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## BITUMEN STABILISATION - A NEW APPROACH TO RECYCLING PAVEMENTS

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### INTRODUCTION

In Australia, as in many other parts of the world, the need for recycling of scarce resources has been recognised as an important activity for today and the future. In the pavements industry this has mostly meant recycling of hot mixed asphalt into base course and surface hot mixes. However, most roads are constructed of crushed rock bases on natural subbases. These crushed rocks are themselves becoming scarcer and have required stabilisation to make them suitable to bear the ever increasing loads. This has often meant stabilisation with cement either in initial construction or in recycling. Cement is subject to shrinkage cracking and pavement stiffness can be markedly reduced quite early in life. Thus hot mix overlays must be designed thicker to overcome this problem.

The solution is to stabilise with bitumen based materials. The effect of using bitumen is to create a water impermeable, flexible layer of superior fatigue resistance to a cement treated base (CTB).

### Methods of Bitumen Addition

The methods of bitumen addition to base materials are:

a) Hot in place or in plant

This creates a hot mixed type material that cools rapidly and so must be kept hot to allow compaction. Laying must be through a paver. This method is not in commercial use.

b) Cutback mixed in-place or in plant

This method allows working time of the cold mix resulting but the cutter added must be evaporated substantially before the mix can be compacted and significant cure time is required. Such a system is best suited to low volume roads.

c) Emulsion mixed in place or in plant

There is a large effort being put into such systems in Europe and these were extensively reported on in Eurobitume (1993). The draw backs of such systems relate to cure time. Emulsions introduce high levels of water and this must be dried out for the system to attain full strength. In some newer systems cement is mixed with emulsion to overcome such difficulties and such systems are currently adopted in Australia by various companies including Mobil (Emoleum).

Emulsion systems, especially in remote areas do have a freight debit.

#### d) Foamed Bitumen

Foamed bitumen is another way of delivering bitumen into a mix. This paper deals with this process. Foamed bitumen rapidly cures and is easy to use. The use of advanced mix design and pavement design techniques from hotmix technology create a system that makes the use of bitumen stabilisation economical and effective.

### FOAMED BITUMEN DEVELOPMENT

#### Historical Development Of Bitumen Foam

The first foamed bitumen processes were described by Csanyi (1957). In this process <sup>steam</sup> water was introduced into hot bitumen, under pressure, through a specially designed nozzle. On ejection the water rapidly expanded and a short lived foam was created.

The major drawbacks of this system were the control of foam life and expansion and thus the coating of aggregates.

In the late 60's and early 70's Mobil developed a low pressure, cold water system. This improvement allowed the introduction of a controlled stream of cold water into a stream of bitumen, mixing in a chamber, delivery to a spray bar, and distribution through spray nozzles. This system was limited because it was unable to deliver bitumen content accurately and the jets were inclined to block.

In the 80's and 90's Mobil has continued to develop the technology and today's system employs individual expansion chambers which allow tight control of distribution of foam. Also the extensive work carried out on bitumen composition and chemistry has allowed the development of a range of specialty additives to control foam expansion and life, thereby allowing the use of any bitumen, and close control of wetting in the mixing process.

#### Physical and Chemical Aspects Of Bitumen Foam

Foamed bitumen is a method of reducing the viscosity of bitumen to allow a dramatic improvement in wetting at the bitumen aggregate interface. This is achieved by substantially increasing the surface area of the bitumen/ aggregate contact and lowering the interfacial tension.

Optimum coating of mineral particles is achieved by careful design of a bitumen/ additive system, control of expansion pressures and temperature, and control of water content and composition.

The foams produced may be used in a number of applications, depending on the foam characteristics. For example, spray seal employs a fine foam that has low expansion (7-10 times). However viscosity reduction is high allowing wetting over a range of conditions and the half life is of the order of 1.5 minutes, but the total life of the foam is around 20-30 minutes. The fineness of the foam creates reduces surface tension and aids wetting.

On the other hand foams for stabilisation are required to cover much higher surface areas ( fines in the mix). In this instance a fine foam is still required to allow rapid wetting but an expansion of up to 15 times is desirable. Half lives are around 40 seconds but the foam remains mobile for up to an hour, allowing compaction.

Laboratory assessment of bitumen for foam takes all of these factors into account and, for each bitumen and application an optimum foam may be designed. The precise nature of the doping systems in the field allows excellent replication. However, because of different temperature loss effects and weather conditions the final result is determined by physical properties and some field adjustment may be required.

