STABILIZATION OF BASE COURSE AGGREGATES WITH ROCK SALT

MICHIGAN HIGHWAY RESEARCH LABORATORY DIVISION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS

STABILIZATION OF BASE COURSE AGGREGATES WITH ROCK SALT

R. C. Mainfort

Prepared for Presentation at
The 48th Annual Meeting of the Highway Research Board
Washington, D. C., January 1969

Research Laboratory Section
Testing and Research Division
Research Project 57 E-15
Research Report No. R-685

State of Michigan
Department of State Highways

Lansing, January 1969

INFORMATION RETRIEVAL DATA

REFERENCE: Mainfort, R. C. Stabilization of Base Course Aggregates With Rock Salt. Michigan Department of State Highways Research Report No. R-685. Research Project 57 E-15. January 1969.

ABSTRACT: The Michigan Department of State Highways has constructed and evaluated some test sections designed to determine the effectiveness of rock salt for stabilizing aggregate base course mixtures containing minus-200 material in amounts up to 12 percent. The test areas form a part of the State trunkline system and carry about 1300 vehicles per day. The test mixtures were prepared in a pugmill and placed on the roadway using normal construction methods. No construction problems were encountered due to the use of salt. Design densities were obtained easily and increased under the action of traffic, particularly in the higher fines areas. All of the test sections are in excellent condition after nine years of service. Much of the salt has leached from the base courses but densities remain high. Roughometer and rutting measurements, however, are beginning to show small, but significant, values in favor of the five percent fines areas and indicate the optimum salt treatment to be about six pounds per ton. Results of this test program indicate that graded aggregates containing up to 12 percent fines can be successfully used when treated with rock salt. Rock salt treatment could be of benefit to highway programs where higher quality aggregates are not readily available.

KEY WORDS: salt/sodium chloride/, soil stabilization, aggregates/physical properties/, base courses, test sections.

STABILIZATION OF BASE COURSE AGGREGATES WITH ROCK SALT

Although sodium chloride, in the form of brine and rock salt, has been used for many years in the construction of aggregate surfaces and base courses, the literature is meager concerning its use and performance under controlled construction conditions.

The Michigan Department of State Highways has used sodium chloride, in the form of rock salt, for stabilizing gravels since the mid-thirties. Originally, this treatment was used to stabilize surfacing aggregates containing approximately 16 percent of minus-200 material. For this type of construction the admixture was applied in a quantity of 10 lb per ton of aggregate and blended in place on the road. This mixture resulted in an excellent surface but eventually became so hard that blade maintenance was difficult. Michigan no longer constructs gravel surfaced roads but does build many miles of aggregate base course to support higher type surfaces. Stabilization of such foundation material requires different methods than those used for the earlier gravel surfaced roads.

During the past twenty years or so, sodium chloride has been specified for use in the base course of about 20 projects in accordance with standard MDSH specifications requiring 6 lb of sodium chloride per ton of aggregate. Results have been entirely satisfactory for all of these. In order to determine more fully the value of sodium chloride as an admixture to base course aggregates, the Department and the Salt Producers Association (now the Salt Institute) formulated a cooperative study to determine the value of various amounts of rock salt for improving different soil-aggregate mixtures. In this study it was planned to investigate the performance of rock salt with soil-aggregate mixtures not only as covered by present Department specifications (6 lb of salt per ton of aggregate having a minus-200 fraction of less than 7 percent) but also by increasing the quantity of salt used and the limits of minus-200 material, referred to in this report as "fines." In this way, it was hoped to determine: (a) the effect of different amounts of sodium chloride on the handling and field performance of soil-aggregate mixtures meeting present specifications; (b) if the addition of sodium chloride would permit larger quantities of fines in aggregate base course mixtures, thereby allowing the use of more economical aggregate sources; and, (c) the effects of various quantities of sodium chloride treatment on the amount of prime required and their subsequent influence on the performance of the asphalt cover.

This study was assigned to the Research Laboratory of the Testing and Research Division and was to include both field evaluation and supplementary laboratory investigation.

The test areas were completed during 1959 and given a final surface in 1960. Their performance has been observed, evaluated, and reported during the past nine years (1, 2).

SALT STABILIZATION

Before the use of sodium chloride for road construction, which began shortly after 1900, there were indications from other fields of definite reactions between soil components and salt. In agriculture, it was noted that the presence of salt increased the difficulties of cultivation and, in the ceramics industries, it was found that the addition of salt to clay retarded moisture evaporation, allowing a longer period during which the clay was workable. In addition, salt strengthened the clay and reduced shrinkage was noticed. All of these are modifications of direct interest to those engaged in road construction.

When first used in the highway field, salt was considered primarily as a dust palliative for open-surfaced aggregate roads. During the thirties its use for base and subbase treatments began, and this application grew rapidly. In spite of increased use, however, the literature concerning the properties of salt-soil mixtures remained meager and research and testing did not keep pace concerning evaluation and the establishment of optimum procedures for its use under field conditions.

One of the greatest problems encountered in trying to evaluate the effectiveness of sodium chloride is the lack of laboratory test procedures that reflect field performance of the material. Miles of satisfactory salt-stabilized roads have been built, yet the normally used laboratory soil tests do not correlate with field observations. These tests, in most cases, show no significant changes in engineering properties due to the addition of salt.

The exact mechanism of the action between salt and the clay fraction of soil is quite complex and, even at the present time, not fully understood. Normal soil tests involve only the physical features of the materials. Because the reactions between sodium chloride and soils involve both physical and chemical processes, special laboratory tests are required for proper evaluation. Until such special tests can be developed, however, the only satisfactory method for evaluating the properties of salt and soil mixtures is by constructing field test areas. Such methods, to be sure, are empirical and the results are applicable only to the materials and conditions encountered in the particular test areas. It has been fairly well established, however, in Michigan and elsewhere, that salt performs best with aggregates containing from about 5 to 15 percent fines. Because this range includes all of our normally processed gravels, it is reasonable to assume that a successful treatment within this range would be generally applicable throughout the State.

When used in constructing a base course, salt behaves very much as it would on an open surfaced road. Moisture is retained during placing and compacting and subsequent evaporation results in crusting at the surface. However, when the prime and surface courses have been added, evaporation ceases, substantially, and no crystallization takes place in the moist base. Any changes or benefits to the base stability under these conditions are thought to be due to the following causes (3) :

1. Lubrication of particles permitting easier initial and continuing compaction.

2. Moisture retention during construction allowing more uniform and easier compaction.

3. Chemical action with the clay fraction of the aggregate.

4. Depression of the freezing point of soil moisture, thereby inhibiting ice lens formation and possibly reducing freeze-thaw cycles.

5. Flocculation of clay due to presence of sodium ions, resulting in a change of grain-size distribution and possible reduction in plasticity index.

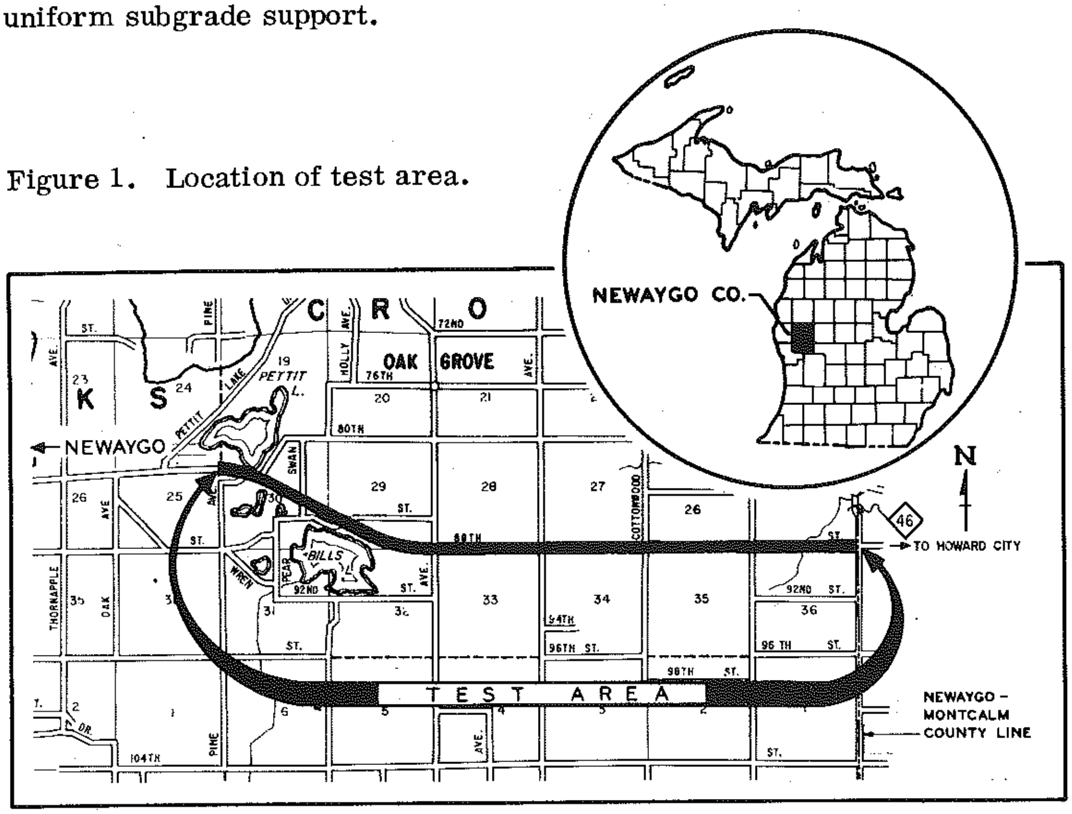
The amount and type of reaction taking place between sodium chloride and soil is dependent upon the type of soil treated; particularly in regard to the kind of clay minerals present and the nature of the adsorbed ions present in the original soil.

