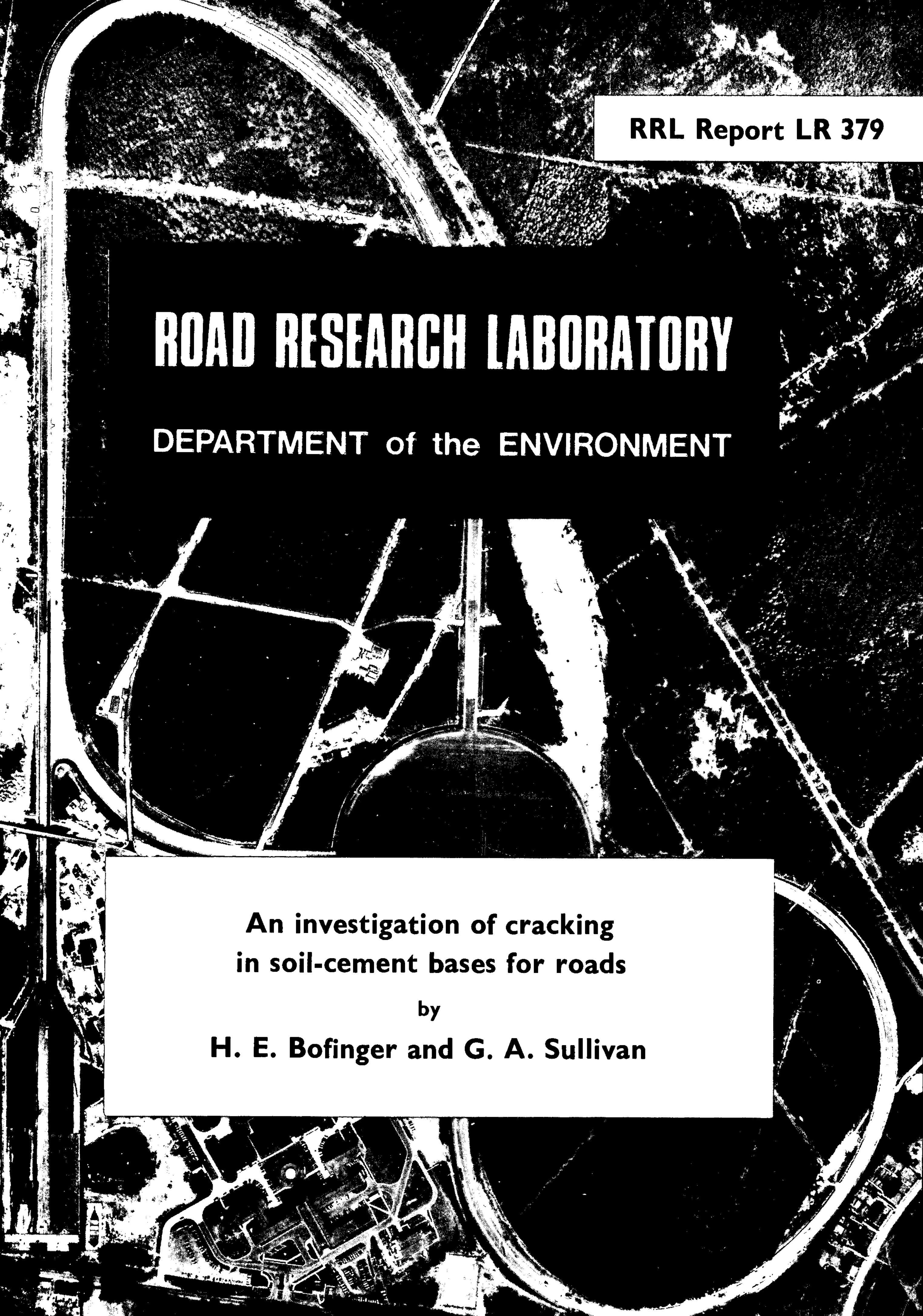

RRL Report LR 379

ROAD RESEARCH LABORATORY

DEPARTMENT of the ENVIRONMENT

An investigation of cracking in soil-cement bases for roads

by

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ABSTRACT

This report describes laboratory and pilot scale studies of some factors that influence the crack spacing in soil-cement bases.

Two lengths of pilot scale soil-cement base were cured for 7 and 11 days respectively before wheel loads were applied. A third control-length of soil-cement base was left untrafficked.

From measurements of tensile strength, shrinkage and subgrade restraint, the crack spacing that should occur in the untrafficked length was estimated. A similar crack spacing was observed in the experiment. The cracking in the other two lengths was more extensive and was related to the time that had elapsed before the wheel loads were first applied. The crack spacing in these lengths was similar to the spacing which has been observed in this type of base in the field, and which is usually attributed to shrinkage stresses.

It is concluded that the crack spacing in soil-cement bases is controlled by their strength at the time that traffic is first admitted. A knowledge of the shrinkage, strength, stiffness and subgrade restraint of soil-cement bases should enable crack size and spacing to be controlled during the construction operation.

1. INTRODUCTION

When soil-cement is used in road bases the size and spacing of the cracks that develop in it are important factors in determining the performance of the whole pavement. If the cracks are closely spaced and small there is less chance that they will be reflected through the surfacing than when the cracks are more widely spaced and larger. It is the cracks which penetrate through the surfacing that most seriously affect the performance of the road since they permit the ingress of surface water to the sub-base and subgrade. In developing countries it is normal practice to surface dress cement-stabilized bases and the control of cracking in the base is much more critical than when thicker bituminous carpets are used as surface layers.

It has often been suggested that shrinkage causes the cracking of soil-cement bases [1-5] and it has been observed that for a given soil the higher the cement content the greater is the crack spacing. Some highway authorities restrict the maximum amount of cement that they allow to be used in their soil-cement bases so as to limit the size and spacing of the cracks.[6] Well-graded gravelly soils that can be adequately stabilized with small additions of cement rarely exhibit "shrinkage" cracking, but it is quite a common phenomenon in the finer-grained materials which require more cement to achieve a specified strength, especially if they have a tendency towards uniform grading.

This Report describes experiments which have attempted to identify the causes of cracking in soil-cement bases with the object of predicting and controlling its occurrence.

2. THE CAUSES OF CRACKING

Many factors contribute to the cracking and crack-spacing of soil-cement bases. Probably the most important of these are:-

- (i) the tensile strength of the material
- (ii) its shrinkage characteristics
- (iii) the subgrade restraint
- (iv) external loadings such as those caused by traffic
- (v) stresses caused by volume changes resulting from temperature or moisture variations.
- (vi) stiffness and creep properties of the material

In this project the effects of the first four factors listed above were studied.

Generally, soil-cement bases are constructed as continuous slabs unless small limited areas are to be stabilized. When a soil-cement base is cured under excellent conditions, i.e. well sealed and completely shaded, it can be assumed that there is no loss of water and that shrinkage within the base will be relatively uniform and independent of depth. When no external loads have been applied to the base, the spacing between the cracks which form should be a function of the subgrade restraint and the tensile strength, the shrinkage, and the tensile modulus of deformation of the soil-cement. The latter three properties are time-dependent and their interaction is complicated.

It is also necessary to consider the possible occurrence of stress-relaxation due to creep. Previous studies [7] have shown that when soil-cement specimens are cured for 7 days or more, stress-relief due to this factor is insignificant. It is appreciated that when tensile strains are applied to soil-cement at an earlier age creep may significantly lower the tensile stresses that develop.

Measured values of the seven-day tensile strength and the subgrade restraint of other soil-cement bases [8] suggest that the spacing between shrinkage cracks could be quite large. Consider a simplified model of a 15 cm (6 in) thick soil-cement base. If a subgrade restraint of 5 kN/m^2 (100 lb/ft^2) has been mobilised over the whole area and the tensile strength is 70 kN/m^2 a slab of length 4.2 m (14 ft) should be stable and remain uncracked. If the stress in the soil-cement is relaxed due to creep in the material during its early life, the stable slab length would be greater than 4.2 m. When moisture dries from the surface of the base due to an inadequate curing technique, differential shrinkage could cause surface stress concentrations which would reduce the spacing between the major cracks.

