Final Report

CHARACTERISTICS OF CHEMICAL

TREATED ROADWAY SURFACES

by

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ABSTRACT

Iowa Highway Commission Project HR-33, "Characteristics of Chemically Treated Roadway Surfaces", was investigated at the Iowa Engineering Experiment Station under Project 375-S. The purpose of the project as originally proposed was to study the physical and chemical characteristics of chemically treated roadway surfaces. All chemical treatments were to be included, but only sodium chloride and calcium chloride treated roadways were investigated. The uses of other types of chemical treatment were not discovered until recently, notably spent sulfite liquor and a commercial additive.

Costs of stabilized secondary roads in Hamilton County averaged $4300.00 per mile even though remanent soil-aggregate material was used. The cost of similar roads in Franklin County was $4400.00 per mile. The Franklin County road surfaces were constructed entirely from materials that were hauled to the road site. Costs in Butler County were a little over $3000.00 per mile some eight years ago.

Chemical investigations indicate that calcium chloride and sodium chloride are lost through leaching. Approximately 95 percent of the sodium chloride appears to have been lost, and nearly 65 percent of the calcium chloride has disappeared. The latter value may be much in error since surface dressings of calcium chloride are commonly used and have not been taken into account.

Clay contents of the soil-aggregate-chemical stabilized roads range from about 6 to 11 percent, averaging 8 or 9 percent. The thicknesses of stabilized mats are usually 2 to 4 inches, with in-place densities ranging from 130 to 145 pcf. Generally the densities found in sodium chloride stabilized roads were slightly higher than those found in the calcium chloride stabilized roads.

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INTRODUCTION

This report is submitted as a final report on Project HR-33 of the Iowa Highway Research Board. The project entitled "Characteristics of Chemically Treated Roadway Surfaces" was originally aimed at all types of chemical treatment. Only sodium chloride and calcium chloride treated roads have been investigated, since these chemicals have been the only types in widespread use for stabilization of secondary roads in Iowa. Only recently has spent sulphite liquor been used in one county.

The chemicals, sodium chloride and calcium chloride, are commonly called and sodium chloride is sometimes called salt although both chemicals are technically salts of hydrochloric acid. The common names will be frequently used in this report.

INITIAL INVESTIGATION

The counties in which sodium or calcium treatment is used were first located, and each county engineer was interviewed. The results of these interviews were submitted as a progress report to the Iowa Highway Research Board. The portion of the research concerning sodium chloride has been published in Bulletin 282 of the Highway Research Board, National Academy of Science. Henceforth, the Iowa Highway Research Board will be abbreviated Iowa HRB and the National Highway Research Board as HRB.

The usage of the respective chemicals in Iowa was summarized, by counties, in tables. The tables list the miles of stabilized roads, the amount of chemical incorporated into the soil during the original treatment and mixing, any additional surface treatment, the original thickness and width of the road, the type of aggregate used, and the type of binder used. A brief summary of comments by each county engineer was also included.

An experimental road was constructed in Story County the purpose of which was to determine whether or not the incorporation of calcium chloride in a crushed rock base aided in compaction. Since the treated and the untreated sections were not constructed by the same procedure, the results did not give a clear-cut answer, and the factors responsible for differences in results could not be isolated. All data from this road has been submitted to the Iowa Highway Research Department for preservation.

A laboratory study of the material used for the base course indicated that the effects of calcium chloride on compaction are not simple. The results are published in HRB Bulletin 309. It was concluded that a general statement could not be made as to whether or not the cost of calcium chloride is offset by reduced compaction costs. The calcium chloride treated base course project which the Iowa HRB comtemplates in Hamilton County should help to answer the question.

FURTHER INVESTIGATIONS

Stabilized roads in Butler, Linn, and Taylor counties were surveyed and sampled. Laboratory analyses of the samples have been made, but the results have not been fully evaluated. The data appear in Appendix A.

Sodium stabilized roads in Franklin County were investigated, and the results are in a Master of Science thesis by J. J. Marley at Iowa State University. The thesis was revised and presented as a paper at the 42nd Annual Meeting of the HRB and will be published in an HRB bulletin.

The electrical resistivity of soil-sodium chloride systems was investigated for a better understanding of the mechanism of sodium chloride stabilization. The values of resistivity were measured as a function of the type of soil, the dry density of the soil, the moisture content, and the sodium chloride content of the soil moisture. This line of investigation did little toward understanding the mechanism of sodium chloride stabilization other than to confirm previous knowledge; it was therefore abandoned. However, the investigation did indicate that electrical resistivity measurements could be an important tool in studying the physical properties of soil-metallic salt systems. Since resistivity is easily and rapidly measured the use of such measurements could expedite investigations involving the determination of properties of many samples. Properties of primary interest would be moisture content, density, and metallic salt content.

