INNOVATIVE GRADED AGGREGATE SURFACINGS REVIEW

Ryan Jansz
National Pavement Manager, Boral Asphalt, Australia

ABSTRACT

Most of Australia’s road network is made of unbound granular material without a sealed surface. With changing climate and urban expansion, these pavements suffer from higher levels of erosion and deterioration than before. Re-sheeting and watering are often increased against a desire for sustainability technology and environment friendly solutions.

Additionally, unsealed roads have to cope with road-user demand for the amenity of higher level facilities including good skid resistance, no dust, reduced noise, less wear and tear of vehicles and safe passage.

This has led to a closer look at ways to slow deterioration and reduce intervention while justifying whole of life cost.

A solution that has emerged is the graded aggregate sprayed surfacing.

It uses graded aggregates instead of single sized stone common with other sprayed surfacing and little or no upgrade is needed to the existing granular base before application. No prime is required; no aggregate pre-coat is required; and, the treatment can be applied all year round using standard spray equipment. Use of the treatment in the rehabilitation of previously sealed surfaces is also covered.

The paper provides a cost comparison of graded aggregate sprayed surfacings against routine maintenance and gives a history of its use worldwide.

Key Words

Environment, Sustainable, Maintenance, Reseal, Rehabilitation, Granular, Reseal, Prime, Pre-coat
BACKGROUND

Almost 60% of the Australia’s proclaimed road network remains unsealed (Figure 1 - BITRE\(^{(2)}\)). Although a major part of this network does not need improved surfacing; there is still a significant length of roadway under increasing pressure to be sealed in order to provide greater functionality and amenity for a growing population and expanding urban zone. In certain circumstances, dust generated from unsurfaced roads can be detrimental to the health of communities living in close proximity of the road as well as effecting amenity for farmers, mining facilities and other rural industries.

Over this, climate changes (Figure 2) \(^{(4)}\) and increases in traffic mean greater erosion and dust generation from these pavements than ever before. Re-gravelling and water spraying frequencies often need to be increased against a community desire for more sustainable technology and environment friendly solutions. This has led asset managers to focus on ways to reduce water consumed for dust suppression, seek long term chemical free treatments to prevent dust, and ways to reduce erosion and reduce maintenance frequencies.

Meanwhile, advancing urbanisation (Figure 3) \(^{(3)}\) and the strong influence of improved living standards means road users expect better amenity, good in-service skid resistance, dust free passage, reduced noise levels, less vehicle wear and tear, and, improved safe passage in all weather conditions. Better living standards have a compounding effect because high quality is demanded more broadly and extends to remote roads that were previously exempt. This compels authorities to consider sealing options instead of routine maintenance to satisfy their communities.
Figure 2: Trend in the annual precipitation for Australia, (ABM, 2006)\(^4\)
The challenge in meeting these expectations is heightened by reduced funding exacerbated by poor economic times since the global financial crisis. Road maintenance activities were valued at about $6.4 billion dollars in 2010/2011, but in 2012, Bis Shrapnel estimated that for every $100 of net assets in Australia only $1.44 was spent on maintenance compared to $1.70 a decade ago. This was partly due to a doubling in expenditure on new roads which contributes to an upward spiral in future maintenance costs.

From another direction, there is pressure on preserving our non-renewable natural resources, again increasing economic justification to seal existing gravel surfaces instead of periodic re-graveling and re-grading. The latter activities result in high consumption of water, diesel fuel and natural gravel for a short term solution. For instance, it is estimated that Australia loses about $(478,000 \text{km} \times 6 \text{m} \times 20 \text{mm})$ 57 million cubic metres of gravel per annum from its unsurfaced roads due to traffic and environmental erosion. This is more than five times the annual amount of aggregates used in the manufacture of asphalt and spray seals applied per annum in Australia.

While the need to seal unbound granular roads is growing, road budgets are becoming tighter, particularly for low volume roads. The asset manager often has to choose between costly reconstruction or continuing to spend limited funds on re-gavelling and re-grading.

