INVESTIGATION OF SEVERAL ADDITIVES FOR CONTROLLING THE EXPANSION OF PIERRE SHALE

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Soil expansion and the accompanying pavement distress in roadways constructed on the Pierre formation have been a serious problem for the South Dakota Department of Highways for many years. Because of the distribution of the Pierre formation in South Dakota, most highways in the western half of the state have been affected. In the last decade, research has been carried out by the highway department and other agencies to find for primary roadways a suitable design that would eliminate or at least minimize roadway heave and the subsequent breakup of the pavement. The investigation summarized in this report is a continuation of that major research effort.

•ALONG Interstate 90 from Wasta west to Rapid City, there are many sections of portland cement concrete pavement that has buckled and faulted. In the New Underwood area, after the pavement had started to fail, 8-in. diameter by 5-ft deep holes were drilled adjacent to the slab, and a water-lime-sand mixture was poured into the holes. A full description of this work has been given by McDonald (1). Selected slabs in this area were also cored and direct water induction applied to the subgrade. This work was reported by Whyte (2). Those techniques, while encouraging, were apparently not sufficient to completely control the problem, and the alternative was to resurface the most critical areas of pavement distress and to patch and repatch many of the other "cut" areas. The patching and repatching have continued to this time and in all likelihood will have to be continued for the rest of the life of the highway.

In 1968 and 1969 an investigation of pavement distress in roadways in western South Dakota was carried out by Hammerquist and Hoskins (3). This investigation attempted to correlate expansive soil properties, soil moisture, and faulting and jointing in the underlying Pierre shale with areas of severe pavement distress. The investigators found that, in sections of primary roadways in which the subrade had been treated prior to construction, pavement heave was still possible. Moisture apparently could get down through the subgrade (or come up if the water table rose) into the faulted and jointed material under the subgrade and cause swelling along the strike of the faults. When the strike of the fault crossed the roadway at approximately a right angle, a prominent sharp bump in the surface resulted. Because swelling is apparently still possible, even after extensive subgrade treatment during construction, it seems obvious that the currently used lime treatment is not totally effective.

The purpose of the investigation we now report on was to find out whether some of the locally available materials with known swell-inhibiting properties might be used to more effectively and more economically control swelling in roadways built in the Pierre shale. The principal materials we chose to investigate were gypsum, lignite, and by-product ash from the state cement plant. We also ran tests on lime, an inert grit (carborundum powder), and slime tailings from the Homestake Mining Company's mill.

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PROCEDURE

Several barrels of Pierre shale were collected during the summer months of 1969. Samples were chosen to obtain "typically difficult" samples of the Virgin Creek member. Shale samples were collected from the Pierre, Fort Thompson, and Draper areas. The samples from the Draper area were obtained from a construction site on Interstate 90.

The samples were placed in plastic bags in order to retain as much of the field moisture as possible. The samples were then mixed together and sieved through a No. 4 sieve and placed again in plastic bags. A standard Proctor test (AASHO Designation T-99) was performed, and maximum dry density and optimum moisture content were found. The results of the Proctor test established the maximum dry density at 81.5 lb/ft^3 and the optimum moisture content at 36 percent. The expansion tests were run at 95 percent of Proctor density and at 36 percent of moisture content.

The cured sample was placed in a Rowe consolidation cell at the required density. The material was compacted in the cell in a single lift in a hydraulic testing machine. The Rowe cell used in this investigation is a hydraulic consolidation cell. It is 10 in. in diameter and 5 in. high. A 3-in. thick sample was used in the cell to allow for 2 in. of expansion during the test.

Tests took from 10 to 30 days to complete. The sample, after being placed in the cell, was allowed to rebound. When the sample had stabilized, as evidenced by constant readings on the dial gauge, the saturation water was introduced into the bottom of the sample at approximately 0.5 psi. Confining or overburden pressure was introduced at the top of the sample, inside a convoluted rubber bellows, at 2 psi or approximately 300 psf. The purpose of the confining pressure was to simulate the weight of the pavement and subgrade on the soil. A dial gauge attached to the bridge on the cover of the cell read expansion of the sample to 0.0001 in.

