control or localize the cracks by introducing planes of weakness in the slab during construction In carrying out the idea the method shown in Figure 1 was used It was decided to introduce these planes of weakness at 40-foot intervals throughout the 2,000-foot section This was done by omitting the steel in a strip 1 foot wide where the plane was to be built in across the slab and at right angles to center line With this exception the construction proceeded and when the final belting was completed at the spot selected a wooden strip 2 inches deep, battered from ¼ to ½ inch and cut to the crown of the road was pushed into the surface of the finished slab until it was flush with the surface and a trowel finish used to smooth at the strip This strip was left in place until the concrete had taken its initial set It was then removed leaving an incision in the slab 2 inches deep, ¼ inch at bottom and ½ inch on the surface Curing, which was by the ponding method, continued as usual After the curing period these incisions were poured with a tar filler same as construction joints This experimental section was poured March 23 and 24, 1925, and it was noted at the end of the curing period that at each plane of weakness the slab had cracked and the crack ran through to the subgrade

Another inspection was made by the writer on October 22, 1925, which was a cold cloudy day, and at this time all the planes of weakness showed open cracks and in nearly every instance the crack continued 4 to 6 inches out into the shoulder dirt No other cracks appeared in the 2,000 foot experiment section but were numerous both on tangents and curves on the remainder of the project which is 9 miles long

As this road is now going into its first winter free of cracks other than at the planes of weakness, we feel that a little progress has been made in the right direction and it will be carefully inspected again in the spring for further results

REPORT ON THE RIO VISTA, CALIF, SUBGRADE TREATMENT EXPERIMENTS

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In November, 1921, experimental subgrade treatment was begun on the Rio Vista Lateral between Denverton and Rio Vista The treatment consisted of loosening and pulverizing the soil to a depth of 6 and 12 inches, after which various adulterants were mixed with the pulverized soil

Eleven 500-foot sections and one 380-foot section were treated as follows

Section 1 Station 177+50 to 182+50, 1 to 10, cement mixture 12-inch depth

Section 2 Station 182+50 to 187+50, 1 to 20, cement mixture, 12-inch depth

Section 3 Station 194+00 to 199+00, 1 to 10, cement mixture, 6-inch depth

Section 4 Station 212+00 to 217+00, 1 to 20, cement mixture, 6-inch depth

Section 5 Station 217+00 to 222+00, 1 to 20, hydrated lime, 12-inch depth

Section a Station 248+50 to 253+50, 1 to 10, cement mixture, 6-inch depth

Section b Station 253+50 to 258+50, 1 to 20, cement mixture, 6-inch depth

Section c Station 258+50 to 263+50, 1 to 10, cement mixture, 12-inch depth

Section d Station 263+50 to 267+50, 1 to 20, cement mixture, 12-inch depth

Section 6 Station 268+00 to 273+00, 1 to 20, limestone dust, 12-inch depth

Section 7 Station 273+00 to 278+00, no foreign substance

Section 8 Station 278+00 to 283+00, 60 per cent asphaltic oil, 12-inch depth

A detailed description of methods used in preparation of the various sections is to be found in the Biennial Report of the California Highway Commission, 1921–1922, pages 61 to 64

The subsoil on sections a, b, c, and d was treated in November, 1921, and the remainder in the summer of 1922 Pavement was constructed in the summer of 1922

The subsoil under the various sections is adobe and silty clay soil There is no record in the laboratory of any analyses of the soil having been made or of any laboratory experimental work in connection with this test In the description of the work it is stated that "it was necessary to select segregated sections as there was no stretch of road which would permit of continuous section " It is reasonable to assume, therefore, that an effort was made to select sections where subsoil conditions were as nearly identical as it was possible to secure There is, however, a considerable variation in the quality of the subsoil on the various sections chosen

A 4-inch gravel subbase was placed on all heavy soil subgrade on the project except on the experimental sections and it is therefore possible to compare this more or less standard method of subgrade treatment with the various admixture treatments

Figure 1 shows the condition of pavement, Station 240 to 285 on April 2, 1924, and Station 172+50 to 227+00 on September 15, 1924