These catalytic factors have led to a closer look at ways to slow deterioration and reduce maintenance while optimising whole of life cost and compelled road agencies to consider sealing options instead of routine maintenance to satisfy their communities. A graded aggregate total treatment (GATT) surfacing has been developed by Boral to provide a cost effective alternative when compared to routine maintenance in these circumstances. Whilst the treatment can be used as an initial treatment it can also be used as a substitute for other bituminous treatments on existing low to moderately trafficked roads. The treatment can be applied directly onto a granular base that has not been primed and is therefore appropriately described as a ‘Total Treatment’ (Figure 4). Other key attributes are that GATT generally uses un-precoated aggregate and can be applied all year round with standard spray seal equipment.

The treatment originates from early spray seal technology when graded rather than one sized aggregates had been used. However, the recent local manifestation of the concept is a development by Boral that is adapted from similar treatments developed in Norway and subsequently used in Scandinavian and Southern African countries since the early 1960s.

Figure 3: Change in population distribution 2001 – 2011 in Australia (ABS, 2010)\

Figure 4: Illustration of the methodology of a self-priming graded aggregate seal
GATT is an alternative to two traditional processes currently available, hot mixed asphalt and spray sealing with single size stone in single or multiple layers. Three current main uses for the product are:

- Alternative to gravel road maintenance
- Resealing crack or aged sealed pavement
- Transitory pavement when funding does not allow full upgrade (re)construction

Despite the socio-economic stimuli for sealed surfacings, quite often, secondary and temporary measures are implemented on the assumption that short term economic benefit cannot be realised with a bituminous surfacing. Temporary relief is sought through routine maintenance and asset managers are sometimes forced to resort to dust suppression or re-sheeting on a frequent basis. A quick economic analysis can demonstrate that these options are more draining on funds when compared to a graded aggregate total treatment surfacing.

Apart from positive environmental features like eliminating dust emissions, reducing demand for water as a dust suppressant and reducing the need for regular use of chemical dust suppressants, GATT also supports the principles of sustainability. This is possible because local or marginal aggregates that are otherwise discarded in quarrying processes can be used as cover aggregate.

**CONCEPT OF A GATT SURFACING**

GATT™ surfacing was first developed in Australia by Boral in 1999. The concept of a GATT surfacing is that it should:

a) Be cost effective and easy to carry out in any location;  
b) Try to use locally available aggregates (natural or crushed);  
c) Be impervious to prevent water entering water susceptible base; and  
d) Be very flexible, durable and easy to maintain.

Graded aggregate total treatment surfacing is a 10 to 30 mm thick bituminous surfacing, consisting of a graded aggregate, ranging from crushed rock to natural gravel, with a relatively soft (low viscosity) binder with or without a sand seal cover. It can be used as a single or double treatment.

GATT is quite different to a conventional spray seal. The comparatively soft binder migrates through the graded aggregate under the effects of rolling and trafficking. Unlike conventional single sized aggregate seals no pre-coating of the aggregates is necessary. The graded aggregate relies on both mechanical interlocking and the modified bitumen for its binding and flexibility.

Graded aggregate bituminous surfacings have many performance advantages over conventional low cost dust palliation treatments. Use of graded aggregate allows a higher application rate of binder without the risk of bleeding thus rendering a more durable surfacing. Regular spray seals consist of a single application of either a single sized aggregate or sand thus limiting the amount of binder that can be applied to 1.0 to 1.3 litres per square metre. In the latter case a second surfacing is required within two years to protect the existing surfacing due to the low binder content.

In a GATT, aggregate retention is achieved through binder adhesion and by the formation of mastic composed of binder and fines that wedges between the larger fractions. This is a fundamental difference to standard spray seals constructed with one sized aggregates.
GRADED AGGREGATE TOTAL TREATMENT DESIGN

Types of GATT

Single coat applications of GATT are the most common; however, depending on traffic volume, granular base conditions, anticipated design life or durability and required surface finish, a two coat GATT may be used. The second coat of GATT can be a repeat of the first application or a sand cover seal. A ‘duplicate’ coat GATT application is the most expensive and should be considered for heavier traffic applications.

