ROAD RESEARCH LABORATORY

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FIELD TRIAL OF THE CONSTRUCTION OF A CEMENT-STABILIZED CHALK SUB-BASE BY THE MIX-IN-PLACE PROCESS

by

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ABSTRACT

This note gives an account of trials made on A.34 at Tidbury Ring, Hampshire to test the feasibility of the mix-in-place stabilization process in the construction of cement-stabilized chalk sub-bases.

The experiment showed that, with the special single-pass type of machine employed, a very low mixing efficiency of about 40 per cent was obtained even after three passes. As a result the strength of the material with 14 per cent of cement was much below the requirements of the current M.O.T. specifications.

It is therefore concluded that the mix-in-place process is not suitable for the construction of cement-stabilized chalk sub-bases for major road works.

1. INTRODUCTION

Following the successful construction of cement-stabilized chalk sub-bases at Cocksford Down A.30, Hants(1) using plant mixed material, consideration was given to the possibility of using the mix-in-place stabilization process as an alternative and possibly more economical method and to observe the long-term performance of this type of construction under traffic.

This note describes the trials which were made during May 1967 at Tidbury Ring on the A.34 Winchester-Newbury road and gives the results of tests made during the construction of the sub-base to measure the mixing efficiency of the plant employed.

2. DETAILS OF EXPERIMENT

The trial length forms part of the southbound carriageway of a dualling improvement on the A.34 (Fig. 1). The site of the trial was a 9-m (30-ft) deep cutting at the highest point on the length of new construction. The 30.5-m (100-ft) trial length of sub-base was founded on an undisturbed soft chalk subgrade. Fig. 2 shows the layout of the experimental sections. A cement content of 14 per cent was used in all the trials and was based on previous experimental work(2) which showed that providing a high degree of mixing was obtained the cement content would give the requisite minimum compressive strength of 3.45 MN/m^2 (500 lb/in^2) at 7 days.

The Ministry of Transport Road Census of 1965 at this site gave the daily number of commercial commercial vehicles as 1000. On the basis of the traffic expected to be using the road after a life of 20 years the road is classified as a Chart 2 road (1500–4500 commercial vehicles/day) as defined in Road Note No. 29.

3. STABILIZATION PLANT EMPLOYED

The stabilization plant used (Plate 1) was a special machine developed for research work into mix-in-place stabilization.[3] It comprised a 1.8-m (6-ft) wide mixing rotor mounted behind a 52KW (70 hp) tractor and included a cement spreader and water spray bar. The mixing rotor (Plate 2) employed in the work was similar to the standard agricultural type of rotor. It had 36 forged steel blades arranged in 12 banks of 3 blades spaced equally around the periphery of the rotor. This type of rotor was used as previous work had indicated that it was likely to be suitable for the pulverization of chalk containing a proportion of flints. A rotor speed of 133 r.p.m. was employed, the rotation being in the forward direction. The machine was set to travel at a forward speed of 1.85-m/min (6-ft/min) and to process to a depth before mixing of about 20-cm (8-in). The speed of rotation and the forward speed of the machine were chosen as being likely to give a high degree of pulverization with a minimum consumption of power.

4. CONSTRUCTION OF THE EXPERIMENTAL LENGTHS

A 30.5-m (100-ft) length of the carriageway was prepared with the insitu chalk at a level of 20-cm (8-in) above the formation level. Three methods of processing the chalk were studied, each trial length occupying a 1.85-m (6-ft) width as shown in Fig.2. The three methods were:

Section 1. The chalk was first ripped by a single tyne attached to the rear of a bulldozer. The cement was then spread and mixed with two passes of the stabilization machine.

Section 2. The cement was spread and mixed with two passes of the stabilization machine with no pre-scarifying of the chalk.

Section 3. Half the required amount of cement was spread and mixed with the chalk with no pre-scarification. This was repeated with the rest of the cement before a third pass was given.

Because of mechanical difficulties with the cement spreader unit at the beginning of the trials the cement on Section 1 had to be spread by hand. Thereafter the cement spreader was used. As difficulties had been expected in trying to pulverise the chalk insitu, pre-scarification of the chalk was carried out in Section 1. As the work progressed however, it became apparent that the machine had no difficulty in processing the chalk and no pre-scarification was used in Section 2 and 3.

