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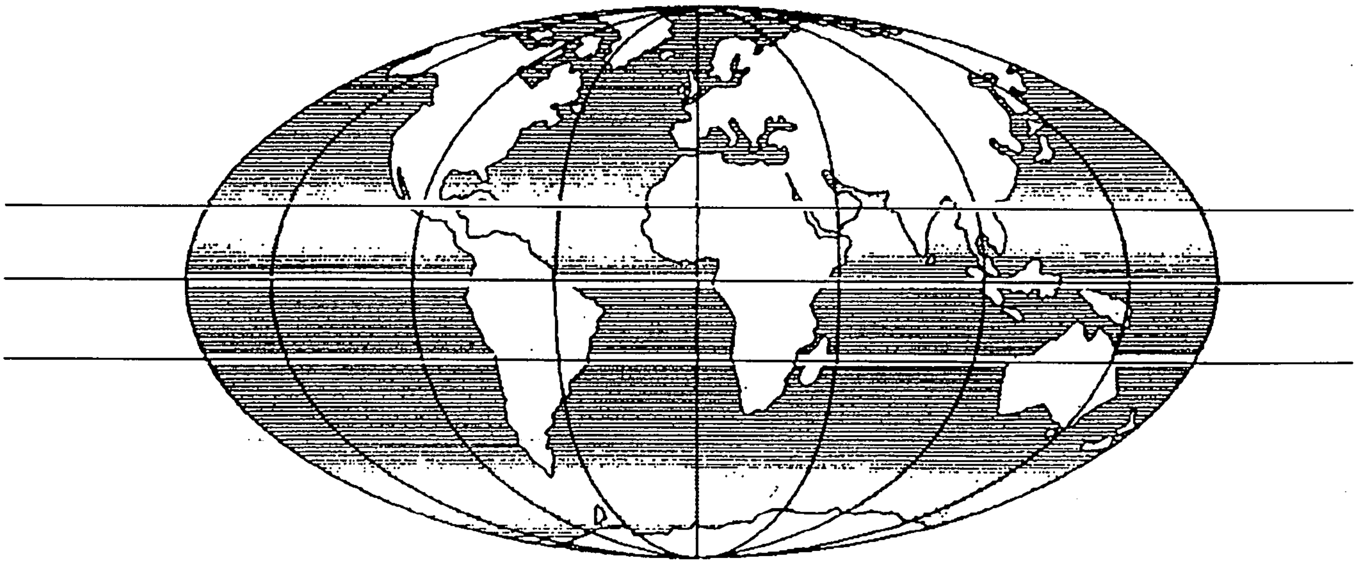

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THE PERFORMANCE OF POLYMER MODIFIED ASPHALTIC CONCRETE ON CLIMBING LANES IN MALAYSIA

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INTRODUCTION

1. The introduction of asphaltic concrete wearing courses in Malaysia over the past 10 years has brought with it the problem of the extensive quality control testing that is required to produce such mixes to the required Marshall tolerances (Asphalt Institute, 1984). Even when these materials are produced to specification they are often inappropriate in areas of high traffic stresses, such as climbing lanes and junctions, as is evident by the rapid rutting and shoving in such areas throughout Peninsular Malaysia.

2. At high temperatures and long loading times conventional bitumen behaves in a viscous manner, allowing the mix to deform under traffic. The subsequent reduction in air voids decreases the material's resistance to deformation as the fine aggregates occupy more of the voids thus reducing the mechanical interlock between the coarse aggregates (Cooper et al, 1985). This eventually results in structural instability and the surfacing shears under trafficking.