### **Foam Composition**

When water is heated rapidly above its boiling point it becomes steam. The rapid nature of this expansion and the subsequent cooling as the foam leaves the nozzles, together with the rapid contact made with damp and cold aggregates creates a multi phase composite system.

Foamed bitumen in this case will consist of bitumen, air, water vapour and water. As the added water is less than 2% in most instances and steam loss does occur the morphological structure of foam is mostly air and bitumen. However some water will incorporate from the contact of the hot foam with cold damp aggregates ( at OMC).

Coating occurs at the aggregate foam interface at the moment of contact. Residual mobility aids in compaction. The foam collapses as the foam structure is unstable.

## **DESIGN OF FOAMED BITUMEN MIXES**

### **Mix Design Procedure**

Design of foamed bitumen mixes follows rational approach now introduced for hotmix. Design is carried out on crushed base material representative of the onsite material. The basic design procedure entails the following steps:

- determine grading of crushed base material
- determine optimum moisture content of foamed mix
- prepare foamed bitumen samples
- cure samples for three days at 60°C
- measure resilient modulus and creep using MATTA

### **Grading Requirement**

The ideal grading requirement is shown as Zone A in Fig. 1. Material meeting Zone B is suitable for low trafficked roads without any grading adjustment. For high trafficked roads coarsening of the grading would be required. Material meeting Zone C would need fines incorporated to bring it to Zone A. Cement works flue dust is normally used to increase fines. Lime addition is used where high levels of plastic fines are present. Coarsening can be achieved with addition of single size large aggregate.