The construction work on either side of the experimental length made it impracticable to employ the smooth-wheeled roller of 8000-kg (8-ton) originally scheduled for the work. The stabilized chalk was therefore compacted with a vibrating-smooth-wheeled roller of 1000-kg (1-ton). The plant was

TABLE I

Results of the mixing efficiency tests

	SECTION 1		SECTION 2		SECTION 3	
Method of mixing	Section ripped and pulverized in two passes		Pulverized only in two passes		Pulverized in two passes each with 7% cement plus an additional pass	
Mix condition	Field-mixed specimens	Laboratory remixed specimens	Field – mixed specimens	Laboratory remixed specimens	Field – mixed specimens	Laboratory remixed specimens
Dry density(Mg/m^3) (lb/ft^3)	1.54 96	1.57 98	1.57 98	1.59 99	1.57 98	1.59 99
Moisture content %*	24	24	23	22	23	22
Design cement content %	14		14		14	
Unconfined compressive strength (MN/m^2) (lb/in^2)	1.17 170	3.45 500	1.86 270	4.69 680	1.52 220	3.72 540
Coefficient of variation of strength %	40	3	20	2	17	3
Mixing efficiency %	34		40		41	

* No allowance has been made for the apparent loss of moisture due to the hydration of the cement.

operated with vibration until the surface of the chalk became spongy. The surface of each length was covered at first with waterproof paper to cure the material. At the completion of the trials the whole area was sprayed with a bitumen emulsion.

The construction of the trial lengths was carried out between 9–11th May, 1967. The sub-base was then covered with a 15-cm (6-in) thick dense bitumen base and a 6.5-cm (2½-in) thick asphalt basecourse. The road was opened to traffic on 27th June 1967. A 4-cm (1½-in) thick wearing course will probably be laid during 1968.

5. TESTS MADE DURING AND AFTER CONSTRUCTION

5.1 Mixing efficiency

Eight pairs of samples of mixed material were taken so as to be representative of each section. One of each pair of samples was used directly to manufacture a 15.25-cm (6-in) cube; the other eight samples were mixed together in a laboratory pan mixer for an extra 5 mins and a further eight 15.25-cm (6-in) cubes were made from the remixed material. All the cubes were cured at a constant moisture content at 20°C and their unconfined compressive strength determined after 7 days. The results are given in Table 1. By expressing the average strength of the field mixed material as a percentage of the strength of the laboratory remixed material a measure of the intimacy of mixing achieved can be determined. The figures given in Table 1 show that in each case a very low mixing was obtained.

The coefficient of variation in the strength of the field-mixed specimens gives an indication of the uniformity of spread of the cement. The initial difficulties with the cement spreader previously mentioned which resulted in the cement being spread by hand for the first section is reflected in the much larger coefficient of variation for Section 1 as compared with the other two sections.

5.2 Dry density measurements

After the completion of the construction work six 10-cm (4-in) diameter cores were cut from each section and their dry density measured. The average value for each section is shown in Table 2. The cores were then sliced into 2.5-cm (1-in) thick slices and the dry density of the slices measured by the weight-in-water method. From these an indication of the gradient of dry density through the cores was obtained. The average result for each section is shown in Fig. 3. The length of each core was measured and the average values are included in Table 2.

TABLE 2

Comparison of the dry densities achieved in the test cubes and cores cut from each section

Section	Dry density: cubes		Dry density: cores		Depth of construction	
	Mg/m^3	lb/ft^3	Mg/m^3	lb/ft^3	cm	in
1	1.53	96	1.57	98	17	6.5
2	1.57	98	1.47	92	19	7.5
3	1.57	98	1.52	95	19	7.5

A comparison of the dry densities of the cores with those of the cubescompacted by an electric vibrating hammer indicate that a rather low state of compaction was achieved in Sections 2 and 3. This may be due in part to the greater thickness of processed layer as shown by the lengths of the cores. With the compaction plant used very large gradients of dry density were produced (Fig. 3) and thus an increase in the depth of construction would result in a reduction in the average dry density. These large gradients of dry density indicate that the compaction plant used (vibrating-smooth-wheeled roller of 1000 kg (1–ton), was not suitable for the compaction of stabilized chalk layers exceeding about 10-cm (4-in) in compacted thickness.

