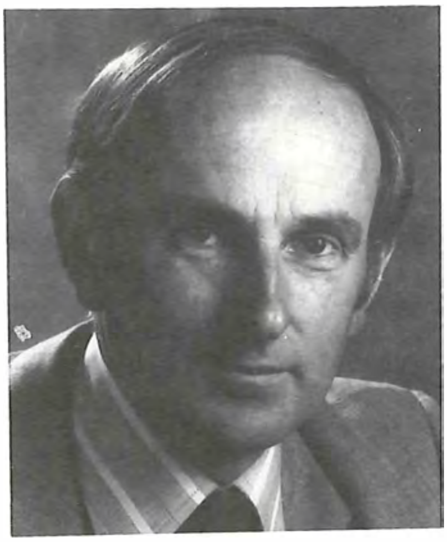

Twelve Years History of Open Graded Asphalt Performance

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SUMMARY

This paper reviews experience of the Road Construction Authority with open graded asphalt wearing course. The porous nature of open graded asphalt reduces the amount of surface water hence reducing water spray and loss of skid resistance in wet conditions. Open graded asphalt provides greatest value where surface water is of concern, for example, wide flat pavements or unusual road geometry causing long drainage paths, particularly if high speeds are involved or a high level of skid resistance is required.

Being porous, the life of such asphalt is reduced in comparison to dense asphalt. Reduction in life can be minimised with high binder contents, soft binders and addition of lime filler. The paper describes experimental sections placed to evaluate influence of binder content and binder type and practical considerations leading to the development of the current specification.

INTRODUCTION

The first trials of open graded asphalt wearing course in Victoria were placed by the Road Construction Authority (RCA) in 1974. Initially the asphalt was placed in four different traffic situations – urban arterial road, through carriageway of a freeway and on and off ramps of a freeway. Specification for the work was based on a survey of literature, mainly from the USA where such materials had been in use for about 10 years. The first reported use in Australia was by the Department of Main Roads, New South Wales, in 1967.

The asphalt mix used in the initial Victorian trials was as follows:

AS Sieves (mm)	13.2	9.5	4.75	2.36	0.60	0.30	0.075
% passing	100	98	32	16	8	5	3.3
Bitumen grade	R90						
Bitumen content	6.0%						
Coarse aggregate	Newer basalt						

Following initial observations of success, some 4000 tonne of open graded asphalt was placed on the Tullamarine Freeway in the following year. In addition experimental sections were placed to assess the influence of binder type and content. Details of the experimental work are discussed below.

The principal advantages of open graded asphalt wearing course are reduced water spray, reduced loss of skid resistance in wet weather and reduced road traffic noise.

At low speeds, skid resistance is largely a function of the micro texture of the road surface. As speed increases, the presence of surface water and the ability of the vehicle tyre to displace that water become increasingly important. Ability to displace water is partly influenced by tyre tread pattern and condition and partly by the macro texture of the road surface.

Open graded asphalt, being comprised essentially of one sized aggregate without fines, provides good macro texture which is retained throughout the life of the surfacing. Similar, or even greater, macro texture can be obtained with a sprayed seal. Compared to a sprayed seal, open graded asphalt offers the following advantages:

- Being porous, the amount of surface water and hence water spray and loss of skid resistance in wet weather is even further reduced. Photographs in Figures 1-3 show the difference in water spray from the same vehicle and same weather conditions on a smooth asphalt surface, open graded asphalt and a size 14 seal in good condition.
- Improved road smoothness and marked reduction in noise level. Measurements taken 5m from the traffic lane have recorded noise levels from traffic travelling on open graded asphalt up to 3 dB(A) less than dense asphalt and up to 5.6 dB(A) less than a 14mm sprayed seal.
- Greater resistance to traffic stresses, particularly shear stresses from stopping or turning traffic and embedment into the underlying surface.

Disadvantages of open graded asphalt relate to the life of the surfacing, lack of waterproofing effect on the underlying surface and susceptibility to damage from oil or fuel spillage. Such factors are discussed later in this paper.