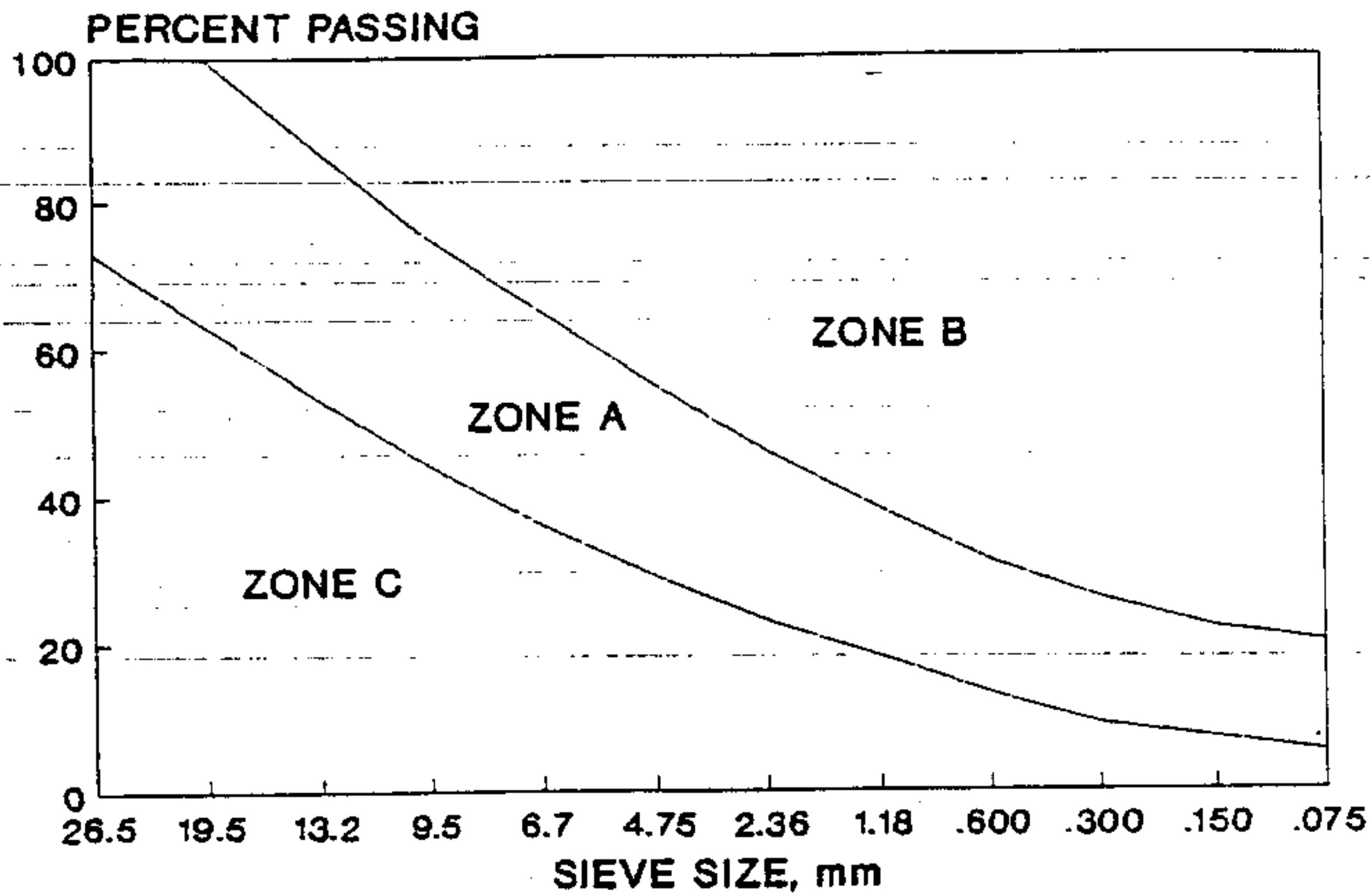


Fig. 1 Material Grading Zones

**Sample Preparation**

Sample preparation consists of bringing the mineral aggregate to optimum moisture content and then mixing intimately with a freshly prepared foamed bitumen. For convenience of using 100 mm diameter mould, oversize material (> 26.5 mm) is removed from crushed base material before stabilisation. On the road the larger size material will impart improved load bearing capacity. A minimum of three binder levels are used to prepare samples and typical range is 3% to 5%. Lab compaction is done with compactive effort to replicate field density. From data to date this is 150 cycles of gyratory compaction (2° angle and 240 kPa loading) or 75 blow Marshall one face. *→ 120 blows*  
 Samples are cured in fan forced oven at 60°C for 3 days.

**Binder Content Selection**

Optimum binder content is selected from modulus vs binder content relationship. A typical relationship is shown in Fig. 2. Modulus is determined on both dry and wet conditioned samples. Wet conditioning consists of 24 hour soak in water bath at 60°C. Optimum binder content is obtained to represent maximum wet modulus or a minimum modulus requirement. Creep properties are measured on dry samples at optimum binder content only.