3. At present there are a number of binder additives available which are claimed to increase the viscosity and improve the temperature susceptibility of conventional bitumens thus making the modified surfacings more resistant to deformation at the high surfacing temperatures usual in tropical climates. The opportunity to study the performance of two such polymers came when a contractor, Binaan Setegap Sdn Bhd, in association with the polymer supplier, Exxon Chemicals, offered to finance a full-scale trial on the Kuala Lumpur-Karak Highway. The offer was accepted by the Malaysian Highway Authority who invited the Pavement Research Unit of the Institute of Public Works Malaysia (IKRAM) to monitor the construction and performance of the trial. This paper describes the performance of the trial until failure and also introduces a

second trial using alternative binder additives. Both trials have been monitored by IKRAM in collaboration with the Overseas Unit of the Transport and Road Research Laboratory (TRRL) of the UK.

DETAILS OF THE EXPERIMENTAL SITE

4. The site selected for the trial was a 530 metre length of climbing lane at Bukit Tinggi on the Kuala Lumpur - Karak Highway. The climbing lane had a grade of 8 per cent and the average speed of the commercial vehicles using it was uniform and measured at 15 km/hr.

5. The site was severely rutted along its entire length and shoving was occurring both at the edge of the road and at the longitudinal joint with the adjacent fast lane. The deformation of the existing surfacing was measured in both the vergeside and offside wheelpaths at 10 metre chainages using a 2 metre straight-edge and calibrated wedge. The results are shown in Table I.

TABLE I

RUT DEPTH BEFORE CONSTRUCTION

Wheelpath	Rut Depth (mm)		
	Mean	SD	Range
Vergeside	40.3	10.7	16 - 78
Offside	22.7	2.9	16 - 29

A visual survey showed there was no cracking anywhere along the experimental site.

6. A series of five cores were taken across the climbing lane at three chainages. One core was taken from each of the wheelpaths whilst the remaining three were taken from where the surfacing was shoving at the edges of the lane and between the wheelpaths. The cores showed that the original asphaltic concrete surfacing had a total thickness of 175 mm and had been subsequently overlaid with a 40 mm layer of asphaltic concrete. The cores also showed that there had been no significant rutting in the original surfacing and that all the present rutting, shown in Table 1, was confined to

the relatively new overlay.

7. The cores were split horizontally and the material from the original asphaltic concrete wearing course and the overlay material analysed. The results, together with the Public Works Department specification (PWD Malaysia, 1985) are shown in Figure 1. The Figure helps to illustrate how sensitive asphaltic concrete mixes are to their precise composition. Although both materials nominally satisfy the specified envelope and probably would have performed adequately under fast moving traffic, in this situation the finer graded overlay material with a higher bitumen content deformed whereas the original wearing course did not.

TRAFFIC LOADING

8. The Kuala Lumpur - Karak highway forms part of the major east-west route across Peninsular Malaysia and carries a large number of commercial vehicles transporting raw materials such as timber and palm oil. A classified traffic count in December 1991 showed that the average daily number of commercial vehicles using the climbing lane was 1130. The majority of these vehicles had single rear axles, which led to severe overloading. A 16 hour axle load survey carried out at a similar time showed that 40 per cent of the rear axles had loads in excess of the legal limit (see Figure 2).

EXPERIMENTAL DESIGN

9. There are various grades of Polybilt polymers being developed and marketed by Exxon Chemicals as bitumen modifiers for use in road construction. They come in the form of free flowing pellets which, when added to bitumen, will absorb some of the lighter oils and consequently swell, creating polymer phases within the bitumen intermolecular structure. These phases grow with increasing polymer content. As the optimum polymer content is reached, these phases interconnect to form a predominant continuous phase. Improvements in the properties of the binder and the subsequent asphalt mix are attributable to the presence of this continuous polymer phase. For this trial the supplier had chosen to use Polybilt 101, a copolymer of ethylene-vinyl acetate and XCS 503, an ethylene methacrylate polymer. In addition to the polymers, the

supplier also introduced an anti-stripping agent, Lilamine VP 75E (Li).

