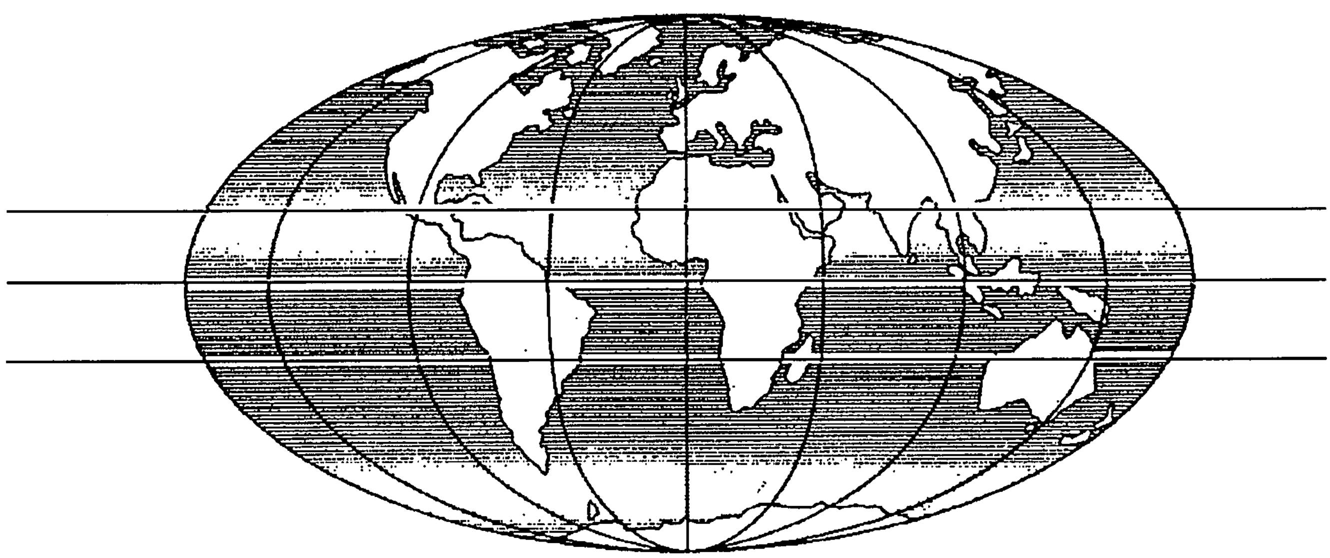
TRANSPORT RESEARCH LABORATORY

ODA

Reprint

TITLE A study of the peformance of various bituminous surfacings for use on climbing lanes

by Mohd. Hizam Harun and G Morosiuk



Overseas Centre
Transport Research Laboratory
Crowthorne Berkshire United Kingdom

HIZAM HARUN, M and G MOROSIUK (1995). A Study of the performance of various bituminous surfacings for use on climbing lanes. In Proceedings: *Eighth REAAA Conference, Taipei, 17-21 April 1995.*

8th REAAA Conference, 17-21 April, 1995, Taipei

A STUDY OF THE PERFORMANCE OF VARIOUS BITUMINOUS SURFACINGS FOR USE ON CLIMBING LANES

Mohd Hizam Harun **Public Works Institute (IKRAM), Malaysia**
Dr Greg Morosiuk **Transport Research Laboratory (TRL), UK**

ABSTRACT: Asphaltic concrete wearing courses which are subjected to severe traffic loading and high temperatures, frequently fail prematurely through plastic deformation. The design of stable mixes presents particular problems because Marshall test results do not correlate with the subsequent performance of these materials under high stress conditions. A number of binder additives exist which are claimed to increase the viscosity and improve the temperature susceptibility of conventional bitumens, thus making the modified surfacings less prone to deformation. This study examines the performance of a full-scale trial located on a climbing lane, in which several binder additives were used. Asphaltic concrete mixes without bitumen modifiers were also included in the trial; one based on a refusal density design method to provide greater inherent resistance to deformation and one with the bitumen content adjusted below the Marshall optimum value.