When stresses induced by traffic exceed the ultimate strength of the material at the time they are applied the fracture pattern would be expected to be dependent upon the rate of application of the stresses and the magnitude of the overload. Many soil-cement bases appear to have been cracked by traffic loads, and approximate analyses [9] suggest that the normal 15 cm (6 in) - thick soil-cement pavement will be heavily overstressed under normal traffic loading.

3. EXPERIMENTAL PROGRAMME

Harmondsworth brickearth was used in the laboratory and pilot-scale experimental testing. Its properties were as follows:

Liquid limit = 53%

Plastic limit = 20%

Plasticity index = 33%

Specific gravity = 2.70

Particle Size:	Sand	= 7%
	Medium & Coarse Silt	= 55%
	Fine silt	= 10%
	Clay ($<$0.002mm)	= 28%

British Standard Compaction Test (BS 1377 : 1967)

Opt Moisture Content (with 8% cement) = 17%

Max Dry Density (with 8% cement) = 1.78 Mg/m^3 (111 lb/ft^3)

The cement used in the programme was "Typical Ordinary Portland Cement" supplied by the Associated Portland Cement Manufacturers Ltd.

Several factors were investigated in the laboratory. The increase with time of the tensile strength of the soil-cement was determined together with the relation between its shrinkage and time. In addition, the unconfined compressive strength after 14 days of moist curing was measured.

The shape of the specimens used in the tensile tests is shown in Fig. 1. The specimens were statically compacted in one layer in the mould which is shown in Plate 1. Tensile tests were performed after curing periods of 15 minutes, 30 minutes, 1½ hours, 4 hours, 1 day, 2 days, 7 days and 14 days. The two groups of specimens that were tested at 15 min and 30 min respectively were cured in a damp atmosphere at 20°C. The remaining specimens were dipped in paraffin wax and cured at 20°C. All of the wax was removed immediately before they were tested.

A photograph of the tensile testing frame is shown in Plate 2. The specimen was gripped in the jaws and deformed at a rate of 0.38 mm/min (0.015 in/min) until failure.

For convenience, the same type of specimen was used in the shrinkage experiments. Steel balls were attached to the centre of each end with quick-setting polyester resin and the specimens were sealed in wax. Within 15 minutes of being moulded they were placed in the measuring rig (see Plate 3) and the change in length was noted at regular intervals.

The 10 cm x 5 cm diameter (4 in x 2 in) compression specimens were statically compacted, sealed in wax and cured for 14 days at 20°C before being tested at a deformation rate of 1.27 mm/min (0.05 in/min).

The pilot-scale investigations were conducted in a 28 m x 7 m (92 ft by 23 ft) pit which was enclosed in a building. The top 90 cm (3 ft) of the insitu clay were removed and replaced by 75 cm (2 ft 6 in) of compacted, unstabilized Harmondsworth brickearth and a nominal 15 cm (6 in) of cement-stabilized base. The moisture content of the Harmondsworth brickearth that was to be stabilized was raised to 14 per cent prior to being placed in a pugmill mixer. 8 per cent of cement was blended with the partly wetted clay and the final mixing water added to give a moisture content of 18 per cent. After mixing was completed, the material was spread, screeded and compacted within 1 hr of mixing by two passes of a 3½ Mg (3½T) steel-tyred roller followed by 16 passes of a 17 Mg (17T) pneumatic-tyred roller. No traffic of any kind was allowed on the lengths of soil-cement base after this time, except as specified in the testing programme.

A plan of the pilot-scale area is shown in Fig. 2. Lengths 1 and 3 were 2.1 m (7 ft) wide while the centre length was 2.8 m (9 ft) wide. The pavement in length 1 was placed directly on top of the rolled, unstabilized clay subgrade. In Lengths 2 and 3, a layer of polythene was used to separate the rolled clay subgrade from the base. After the compaction was completed, 7.6 mm (0.3 in) wide transverse grooves, 50 mm (2 in) deep, were cut by hand at approximately 3 m (10 ft) spacing for 12 m (40 ft) of lengths 1 and 2, and 9 m (30 ft) of length 3. These grooves were included at one end of each length so that the maximum tensile stress during the initial shrinkage in the short slabs that were formed would be approximately 60 per cent of the tensile stress in the ungrooved section. Any deleterious effects of the higher maximum stresses during the early life of the ungrooved sections could then be detected.

No traffic loads were applied to Length 2. Lengths 1 and 3 were subjected to 50 passes of a 5 Mg (5T) fork-lift truck with wheel loads of 1910 kg (4210 lb) and 1170 kg (2574 lb) after a curing period of 11 days and 7 days respectively.

Approximately four months after the construction was completed beams 15 cm wide (6 in) and 60 cm (24 in) long were taken from the pilot-scale lengths of base. The positions of the beams are shown in Fig. 2.

The beams were cut out partly by a machine saw and partly by hand: a pavement saw was used to cut the top 7.5 to 10 cm (3 to 4 in) but the remaining material was carefully broken out by hand. All of the beams that were removed in one piece were tested to failure in flexure. They were loaded at the third points over a span of 45.7 cm (18 in), the bitumen surface being placed uppermost. Plate 4 shows a beam positioned in the testing rig.

Subgrade-restraint tests were performed on square blocks approximately 45 cm x 45 cm (18 in x 18 in) from which the surrounding base material had been removed. A jack applied a horizontal load to the block through a proving ring and the horizontal movement of the block was measured by a dial gauge. A photograph of a subgrade restraint test is shown in Plate 5.

4. RESULTS

4.1 LABORATORY TESTING

4.1.1 Tensile strength v Time of curing. The strengths of direct tensile briquettes that were cured for periods ranging from 15 minutes to 14 days are given in Table 1 and the results are plotted in Fig. 3. Each of the specimens was moulded at 18 per cent moisture content to a density of 1.78 Mg/m^3 (111 lb/ft^3) and cured at constant moisture content for up to 14 days at 20°C.

TABLE 1

The direct tensile strength of the soil-cement briquettes at different ages

Curing Period	Strength (x)		Average strength ($\bar{x}$)		Coefficient of variation percent $\frac{s^*}{\bar{x}}$
	kN/m^2	lb/in^2	kN/m^2	lb/in^2	
15 min	69.6	10.1	67.6	9.8	7.8
"	60.0	8.7			
"	67.6	9.8			
"	74.5	10.8			
"	66.2	9.6			
30 min	71.0	10.3	69.1	10.0	4.1
"	67.6	9.8			
"	71.0	10.3			
"	64.8	9.4			
"	71.0	10.3			
1½ hrs	101.4	14.7	106.7	15.5	8.6
"	106.2	15.4			
"	100.0	14.5			
"	122.7	17.8			
"	103.4	15.0			
4 hrs	203.4	29.5	218.6	31.7	8.8
"	217.2	31.5			
"	237.9	34.5			
"	196.5	28.5			
"	237.9	34.5			
1 day	284	41.2	311	45.1	5.3
"	329	47.7			
"	313	45.4			
"	313	45.4			
"	316	45.9			
2 days	332	48.2	332	48.1	2.7
"	316	45.9			
"	332	48.2			
"	339	49.1			
"	339	49.1			
7 days	429	62.2	372	53.9	9.3
"	355	51.5			
"	339	49.2			
"	359	52.0			
"	378	54.8			
14 days	429	62.3	398	57.7	7.4
"	390	56.5			
"	381	55.2			
"	362	52.5			
"	427	62.0			

* S = standard deviation

4.1.2 Shrinkage v Time of curing. The relationship between the shrinkage and the period for which four soil-cement specimens were cured is shown graphically in Fig.4.

4.1.3 Unconfined Compressive Strength after 14 days of curing. Five compression specimens tested after 14 days of curing had strengths ranging from 2860 kN/m^2 (415 lb/in^2) to 3070 kN/m^2 (445 lb/in^2) with an average of 2970 kN/m^2 (431 lb/in^2). The Ministry of Transport's Specification[13] for road and bridge works requires that soil-cement should have an unconfined compressive strength of 2760 kN/m^2 (400 lb/in^2) after 7 days of curing. Harmondsworth brickearth, with the addition of 8 per cent of cement, approximately complies with this specification.