6. DISCUSSION OF RESULTS

The reason for the low mixing efficiency measured appears to lie in the type of mixing action that the mix-in-place process imparts to the chalk-cement matrix. After three passes of the machine the the cement appeared to be well distributed although the cement still appeared to a large extent as discrete particles. When the material was further mixed in the laboratory pan mixer the kneading action of the paddles pushing the material against the sides of the pan changed the consistency of the the mix to a more putty-like condition and thus brought the cement into more intimate contact with the chalk. The effect of the different mixing actions can clearly be seen in Plate 3, which shows sections of 10 cm cores cut from stabilized chalk bases constructed by the two processes. In Plate 3(a) although the mix-in-place process has imparted a high degree of pulverization to the chalk the cement still appears as a coating around the particles. In Plate 3(b) the effect of the pan-mixer has been to blend the chalk fines and the cement together as a paste.

The degree of mixing as observed visually and shown in Plate 3(a) appeared to be quite satisfactory and it was at first though that the low strengths measured were due to the inability of the cement to obtain sufficient water from the chalk to hydrate properly. A short laboratory investigation was made to test this theory. Mixtures of chalk and cement were made to the same consistency as that produced by the mix-in place method. In one batch the cement was added dry and in the other the cement was first wetted with sufficient water to obtain full hydration. The overall moisture content of each batch was adjusted so that they were identical. Specimens were then made from each mix and and their unconfined compressive strength measured after 7 days curing. There was no significant difference between the two sets of results indicating that the cement when added dry introduced no hydration problems.

It would appear therefore that whereas with most materials a macro-distribution of the cement is sufficient to produce the necessary strength, with chalk a micro-distribution is required. The field trial showed that with the special machine used it was not possible to mix the material to this degree of intimacy and it therefore appears unlikely that with the mix-in-place process insitu chalk can be satisfactorily stabilized.

Further evidence for the low mixing efficiences likely to be obtained with the insitu stabilization of chalk was provided by an experiment that had previously been made in the Laboratory grounds. In this experiment chalk had been brought in from the site of the Cocksford Down experiment and spread so that it would give a compacted depth of 15-cm (6-in). Cement had been spread over the chalk to give an area with a nominal cement content of 10 per cent and another with a cement content of 14 per cent.

The chalk and cement were mixed with 4 passes of a Seamen pulvimixer and 2 passes of a Howard Uni-mixer. The mixing efficiencies obtained were determined in the same manner as in the Tidbury Ring experiment. The results (Table 3) show that the same low mixing efficiencies had been obtained.

TABLE 3

Results of the mixing efficiency tests made during construction work in the Laboratory grounds

	Section 1		Section 2	
Nominal Cement Content (%)	10		14	
Mix Condition	Field mixed specimens	Lab. remixed specimens	Field mixed specimens	Lab. remixed specimens
Dry density (Mg/m^3) (lb/ft^3)	1.62 101	1.63 102	1.68 105	1.70 106
Moisture Content (%)	22	22	20	20
Unconfined Compressive Strength MN/m^2 (lb/in^2)	1.21 175	3.24 470	3.31 480	7.31 1060
Coefficient of variation of strength (%)	22	3	18	3
Mixing Efficiency (%)	37		46	

This was originally attributed to the unfavourable conditions under which the experiment had been carried out but the further evidence from Tidbury Ring suggests that the mix-in-place method is inherently unsuitable for the stabilization of chalk.

The mixing efficiencies measured for the mix-in-place process compare unfavourably with that measured for a pan-mixer used in a previous laboratory trial[2]. In this experiment the results (Table 4) show that a very high mixing efficiency was achieved even for short mixing times.