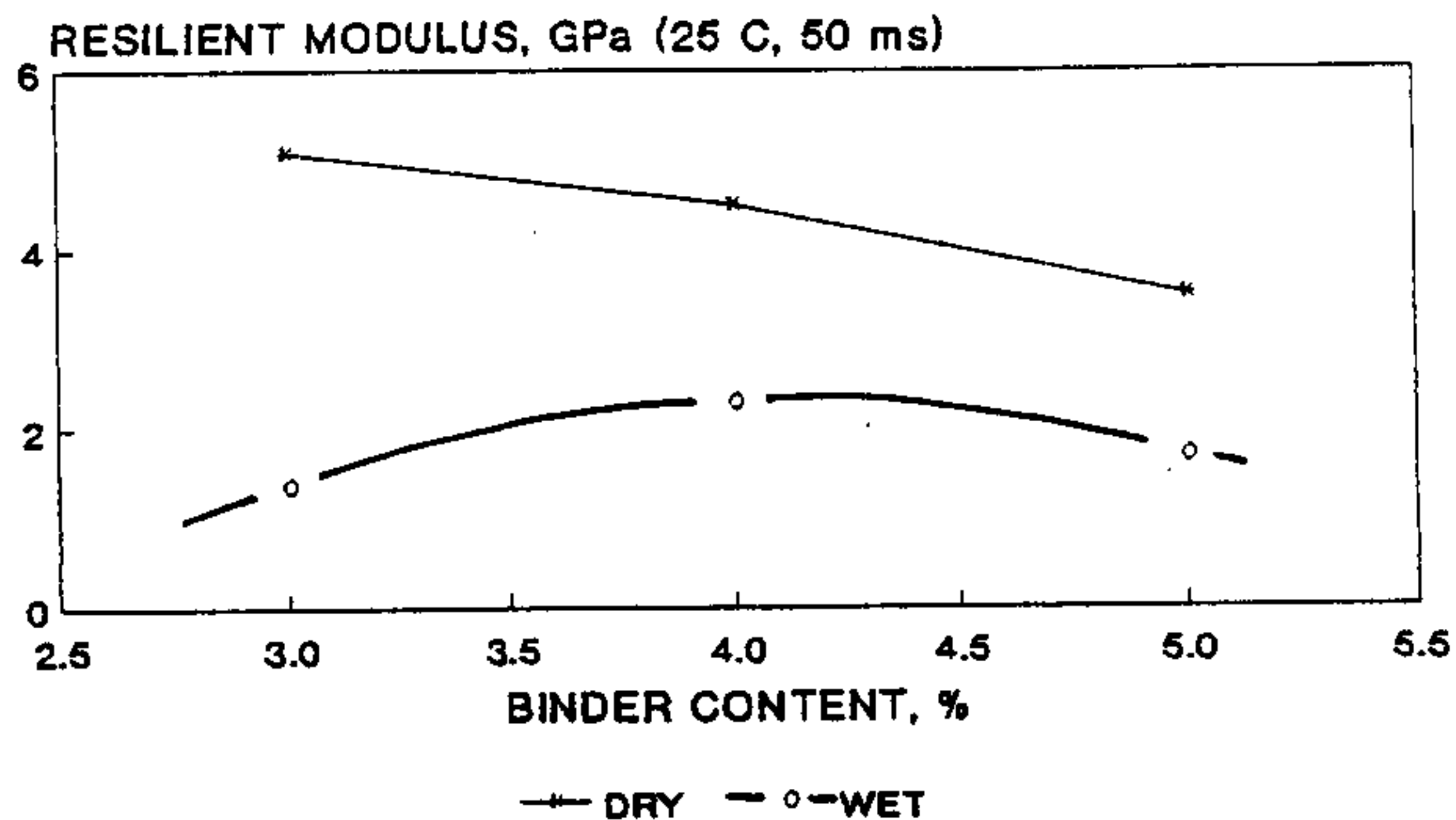


Fig. 2 Modulus - Binder content relationship for bitumen foamed sample



## PAVEMENT DESIGN

The principles of pavement design in AUSTRROADS Pavement Design are used for foamed bitumen mix. The same fatigue relationship used for hotmix is used as TRRL testing has shown that fatigue of foamed bitumen mix is similar to hotmix. Modulus determined from wet conditioned testing is used as input for CIRCLY strain calculations. Typical value is 2000 MPa at 25°C and 50 ms rise time. Modulus at this rise time is about 35% lower than for 10 ms rise time (80 km/h traffic speed) and serves as a tolerance for construction practices. Volumetric binder content depends on effective residual binder content of pavement being recycled. Typical range of binder volume content is 9% to 11%; the lower level for granular pavements and the higher level for pavements containing considerable amounts of asphalt.

Insitu modulus, in reality is likely to be well above the wet modulus value, especially in well drained pavements, after several months of field curing. This will serve as an extra safety factor for design.

## REHABILITATION OF SOMERTON ROAD - SHIRE OF BULLA

### Initial Conditions

The 2 km section of Somerton Road from Pascoe Vale Road to Hume Highway, 20 km north of Melbourne, carries about 20,000 vehicles per day with 15% heavy vehicles. The condition of this section of road was visibly distressed before rehabilitation works were commenced. There were extensive areas of bad cracking, severe rutting, patching and general shape loss.

For most part the pavement consisted of a granular make up of about 400 mm depth with a bitumen seal. A small section of the road had a 50 mm asphalt overlay.

Deflection results indicated that more than 30% of the tested pavement needed strengthening to resist rutting induced by heavy vehicle traffic. The poor condition of the pavement was further supported by curvature results. Design curvature was exceeded for most of the pavement.

### Rehabilitation Alternatives

Initial rehabilitation alternatives ( VicRoads, 1992) consisted of the following:

- thick asphalt overlay
- thick asphalt overlay and cement recycling
- cement recycling and thin asphalt overlay

For 20 year design life as required by VicRoads only the first two treatments would be suitable. The third option would only be suitable for a relatively short term. A thick asphalt overlay ( minimum of 175 mm) is required to inhibit reflective cracking initiated in the cement treated layer.

A foamed bitumen stabilisation option was considered as this offered considerable savings. A comparison of predicted pavement lives for conventional deep strength asphalt and foamed bitumen stabilisation alternative is shown in Table 1. The foamed bitumen stabilisation alternative offered an increased life at reduced cost.