1. INTRODUCTION

The use of asphaltic concrete wearing courses, designed using the Marshall method (Asphalt Institute, 1984), in areas of high traffic stresses such as climbing lanes and junctions is often not appropriate, particularly at high temperatures. The density and particle orientation obtained during the Marshall test does not represent the ultimate condition and density in the road pavement after compaction by slow moving heavy vehicles. At high temperatures and long loading times conventional bitumen behaves in a viscous manner, allowing considerable secondary compaction of the mix under traffic. The subsequent reduction in air voids can cause the matrix of fine aggregates and bitumen to reduce the mechanical interlock between the coarse aggregates (Cooper et al, 1985). This eventually results in structural instability and the surfacing shears under further trafficking.

A number of additives exist that increase the viscosity of a binder and improve its temperature susceptibility, which should make the modified surfacings more resistant to deformation at high temperatures. An alternative to the use of additives is a modification of the mix design and compaction method to produce a more mechanically stable material, again making it more resistant to deformation at high temperatures. One such technique is the design of mixes using refusal density testing.

The Pavement Unit of the Public Works Institute, Malaysia (IKRAM), in cooperation with the Transport Research Laboratory (TRL), UK, monitored the construction and subsequent performance of two full-scale trials in which various binder additives and mix designs were used. These trials were constructed on a climbing lane on the Kuala Lumpur - Karak Highway in Malaysia. The performance of the first trial, constructed in September 1989 using polymer modified asphaltic concrete, was reported by Harun and Jones (1992).

The second trial, comprising five test sections, was constructed in August 1990. The materials used included asphaltic concrete wearing course modified with Caribit-Plus, Chemcrete and Gilsonite, a wearing course with no modifier as a control and an asphaltic concrete mix designed using refusal density testing. This paper describes the design, construction and the first three years performance of these test sections.

2. EXPERIMENTAL DESIGN

The trial was designed to compare the relative performance of a control 20 mm asphaltic concrete wearing course (ACW20) made with 80/100 pen bitumen with similar material modified with Caribit-Plus, Chemcrete and Gilsonite, and an asphaltic concrete mix designed using refusal density testing.

An 850 metre length of climbing lane was selected for the trial at Bukit Tinggi on the Kuala Lumpur - Karak Highway. The climbing lane had a uniform gradient of 8 per cent and the average speed of the commercial vehicles using it was 15 km/h. A classified traffic count conducted at the site 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. An axle load survey indicated that 40 per cent of the rear axles had loads in excess of the legal limit of 9 tonnes, with 10 per cent exceeding 13 tonnes.

The test sections were each 200 metres in length, except for the control section which was 50 metres long. Test points were marked out at 10 metre intervals, at which rut depth measurements were taken periodically.

2.1 Refusal Density Testing

The full benefit from the use of bituminous materials in road construction can only be achieved if a satisfactory degree of compaction is attained during construction. If shear failure is to be prevented then secondary compaction of the material after construction must be limited to a safe value. 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. Laboratory studies (Cooper et al, 1985) have shown that increased compactive effort on continuously graded materials results in a corresponding increase in resistance to deformation. However, when the compactive effort is increased further until the voids in the mineral aggregate (VMA) reach 15 per cent, the fine aggregate starts to fill more of the voids. This process reduces the contact area between the coarse aggregate particles and, in consequence, the resistance to deformation decreases. The results indicate that if a mix can be designed such that traffic does not reduce the VIM and VMA to less than 2 and 15 per cent respectively, it should perform satisfactorily.

The compaction procedure used in the Marshall design method does not simulate the compactive effort of slow moving commercial vehicles on dense bituminous surfacings at high temperatures and therefore cannot be used to establish whether a mix will meet the minimum requirements of VIM and VMA. The percentage refusal density (PRD) test method (BSI, 1989) is considered to provide a more appropriate level of compactive effort for bitumen macadams. A refusal density design method is currently being extended from basecourse and roadbase mixes, for which the PRD test was developed, to wearing course mixes (TRL, 1993). A test section was incorporated in this trial using 28 mm asphaltic concrete binder course material (ACB28) designed to meet the specifications of VIM and VMA at refusal density.