THE NEWAYGO TEST PROJECT

The test areas for the salt stabilization project are located in Newaygo County and form a five-mile portion of trunkline M 46 between Howard City and Newaygo (Fig. 1). This trunkline is one of Michigan's east-west highways and has an average daily traffic count that has increased from 400 to

1300 vehicles per day during the life of this project. About 20 percent of the vehicles are commercial. Soil composition varies throughout the test area; about one-third of the test area is located on sand, the remainder on sandy loams and heavier textured materials. The soil types were not a significant factor in obtaining a uniform support for the test sections, however, because of the thickness and granular nature of the base and subbase support. At least 15 in. of sand subbase was placed under the selected aggregate bases. In the sandy areas, the existing material served this purpose. In other areas it was necessary to haul sand from a nearby pit. At no time during the life of this project has there been any indication of non-uniform subgrade support.

Figure 1. Location of test area.



The subbase was topped by a 3-in. compacted granular base course meeting Departmental 22A aggregate specifications and treated at the plant with 6 lb of salt per ton of aggregate. The special base courses forming the test sections were placed over this selected subbase and consisted of a standard 22A aggregate treated in the manner required for the individual test sections and compacted to a depth of 7 in. Figure 2 shows a typical cross-section of the test areas. The shoulders were constructed of 23A aggregate treated with 6 lb of rock salt per ton, added at the pit, and stockpiled.

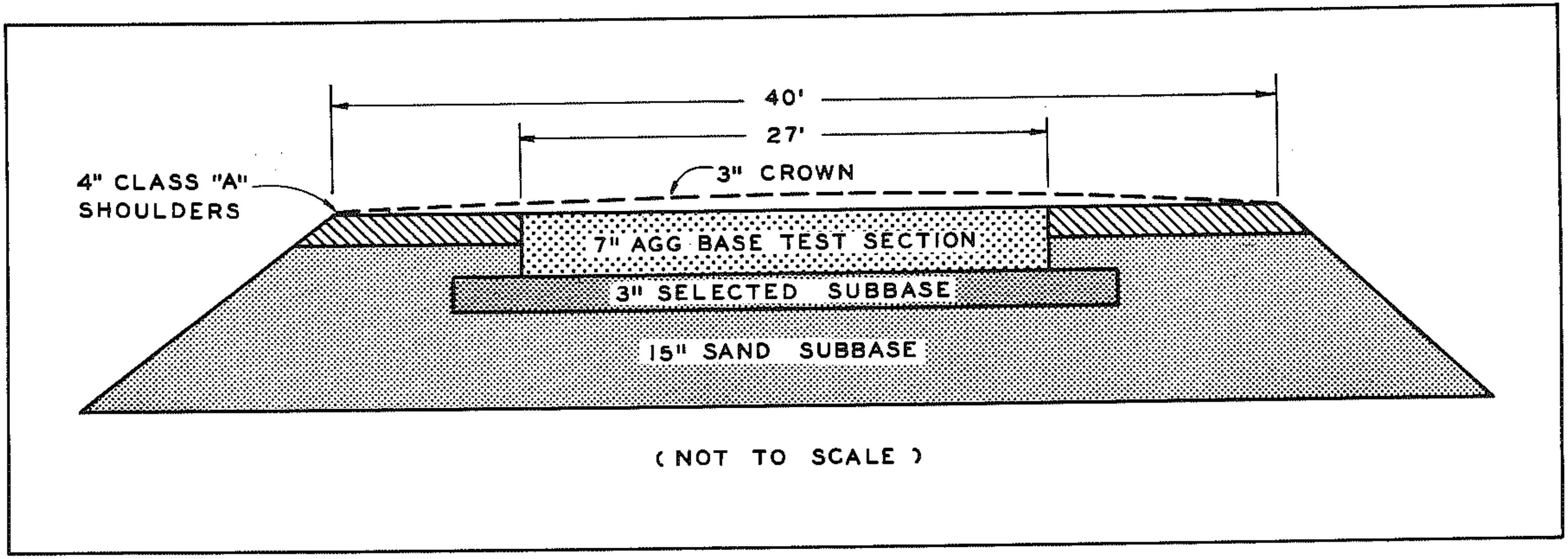


Figure 2. Cross-section of roadway structure (surfacing not shown).

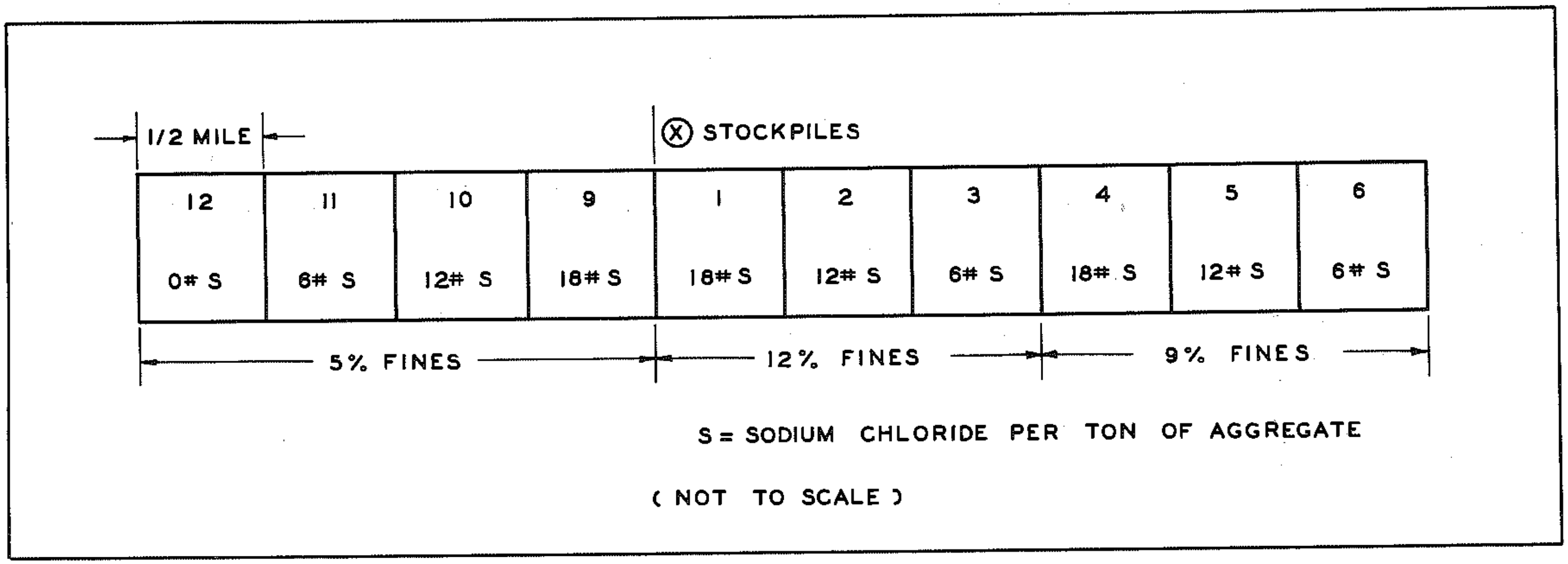


Figure 3. Arrangement of test sections.

The arrangement and variations of each test section are shown in Figure 3. The sections were constructed in the order indicated. Sections 1, 2, and 3 contained 12 percent fines and were treated with 18, 12, and 6 lb of salt per ton of aggregate, respectively. Sections 4 through 6 contained 9 percent fines and were treated with salt in the same manner as the 12 percent fines areas. Sections 9, 10, 11, and 12 contained 5 percent fines treated with 18, 12, 6, and 0 lb of salt per ton, respectively. Sections 7 and 8 were of standard construction and not included in the test observations.

TABLE 1
CHARACTERISTICS OF
AGGREGATE AND ADDED FINES

Sieve Analysis		
Sieve Size	Percent Passing	
	22A Aggregate	Added Fines
1"	100	----
3/4"	98	----
3/8"	76	----
#4	56	----
#10	38	100
#40	12	88
#200	4.7	46

Atterberg Limits		
Liquid Limit	----	21%
Plastic Limit	----	13%
Plasticity Index	N. P.	8

All of the experimental sections were built during the 1959 construction season in accordance with Michigan's Standard Specifications for Road and Bridge Construction, with special emphasis on uniformity of procedures and equipment throughout the project. The basic aggregate for the test sections was specified to be 22A with a maximum of 5 percent fines (minus-200). The average for the total amount produced was 4.7 percent. The additional fines required for sections 1 through 6 were obtained from natural ground near the test site. Table 1 gives the average characteristics of the 22A aggregate and the added fines. The fines were selected to be friable enough for easy and satisfactory mixing with the aggregate.

