

VICROADS EXPERIENCE WITH FOAMED BITUMEN STABILISATION

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SUMMARY

Increases in traffic loading and the need to efficiently allocate available road funds to maintain an ageing road network mean that the rehabilitation treatments adopted for roads must result in best returns in terms of a whole-of-life cost/benefit analysis. Innovative rehabilitation treatments such as Foamed Bitumen Stabilisation must be investigated to develop design criteria to enable a proper economic comparison with alternatives.

Foamed bitumen stabilisation is an in situ pavement recycling technique to extend the life a distressed pavement. Fresh, foamed bitumen is added to existing pavement materials to form a bound layer. This paper documents VicRoads' experience with foam bitumen stabilisation trials conducted on three major roads in Melbourne in 1993.

Two of the trials were on heavily trafficked arterial roads, where major rehabilitation of flexible granular pavements was required and a third trial was conducted on a freeway where pavement strengthening was needed to convert the shoulder into an additional traffic lane.

This paper discusses the requirements for initial pavement investigation; field and laboratory testing and design criteria; construction aspects of the field trials, such as details of the siteworks and traffic staging; and a recommended specification for future foamed bitumen stabilisation works based on experience gained from the trials.

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Lachlan McArthur obtained his Diploma of Applied Science from the Caulfield Institute of Technology in 1977. Lachlan was employed by ARRB from 1977 to 1982 as a Technical Assistant and gained experience in the use of scrap rubber in bitumen and later the physical testing of roadmaking materials. During his time at ARRB, Lachlan also completed a Postgraduate Diploma in Applied Polymer Science. In 1982 Lachlan joined VicRoads as a Technical Officer and was involved with the testing of road and bridge construction materials. From 1990 Lachlan was employed as a Scientific Officer in the Pavement Design area and then in the Metropolitan area on several construction jobs. He is currently a Project Team Leader with the Northern Region of VicRoads in Bendigo.



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INTRODUCTION

1. This paper describes recent VicRoads experience with in-situ foamed bitumen stabilisation where three different trial sections have been carried out and are continuing to be closely monitored. Two of the trials were on heavily trafficked arterial roads, where rehabilitation of flexible granular pavements were required, and a third trial was conducted on a freeway where pavement strengthening was required to convert the shoulder into an additional traffic lane.
2. As all of the roads concerned were on a program of rehabilitation, a thorough pavement investigation had been carried out and various alternative treatments had been formulated. Following a submission by Emoleum (Australia) Limited it was agreed to carry out full scale trials of the foamed bitumen stabilisation process under a Quality Assurance Contract. This process provided for the in-situ foamed bitumen stabilisation of the granular pavement materials, followed by the application of a thin asphalt wearing course.
3. As the process had not been used for some time it was necessary to establish design criteria in line with current design practices and prepare new specifications for the work. The paper documents the trials with discussion of construction aspects and field and laboratory testing undertaken to characterise the stabilised product and subsequently investigates the design process. The paper outlines recommended pavement investigation and design techniques for future in-situ foamed bitumen works, based on experience from the trials.

LOCATION OF WORK

4. The trials were carried out on the following roads in the Melbourne Metropolitan area:
 - (a) **Somerton Road, Campbellfield**

The trial was carried out on the section of Somerton Road between the Hume Highway and Pascoe Vale Road. The road at this location is a declared Main Road under the joint control of the City of Broadmeadows and the Shire of Bulla. The road is heavily trafficked with high volumes of commercial vehicles and the pavement condition prior to rehabilitation was very poor with large areas of cracking and extensive rutting. Due to the strategic nature of the road and the amount of work required to rehabilitate it, it was agreed that VicRoads would carry out the work on behalf of the Municipalities.

(b) **Tullamarine Freeway, Bulla Road Entry Ramp**

The entry ramp at Bulla Road was originally constructed in about 1970 as a single lane ramp with an emergency stopping lane. The pavement makeup of the stopping lane was different from the running lane and was inadequate for heavy traffic. Due to the increase in traffic volumes in the general area, it was decided to convert the entry ramp and a short section of the freeway to two lane operation and to improve the strength of the stopping lane by in-situ stabilisation using foamed bitumen. One of the main reasons for choosing this method was that the work could be done over one weekend with minimal disruption to traffic - a major consideration in this area.

(c) **Stud Road, Rowville**

The trial was carried out on two sections of the north bound lanes of Stud Road between High Street Road and Glenifer Avenue and Waradgery Avenue to Lakeview Drive. Stud Road is a major north-south route in Melbourne's eastern suburbs and carries high traffic volumes. The section of the road that was treated had deteriorated badly and was in urgent need of repair.

