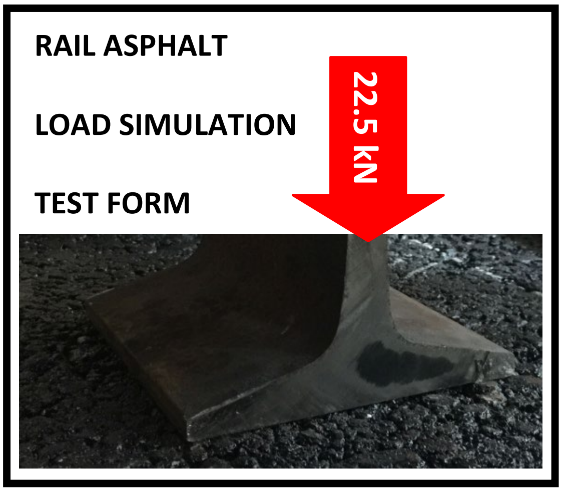

Figure 12: Rail Asphalt Load Simulation Test

4 INSTALLATION PROCESS

In addition to the design of the system structure the IVES product development also refined installation processes to deliver to clients cost-efficiencies, providing IVES with its competitive advantage in the track slab market. One of the core ideas is to combine the simplicity, robustness and speed of the bottom-up systems using pre-cast elements with the high precision of the top-down systems using in-situ concrete. IVES requires precision only for the top-down elements, where it is really important; the larger portion of work for the construction of base layers is done with less accuracy but more rapidly using the bottom-up principle without impacting the quality of the final track product. The final alignment and the fixation of rails can be done with ease but with the utmost care applying the top-down principle. The following text describes the replacement methodology from a ballasted track to the IVES system over multiple short term possessions.

4.1 Formation reconditioning (if required) – 1st Shutdown (58 hrs)

After extensive geotechnical investigations including test pits up to 3.6m deep, associated laboratory tests and finite element modelling using the program PLAXIS 2D, a reconstruction of the existing formation was recommended in order to comply with the tolerable settlement criteria of maximum 5mm.

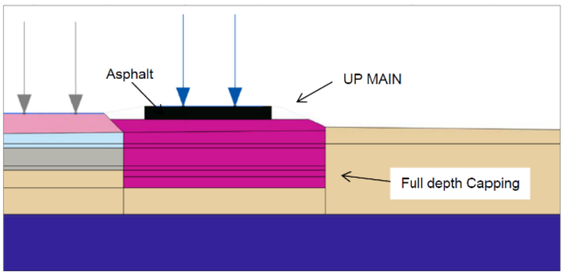

Figure 13: Sample PLAXIS model of reconstructed formation with asphalt and IVES system.

It should be noted that every track slab system requires a formation that eliminates the risk of differential settlement in order to fully benefit from the track slab advantages. In case of the Branxton project and the high-speed weighbridge application, the differential settlement free formation was of utmost importance. The reconditioning was completed over a 58hrs period, up to 2.1m deep and 220m long. In addition, the adjacent 'DOWN' track was also reconditioned during the same possession with up to 1.4m deep.

Figure 14: Excavation for double track reconditioning works

4.2 Installation of abutments for transition VTRAS – 2nd shutdown (62 hrs)

To provide a reliable transition between ballasted track and IVES (slab track) Rhomberg's own transition system VTRAS was installed at either end of the IVES system. The VTRAS system – like most other transition systems – requires an abutment structure, which is ultimately combined with the substructure of the IVES. Due to the short possession, a world's first pre-cast VTRAS abutment solution had been designed and installed. Each abutment consist of 2 pre-cast elements, embedded in cementitious grout.

Figure 15: Placement of pre-cast abutment elements

Figure 16: Insitu grout pouring

On top of the abutment sits the VTRAS structure, a steel structure with padded plates reflecting the concrete sleeper footprint. The sleepers will be placed directly on the VTRAS pads, embedded in ballast, followed by compaction of ballast (e.g. using hi-rail excavator and tamping had attachment).