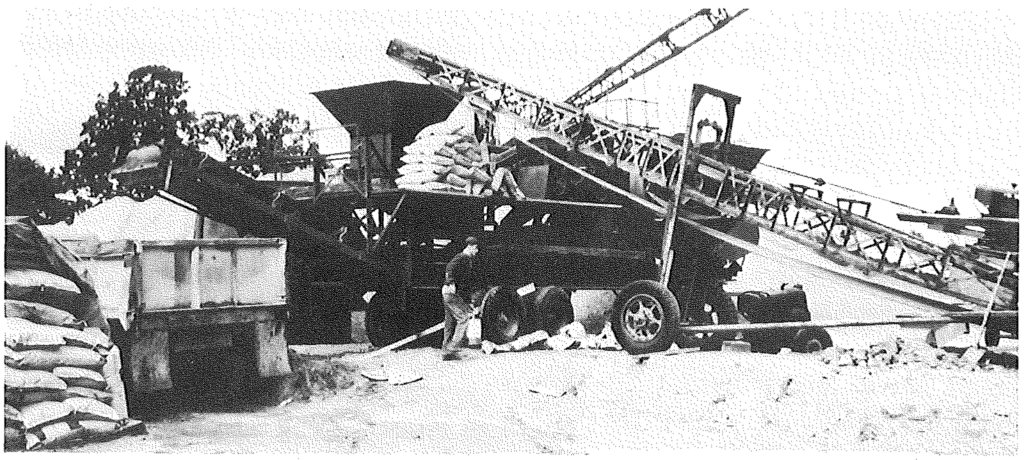


Figure 4. Pugmill (above) for mixing aggregate, fines and salt. Conveyor and baffle-box (below).

The sodium chloride used was in the form of rock salt meeting Departmental Specifications, with 100 percent passing the 3/8-in. sieve. It was delivered and stored on the job in both bulk and bags.

The aggregate, fines, and rock salt were all stored at the site of mixing and were proportioned as required for the individual test sections.

A Pioneer Stabilizer pugmill was used for processing the treated base materials for sections 1 through 6. For sections 9 through 12, where no fines were added, the contractor requested, and obtained, permission to eliminate the pugmill and add the salt to the aggregate on a conveyor belt with the mixture passing through a special baffle box as it was loaded onto the truck. Both methods produced very uniform blends (Fig. 4).

Because of the possibilities of segregation and loss of salt due to rainfall, none of the base course mixtures were stockpiled. All were fed into trucks as prepared and hauled directly to the grade for placement. Samples were taken for field and laboratory testing throughout the operation, both as controls to construction and for recording the actual quantities and qualities of the different sections.

Prepared aggregates were placed and spread by aggregate spreaders and compacted with self-propelled five-ton rubber-tired rollers, in accordance with normal construction procedures. The test base courses were placed in two layers with a final compacted depth of seven inches. Design densities were determined by the standard Proctor test (ASTM T-99) and controlled in the field by the Department's Rainhart Balloon compaction control method. In the low fines section, field density control was supplemented by use of the Michigan Cone Test. Each section was completed before its adjacent section was begun.

The materials handled well during construction and compacted easily to higher than design density. Densification continued after compaction under the action of construction traffic. The rock salt dissolved readily in the moist aggregate so that no salt crystals remained in the mix the day following placement. In the higher salt areas, there was some surface hardening due to recrystallization of the salt, but this caused no construction difficulties. No rutting or shifting of the base was noted after final compaction.

It was found during the initial construction of section 1 that the moisture content was too high, resulting in a spongy surface that was hard to compact. This was corrected by cutting out the compacted area, blading it on the grade to allow drying, replacing, and compacting. Even though there had been surface hardening, this caused no difficulties and an excellent base was obtained after recompaction. The rest of the aggregates for the test areas were placed at moisture contents between 1 and 1-1/2 percent below optimum and no further problems were encountered.

Figure 5 shows typical conditions of the sections after compaction and shaping prior to priming. The higher fines areas appear more dense, a fact substantiated by subsequent testing. Within the three fines areas (12, 9, and 5 percent) there were no noticeable differences due to the varying salt contents.

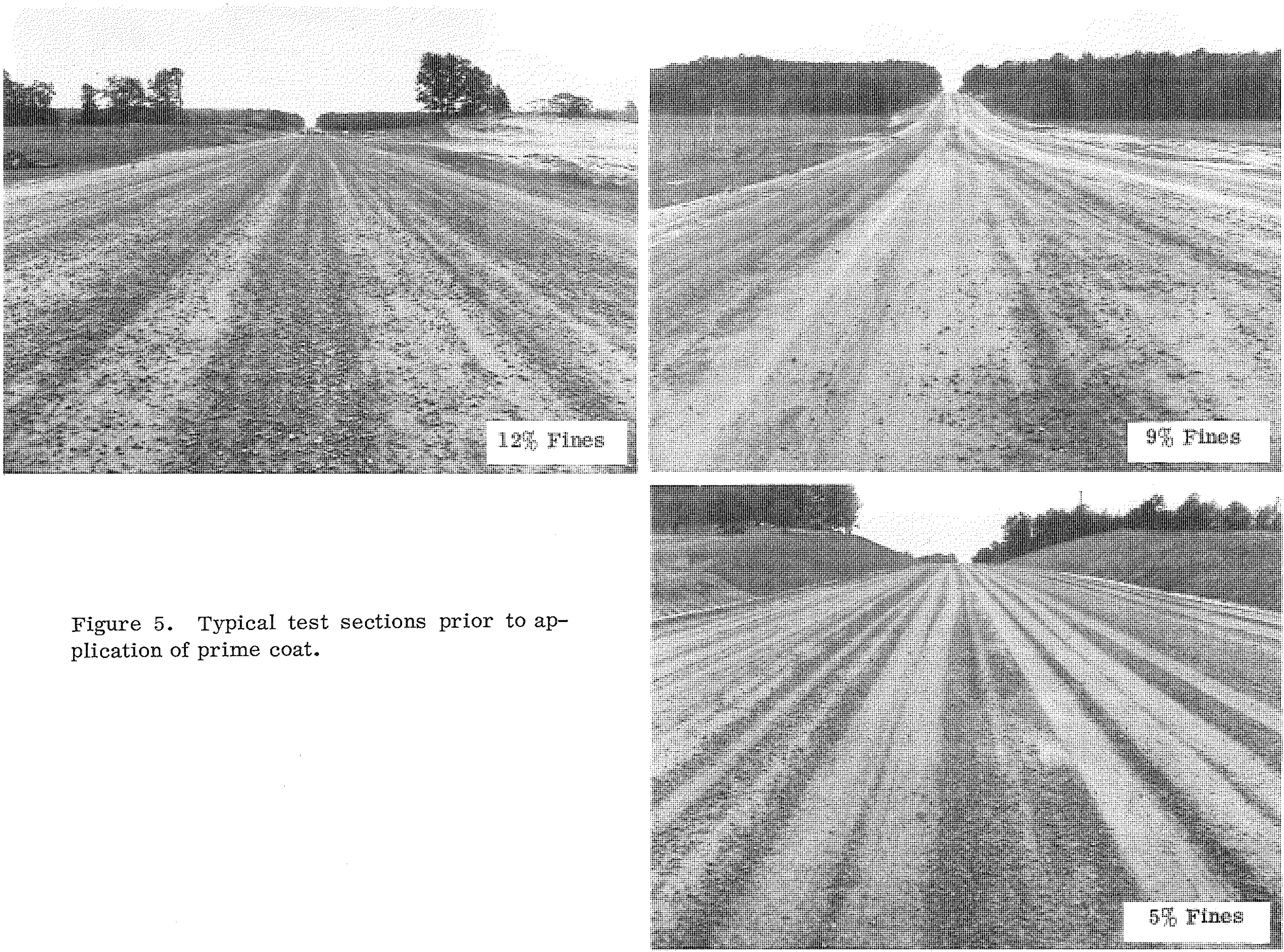


Figure 5. Typical test sections prior to application of prime coat.