2.2 Chemcrete

Chemcrete is a liquid additive composed of organo-metallic components dissolved in a softening oil. It reacts with bitumen and changes the chemistry and the molecular structure of the bitumen under the influence of temperature and oxygen, resulting, it is claimed, in the formation of ketones. The presence of these ketones increases resistance to bitumen ageing by oxidation, improves the anti-stripping properties and reduces temperature and shear susceptibility.

2.3 Gilsonite

Gilsonite is a natural solid hydrocarbon containing a high concentration of high molecular weight asphaltenes and nitrogen compounds. It comes as a free flowing granular solid that can be incorporated into the bituminous mix by pre-blending with bitumen or by direct addition during hot mix manufacture.

2.4 Caribit-Plus

Caribit-Plus is a polymer modified bitumen. It is manufactured from selected grades of bitumen into which thermoplastic rubber of the type Styrene-Butadiene-Styrene (SBS) is incorporated by high shear mixing. It is claimed that when used in wearing courses, the binder offers advantages of reduced permanent deformation, longer fatigue life, allows use of thinner overlays and improved resistance to secondary compaction.

3. CONSTRUCTION

The experimental sections were constructed in August 1990. The existing deformed surfacing was milled off to a depth of 125 mm. Asphaltic concrete binder course was laid to a thickness of 60 mm throughout the 850 metre length of the trial site. This was then overlaid with 65 mm of wearing course using the modifiers and mix designs described above. The quantity of each modifier was selected by the respective supplier. Results of aggregate grading and binder content tests conducted on samples taken from the sections during construction are summarised in Table 1.

3.1 Chemcrete Section

A known quantity of bitumen was transferred from the storage tank to the pugmill through a static mixer. Chemcrete additive at 2 per cent by weight of bitumen was introduced on the upstream side of the mixer. The first 100 metres of this test section was constructed using the 20 mm wearing course material modified with Chemcrete having the normal contractual design bitumen content of 6.0 per cent.

At the request of the Chemcrete supplier, the second 100 metre length was constructed with 28 mm binder course material, as designed for the refusal density test section. This mix had a design bitumen content of 5.0 per cent with a similar addition of 2 per cent of Chemcrete by weight of bitumen.

Table 1 Aggregate Grading and Bitumen Content

Sieve size (mm)	Material						
	ACW20					ACB28	
	JKR Specs	Chemcrete	Gilsonite	Caribit	Control	Chemcrete B/C	Binder Course
28	-	-	-	-	-	100	100
20	100	100	99	100	100	93	95
14	80 - 95	91	91	87	89	79	74
10	68 - 90	77	82	78	79	72	65
5	52 - 72	65	71	67	69	64	58
3.35	45 - 62	56	62	62	61	59	53
1.18	30 - 45	31	37	43	38	38	33
0.425	17 - 30	18	21	24	21	21	17
0.150	7 - 16	11	10	11	10	11	8
0.075	4 - 10	7	6	6	6	6	4
Bitumen Content (per cent)							
Design	6.0	6.0	5.4	5.0	6.0	5.0	5.0
Actual	-	5.8	5.6	5.1	5.1	5.1	4.8

3.2 Gilsonite Section

Gilsonite was mixed in the batch plant by adding 10 per cent by weight of bitumen directly into the pugmill, effectively reducing the bitumen content from the optimum 6.0 per cent to 5.4 per cent. The mixing period in the pugmill of 45 seconds was prolonged by 20-25 seconds, as requested by the supplier. The 200 metre long test section was constructed with 20 mm wearing course material modified with Gilsonite.

3.3 Caribit-Plus Section

The imported Caribit-Plus modified binder had to be reheated slowly to avoid damaging the binder, needing about 8 days of heating before the desired temperature of 160 deg C was reached. The optimum Caribit-Plus binder content for use with the 20 mm wearing course material was designed at 5.0 per cent by the supplier. At the request of the supplier, the first 100 metres was constructed in two layers of 25 mm and 40 mm. The second 100 metres was laid in one lift of 65 mm.

