INNOVATION IN SUSTAINABLE ROADS SERVICES IN RURAL SETTING

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Paper Summary

The existing practice within Narrandera shire, and often elsewhere in rural shires, had been the application of a road seal that is suitable for an urban environment with thousands of traffic movements a day rather than a rural environment with low traffic volumes. This leads to a seal that has all the same costs associated with a heavy use urban road. Rural roads do not need the same hard stone treatment as urban areas. There has been the realisation that the main reason for a reseal becoming due is the oxidation of the bitumen. This is because the stone does not get polished to the same extent as it would on a high volume traffic road.

Otta seal is a technology that has been used in Norway and is used in developing countries as it is very economical. The similar technology is utilised in Narrandera using locally available material and local resources. Narrandera Shire Council sealed 6 km of roads using this technology and they are performing well. Firstly, we used locally available graded gravel which meets required plasticity index, gradation and hardness. This reduces cost of material and material haulage cost due to reduced travel distance. There will be additional cost reduction due to simplified installation and ability by local contractors to install this type of sealing. Furthermore, because of graded aggregate used on sealing, the exposed area of bitumen is reduced, which adds the longevity of pavement. Therefore, Otta seal is essentially simplified version of spray seal which is about 40 % cheaper and lasts 40 % longer compare to conventional seal. This cost benefit assist local Councils to extend seals on local unsealed roads or reseal existing sealed road with Otta Seal. This will eventually reduce the maintenance cost of vast rural sealed and unsealed road network of Australia.

The recent financial analysis suggest that Otta Sealing a road to an existing unsealed road will reduce the lifecycle cost of road by half, while analysed only the reduction of capital and maintenance cost on road. the overall cost reduction will be even more if we consider the economic benefit of sealed road vs unsealed road, reduction on plant repair and maintenance cost and the environmental cost as need for continuous resheeting of road will be curtailed. This piece of work won Highly Commended Award from LG Professional Awards 2016.

Introduction

What is Otta Seal?

There is only slight difference between conventional spray seal and Otta Seal. In Otta Seal, instead of using precoated hard stones of uniform sizes, gravel with specified gradation is used. Because there are certain fraction of material are fine particles in gravel, bitumen spray rate is kept higher in Otta Seal. Usual spray rate is 1.7-1.8 L/m². Cutter in the range of 3-5 % which is significantly higher than Conventional spray seal. In general, Otta Seal is an inexpensive method
of sealing roads of low traffic volume (<300 vpd) using material, manpower and plants available locally \[6\].

**The Challenge faced by rural road infrastructure of Australia**

The main challenge faced by rural roads infrastructure is sustainability. There is a vast roads network on sparsely populated rural Australia. Barely 40% of total expenditure on roads upgrades and maintenance could be funded by the income generated by these roads. Obviously, the low utilization is the main reason of this unsustainability. However, these affordability ratio can be increased significantly by change of current road construction and maintenance culture.

At present, the sealing technology used for a Street in Sydney with traffic 20,000 vpd is similar to the one we use for sealing a rural roads with traffic volume 100 vpd. It is believed that technology hasn't been changed to suit the need, especially on sealing industry. For large number of repetition of wheel loads in case of roads with high traffic volume, it is understandable that hard rocks of uniform sizes are used so that bitumen oxidation matches with stone polishing. This way, the reseal could be optimised. However, if we use similar technology on rural roads with nearly 200 times less traffic per day, it is obviously make limited sense to common public let alone to the scientists, economist and engineers. There are three key questions to the existing rural road construction and maintenance culture and belief:

1. Do we really need such a hard rock on rural reseal/seal works? Many a times we have to travel hundreds of kilometres to cart these material which exactly confirms to the specification of spray seal. Obviously, the answer is NO, because there is very limited traffic count to cause stone polishing effect. Needs of rural reseals are due to bitumen oxidation \[8\].

2. What is key causes of bitumen oxidation and how we can decelerate oxidation rate? One of the key factor of bitumen oxidation on sprayed seal is the exposure of bitumen to the ultraviolet light and oxygen. Uniform size stones are used for spray sealing, therefore, the voids between stones are large causing large bitumen area exposed to ultraviolet light. The resultant effect of this is less pronounced for spray sealing for high traffic volume roads because reseals are mostly governed by combined effect of bitumen oxidation and stone polishing. In case of rural reseals, the reseals are directly governed by bitumen oxidation, therefore these voids between stones causes major reduction of life of seal.

3. What is the economic way to manage rural roads? Should we do more seal or leave it unsealed? At present, there is no clear answer to road engineer whether to extend the seal gradually OR convert existing seal road to unsealed. There are multiple benefits of sealing an existing unsealed rural roads. The following are a few of many benefits:
   a. No need to do maintenance grading.
   b. No need to do resheeting at 10-15 years interval. Carting water, gravel and big road machineries on Council’s local roads usually make destruction on unsealed roads, resulting excessive maintenance costs. We have to cart about 1500 tonnes of gravel per km of resheeting works. This additional movement generates additional heavy traffic on the local roads which damages the roads further \[4\].
   c. Less dust and reduced safety and health issues
   d. Less road closures or other downtimes due to various long term roadworks.
e. Substantial reduction in flood damage costs. This has been proven based on several flood events in NSW. The damage claim on unsealed roads are quite high in comparison to unsealed road.

f. There are other intangible benefits e.g. sealed roads give confidence to user all year accessibility; provides confidence to investors and leads a happier growing economy.