4.2 PILOT-SCALE EXPERIMENTS

4.2.1 General comments. During the construction of the pilot-scale lengths of base the maximum time that was allowed to elapse between the initial mixing of the materials and their final compaction into the base was one hour. The capacity of the mixer was small and the full 28 m (92 ft) length could not be mixed, laid and compacted within the time limitation. Hence the roller operated on small runs of up to 6 m (20 ft) in length. The surface profile of the compacted length of base was poor and depressions were often produced at the position where the roller was stopped and reversed. A grader was not used to trim the surface as these construction loadings would have stressed the base after the one-hour time limitation. The average daily temperatures during the four months of the testing programme were 8.3°C, 10.6°C, 15.5°C and 15.7°C.

4.2.2 Length 1. Prior to and after the application of the wheel loads at 11 days, no cracks were visible in the bituminous surfacing of any portion of this length.

Beams were extracted after four months from the positions marked in Fig.2 and the average depth of the base was found to be 13.3 cm (5¼ in). The moisture contents of the beams were determined and the average was 18.1 per cent.

When the side of a beam had been exposed (see Plate 6) it was examined for any signs of cracking and then carefully removed.

Details of the extraction of the beams in Length 1 are given in Table 2. The beams that were successfully removed were tested in flexure and their failure loads are included in Table 2.

TABLE 2

Beam Tests on Specimens removed from Length 1

Beam	Successfully removed	Flexural load	Remarks
1	NO	–	No cracks were visible in the sides of the beam but it separated across the centre when it was first moved.
2	NO	–	Two cracks visible; extracted in 3 pieces.
3	YES	1068 N (240 lb)	–
4	NO	–	1 crack visible; extracted in two pieces.
5	NO	–	1 crack visible; extracted in two pieces.
6	YES	765 N (172 lb)	–
7	YES	1272 N (286 lb)	–
8	NO	–	1 crack visible; extracted in two pieces.
9	YES	658 N (148 lb)	–
10	NO	–	1 crack visible; extracted in three pieces.

4.2.3 Length 2. Three major cracks appeared in the bituminous surfacing of the 16 m (52 ft) section of this length of base 15 days after it was laid. The positions of these cracks are shown in Fig.5. Each of the cracks formed at a transverse surface depression that was produced by the roller. No other cracks were visible in the surface.

After four months, during which no loading was allowed on the base,beams were cut from the positions shown in Fig.2. The average depth of this length of base was 13 cm (5 1/16th in) and its moisture content after four months was 18.6 percent.

A commentary on the removal of the beams from length 2, together with their test results, is included in Table 3.

TABLE 3

Beam tests on specimens removed from Length 2

Beam	Successfully removed	Flexural load	Remarks
11	NO	–	No cracks were visible but the beam broke as it was lifted from the excavation
12	YES	600 N (135 lb)	1.8m (6 lineal feet) of beam was removed intact and then separated into 0.6m (2 ft) lengths for flexural testing
12A	YES	560 N (126 lb)	
13	YES	916 N (206 lb)	
14	YES	743 N (167 lb)	
15	YES	1744 N (392 lb)	
16	YES	1383 N (311 lb)	
17	YES	387 N (87 lb)	Approximately 0.6m (2 ft) of beam between 17 and 18 was also successfully extracted
18	YES	418 N (94 lb)	
19	Removal not attempted	–	The area was badly damaged by the operation of the pavement saw.

4.2.4 Length 3. No cracks were visible in the surface of this length of base before wheel loads were applied 7 days after it had been laid. Subsequently, surface cracks were visible in most sections of this length. Between the major cracks 14.3 and 20.1m (47 and 66 feet) from the northern end (see Fig.5), there was an area of pronounced surface cracking at spacings of 8 to 40 cm (3 to 15 in). At the southern end, cracks were spaced at approximately 30 cm (12 in); Plate 7 shows part of this section. Over the remainder of this length surface cracks were visible at approximately 45 cm (18 in) spacing.

In an attempt to remove two beams successfully, Beams 23 and 24 were cut from two limited areas approximately 1m (3 ft) long which showed no surface cracking. The remainder were cut on a regular pattern without regard to the existence of surface cracks.

Notes on the cracking in the beams that were removed from this length of base are included in Table 4.

TABLE 4

Beam tests on specimens removed from Length 3

Beam	Successfully removed	Flexural load	Remarks
20	NO	–	3 cracks were visible; beam was removed in 4 pieces
21	NO	–	Extensively cracked; Beam fractured into many pieces at it was removed
22	NO	–	As above
23	YES	1401 N (315 lb)	The positions from which these beams were taken were specially selected
24	YES	992 N (223 lb)	
25	NO	–	2 cracks were visible; beam was removed in 4 pieces
26	NO	–	Beam fractured into many pieces. Many cracks were visible
27	NO	–	4 cracks were visible. Plate 6 is a photograph of this beam

4.2.5 Subgrade Restraint. The subgrade restraint was measured in Length 1, in which the pavement was laid directly on the rolled subgrade, and Length 2 which had a layer of polythene included between the rolled subgrade and the base.

In Length 1 the restraint was 6.2 kN/m^2 (130 lb/ft^2) whereas the plastic sheeting reduced the restraint in Length 2 to 3.4 kN/m^2 (72 lb/ft^2).

5. DISCUSSION OF RESULTS

From the graphs in Figs. 3 and 4 it is seen that the rate of gain of tensile strength and the shrinkage rate are both very high during the first few hours of curing.

There is a practical difficulty in measuring the shrinkage which occurs during the first 15 minutes. After 15 minutes, the shrinkage rate decreases with increasing time of curing. Between 15 and 20 minutes the average shrinkage strain is 1.11×10^{-4} while from 20 to 25 minutes and 25 to 30 minutes the average strain is 0.86×10^{-4} and 0.54×10^{-4} respectively. If it is assumed that the shrinkage strain during the first 20 minutes is linear, a strain of approximately 3.3×10^{-4} would have occurred before any strain measurements could be taken.

The shrinkage strain in a continuous soil-cement slab that is uncracked after 3½ hours of curing is estimated to be 9.8×10^{-4}. Curves relating tensile stress and strain [10] for specimens of Harmondsworth brickearth stabilised with cement and cured for 14 days indicate that a tensile stress of 128 kN/m^2 (18.5 lb/in^2) would be developed at this strain provided that there is no relaxation of stress due to creep. It would be expected that the value of the tensile secant modulus, E_t, at 3½ hours would be less than E_t at 14 days. Hence the estimate of ~~207~~ 128 kN/m^2 (18.5 lb/in^2) is probably greater than the actual stress.

At 3½ hours, the measured tensile strength of the material was approximately 207 kN/m^2 (30 lb/in^2). It is unlikely therefore that a continuous slab that was uncracked after 3½ hours of curing would subsequently crack from shrinkage stresses alone. This conclusion can also be drawn when curing periods of more than 3½ hours are considered.

After 30 minutes of curing, a continuous slab would have an estimated shrinkage strain of 6.5×10^{-4}. The stress that would be developed (from the previous stress-strain curves [10]) is approximately 83 kN/m^2 (12.0 lb/in^2). Since the measured tensile strength at 30 minutes was 69 kN/m^2 (10 lb/in^2) the cracking due to shrinkage alone in a base made from Harmondsworth brickearth stabilised with cement probably occurs within the first 30 minutes.

Such early cracking was not observed in the pilot-scale lengths; if it did occur it may have been concealed by the bituminous membrane. In length 2, widely spaced reflected cracks in the surface were noted after 15 days. When they appeared their widths ranged from 4.6 mm to 6.4 mm (0.18 to 0.25 in). These cracks had undoubtedly formed in the base at an earlier age and the sudden appearance of cracks of this width was probably due to the breakdown of the thick bituminous membrane over the cracks. No cracking could be seen in the surface of length 1 during four months of observations. When beams were extracted from this length a number of fine cracks were observed in the base material but none of these cracks could be detected in the curing membrane. Length 3 showed extensive surface cracking after wheel loads had been applied.