Sand cover seals can be considered for low to moderate traffic environments and are used to:

a) Improve stone retention in the underlying GATT;
b) Add to the durability of the surfacing by increasing overall binder volume;
c) Close texture between coarse aggregate and so increasing tenacity in shear;
d) Protect the aggregate in the underlying seal if very marginal quality materials have been used; and
e) Reduce risk of damage in the case of imperfections in the underlying seal.

In general, the following table may be used as guide in choosing GATT applications:

<table>
<thead>
<tr>
<th>Type of GATT Surfacing</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single GATT Surfacing</td>
<td>Surfacing of gravel roads to reduce routine maintenance</td>
</tr>
<tr>
<td></td>
<td>Temporary Surfacings (diversions, temporary access, etc.) Resurfacing</td>
</tr>
<tr>
<td></td>
<td>(all traffic classes which apply to spray seals)</td>
</tr>
<tr>
<td>Single GATT Surfacing with Sand Cover Seal</td>
<td>AADT &lt;200</td>
</tr>
<tr>
<td>Double GATT Surfacing</td>
<td>AADT &gt;200</td>
</tr>
<tr>
<td>Polymer Modified GATT</td>
<td>Resealing oxidised, cracked seal surfaces. Localised high shear, short</td>
</tr>
<tr>
<td></td>
<td>duration events (eg. harvest season; construction sites)</td>
</tr>
</tbody>
</table>

Table 1: Selection criteria for type of GATT*

Aggregate

Unlike conventional spray seals, there is great latitude in choosing the grading of the aggregate used for GATT surfacing (refer Figure 5). However, there are critical controls applied by the designer to determine the grading best suited to traffic volume, expected design life and whether one or two coats is best for the application. The limits on smaller aggregate fractions, fines and moisture content are major influences in the design process.

Consideration must also be given to the method of spreading aggregate to avoid clogging in the spreader due to the inappropriate combination of fines and moisture. Interruptions to discharge from a spreader box will lead to variability in surface texture, and in extreme cases premature distress.
There is significant flexibility in the tolerable moisture content in GATT and while some moisture can emulsify binder and lower its viscosity to aid the aggregate wetting process, exceeding moisture limits can lead to premature stripping and then potholing.

The use of graded aggregate permits the use of higher binder volume without the risk of bleeding thus improving the durability of the seal. By the same token, excessive fines must be avoided and care must be taken to ensure that the percentage passing the 0.075 mm sieve is below the maximum limit. High fines can lead to an increase in binder viscosity thus limiting the amount of free soft binder from adhering to the larger sized aggregates.

Although aggregate application rates are depended on the nominal size and grading adopted, the range of application rates are similar to conventional sprayed seals.

**Binder**

Both cutback and emulsion bitumen binders are used in GATT surfacing. The base bitumen is generally Class 170 bitumen and for certain applications it is modified with a suitable elastomeric polymer. The application rate will vary depending on the level of dilution and the influence of aggregate grading but the target residual cold binder rate will generally fall between 1.4 and 2.6 litres per square meter within the envelope used for conventional sprayed seals.

Binders are cutback or emulsified to reduce viscosity. Apart from facilitating binder flow within the GATT matrix, lowering of viscosity improves the penetration of the binder into the underlying gravel surface which results in improved adhesion between the new surfacing and the base.
Work has also been completed with polymer modified GATT in specific applications requiring enhanced aggregate retention. Polymer has also been used where an ability to withstand high bearing and shear loads over a short space of time such as wheat grain transport vehicles was required. Additionally, the elastomeric polymer renders a more elastic seal and helps retard cracking from localised weakness in the base or existing cracked sprayed surfacings. Polymer modified GATT has seen increasing used as a reseal in some jurisdictions in Victoria.

