

Salt Stabilization Research

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●SALT stabilization has been practiced for many years, generally with success but occasionally with failures. This has brought about a need to know the conditions that favor salt stabilization and those to be avoided, so that we can predict the required conditions for optimum results. The most satisfactory place for determining these conditions would appear to be in the laboratory. We should then be able to translate these results to satisfactory practices in the field.

Previous research consisted of laboratory tests to find the types of soils most amenable to salt stabilization or field tests in which salt stabilization was tried without prior consideration being given to soil type. The efforts have yielded inconsistent results.

In our research, we decided to try a different approach. Instead of starting with soils and trying to stabilize them in the laboratory, we started with cores removed by a special coring machine from successfully salt-stabilized roads and tried to determine what conditions were present to yield the satisfactory results.

The cores studied came from successfully salt-stabilized roads in Monroe, Michigan (Fig. 1); Steuben County, Indiana (Fig. 2); Montpelier, Ohio (Fig. 3); roads composed of blast-furnace slag from South Gate, Michigan (Fig. 4); and roads composed of galena stone from Wisconsin (Fig. 5).

Our approach in investigating this subject was the scientific method consisting of (a) the observation and analysis of previous occurrences of the phenomenon, (b) the inference from the observations of a specific law or causation, and (c) the testing of this law by trying specific applications. Our observations were made on thin sections (approximately $\frac{3}{100}$ -mm thick) taken from the Monroe County, Michigan, core and studied under an optical microscope at magnifications between 10 \times and 160 \times using transmitted and polarized light, and under an electron microscope at 660 \times . The following observations were made from the microscope slides:

1. The cores are very dense, much denser than the original material.
2. Salt particles are observed at high magnification (660 \times) and evidently contribute to bonding.
3. Cracks are present. This could be evidence of cementation. Apparently the clay has been homogeneously dispersed throughout the matrix and has formed layers around the larger particles and cemented them together in one common mass. The evaporation of water from these clay layers would cause shrinkage and produce cracking.
4. There appear to be secondary growths of limestone and silica.
5. Some reduction in the size of some of the limestone particles appears to have taken place, thus indicating that this material has entered into a reaction.

The important result to be gleaned from these observations is the explanation of the cause. Some mass transfer has taken place, with secondary growths of limestone and silica also being present. Furthermore, clay particles appear to have surrounded the larger particles.

The inference we might draw from these observations is that migration of material has taken place. But migration under what conditions? Very possibly migration occurred under changing temperature and water conditions. We have thereby developed a possible explanation for the cause of this phenomenon. Laboratory samples were prepared for a test of this hypothesis.



Figure 1. Salt-stabilized core from Monroe, Michigan.

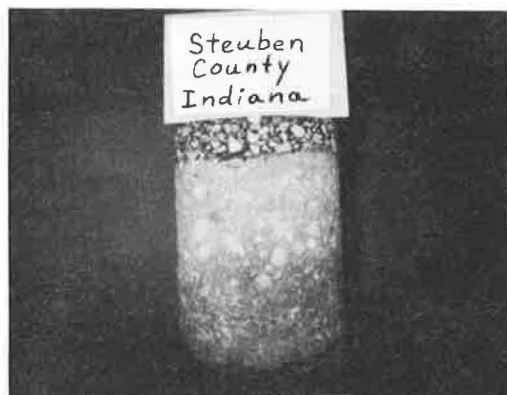


Figure 2. Salt-stabilized core from Steuben County, Indiana.



Figure 3. Salt-stabilized core from Montpelier, Ohio.



Figure 4. Salt-stabilized core composed of blast-furnace slag from South Gate, Michigan.



Figure 5. Salt-stabilized core of galena stone from Wisconsin.

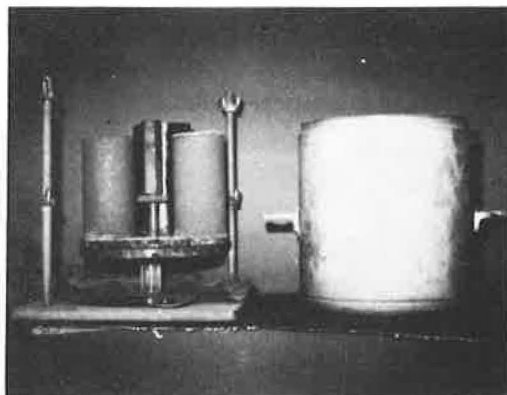


Figure 6. Extruded synthetic cores before curing, mounted on an elevated and perforated base that rests on a rubber gasket and large baseplate; mold is at the right.

The formula for the mixture used for these tests is as follows: 10 percent clay (Grundite), 30 percent calcium carbonate, 60 percent sand, and 1 to 2 percent sodium chloride. This formula is a first approximation of the ingredients and percentages of ingredients that should produce the desired effect.

Grundite is a trade name for an illitic clay from Grundy County, Illinois. It was selected as being typical of a glaciated clay of intermediate plasticity, which is characteristic of the northeastern United States. The amount was limited to 10 percent in the samples used because, if higher percentages were used, the plasticity in the presence of sodium ions could increase to the point where the initial formula would be unstable.