Cooperative research with the county engineers of Franklin and Hamilton counties has been initiated. Five experimental roads have been constructed in Hamilton County. Four of these roads were constructed with sodium chloride treated soil-aggregate material with each road containing a non-treated control section. The roads were constructed from existing gravel roads by combining the granular material then on the roads, additional granular material consisting of 50% pit-run gravel, and 50% class A crushed stone, and fine material (clay portion) obtained by scarifying the road bed and the shoulders. The sodium chloride was mixed integrally with the soil materials in place. Each road received a surface application of calcium chloride to prevent ravelling.

The fifth road in Hamilton County was constructed with several chemical treatments. All sections were constructed from the basic soil-aggregate material as for the four roads, except that the additional granular material was 100% class A crushed rock. The various stabilized sections received the following chemical treatment and were constructed according to the specifications shown in Appendix B.

Section	Stabilization Treatment	Surface Treatment
1	NaCl	$CaCl_2$
2	$CaCl_2$	$CaCl_2$
3	None	$CaCl_2$
4	NaCl	$CaCl_2$
5	None	$CaCl_2$
6	Armac T	None
7	Armac T	$CaCl_2$
8	None	None

A method of in-place mix control was developed for use in the construction and calculation of quantities of materials for the five experimental roads in Hamilton County. The method depends on trench sample data and has been published in HRB Bulletin 357.

An experimental road has also been constructed in Franklin County. The road is a salt-soil aggregate surface on a five mile, newly graded project and includes two control sections. The materials, including glacial clay from a clay pit, were hauled to the construction site. The specific use of glacial clay has been standard practice in Franklin County soil-aggregate stabilization for some time. The entire road was constructed by county personnel and is described in Appendix E.

PRESENTATION AND DISCUSSION OF DATA

The data appearing in the various appendices are discussed by county as follows:

Butler County

After they were constructed, five sodium chloride stabilized soil-aggregate roads were investigated in Butler County. The roads were chosen so that each was constructed during a different year. The samples are identified by number-letter combinations as indicated in Table 1. For example, the number 12 corresponds to the county numbering system of Iowa and indicated Butler County, the letter following indicates a mile segment of a road, and the final number indicates the location of the sample site within the mile. The latter numbers represent sites as follows: 1 west or south end of the mile section, 2 the mid-mile section, 3 east or north end of the mile section.

Density values were determined by the sand cone method and ranged from 134 to 163 pcf as shown in Table 1 of Appendix A. Standard Proctor values ranged from 133 to 140 for material taken from the sites where the in-place density values were determined. Such values were compared, and the in-place values expressed as a percent of standard Proctor varied from 99 to 117 percent. Averaging the values for each road gave values ranging between 103 and 109 percent of standard Proctor. The average of all in-place densities was 144 pfc and the average of all values of standard Proctor densities was 135 pcf, giving an average in-place density of 107 percent of standard Proctor.

Representative composite samples of soil material were taken at each site by digging through the stabilized surface and dividing the excavated material by the cone and quarter method. Samples were also taken in successive one inch layers. All excess sample material was returned to the hole, moistened, and compacted even with the original surface. Any discrepancy was made up from float material or from windrowed material.

The results of laboratory tests on the composite samples are shown in Table 2, Appendix A. The samples of material were generally a dark brown to a dark yellow brown, and all were classed texturally as a gravelly sandy loam with the exception of one sample (12 A 3) which classed as a gravelly sandy clay loam. The latter sample had a higher than usual clay content, a high PI value; and it exhibited an unusual toughness during the sampling procedure. The samples all classed as either A-1-b(o) or A-2-4(o) with the exception of 12 A 3 which classed as A-2-6(o). Gravel contents ranged from 23 to 48 percent, sand from 31 to 54 percent, silt from 8 to 17 percent, and clay from 6 to 12 percent.

The values of the liquid limit and the plastic limit of these composite samples fall well within the limits of the 1960 Iowa Highway Commission Specifications with the exception of two samples. These samples, 12 A 1 and 12 D 3, have PI values of 4 and 2 respectively; the minimum allowable valus is 5. The dust ratio, which is the ratio of the material passing the No. 200 sieve to that passing the No. 40 sieve, is specified to be 2/3 or less. All samples had dust ratios less than 2/3.