3.4 Binder Course Section

This 200 metre test section was constructed with 28 mm binder course material designed using refusal density testing with a design bitumen content of 5.0 per cent.

3.5 Control Section

The 50 metre control section was constructed to the normal contractual procedures using 20 mm wearing course material without any modifier. Although the design bitumen content for the ACW20 mix was 6.0 per cent, this section was constructed with a bitumen content of 5.1 per cent. This is discussed in more detail below.

3.6 Compaction of Sections

On the four test sections using the ACW20 mix, the compactive effort was similar. The rolling pattern was four passes (2 static, 2 vibratory) with an 8 tonne steel-wheeled roller, followed by twelve passes of a 12 tonne pneumatic tyre roller and finally 2 further static passes with the steel-wheeled roller.

On the two sections constructed with 28 mm binder course material (Chemcrete modified sub-section and binder course section) a higher compactive effort was applied in order to achieve relatively low initial VIM and VMA and consequently a higher density. The rolling pattern on these sections was four passes (2 static, 2 vibratory) with the steel-wheeled roller, twenty passes with the pneumatic tyre roller and then 2 further static passes with the steel-wheeled roller.

3.7 Comparison of Construction Specifications

The envelope covering the gradings of the aggregate for the four ACW20 sections as listed in Table 1, has been plotted in Figure 1 together with the Malaysian Public Works Department's (JKR) grading specifications envelope. This Figure illustrates that the gradings on the four sections were similar and conformed to the JKR grading specifications.

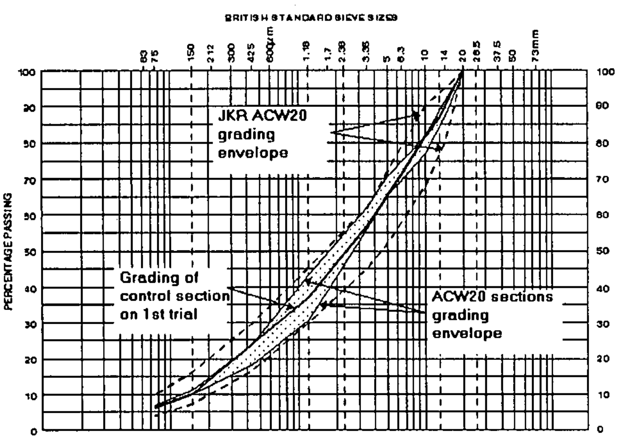


Fig. 1 Aggregate grading of the ACW20 sections

In the first trial on this climbing lane (Harun and Jones, 1992) in which the performance of three polymer modified asphaltic concrete mixes were studied, the control section was also constructed using an ACW20 mix with a design binder content of 6.0 per cent. The grading of the aggregate from this section has also been plotted in Figure 1 which shows that the grading on the first control was similar to the four ACW20 sections. Therefore, since the same aggregate type has been used, it is not unreasonable to compare the performance of the first control section with that of the ACW20 sections from the second trial.

The aggregate gradings for the two ACB28 sections listed in Table 1 shows that the two materials were similar.

4. PERFORMANCE

4.1 Rut Depth Progressions

Rut depth measurements were made at regular intervals of time in both wheelpaths at the 10 metre spaced test points using a 2-metre straight-edge and calibrated wedge. As expected, the deformations in the vergeside wheelpath were greater than in the offside wheelpath. The progressions of rut depths in the vergeside wheelpath have been plotted in Figure 2 which shows that after more than three years (1250 days), the average rut depths on the test sections were less than 6 mm, with the exception of the Chemcrete ACW20 section where the average rut depth was 10 mm.

These progressions of rut depth compare favourably with the performance of the test sections in the first trial. Harun and Jones showed that all but one of the test sections had reached a failure criteria of an average rut depth of 15 mm within one year of trafficking. In particular, the ACW20 control section, which had a binder content of 5.9 per cent, reached this level of deformation within six months. Harun and Jones also illustrated that the original wearing course with a binder content of 5.2 per cent had not deformed after a number of years of trafficking prior to being overlaid. The average rut depth on the control section in the second trial, constructed with a binder content of 5.1 per cent, had only increased to 4 mm after three years of similar trafficking.