When a continuous base slab first cracks its crack spacing is controlled by the subgrade restraint. During the first 30 minutes of curing the tensile strength of the soil-cement was 69 kN/m^2 (10 lb/in^2). For a 13 cm (5 in) thick base which has a subgrade restraint of 3.4 kN/m^2 (72 lb/ft^2) (the measured value for Length 2), an uncracked length of 5.1m (16 ft 8 in) should be stable. The spacing of the cracks that formed in Length 2 ranged from 3.6 m (9 ft 6 in) to 5.0 m (16 ft 3 in).

The three pilot-scale lengths of base were cured under conditions that minimised the possibility that vertical differential shrinkage would occur in the pavement. Length No.2 was subjected only to shrinkage stresses. The thick bitumen seal and the polythene sheeting restricted the loss of water from the pavement and the shrinkage stresses could be expected to be uniform from the top to the bottom. Under these ideal curing conditions, no cracks were detected in the 3m (10 ft) slabs at the end of Length 2. In the uncut section 16 m (52 ft) long, three major cracks formed at sections that had been weakened by the rolling and it was concluded that these points of weakness partly controlled the crack spacing. The cracks divided the length into slabs 3.6 m (11 ft 9 in), 5.0 m (16 ft 3 in), 4.4 m (14 ft 6 in) and 2.9 m (9 ft 6 in) long, as is shown in Fig 5. While the possibility that other cracks existed in Length 2 cannot be excluded, the recovery of intact beams shows that these should be rare. Eight out of 9 beams were successfully removed and, in two instances, 1.8 m (6 ft) lengths of pavement were proved to be uncracked. Only Beam 11 was damaged on removal and, as no cracks were visible in the sides of the beam, this damage may have been caused by the handling stresses.

No attempt has been made to estimate the flexural stresses in the beams at failure. The flexural tests were performed simply to indicate the degree of cracking that had occurred in the base slab. Previous work [10] has shown that the calculation of stresses is complicated for a homogeneous beam with an irregular cross-section. The beams extracted from the base had a density gradient from top to bottom and stress estimations would have little value.

It could be expected that the crack spacing in Length 2 would be reduced proportionately by any increase in the subgrade restraint. Subgrade restraints ranging from 5.2 kN/m^2 (109 lb/ft^2) to 9.6 kN/m^2 (200 lb/ft^2) have been measured for soil-cement bases that were constructed by the "mix-in-place" method[8]. No values for premixed soil-cement bases could be found.

Both Lengths 1 and 3 were much more extensively cracked than Length 2. A comparison of Tables 2 and 4 shows that Length 3, which was loaded 7 days after construction, had cracks at a closer spacing than Length 1, which was loaded after 11 days. The failure loads of beams that were successfully removed could not be correlated with the difference in crack spacing.

It is concluded that soil-cement bases with properties similar to Harmondsworth brickearth stabilized with 8 per cent of cement and which have a minimal loss of moisture during curing will have a crack spacing due to shrinkage alone of the order of 3m (10 ft) or more. More closely spaced cracks that are normally attributed to shrinkage may have been initiated by stress caused by traffic or by poor curing conditions.

If a soil-cement base can be loaded with carefully controlled wheel loads after a short curing period it may be possible to use this method to control the crack spacing. There is some evidence that this method is feasible. In Japan [11], when roads with soil-cement bases were opened to traffic immediately after construction, there were no detrimental effects on their performance. A report from Sweden [12] describes the use of vibrating rollers to apply loads to a stabilised soil base during the early curing period to minimise the size and spacing of cracks.

At the present time the cement content in stabilized-soil road bases is often limited to ensure that the base is sufficiently weak to crack at close spacings but a possible disadvantage of this approach could be that the resulting "blocks" are also weakened and the pavement is less durable.

6. CONCLUSIONS

1. When Harmondsworth brickearth is stabilized with 8 per cent of cement, the shrinkage and rate of gain of tensile strength are high during the first few hours. Approximately 50 per cent of the 14 day tensile strength was attained after only 3½ hours of curing. During the same period approximately 75 per cent of the 14-day shrinkage had occurred. From an examination of the shrinkage and tensile characteristics it was concluded that cracks due to shrinkage alone probably develop in soil-cement bases of this type within the first half-hour after final compaction has been completed.

2. It is concluded that for soil-cement bases of the type investigated that are compacted within 1 hour of mixing and are properly cured:

(a) If no external loads are applied after final compaction the spacing of cracks caused by shrinkage alone is governed by the subgrade restraint that is mobilised and by the tensile stress-strain characteristics of the material. (In the pilot-scale length of base that was examined, a shrinkage crack spacing of up to 5.0 m (16 ft 3 in) was measured and this is much greater than the crack spacing that is normally found in soil-cement roads).

(b) The crack spacing in such a base depends primarily on the length of time that elapses between the final compaction and the passage of traffic over it. As this length of time increases there is a corresponding increase in the strength of the material and an increase in the crack spacing.

3. It may be feasible to control the spacing of cracks, and hence the size of "blocks" in soil-cement bases, by the application of external loads during the initial curing period. The results of investigations in Sweden and Japan support this conclusion.

Further studies are therefore to be made aiming at defining and producing an acceptable pattern of base-cracking in stabilised soils as used in tropical countries, i.e. with running surfaces consisting of single or double surface dressings.

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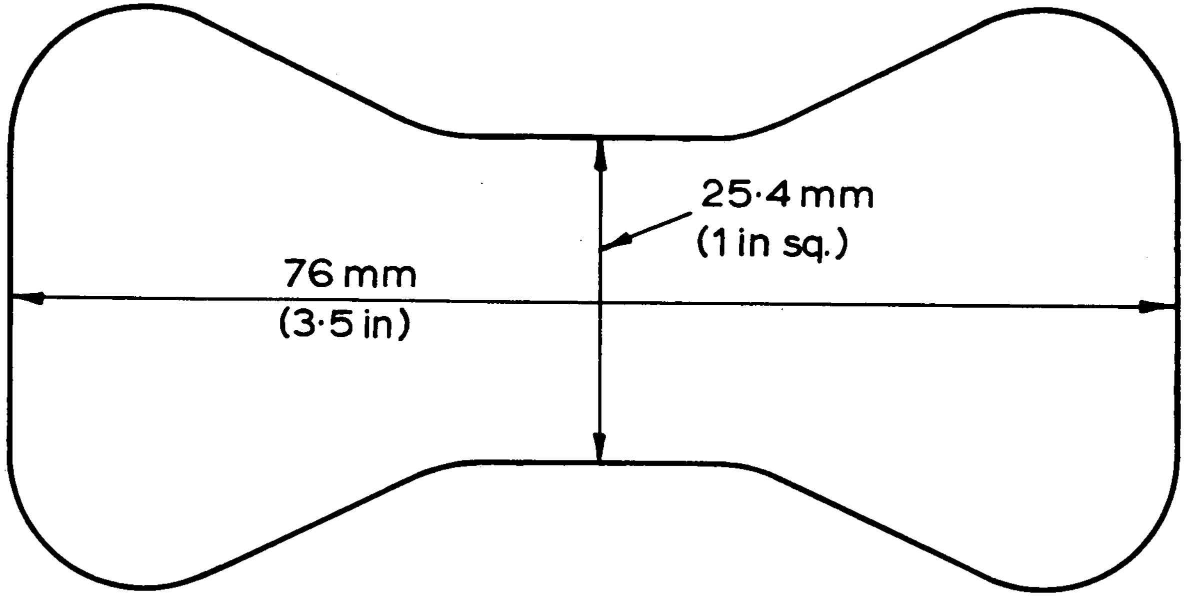