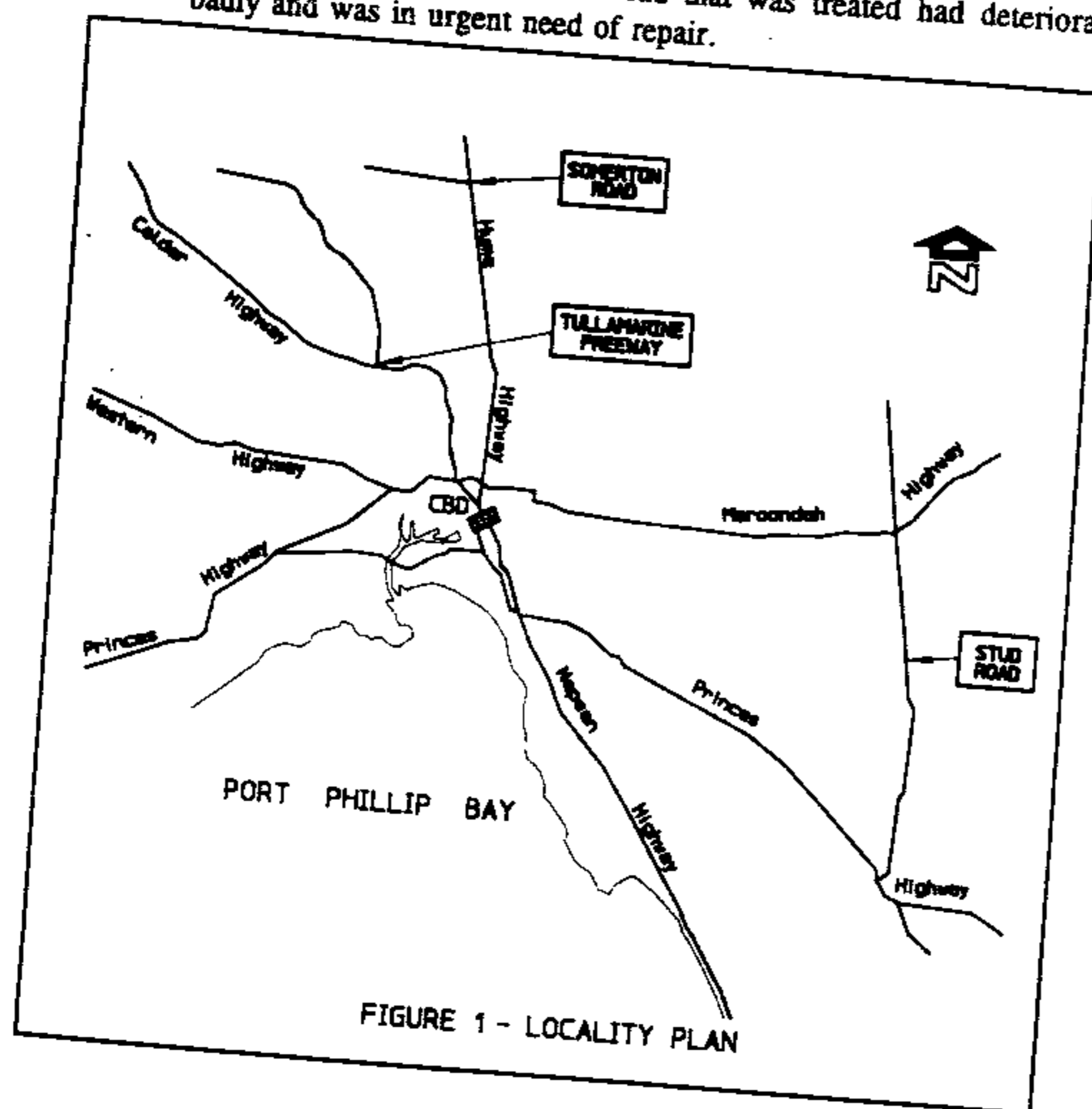


FIGURE 1 - LOCALITY PLAN

BACKGROUND

WHAT IS FOAMED BITUMEN STABILISATION?

5. Foamed bitumen stabilisation of granular pavements is achieved by the injection of water into hot bitumen, which causes a foaming action that aids bitumen dispersal onto granular material. The foamed bitumen preferentially coats the finer particles in the mineral aggregate, rather than coating all particles as with normal asphalt and emulsions. When wet it has the same appearance as untreated granular material, however, the bitumen and fines form a binder between the coarse particles. When dry, small specks of bitumen can be seen throughout the mix. Bitumen content is usually 4% by mass of the mix.

WHY TRY IT?

