1. **Introduction**

Two major challenges facing road authorities are the need to rehabilitate existing pavements composed of marginal materials being subjected to higher loads than originally anticipated, and the increasing shortage of quality quarried materials available for new construction. The problem is exacerbated by the trend towards the introduction of environmental legislation, which is adding to the costs of commissioning new quarries and opening up new pits.

One option being considered is the use of marginal materials which are upgraded to acceptable quality through the use of insitu stabilisation. However, before such a strategy can be implemented, road authorities need to gain an understanding of the impact that the use of such materials may have on the long-term performance of the road network, and whether the additional costs associated with this process adds value to the asset in terms of increased pavement life.

To this end, in 1995, the Austroads Pavement Reference Group (APRG), in conjunction with members of the Australian asphalt (AAPA) and stabilisation (AustStab) industries, and Transport South Australia, undertook the construction and field testing, using the Accelerated Loading Facility (ALF), of several trial pavements at a site in Dandenong, Victoria. Extensive complementary testing was also conducted in the laboratory.

3. **Results of Laboratory Testing**

The marginal material was a ripped-sandstone rubble from the Woollen Rises Quarry in central Victoria. This type of material is commonly used as a base and sub-base pavement material in this region. The material had a PI of 7, a soaked CBR of about 50 and an indicative resilient modulus of 400 MPa.

The main conclusions were as follows:

- There was a linear relationship between resilient modulus and dry density for both stabilised materials but significant differences in the results depending if the samples were prepared using the gyratory or dynamic compaction methods.
- The importance of compacting the bitumen/cement-stabilised material as soon as practicable after mixing was highlighted.
- The modulus of cores of both materials varied over the test site. Typical modulus values of the top 100 mm of the bitumen/cement cores were 1,800 MPa after 35 days and 3,000-3,500 MPa after 450 days. Typical values for the slag/lime cores were 5,000 MPa after 70 days and 7,500-10,000 MPa after 550 days. There was, however, little if any increase in the modulus of the bottom 100 mm of the cores over time.
- The current Austroads relationships between resilient modulus and UCS over-estimated the moduli of the asphalt surfacing layer was used to ensure that the ALF wheel load assembly operated efficiently.

In addition to the need to assess the performance of these pavements, APRG sought to: develop indicative pavement material performance characteristics in the laboratory; examine the influence of curing time on performance; and generally provide input into the revision to the Austroads Guide to Stabilisation of Roadworks.

The trial pavements were considered suitable for local government roads and low-trafficked rural highways having a design traffic in the range of $10^3$ to $10^5$ ESAs. It was anticipated that this type of pavement would have a sprayed-seal wearing surface in service.

2. **Trial Pavements**

The trial pavements consisted of the following base materials:

- **S1** high quality crushed rock
- **S2** marginal material (sandstone rubble)
- **S3** marginal material stabilised insitu with 2% bitumen & 2% general-purpose (GP) cement
- **S4** marginal material stabilised insitu with 5% ground granulated blast furnace slag/lime (85/15)

The pavements consisted of a 200 mm thick base, and an imported subgrade 400 mm thick having an unsoaked CBR of 10 and a soaked CBR of 3. A 30 mm thick asphalt surfacing layer was used to ensure that the ALF wheel load assembly operated efficiently.
bitumen/cement cores but appeared to be more appropriate for the slag/lime cores.

4. Performance Under ALF Loading

In general, the performance of both the stabilised materials was satisfactory, with no fatigue cracking or subgrade deformation observed. The performance of the stabilised pavements was also superior to that of the unstabilised sandstone test section.

Problems during construction resulted in a less than ideal curing regime for both of the bound pavements. In addition, hot weather during construction resulted in considerable drying out of the top of both materials, particularly the slag/lime pavement, and considerable numbers of shrinkage cracks were observed prior to the application of the prime and asphalt surfacing. Typically, stabilised pavements require seven days moist curing or to be sealed immediately with an approved curing compound. Alternatively, the next layer of the pavement should be constructed to prevent excessive drying of the stabilised surface that may lead to cracking.

During ALF trafficking the asphalt surfacing separated away from the bound base material at some locations. This was related to the poor bond between the asphalt and the bound base material, which meant that the asphalt was easily sheared under this high ALF load, leading to a breakdown of the material. The poor bond was found due to the presence of a thin (10-15 mm thick) layer of unbound material sandwiched between the asphalt and the bound base.

It was observed that the top material in the slag/lime layer was not formed into a tight fully-bound material, but was composed of very fine, mostly horizontal, shrinkage cracks. This cracked material was effectively unbound and had no tensile strength and, under the (heavy) loading, was crushed, resulting in a fine material with particles sizes no larger than the fine sand which constituted the sandstone material. As a result, the pavement did not gain strength and the ability to form a satisfactory interface with the asphalt surface layer. Under subsequent heavy trafficking this fine material was shoved to the sides of the test strips as shown below.

With respect to the bitumen/cement, the observed surface deformation and shoving was caused by the movement of the surface of the material under the ALF 80 kN dual-wheel load. Unlike the slag/lime, there was no delay between the insitu stabilisation process and the application of the primer. However, the presence of fine surface cracks was again observed prior to the placement of the asphalt surface and, under the heavy loading (twice the legal limit), the surface of the layer was crushed.

On the basis that the stabilisation process is efficient enough to guarantee uniform mixing of the materials throughout their depth, it is possible that over-compaction of the material during construction resulted in a breakdown of the marginal sandstone.

5. Construction Requirements

The adoption of best construction practice is important if optimum performance of the stabilised marginal material is to be achieved. It is recommended that:

- Compaction should proceed immediately after mixing the binder into the pavement material and a maximum compaction standard of 95% of Modified MDD be adopted when the parent material is a marginal sandstone liable to break down under load.
- All waste material resulting from trimming to meet the final alignment should be removed and not incorporated as a thin layer of surfacing material; otherwise, a lack of bonding between the stabilised layer and the surface treatment may result.
- Controlled curing should take place immediately after construction and proceed for at least 7 days, or until the next pavement layer, or the surfacing, is constructed. Trafficking of the pavement during curing is desirable.

6. Relative Costs

The relative cost of constructing the unbound marginal pavement and the stabilised pavements was compared in terms of the observed performance under ALF loading. Whilst the cost of constructing the stabilised pavements was 2 to 3 times the cost of constructing the unbound pavement, the performance of the stabilised pavements, in terms of deformation under repeated heavy loading (i.e. equivalent to a 16 tonne axle load), was 6 to 10 times superior to that of the unbound section.

Further Reading