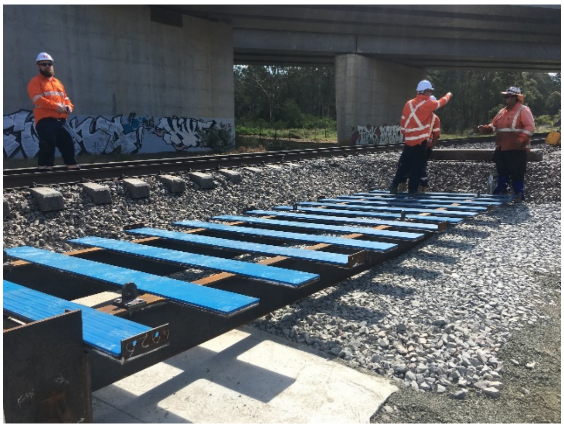

Figure 17: VTRAS support structure prior to ballast placing

The VTRAS system, its details and advantages compared to other transition systems will not be discussed any further in this paper.

4.3 Installation of base asphalt layers – 3rd shutdown (72 hrs)

This shutdown is the first of two shutdowns to install the IVES system incl. RailPave layers. In consultation with ARTC and due to the short track possessions, the IVES install works were undertaken over two scheduled regular ARTC possessions.

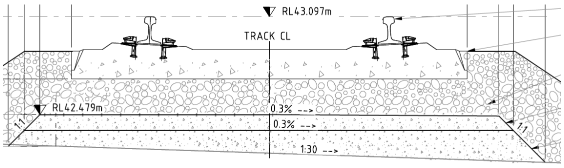

Figure 18: Cross section of completed track after 3rd shutdown, top to bottom: rails and sleeper, bottom ballast, 2 x Railpave layers

The first possession included the following steps:

a) Placement of asphalt compensation layer to address the difference of 1in30 cross fall of top of capping layer to 1in300 cross fall of top of compensation layer.
b) Placement of 1st layer asphalt RailPAVE (approx. 100mm thick).
c) Placement of 2nd layer asphalt RailPAVE (approx. 100mm thick).
d) Re-instatement of ballasted track on top of asphalt layer. A minimum ballast depth of 200mm between top of 2nd asphalt layer and bottom of concrete sleeper had to be maintained. In order to protect the asphalt layer against imprints from the ballast under load a geofabric had been placed on top of the asphalt layer. It has to be noted that no ballast rock imprints were noticed on the asphalt layer once geofabric was removed a month later.

Figure 19: Placement 1st asphalt layer RailPAVE with road finisher

Figure 20: Asphalt layer joining pre-cast VTRAS abutment elements

4.4 Installation of top asphalt layer and IVES – 4th shutdown (96 hrs)

This shutdown is the second and final of two shutdowns to install the IVES system incl. final Railpave layer. The works included the following tasks:

a) Removal of ballasted track and geofabric and stockpile components on site.
b) Placement of 3rd layer asphalt RailPAVE to final tolerances (approx. 100mm thick, with top of asphalt tolerances +10/-20mm and 0.3% crossfall)
c) Installation of IVES, DFF304 fastenings, rails and weighbridge rail components. This step included the installation of dowels in the asphalt layer to allow for lateral stabilisation of IVES, final adjustment of track panels using Rhomberg Fine Adjustment (RhoFAS) equipment and survey trolley HERGIE, followed by pouring of grout into the DFF304 baseplates. Curing of epoxy grout was recommended to be 6 hrs prior to open for 30T axle load traffic.
d) Install VTRAS transition steel structure and compact ballast.

Figure 21: Placement of IVES elements

Figure 22: Final track adjustment with RhoFAS and HERGIE prior to grout pouring

Figure 23: Completed IVES with customised spacing to suit the weighbridge transducer sets.

5 ASPHALT CONSIDERATIONS

Previously, in many circumstances, the base layer has consisted of road asphalt mix and has not been optimised for use in the rail sector and this means that a better engineering approach could be found. Just as there are different asphalt mixes for heavy road traffic, shipping container yards and airport runways, so there must be an engineered asphalt for rail ballastless track applications. Container handling vehicles can have a gross mass greater than 100 tonnes, while aircraft wheels can apply in excess of 2000 kPa pressure and rail axles can apply more than 30 tonnes to the rail which gets distributed through sleepers to the asphalt layer beneath.