6. As the foamed bitumen stabilisation process had not been used for quite some time and as advances in technology had been made, it was agreed that full scale trials should be carried. It should be noted that the process was not necessarily the cheapest alternative in each case in terms of whole of life cost.

OTHER ALTERNATIVES

7. At the time of preparation of the rehabilitation strategies for these jobs, various other alternatives were considered, these included:
 - * Removal of existing pavement and replace with asphalt
 - * Thick asphalt overlay
 - * Cement stabilisation of existing pavement
 - * Thick asphalt overlay and cement stabilisation
 - * Granular resheet
 - * Total reconstruction
 - * Crack sealing, patching, improve shoulders and drainage
 - * Thin asphalt surfacing.

PREVIOUS EXPERIENCE WITH BITUMEN STABILISATION

8. In recent times a number of different types of bitumen stabilisation have been trialled in VicRoads, the main one being cold emulsion stabilisation. Only limited information is available from a number of trials and the results are not conclusive, however the indications are that in situ cold recycling using the above techniques reduces both deflections and curvatures, which increases strength and stiffness of the pavement respectively. Trials of emulsion and foamed bitumen stabilisation of sand done about 20 years ago are still in generally good condition.

determined. Analysis of curvatures indicates remaining life of the existing asphalt or the likely performance of an asphalt surfacing on an existing pavement that does not contain asphalt. Subsequently, asphalt overlay thickness can be determined, to avoid premature fatigue induced cracking.

16. Deflection testing has been done both before and after the stabilisation works. Further deflection testing is programmed for all trials for November 1993 and April 1994, to gauge strengthening/stiffening changes and/or fatigue effects, in time. For proper comparisons, it is preferable to test during the same period each year, to avoid seasonal effects.

RESULTS OF FIELD TESTING

(a) Somerton Road

(i) Prior to Foamed Bitumen Stabilisation :

17. Pavement deflection testing was done in July 1992 as part of a VicRoads pavement report (Jansz 1992), which discussed rehabilitation options. The Design Deflection of 0.81mm was for the Design Traffic Loading (DTL) of 3.5×10^7 Equivalent Standard Axles (ESAs) anticipated over the 20 year design period. This DTL is now considered to be high, however, as it does not allow for reduced traffic loadings due to traffic diversion to the new Western Ring Road and a DTL of 2×10^7 ESA may be more appropriate.
18. Deflections recorded were generally below the design value, except for weaker areas in the Left Wheel-Paths (LWP), probably due to inadequate subsurface drainage of moisture trapped on the low side of the boxed-in pavement on the relatively impermeable clay subgrade. Deflections in the LWPs were generally between 0.6mm and 0.85mm, indicating that only a nominal, say 50mm resheet of base quality crushed rock was needed to correct pavement shape and resist excessive subgrade rutting during the next 20 years. Considering the poor drainage condition though, deflection testing done after the wetter months may have recorded higher deflections. Deflections in the RWPs were generally between 0.4mm and 0.6mm, indicating that no pavement strengthening was needed. Isolated weaker areas may be attributed to poorer surface drainage and/or poorer quality pavement material, for example, near the eastern end of the job, high deflections corresponded with an area having wet granitic sand as pavement material.
19. Curvatures recorded were generally between 0.2mm and 0.4mm, which is typical for a (flexible) granular pavement. The asphalt overlay thickness required to strengthen the pavement was generally only about 25mm thick, which corresponds roughly with a 50mm thick granular resheet. However, because of the high curvatures, the asphalt would need to be at least 120mm thick to avoid premature fatigue induced cracking of the asphalt.