Fig.1. TENSILE SPECIMEN

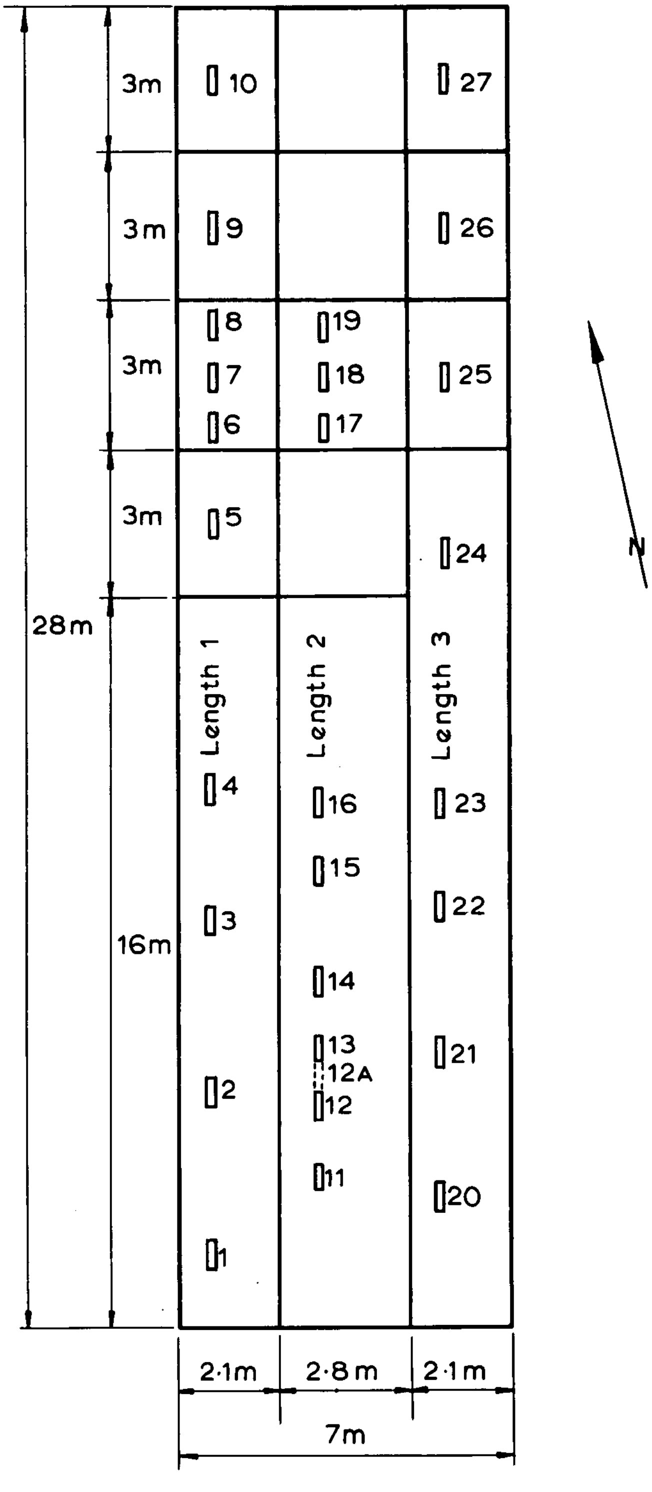


Fig. 2. LAYOUT OF TRIAL LENGTHS OF STABILIZED BASE AND POSITIONS FROM WHICH BEAMS WERE CUT

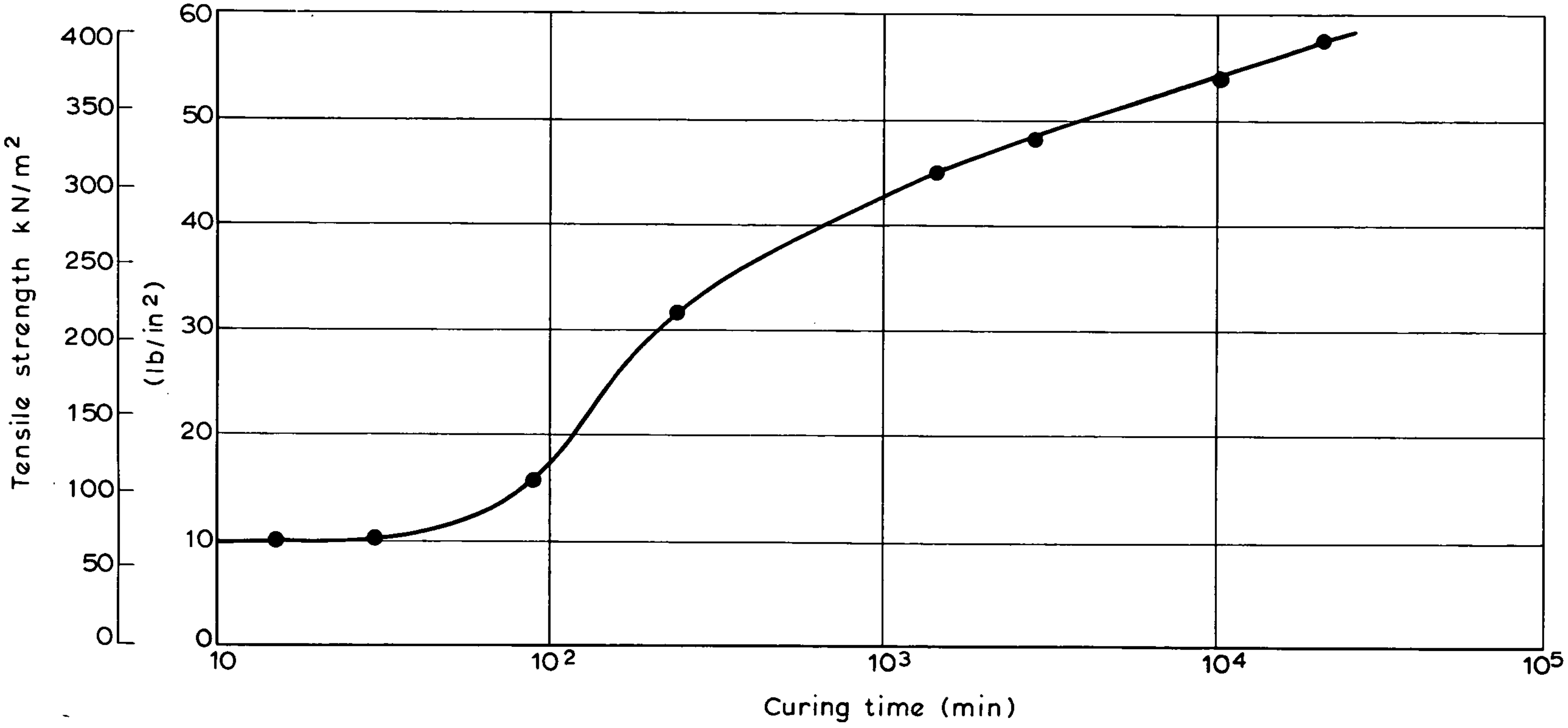


Fig.3. VARIATION IN THE AVERAGE TENSILE STRENGTH WITH THE LENGTH OF CURING TIME

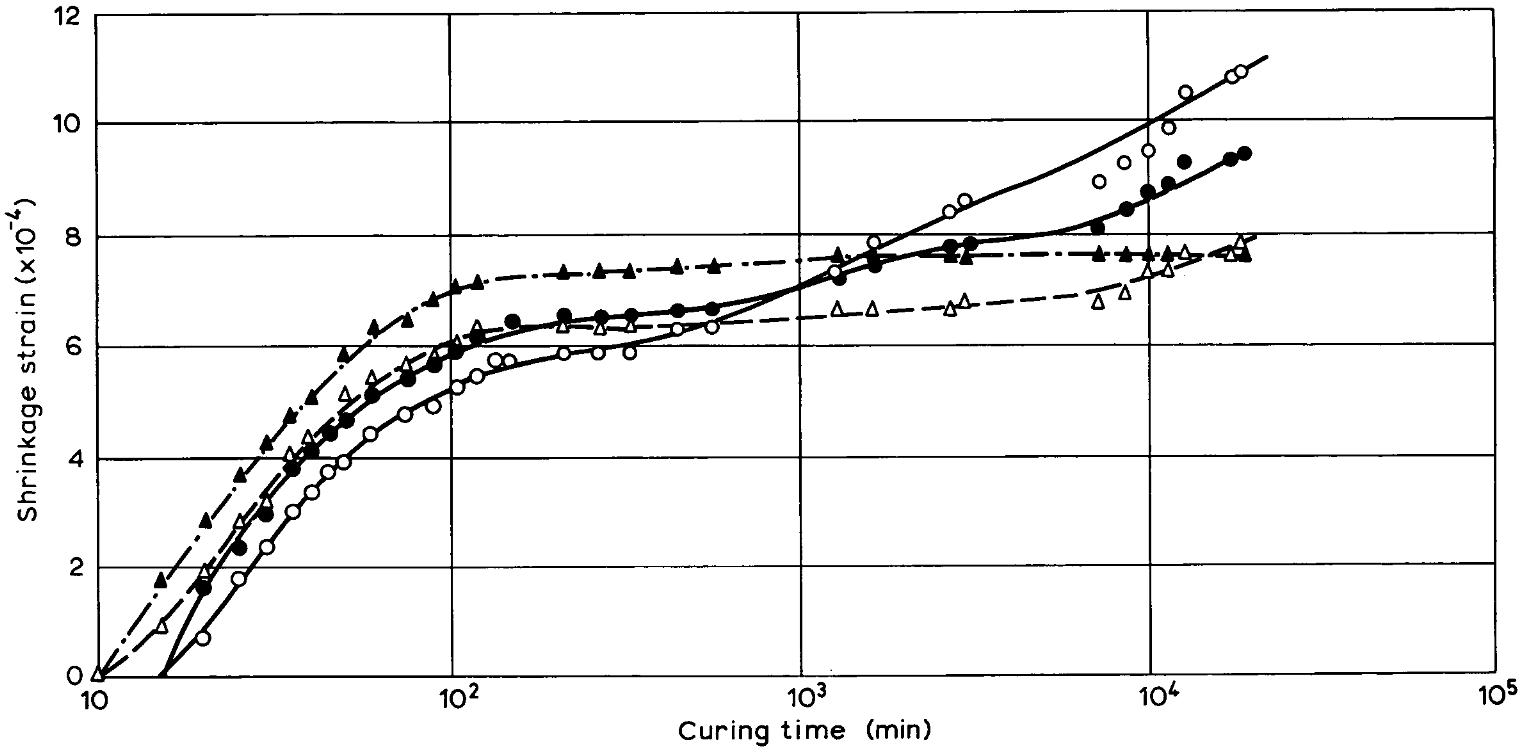


Fig. 4. RELATIONSHIP BETWEEN SHRINKAGE AND TIME OF CURING FOR FOUR SPECIMENS OF CEMENT STABILISED HARMONDSWORTH BRICKEARTH