Railpave aims to apply better engineering practice by taking into account, the loading, climate and operational conditions relevant to rail. This asphalt base layer mix can be up to approximately 15 cm thick and preferably applied with a conventional paver unit according to the bottom-up principle. The IVES system permits a lateral tolerance of ± 50 mm and a height tolerance of +10/-20 mm. However, the construction tolerances targeted are sometimes much lower in an attempt to reduce dependence on subsequent components to correct levels.

Accurate placement of the asphalt to required levels reduces the expenditure on other levelling compounds that are more expensive and more labour intensive in delivering track levels. Track levels must be achieved and maintained so that calibrated operation of the high speed weigh-bridge is possible. Other rolling stock inspection devices will also depend on the successful delivery of the IVES track system.

Due to time limits on shutdown periods, the installation of new track had to occur in several stages. Initial stages involved preparation of the subgrade and placement of capping layer. Ballast, sleepers and rail were reinstated to return the track to operation until the next stage. There were two asphalt stages. In the first stage, elements above the capping layer were removed and two layers of asphalt each 100 mm thick were placed to build an overall thickness of 200 mm. Care was exercised in managing asphalt mix temperatures and placement timing throughout the night in order to prevent deformation due to retained heat which reduces viscosity and stability in the asphalt mix. Sufficient cooling also had to be achieved in time for ballast and track to be reinstated before the end of the shutdown. Stage two of asphalt placement took place about a month later. Ballast was removed to expose stage-one asphalt and visual inspect its surface to ensure there was no damage due to its recent short period in service under the granular layer. The final 100 mm layer of asphalt was paved to provide a structurally monolithic 300 mm total asphalt thickness that was required to meet a final surface evenness of +/-2 mm within 4 m and a cross fall of 0.3% for the straight track section.

The paving width of the bottom-most asphalt layer at Branxton was 3300 mm so that a 150 mm step inward could be applied in consecutive layers to finish with a 3000 mm asphalt platform for the IVES elements to be placed.

Figure 24: Asphalt layer suitable for road traffic during construction period

The base asphalt layer is traffickable by typical vehicles almost immediately after placement but excessive construction vehicle loads need to be managed. The few additional steps to complete the track system can commence within a few hours of asphalt placement.

Although IVES is primarily a combination of advantages of proven slab track systems elements, it was necessary to test and to seek approval as if it were a completely new type of superstructure.

Figure 25: Asphalt layer with sufficient shoulder width

6 EXPERIENCES AND LESSONS LEARNT

One of the major challenges for this project was the limited time on track to complete the works. As already discussed, the need for multiple possession (58-96hrs) represented a challenge in itself, trying to fit as many works in each possession as possible, but always keeping in mind that the track had to be ready for operation at the end of each possession. When planning the number of required possessions, the idea was discussed if the Railpave asphalt layers can be placed in one possession and the track re-instated for operation. The minimum depth of bottom ballast underneath the concrete sleeper didn’t allow for this without adding ballasted ramps at either end. Consequently, these ramps would have had to be lowered once the IVES would be completed. In the end the decision was made against this approach as there were no real time savings associated; , e.g., reducing the total number of possessions.

Asphalt had to be placed in thicknesses which were equal to or exceeded the maximum thicknesses used in road construction. Together with the hot weather at the time, this meant that the risk of deformation due to retained heat was increased. Constant assessment of the tenderness of the mat and frequent review of temperatures throughout the shift allowed control of finished levels and provided lessons for refining logistics, mix management and placement processes placement for future – particularly large scale – work

Further investigation for methods of cooling the mat as rapidly as possible without compromising the integrity of the asphalt and composite system are part of the next refinement. Automated, digital level control based on intelligent systems (and possibly autonomous plant) more suited to large scale projects can be introduced provide closed loop real time data and smaller tolerances on finished surface level.A time saving factor had been identified in choosing the right grout material for the final casting of the base plates. The material had to withstand the pull out forces as well as the compressive forces. In the past two different products have been used on various projects. This approach would have had a negative impact on the work program. Therefore a trial was undertaken to verify the early strength pull-out forces. A worst case scenario was chosen with smooth IVES pocket walls (rather than roughened as used in Branxton) and reduced embedment depth of the dowels reaching into the pocket (approximately 30mm reduced embedment depth).