4.2 Change in Voids

Throughout the three-year monitoring period, 150 mm diameter core samples were taken from the test sections and tested to determine their densities and air voids in the mix (VIM). When these core samples were taken, rut depth measurements were also made. These point specific measurements of rut depths and air voids, plotted in Figure 3, indicated that in areas where the voids were lower than 3 per cent, 40 per cent of the points had rut depths in excess of 5 mm. In comparison, where the voids were greater than 3 per cent, only one point had a rut depth in excess of 5 mm.

The four ACW20 sections received the same level of compaction during construction and a higher level of compaction was applied to the two ACB28 sections (see Section 3.6). In order to examine the change in voids with time, the average voids calculated for cores taken from a section at each point in time, have been plotted against time in Figures 4 and 5 for the ACW20 and ACB28 sections respectively. These plots indicate that the voids decreased by 2 - 4 per cent in the first 150 to 250 days. This initial rapid decrease in voids, averaging 2.75 per cent, occurred irrespective of whether the bitumen in the mix had been modified or not. This was then followed by a much slower rate of decrease.

5. DISCUSSION

The rut depth progressions on the six test sections indicate that, in terms of rutting, the modified sections performed no better than the two non-modified sections (binder course and control).

The study has shown that it is possible to produce a bituminous surfacing material which is resistant to deformation under severe loading conditions without recourse to expensive bitumen modifiers. The binder content of the control section in the first trial was 5.9 per cent compared with 5.1 per cent in the second trial. The control section in the first trial had exceeded an average rut depth of 15 mm within six months, whereas in the second trial the average rut depth of the control was less than 4 mm after more than three years of similar trafficking. Also results of a coring survey carried out prior to construction of the first trial indicated that there had been no significant rutting in the original asphaltic concrete surfacing and that the deformation was confined to the relatively new overlay (Harun and Jones, 1992).

Results from this study have indicated that, under severe loading conditions, rutting is likely to occur when the value of VIM drops below 3 per cent. In this trial, 40 per cent of the samples below this value had rut depths in excess of 5 mm.

An examination of the decrease in voids with time showed that VIM decreased rapidly during the early life of the surfacing on all the sections. An average decrease in VIM of 2.75 per cent was recorded over the first 150 to 250 days. This decrease was not affected by the use of modifiers or the initial value of the voids at the time of construction.

There was a large range of initial voids from almost 9 per cent to below 4 per cent. A higher compactive effort used on the two ACB28 sections resulted in lower initial voids, but this did not reduce the subsequent rate of decrease in voids over time.

6. ACKNOWLEDGEMENTS

This study was carried out under a joint cooperative research programme between the Transport Research Laboratory (TRL) of the United Kingdom and the Public Works Department (JKR) of Malaysia. The authors would like to thank the Director General of the Malaysian Highway Authority for the opportunity of monitoring the experimental sections.

The work described in this paper forms part of the research programme of the Overseas Resource Centre (Programme Director: Dr J Rolt) of the TRL carried out on behalf of the Overseas Development Administration. Any views expressed are not necessarily those of the Administration, the Department of Transport or the JKR. The paper is published by permission of the Chief Executive of the TRL and the Director General of JKR.

7. REFERENCES

ASPHALT INSTITUTE (1984). Mix design methods for asphaltic concrete and other hot-mix types. Manual Series No. 2 (MS-2). (Asphalt Institute).

BRITISH STANDARDS INSTITUTION (1989). Sampling and examination of bituminous mixtures for roads and other paved areas. BS 598: Part 104: 1989. (British Standards Institution).

BROWN, S F (1988). Improved asphalt pavement engineering. Seventh AAPA, International Asphalt Conference, Brisbane. August 1988, pp 35 - 48.