RESULTS AND CONCLUSIONS

The results of this investigation are shown in Figure 1. The results have been computed in terms of percentage of volume increase of the soil sample versus elapsed time. These results are given quantitatively in Table 1.

The conclusions to this investigation depend on the criteria one chooses to evaluate the results. If reduction of the swelling ability of the subgrade is the principal aim of using the additive, then from our tests lime appears to be slightly better than the other additives at the same concentration. All of the additives we investigated, however, including inert grit reduced swelling by at least one-third compared to the raw soil.

Permanence of the treatment is another criterion that must be considered. Lime treatment has now been shown to still be effective after 8 years (1). None of the other materials has yet been evaluated for long-term effectiveness.

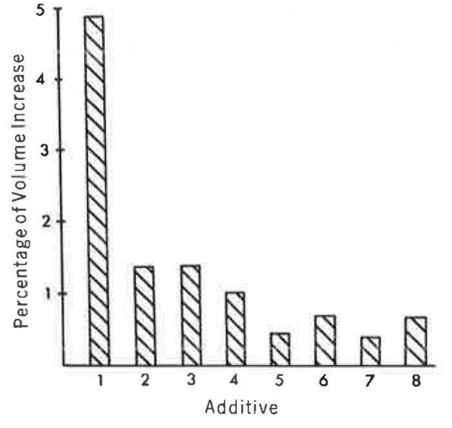
The effect of the various additives on the strength or bearing capacity of the subgrade is also extremely important. Part of the economy of using lime as a stabilizing agent is in the reduced thickness of pavement that is required because of the increased strength of the subgrade. The effect of the other additives on a measure of strength, such as a California bearing ratio test, has not been investigated. The increased bearing capacity of treated subgrades also aids in the construction of the highway by giving the contractors an all-weather road for their construction equipment. This relatively stable temporary surface reduces the amount of construction time lost because of bad weather.

Finally, the relative costs of the various additives must be considered. The cost of producing lime is probably much higher than the cost of producing any of the other additives. It is quite probable, for example, that the cost of buying and shipping a ton of mill tailings from the Homestake mine to a highway construction site anywhere in western South Dakota would be much lower than the cost of getting a ton of lime to the same site. If so, a higher percentage of mill tailings might be used in the subgrade to secure a treatment equal to or perhaps better than that the lime is currently giving. A greater thickness of subgrade might also be treated. Lignite and waste products from the state cement plant may have similar cost-effectiveness characteristics. The only way to substantiate any of these suppositions is to make a detailed cost study of the various materials, and such a study was not included as a part of this investigation.

Table 1. Percentage of volume increase.

Elapsed Time (min)	Type of Additive							
	1	2	3	4	5	6	7	8
10,000	4.30	0.92	1.13	0.92	0.35	0.52	0.31	0.36
15,000	4.69	1.32	1.32	0.95	0.37	0.63	0.35	0.54
20,000	4.91	1.39	1.39	1.02	0.44	0.71	0.43	0.70

Figure 1. Percentage of volume increase ater 20,000 min for 8 additives.



Note: The additives, given by number in Figure 1 and Table 1, are as follows:

Number	Additive	Percent
1	Raw soil	0
2	Gypsum	5
3	Inert grit	3
4	Waste product from state cement plant	5
5	Lime, dry	5
6	Lignite	5
7	Lime, slurry	5
8	Slimes	5

REFERENCES

1. McDonald, E. B. Lime Research Study, South Dakota, Interstate Routes (16 Projects). South Dakota Department of Highways, final rept., 1969, 33 pp.
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3. Hammerquist, D. W., and Hoskins, E. R. Correlation of Expansive Soil Properties and Soil Moisture With Pavement Distress in Roadways in Western South Dakota. Final rept., 1969, 61 pp.