2. TERMINOLOGY

2.1 Open Graded Friction Course Asphalt

Various terms have been used for open graded asphalt used as a wearing course including pervious asphalt, porous asphalt, porous friction course and "popcorn". The term adopted by the RCA is Open Graded Friction Course Asphalt, referred to as open graded asphalt in this paper. The term adopted by the RCA is consistent

Figure 1. Water spray from heavy vehicle during steady rain. Dense asphalt surface.

Figure 2. Same vehicle and conditions as Figure 1. Sprayed seal surface.

Figure 3. Same vehicle and conditions as Figure 1. Open graded asphalt surface.

with that used by the United States Federal Highway Administration (FHWA).

2.2 Bitumen Classification

Prior to 1977, bitumens used in Australia were classified by penetration at 25°C in accordance with Australian Standard A10 – Residual Bitumen and Fluxed Native Asphalt for Roadmaking Purposes. Since 1977 bitumens have been classified by viscosity at 60°C in accordance with Australian Standard 2008 – Residual Bitumen for Pavements. Relevant grades were replaced as follows:

Bitumen Grade (AS A10)	Replacement Class (AS 2008)
R200	50
R90	170
R65	320

3. EXPERIMENTAL WORK AND DEVELOPMENT OF RCA SPECIFICATION

Details of field trials and laboratory testing have previously been reported by Currie and Bethune (1976) and Rebbechi (1979). An outline of the work and conclusions reached are summarised below.

3.1 Field Trials

In April 1975 nine experimental sections were placed on an urban arterial road using bitumen contents of 5.0, 6.0 and 7.0 per cent and bitumen grades R200, R90 and R65. The following conclusions were made:

(a) Bitumen content has very little influence on laboratory stability. While there is some variation in laboratory stability with bitumen grade, mix stability is not a major consideration in choice of grade of bitumen.

(b) Bitumen film thickness, which is a function of the aggregate particle size distribution and bitumen content, has a major influence on the rate of hardening of the binder. Hardening was assessed by measurement of viscosity of recovered binder and observation of the onset of ravelling.

(c) Softer grades of bitumen take a longer time to harden to the stage where ravelling occurs.

(d) Drainage of bitumen from the mix during transport can be a problem with softer bitumens and at high bitumen contents thereby reducing bitumen film thickness. This confirms the reasons given by the Transportation Research Board (1978) in warning against the use of a low viscosity bitumen in order to obtain a better starting point for long term hardening.

Based on the above it was concluded that the optimum specification for all traffic situations was the use of Class 170 bitumen at binder contents in the range 6.0 to 7.0 per cent.

3.2 Laboratory Design by the FHWA Method

Design practice for open graded mixes is not well defined. In many cases designs are based on broad limits for aggregate gradation and binder contents developed from field experience.

One of the attempts at a formalized procedure is that put forward by the FHWA (Smith, Rice and Spelman 1974). The procedure involves the following stages:

(a) Determination of binder content by a two step procedure.

(i) A measurement of surface capacity (Kc) of the coarse aggregate from the quantity of lubricating oil retained on the aggregate.

(ii) Calculation of binder content (X) by standard linear relationship

$$X = 2.0\ Kc + 4.0$$

(b) Measuring the voids in a compacted sample of the coarse aggregate.

(c) Calculation of optimum quantity of fine aggregate to fit between the coarse aggregate to chock the mix but allow sufficient voids for adequate internal drainage.

(d) A binder drainage test to check mixing temperature.

(e) A check on retained strength after soaking in water for four days at 49°C.

A later amendment to the procedure (Transportation Research Board 1978) provides correction factors for unusual densities of aggregates.

Comparison with the mix adopted by the RCA gave the results shown in Tables 1 and 2.

Table 1 - Comparison of RCA mix with grading and bitumen content determined by FHWA method.