COOPER, K E, S F BROWN and G R POOLEY (1985). The design of aggregate gradings for asphalt basecourse. Proc. of the Association of Asphalt Paving Technologists, Vol. 54 (1985), pp 324 - 346.

HARUN M H and C R JONES (1992). The performance of polymer modified asphaltic concrete on climbing lanes in Malaysia. Proceedings of the Sixteenth ARRB Conference, November 1992, Perth.

TRANSPORT RESEARCH LABORATORY (1993). A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical countries. Overseas Road Note 31 (Fourth Edition), TRL, Crowthorne, UK.

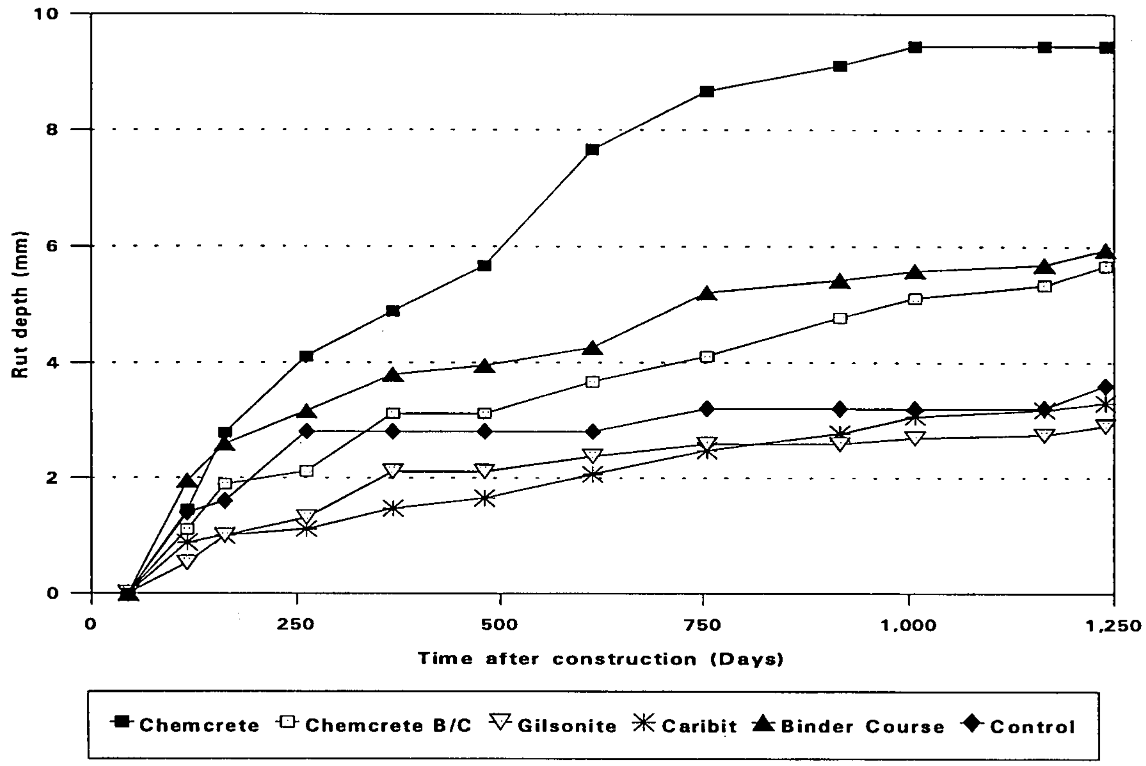