TABLE 1. COMPARISON OF TWO REHABILITATION ALTERNATIVES	
Conventional Deep Strength Asphalt	Foamed Bitumen Alternative
45mm Wearing Course Asphalt	45mm Wearing Course Asphalt
90mm Intermediate Layer	
100mm Base Layer	300mm Foamstab (4% Bitumen)
150mm Cement Treated Base	
Life: $3 \times 10^7$ ESA's	Life: $5 \times 10^7$ ESA's

## WORK PROGRAM FOR SOMERTON ROAD

The rehabilitation work consisted of:

- Pulverisation of the existing pavement to a depth of 300mm
- application of water to bring the moisture content to optimum moisture content
- spreading of cement works flue dust
- stabilisation with foamed bitumen
- shaping, trimming and compaction of the pavement
- application of a 7 mm primerseal
- application of asphalt wearing course

VicRoads required that the road be opened to traffic at the end of each day. This meant that the extent of works was limited to ensure satisfactory finishing of the section to be stabilised on any particular day. Greater efficiencies could be achieved under full road (lane) closure. In such a case extensive areas can be pulverised in advance, stabilisation can be carried out in the morning with further pulverisation carried out in the afternoon for the next days work. The sequence of work at Somerton Road generally followed alternating half road widths of about 400 m length. Once the foamed bitumen had been injected and mixed into the pavement the shaping, trimming, and compaction was carried out over a period of 3 to 4 hours. Average output was about 1,400 m<sup>2</sup> per day. Because of the rapid curing capabilities of foamed bitumen stabilisation the road was able to be opened to traffic immediately after compaction.

The 7 mm primerseal was not always applied after each day's stabilising. As the overnight traffic was not harming the unsealed stabilised base, the primerseal was deferred until areas of about 4,000-5,000m<sup>2</sup> were available. This was possible because of relatively dry period. When rain is imminent application of a primer seal is required at the completion of each day's stabilising. The asphalt wearing course was applied 1-2 weeks after completion of stabilisation.

### Sections of Road with Very Fine Gradings

Some sections of the Somerton Road pavement consisted of asphalt wearing course over a granitic sand base. In these areas the granitic sand was removed and replaced with size 20 mm fine crushed rock before stabilising. Whilst it is possible to stabilise the granitic sand, the resultant pavement

strength would have been insufficient for the Somerton Road traffic loadings.

### Stabilisation Equipment

The equipment used for the stabilising and ancillary activities was as follows:

- Caterpillar RR250 Road Reclaimer specially fitted with foam spray bar and associated additive system.
- Bitumen tanker specially fitted for feeding hot bitumen to the Caterpillar.  
( Bitumen is accurately metered through a computerised flow meter )
- Water cart for accurate distribution of water
- Caterpillar 12 motor grader
- Single drum vibratory steel roller; 11 ton static weight, Dynapac CA 25
- Pneumatic tyred roller; 19 ton (fully ballasted)

The use of the pneumatic tyred roller has been discontinued as compaction levels down to 300 mm have been suitably achieved by replacing the single drum vibratory steel roller with a tandem vibratory steel roller (12 ton static weight).

### FIELD PERFORMANCE

#### Field Compaction and Resilient Modulus

As part of quality assurance the work was monitored for compaction and resilient modulus.

Field compaction measurements were carried out using a Troxler series 33 nuclear density gauge. Density results were corrected for moisture content of insitu material. Measurements were taken down to 275 mm depth. Results (Fig. 3) indicate that compaction was achieved to full depth of stabilisation. Minimum target compaction of 92% ( based on laboratory Marshall compacted density ) was exceeded in all cases.

Resilient modulus results were obtained on foamed material taken from the field and compacted in the lab. Fig. 4 shows that target wet modulus of 1300 MPa was exceeded in all cases.