Despite having all these benefits, many technicians in rural Australia consider that sealing a road is costlier, and therefore many occasions they have converted sealed road to unsealed roads. This is particularly because they have been putting reseal life of 10 years for rural seal in their financially modelling. This data may be correct in coastal environment with lots of rainfall, however not applicable to majority of Australian continent which is arid and dry. ARRB (Australian Road Research Bureau) hasn’t done enough research to identify the useful life of seals in rural environment which is causing this confused state to road managers. Author has investigated various spray seals older than 15 years in Balranald Shire Council, Wentworth Shire Council and Narrandera Shire Council and found to be serving well. Author has also started working with ARRB in a project to determine true useful life of rural reseals. If we assume that 14 mm spray seal will have useful life of 16 years (Average of RAMROC* and REROC**), Otta seal should definitely have useful life of 20+ years, which has been supported by various publications regarding Otta Seal. Considering this useful life, it can be proven with financial analysis that continuous extension of seal is economic and sustainable way of managing rural roads.

What are benefits of Otta Seal over Conventional Seal?

Firstly, the material cost at quarry is much cheaper, usually five times cheaper than precoated stones. Secondly, as the material are sourced locally, the material carting cost is significantly reduced. The reduced distance of cartage has other benefits about reduction in vehicle operating cost, road maintenance cost, reduced environmental cost and reduced injuries and safety costs. Thirdly, as the sealing material is mix of large and small size particles, the exposure area of bitumen to ultraviolet light is limited. This significantly increases the useful life of the seal [3]. Last but not the least, it can be used by local contractor with limited supervision which further reduces cost of installation of Otta Seal. Therefore, Otta Seal has multifold benefits [3]. Thus, lifecycle costs is reduced with Otta Seal compare with conventional seal.

How lifecycle costs is reduced with Otta Seal compare with unsealed roads?

It usually cost about $3400 per km of maintenance grading (Grading once a year). At least once in 5 years, shoulder grading and table drain maintenance is required. Besides, a very optimistic estimate is to resheet road by 120 mm compacted (150 mm loose) gravel at 15 years interval.

On the other hand, if the same section of road is sealed using Otta seal, the maintenance cost will be reduced dramatically. Therefore, lifecycle cost/year is very low for Otta sealed road.

In Figure 1(a) and Figure 1(b), it is assumed that local gravel is used for resheeting works and gravel is available at a distance of 25 km from the subject road. These charts and cash flow diagrams which are based on actual expenditure on maintenance and renewal cost for reseals clearly depicts why is it economic to extend the seal. Cost benefit ratio of Otta Seal vs unsealed is in the range of 1.8-2.
Fig 1(a): Lifecycle cost for Otta Sealed and unsealed road

Economically Maintaining roads with low traffic volume (30-50 traffic per day):
Various cashflows for sealing a road or leaving it unsealed. Benfit Cost Analysls - 1.8

Fig 1(b): Various cash flow for Otta Seal and unsealed gravel roads
Otta Seal trial works at Narrandera Shire Council

Narrandera Shire Council and Local sealing contractor, Menzplant Pty Ltd have been doing trial of Otta Seal in Narrandera Region since 2013. Until 2016 June about 6 km of Otta Seal has been laid with very satisfactory result. In 2016-2018 Narrandera Shire Council is to widen about 17 km of roads with Otta Seal and about 10 km of new seal extension using Otta Seal.

Otta Seal was started from Norway. However, it has been predominantly used in various countries with very low human development index for example Nepal [7], African countries [5], Vietnam etc. In those countries, especially, when it is hilly region, transporting chip stone is inconvenient and costly. On the other hand, gravel for Otta Seal could be produced locally beside job site using cheap labour force. In those region, benefit cost ratio of Otta Seal compare to conventional spray seal is very high. Therefore, it has been widely used in those regions.

Adapting the technology Australia hadn’t been easy because i) high labour cost, ii) high level of expectation from community and iii) advanced technology in crushing, precoating and sealing works.

In 2013/2014 financial year, total of 600 meters of Otta Seal was trialled at Deep Creek Narrandera and on Landervale Road Narrandera. One of the major setback from this trial was issue of spreading stones from spreader box. Because of finer particles, gravel clogged at the end of spreader box. To stop clogging, particles below 5 mm was screened off as depicted in Fig 2(a). This solved the issue, however, due to requirement of second screen, it reduced quantity of crushing per hour, resulting high cost of gravel (Only 3 times lower than conventional pre-coated stones).

In 2014/2015 financial year, NSC did extensive trial of gravel from various places. The attempt was to find a suitable material which meet the gradation specification without need to sieve out 5 mm below particles. Figure 2(b) depicts gravel spread trials at Narrandera. It was found that if we limit the moisture content on the gravel, and material with plasticity index less than 5 is used, and proper tilt angle is selected, then thin thickness of gravel can be spread without being clogged.