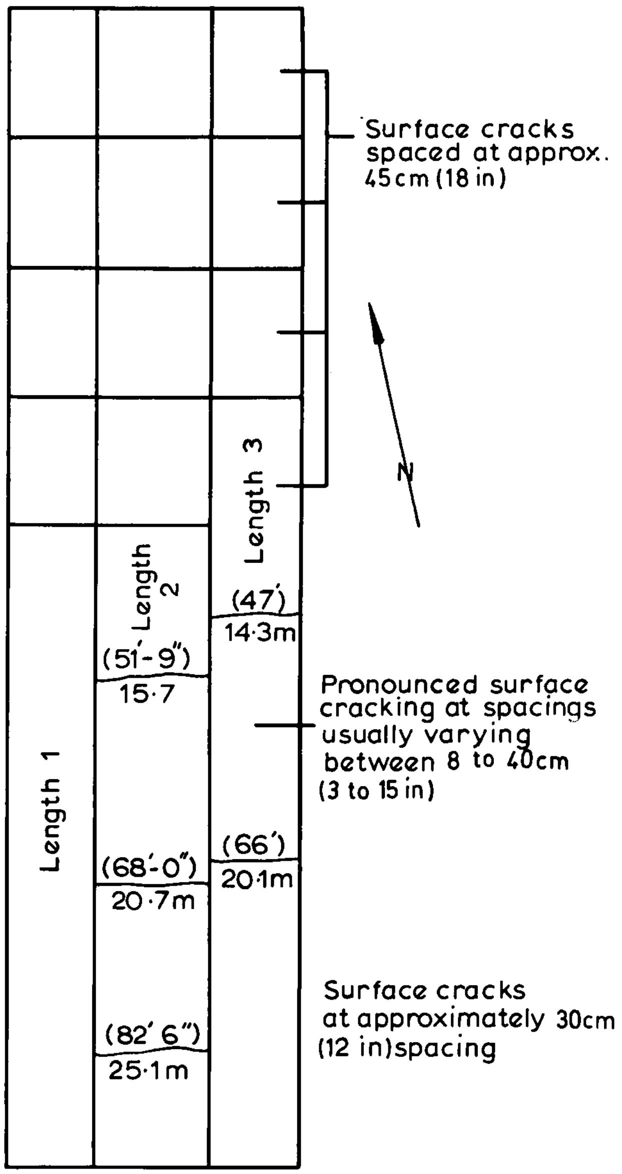


Fig. 5. CRACKING VISIBLE IN SURFACE OF LENGTHS 2 & 3 DISTANCES ARE MEASURED FROM NORTHERN END