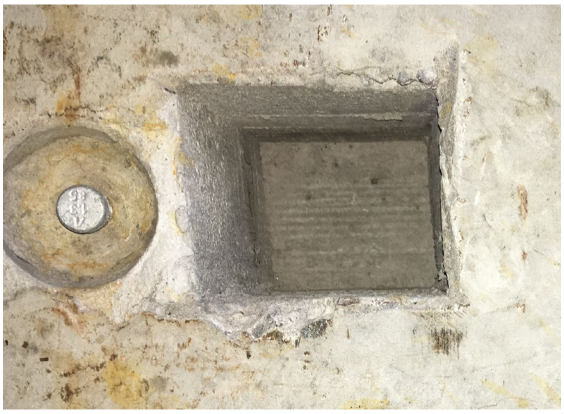

Figure 26: trial pocket with smooth walls

Figure 27: IVES pockets with roughened surface for optimised bonding characteristics

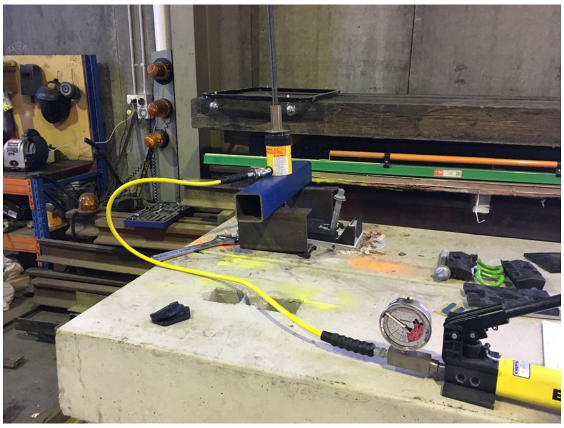

Figure 28: Trial set up

The specification requires a pull out force of 60kN to be applied and hold over 3 minutes. Four coachscrews were tested:

Screw	Cure time	Applied force	Result
1	4:50hr	60kN	Passed
2	4:55hr	60kN	Passed
3	5:05hr	60kN	Passed
4	5:10hr	60kN	Passed

Table 1: Pull out test results

The product Megapoxy 206 Accelerated fulfilled all the requirements for compressive strength, pull out strength, grout pad thickness variance with one pour and high early strength.

Based on the abovementioned results a 6 hrs curing period was determined. This is a huge advantage compared to cementitious grout material with 48 hrs curing times.

The lateral stabilisation of the IVES was realised by means of dowels reaching half into the Railpave layer and half into the IVES block.

Figure 29: Dowel connection placed in asphalt layer

The dowels were installed every 3^{rd} IVES element and cast-in using an epoxy grout. Depending on future project requirements, alignment and axle loads the design for these dowels can be reviewed. Straight track sections might require an increased spacing or the lateral stabilisation can be achieved be means of shoulder ballast. In case of structures close to the track, e.g. walls or walkways in tunnels these could be incorporated in the design for lateral stabilisation using pre-cast elements to be "wedged-in" between edge of IVES element and adjacent structure. This could be done after installation of IVES resulting in a more efficient installation method.

Other topics from the lessons learnt include the optimisation of placing the IVES blocks in a more efficient way by means of customised IVES placing plant and equipment (similar to a sleeper placing machine). The Branxton project was a relatively short installation with 204m in length with track access from one side along the whole project. For larger projects an approach for a line construction site will be beneficial with Railpave placing at the start, followed by IVES placing, track assembly and adjustment all the way to pouring of grout using plant and equipment to optimise production rates.

Although IVES is able to deal with a range of asphalt levels, the final level of the asphalt layer plays a very important part in reducing the amount of epoxy grout used and the production rate of placing and curing the grout material. It is therefore imperative that the final layer of asphalt is placed to the highest level of accuracy possible.