The relative efficiency of the various methods of treatment based on the present condition of the pavement is as follows

Four-inch gravel subbase on untreated subsoil is found to be very efficient All sections in good condition. No longitudinal cracks and transverse cracks are 40 to 100 feet apart

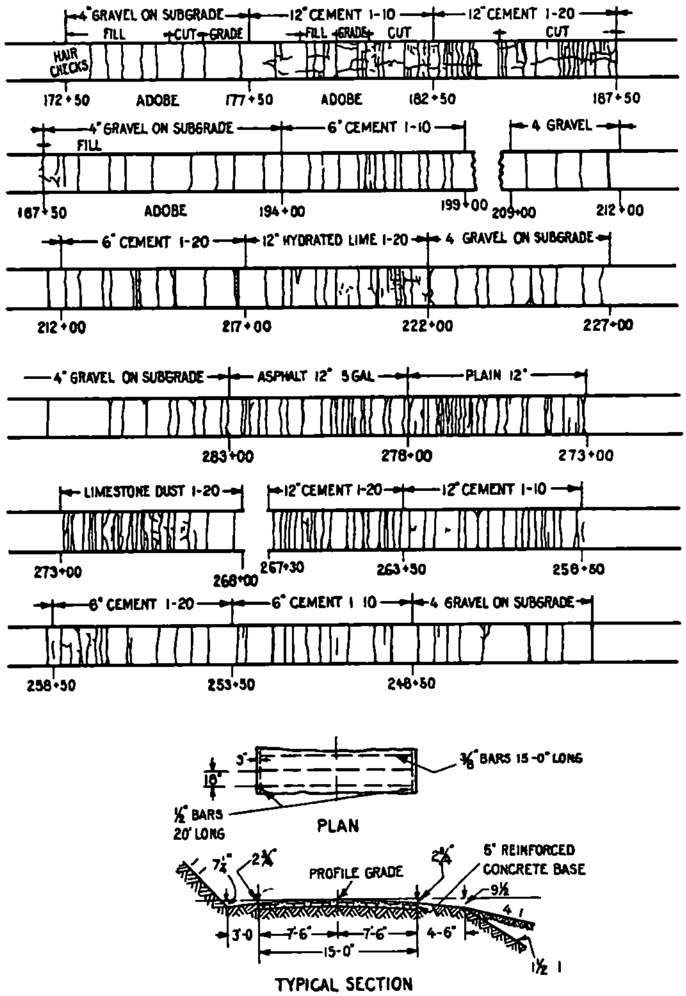

Figure 1—Condition chart of the Denverton-Rio Vista (Calif) experimental road

Six-inch Portland cement (Secs a, b, 3, and 4) Where subsoil is similar there is little or no difference apparent between sections having 1–10 and 1–20 admixtures Failures consist of transverse cracks averaging about 40 feet apart

Twelve-inch asphaltic oil (5 gal per sq yd , Sec 8) This section has transverse cracks averaging about 25 feet apart There is little difference in condition between this section and the 12-inch Portland cement sections

Twelve-inch hydrated lime (Sec 5) This section has transverse cracks 10 to 60 feet apart and several short irregular longitudinal cracks Some surface checking was also noted

Twelve-inch Portland cement sections Sections 1 and c with 1–10 admixture are in slightly better condition than sections 2 and d having 1–20 admixture Transverse cracks on average about 30 feet apart on sections 1 and c and about 25 feet on sections 2 and d Sections 1 and 2 have a number of longitudinal cracks The average condition of these sections is slightly better than the plain untreated section 7 but not enough to justify any expenditure

Plain 12-inch This section was plowed up and soil pulverized as for admixture treatments It was then rerolled without the addition of any adulterant Pavement on this section is in a little worse condition than on 12-inch 1–20 cement section, but the soil is apparently heavier than on any other section of the experimental work A comparison of this section with gravel subbase sections shows clearly the benefit to be obtained from the use of a gravel subbase