**CONSTRUCTION**

*Base Preparation*

Preparation of the granular base for GATT is usually minimal, as long as the base quality material is of adequate depth and has a history of providing sufficient in-situ bearing strength. Ideally, the base should have a CBR in excess of 50% under equilibrium conditions, but experience has shown that this bearing capacity can be relaxed if GATT is applied in dry climates and traffic volumes are low or if moisture ingress can be avoided.

A good bond between the base and the surfacing is as important as for conventional seals. Maintenance grading and rolling to a tightly compacted finish, without any loose material at the surface, is all that is needed in most cases.

Priming of the base is not necessary as the cutter or emulsion in the binder acts as a prime by penetrating into the upper surface of the base. Prior to spraying the self-priming binder, the gravel surface should be broomed free of dust and other foreign matter. Light watering should be carried out before spraying to settle any dust and allowed to dry to a damp, but not wet, state. This will help break the surface tension between the gravel base material and sprayed binder to avoid pin holing or fish eyes forming.

![Figure 6: Pin-holing when binder is applied to a dry base](image)

**GATT Application**

Like sprayed sealing, graded aggregate total treatment pavement surfacing involves a two step process. First, binder is sprayed onto a suitable granular base at a metered rate. Graded aggregate is then spread over the binder, using conventional box spreaders. Specialised aggregate chip spreader can be used to optimise performance, particularly for aggregates that may choke when flowing through boxes.
The soft, low viscosity binder used has a dual action. Part of the binder primes the base while the remainder migrates into the GATT aggregate to provide cohesion and adhesion. Although no laboratory studies have been undertaken to assess the internal formation of GATT, field observations indicate that binder is pumped through the aggregate skeleton during rolling. This creates mastic with fines and coats the larger aggregate fractions in similar manner to [foam] bitumen stabilisation processes. An examination of GATT samples removed from the field reveals uniform and complete coating with the larger particles surrounded and held by the mastic.
Rolling

Multi-wheel rollers are used to knead the aggregate into the underlying binder. This kneading is also the mechanism by which binder is squeezed up through the aggregate to form mastic with fines and provide sufficient binder film thickness throughout.

Rolling creates a surface with an almost flush appearance albeit dull due to mastic rather than raw binder between aggregate and the resultant texture is not as deep as that of a sprayed bituminous seal. With trafficking the surfacing develops a texture between a spray seal and highly textured asphalt.

![Figure 9: Final surface texture after rolling](image)

Post Sweeping

Aggregate in GATT is usually embedded into the surfacing more so than in normal spray seals and a need for post sweeping is driven factors other than GATT performance, especially in low traffic environments. It may be necessary to sweep back any loose aggregates dislodged from traffic in the first two weeks of application to allow some secondary ‘matting’ to take place.

Versatility of GATT surfacings

Although GATT surfacing is an all year round treatment, it should not be applied during, before or soon after rain. Due to the use of the low viscosity binder, GATT surfacings are sensitive in their early life to any severe traffic turning actions. It should not be applied where frequent heavy axle manoeuvring loads are expected. However, the rich binder mastic has demonstrated a safe healing ability, and, any localised damage caused to a freshly applied GATT surfacing can be easily repaired by further traffic rolling or applying a light emulsion to the damaged area and sweeping back lose aggregates.

Traffic Management

Trafficking of the graded aggregate total treatment surfacing immediately after rolling not essential and its final appearance is formed after 4 to 8 weeks, giving an asphalt-like appearance in the wheel paths, especially with double coats.
Double GATT Surfacing

Where a Double GATT surfacing is used, the second coat is seldom applied on the same day and it is preferable to allow at least one week prior to the application of the second coat. Ideally, a 8 to 12 week period should be allowed between first and second layers to allow for trafficking and evaporation of the cutter, more so for traffic volumes >200 vehicles per day or where lighter grade binders are used.