As a precaution a temporary speed restriction (TSR) was introduced to manage the reduced bottom ballast height after the third possession. The TSR was lifted once the first inspections of the completed IVES system showed no further need for it.

7 performance monitoring of the branxton project

Part of ARTC's type approval conditions and also Rhomberg's quality control and monitoring process include regular inspections of the IVES system at Branxton. An inspection regime was established to closely monitor the condition of IVES and VTRAS under 30 tonne axle loads started with weekly inspections right after installation in November to monthly inspections started in August 2018. The increased interval of inspection had been chosen based on the very good performance of the IVES.

The regular inspections focused on conditions of rails, shoulder (incl. visible asphalt layer), drainage, DFF304 fastening system, IVES blocks, gauge and superelevation. In addition more detailed survey was undertaken in February and June 2018 using the total station based Hergie system. The survey data included:

- Height change in short distance
- Height change in long distance
- Superelevation
- Change of superelevation
- Horizontal alignment
- Vertical alignment left and right rail

The results from February and June 2018 have been compared with the as-built data from the installation in November 2017 with very small variations of each value. This underlines the very good performance of the IVES with literally zero maintenance works.

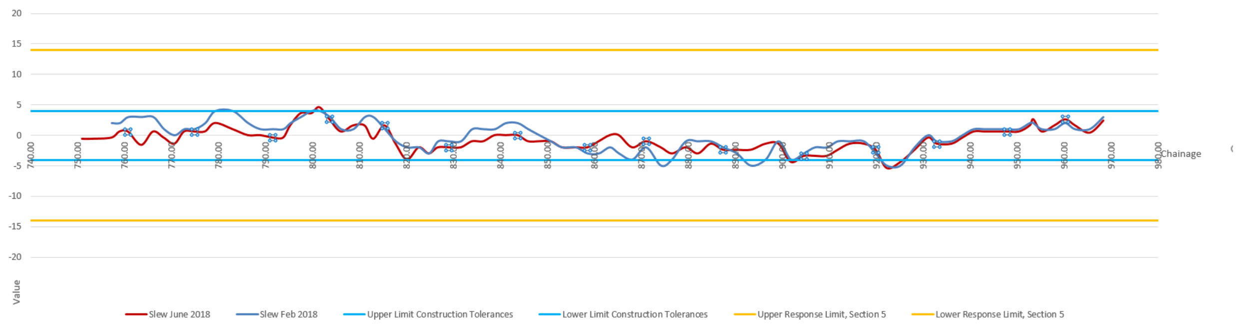

Figure 30: Comparison of horizontal track alignment February and June 2018

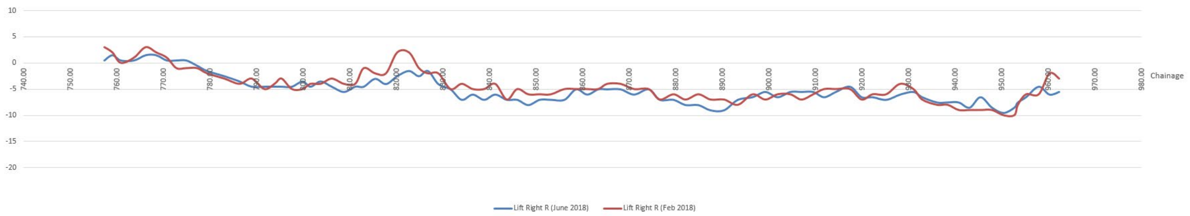

Figure 31: Comparison of top of right rail February and June 2018

Visible inspections and spot checks of the asphalt layer have been undertaken and showed no impressions of IVES into teh Railpave layer. The surface of Railpave is even and very well compacted with no signs of loose asphalt grain.

Figure 32: Railpave layer under IVES

Figure 33: First coal train approaching IVES and high speed weigh bridge

8 SUMMARY

After one year of operation an estimated 160 million tons have passed the IVES, equalling 0.5 million tons each day, mostly fully loaded coal trains from the Hunter Region travelling to the Port of Newcastle.

The positive feedback from the high-speed weighbridge maintainer, showing very good weighing results, is another indication of the successful implementation of this new system.

All these results show that IVES and the supporting layers, namely Railpave, work as expected.