TABLE 4

Results of mixing efficiency tests using a 400dm^3 (14 ft^3) pan mixer

Mixing time – mins	1		2		3	
Mix condition	Plant mixed specimens	Lab. remixed specimens	Plant mixed specimens	Lab. remixed specimens	Plant mixed specimens	Lab. remixed specimens
Dry density Mg/m^3 lb/ft^3	1.49 93	1.51 94	1.52 95	1.52 95	1.52 95	1.54 96
Moisture content %	26	26	26	25	25	25
Unconfined compression strength MN/m^2 lb/in^2	3.38 490	3.17 460	3.31 480	3.31 480	3.17 460	3.38 490
Coefficient of Variation %	8	2	15	7	9	5
Mixing efficiency % *	106		100		94	

* Although the mixing efficiencies are shown to be greater than 100% the difference between the mean strengths measured are not statistically significant at the 5% level.

Although the trial sections at Tidbury Ring are below the strength requirements of Clause 818 of the M.O.T. Specification(4) it will nevertheless be interesting to observe their subsequent performance. It may be found that under the existing site and traffic conditions the strengths obtained are sufficiently high to produce an acceptable sub-base material. Laboratory tests have already indicated that with pan-mixed material a chalk stabilized with 14 per cent of cement and tested after curing for 7 days should not be susceptible to frost heave. The mix-in-place process produces a different type of mix but since the primary effect of the cement is to reduce the permeability of the chalk it is unlikely that the chalk mixed in this way would be any more susceptible to frost heave. Furthermore the results of frost heave tests made on specimens cured for a period of 8 weeks(1) suggest that as the hydration of the cement proceeds so the permeability of the chalk is decreased.

Thus under field conditions where construction is usually carried out during the summer with a long curing period before the likely occurrence of frost, the possibility of frost heave would be reduced still further.

7. ACKNOWLEDGEMENTS

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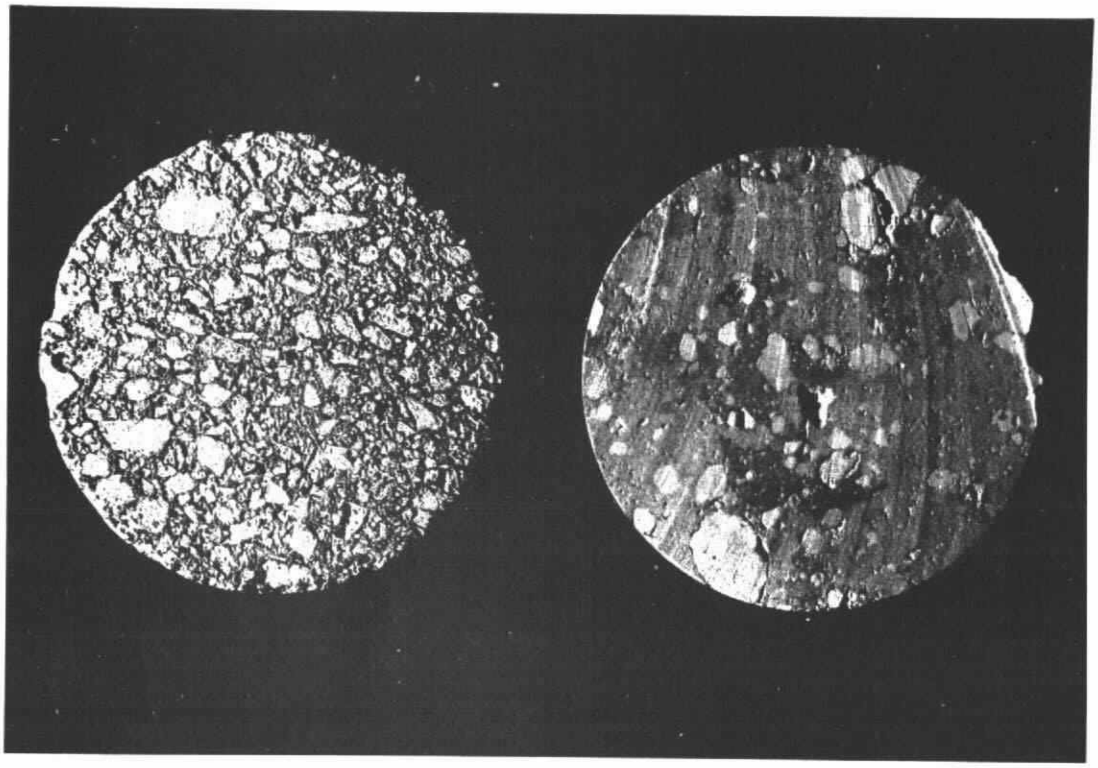
PLATE 1.
Stabilization machine used for mix-in-place stabilization trials.