Sand Cover Seal

Where a Sand Cover Seal is applied, it is important to ensure that enough aggregate is applied and that aggregate dislodged by traffic is regularly broomed back into any exposed areas until it is fully embedded, which normally takes about 4 weeks.

Joints

Extra care is needed at joints. A minimum longitudinal joint overlap of 150 mm for longitudinal joints and 300 mm for transverse joints is recommended and additional heavy rolling is necessary to even out the joints. Preferably, longitudinal joints should be avoided by spraying the road full width.

Intersections, Roundabouts and Steep Gradients

Due to the relatively soft binder and high application rate, trucks may shove the surfacing across the carriageway during early life.

In steep gradients, lower binder rates should be used to avoid shoving or bleeding. The same applies to downhill gradients with sharp curves where the vehicles tend to break heavily.

In these cases, binder application rate is reduced and a coarse aggregate grading is used. Consideration may be given to the use of a harder binder in exceptional circumstances.

The application of graded aggregate total treatments at intersections with volumes greater than 500 vehicles per day must be undertaken with due attention to binder and aggregate application rates, choice of aggregate grading and aftercare measures.

The combination of binder and mastic in a GATT™ surfacing has been found to provide a self-healing effect where torsion and high shear loads disturb the surface. This action depends on low frequency load applications, so that the binder or mastic has time to migrate under the kneading action of traffic.

GATT PERFORMANCE

The life expectancy of GATT surfacing is:

- 6 years or more for single surface applications;
- 10 to 12 years for polymer modified binder applications; and,
- 10 to 12 years for double surface applications.

The quality of the base, traffic and environmental conditions will all have an impact on the performance and life of a GATT seal and in certain situations much longer lives may be attained.
EXPERIENCE TO DATE

Graded aggregate total treatment surfaces have to-date been used to surface around 600,000 m² of pavement in Australia. These surfacings are performing successfully. Some jurisdictions in which graded aggregate total treatment surfaces have been used are:

- Vic Roads, Victoria, Australia
- Shire Of Bruce Rock (WA)
- Perth Airport (WA)
- Shire Of Swan Hill (VIC)
- Shire Of Gannawarra (VIC)
- Shire Of Strathbogie (VIC)
- Shire Of Mt Alexander (Reseal) (VIC)
- Shire Of Campaspe, Victoria (VIC)
- Rural City Of Wangaratta (VIC)
- Shire Of Hervey Bay (Qld)
- Shire Of Isis (Qld)
- Greater City Of Bendigo (First GATT Trial)
- Civil Clients/Industrial Sites
- Shire Of Golden Plains (VIC)
- Shire Of Bass Coast (VIC)
- Shier Of Surf Coast (VIC)
- City Of Greater Geelong (VIC)
- Shire Of Melton (VIC)
- Shire Of Balranald (NSW)
- City Of Randwick (NSW)
- Shire Of Pyrenees (VIC)

Specific sites of interest where graded aggregate total treatment has been used are:

- Calder Highway shoulders (Maiden Gully To Bridgewater), Victoria (150,000 m²)
- VicRoads, Northern Region
- South Gippsland Highway shoulders (Fiveways – Tooradin) (50,000 m²), VicRoads, SEM Region
- City Of Bendigo, Mills Road (1999-2009, 9 Years - Resealed 2009)
- Arunga Drive (Bendigo)

Reviewing Recent Trials In Western Australia

Bruce Rock Shire undertook the first GATT trial in Western Australia on 16 November 2012. The impetus for the Shire was to utilise localised materials and obtain a sealed surface with improved accessibility and reduced impact on wheat transport vehicles.