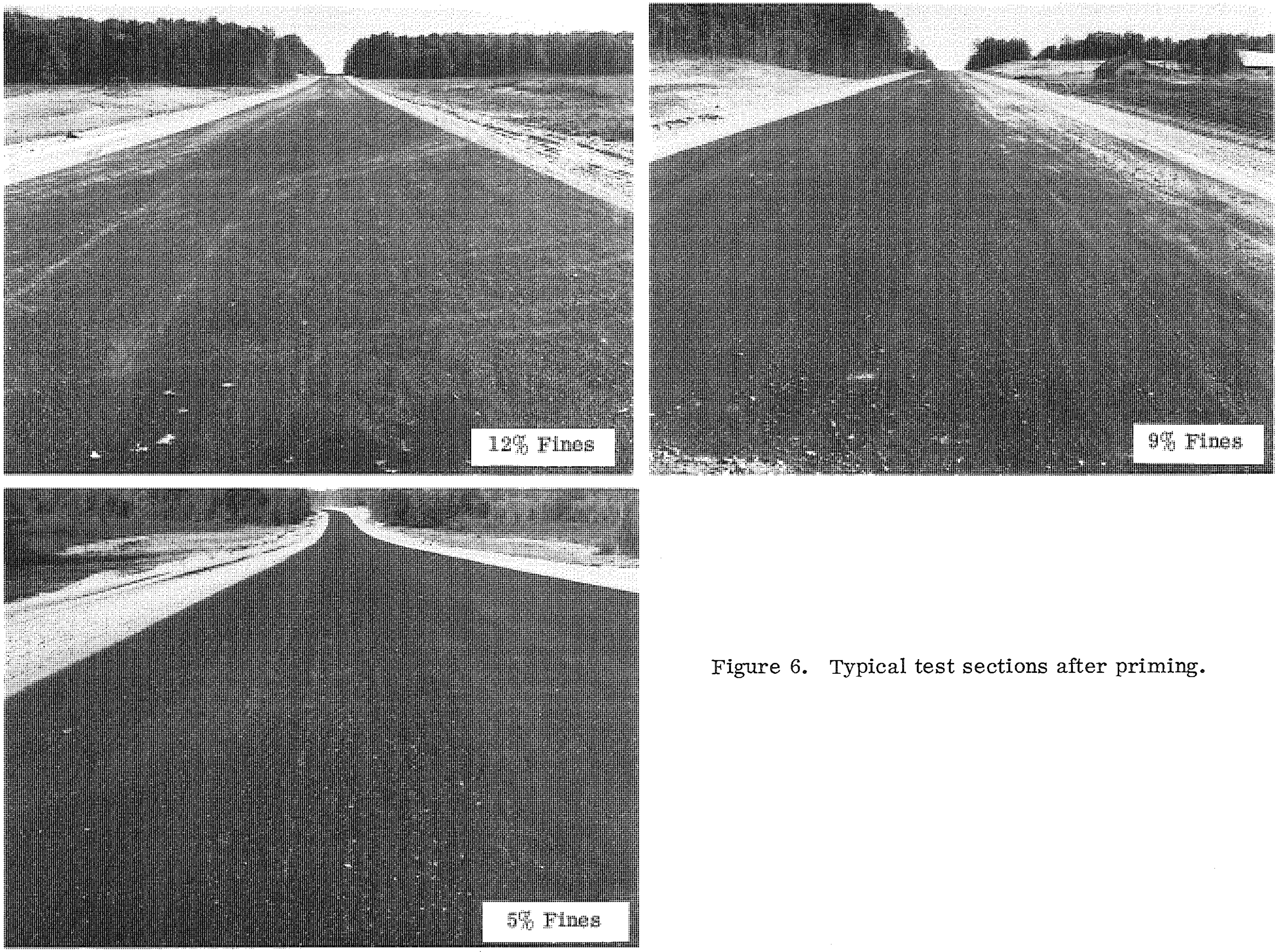


Figure 6. Typical test sections after priming.

The surfaces were primed with MC-1 cut-back asphalt at rates ranging from 0.12 to 0.25 gal per sq yd, depending upon the fines content and density of the surface. Good penetration was obtained in all cases and there was no significant runoff once proper application rates were determined (Fig. 6).

After curing of the prime, a double seal coat was applied which served as the roadway surface until the following summer when a 250-lb bituminous concrete wearing course was placed. Figure 7 shows typical conditions of the sealed sections after the first winter. These particular photographs are of the high fines area showing the three different salt contents. Although these represent only one winter, it is indicated that the higher salt sections (18 and 12 lb per ton) performed the best with a double seal surface. This same trend was observed in the 9 percent fines area. No significant differences were found in the 5 percent fines areas. All were in good condition.

EVALUATION OF THE NEWAYGO PROJECT

This project was set up on a long-term basis in order to obtain information concerning the performance of the sections over a significant period of use. It was estimated that at least five years would be required with additional studies tobe made if warranted. The project is now in the ninth year of service, during which time continuing tests have been made to evaluate its performance through measurements of density, moisture content, quantity of salt, roughness, rutting, compressive strength of core samples, and observation. Figures 8 through 10 show the results for the basic tests from the start of the project through the latest testing time. Results of special tests are shown separately.

Density Measurements

All field densities were measured by the Department's conventional method using the Rainhart rubber balloon. Although all passed minimum specification values, there were considerable differences in density within each test section. Results, therefore, represent trends rather than specific values. No attempts were made to control or test the areas by statistical control procedures.

After the surfacing was placed, density measurements of the base were made through holes cored through the asphalt. Densities in the high fines areas were very high for all salt treated areas. Densities obtained by the Rainhart method were periodically checked by measuring the density of cores. The two methods checked quite closely.

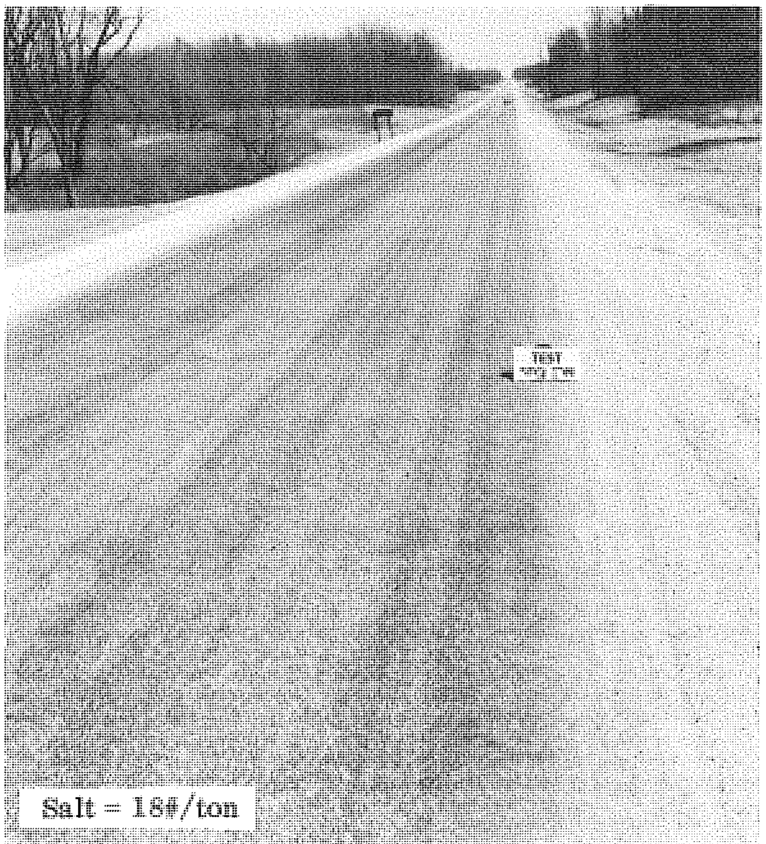
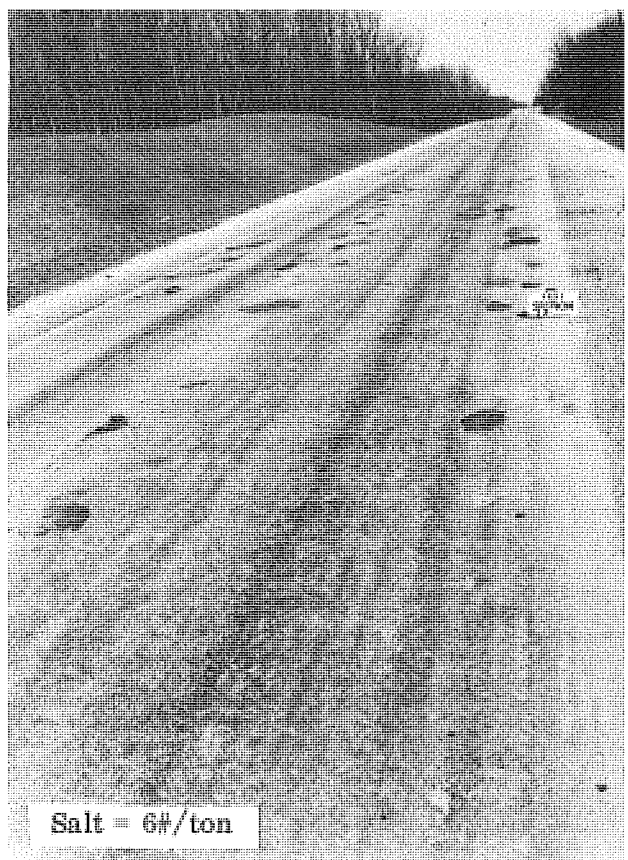


Figure 7. Condition of seal coats after one winter in the 12 percent fines areas.



