An Effective Bond Coat for Longer Pavement Life

INTRODUCTION
Tack or bond coat emulsions are used routinely in pavement construction and maintenance to achieve a bond between asphaltic concrete layers; however, their effectiveness can vary depending on type and application rate.

Tack coats are normally unmodified bitumen emulsions while bond coats are generally modified bitumen emulsions with improved adhesive performance. The importance of achieving an effective bond between pavement layers is an essential part of achieving designed structural performance. A survey commissioned by IBEF (European emulsion manufacturers association) in 1998 found that amongst the respondent countries the application rate for tack coats ranged from 0.12 to 0.40 kg/m² residual for bond coats used with conventional asphalt mixes with time between application and overlay ranging from 20 minutes for partially broken emulsion up to several hours for ‘dry’ or cured binder. An analysis technique designed by LCPC/SETRA in France demonstrated that the absence of an effective bond coat can reduce pavement design life by nearly two thirds (Roffe, 2002).

Similarly, a project study carried out at NCHRP concluded that “no bond or insufficient bond may cause tensile stresses to be concentrated at the bottom of the wearing course. Such concentrated stress may accelerate fatigue cracking and lead ultimately to pavement failure” (NCHRP 2008).

The increasing adoption of the concept of separation of pavement function (structural versus surfacing) has seen the proliferation of thin and ultra thin pavement surfacings designed to meet user requirements of safety, comfort and low cost. The merits of these surfacings has been extensively reviewed and acknowledged (Oliver, 1999). Since these surfacing treatments can range down to less than 15mm in thickness the tensile stresses at the interface with the structural layer can be considerable. Consequently, a strong interfacial bond is of critical importance to achieving a satisfactory service life of these thin wearing courses. Some of the key issues associated with the use of tack coats and bond coats include; rate of set (construction traffic access time), sprayability, tyre track-off, and bond strength.

The rate of break can be a concern, particularly under cool and damp conditions and can result in track-off by asphalt trucks. Similarly, under warm pavement conditions, the residual bitumen after emulsion break can become sticky and pick-up on hot construction vehicle tyres resulting in a loss of effective binder from the surface and the deposition of unsightly black tyre tracks along adjacent pavements.

Early development work with bond coats showed up a potential problem with conventional polymer modification which made them prone to pick up if not completely cured when trafficked by construction vehicles. The purpose of this work was to develop an improved emulsion to avoid this problem and still achieve high cohesive and adhesive strength that is necessary for use under a range of overlays. A complementary objective was work was to produce an emulsion that eliminated tackiness of the cured bondcoat at elevated pavement temperatures. Excessive tackiness results can result in substantial track-off by construction vehicles with consequent reduced function in the overlay structure. As there is no agreed standardised test for bondcoat strength measurement, an in-house method was developed to support this work.
DEVELOPMENT AND TESTING

A number of test methods are in use to measure bond strength with the Leutner shear test being well documented (Leutner, 1979). An alternative method was devised based on use of the Universal Materials Testing Apparatus (UMTA) a relatively low cost general-purpose computer (PC) controlled, closed loop servo pneumatic loading machine capable of logging load and deformation data in digital format. This equipment is widely available in Australia and principally used to determine indirect tensile and fatigue performance properties of asphaltic concrete. The test sample configuration was designed so as to enable the application of a uniform shear rate across the test specimen and to fit within the loading capabilities of the UMTA. All tests were carried out without any load applied normal to the bond interface. The loading rate used was 50mm/minute.

Sample Preparation and Testing

The sample preparation method chosen for tack coat evaluation was based on test specimens cut from a slab of asphaltic concrete prepared in a shear box compactor (Gabrawy, 2000). The latter is now a commercially available compaction device that consolidates hot mix to a predetermined volume by the shearing action of a pair of parallel steel plates under a constant vertical confining stress. The shearing action simulates the effect of roller compaction in the field.

Initially test specimens were all cut from the same compacted slab, and ‘glued’ together with the test tack coat before conditioning in an oven overnight to cure the tack coat. The test provided a good means of discriminating between tack coat bond strength as illustrated in Fig.1. Here the developmental bond coat BC, is compared with a conventional cationic bitumen emulsion tack coat emulsion CRS, at shear test temperatures of 25°C and 40°C. The tack coat application rate used (0.3 L/m²) for the study was at the higher end of the range used in practice. This was considered to be consistent with achieving optimum bond strength.