Twelve-inch limestone dust (Sec 6) This section is in the worst condition of all The pavement is broken up into narrow strips by the many transverse cracks and in some places short longitudinal cracks are numerous Had it not been for transverse reinforcement this section would probably be a total failure

When this experimental work was started in 1921, A C Rose, who had for 18 months previously been making soil studies in U S B P R,

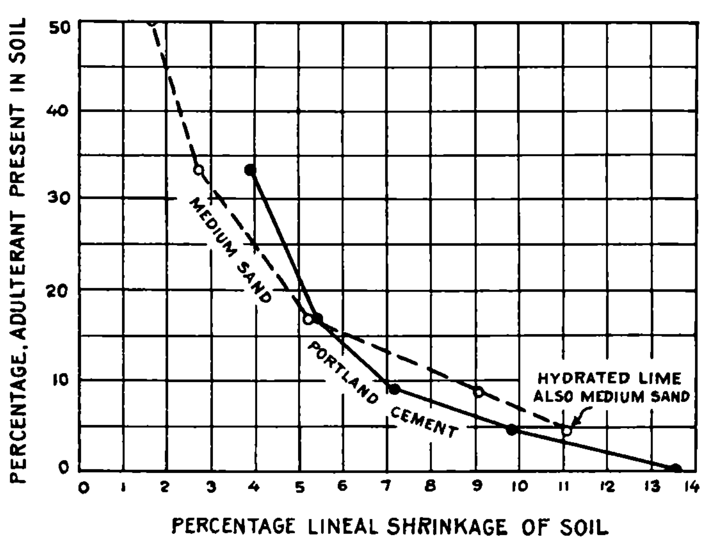

Figure 2—Effect of various admixtures on a sample of Cove Clay subsoil

District One, under my immediate supervision, called to my attention the press reports of the proposed work on Solano-53-B At my suggestion he immediately started a series of tests to determine the probable effect of the proposed adulterants upon what we believed to be the two most important characteristics of a soil, namely, shrinkage and moisture retaining capacity as indicated by its moisture equivalent In addition to the use of lime, cement, and limestone as adulterants, we included specimens adulterated with fine medium and coarse sand believing that these adulterants would be found equally efficient The soil selected for the experiment was Cove clay, which corresponds very closely with the soil on Solano-53-B It contained 44 9 per cent clay and 40 6 per cent silt, against 41 6 per cent clay and 37 2 per cent silt in a typical sample from the Solano project

The results of the tests made by Mr Rose are shown in Table I and Figure 2

TABLE I

Kind of mixture	Moisture equivalent average of 2 runs	Lineal shrinkage average of 2 runs	Volumetric shrinkage (computed)
	Per cent	*Per cent*	*Per cent*
1 Portland cement to 2 soil	31 4	3 90	12 8
1 Portland cement to 5 soil	36 7	5 40	15 2
1 Portland cement to 10 soil	42 4	7 20	20 2
1 Portland cement to 20 soil	43 3	9 84	26 8
1 hydrated lime to 20 soil	47 3	11 10	29 8
1 pulverized limestone to 20 soil	41 4	13 82	36 0
1 medium sand to 1 soil[1]	20 1	1 64	5 0
1 medium sand to 2 soil	25 7	2 73	8 0
1 medium sand to 5 soil	35 4	5 30	15 0
1 medium sand to 10 soil	38 1	9 08	24 9
1 medium sand to 20 soil	39 4	11 10	29 9
1 coarse sand to 2 soil[2]	25 9	5 20	15 0
1 fine sand to 2 soil[3]	27 5	7 32	20 5
All soil	40 5	13 46	35 2

[1] Medium sand Passing 10 mesh and retained on 20 mesh, 33 per cent, passing 20 mesh and retained on 40 mesh, 67 per cent

[2] Coarse sand Passing ¼ inch and retained on 10 mesh, 33 per cent, passing 20 mesh and retained on 40 mesh, 67 per cent

[3] Fine sand Passing 40 mesh and retained on 200 mesh 100 per cent

The results were summed up as follows

1 Portland cement and ordinary sand of medium coarseness were found to be *equally effective* in lowering the moisture equivalent and shrinkage factors of a soil A 1 to 10 or 1 to 20 mixture of either cement

or sand with clay soil was found to reduce the shrinkage factor only a few points and the soil after such treatment was not suitable for use in subgrade for pavement. Such admixtures were therefore reported to be useless. In order to lower shrinkage to a point of approximate safety (5 per cent lineal shrinkage), it was found necessary to use one part of cement to two parts of soil. Such a treatment would, of course, be extremely costly. Sand used in the same proportion (1 to 2) changed the soil from a clay to a clay loam and reduced the shrinkage somewhat more than did the Portland cement.