Since 2014, council completed about 5.5 km of Otta Seal works with great success. The performance is monitored in last 3 years and no sign of premature failure of seal has been noted. Initially, there was some level of reservation and resistance was felt from the community. However, as time goes by, bitumen came to the surface and the seal started to appear like normal spray seal, which returned confidence from the public. At present, Narrandera Council adopted strategy to continue extending seal using Otta Seal and continue doing more trial for reseal on existing spray seal using Otta Seal. Figure 3, 4 and 5 presents Otta Seal at various stages [2].

Fig 2 (a): Depicting gravel produced removing finer particles in beginning of trial
Fig 2(b) : Menzplant Pty Ltd. doing trial of stone spread at Narrandera

Fig 3(a): Otta Seal Della pool Road after 15 months of application
Fig 3(b): Close up photo of Otta Seal Dellapool Road

Fig 4(a): Otta Seal works Deep Creek Narrandera
Fig 4(b): Deep creek Otta Seal after 4 months  Fig 4(c): Deep creek Otta Seal after 2 months

Fig 5: The thickness and cross section of Otta Seal - Coorawondool Street Grong Grong

Fig 6: Landervale Road Otta Seal after a year of application

Key technical details of Otta Sealing:
Gravel specification, bitumen viscosity and amount of rolling are key characteristics that determine successful application of Otta Seal.

a) Gravel specification

Gravel specification, bitumen viscosity and amount of rolling are key characteristics that determine successful application of Otta Seal.

b) Viscosity of bitumen (C170 or C240)

For better penetration of bitumen, more cutter is used. Binder should be soft enough to initially coat the fines in the aggregate and rapidly move up by the action of rolling and traffic. In various trial works at Narrandera cutter as high as 5% was used depending on weather. The bitumen should be soft enough to continue moving up through the matrix of aggregate over period of 4-8 weeks.

c) Rolling

Rolling is important step in Otta Seal. Therefore, there is stricter requirement of rolling for better bond between aggregate and bitumen. Norwegian Public Roads Administration recommends 15+ passes with pneumatic tyred roller (gross weight >12 tonnes) on the day of sealing. Then, 1 pass with static steel drum roller on 1st day after application[1]. In all trial works at Narrandera Shire Council 15 passes was done with pneumatic tyred roller on the day of application. No after installation rolling was done in the trial works.

### Table 1: Otta seal gravel specification from Norway[1] and ADB( left to right)

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<th>Sieve sizes (mm)</th>
<th>Open grading (%) passing</th>
<th>Specified requirement(Passing)</th>
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<tbody>
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<td>19</td>
<td>100</td>
<td>Min. 100.00  Max. 100.00</td>
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<tr>
<td>16</td>
<td>80-100</td>
<td>Min. 80.00  Max. 100.00</td>
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<td>52-82</td>
<td>Min. 50.00  Max. 80.00</td>
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<td>36-58</td>
<td>Min. 35.00  Max. 55.00</td>
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Potential future works regarding Otta Seal

Author of this publication is working with Australian Road Research Bureau (ARRB) to develop a procedure to determine the useful life of Otta Seal and sprayed seal in rural environment. At present it is assumed that Otta Seal will have at least 5 years longer useful life compare to sprayed seal of similar category (The useful life should be compared with 20 mm thick sprayed seal or equivalent). This hypothesis appears to be true based on various references regarding Otta Seal. However, this is yet to be verified scientifically. Furthermore, more trial works are to be done to see the performance of Otta Reseal on top of existing spray seal.
Conclusion

Otta Seal is already tested technology which was not used predominantly in Australia. Narrandera Shire Council conducted about 6 km of Otta Seal works with successful outcome. Therefore NSC is doing 17 km of Otta Seal shoulder widening and about 10 km of seal extension of Otta Seal. The rapid use of Otta Seal in Narrandera is due to obvious advantages it has over conventional sealing.

Provided pavement is sound and drainage is abundant, road engineers can safely assume 40% more useful life from Otta Seal in comparison to sprayed seal of similar thickness. This result which is mainly due to reduction in rate of bitumen oxidation, makes extension of seal more competitive than leaving roads unsealed. This is proposed a strategy many rural council should take in management of their vast road asset.

References


2. Krishna Shrestha, Road Services Review, Narrandera Shire Council, Department of Infrastructure Services, pp 40, June 2016.


Author Biography

Krishna Shrestha is Chartered Professional Engineer of Australia under Civil and Structural engineering stream, who is working as Manager of Works at Narrandera Shire Council. He completed his undergraduate degree in Civil Engineering from best engineering institute of Nepal. He completed Masters of Science in Structural Engineering with distinction in 2005. He completed Ph.D degree in Bridge and Structural Engineering from Fuzhou University China in 2010.

Krishna has worked as lecturer, structural designer, site engineer and high level structural analyst before starting works in regional Australia in 2011. Krishna is also continuing research with Fuzhou University on High Performance Concrete, besides exploring the best way to manage rural roads and bridges infrastructure.

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