![Temperature and Shear Strength of PRS Bond Coat and CRS 170](image)

Fig.1
The initial test values appeared relatively low by comparison with other data. Researchers tested a coarse and a fine graded mix on the NCAT shear test apparatus (similar in principle to the Leutner test) under a range of conditions including one similar to this work (no normal loading and tack application 0.36L/m²), and reported shear values in the range 1.50 to 1.86 MPa at 25°C for bituminous tack coats, CRS2 and CSS-1 (West et al, 2005). Further investigation revealed that the shear strength was highly dependent on the tack coat curing conditions with increased strength being associated with higher curing temperature as illustrated in Fig. 2 below.

All subsequent testing on the UMTA was carried out with tack coat layers cured in-situ during placement and compaction of the upper layer. A number of surface treatments were incorporated in the one composite slab by allocating specific areas of the lower slab to each of the various tack coat treatments before addition of the top layer. The test specimens were then cut from the bonded slabs.

![Effect of Bond Coat Cure Temperature on Shear Strength](image)

Test slabs were approximately 300mm square and each layer was a nominal 50mm thick. The test specimens were cut as 50mm square sections from the bonded two-layer slabs. Each test specimen was clamped into a test frame and placed in a temperature controlled cabinet to minimise temperature variations through handling when setting up the test. The test apparatus was also housed and operated in the temperature controlled cabinet. A minimum of three replicate samples was tested for each reported data point. The mix used was stone filled sheet asphalt with a high sand component to give a uniform low texture surface to minimise effects of contact surface variability. The test results are reported in Fig. 3 below.
Interfacial Shear Strength of Various Tack Coats
Measured at 25C for 5 Replicates

![Graph showing shear strength values for different tack coats.](image)

The untreated interface, on average, produced the highest shear strength of the surfaces tested. This phenomenon has been observed by others (Raab 2004; Young 2005). The uncut faces had a light coating of binder from the initial sample compaction which is believed to have been adequate to form a good bond formation under final compaction. Under shear testing the interlock of surface irregularities is believed to have resulted in the high test values for the non tack coated samples. Additional testing with dusty surfaces was carried out where basalt dust (<75µ) was applied to the test surface with a soft brush and the excess swept off before tack coating. The results of this work are illustrated in Fig.4 below.

Bond Shear Strengths for Various Tack Coat Conditions
Measured at 25C

![Bar chart showing shear stress for different bond coat conditions.](image)

Fig. 4
Field Trials
The bond coat development project examined the effect of the treatment on surface permeability and skid resistance. If the bond coat is to be placed well ahead of the surfacing overlay then it would need to demonstrate satisfactory skid resistance properties. Surface permeability is also a significant property where the underlying pavement is vulnerable to moisture damage. Ideally an effective bond coat, in addition to providing a strong bond between the layers, should also provide a significant reduction in surface permeability but not render the surface totally impermeable as this could create excessive water vapour pressure build-up with its own attendant risks of disbonding.

The trial pavement consisted of three deep lift asphalt patches that were less than 12 months old. The test sections were tested for skid resistance and permeability before and after bond coat application and at least three sets of test results were obtained for each of the three tack coat application rates used. The latter was applied at 0.1, 0.2 and 0.3L/m² residual binder. The 0.3L/m² section was affected by rain fall soon after treatment and would have resulted in a lower than target final residual level.

The skid resistance was measured by means of British Pendulum Tester and was carried out within 1 hour of application and before any trafficking of the bond coat. Results are shown in Fig.5.

![Bond Coat Skid Resistance Data](image)

The skid resistance data indicate that there were no adverse effects by any of the bond coat treatments on the asphalt surface with respect to skid resistance measurements (all data was temperature corrected to 25°C).

Table 1. summarises the permeability data for the various test sections.
### DISCUSSION AND CONCLUSIONS

A drop off in bond strength with increase in test temperature was observed and has also been reported elsewhere in the literature (West 2005, Young 2005). The absence of tack coat between the layers generally gave high maximum shear strength results; a phenomenon that has been observed by others (Raab 2004, Young 2005). The reason for the apparently good performance of these non tacked samples could be the relatively high coefficient of friction for surface particle interlock, whereas a relatively thick adhesive layer may act to lubricate the interface under shear. This measurement of shear strength may be only part of the complete bond strength picture since the field performance of the bond also includes a tensile element. The latter has been measured (Raab & Partl 2004) in the form of a tensile “pull-off” stress test when investigating bonding of glass and steel reinforcing interlayer membranes. They reported that the maximum tensile stress for conventional tack coated specimens was similar in magnitude to the maximum shear stress.