AS Sieve (mm)	13.2	9.5	6.7	4.75	2.36	1.18	0.60	0.30	0.15	0.075	Binder %	Binder Class
FHWA	100	96	63	32	15	13	10	7	4	4.0	6.6	170
RCA	100	96	62	29	12	10	8	6	4	4.0	6.5	170

Table 2 - Comparison of test properties

Mix	Test	Stability (kN)	Retained Stability %	Flow (mm)	Air Voids (%)	VMA* (%)	Cohesiometer	Film Thickness (Microns)
FHWA	Normal	4.4		1.6	18.5	31	87	16.5
	Soaked	3.7	83.7	2.0	18.1	31	77	
RCA	Normal	4.3		1.4	20.5	33	78	19.0
	Soaked	3.2	74.8	1.6	20.2	32	88	

* VMA = Voids in Mineral Aggregate

For the purposes of the above comparison the same binder content was adopted for the RCA mix as was determined by the FHWA method.

The mix determined by the FHWA method was not significantly different to that in use by the RCA except that the slightly finer aggregate grading resulted in a lower calculated bitumen film thickness.

3.3 Use of Hydrated Lime Filler

No added filler was used in the earlier work. The literature surveyed had indicated that lime filler was desirable where stripping was a problem. Stripping of binder in asphalt mixes is rare in Victoria and the above testing by the FHWA procedure had indicated satisfactory levels of retained stability of water soaked samples.

There is now growing evidence that hydrated lime added to bitumen also improves its durability. All open graded asphalt work done by the RCA since 1980 has included a requirement for hydrated lime to be added at the rate of one per cent by mass of the mineral aggregate.

3.4 Current Specification

The RCA specification has now evolved to the following basic technical requirements.

(a) Aggregate grading

AS Sieve (mm)	13.2	9.5	6.7	4.75	2.36	1.18	0.60	0.30	0.15	0.75
% passing	100	95	61	30	12	10	8	6	4	4.0

(b) Added filler
the mix shall contain at least 1% added filler being hydrated lime.

(c) Bitumen content 6.5%.

(d) Bitumen class 170.

(e) Maximum temperature at mixing plant 145°C.

4. CASE STUDIES

The following is not a complete list of all open graded friction course asphalt work done by the RCA. Examples have been selected to illustrate the job circumstances where such a treatment may be applicable.

4.1 Urban Freeways

Prior to 1974 the asphalt surface on a four kilometre length of the Tullamarine Freeway adjacent to the southern boundary of Essendon Airport had become flushed and smooth. Attempts to texture the surface by coking and by applying a sprayed seal were both unsuccessful due to the softness of the underlying asphalt. Open graded asphalt was applied to both carriageways and on and off ramps during 1974 and 1975.

Some of the surfacing on the ramp areas was removed and replaced with dense asphalt in 1979. The through carriageways were not retreated until 1985, having retained a good surface texture but suffering gradual deterioration due to surface ravelling. Some areas were treated with a sprayed seal and the remainder removed and replaced with similar material. Further areas of the freeway have also been treated with open graded asphalt.

4.2 Urban Arterial Roads

One of the early open graded asphalt jobs, done in 1977, was a length of urban arterial road with several bends and changes of grade which had a poor record for wet weather accidents particularly single vehicles losing control and leaving the carriageway. After surfacing, skidding accidents dropped significantly. The surfacing is still in good condition with slight ravelling.

Other examples include poor road alignment where vehicles have to contend with combined effects of unsatisfactory superelevation and long drainage paths causing increased depth of water on the road.

4.3 Rural Arterial Roads

One example, surfaced in 1980, has a steep grade and series of bends approaching a narrow bridge. The road carries a large volume of trucks carting quarry products. The surfacing is currently in excellent condition.

A similar example on a rural main road was placed in 1984.

4.4 Frost Prone Areas

In some of the colder parts of the state, sub-zero temperatures can occur after rain thereby forming ice on the surface. One rail overpass on a rural highway seemed to be particularly susceptible due to exposure of the elevated structure and the multi-curved alignment. After surfacing with open graded asphalt in 1977 there were no further reports of cars skidding on ice.