The PI values correlated well with the 5 micron clay content; PI and the material passing the No. 200 sieve did not correlate well. The relationship between PI and clay content was linear, the equation of which is PI = clay content-2.85. A plot of PI versus material passing the No. 200 gave a wide scattering of points which indicated no correlation.

Samples were also taken from the surface of the roads by sweeping a fifteen inch swath with a medium stiff broom. These samples were weighed and analyzed in the laboratory. The results are shown in Table 3. The colors are, in general, the same as for the composite samples; but the textural class is different for every sample. The swept samples are coarser than the composite. This can be seen by comparing the amounts of silt and clay contained in the two sets of samples. The fine material from the surface has been washed or blown away.

Table 3 also shows the amount of loose float material at each sample site. These values are for a 15 inch swath from side to side and includes any windrowed material. The inclusion of windrowed material accounts for the high and low values. Some roads have large windrows and some have small, depending on how they are maintained.

Subsequent surface sampling studies did not include windrows.

Tables 4, 5 and 6 present data for successive one-inch layers. These data indicate a slight increase with depth of fine material. The highest amounts of clay are in the bottom layer. This may be because some subgrade material was included in the sample.

Table 7 presents the sodium chloride contents found at various depths in the Butler County roads. Samples were leached with distilled water, and the resultant solution was analyzed for chlorine content and for sodium content, since calcium chloride is used for surface maintenance. Samples taken in successive one-inch layers include the top inch of the subgrade. Water contents of the layers are also included and indicate that the amount of water increased with depth. The upper 1 inch held about 3 percent water; the subgrade held from 6 to 16 percent water.

A comparison of values of sodium chloride content, as determined by the Mohr chloride method and the sodium-flame photometer method, indicate that the determination of salt through the Mohr chloride method may give errorous results. This should be expected because the chlorine percent comes from both sodium chloride and from calcium chloride. However, the amount of sodium chloride is undoubtedly low, since only the free sodium ions were leached out. The ions held on the exchange positions of the clay remained and were not included in the final sodium determination. The effect of cation exchange capacity on the determination of salt content through the positive ion should be investigated.

The average values of sodium chloride content found at various depths in Butler County roads is given in Table 8. These values are very low as compared with the amount of sodium chloride in the original material. Originially about 1/2 percent sodium chloride was added. Apparently a good share of the chemical leaches out of the road rather quickly. The older roads contained less salt than the newer roads, but compared with the original salt content the difference is insignificant. A plot of the average values of salt content versus age shows a linear relationship after the first year. Extrapolation indicates that all of the sodium chloride would be gone at about 6.5 years. Curiously, this figure agrees well with Otmar Zack's (county engineer of Butler County) statement that his sodium chloride treated roads are worn out after seven years use.

Table 9 presents some measurements also taken on the Butler County roads in 1959. In the Burggraf shear test the shear strength values of the roads ranged from 20 to 141 psi with angles of internal friction varying from 15 to 30 degrees.

Attempts to correlate these values with other properties of the roads failed, with the possible exception of that of density. Here a plot of the Burggraf shear strength versus density gave a very rough linear correlation. The standard deviation was not computed, but it would be very high.

In-place densities were also determined using the oil method; since it was felt that the sand-cone method gave unreliable results. The over-all results from the oil method and the sand cone method compare favorably. However, the oil method indicated much less difference between the high and the low values; and the results appear to be more reasonable. The over-all average from the oil method gives an in-place density of 106 percent of standard Proctor density compared with the 107 percent determined by the sand-cone method.

The float material was measured and was found to vary from 8 to 38 pounds per square foot. This represents the loose material on the surface of the roads only; it does not include the loose material in windrows.

The crown was also measured and varied from about 3 to 6 inches. The thickness of the stabilized material varied from about 1 inch to 3.5 inches. The road constructed in 1956 was somewhat thinner than expected, but there seems to be no immediate explanation.

Taylor County

A mile of calcium chloride stabilized soil-aggregate road was constructed in Taylor County by the county engineer on a trial basis using loess as the binder. Samples were taken from two sites and are designated by the same system used for Butler County. The data indicate a slight textural difference from the Butler County samples. The Taylor County samples were gravelly clay loam; the Butler County samples were gravelly sandy loam. The Taylor County samples were classed as A-2-4(o), and the Butler County samples were generally A-1-b(o). The Taylor County samples were also quite high in clay content, ranging from 10 to 13 percent. However, the PI values ranged only from 4 to 6. The swept samples indicated that the gravel was of good quality, since the gravel content was considerably higher than that in the underlying material. The dust ratio was somewhat high for the surface course, and the float material gave a dust ratio near the upper limit.