The presence of a light dusty surface was found to improve the shear strength for all tack coat binders. However, where no tack was applied the test clearly demonstrated the negative impact of dust on the shear bond strength. The improved shear strength of the dusty tacked sections is possibly due to the stiffening effect of the dust/binder mastic at the interface. The development bond coat produced shear test results higher than those achieved with a typical polymer modified bond coat. While the conventional tack coat performed very well under controlled laboratory conditions, this may not be the case in the field where binder track-off is an issue. In practice, the final bond strength may be compromised if a significant proportion of the residual bitumen from a tack coat is tracked off during construction.

Field testing showed that the development bond coat did not compromise the skid resistance of the treated pavement and that it reduced pavement water permeability by up to 98%. Initial field observations indicate that the bond coat has a low level of surface tackiness.

Subsequent field work has confirmed the low tack nature of the product and tenacious bond achieved with the underlying pavement. Currently promising work is underway in North America to validate a practical field test device to enable routine bond testing for adequate adhesion between asphalt layers (Reynolds et al, 2008).
CASE STUDIES
Since the development work was concluded in 2005, PRS Bondcoat emulsion has been used at a high stress site near Queensland under a PRS Megatex friction course in 2008 and under an AC overlay on the V8 Supercar racetrack in Townsville in April 2009.

Mount Cotton
QDMR engaged PRS to trial a thin friction course overlay, on a heavily trafficked section of Mount Cotton Road some 30km SE of Brisbane. The test section comprised 1.6km of sealed single carriageway providing the main access to a busy quarry servicing the Gateway Upgrade project. The traffic conditions in sections were up to 13000 AADT and 13% heavy vehicles. Pioneer Road Services Megatex system was accepted for the project under an extended warranty contract. The system comprised proprietary thin asphalt wearing course of minimum 25mm and on average 30mm in thickness bonded with PRS Bondcoat emulsion. The latter was used to ensure effective adhesion to the existing pavement. One 200m section of the job is over a 10% slope under braking in one direction. A total of 1700 tonnes of overlay was placed as a holding treatment with a 2 year warranty period. The overlay was placed in July 2008 and over the past 14 months has been functioning well within the agreed warranty conditions that cover; surface texture, delamination, stripping, bleeding ravelling and deformation.

Strength of the Bondcoat was measured with standard QDMR equipment comprising in situ coring and application of a torsional shearing force to a plate glued with epoxy resin to the core surface (see photo). Testing showed that bond strength was greater that 890 KPa (torque wrench limit of 200Nm was below that required to break the bond).

Fig. 6  Torsional shear test, Mount Cotton Road
Few countries specify bond strength limits for tack coat. Switzerland is one that does (Standard 671 961) and uses a shear test similar to the Leutner one on 150mm diameter cores. The minimum limit for thin overlays is 15KN (approximately 0.85 MPa) comfortably exceeded by PRS Bondcoat.

Fig. 7  Spraying of Bondcoat emulsion, Mount Cotton

Fig. 8  Megatex 10 over Bondcoat (note light grit used on binder rich Megatex surface)
Townsville V8 Supercar Racetrack, Queensland
The Townsville V8 racetrack was built by Leighton Contracting in the first half of 2009 in time for the July Townsville 400 races. In order to ensure that the asphalt layers used in the pavement’s construction were securely bonded Leighton nominated PRS Bondcoat as the tack coat for the job. Boral, a local contractor carried out the paving works and sprayed the Boncoat with their regular bitumen sprayer. An added benefit of Bondcoat on this job was the ability to pre-spray a given work area well in advance of the paving operation enabling the paving crew to work unimpeded on a non tacky surface, even under pavement temperatures of 50°C. The use of the Bondcoat emulsion also eliminated contractor concerns that construction vehicles would track loose aggregates from an unsealed access track from the site onto the main roadway and create a stone damage hazard for passing vehicles.

The bondcoat was applied at 0.2L/m residual by means of a conventional bitumen sprayer at ambient temperature and cured within 30 minutes under fine weather conditions. On site feedback was very positive following initial reservations about applying tack at the design application rate given past experience with conventional tack coats at lower rates.

![No pick-up under paver wheels](image)

**Fig. 9** No pick-up under paver wheels
REFERENCES

NCHRP Project 09-40 (10/31/2008) Optimization of Tack Coat for HMA Placement
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