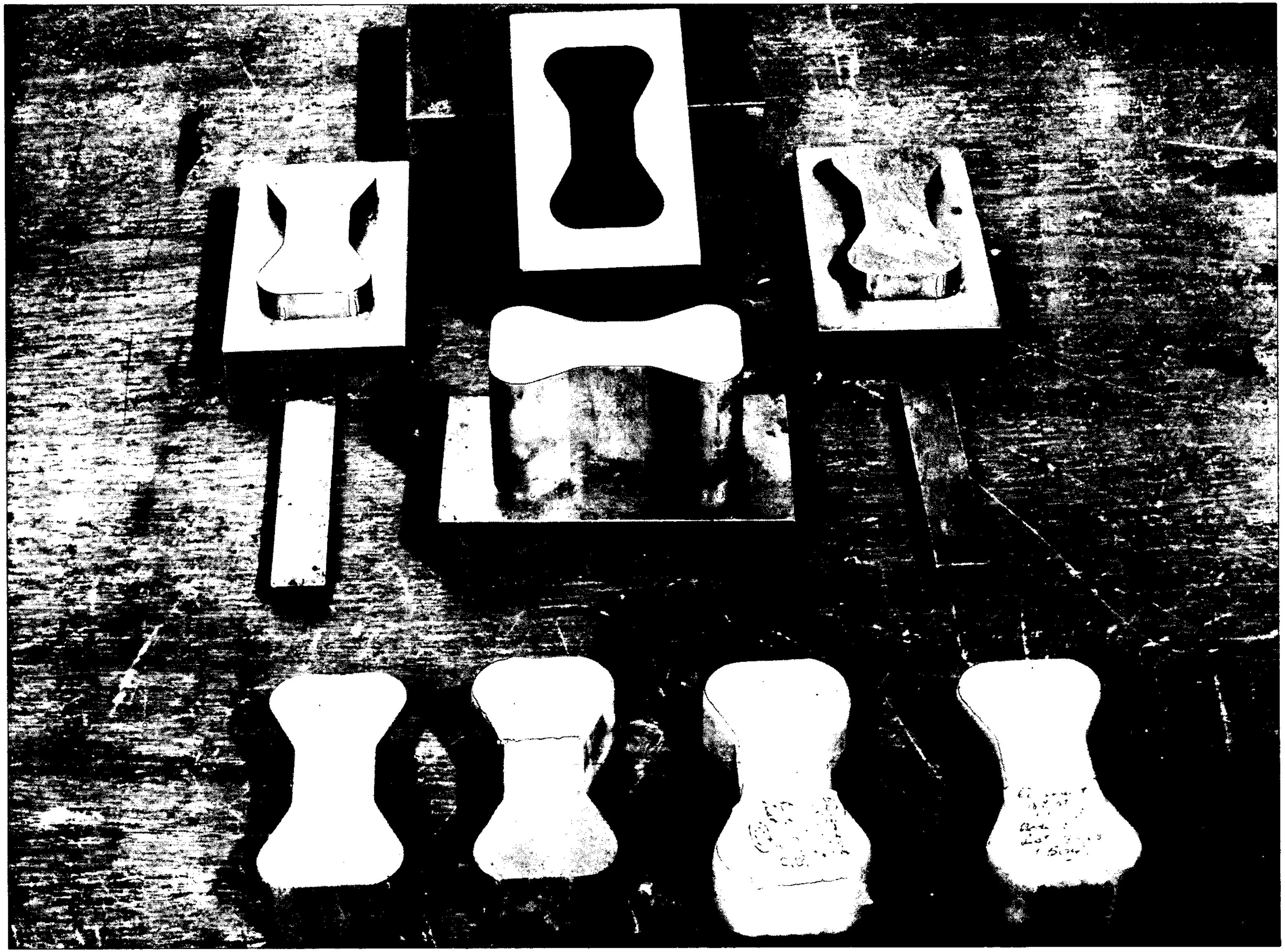
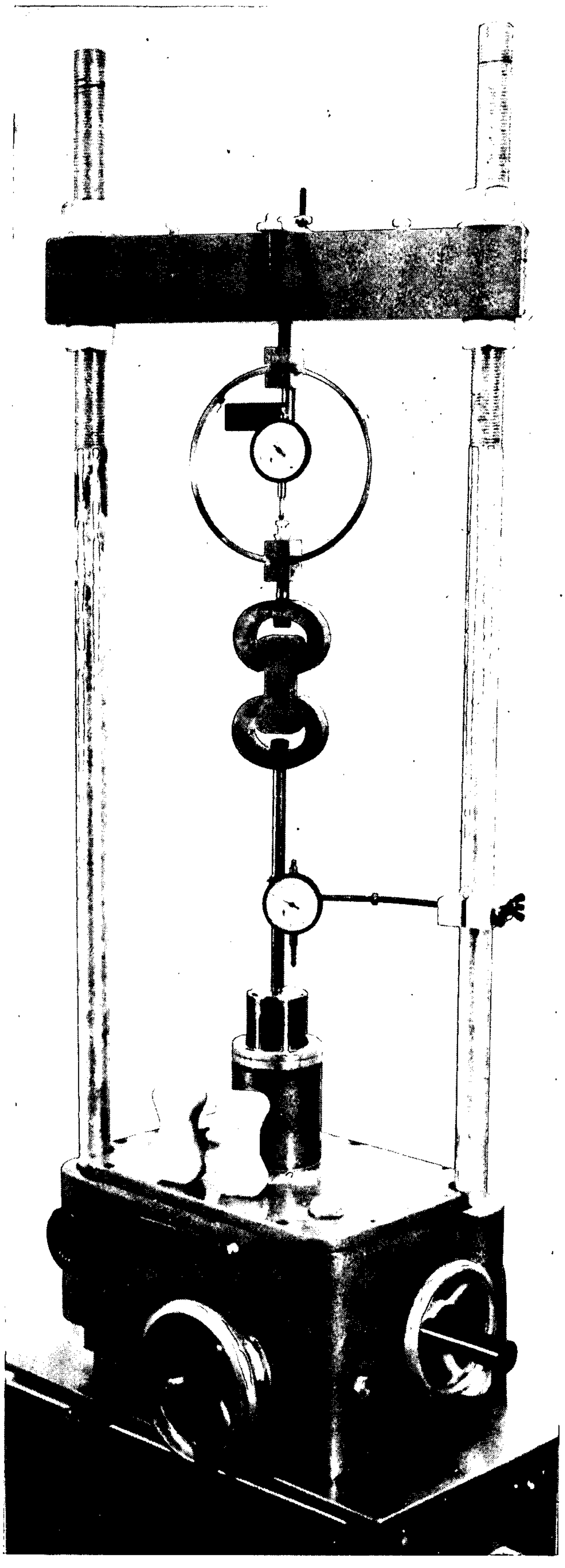
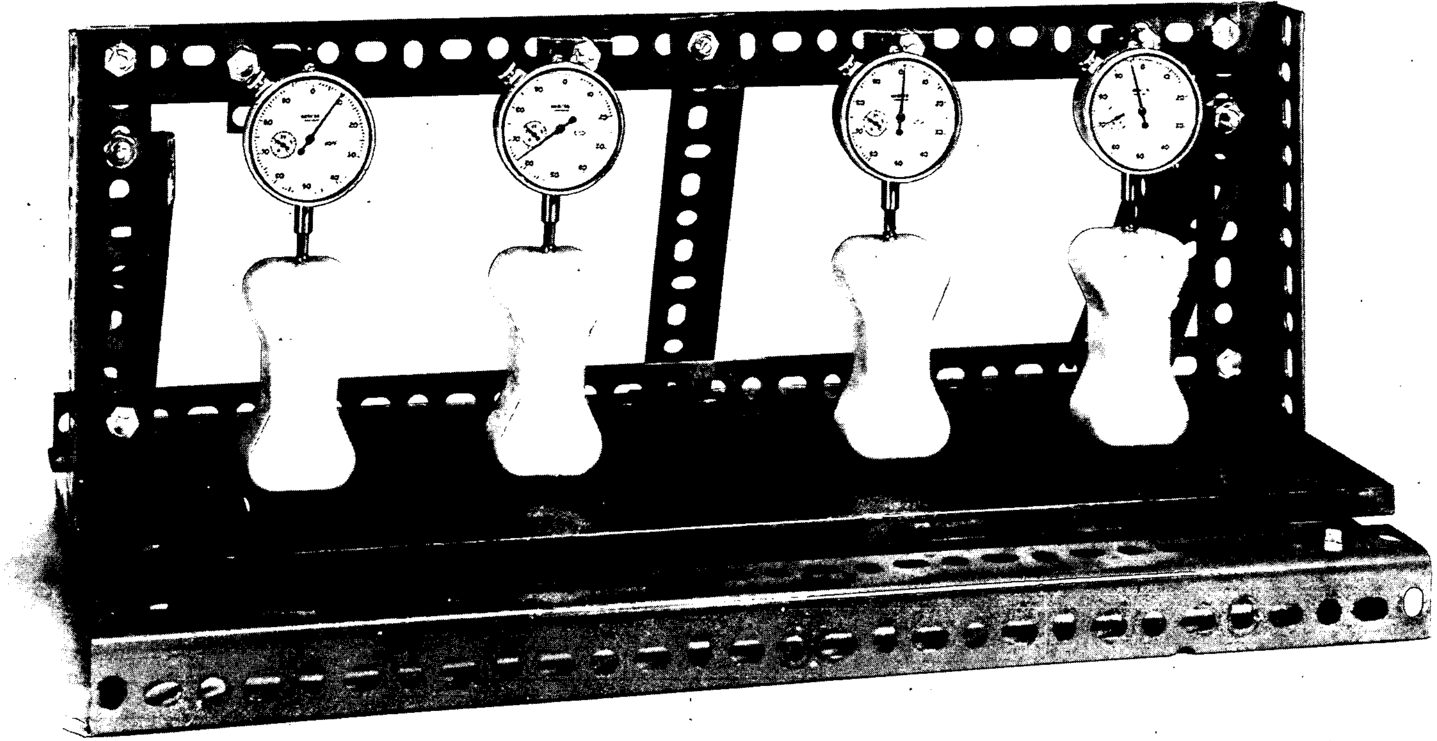


