AAPA
AUSTRALIAN ASPHALT PAVEMENT ASSOCIATION

advisory note 16

LARGE AGGREGATE MIXES

INTRODUCTION

Large aggregate asphalt mixes are those with a nominal size of 28 mm or greater. Large mixes for thick asphalt base layers offer greater stiffness, deformation resistance and structural load carrying capacity than multiple layers of smaller nominal size mixes, as well as economies due to lower binder content. Disadvantages in the use of large aggregate mixes relate primarily to problems of segregation and handling. Some methods traditionally used for mix laboratory design of asphalt mixes are also unsuited to the very large sizes.

The purpose of this advisory note is to discuss some of the factors which may have inhibited greater use of large aggregate mixes in Australia, with a view to developing a better understanding of their effective use.

FACTORS INFLUENCING USE

The use of dense graded 28 mm mixes in heavy duty base applications has shown some increase in recent years due to the ability to obtain greater stiffness and deformation resistance, and greater economy, than with 20 mm mixes. The use of 40 mm mixes, that potentially provide even greater levels of performance, is extremely rare, although such mixes were moderately popular 20 to 30 years ago.

Factors that influence the use of large aggregate mixes include:

- Available quarry fractions
- Suitability of design procedures
- Handling and segregation
- Required layer thickness.

Available Quarry Fractions

The closeness in particle size distribution of 20 mm and 28 mm nominal size aggregates means that many quarries only screen to one or the other, not both. The wider uses for 20 mm aggregates means that they are more likely to be stocked in preference to 28 mm.

Similarly, the asphalt producer has a wider demand for 20 mm asphalt and hence additional stockpiles and change of cold feeds to accommodate 28 mm mixes incurs some cost and inconvenience. One outcome is a tendency in some places for so-called 28 mm asphalt mixes to be merely a 20 mm mix produced to the coarse side of the grading envelope, or with a small proportion of oversize material. A genuine 28 mm asphalt mix should be manufactured using a 28 mm aggregate that has 85-100% passing the 26.5 mm sieve and a significant proportion (at least 40%) retained on the 19.0 mm sieve.

40 mm aggregate should represent a readily available quarry fraction provided that the customer demand warrants its production. Similarly it represents an additional, or alternative cold feed size that must be catered for at the asphalt production plant.

Suitability of Design Procedures

The reliance on 100 (or 101.6) mm cylinders for compaction of asphalt using the Marshall procedure precluded the use of 40 mm aggregates. Some users even doubt the suitability of using such size moulds for 28 mm mixes.

Various surrogates have been used, including design of 20 mm minus fraction and then adding 40 mm aggregate, or modified Marshall compaction procedures using 150 mm moulds. An example of the latter was promoted by AAPA as Advisory Note 6 – *A Guide to Test Procedures for Large Aggregate Asphalt Mixes by Modified Marshall Test*. Satisfactory mixes were also developed and used based on arbitrary grading limits and field density. Such mixes were the basis of a number of the early full depth/ deep strength asphalt pavements constructed in Melbourne in the 1970s, and which have given excellent performance.

In spite of the good field performance, suspicion surrounding the use of arbitrary and surrogate design procedures (along with the handling difficulties referred to below) was a significant factor in the decline in popularity of 40 mm mixes.

continued

Head Office: Level 2, 5 Wellington Street, KEW Victoria 3101
Tel: (03) 9853 3595 Fax: (03) 9853 3484 E-mail: info@aapa.asn.au Web: www.aapa.asn.au

Gyratory compaction, in either the Gyropac or Servopac, provides for the use of 150 mm diameter samples in addition to 100 mm samples used for smaller nominal sizes. This allows production of laboratory compacted asphalt samples with nominal sizes up to 40 mm. The previous inability to obtain basic test data is thus largely overcome, although some tests such as fatigue may still be difficult. Newly developed procedures for compacting larger slabs of asphalt can also be applied to the larger size mixes. The refusal density test, as used in Britain, is a further option for confirming volumetric properties and deformation resistance of large aggregate mixes.

Handling Properties (Segregation)

The principal difficulty in handling larger size mixes is controlling segregation. The tendency of asphalt mixes to segregate increases with increasing nominal size. Wherever mix falls or flows in a stream there is a tendency for coarse particles to roll to the outside of the flow. Critical handling situations occur in operation of surge storage and loading systems, flow of mix from trucks into the paver hoppers, paver distribution augers and any type of handwork. The problems are greatest at the start and finish of any particular batch or sequence.

Segregated asphalt leads to poor surface finish with variable texture. Bony areas can be viewed with concern as having reduced stiffness and increased permeability.

A great deal of literature has been written on causes and control of segregation in asphalt mixes. AAPA Advisory Note 8 – *A guide to the Use of Large Stone Asphalt Mixes* provides a list of references. A further recent publication is published by AASHTO in 1997 under the title *Segregation – Causes and Cures for Hot Mix Asphalt*.