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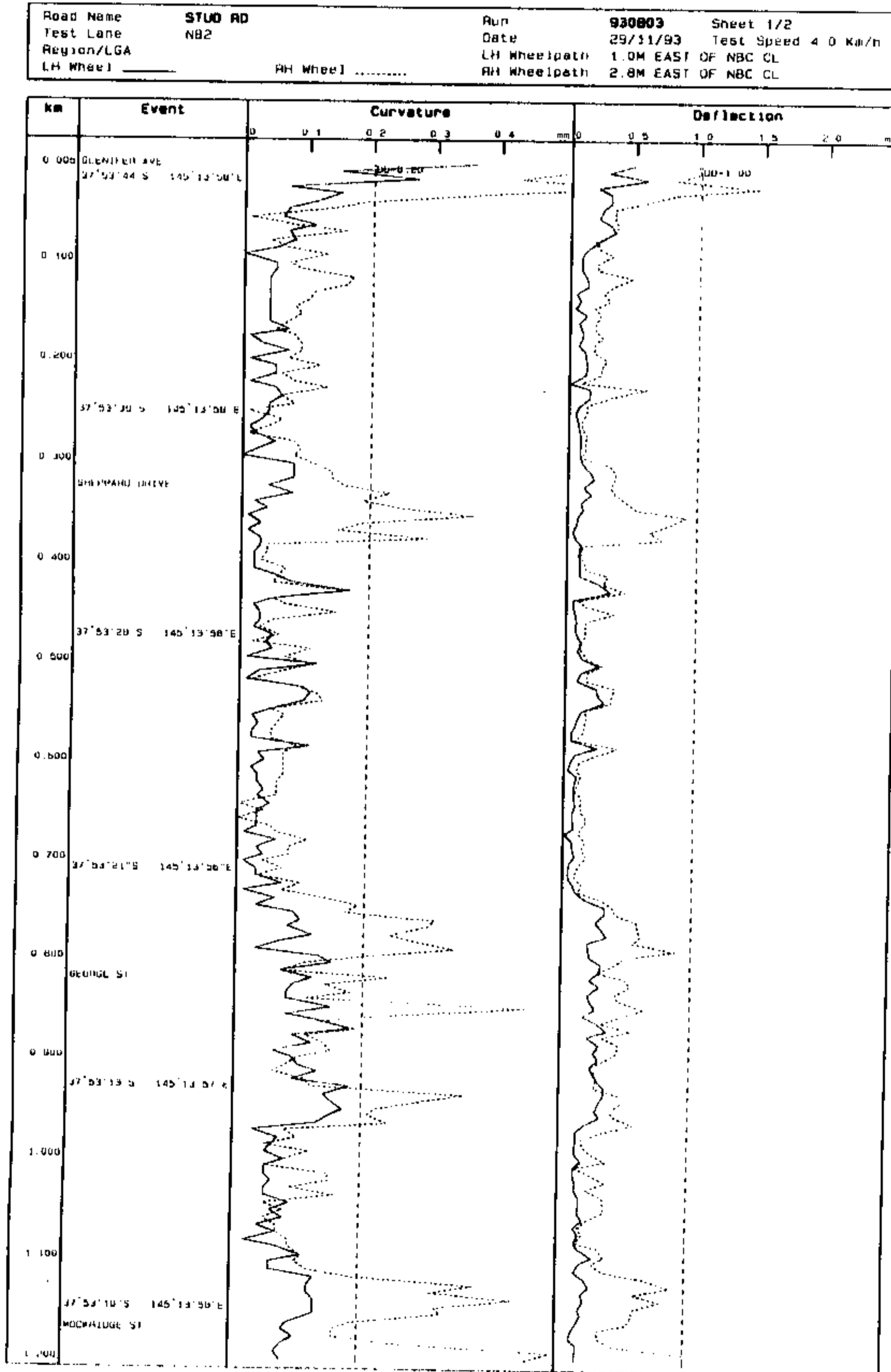
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(ii) After Foamed Bitumen Stabilisation :

20. Deflection testing was done on 15 April 1993, which was 1 -3 weeks after stabilisation. Characteristic deflections (i.e at 95% Confidence Level) in the LWP generally reduced by 0.3mm. In the RWPs, however, characteristic deflections ranged from an increase of 0.1mm to a decrease of 0.2mm. Mean curvatures in the LWP reduced by 0.1 - 0.2 mm, but with generally no change in the RWP. If the stabilised material was assumed to have the same characteristics as normal asphalt (current overlay procedures for determining thickness only pertain to deflection and curvature results of dense graded asphalt) then based on curvature analysis, an asphalt overlay 100mm thick would be required to inhibit fatigue induced cracking in about 65% of the tested area in the next 20 years.

A cursory analysis of deflection test results done late in November 1993 shows no significant change in deflection or curvatures. A more thorough analysis will be carried out as part of continuing monitoring.

(b) Stud Road

(i) Before Stabilisation :

21. A pavement rehabilitation design life of 5 - 10 years was required, because of the inadequate pavement depth and level controls which precluded placement of thick resheets. A DTL of 5×10^6 ESAs was adopted, which corresponds to a 10 year traffic loading between High Street and Glenifer Avenue and a 6 year traffic loading between Waradgery Avenue and Lakeview Drive. For the above DTL, the Design deflection was 0.90mm and the Design Curvature was 0.11mm. Deflection testing was done on 31 March 1993.
22. In the section from Waradgery Drive to Lakeview Avenue, deflections were generally between 0.4mm and 0.7mm, indicating adequate pavement strength to avoid excessive rutting during the design period. There was a weak area about 100m long, however, where a 120mm thick resheet with base quality crushed rock was needed. The frequent occurrence of edge defects was attributed to inadequate surface drainage.
23. Curvatures were between 0.15mm and 0.3mm, which appear appropriate for a flexible pavement of suitable depth and of adequate quality material, on a firm subgrade.