10. The copolymer of ethylene and vinyl acetate (EVA) offers a means of modifying the rheological properties of conventional penetration grade bitumens. Small additions of the copolymer increase the softening point of the binder and improve its temperature susceptibility (Button and Little, 1987). In addition, EVA modified binders increase the stiffness of rolled asphalt wearing course material without reducing its resistance to fatigue cracking (Denning and Carswell, 1981). Full-scale trials have also shown that EVA copolymers improve the mixing and laying characteristics of rolled asphalt (Denning and Carswell, 1981). Wheel tracking tests carried out with permeable macadams, dense bitumen macadams, rolled asphalts and asphaltic concrete have all shown that the addition of the EVA copolymer improves the resistance to deformation by a factor of between 3-4 (Daines, 1986; Rant and Schoepe, 1989; Carswell, 1986; Choyce and Woolley, 1989).

11. Carswell (1987) showed that for equivalent wheel tracking performance, the Marshall stability requirement for EVA modified rolled asphalt was substantially less than for non modified material. This is shown in Figure 3. It was also shown in the same study that the addition of 5 per cent of EVA in rolled asphalt materials increased the Marshall stability by 35 per cent. Choyce and Wooley (1989) reported an increase in Marshall stability of 25 per cent in EVA modified rolled asphalt but only a 10 per cent increase in asphaltic concrete. This despite the fact that the modified asphalt improved the resistance deformation by a factor of over three. These results highlight the need for caution in the interpretation of the Marshall properties of modified materials as they tend to underestimate their performance in terms of resistance to deformation.

12. This experiment was designed to compare the relative performance of a 'control' asphaltic concrete wearing course made with 80/100 pen bitumen with similar material modified by the addition of the different polymers. The amount of polymer was selected by the supplier and resulted in the following experimental design.

Section 1	80/100 pen + 7.5% Polybilt 101 + 0.2% Li†
Section 2	80/100 pen + 5% Polybilt 101 + 0.2% Li
Section 3	80/100 pen + 5% XCS 503 + 0.2% Li
Section 4	80/100 pen bitumen

† By weight of bitumen

13. Mix design was by the 75 blow Marshall method using 80/100 pen bitumen modified with 5% Polybilt 101 plus 0.2% Lilamine. The results of the design testing is given in Table II.

TABLE II

RESULTS OF CONTROL TESTING

Marshall Property	Design	Tolerance	Material			
			Control	5% 503	5% 101	7.5% 101
Binder Content (%)	6.0	+/-0.3	5.9	6.0	5.9	5.9
Density (Mg/m^3)	2.35	-	2.34	2.35	2.35	2.35
VMA (%)	-	-	17.2	17.2	17.1	16.9
VIM (%)	3.2	+/-1.0 (3-5)*	3.7	3.3	3.5	3.4
Stability (Kg)	1136	(>500)	1244	1254	1281	1305
Flow (mm)	2.4	(2-4)	2.8	2.8	2.9	2.8
Sieve Size (mm)	Per Cent Passing					
20.0	100	+/-5	100	100	100	100
12.5	84	+/-5	87	87	87	85
10.0	79	+/-5	82	81	81	79
6.3	69	+/-5	71	71	70	69
3.15	56	+/-4	57	56	55	54
1.18	36	+/-4	37	36	36	36
0.425	23	+/-3	24	23	23	23
0.150	9	+/-3	10	10	9	9
0.075	5	+/-2	6	4	4	4

( )* Marshall design requirements

ASPHALT PRODUCTION

14. The polymers and anti-stripping agent were blended with the 80/100 pen bitumen in a ten tonne capacity tank fitted with a motorised stirrer. Mixing took approximately two hours at 160°C and, where possible, the modified binder was used immediately. If storage was necessary then the temperature was reduced to 100°C overnight. After blending, samples of modified binder were tested to ensure that the properties were similar to illustrative results supplied by Exxon Chemicals. These results are shown in Table III.

