Salt Stabilization of Soils

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ABSTRACT

The addition of salt to aggregates containing a quantity of material passing 200 mesh has proven advantageous in increasing density, load bearing values, resistance to penetration of moisture, and in transforming otherwise frost susceptible material into frost resistant all weather road material.

The quantity of fines required varies with different types of aggregate, limestone, gravel, slag or cherts, but the salt required remains constant at one percent by weight of the mass to be stabilized or upgraded.

The best results are obtained when the best construction procedure is followed, however much work has been done with material and equipment available and results have been satisfactory.

The addition of salt is recommended to reduce maintenance and replacement costs and furnish better riding qualities both when used as a base or a temporary wearing course during stage construction.

The use of salt as an additive for the purpose of stabilizing aggregates is not new. Salt has been used for at least thirty years with all types of aggregates including gravel, limestone, slag, dirt, sand, and clay. When we first started adding salt it was in minor quantities and with the idea that the consolidation of the aggregate would reduce the tendency of the road to dust during dry weather. However, salt is much less effective as a dust palliative than other more deliquescent chemicals. The addition of salt to different types of aggregates resulted in stabilization and better roads.

When Michigan initiated the use of salt as an additive, the primary purpose was to prevent the fire engine type of maintenance that they had found necessary where calcium chloride had been applied to a road. Roads treated with calcium chloride became slippery after rains and it was necessary to maintain a practically constant patrol grader operation in order to prevent rutting. However, the addition of salt eliminated this condition and the hardness which developed stimulated additional investigation. The primary purpose was to determine how much salt should be added in order to hold the moisture content at a level where densities could be achieved in less time during compaction. Michigan has found that where salt is specified the contractor's bid is often lower than the bid would be without the addition of the salt because there is so much less rolling required. Once several roads were constructed this way, they found that they had an additional benefit which had not been expected: the frost action was greatly reduced and the greater density and hardness made a better base for either blacktop or concrete. The base maintained its character: it did not absorb water and it did not shrink in a dry period nor swell during a frost period. Uniformity of the base structure provided many advantages which had not been expected from the original construction.

We have not been able to determine exactly how the salt recrystallizes when it is added to road materials, but we have found that aggregates containing better than 12% of fines passing the 200 mesh screen are superior to those with a lesser content of fines when salt is added. The addition of one percent of salt (20 pounds per ton of aggregate, or one pound per square yard per inch of depth) will result in rapid consolidation with densities of 154-160 pounds per cubic foot developing after water is applied.

The men who have been using this type of construction are well aware that once the road is compacted there is practically no penetration of water from the surface. They post a sign in their garages which says a salt stabilized road must not be graded except during the rain. Grading must be accomplished before the rain is over because hardness will set in immediately thereafter.

The failure of the base to absorb water is effective in preventing penetration of capillary water from the bottom. Apparently, once roads are compacted, the salt goes to the outside of the compacted mass, both top and bottom, as it dries. It is my theory that the recrystallization of the salt acts as a capillary choke. We have been able to study airstrips where the water table is a half-inch below the surface adjacent to the airfield. Cores from the airstrip itself show a compacted mass of six to eight inches of salt stabilized section overlying a saturated zone. Because the water table is higher on the sides than in the stabilized section the recrystallization of the salt in the stabilized area must have acted as a capillary choke. Whether this has been caused by ion exchange or by the formation of a unique substance, is debatable.

We have developed a core cutting machine in which we use a diamond drill and bentonite. The core has very much the appearance of a concrete core cut from a highway. We found that, where a city or municipality had used salt in compacting or stabilizing their residential streets, that they had to use an air compressor in order to cut a section out to make a service connection. Core studies show that where the quantity of salt added to the aggregate is less than one percent, the compressive strength or load bearing value is below the desirable level. We have found that we can add salt to materials containing less than 5% of fines, but again, do not get the load bearing value that we achieve by the addition of sufficient fines to fill all voids. Where densities of from 154 to 160 pounds are recorded, all the voids are filled and there is no air space available for penetration of water. It has been a common practice to cover this hard base. Many of the counties are using a prime and seal on airport runways. The city of South Bend last year felt that the use of the salt stabilized base and a simple slurry seal gave them an improved and adequate residential street. However, the State of Michigan has found it of value to add salt to the base of all road types including the interstate system because of the reduced compactive effort necessary to achieve the required density and because of its value as a frost deterrent plus the long lasting uniform frictional resistance to movement which may result from expansion and contraction. The uniform base has proven of great value in maintaining a bump-free long lasting surface.

Cores from a section in Macomb County, Michigan, where we had added lime and salt, were taken to a university for petrographic study. It was reported that no sodium chloride was found and we were asked to provide samples of everything that went into the construction of the road. On further study they determined though no salt was present in the core of the compacted road, there were nine new sodium minerals which had not been present in the materials that we had used in the construction of the road. I feel that this indicates that ion exchange takes place. Because of the changed character of the compacted materials, we have made an attempt to have several universities study the geochemistry of the salt. Although we find that water does not penetrate into the mass where cores were pulled from wet areas, we cannot take the same core into a lab and set it in a pail of water without the water penetrating into the core and causing it to slough. This leads me to believe that the recrystallization in the outside of the mass is the principal deterrent to the penetration of the moisture and the principal reason for the stabilization achieved by the use of salt. This embarrassing situation of not being able to prove in the laboratory the result achieved from the addition of the salt in the field has deterred the expansion of the program. However, field operations have definitely shown that there is a benefit to be achieved from the use of salt.