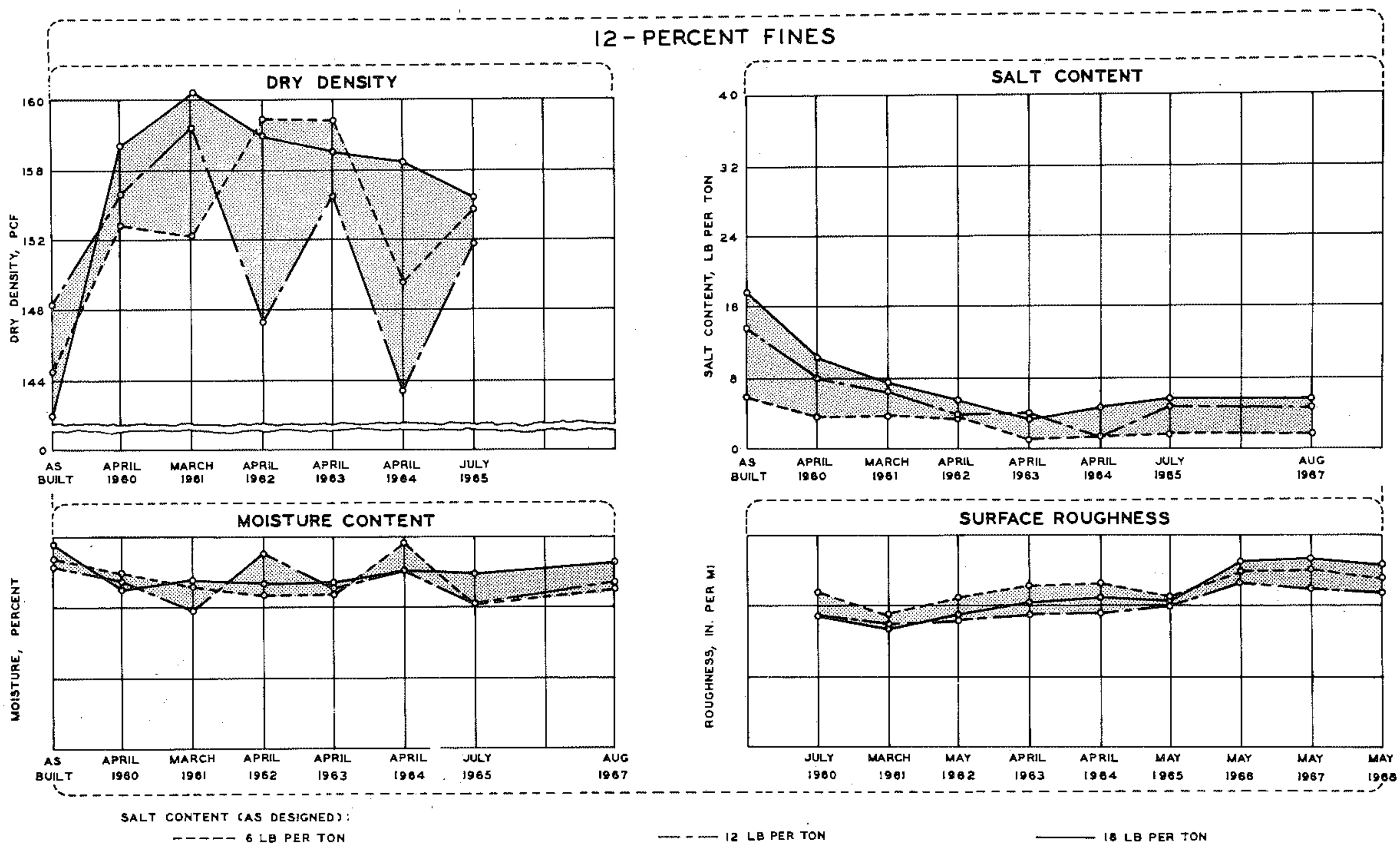


Figure 8. Yearly variation in base and surface properties (Sections 1-2-3).

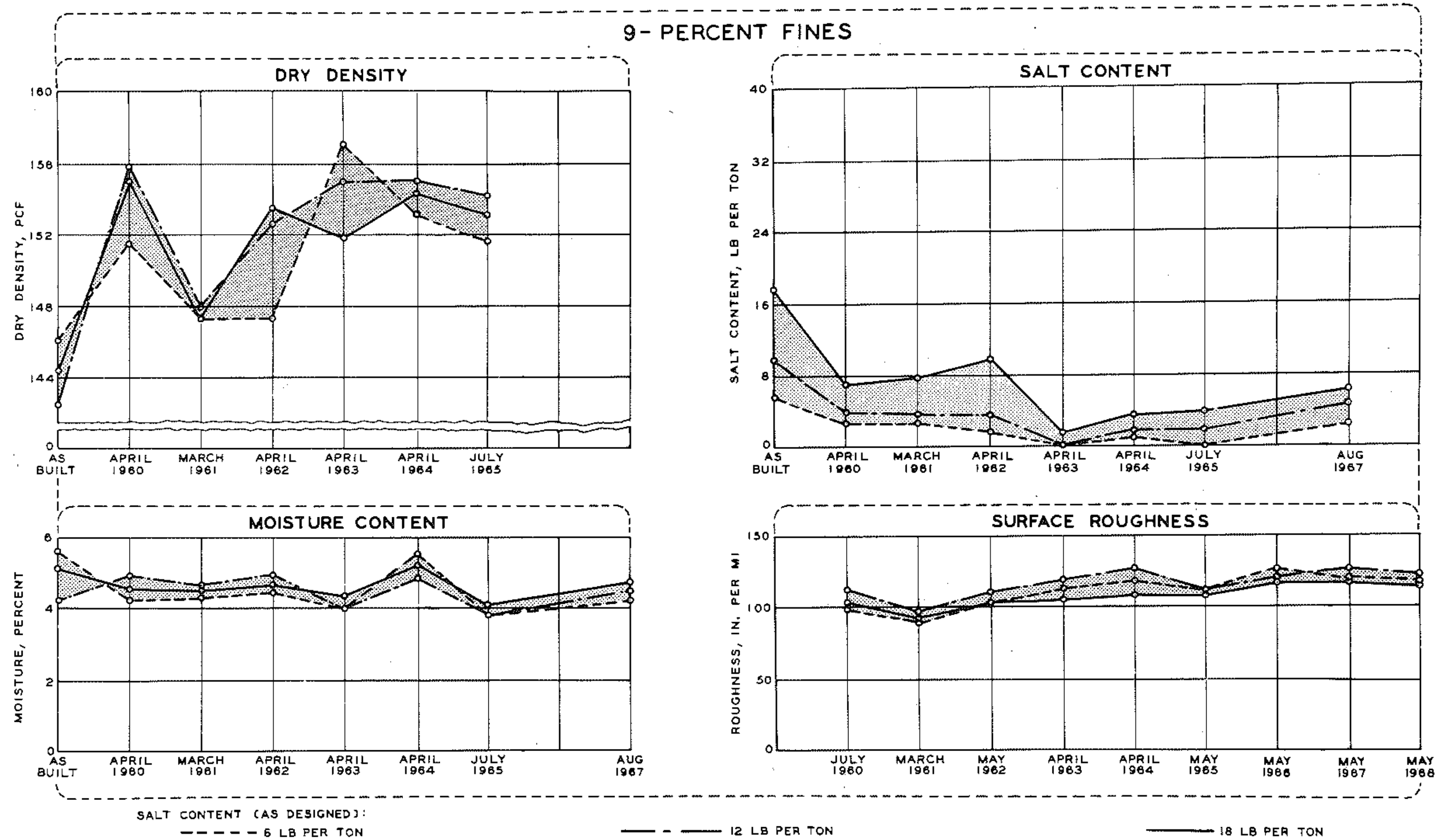


Figure 9. Yearly variation in base and surface properties (Sections 4-5-6).

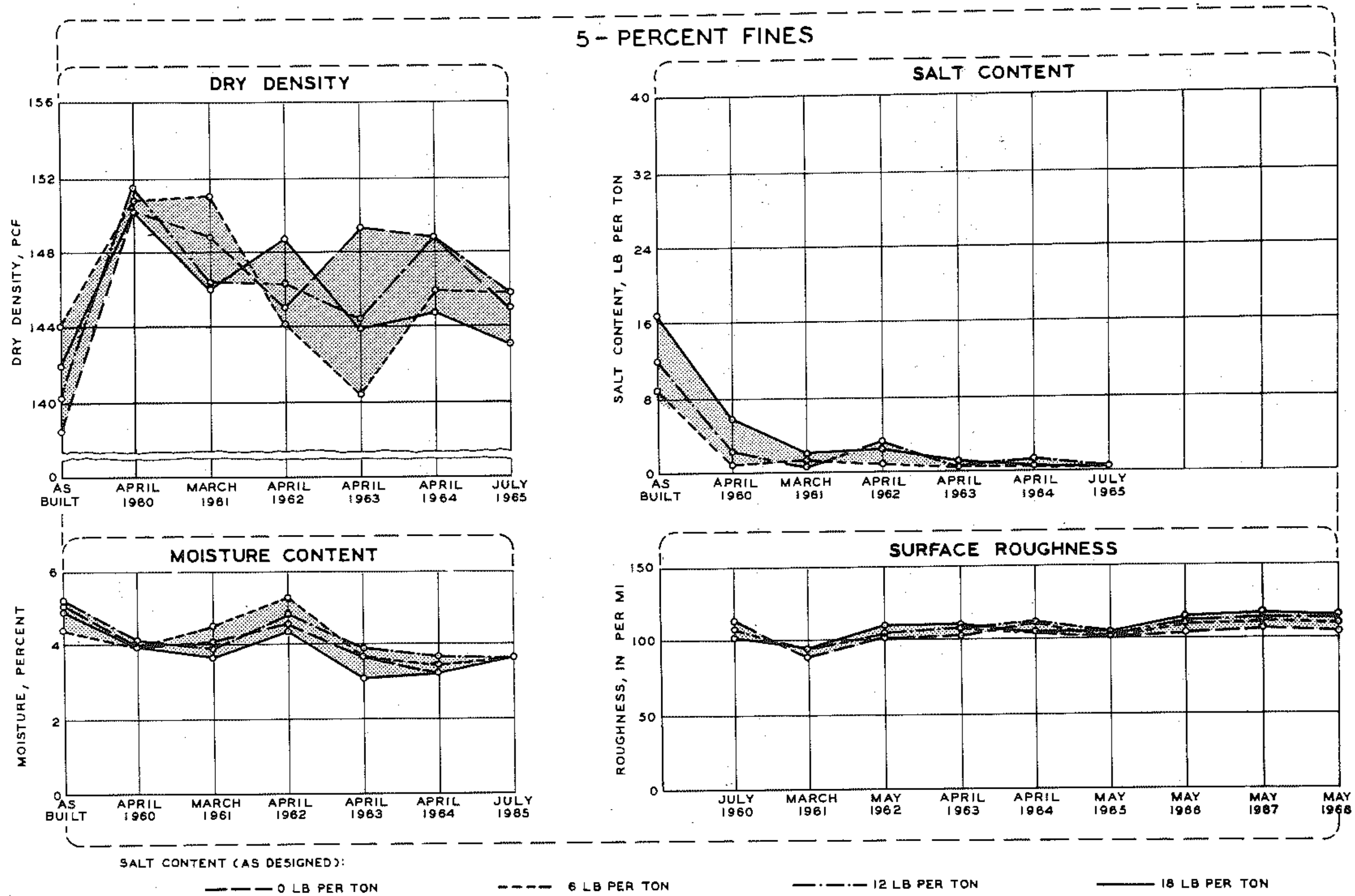


Figure 10. Yearly variation in base and surface properties (Sections 9-10-11-12).