PLATE 1 Tensile specimens Neg No R 2437/68



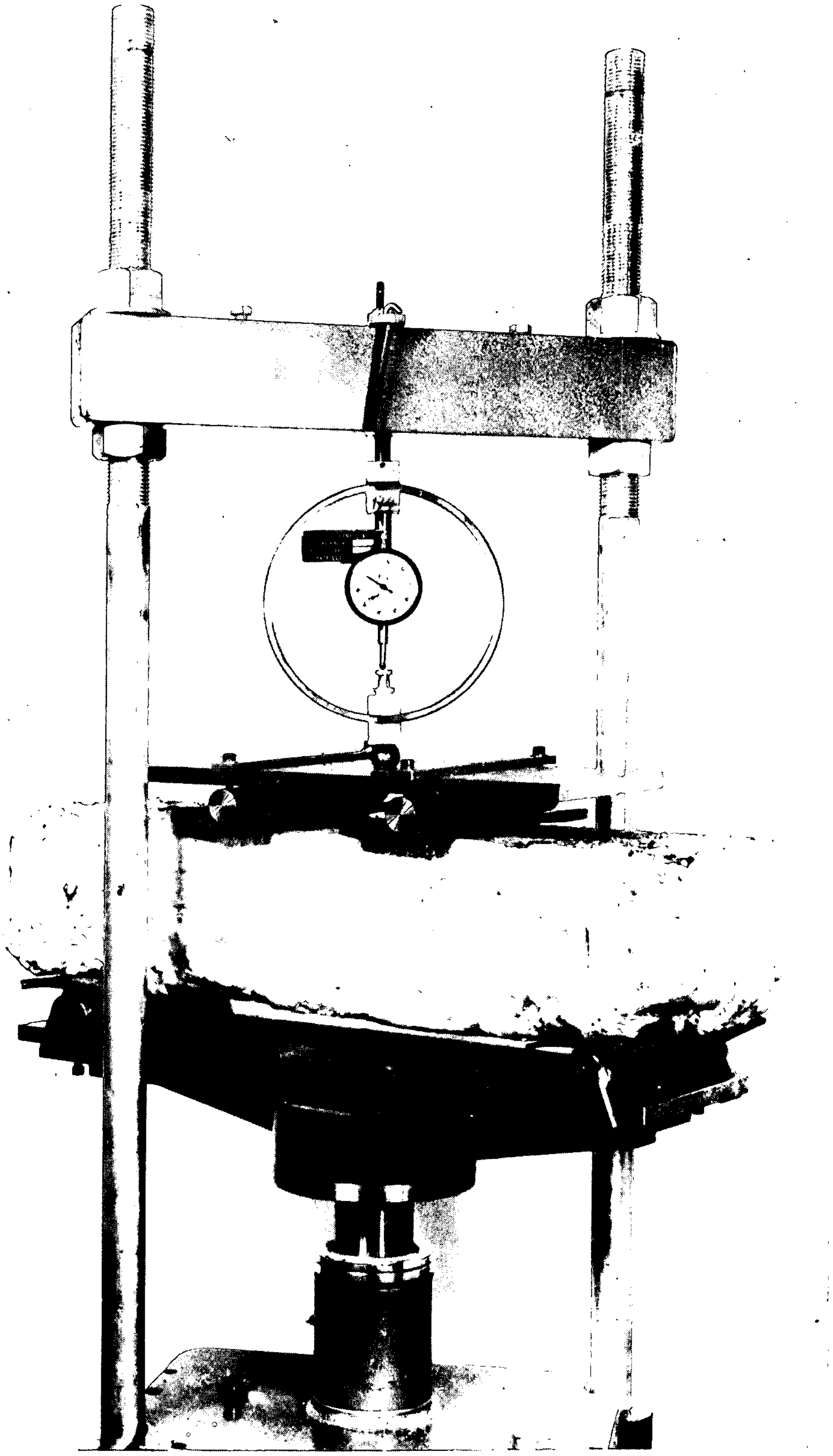
Neg No B 2440/68

PLATE 2 Tensile specimen in testing frame



Neg No H 1522/70

PLATE 3 Measuring rig for shrinkage tests



Neg No H 411/68

PLATE 4 Testing a beam

Neg No B 1599/69

PLATE 5 Subgrade restraint test

Neg No B 3090/68

PLATE 6 Edge of beam showing cracking

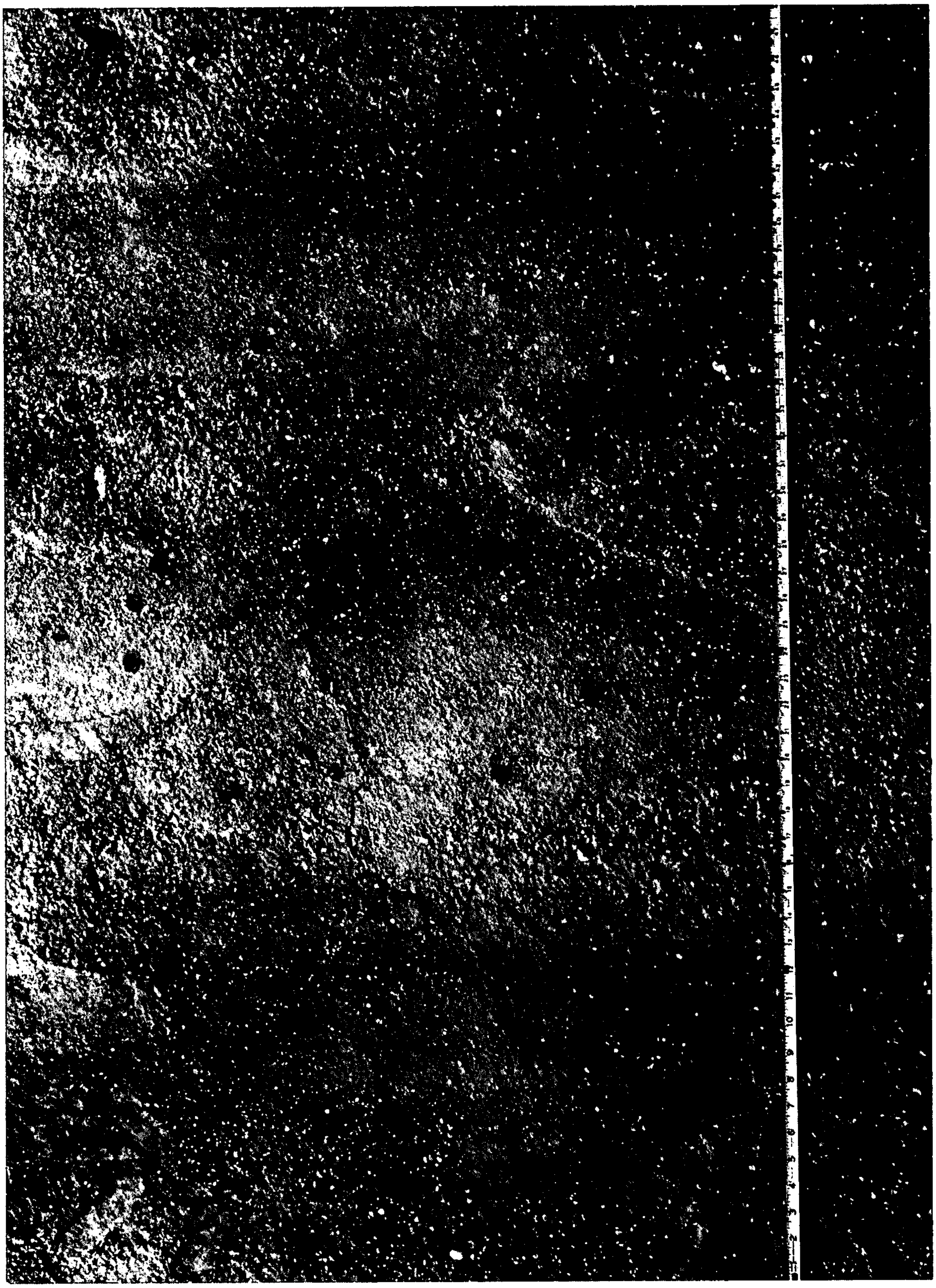


PLATE 7 Cracking in Length 3

Neg No B 3089/68

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ABSTRACT

An investigation of cracking in soil-cement bases for roads: H. E. BOFINGER and G. A. SULLIVAN: Department of the Environment, RRL Report LR 379: Crowthorne, 1971 (Road Research Laboratory). This report describes laboratory and pilot scale studies of some factors that influence the crack spacing in soil-cement bases.

Two lengths of pilot scale soil-cement base were cured for 7 and 11 days respectively before wheel loads were applied. A third control-length of soil-cement base was left untrafficked.

From measurements of tensile strength, shrinkage and subgrade restraint, the crack spacing that should occur in the untrafficked length was estimated. A similar crack spacing was observed in the experiment. The cracking in the other two lengths was more extensive and was related to the time that had elapsed before the wheel loads were first applied. The crack spacing in these lengths was similar to the spacing which has been observed in this type of base in the field, and which is usually attributed to shrinkage stresses.

It is concluded that the crack spacing in soil-cement bases is controlled by their strength at the time that traffic is first admitted. A knowledge of the shrinkage, strength, stiffness and subgrade restraint of soil-cement bases should enable crack size and spacing to be controlled during the construction operation.

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