I worked with the pulp wood haulers in Maine where we have improved logging roads on which they are hauling 80 cord loads of logs to railheads at high speeds. In fact, in one section I was told that when I entered the woods if I saw a cloud of dust, to get off the road because it meant a truck was coming. In 1961 we went in and built 3-1/2 miles of logging road in four days using the materials in place, with the addition of salt at the rate of 1% of the aggregate. At our meeting last fall the International Paper Company reported to the North American Pulp Wood Association that these roads had less dust. Further, the roads were used at least a month earlier because the frost did not make the roads unusable, had cut their maintenance cost, and the general overall result was exceptionally good.

The State of Michigan built a road, M-46, in which they varied the quantity of fines and the quality of salt and reported on this to the American Road Builders. This road is now five years old and their engineer made the statement to the Highway Research Board that if salt had not been used five sections of the road would have failed by 1965. When we constructed this we used a control section which the State of Michigan knew would not be frost susceptible. Then we added fines and added salt until the salt represented 1% of the aggregate and fines which passed through a 200 mesh represented 12% of the aggregate. We have been able to pull cores from all of the sections that had the salt in them and tests have indicated that densities are as high as 160 pounds to the cubic foot and that the compressive strength ranges up to 800 psi.

In Steuben County, Indiana, we built a test road from a gravel pit out to U.S. 20 in which we varied materials. The first third of the road was built under the Indiana State specification which allows no more than 5% passing the 200 mesh, but is called Moisture Controlled Aggregate. With this material as a base we then added 1% salt in the next section of the road to the same aggregate and then added fines until we had 13% passing the 200 mesh and used salt in the same quantity. This road has carried in two summers over two million tons of aggregate, all of which is moved in trucks which are loaded to maximum axle allowables. There are two black top plants on the end of this road and this material has also been hauled. There is a slight grade down to U.S. 20 and it is only reasonable that truck drivers would have hit their brakes pretty hard coming down the grade and there is no apparent or measurable variation or corrugation in the surface of this road near U.S. 20. The only protective cover put over the salt stabilized base was a prime and single seal which amounted to approximately one-half inch in thickness. Cores pulled from this road have gone as high as 160 pounds to the cubic foot and over 1,000 pounds per square inch compressive strength. The crushing and testing on this project was under the supervision of Tri-State University at Angola, Indiana, and although we have not been able to show in the laboratory increased C.B.R. values, the field has definitely demonstrated that these roads are far superior to those without the salt.

In this section of Indiana there are many types of geologic structure. It is a lake area and there are now about 175 miles of salt stabilized section in the county. The salt stabilization has been able to support the surface over the muck sections. Even though there is a tendency to show alligator cracks, there has not been any breakthrough or any frost heave action. This in itself would well justify the additional cost of the salt, which is, of course, minimal because we are using such a small amount. The State of Michigan, having constructed M-46 with surprisingly good results, realized that their only objection to this road is that it is carrying too little vehicular traffic. They are now designing a section in which they expect to use the same type of construction on a road known to carry approximately 10,000 vehicles a day and in this way they can determine better the lasting qualities of the road.

I spent some time with the armed forces, and at Fort Belvoir, Virginia, built helicopter pads and roads around Davidson Air Field. These roads were maintained for a period of nine months without being patrolled in any way; that is, no maintenance costs were generated. As a result of this, the 82nd Airborne and the 18th Air Assault (who find it necessary to build airstrips one day and use them the next) have just completed a series of construction experiments at Fort Bragg and Fort Benning. We built 3,000 foot sections 75 feet wide or 50 feet wide in one day and landed planes at 6 o'clock the next morning. The resultant lack of dust was very impressive, but the fact that the runways accepted the loads even where they locked the wheels and revved up the engines in order to make landing and take-off sorties, impressed this group of men to the point that they have recommended further investigation of the use of salt.

In conclusion I can only say that the addition of salt has resulted in a betterment of every type of aggregate that we have worked with such as (1) sand clay which we used in Delaware, (2) well-graded aggregate, (3) limestone, which is perfect, of course, or (4) slag which was surprisingly good. The main objection to the slag in our opinion is that when we try to cut cores it is rough on the diamond bits. But this type of work has been done successfully in the South, in New England, in the Northwest, as well as in the Central States where the bulk of the work has been done. Ohio had one period when they were building 100 miles a year of known frost brakeup sections. They used this 100 miles to train or allow the asphalt contractor to expedite the organization of his crews so that he could be ready for the start of the asphalt season.

The use of salt as a stabilizer is a cheap, efficient, practical way to upgrade the highway system.