TABLE III

BINDER PROPERTIES AFTER BLENDING

Material	Pen @25°C (0.1mm)	Softening Point (°C)	Viscosity $0.05sec^{-1}$ (Poise)		Temperature Susceptibility $\eta60/\eta45$	Pen @25°C after mixing (0.1mm)
			45°C ($\eta45$)	60°C ($\eta60$)		
5% - 101	67	67	$1.1x10^5$	$1.5x10^4$	0.13	44
7.5% - 101	58	73	$2.2x10^5$	$2.9x10^4$	0.13	40
5% - 503	69	60	$1.1x10^5$	$1.3x10^4$	0.12	54
Control	95	49	$2.0x10^4$	$3.5x10^3$	0.18	58

15. The results showed that there was a decrease in penetration and increase in softening point for all three modified binders compared to the control sample. The addition of Polybilt 101 and XCS 503 at 5 per cent concentration increased the binder viscosity by a factor of five. When the concentration of Polybilt 101 was increased to 7.5 per cent, the binder viscosity was increased by a factor of ten. In addition, all three modified binders had improved temperature susceptibility compared to the control bitumen. These results compared favourably with those from the results of previous work by the supplier and indicated that the stock bitumen used was compatible for modification.

16. Penetration tests were also carried out on binder recovered (BSI, 1991) from the various mixes after the production of the asphalt. These results are

shown in Table III. The binders modified with Polybilt 101 remained significantly more viscous after mixing than the control. The penetration of the binder modified with XCS 503 was comparable to the control despite its initial high viscosity. Despite being more viscous, the binder modified with Polybilt 101 had no significant effect on the Marshall stability of the mix (see Table II).

17. During the manufacture of each surfacing material two samples were taken to determine both Marshall properties and composition. A summary of these results is given in Table II. The results showed that the mixes were within the specified tolerances and were similar in all physical aspects.

CONSTRUCTION

18. As the existing surfacing was so severely deformed it was necessary for the milling machine to make two passes to ensure that all the previous overlay material was removed. Practical constraints also meant that the transverse depth profile of the milled area was a wedge, varying in thickness from approximately 50 mm at the longitudinal joint with the adjacent lane to 85 mm at the verge. After milling, the surface was swept with a mechanical broom prior to the application of a bitumen emulsion tack coat.

19. Compactive effort on all four sections was similar, being 5 passes with a 6.5 tonne steel-wheel roller, followed by 10 passes of 10.0 tonne pneumatic tyre roller.

PERFORMANCE

20. The performance of the different surfacing materials was assessed by rut depth measurements taken in both the verge and offside wheelpaths. The results of these regular surveys were corrected for any minor surface irregularities due to construction which were measured just after the completion of the experimental sections. The results of these surveys are shown in Figure 4.

21. The results show that the control material failed very rapidly, reaching a nominal failure criteria of 15 mm in the vergeside wheelpath after only 170

days. The increase in deformation in the offside was not quite as rapid probably because, as described above, the surfacing was not as thick in this wheelpath.

22. The materials modified with 5 and 7.5 per cent of Polybilt 101 performed better, reaching the failure criteria in both the vergeside and the offside wheelpath after approximately 450 days.

23. The surfacing material modified with 5 per cent of XCS 503 performed the best, having rut depths of only 9 and 4 mm in the verge and offside wheelpaths respectively after 800 days. There was also no cracking in the material after this time.

24. The rates of deformation in the vergeside wheelpath at the time the control material was milled off are given in Table IV.

TABLE IV

RATE OF DEFORMATION

Material	Rate of Rutting (mm)	
	Per 100 days	Per 0.5 x 10^6 esa
5% - 101	3.9	3.6
7.5% - 101	4.4	4.0
5% - 503	1.9	1.7
CONTROL	8.8	8.1

DISCUSSION

25. The control material failed rapidly, reaching the failure criteria within six months. This type of failure is not untypical of the performance of asphaltic concrete used in areas of slow moving commercial vehicles. For instance, the deformation on another climbing lane (Institute of Public Works Malaysia, 1989) in Malaysia, superimposed on Figure 4, shows a similar rate of rapid deterioration. The results from both these trials illustrate the

urgent need to develop a test procedure that can be used to design asphalt surfacings to withstand the excessive loading conditions that are common on climbing lanes. Similar results have been reported elsewhere (Murfee and Manzione, 1992) and asphaltic concrete designed using gyratory compaction has been suggested.