Observations in March 2013 reveal that the GATT is providing a functional surfacing for the Shire and a viable road for primary industry vehicles. Figures 10, 11 and 12 show the aggregate surfacing during application and after months of trafficking.
Figure 10: First Western Australian trial of GATT in Bruce Rock Shire (Nov 2012)

Figure 11: Close-Up Bruce Rock GATT

Figure 12: Bruce Rock GATT March 2013
A graded aggregate total treatment surface aims to provide a cost effective alternative to short-cycle, routine maintenance of unsealed roads. As such it is expected to break-even in cost compared to routine maintenance activities, such as regrading and on-going dust suppression methods, within a 4 year period for roads carrying as few as 50 vehicles per day. In rescaling applications graded aggregate total treatments are compared to alternatives that can provide similar design life, and in these comparisons, have proven to deliver better cost/benefit ratios.

Analysis has been completed for an unsealed road approximately 8 m wide on a per kilometre basis, as shown in Figure 13. When compared against a routine maintenance cost of 25¢ /m² and 4 regrading cycles per annum, GATT can breakeven at 4 years. The analysis does not take into account other costs such as gravel loss which can increase the benefit of GATT over time. Value engineering must also account for improvements to:

- rideability (reduced roughness, Figure 14) and lower vehicle operation costs
- agricultural-business benefits by reducing dust and travel time
- social equity and improve standard of living;
- reducing consumption of natural resources; environmental advantages; and,
- benefits to tourism
CONCLUSION AND SUMMARY

A graded aggregate total treatment surfacing offers the road owner a cost effective technique to reduce the whole of life cost for maintaining low trafficked roads. By the same token, GATT has also been successful under high intensity loads at industrial sites. The key benefits of GATT™ surfacing can be summarised as follows:

- Improves the riding quality of local gravel roads compared to gravel surfaces
- Can use locally available marginal aggregates
- More cost effective than short cycle routine maintenance of unsealed roads
- More long-term benefits compared to primer-seals and dust palliation treatments
- Improves motorists safety by eliminating problems due to skidding in wet weather and loose gravel in dry conditions
- Suppresses dust permanently
- Has ecological and environmental benefits - reduced water consumption in arid regions with routine maintenance works, reduces use of non renewable natural or local aggregates, better use of a larger range of gravels with less waste
- Has a closed texture that provides a smooth riding surface reducing overall road user costs
- Provides an impermeable surface that prevents water entering the base course

Graded aggregate total treatment surfacing provides a range of benefits to the local road authority, the road user and the community. It turns gravel roads into bitumen sealed roads, eliminating potholes and costly, disruptive ongoing maintenance as well as providing a safer and cleaner environment for the road user and community.

GATT™ challenges the traditional belief that ‘bitumen and fines do not mix’ in spray technology and now has a proven track record as a cost effective option to routine maintenance that delivers a better facility for
road users and asset managers. These benefits are achieved while meeting principles of sustainability and being environment friendly.
REFERENCES

(1) Bureau of Infrastructure, Transport and Regional Economics, Australian Infrastructure Statistics Yearbook 2012
(2) Austroads, Road Facts 2005, An overview of the Australian and New Zealand road systems, Austroads, Australia
(3) Australian Bureau of Statistics, 2010
(4) Australian Bureau of Meteorology, 2006
(7) Foley, G, Cropley, S and Giummarra, G, 1996, ARRB Transport Research, Special Report 54, Road Dust Control Techniques, ARRB, Victoria, Australia

BIOGRAPHY

Ryan Jansz is National Pavement Manager, Boral Asphalt, appointed in 2009 after joining as Pavement Solutions Engineer with Boral Asphalt Victoria in 1997. His role involves technology transfer to clients and staff, contributing to technical strategy and assisting research and development in asphalt and sprayed seal technology at the national level. This portfolio includes pavement design advice and pavement engineering solutions to clients and to Boral’s contracting business. He has worked in quality management of road projects and also has wide experience in business development. Before Boral, Ryan worked in materials technology, road construction and traffic engineering for VicRoads, the state road authority in Victoria, Australia. He has a Bachelor of Engineering (1983) from the Royal Melbourne Institute of Technology, Australia, and is currently completing a Master of Pavement Technology.