In the section from High Street Road to Glenifer Avenue, deflection testing indicated that about 15% of the tested area required strengthening. Deflections generally ranged from 0.4 - 1.2mm. Curvatures ranged from 0.1 - 0.5mm. Curvature analysis indicated that the pavement lacked stiffness, whereby

generally all of the asphalt surfaced area required an asphalt overlay at least 80mm thick, to inhibit fatigue induced cracking.

(ii) After Foamed Bitumen Stabilisation :

24. Deflection testing was done on 2 August 1993. In the section from Waradgery Drive to Lakeview Avenue, deflections and curvatures only changed marginally compared to before stabilisation, with the deflections being slightly more uniform, in the range 0.45 - 0.6 mm and curvatures reduced by only 0 - 0.05mm. The weak area 100m long, mentioned above, recorded no strength gain, whereby a granular resheet 120mm is required to inhibit excessive rutting during the design period. Deflection testing done on 24 November 1993 again showed little change in deflection or curvatures, with about 80% of the pavement requiring a further asphalt overlay to stiffen it.
25. In the section from High Street Road to Glenifer Avenue, deflections and curvatures reduced markedly and appeared more uniform, which may not be attributed solely to the effects of foamed bitumen stabilisation, considering that granular resheeting and surface drainage improvements have also been made. Deflections generally range from 0.4 - 0.65mm, corresponding to reductions of 0.5mm in places, with only about 1% of pavement area tested still requiring further strengthening. Curvatures ranged from 0.1 - 0.3mm. Curvature analysis indicates that the majority of the pavement requires an asphalt overlay 50mm thick, to avoid premature fatigue induced cracking of the asphalt during the design period.

MIX DESIGN

26. Proprietary bitumen foaming equipment is used in the laboratory mix design. The road authority should conduct surveillance of mix design performed by contractors.

MATERIALS CHARACTERISTICS

27. Analysis of the particle size grading of the in-situ material will determine if mechanical stabilisation is needed in the form of blending one or more other granular materials (eg. sands or coarse aggregate) prior to foamed bitumen stabilisation. An allowance should be made for further particle breakdown due to pulverisation in the stabilisation phase, which is discussed under "Mix Design" below. If the material is lacking in fines, then an additive such as Cement Works Flue Dust (CWFD) could be used, which should also provide some cementitious bonding within the mix. Although the foamed bitumen apparently preferentially coats the finer particles (eg. such as CWFD), the amount of cementitious additives should preferably be a maximum of 2% by mass of the mix, to minimise the potential for shrinkage cracks.

28. If the PI of the material is greater than 12, then consideration should be given to lime stabilisation prior to foamed bitumen stabilisation which would subsequently be delayed for a time, dependent upon initial PI and weather conditions.
29. Figure 2 below shows three material grading zones, for after compaction, designated by the contractor. Zone A is appropriate for heavily trafficked roads and zone B is for lightly trafficked roads. Material conforming to zone C lacks fines and would need addition of finer materials prior to stabilisation. Similarly, the performance of material conforming to zone B could be enhanced by the addition of coarse particles to adjust the grading to zone A.