26. The material modified with Polybilt 101 performed better than the control section, reducing the rate of deformation by a factor of over two. However, even though the modifier had a substantial effect on performance, its relatively short survival time means that it is unlikely to be cost effective. Increasing the polymer content to 7.5 per cent did not improve its resistance to deformation (see Table IV).

27. The rate of deformation in the section modified with XCS 503 was a factor of 4-5 lower at the time the control material was milled off, and after two years the average rutting in the vergeside had still not exceeded 10 mm. At the present rate of deformation the material would reach the failure criteria of 15 mm after 6 years. This result would indicate that the use of this polymer could be cost effective for climbing lanes having a similar traffic loading to that described here. However, it should be noted that the addition of XCS 503 has not prevented rutting, merely retarded it.

FURTHER TRIALS

28. If the shear failure of dense asphalt surfacings is to be prevented then secondary compaction of the material after construction must be minimised. It has been estimated (Brown, 1988) that if the terminal air voids in the mix (VIM) after trafficking can be maintained above 2 per cent then the mix will remain stable. It has also been shown (Cooper et al, 1985) that increased compactive effort on continuously graded materials results in a corresponding increase in resistance to deformation. However, when the voids in the mineral aggregate (VMA) reach approximately 15 per cent, the fine aggregate starts to fill more of the voids, reducing the contact between the coarse aggregate and, in consequence, the resistance to deformation decreases.

29. The results indicate that if a mix can be designed such that traffic does not reduce the VMA and VIM to less than 15 and 2 per cent respectively,

it should perform satisfactorily.

30. The dynamic compaction procedure employed in the Marshall design method does not simulate the compactive effort of slow moving commercial vehicles on dense surfacings at high temperatures and therefore cannot be used to establish whether a mix will meet this minimum requirement. The Percentage Refusal Density (PRD) (BSI, 1989) test is considered to provide a more appropriate level of compactive effort.

31. A second trial, incorporating an asphaltic concrete binder course material that met these specifications at refusal density, was constructed along the same climbing lane in September 1990. In addition to this material, three other bitumen additives were used in an asphaltic concrete wearing course designed by the Marshall method. These were:

1. Caribit
2. Chemcrete
3. Gilsonite

The results from this second trial will be reported at a later date.

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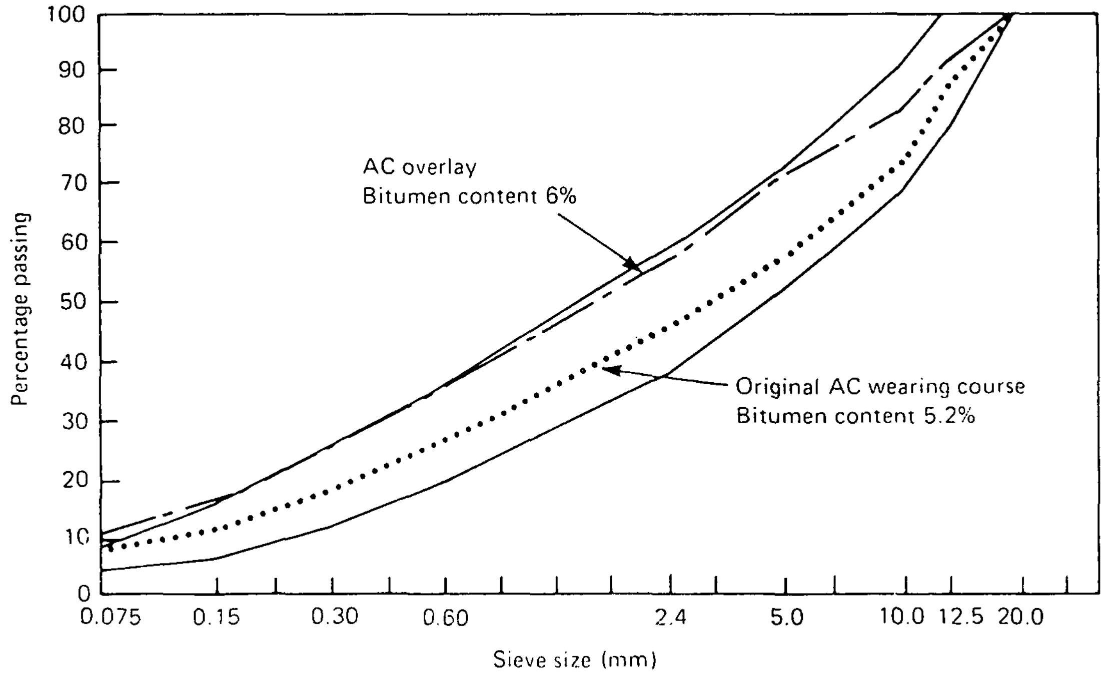