Calcium chloride contents for the stabilized material were from 0.15 to 0.17 percent. The upper one inch of the subgrade contained from 0.06 to 0.08 percent calcium chloride. The water content followed a pattern similar to that found in Butler County but the amounts were less. Low water contents were found in the surface mat, but the water content increased in the subgrade.

Linn County

Four roads were investigated in Linn County and were chosen so that four different construction years were represented. These roads were constructed by contractors from calcium chloride treated crushed stone. The samples were identified by the same system used for Butler County.

In-place densities ranged from 130 to 159 pcf, and standard Proctor densities varied from 135 to 140 pcf. The variance of in-place density expressed as a percent of standard Proctor ranged from 95 to 118 percent. The average in-place density was 143 pcf and the average standard Proctor density was 137 pcf giving an average value of in-place density of 104 percent of standard Proctor.

The float material varied from 13 to 43 pounds per linear foot compared with a range of 20 to 139 found in Butler County. The difference is primarily due to the size of the windrows left by the maintenance crews.

Table 13 presents the results of the laboratory tests run on composite samples from Linn County. The colors range from light yellow brown to dark yellow brown and the textures range from gravelly clay to gravelly sand. The materials are classed from A-1-b(o) to A-2-4(o) as in Butler County.

The clay contents of the Linn County roads are, in general, somewhat higher than those of the Butler County roads; but the values of PI are lower. This indicates a much less surface active clay-size material in the Linn County samples. This was to be expected, since the Linn County material is entirely crushed rock, and any clay-size material must come from the resulting fines, and clay material was purposefully added from a clay pit in Butler County.

The dust ratio of the Linn County samples was high in most cases, and the PI values were low. However, the roads appear to give satisfactory performance. Apparently the calcium chloride attracts enough moisture to make up for the discrepancy in binder and binding qualities.

The swept sample data in Table 14 show that the loose material on the surface of the roads is mostly sand and gravel. As in Butler County, the silt and clay were lost by wind and water erosion soon after the material was loosened from the compacted mat. The loose material all classed as a gravelly sandy loam and as A-1-a(o) or A-1-b(o). The dust ratio of the float material was also reduced below that of the mat.

The data from the various layers did not indicate any significant differences in texture or other properties from the composite samples. One sampling site, 57B2, was near the base of a hill and was apparently a zone of accumulation. The extra material probably came from blading off the top of the hill. Investigation at the top of the hill revealed very little granular material remaining. The material in the lower 4 to 7 inches appeared to be from a different source than the surface material.

Calcium chloride content data are given in Table 19. The data indicate more retention for the calcium chloride than for the sodium chloride. However, compared with the original content of about 1/2 percent, the calcium chloride content is quite low.

Table 20 shows the average values of calcium chloride content at different depths. One should note that the amount of chemical in the upper one inch grows less with age.

Hamilton County

The Hamilton County road mixtures were all designed using the method described in HRB Bulletin 357. The criteria of design was clay content, and a value of 9 percent 5 micron clay was used. Preliminary investigations showed that a value of 9 percent clay for the materials to be used would keep the PI of the final mixtures within the allowable limits of 5 to 12. Table 22 of Appendix D gives ranges of values found in the Hamilton County roads after construction. Table 22 is a summarization of Tables 24 through 28.

The data of Table 22 show that the design value of clay content was closely approximated in the roads. The ranges of PI also fell within the desired range, except for the 6-Mile Road, which is low. The latter is possibly due to the adding of crushed rock only which contributes very little surface active material as has been discussed for the Linn County data. The textures of these roads fall in the gravelly sandy loam class.

Table 23 gives surface data for the 6-Mile Road in Hamilton County. The thicknesses were determined by digging a trench half way across the road and taking an average value from the trapezoidal rule. The float material was measured by collecting all loose material within a template (as described by Mr. J. J. Marley in his M. S. thesis at ISU). The in-place densities were determined by the oil method and generally averaged about 135 pcf.

Plate bearing and Benkleman beam data have also been taken in Hamilton County, but the results are not completed enough to be included in this report.

The thickness data show that there are some unusually thick areas. There is a possibility that these places of unusual thickness coincide with areas that had to be removed and replaced. Several very soft areas were discovered by the county engineer in the Spring of 1962 and on investigation were found to be underlain by peat. The stabilized material was removed and set aside, and the peat was discarded and replaced by more stable soil materials. The road surface was then rebuilt with the old granular material plus some new aggregate.