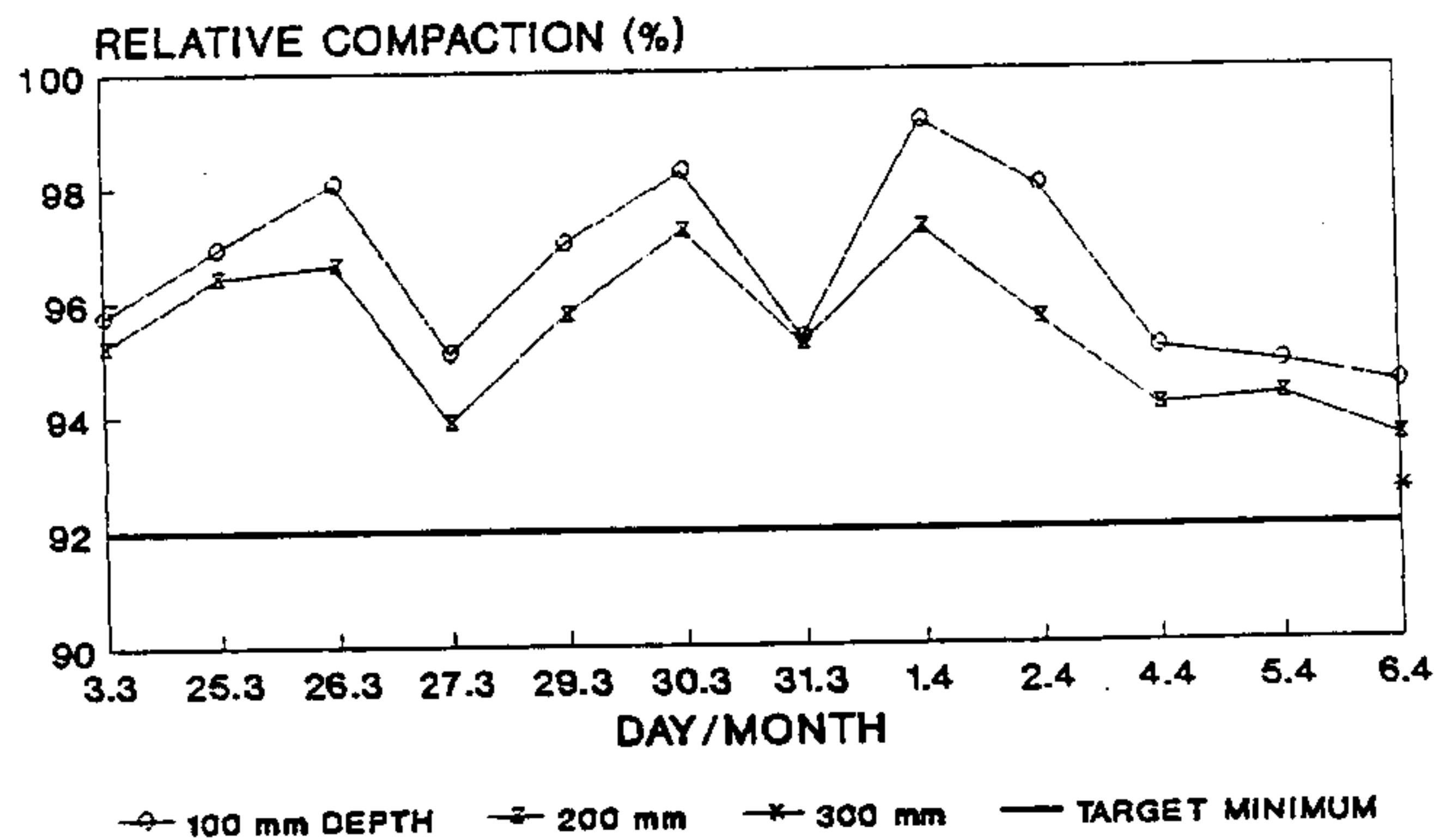


Fig. 3 Field compaction results at Somerton Road

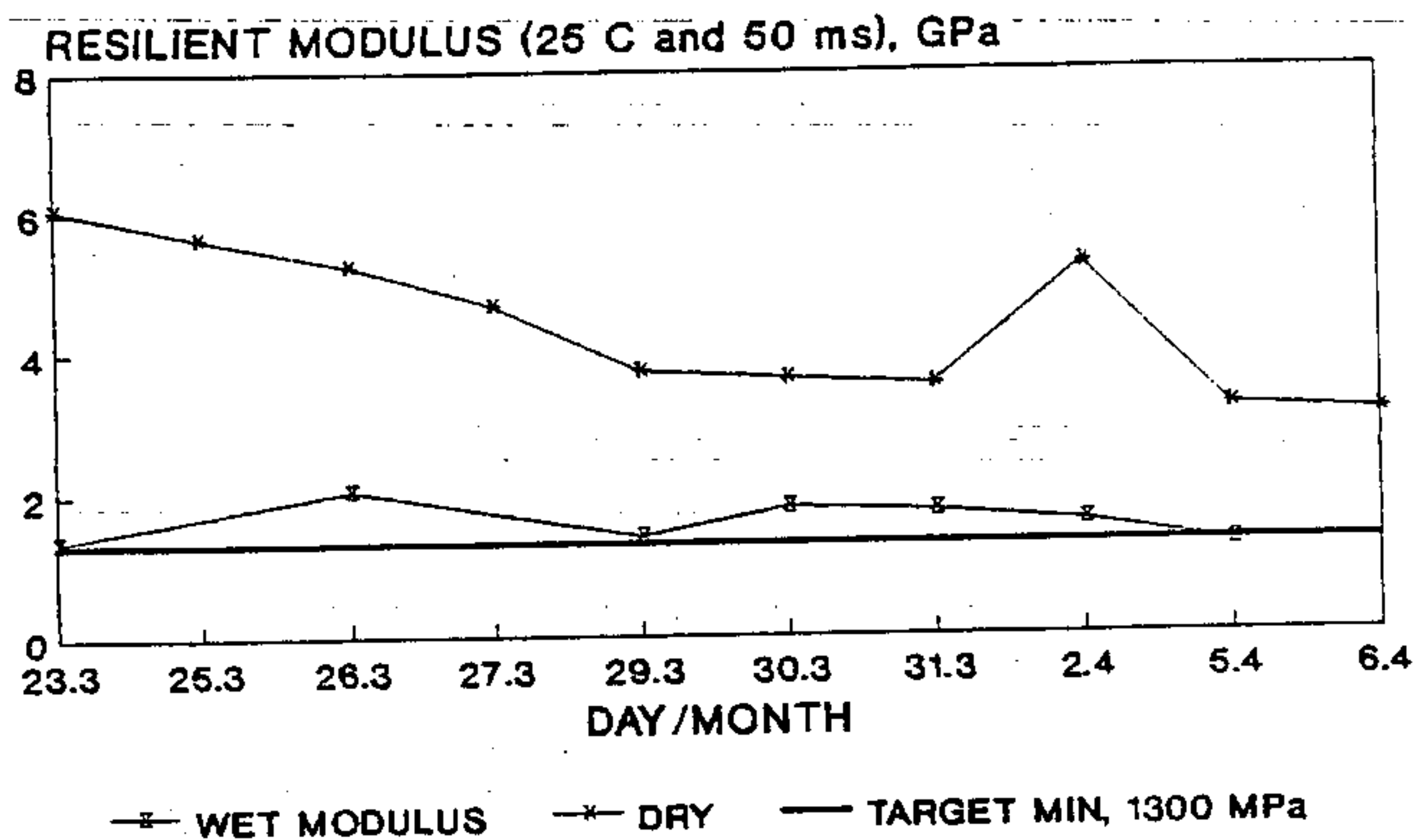


Fig. 4 Field modulus results at Somerton Rd

**Deflection Results**

Deflection results are shown in Fig. 5. For the purpose of simplification results are for the outer wheel path of the west bound lane only. Deflection results two weeks after stabilisation are markedly lower than the before the rehabilitation work. Average deflection results for the entire 2 km section reduced from about 0.7 mm to 0.4 mm after the stabilisation work. Deflection results are expected to improve over the next 12 months and monitoring of results will be continued to confirm this.