Fig. 1 Composition of existing bituminous surfacing

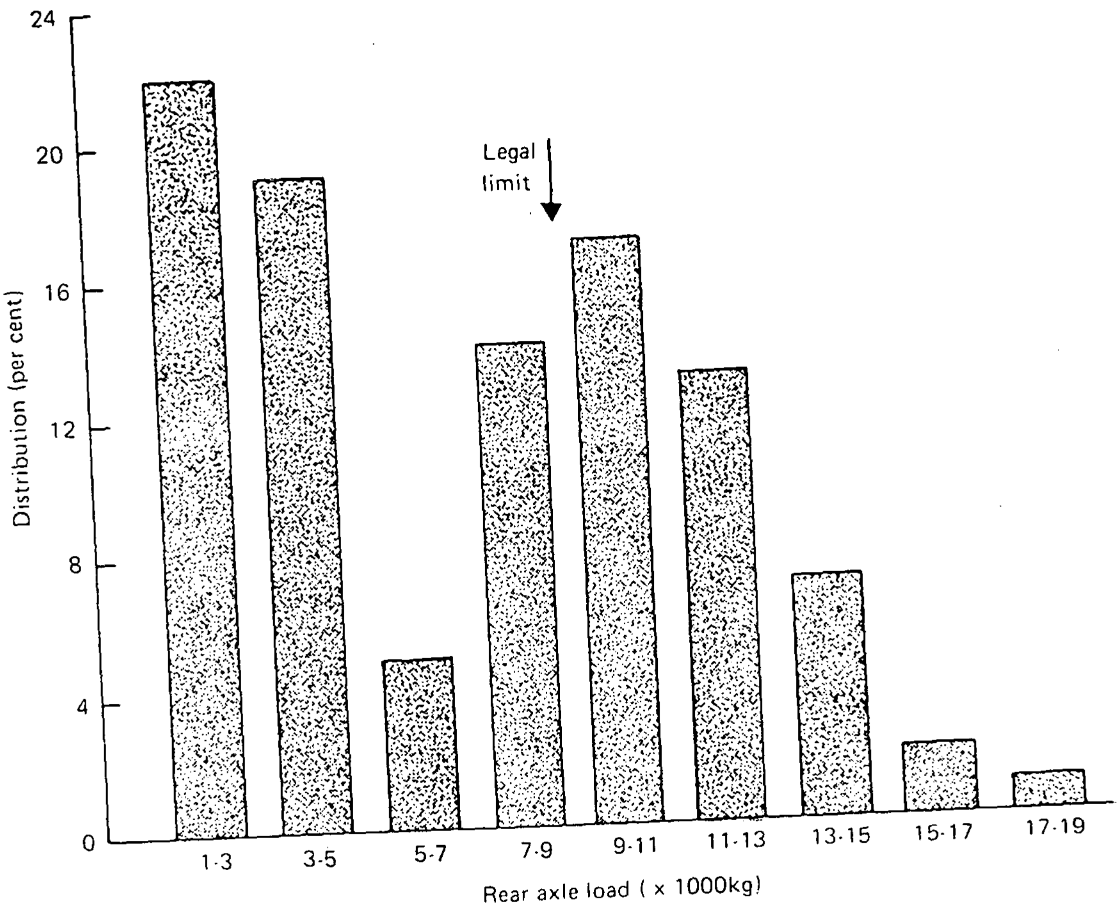

Fig. 2 Rear axle load distribution