Franklin County

The experimental road in Franklin County was constructed as described in Appendix E. Table 29 summarizes the mechanical analysis data of Tables 30 and 31, which are for sodium chloride treated and untreated soil materials respectively. The discrepancies between the treated and the untreated materials apparently result from sampling techniques or from segregation following mixing. The tendency for sodium chloride treated soils to form clay balls is mentioned in Appendix E and is a possibility, since the treated material compared with the untreated material tends toward an increased silt-clay content. The PI and the dust ratio of either treated or untreated material lie well within the permissible range.

Table 32 presents the data from the stabilized surface of the Franklin County road. The data indicate more uniformity in the Franklin County road than in the 6-Mile Hamilton County road. Values of thickness, float material, and in-place density are more uniform. These differences should be expected because different methods of construction were used. The Franklin County construction procedure lends itself to good quality control much more than does the Hamilton County procedure which includes scarification. The depth of scarification is difficult to control at best, and therefore irregular amounts of scarified material result. The Franklin County road, on the other hand, was constructed with known amounts of materials hauled to the site. These differences are most apparent in the thickness measurements. The Franklin County road varies from 3.51" to 5.83", discounting extremes; the Hamilton County 6-Mile road varies from 1.87" to 5.36", discounting extremes. Density also varies more in the Hamilton County road, covering a range of 122 to 142 pcf; the Franklin County road varies from 132 to 140 pcf, discounting extremes in both cases.

The float material on the Franklin County roads is in general quite a bit higher than on the Hamilton County road. Comparison of the average values of mechanical analysis indicates that the reason may lie in the amount of binder material. The following table is taken from average values of the usual ranges found in Table 22 of Appendix D and Table 29 of Appendix F:

County	Float	Gravel	Sand	Silt	Clay	PI
Franklin	High	46.5	37.0	9.5	6.5	6.5
Hamilton	Low	46.5	27.5	15.0	8.0	5.5

Hamilton has less sand and more silt-clay material than Franklin and has a lower incidence of float material.

CBR values of untreated materials from Franklin County were determined and the results are presented in Table 33. The CBR values are quite low for all except one sample which has an unusually high gravel content. The CBR value after soaking was found to be higher than the dry CBR value for all. This is probably due to the high density obtained, which results in a low permeability and a low absorption of water on soaking. Table 33 shows that water contents increased only 1 to 2 percent after soaking.

The distribution of moisture in CBR specimens molded with material from Franklin County was investigated; the results are given in Table 34. These results show that most of the moisture increase occurred in the outer parts of the specimens.

The increase in CBR value is probably due to a higher degree of saturation, which together with a low permeability gives a greater resistance to penetration. The greater resistance is because the water cannot escape rapidly enough.

APPENDIX A

DATA FROM BUTLER, LINN AND TAYLOR COUNTIES

The color standards used throughout these appendices are taken from a set of standards developed by the Iowa Highway Commission. The soil classifications are given on the IHC reports as PRA (Public Roads Administration) Class. The textural classification is from the same source and is given in issues of the PCA Soil Primer prior to 1956. The word <u>gravelly</u> is prefixed to all textural classifications if the soil material contains more than 10 per cent gravel. The following abbreviations are used in the tables in all the appendices which follow for all textural descriptions:

Gy - Gravelly

Sa - Sand or sandy

Si - Silt or silty

Cl - Clay or clayey

Lm - Loam or loamy

Table 1. Density Data From Butler County, 1958.

Sample	Construction	Density Values: In-place (Sand-Cone) pcf	Density Values: Standard Proctor pcf	Density Values: Percent of Std. Proctor	Average Percent of Std. Proctor
12 A 1	1953	159	139	114	108
2		143	136	105	
3		139	132	105	
12 B 1	1954	145	137	106	109
2		163	140	116	
3		146	136	107	
12 C 1	1955	134	136	99	103
2		141	134	105	
3		139	133	104	
12 D 1	1956	138	136	101	109
2		---	134	---	
3		159	136	117	
12 E 1	1957	144	133	108	103
2		134	134	100	
3		134	133	101	

Average of all in-place densities = 144 pcf

Average of all Standard Proctor densities = 135 pcf

Average value of in-place density = 107 percent of standard

Table 2. Butler County Composite Samples, 1958.