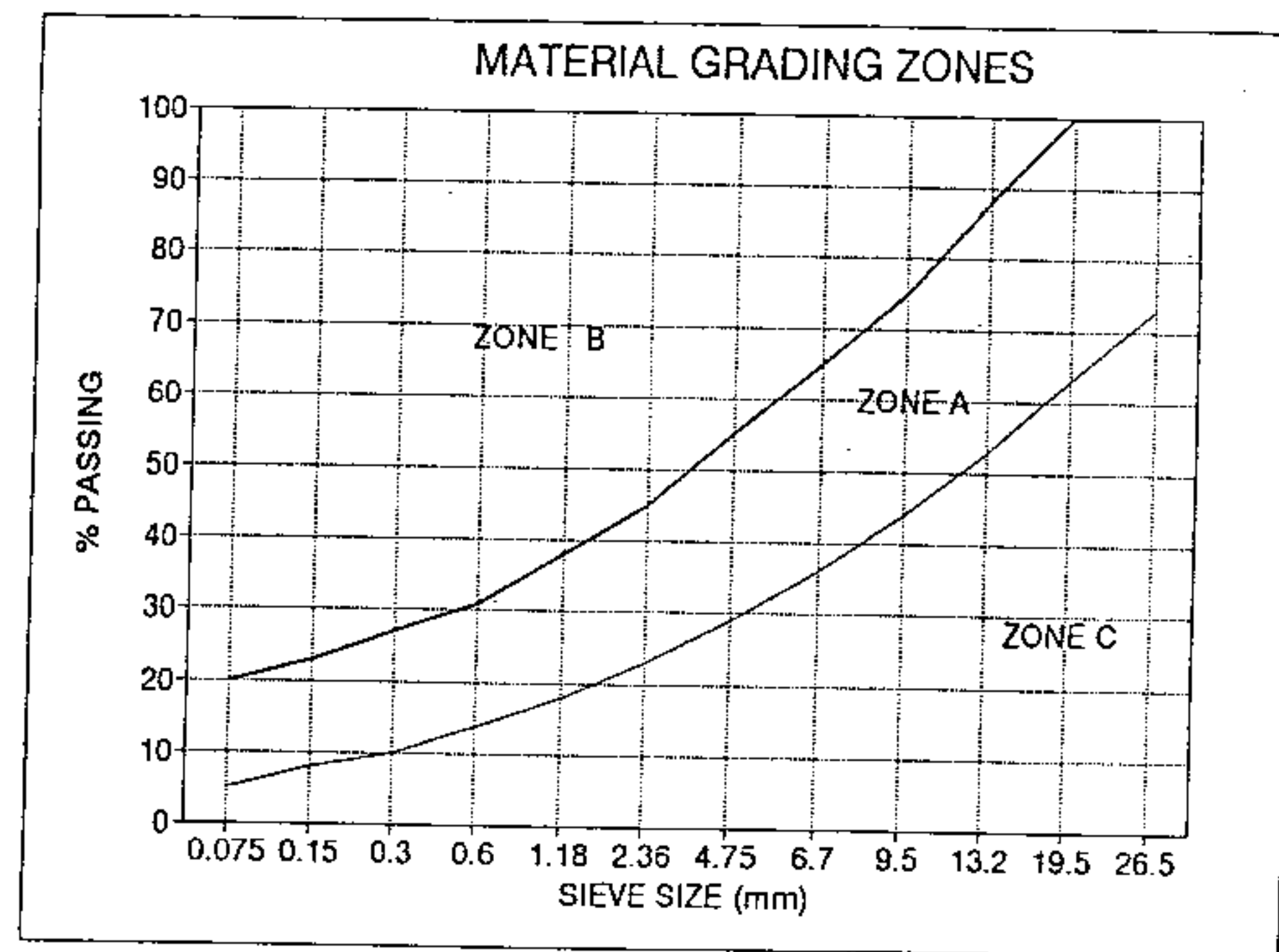


Figure 2 - Material Grading Zones

30. Additives such as lime or CWFD may affect the foaming action and nature of the stabilised product - this is assessed in the mix design. The timing of additives mixing and subsequent compaction should be similar for the laboratory and field situations.

COMPACTION

31. Optimum Moisture Content and Maximum Dry Density and density adjustments for oversize material are determined in a similar way as for unbound granular materials. On the field trials, the contractor has determined maximum density by usage of a nuclear density gauge. Laboratory compaction was then calibrated

against the field compaction level as the reference density for relative field compaction. Traditional laboratory compaction equipment for hot mix dense graded asphalt, namely Marshall and gyratory compaction were investigated. The number of gyratory cycles, or alternatively, the number of blows of the Marshall hammer, should be calibrated against the required minimum relative compaction level allowed in the specification. The contractor advised that maximum field compaction monitored with a nuclear density gauge in the field, correlated in the laboratory with 75 Blows on one face of the sample using a Marshall hammer and also with 150 cycles in a gyratory compactor at 240 kPa and 2° gyratory angle.

32. In the trials, the contractor advised that a (minimum) density ratio of 92% (ratio of field to laboratory compaction) is appropriate. The low compaction level may be offset by the binding effects of the bitumen. The foam stabilised material is compacted cold, remaining workable for up to 2 - 4 hours, depending upon weather conditions. Performance of the field trials will be monitored, to determine if the above compaction standard is appropriate, or if it should be increased.
33. After pavement investigation, representative samples of pavement material are stabilised with a range of binder contents and subjected to either gyratory, or Marshall compaction to the relative level required by the specification. For larger stone size mixes (eg. 40mm nom. mixes), a 150mm mould could be used, which precludes use of standard 100mm diameter Marshall moulds, but should not preclude use of gyratory compaction and subsequent resilient modulus and dynamic creep testing.