Densities increased under the action of traffic, mostly during the first year. After placement of the asphaltic concrete surface, there was a levelling-off of density and a slight decrease in those of the 5 percent fines areas. All densities remain well above the design values, however. Some variations might be attributed to reasonable variation in the density of the material, and the difficulty of making precise measurements through the core holes. Each measurement represents the average of three Rainhart tests.

Moisture Content

Other than for some seasonal variations, the moisture content of the bases has remained constant after an initial moisture loss during the first year (Figs. 8-10). At the end of six years (1965) the 5 percent fines area, as to be expected, had a slightly lower moisture content than did the higher fines areas. Values shown are the average of three oven-dried samples from different locations.

Salt Content

The amount of sodium chloride in the base course was determined by ASTM Designation D-1411 56T in which, basically, the chemical is washed from the aggregate by agitation and the resultant solution tested for chloride ion content. Control sampling indicated the method to be accurate. Because sodium ions can combine with clay particles, it is possible that some sodium is not released by washing.

Field test data show that during the first year the salt content of the bases decreased rapidly from the design quantities (Figs. 8-10). In the high fines areas, the decrease has leveled off to from 2 to 5 percent, depending upon the rate of initial treatment. In the low fines areas, only a trace of salt remained in the base after three years, regardless of the quantity originally present. Testing of the subbase beneath the treated sections showed the salt to have leached into the subbase and beyond.

Surface Roughness

Surface roughness measurements were begun in the summer of 1960, following application of the bituminous concrete surface, using the Department's Roughometer (Bureau of Public Roads type). Very little change in the riding quality or roughness of any of the test sections has been measured or otherwise noted. There appears to be a slight trend toward increased roughness during the past three years but all values remain within the "Good" riding category. The values show the average roughness of the four wheel-tracks expressed in inches per mile (Figs. 8-10).

Rutting Measurements

In 1965, a new method of evaluating the pavement sections was begun in which the maximum rutting of the wheel tracks was measured. The device used for this purpose was developed by E. C. Novak, Jr. of the Research Laboratory (Fig. 11). In operation, the hand-held cable is unwound from the storage reel and stretched tightly across the roadway. One end of this cable is connected to a battery contained in the device. A calibrated wedge, also wired to the battery, is placed under the cable until contact is indicated by bell signal. The wedge, stepped in graduated readings of 0.025 in., is placed in the low point of each wheel track to obtain a depth measurement. The device is self-contained and has a counter for measuring the distance between reading sites. Three men are required to operate the equipment.

Figure 12 shows the rut-depth measurement values obtained since 1965. Each point represents the average of four wheel-track measurements taken every 100 ft within the test section. These results and testing procedures have been analyzed and found to be statistically meaningful.

Although none of the ruts were deep enough to cause concern at this time, the rut depths are noticeably greater in the higher (12 percent) fines areas and, generally, in the higher salt content sections. The least rutting is in the Department's standard design section (6 lb per ton and containing 5 percent fines).

Core Samples

Attempts were made to core the test areas with the Department's concrete coring device but this operation was not successful. The gravel broke up when both dry and wet coring methods were attempted. Short cores were obtained from the high fines areas and the core drill operator noticed that these areas also offered considerably more resistance to drilling than did the 5 percent areas. The following year (1961) a new core drill developed by the International Salt Co. was tried on the job and was successful in obtaining cores from the 12 and 9 percent fines areas but not from the 5 percent fines areas. The cores obtained were in excellent condition, being well bonded and very dense. Figure 13 shows such a core from section 5 (9 percent fines and 12 lb salt per ton) which is typical of the other

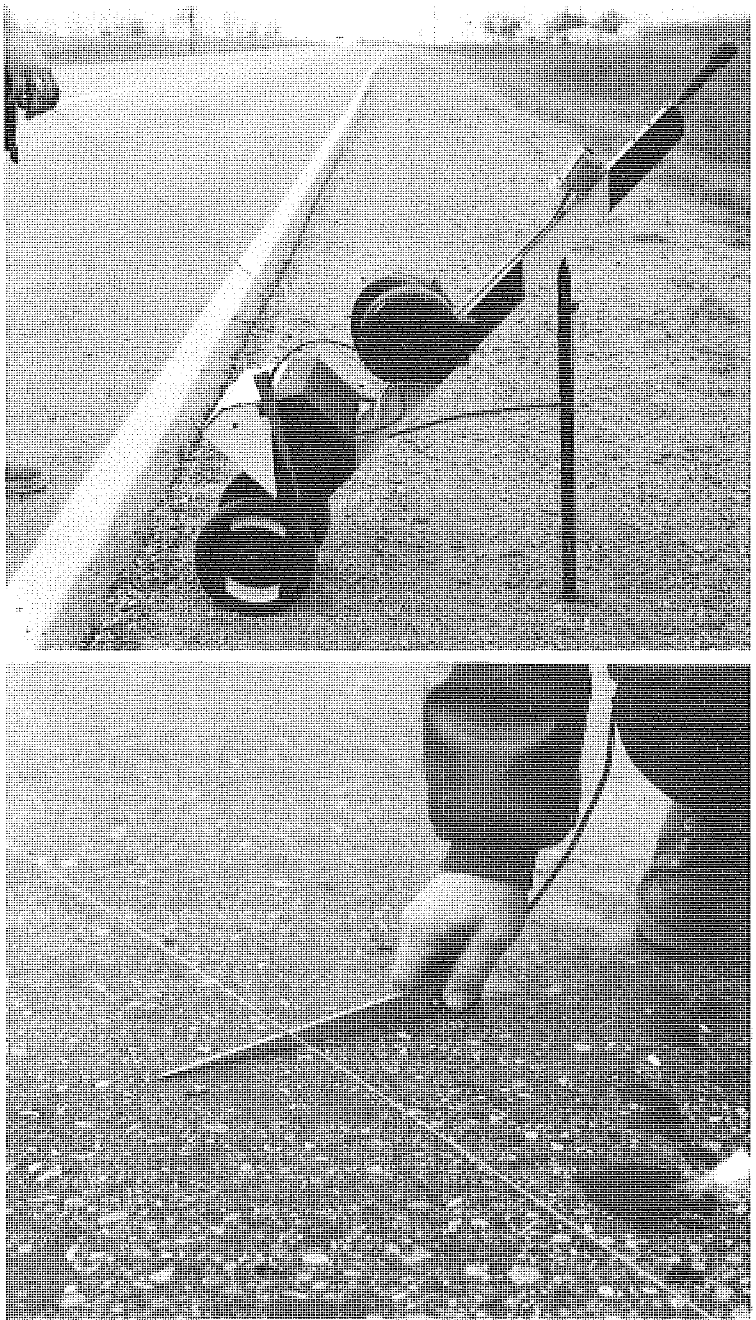


Figure 11. Rutting Measurement Device. General view of unit (top) depth indicator (bottom).

Figure 12 (right). Periodic rutting values for the test areas.