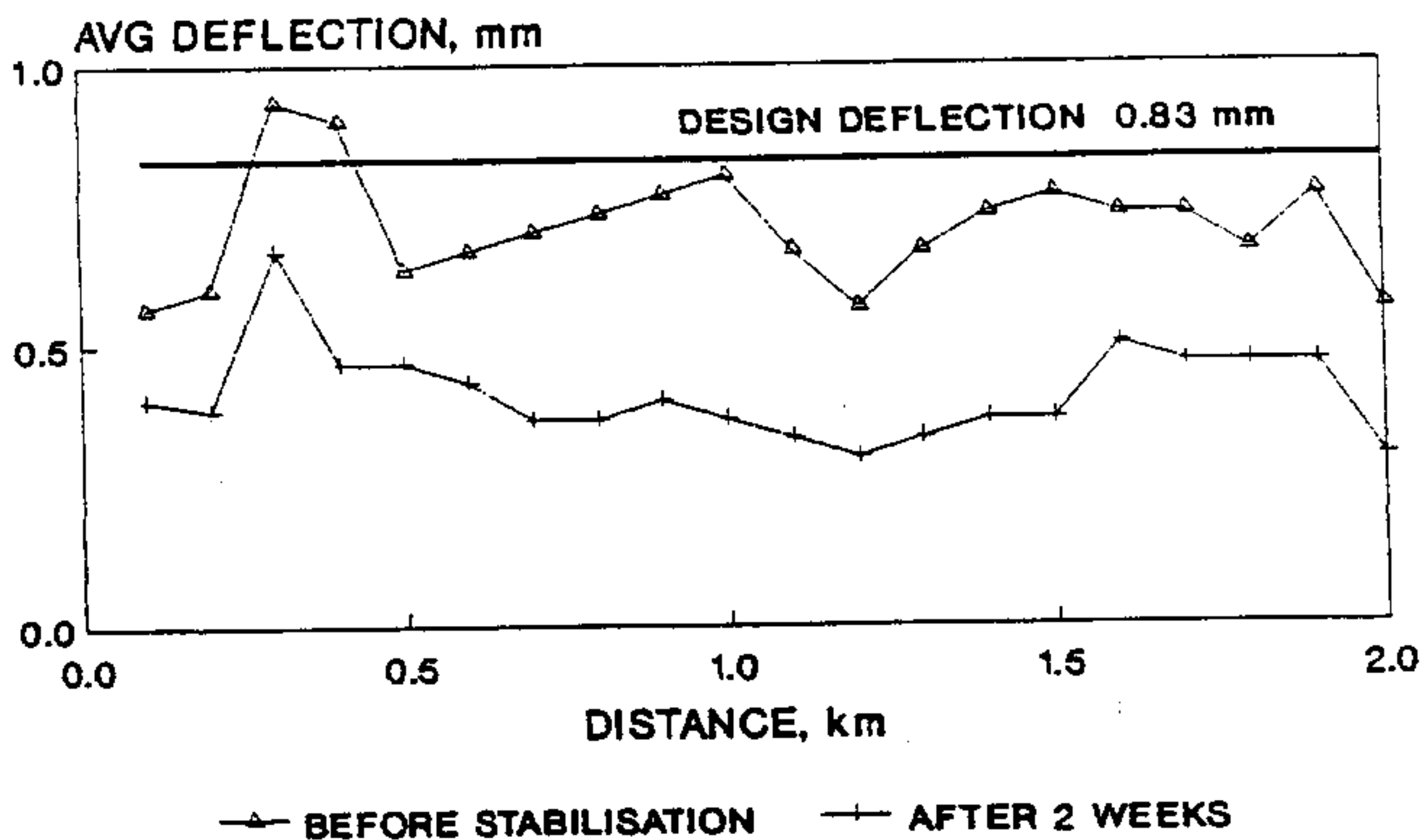


Fig. 5 Deflection results at Somerton Rd



## **COST COMPARISON**

The cost of rehabilitation of Somerton Road using foamed bitumen stabilisation, 7 mm primerseal and 45 mm asphalt wearing course was approximately 40% less than an equivalent pavement rehabilitation using a deep strength asphalt pavement.

## **ADVANTAGES OF FOAMED BITUMEN STABILISATION (FOAMSTAB)**

Foamstab offers a number of advantages when compared with traditional stabilisation techniques:

- Bitumen treated pavement will provide superior fatigue properties than cementitious pavements, thereby avoiding premature cracking
- Foamstab cures rapidly allowing much quicker trafficking than cementitious or emulsion based pavements
- Foamstab allows more time for compaction, shaping and trimming than cementitious pavements thereby leading to improved riding qualities
- Foamstab is less sensitive to extreme weather conditions than cement treated pavements or emulsion bound pavements
- Foamstab does not have the potential for losses of material like cement stabilisation in windy conditions and is therefore more environmentally acceptable
- Binder content for the Foamstab process is more precisely controlled than for cement materials
- Quality control testing of Foamstab is more exact than for cement treated pavement materials

## **CONCLUSION**

Foamed bitumen stabilisation, FOAMSTAB, offers a cost effective, rapid form of road rehabilitation in which 100 percent of existing failed or fatigued pavement materials are re-used to obtain a new flexible pavement base.

At Somerton Road the FOAMSTAB process offered significant savings and improved life by improving the strength and durability of the existing pavement materials with minimal disruption to the travelling public.

## ACKNOWLEDGEMENTS

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