Sample	Year Constructed	Color	Texture	PRA Class	Standard Proctor Density pcf	Optimum Moisture %	Grav %	Sand %	Silt %	Clay %	LL	PL	PI	Dust Ratio No. 200 / No. 40
12 A 1	1953	Dk Br	Gy Sa Lm	A-1-b (0)	139.3	6.1	39	47	8	6	17	13	4	0.43
2		Dk Br	Gy Sa Lm	A-1-b (0)	136.4	7.2	33	50	9	8	19	13	6	0.52
3		Dk Yel Br	Gy Sa Cl Lm	A-2-6 (0)	131.9	9.0	48	31	9	12	24	13	11	0.60
12 B 1	1954	Dk Yel Br	Gy Sa Lm	A-2-4 (0)	137.0	7.0	35	39	16	10	22	15	7	0.59
2		Dk Yel Br	Gy Sa Lm	A-1-b (0)	140.0	7.3	31	48	13	8	19	14	5	0.57
3		Dk Yel Br	Gy Sa Lm	A-1-b (0)	136.0	6.9	32	45	14	9	21	15	6	0.58
12 C 1	1955	Dk Br	Gy Sa Lm	A-2-4 (0)	136.0	7.0	27	48	15	10	21	13	8	0.56
2		Dk Br	Gy Sa Lm	A-2-4 (0)	134.0	6.9	24	54	14	8	20	13	7	0.53
3		Dk Yel Br	Gy Sa Lm	A-1-b (0)	133.0	8.0	23	54	14	9	18	13	5	0.51
12 D 1	1956	Dk Yel Br	Gy Sa Lm	A-1-b (0)	136.0	7.1	28	51	13	8	19	14	5	0.53
2		Dk Yel Br	Gy Sa Lm	A-2-4 (0)	134.0	8.0	29	44	17	10	20	13	7	0.56
3		Dk Yel Br	Gy Sa Lm	A-1-b (0)	136.0	7.1	24	55	14	7	16	14	2	0.43
12 E 1	1957	Dk Yel Br	Gy Sa Lm	A-2-4 (0)	133.0	7.9	31	42	16	11	24	15	9	0.64
2		Dk Yel Br	Gy Sa Lm	A-2-4 (0)	134.0	7.7	30	46	13	11	22	13	9	0.60
3		Dk Br	Gy Sa Lm	A-2-4 (0)	134.0	8.0	30	48	10	12	23	14	9	0.57

Table 3. Butler County Swept Samples, 1958.

Sample	Year Constructed	Color	PRA Class	Texture	Gravel	Sand	Silt	Clay	Swept Weight lbs./lin. ft.
12 A 1	1953	Dk Yel Br	A-1-b(0)	Gy Sa	36	54	6	4	25
2		Dk Yel Br	A-1-b(0)	Gy Sa	34	60	3	3	30
3		Gry Br	A-1-b(0)	Gy Lm Sa	44	46	5	5	27
12 B 1	1954	Dk Yel Br	A-1-a(0)	Gy Sa	50	44	4	2	30
2		Dk Yel Br	A-1-b(0)	Gy Sa	38	57	3	2	42
3		Dk Yel Br	A-1-b(0)	Gy Sa	41	51	5	3	81
12 C 1	1955	Dk Yel Br	A-1-b(0)	Gy Lm Sa	40	50	7	3	104
2		Dk Br	A-1-b(0)	Gy Lm Sa	37	52	7	4	90
3		Dk Yel Br	A-1-b(0)	Gy Lm Sa	31	55	10	4	77
12 D 1	1956	Dk Br	A-1-b(0)	Gy Sa Lm	43	45	8	4	80
2		Dk Yel Br	A-1-b(0)	Gy Sa	35	55	7	3	139
3		Dk Yel Br	A-1-b(0)	Gy Lm Sa	31	57	8	4	109
12 E 1	1957	Dk Br	A-1-b(0)	Gy Lm Sa	46	43	6	5	20
2		Dk Yel Br	A-1-b(0)	Gy Lm Sa	45	44	6	5	21
3		Dk Yel Br	A-1-b(0)	Gy Lm Sa	42	48	5	5	27

Table 4. Butler County Top 1" layer, 1958.