The surfacing was removed and replaced, again with open graded asphalt, in 1985. Good texture had been retained but the surfacing was deteriorating due to ravelling and some cracking over weaker pavement areas. Distressed pavement areas were patched with conventional asphalt prior to resurfacing.

4.5 Shaded Forest Area

In some forest areas, shading and cold conditions mean that the surface is almost always damp. Combined with the scuffing effects of vehicles on sharp curves, good quality sprayed seal work can be difficult. A section of the Mount Dandenong Tourist Road in the Dandenong Ranges near Melbourne was successfully surfaced with open graded asphalt in 1983.

5. CONCLUSIONS

5.1 Use of Open Graded Asphalt

Open graded asphalt is useful as a road surfacing where presence of surface water is of concern. Such situations include high speed roads with wide flat pavements or other roads where road geometry causes long drainage paths for surface water and particularly if the circumstances also require a high level of skid resistance due to factors such as road alignment, adverse crossfall, etc.

Suitable surface texture depth for such situations may also be provided by a sprayed seal. Factors which would influence the choice of open graded asphalt in preference to a sprayed seal include the provision of a smoother, quieter surface, greater resistance to traffic stresses and not being affected by existing surface conditions such as flushed bitumen that could make sprayed seal work difficult. Certain practical considerations must also be taken into account in using open graded asphalt and these are summarised below.

5.2 Practical Considerations

(a) In order to maintain skid resistance, open graded asphalt requires the use of polish resistant aggregates.

(b) Open graded asphalt surfacing adds little to the structural strength of the pavement and being porous, it is essential that it only be placed on a sound, waterproof base.

(c) The surface on which the open graded asphalt is placed should be free draining to avoid water being trapped in the mix. Edges should also allow water to drain and it is usually necessary for open graded asphalt to be finished above adjoining surfaces.

(d) Open graded asphalt cannot be feathered out to thin layers (less than twice the maximum aggregate size).

(e) Upper temperature limits must be strictly controlled to avoid binder drainage during transport and handling. Such drainage can reduce the effective bitumen film thickness in the mix and may also show up as slick fatty areas in the finished work.

(f) Open graded asphalt is susceptible to damage from oil or fuel spillage. Oil droppings at signalised intersections and moderate traffic volumes has not been a problem in RCA experience but use at heavily trafficked intersections has been avoided. In one incident, spillage of petrol from a vehicle accident caused rapid and substantial damage to an open graded asphalt surface.

5.3 Life of Surfacing

Apart from some smaller sections retreated after four years, most of the earlier open graded asphalt placed by the RCA gave satisfactory service for 8 to 11 years. With development of mix specification in terms of bitumen grade, bitumen film thickness, the use of more durable bitumen and the addition of hydrated lime filler, it is expected that longer service life will be obtained from more recent work.

Substantially longer lives have been reported by Gaughan and Leung (1978) who also state that through traffic compaction and possibly some build up of detritus, the surfacing had reached low permeabilities, comparable to dense graded mixes. Subsequent life comparable to a dense graded asphalt mix is therefore to be expected.

Permeability has not been measured on RCA mixes but all open graded asphalt surfacings have remained visibly porous throughout their life. Testing of cores taken four years after placing gave air voids generally in the range 15 to 20 per cent.

5.4 Resurfacing

Where the RCA has retreated areas of open graded asphalt there has generally been constraints on level so that the surfacing has either been removed and replaced or surfaced with a sprayed seal. In the case of sprayed seals the RCA has adopted bitumen scrap rubber binder on the basis that the higher viscosity binder is less likely to be absorbed into the porous surface.

6. ACKNOWLEDGEMENT

This paper is presented with the permission of the Managing Director of the Road Construction Authority Mr T.H. Russell. However, responsibility for the content and opinions expressed therein remain with the author and should not be taken as necessarily reflecting the attitude of the Authority or of individual officers.

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