PLATE 2.
Agricultural type rotor used in stabilization trials.



SCALE

0 2.5 5 cm

3(a) Mix-in-place process

3(b) Pan-mixed material

PLATE 3.
Sections of chalk-cement cores showing the effect of the different mixing action.

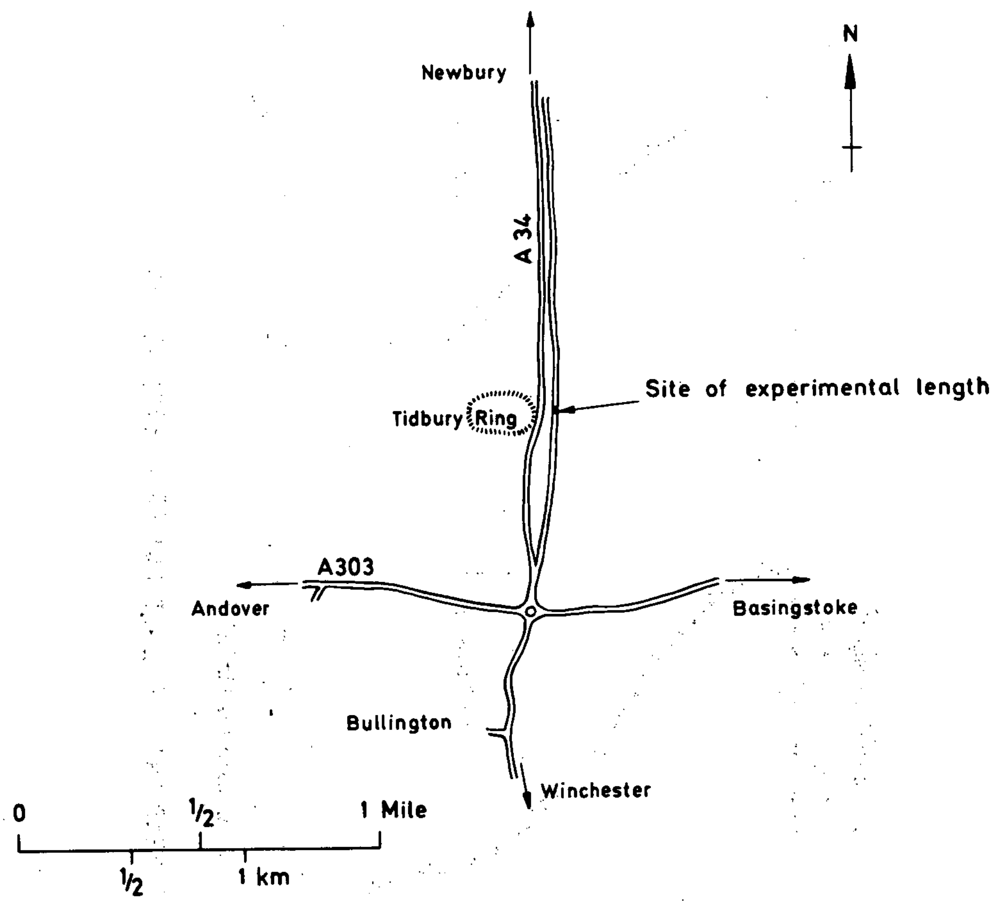