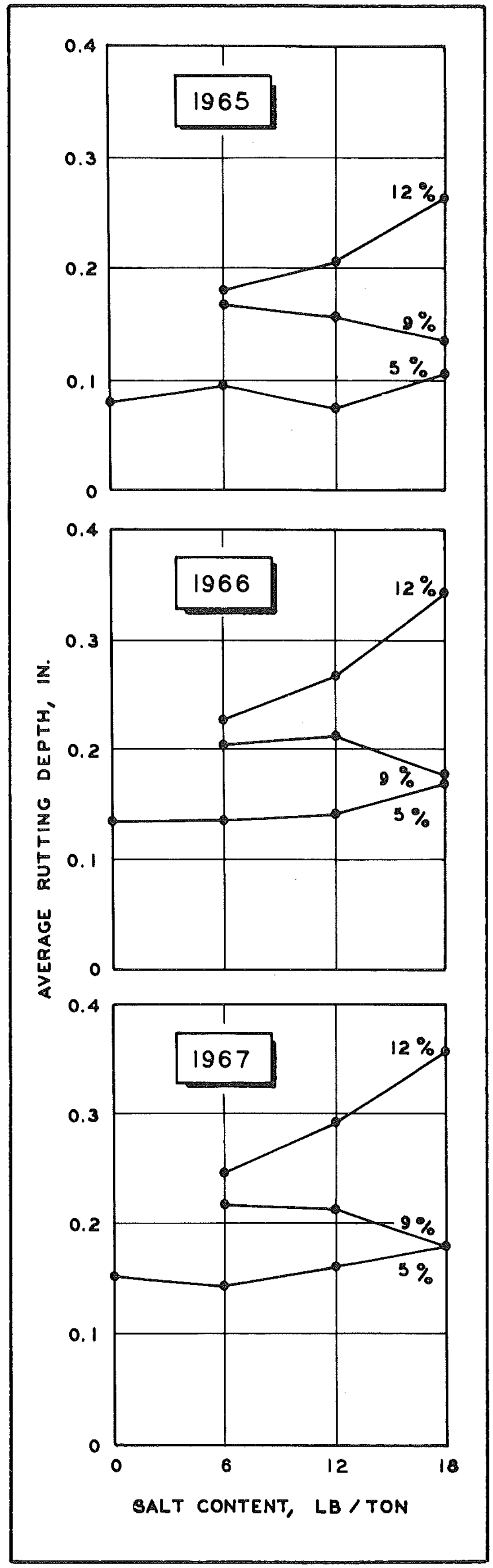
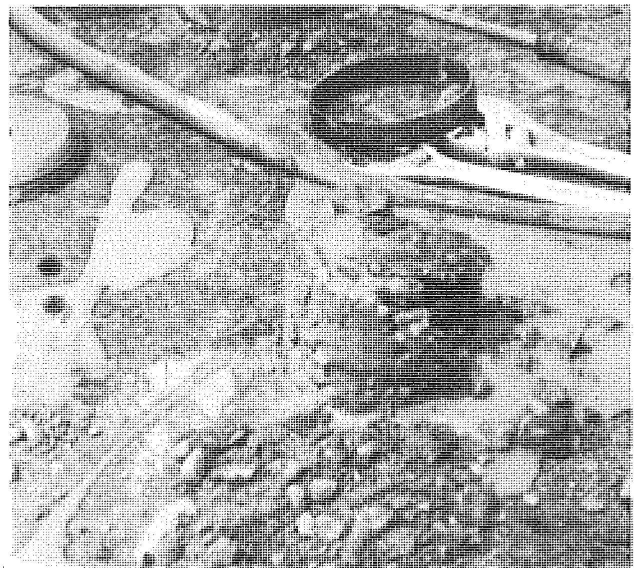


Figure 13 (left). Typical core from high fines area in 1961 (Section 5).



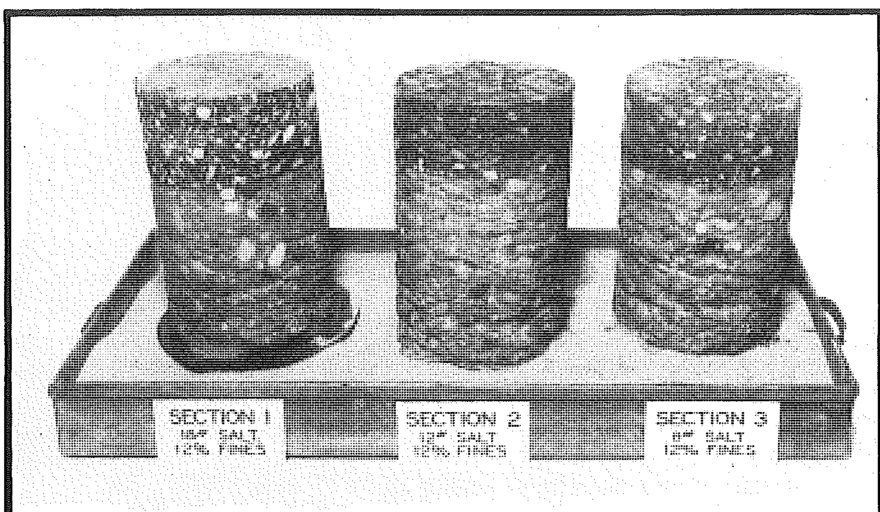


Figure 14 (above). Best core obtained from low fines area in 1961 (Section 9).

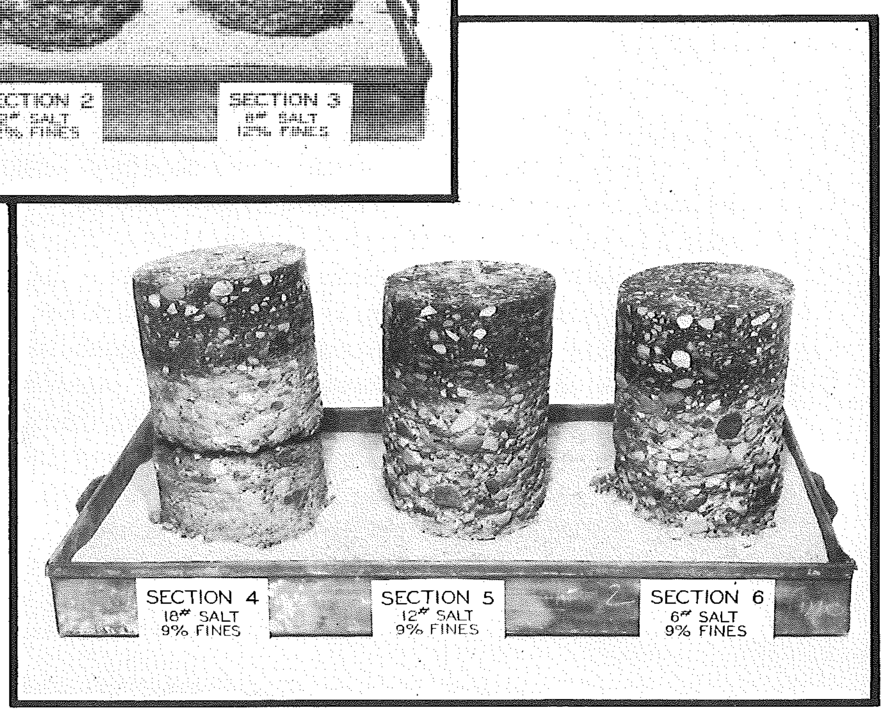


Figure 15 (top and right). Cores from high fines areas (1967).

cores from the 12 and 9 percent fines areas. The best attempt at obtaining cores from the 5 percent fines area (section 9 containing 18 lb salt per ton) is shown in Figure 14. No core portions at all were obtainable from sections 10, 11, and 12.

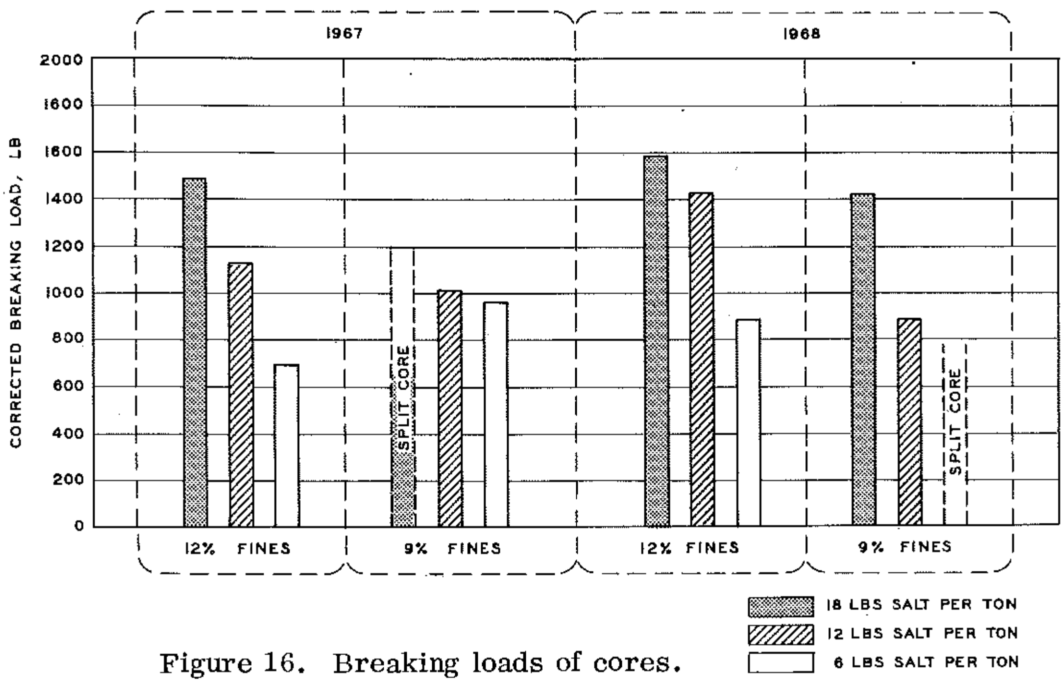


Figure 16. Breaking loads of cores.

Cores from the test areas were obtained again in 1967 and 1968. As before, no usable cores could be taken from the 5 percent fines area. Figure 15 shows the cores obtained in 1967. The core from section 4 was broken along the compaction plane of the two layers of compacted aggregate. The breaking loads (corrected to a 2:1 height to diameter ratio) for the 1967 and 1968 cores, are plotted in Figure 16. It can be seen that the compressive strength increased with the percentage of salt for the test sections containing 12 percent and 9 percent fines. The cores were broken at approximately field moisture conditions of from about 4 to 5 percent. These cores again showed the salt-treated high fines bases to be in excellent condition, well bonded and very dense.