Sample No.	Year Constructed	Color	PRA Class	Texture	Gravel	Sand	Silt	Clay	LL	PL	PI
12 A 1	1953	Dk Br	A-1-b(0)	Gy Sa Lm	38	48	7	7	18	13	5
2		Dk Br	A-1-b(0)	Gy Sa Lm	39	48	6	7	17	13	4
3		Dk Yel Br	A-2-6(0)	Gy Sa Cl Lm	49	27	11	13	26	14	12
12 B 1	1954	Dk Yel Br	A-2-4(0)	Gy Sa Lm	43	37	12	8	21	14	7
2		Dk Yel Br	A-1-b(0)	Gy Sa Lm	31	46	14	9	19	14	5
3		Dk Yel Br	A-2-4(0)	Gy Sa Lm	33	38	19	10	21	13	8
12 C 1	1955	Dk Yel Br	A-1-b(0)	Gy Sa Lm	30	54	10	6	20	14	6
2		Dk Yel Br	A-1-b(0)	Gy Sa Lm	22	53	16	9	19	13	6
3		Dk Yel Br	A-2-4(0)	Gy Sa Lm	25	47	19	9	19	14	5
12 D 1	1956	Dk Yel Br	A-1-b(0)	Gy Sa Lm	33	46	12	9	20	14	6
2		Dk Yel Br	A-1-b(0)	Gy Sa Lm	36	43	12	9	19	13	6
3		Dk Yel Br	A-1-b(0)	Gy Sa Lm	27	52	13	8	18	13	5
12 E 1	1957	Dk Br	A-2-4(0)	Gy Sa Lm	35	41	13	11	23	13	10
2		Dk Yel Br	A-2-4(0)	Gy Sa Lm	33	45	12	10	20	13	7
3		Dk Br	A-2-4(0)	Gy Sa Lm	38	39	12	11	24	14	10

Table 5. Butler County 2nd 1" Layer, 1958.

Sample No.	Year Constructed	Color	PRA Class	Texture	Gravel	Sand	Silt	Clay	LL	PL	PI
12 A 1	1953	Dk Br	A-2-4(0)	Gy Sa Lm	31	49	11	9	20	13	7
2		Dk Yel Br	A-1-b(0)	Gy Sa Lm	38	45	9	8	19	13	6
3		--	--	--	--	--	--	--	--	--	--
12 B 1	1954	Dk Yel Br	A-2-4(0)	Gy Sa Lm	26	44	19	11	24	14	10
2		Dk Yel Br	A-2-4(0)	Gy Sa Lm	28	47	16	9	19	14	5
3		Dk Br	A-2-6(0)	Gy Sa Lm	21	44	22	13	25	13	12
12 C 1	1955	Dk Yel Br	A-1-b(0)	Gy Sa Lm	28	50	14	8	20	15	5
2		Dk Yel Br	A-2-4(0)	Gy Sa Lm	25	48	16	11	20	13	7
3		Dk Yel Br	A-2-4(0)	Gy Sa Lm	23	49	17	11	20	14	6
12 D 1	1956	Dk Yel Br	A-1-b(0)	Gy Sa Lm	28	47	15	10	20	14	6
2		Dk Yel Br	A-2-4(0)	Gy Sa Lm	30	44	16	10	20	14	6
3		Dk Yel Br	A-2-4(0)	Gy Sa Lm	18	57	15	10	17	14	3
12 E 1	1957	Dk Yel Br	A-2-4(0)	Gy Sa Lm	26	43	16	15	24	14	10
2		Dk Yel Br	A-2-4(0)	Gy Sa Lm	38	42	11	9	22	13	9
3		Dk Br	A-2-4(0)	Gy Sa Lm	29	45	13	13	24	14	10

Table 6. Butler County 3rd 1" Layer 1958.

Sample	Year Constructed	Color	PRA Class	Texture	Gravel	Sand	Silt	Clay	LL	PL	PI
12 A 1	1953										
2											
3											
12 B 1	1954										
2											
3											
12 C 1	1955	Dk Yel Br	A-1-b(0)	Gy Sa Lm	24	49	17	10	21	15	6
2		Dk Yel Br	A-2-4(0)	Gy Sa Lm	26	49	15	10	21	14	7
3		Dk Yel Br	A-2-4(0)	Gy Sa Lm	21	49	18	12	20	14	6
12 D 1	1956	Dk Br	A-2-4(0)	Gy Sa Lm	18	56	16	10	23	13	10
2											
3											
12 E 1	1957										
2		Dk Yel Br	A-2-6(0)	Gy Sa Lm	29	43	14	14	25	13	12
3		Dk Br	A-2-6(1)	Gy Sa Cl Lm	27	38	17	18	28	16	12

Table 7. Butler County, Sodium Chloride Content Data.