Fig. 1. LOCATION OF THE EXPERIMENTAL LENGTH ON A34 AT TIDBURY RING, HAMPSHIRE

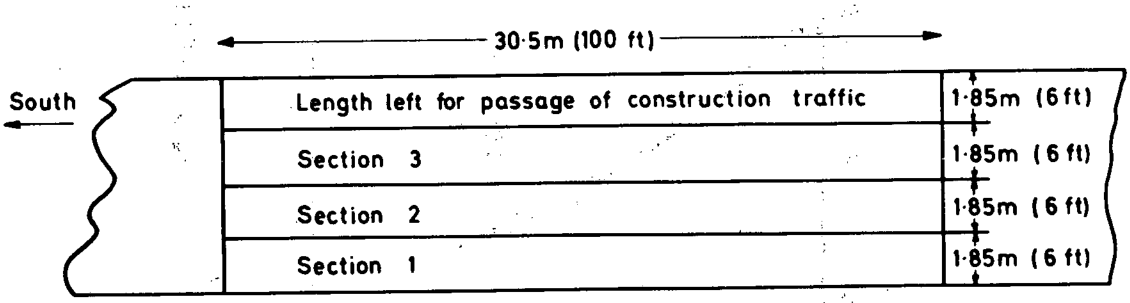


Fig. 2. PLAN OF THE EXPERIMENTAL SECTIONS

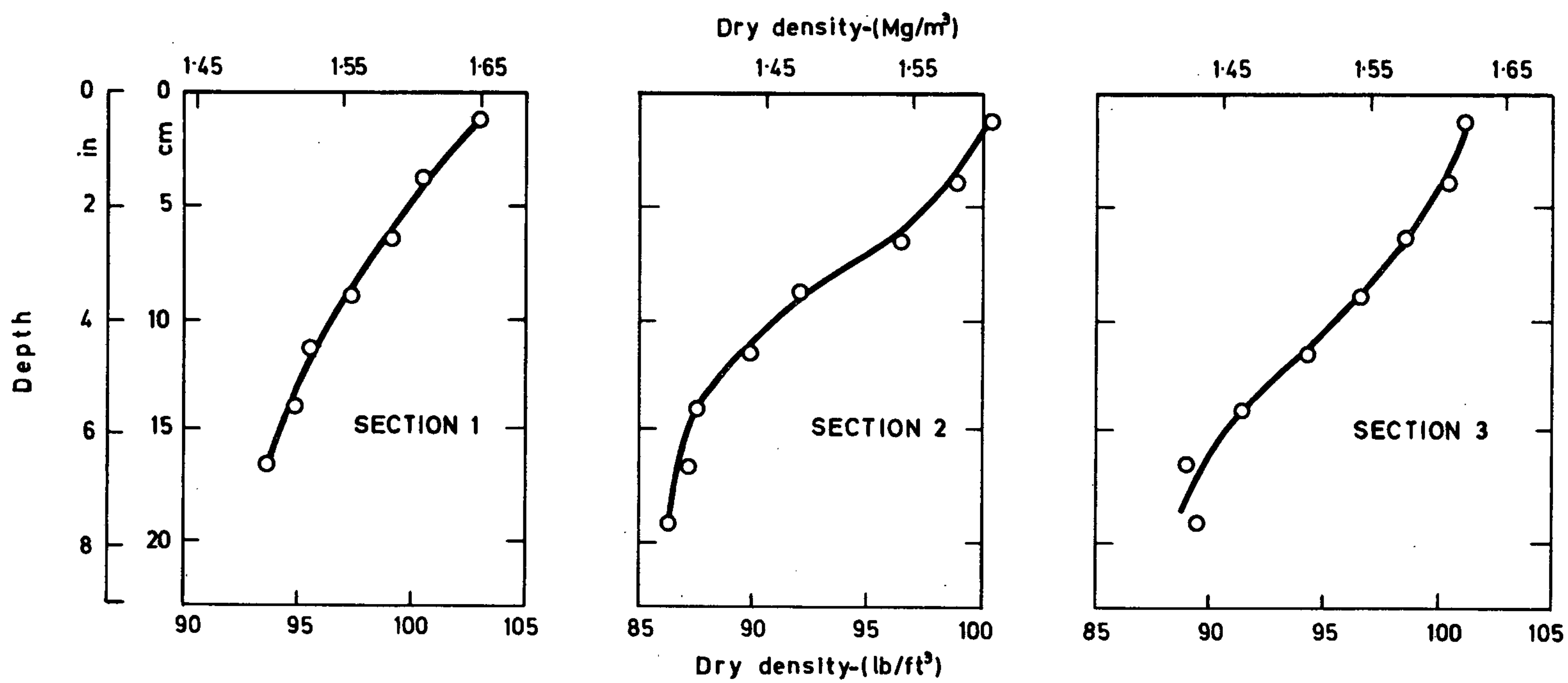


Fig.3. AVERAGE DENSITY GRADIENTS ON CORES CUT FROM EACH SECTION

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