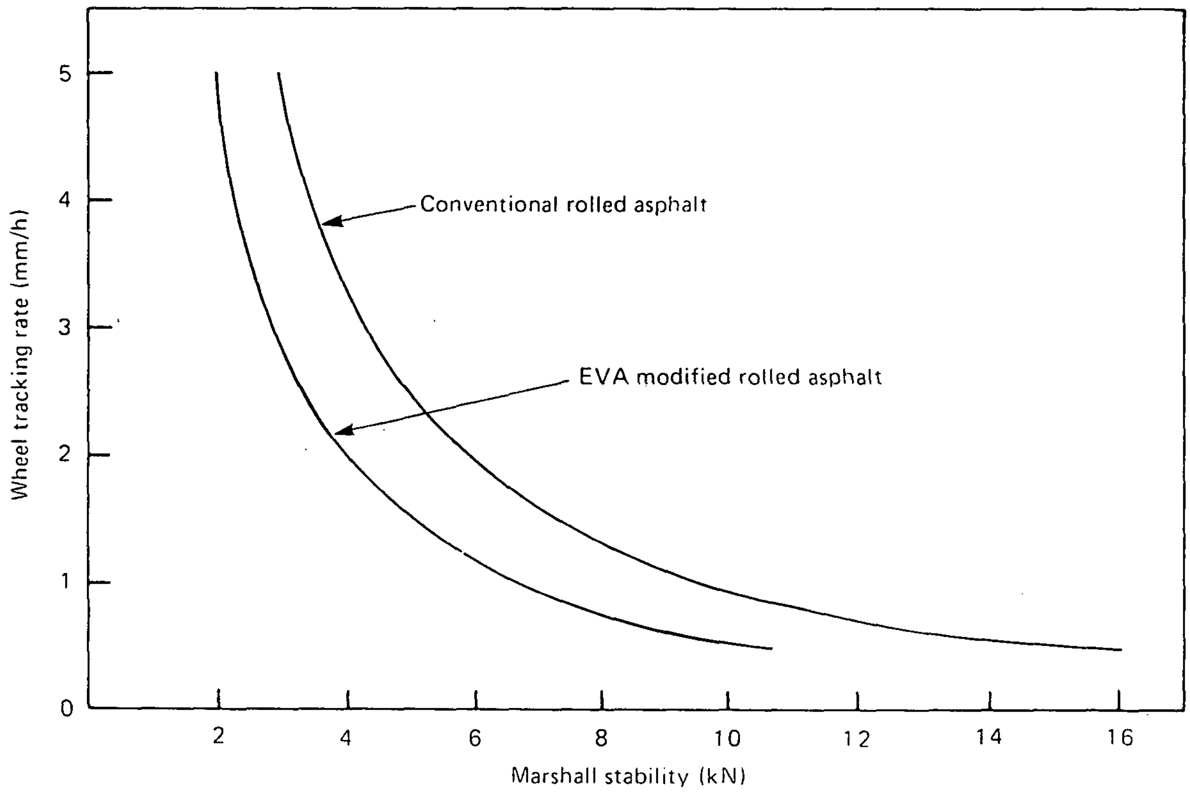

Fig. 3 Relation between deformation and stability
(after Carswell, 1987)