Fig. 2 Rut depth progressions - vergeside wheelpath

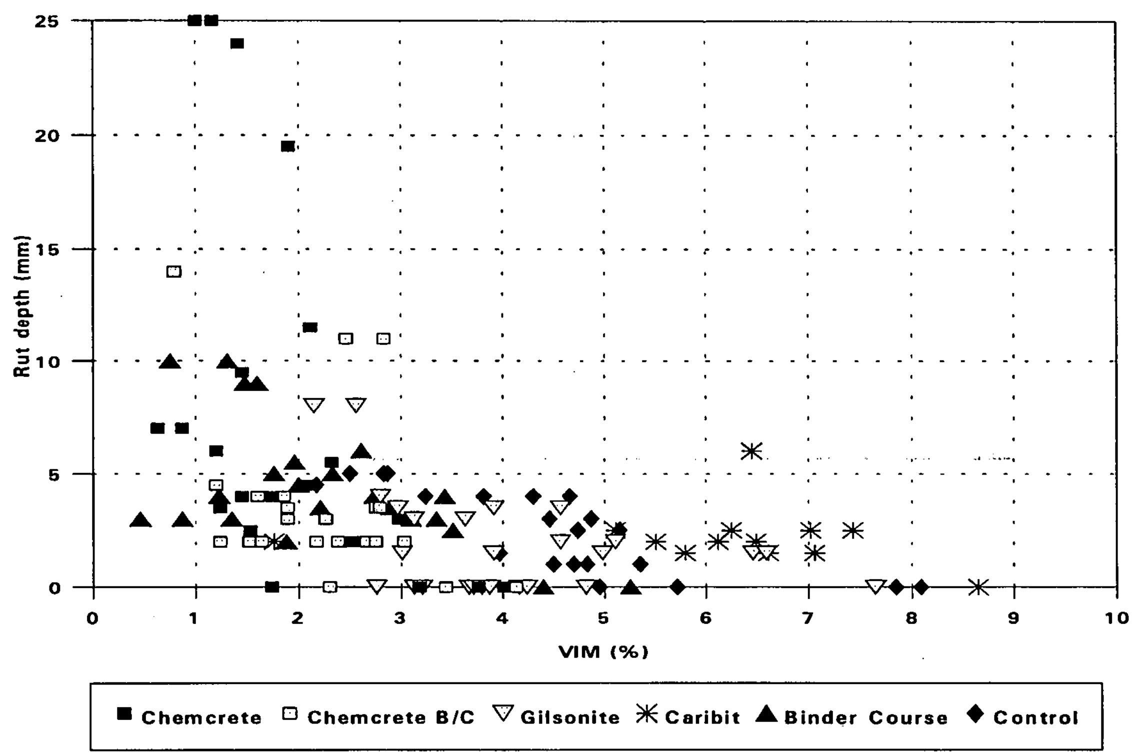


Fig. 3 Rut depth vs Air voids

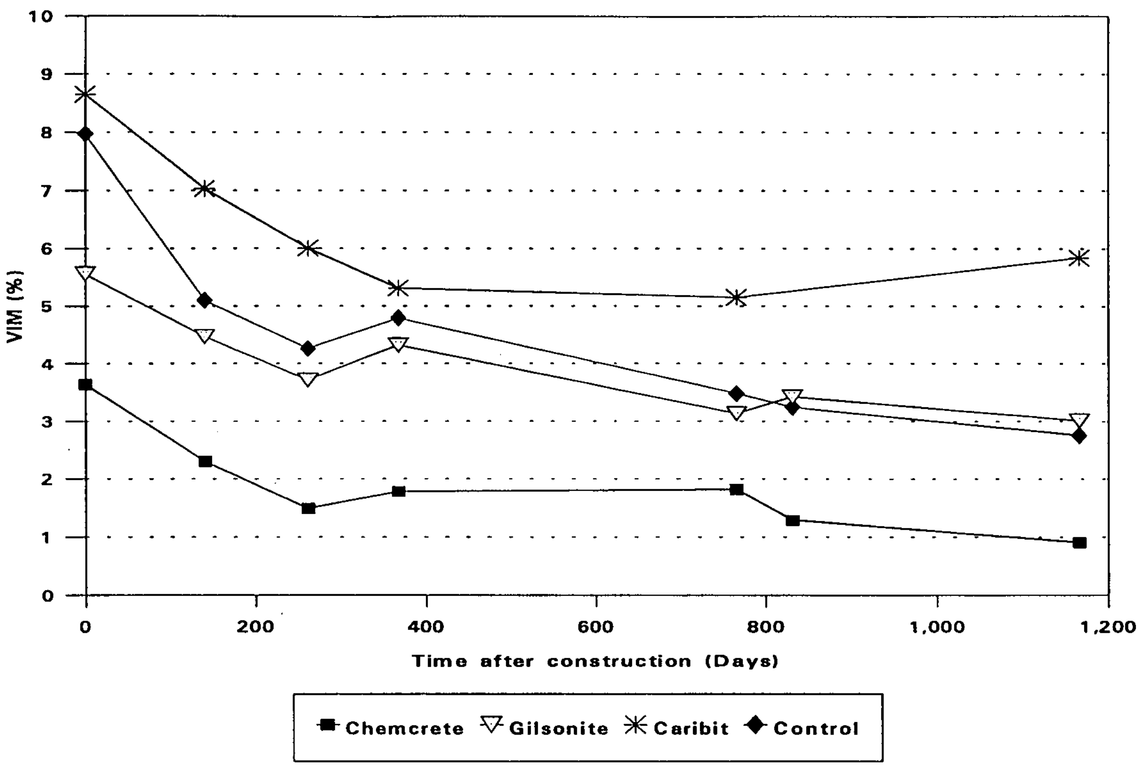


Fig. 4 Air voids vs Time - ACW20 sections

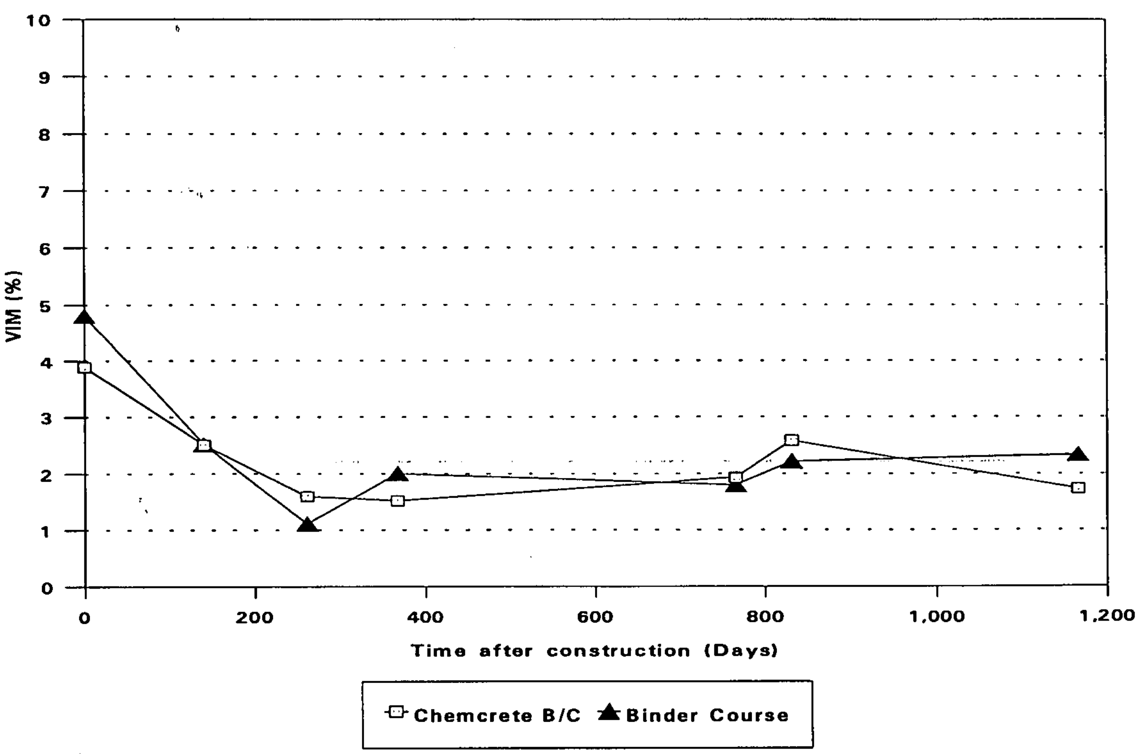


Fig. 5 Air voids vs Time - ACB28 sections