MODULUS AND CREEP TESTING

34. After laboratory compaction, samples are oven cured for 3 days at 60°. MATTA (MATerials Testing Apparatus) testing for Resilient Modulus and Dynamic Creep are then performed to Draft Test Methods AS 2891.13.1 and AS 2891.12.1, respectively. MATTA tests are also done on samples that have been soaked in water at 60°C for 24 hours, after the previous dry curing. Modulus testing should be done over a range of rise times as discussed in the section on pavement design below. Samples of stabilised material taken from the roadbed on Stud Road were tested by the contractor for modulus, as a means of quality control against specification limits. Dry modulus values however ranged from 5000 to 10,000 mPa with corresponding soaked values of 2000 to 6000 mPa. These modulus ranges show both the moisture sensitivity of the material and the effects of construction variables such as bitumen, moisture and density.
35. The design binder content corresponds to the highest modulus value, considering both the dry cured and soaked modulus test results. The dynamic creep results should also be examined to determine the possibility of premature permanent deformation of the material.

PAVEMENT DESIGN

36. The design assumption made by the Contractor, based on testing by TRL in England, is that foamed bitumen stabilised material has the same fatigue performance as hot mix dense graded asphalt. TRL's work involved fatigue testing of foam stabilised material cut from the roadbed, which indicated a favourable correlation with fatigue performance of a dense graded asphalt. Further investigation of fatigue characteristics of the stabilised material is still necessary, however, to gauge the effects of moisture, curing, compaction and variable quality in-situ material and comparison with local asphalt properties.
37. The mechanistic design procedure described in the AUSTRROADS pavement design guide, which uses linear elastic theory, is a means of determining critical strains in the pavement under traffic loading. The foamed bitumen stabilised material is analysed as a bound layer, with Modulus derived from extrapolation of MATTA resilient modulus test results (ie. modulus adjusted to traffic speed as per section 6.4.3.2 of VicRoads Technical Bulletin No.37). The adopted Modulus should also be at the specified field compaction level. Both dry cured and 'soaked' moduli should be alternately used in the pavement design, as a sensitivity analysis of the design. Field measurement of Modulus on the trials will be measured using a Falling Weight Deflectometer. The variable nature of in-situ pavement materials make it difficult to adopt a single modulus value for mechanistic pavement design. FWD testing after construction and MATTA testing of field cores is recommended to confirm pavement design assumptions.
38. To determine the design life of the stabilised layer, however, its fatigue performance needs to be characterised. VicRoads will attempt to cut slabs from the trial pavements after the summer of 1993/94 (ie. after about 1 year field curing) and test them in a laboratory fatigue test machine. The results will then be compared to results for dense graded hot mix asphalt.
39. As mentioned earlier, a thorough pavement investigation is required to ensure that the variable quality of pavement material is taken into account in the design.

SURFACING

40. After stabilisation, the unsealed road may be opened to traffic temporarily. If rainfall is imminent, however, then it would be necessary to apply a primerseal soon after construction, to waterproof the pavement. A final sprayed seal, or asphalt wearing course may later be placed, to provide the final wearing surface. If an asphalt wearing course is to be placed soon after construction, then firstly a size 7mm Emulsion Primerseal should be applied. If the asphalt is to be deferred at least 9 - 12 months, then a size 10mm Cutback Primerseal, or an Emulsion Primerseal with improved surface penetration, should be applied.

Deflection testing of the pavement should be done prior to placement of an asphalt surfacing, to confirm that the proposed asphalt thickness is adequate, to avoid premature fatigue induced cracking.

CONSTRUCTION

TRAFFIC ARRANGEMENTS

41. As Somerton Road at the location of the works is very heavily trafficked, it was necessary to do most of the work under traffic. However, it was possible to completely close a section of the road for 7 days to give the contractor complete possession of the most difficult narrow section of road.
42. One of the advantages of the foamed bitumen stabilisation method is that the work can be trafficked soon after completion without causing damage to the pavement, e.g. rutting.

Accordingly, the method of construction adopted at Somerton Road was as follows:

- * Pulverise and stabilise half width of road for a length of approximately 300 metres during daylight hours. Traffic was operated on a one way basis controlled by a flagman.
- * Open to two way traffic overnight.

VIC ROADS supplied road signs and variable message signing while assisting Emoleum with on site work zone Stop/Go traffic control where required.

EQUIPMENT USED

43. The recycling machine used was the Caterpillar Model RR250 with all compaction being carried out by a 15 tonne Pennell vibrating roller.

LEVEL CONTROL

44. The careful control of road level and alignment is considered crucial when a pavement is to be recycled to ensure a satisfactory outcome. Somerton Road had no level control by way of kerb and channel and therefore control was undertaken with use of the machine screed settings and boning rods and dumpy level. An alternative to the above would have been a peg every 20 metres and laser or sting line across the road.