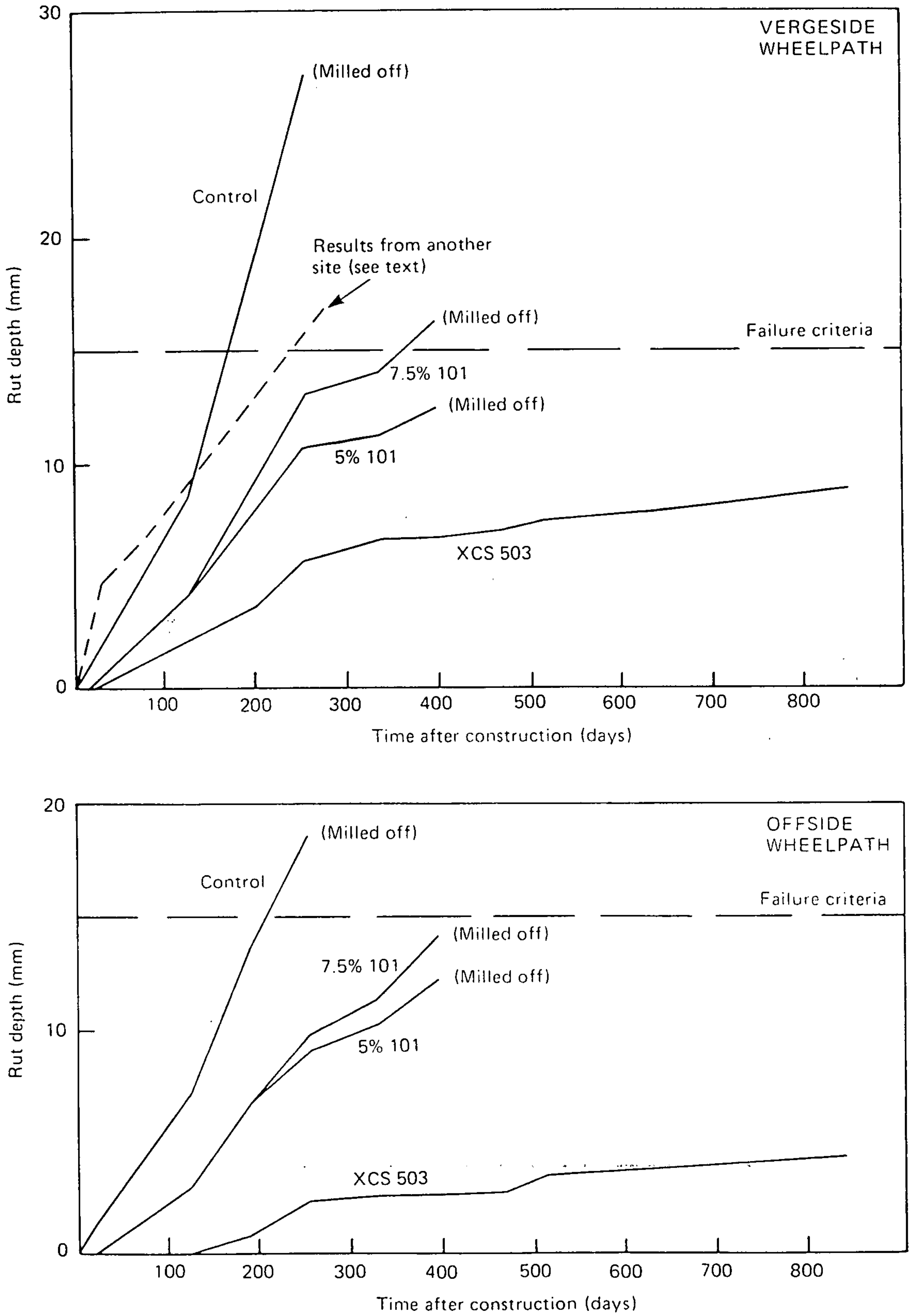

Fig. 4 Progression of rutting