2. Hydrated lime in a 1:20 proportion was found to be practically useless, the lineal shrinkage being reduced only 2 per cent (13 per cent to 11 per cent).

3. Pulverized limestone was found to be positively detrimental in that it increased both shrinkage and moisture equivalent.

The conclusions from the laboratory experiments made two years ago are entirely verified by the present condition of the several experimental sections.

In the report of his tests, Mr. Rose stated the conclusion which he had reached as a result of this and many other investigations. It is so pertinent to the subject now under consideration that it may well be quoted at this time:

> "Adulterating the subgrade with a lime compound or sand to a depth of 1 foot reduces shrinkage in the portion adulterated, but the subsoil for a considerable depth beneath this treated layer would continue to swell and shrink and displacement of the upper layer and of the pavement would doubtless continue although to a less degree. The efficiency of this method of subgrade treatment is doubted. It is believed that a better treatment of heavy soil subgrade is:
>
> 1. To use a sand cushion to act as an equilibrant to run into irregularities of the subgrade which is deformed by shrinkage or swell of the soil and thus to maintain a uniform surface in contact with the base of the pavement, or
>
> 2. To establish an unchanging moisture content in the immediate subgrade."

The sand cushion treatment was adopted in 1921 on a 4-mile stretch of pavement constructed on this same Cove clay and this spring after two and one-half years the pavement without reinforcement was entirely free from longitudinal cracks and transverse cracks were infrequent. (Expansion joints were used at 30-foot intervals.)

The results of the Rio Vista lateral experiment appear to justify three conclusions:

1 That the soil adulteration with cement or lime compounds is not an efficient or economical method of securing stability in heavy soils
2 That the suitability of soil for subgrade purposes, or of the merits of various methods of soil treatments can be determined by relatively simple laboratory tests and that expensive field tests can in some cases, at least, be avoided by first resorting to a properly conducted laboratory investigation
3 That a sand or gravel layer is an efficient and economical method of minimizing damage to pavement resulting from swelling or shrinkage of the subsoil "

DISCUSSION OF REPORT OF COMMITTEE ON STRUCTURAL DESIGN OF ROADS

Led by CLIFFORD OLDER
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It has been a great privilege to listen to the briefs of the results of such a vast amount of intense research work I will not attempt to enter into a detailed discussion of any of the papers Two thoughts occur to me, however

One comes from a realization of the volume of the data represented by these briefs. I am inclined to believe there are many engineers who, for lack of time to study such data for themselves, would gladly welcome and accept such interpretations as the authors might see fit to make It would seem to me, therefore, that it would be a boon to many busy engineers to have available a concise discussion of the significance of the data accumulated as interpreted by the authors

The other relates to the research possibilities that might be developed along the lines of Mr Hogentogler's investigation of the service value of reinforcing steel in concrete pavements The laboratory investigations of Dr. Hatt and Mr Breed show possible advantages of using reinforcing steel in percentages so small that in accordance with theories heretofore generally accepted, its strengthening value would ordinarily be neglected The condition survey made by Mr Hogentogler of pavements reinforced with comparable percentages of steel shows the unmistakable advantage of such reinforcement Many engineers who might hesitate to accept laboratory results, except those of the most positive character, would not hesitate when such results are confirmed by an extensive survey of field behavior

It appears to me that condition surveys along other lines might add greatly to our knowledge of pavement design For example, we have listened to an excellent paper on subgrade investigation Unquestionably there is a vast amount of information available concerning the