45. It is difficult to accurately raise or lower levels when recycling as material has to be added or taken off the pulverised material in situ prior to the stabilisation run. Common practice suggests levels 'before' stabilisation will approximate to levels 'after' assuming no material has been taken from or added to the pulverised material although with different levels of compaction before and after this may alter. The final pavement shape and rideability on Somerton Road is only reasonable and for any future work it is recommended that some form of level control should be specified to give better control of the final product.

PERFORMANCE

46. Monitoring of the stabilised pavement's performance should involve the following:
- assessment of 'before' and 'after' deflection test results
 - automated survey of roughness and rutting
 - visual survey of pavement defects.

Deflection testing, on trials to date, generally indicates that the foam bitumen stabilisation initially stiffened the pavement. Deflections were generally previously only high in the outer wheelpaths, probably due to moisture effects. Reduction in those deflections suggests that the stabilised material is less moisture sensitive and/or the stabilised material provides a bridging effect over weaker subgrade areas.

Future monitoring of the trials is essential to assess any changes in the stabilised material's performance, due to field curing and/or fatigue effects.

SPECIFICATION

47. As there was no standard specification for the foamed bitumen stabilisation process it was necessary to prepare various clauses outlining the requirements. Discussions were held with overseas experts from Canada and England who were conversant with the process and also with staff from Emoleum (Australia) Limited who were promoting it. These discussions resulted in the following end product requirements being specified (for Somerton Road only):

MIX DESIGN

48. The mix to be used was required to be approved by VIC ROADS prior to commencement. The approval of VIC ROADS was also required before any changes would be made to the components or proportions of components used in the approved mix.

The following information was required to be submitted for the proposed mix design:

- (a) Grading of the combined mix.
- (b) Unsound and marginal rock content of the coarse aggregate fraction.
- (c) Plasticity Index.
- (d) Marshall Test results, including graphs showing the various properties plotted against the respective bitumen contents.
- (e) Modulus results

ORDER OF WORK

49. The stabilisation process was required to be carried out in the following order:
- (i) The existing pavement to be pulverised to a consistent grading, watered and any additives spread.
 - (ii) The pulverised material to be graded, shaped and rolled to the final profile.
 - (iii) The pulverised material to be bitumen foam stabilised to a depth of 300 mm in accordance with the pavement design.
 - (iv) A Size 7 mm primerseal to be applied to the finished surface prior to opening to traffic.
 - (v) A 40 mm layer of Size 14 Type H asphalt to be placed over the whole area within 14 days.

ACCEPTANCE CRITERIA

50. (i) Finished Shape of Surface

The finished surface of asphalt wearing course to be of uniform appearance, free of dragged areas, cracks, open textured patches and roller marks.

- (ii) Strength

The stabilised layer was required to have a wet modulus (24 hour soak at 60°C) of at least 1500 MPa measured with a rise time of 50 ms and temperature of 25°C.

Also, a dry modulus of 6000 Mpa (minimum) for samples oven cured for 3 days at 60°C and tested at 25°C is required.

(iii) Compaction

The insitu density was required to be 95% minimum of uncured Marshall density for samples prepared by 75 blow on one face and curing for 3 days at 60°C.

(iv) Deflection of Pavement

Deflection testing would be done (by VIC ROADS) one to two weeks after recycling pavement stabilisation with the design curvature and design deflection (assuming a DTL of 2 x 10' equivalent standard axles) being 0.091 mm and 0.83 mm respectively at deflectograph speed of 3 km/hr for a 20 year design life.

SUMMARY

51. In summary, the results of the trials carried out to date indicate that foamed bitumen stabilisation of existing pavements provides a reduction in deflection (ie. improved stiffness). The trials will be monitored on continuing basis to assess the long term performances of the process. If the process is being considered for future work, the following factors must be considered:

- * A thorough pavement investigation is vital, especially ground radar for detecting asphalt patches.
- * The construction process needs to be properly planned, ie, relocate all services, have a plan for traffic control during construction, and also avoid working in the wetter months.
- * Drainage of the rehabilitated pavement must be properly considered.
- * Some form of level control during construction must be implemented.
- * Long term monitoring must be carried out to characterise material performance and enable whole of life economic analyses to be carried out.

The process will be monitored in the future and in particular the following:

- * Monitoring field deflection and curvature to see if strengthening and stiffening changes over time.
- * How to treat a pavement if it fails ie, re-recycle?

- * Analyse modulus of foamed bitumen layer and creep of the wearing course layer.
- * Confirm design criteria via fatigue testing and falling weight defelectometer testing.

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