Layer Thickness

Achieving good compacted density in asphalt mixes generally requires a minimum layer thickness of about 2.5 times the nominal size of aggregate. That translates as 70 and 100 mm for 28 and 40 mm mixes respectively. Such layer thicknesses only occur in the lower layers of heavy duty deep strength and full depth asphalt pavements. Even where the overall thickness of asphalt pavements allows single layers of 100 mm or more, multiple layers may be chosen in order to provide better control over shape and ride quality outcomes, particularly where achievement of a high standard of ride quality is a specification criterion.

All the above factors have combined to various degrees to influence either confidence in outcomes or commercial desire to promote larger mixes, particularly 40 mm. Many of the negative issues can be overcome to provide beneficial outcomes in performance and cost effectiveness of thick asphalt pavements.

DESIGN OF DENSE GRADED LARGE AGGREGATE MIXES

Continuously graded asphalt mixes rely on load being transferred down through progressively smaller aggregate sizes interlocked with the previous larger size. The usual aggregate gradation relationship is:

$$P = \left(\frac{d}{D}\right)^{n} * 100$$

Where:

P = percentage passing sieve size d (mm)

D = maximum stone size

n = a parameter established by Fuller to determine shape of grading curve.

For maximum density, values of n = 0.45 or 0.5 are commonly used.

Optimum performance (flexural stiffness and deformation resistance) is achieved with a continuous grading with no gaps in any particular size fraction. In this type of mix the fine fraction is equally as important in load carrying capacity as the coarse fraction. Shape, surface texture and quality of fine aggregate has a substantial influence. Binder and filler characteristics (which influence binder stiffness) also play a major role.

High levels of performance therefore require good quality crushed aggregates and stiff binders. Most of these aspects are adequately covered in existing specifications. General procedures for the design of asphalt mixes, including large aggregate mixes are described in APRG 18. Typical volumetric requirements for dense graded large aggregate mixes are shown in Table 1.

continued

Mix Size	28 mm	40 mm
Sieve size (mm)	Percentage Passing	
53.0		100
37.5	100	90-100
26.5	90-100	80 - 95
19.0	75 - 95	65 – 85
13.2	60 - 80	
9.5	50 - 70	40 - 60
2.36	25 - 40	18 - 35
0.075	3 - 6	4-6
Binder content (%)	3.5 – 5.5	3.0 – 5.0
Air voids (Gyropac 80 cycles)	3 - 7	3 - 7
VMA (%)- minimum	13	12
Binder film thickness (µm) - minimum	7.5	7.5

Table 1. Typical volumetric requirements for dense graded large aggregate mixes

COARSE GRADED AND GAP GRADED LARGE AGGREGATE MIXES

Efforts to develop coarse graded and gap graded large aggregate mixes have been undertaken in other countries, particularly South Africa and at the Texas Transportation Institute, Texas A&M University, USA.

In South Africa continuously graded mixes were developed with grading exponents (n) as high as 0.7. It was found that the coarse graded mixes gave good structural performance but had significant problems with segregation that resulted in changes to design recommendations that adopted dense (n = 0.45) continuously graded mixes in preference to more coarsely graded mixtures.

The mixes developed in the USA use the concept of a coarse aggregate skeleton to carry the structural load and to fill the voids in the coarse aggregate with a matrix of fine aggregate, filler and bitumen to provide cohesion and durability. The design concept is somewhat similar to stone mastic asphalt, but with lower binder contents. The USA work is published as an NCHRP report No 386.

Tentative criteria for coarse gap graded mixes, based on the work done in the USA, are shown in Table 2. It should be noted that there is very little field experience using such large aggregate mixes. A preliminary assessment has shown that control of segregation in small quantities of mix in the laboratory is very difficult, thereby increasing the difficulty of representative samples for design purposes. Bulk samples produced in an asphalt mixing plant, however, do not show the same degree of segregation but still require more care in handling than similar sized dense graded mixes.

Due to its dominance in such mixes it is important that the coarse aggregate be of good quality and good shape (maximum 20% flakiness index).

REFERENCES

APRG Report No.18 (1997)– *Selection and Design of Asphalt mixes – Australian Provisional Guide*.

AAPA Advisory Note 8 – *A Guide to the Use of Large Stone Mixes*.

AASHTO (1997) *Segregation – Causes and Cures for Hot Mix Asphalt*.

SABITA (1997) *LAMBS – The design, construction and use of large aggregate mixes for bases*.

National Cooperative Highway Research Program (NCHRP) Report No. 386 (1997) – *Design and Evaluation of Large-Stone Asphalt Mixes*.

Mix Size	28 mm	40 mm
Sieve size (mm)	Percentage Passing	
53.0		100
37.5	100	90-100
26.5	90-100	40-60
13.2	40-60	30-45
9.5	30-45	
2.36	20-30	20-30
0.075	4-6	4-6
Binder content (%)	3.5 – 4.5	3.0 – 4.0
Air voids (Gyropac 80 cycles)	4 - 6	4 - 6
VMA (%)- minimum	12	11
Binder film thickness (µm) - minimum	7.5	7.5

Table 2. Tentative criteria for coarse gap graded large aggregate mixes

Head Office: Level 2, 5 Wellington Street, KEW Victoria 3101
Tel: (03) 9853 3595 Fax: (03) 9853 3484 E-mail: info@aapa.asn.au Web: www.aapa.asn.au