Calcium carbonate was included in the mixture because secondary calcium carbonate appeared to be present in the sections observed. A sufficient amount was used to give contact between limestone particles in the final mixture. Sand was included because secondary silica also appeared to be involved in some of the growth between particles. The amount selected was sufficient to make up the remainder of the formulation.

The quantity of sodium chloride was selected on the basis of the amount commonly used in salt stabilization.

The equipment used for preparing the compacted core consisted of a standard Proctor mold, baseplate, and collar. Optimum moisture was first determined, the samples were blended with water at optimum moisture, and then compacted to optimum density. The synthesized core was extruded from the mold after compaction. The cores were quite fragile at this point and considerable care was required to transfer them.

A large mold was set in place on a correspondingly large baseplate using a rubber gasket between the baseplate and the mold. A perforated and elevated base was placed over the baseplate and the extruded samples were then placed on the perforated base. A small amount of water was added to the bottom of the container. A second baseplate with gasket was then placed on top of the container, and the bolts were drawn onto the studs until a tight seal was obtained (Fig. 6).

The samples were then cycled according to the following procedure: (a) the mold was first placed in an oven at 120 F for 48 hours; (b) it was allowed to stand at room temperature for 24 hours; (c) the cover was removed, and the mold was placed in the oven without a cover at 120 F for an additional 48 hours; (d) the sample was then allowed to stand at room temperature for 24 hours. This procedure was repeated 30 times. This number of cycles was chosen because it was believed to be in excess of any number of natural cycles of this type that might be encountered.

Well-hardened synthesized cores resulted from applying this procedure (Fig. 7). No salt was observed on the outside of the core to which 1 percent salt had been added.

Salt was seen on the outside and at the top of the core containing 2 percent salt. These cores were oriented to be in the same position as they were before being removed from the cycling apparatus. It is interesting to note that the salt remaining on the outside of the core had migrated to the top. One conclusion that appears valid from this observation is that the required amount of sodium chloride is between 1 and 2 percent.

Thin sections taken from the synthetic cores were examined with an electron microscope at high magnification (7,200 \times). It was observed that the limestone particles were fused together and that some unreacted salt was present in the voids. The indistinct appearance of the particles indicated that the clay had been uniformly dispersed.

Is this the end of our research? No, we are quite frank about admitting that it



Figure 7. Two synthetic cores, one containing 1 percent salt and the other containing 2 percent salt, after being subjected to 30 cycles in the cycling apparatus.

is just the beginning. We are very pleased with the results, but we realize that there is still much to be done.

Future avenues of research that should be pursued include the following:

1. The minimum number of cycles should be determined. It is proposed that this be done with a density pycnometer and surface-area measurements. We believe that maximum bridging between the particles should be indicated by the number of cycles required to obtain minimum surface area and maximum density.
2. The formulation should be optimized. This should include determination of the optimum amount of salt required as well as varying the amount of calcium carbonate. One experiment would completely eliminate calcium carbonate to determine if this is an ingredient that enters into the stabilization reaction.
3. Various types of clays should be substituted. The grundite clay, as mentioned before, has been chosen as a typical example of glaciated clay of intermediate plasticity that is typical of the northeastern United States. It is proposed that kaolinite clays, which are typical of the southern United States, and montmorillonite clays, which are typical of the central United States, should be substituted to determine the limitations of these clays in other areas of the country.
4. The function of the clay and the function of the salt should also be determined. The tool for determining this appears to be the electron microprobe. With this tool, an attempt will be made to find the location of sodium ions in the thin sections. It is believed that these will be found in the clay areas, indicating that the sodium ion has served as a means of dispersing the clay particles.

In summary, thin sections removed from cores taken from successfully salt-stabilized roads and observed under the microscope show the cores to be more dense than would be expected of untreated material. Furthermore, none of the original salt has been observed to be present in these sections, and cracks are present, possibly indicating cemented areas. Secondary growths of limestone and silica also appear to be present, and erosion of these materials from other locations in the sample seems evident. We infer from this that migration has taken place, and we attribute the cause to cycling moisture and temperature conditions.

We have tested this theory in the laboratory using materials of the approximate composition to be found in the field. They were cycled under moisture and temperature conditions much more severe than believed to be encountered in the field. We are pleased to report that cores of good quality have been obtained. We fully realize that much future work remains to be accomplished before the results of this research can be applied in the field.

DISCUSSION AND SUGGESTIONS

Dr. John B. Sheeler of the University of Iowa suggested that consideration be given to coating the thin sections removed from cores taken from successfully salt-stabilized roads with a solution of zinc uranyl acetate. Exposure of the sections to ultraviolet light, instead of using the electron microprobe, could then be used to determine the location of sodium ions.

It was also suggested that a control synthesized core containing no salt be included in plans for subsequent research, and plans have been made to include synthesized cores of this type.

In response to a question, the author confirmed that water is added to the cycling apparatus at the beginning of each cycle.

A representative believed to be from Ottawa, Canada, suggested that foreign material in the cracks should be identified as secondary calcium carbonate, etc. This identification is necessary because it is possible to introduce impurities into these areas during the preparation and mounting of the thin section.

It was further suggested by a representative from the U. S. Bureau of Public Roads that toy samples, i. e., samples prepared from absolutely pure materials, could be prepared to make sure that the ions identified by the electron microprobe are the result of migration and not impurities present in the materials used to prepare the synthesized materials.