Asphalt Surface Performance

Throughout this project there has been no indication of any detrimental effects on the application and performance of the asphalt surfacing due to salt content of the base. The adhesion of the prime and seal coat was, however, a definite function of the fines content. During testing, prior to applying the surface, it was necessary to remove the seal coat before measuring densities of the base. In the low fines areas, this could be done easily by peeling back a cut section by hand. In the high fines areas it was necessary to chip the seal coat from the base, a rather laborious operation (Fig. 17). As shown in the Figure, there was good adherance between the seal coat and base even in the low fines area, the separation taking place within the gravel itself. Examination of the cores also showed good adhesion of the asphalt to the salt surfaces, as has the performance of the pavement structure during the life of this project.

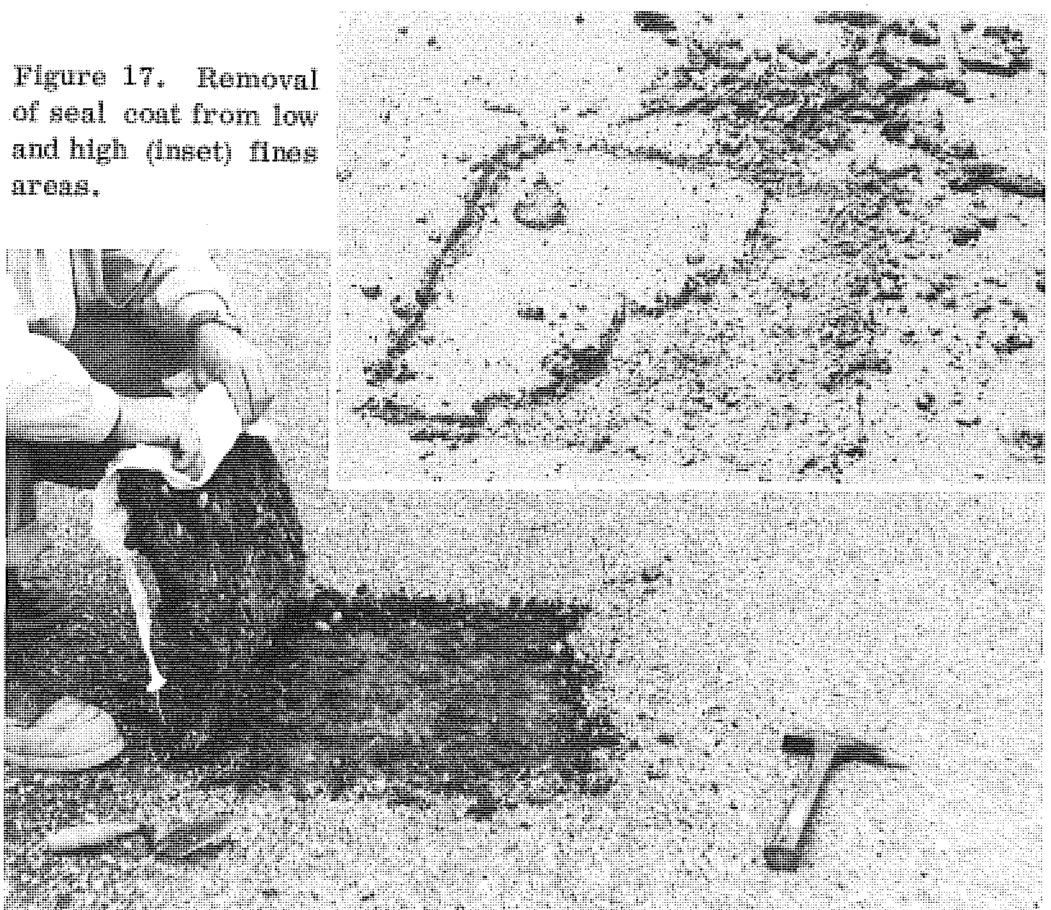


Figure 17. Removal of seal coat from low and high (inset) fines areas.

CONCLUSIONS

The nine-year evaluation of the Newaygo test sections indicates that aggregate containing up to 12 percent fines can be successfully used in base course construction when treated with rock salt. Densities, riding qualities, and rutting resistance were not a function of increased salt content but were better in all cases with the minimum (6 lb per ton) salt treatment. Michigan standard construction (in this project, 5 percent fines with 6 lb of salt per ton) performed as well as, or better than, any of the sections so that, based on the results of this project, there is no reason to change Michigan's current specification base course materials where such are economically available.

More specific conclusions are:

1. No construction problems were encountered using salt, and design densities were easily obtained. The salt dissolved readily in moist aggregate.

2. Salt-treated aggregate handled and compacted best when moisture contents were 1 to 2 percent below optimum moisture.

3. Densities of the sections increased under the action of traffic and were particularly high in the high fines areas.

4. Salt content diminished with time to constant values in the high fines sections. No significant amount of salt was found in the low fines areas after about three years.

5. Excellent cores were obtained from the high fines areas but none could be obtained from the 5 percent fines area. Core strengths from the 12 and 9 percent fines areas increased with salt content.

6. Excellent adhesion between asphalt and the salt-treated bases was obtained.

7. Sieve analysis of the bases during evaluation indicate that all of the test section aggregates had degraded by about 2 percent so that the fines were higher than the design values.

APPLICATION OF FINDINGS

As a direct result of the Newaygo studies, rock salt has been used on two other special projects in Michigan. These are in addition to its use as an allowable specification item for base course aggregate treatment.

Ontonagon Project

Rock salt was used during 1967 in an effort to upgrade an aggregate which had degraded or become contaminated with fines during use as an open surface road prior to the application of a seal coat. The area involved was an 8-1/2-mile length of the relocation construction of M 64 just west of Ontonagon in the Upper Peninsula. Originally meeting 22A specifications, the aggregate, when tested, contained much higher than the allowable 7 percent fines in amounts varying up to 16 percent, but averaging about 11 percent.

Because this gradation was similar to that which had been benefitted by salt treatment in the Newaygo project, it was decided to try the same treatment on the M 64 construction. Although 6 percent salt treatment had proven satisfactory at Newaygo, it was felt that due to possible non-uniformity of the in-place mixing required, on the present job, that the amount of treatment be increased to 12 percent.

The aggregate base was scarified, the salt spread on the surface and mixed to a full 8-in. depth with a Seaman Duo Stabilizer No. 642. The salt treatments were handled in approximately 3000-ft long sections. Figure 18 shows the mixing operation and the appearance of a mixed section after passage of the Duo Stabilizer and the appearance of the salt-treated area prior to mixing. No problems were encountered in the salt application.

The stabilization and surfacing were completed during 1967 and the job has now gone through one winter. No detrimental effects of this exposure have been noted to date. Roughometer and rutting measurements are being made periodically but it is too early to obtain any significant changes in physical characteristics. A nearby project constructed from the same aggregate source and in the same manner as the salt stabilization project has been selected as a control section for comparative roughometer and rutting measurements.

Alpena Shoulder Project

Rock salt was one of several admixtures used by the Department in an experimental project designed to evaluate the suitability of various stabilizing agents for upgrading open-surfaced aggregate shoulders. This project, located on US 23 just north of Alpena, was constructed in 1962 and includes--in addition to the salt treatment--sections treated with various quantities of asphalt and cement. The in-place aggregate approximated Michigan's 23A shoulder gradation with about 13 percent passing the No. 200 sieve, and was non-plastic.

Two rock salt sections were constructed, one containing 6 lb, the other, 12 lb of salt per ton of aggregate. Each section was two miles long, by

Figure 18. In-place mixing of salt and aggregate on the Ontonagon project (inset). Salt-treated base after mixing (unmixed salt in background).

four feet wide, by six in. compacted depth. The salt was incorporated into the aggregate by means of a Seaman Duo Stabilizer. Three passes of the mixer were required for satisfactorily mixing the salt, water, and aggregate. The test areas were surfaced with a single seal coat.

The salt sections were the easiest to construct and compact of all the test areas used in this study. With the exception of the untreated control section, the salt sections were the cheapest to construct. Periodic roughometer measurements have shown the salt sections to be among the smoothest riding of all the test areas. Throughout the project the 6 lb per ton salt sections performed as well or better than the 12 lb treatment, based on roughometer tests.

This study shows, as did the Newaygo project, that the Department specification aggregates perform satisfactorily with or without rock salt treatment. As a construction aid, however, salt offers significant benefits when used with such aggregates. These benefits do not appear to be a function of the salt content but are as readily obtainable with Michigan's recommended 6 lb per ton treatment as with higher amounts.

REFERENCES

1. Greenman, R. L., "Michigan Experiments with Sodium Chloride Stabilization," American Road Builders Association 58th Annual Meeting, January 18-21, 1960.

2. Mainfort, R. C., "Progress Report on Salt-Stabilized Sections of M 46 (Howard City to Newaygo)," MDSH Research Report No. R-548, September, 1965.

3. Gow, A. J., Davidson, D. I., and Sheeler, J. B., "Relative Effects of Chlorides, Lignosulfonates and Molasses on Properties of a Soil-Aggregate Mix." HRB Bulletin 282, pp 66-83, 1961.