Sample	Layer[a]	NaCl[b] Content % Cl Basis	NaCl[c] Content % Na Basis	Average[d] NaCl Content % Na Basis	Water Content %
12 A 1	1	0.009	0.008	0.014	2.7
	2	0.019	0.012		5.2
	3	0.033	0.022		8.2
	4	0.023	0.018		5.9
12 A 2	1	0.012	0.014	0.029	2.8
	2	0.022	0.019		3.8
	3	0.083	0.053		13.8
	4	0.174	0.150		15.7
12 A 3	1	0.025	0.009	0.014	4.7
	2	0.050	0.019		9.4
	3	0.091	0.028		12.9
12 B 1	1	0.009	0.014	0.015	3.6
	2	0.013	0.016		5.9
	3	0.023	0.024		8.5
12 B 2	1	0.013	0.011	0.013	5.6
	2	0.016	0.014		5.6
	3	0.016	0.018		7.6
12 B 3	1	0.009	0.012	0.016	4.1
	2	0.016	0.019		5.0
	3	0.021	0.026		9.7
12 C 1	1	0.069	0.026	0.028	3.8
	2	0.066	0.026		4.1
	3	0.047	0.021		4.9
	4	0.117	0.068		17.3
12 C 2	1	0.131	0.033	0.035	3.1
	2	0.092	0.037		5.0
	3	0.061	0.025		5.5
12 C 3	1	0.246	0.069	0.055	4.4
	2	0.155	0.053		4.8
	3	0.138	0.042		6.0
	4	0.089	0.031		10.7

Table 7. (cont'd.)

Sample No.	Layer[a]	NaCl[b] Content % Cl Basis	NaCl[c] Content % Na Basis	Average[d] NaCl Content % Na Basis	Water Content %
12 D 1	1	0.053	0.034	0.036	2.4
	2	0.047	0.029		3.1
	3	0.092	0.045		5.2
	4	0.110	0.066		11.3
12 D 2	1	0.078	0.041	0.048	2.8
	2	0.053	0.054		3.8
	3	0.136	0.078		12.6
12 D 3	1	0.096	0.049	0.048	2.3
	2	0.082	0.046		4.0
	3	0.145	0.068		8.8
12 E 1	1	0.056	0.054	0.046	2.8
	2	0.038	0.038		4.0
	3	0.025	0.025		7.6
12 E 2	1	0.077	0.082	0.065	2.3
	2	0.055	0.066		2.1
	3	0.038	0.047		5.0
	4	0.033	0.033		8.0
12 E 3	1	0.059	0.052	0.047	2.8
	2	0.057	0.053		4.0
	3	0.038	0.035		5.4
	4	0.065	0.054		12.5

[a]Layer numbers represent layers one inch thick. Layer 1 is the top 1 inch of material. Layer 2 is the 2nd inch of material, etc.

[b]Chlorine content determined by Mohr's method and expressed as sodium chloride.

[c]Sodium content determined by flame photometer and expressed as sodium chloride.

[d]This value is a numerical average computed from values for the upper layers only. The value from the lower layer was excluded because the lower layer lies entirely within the subgrade.

Table 8. Average Percentages of Sodium Chloride Content Found at Various Depths in Butler County Roads Tabulated Under The Year The Road Was Constructed.

	1953	1954	1955	1956	1957
1"	0.010	0.012	0.043	0.041	0.063
2"	0.017	0.016	0.039	0.043	0.052
3"	0.034	0.023	0.029	0.064	0.039
4"	0.034		0.050	0.066	0.044

Table 9. Butler County Test Results, 1959.

Sample No.	Construction Year	Burggraf Shear Test Shear, psi	Burggraf Shear Test Ø, degrees	In-place (oil-method) pcf	Standard Proctor pcf	Percent of Std. Proctor	Float Material, lbs. per linear ft.	Crown Height, inches	Thickness of Surface Course, inches
12 A 1	1953	85.2	21.5	146	139	105	24	5.9	0.9
2		54.6	23.6	141	136	104	8	6.2	0.8
3		114.0	24.0	150	132	114	29	5.7	1.0
Average		84.6	23.0	146	136	107	20	5.9	0.9
12 B 1	1954	53.3	14.9	152	137	111	17	3.9	0.8
2		28.1	18.8	135	140	97	31	2.7	1.4
3		39.7	25.3	151	136	111	13	3.4	1.4
Average		40.4	19.7	146	138	106	20	3.3	1.2
12 C 1	1955	30.6	20.8	135	136	99	21	5.3	2.3
2		42.2	20.1	137	134	102	36	6.0	2.4
3		33.5	20.6	143	133	108	38	5.1	3.5
Average		35.4	20.5	138	134	103	31	5.5	2.7
12 D 1	1956	20.6	28.4	146	136	107	22	4.5	0.9
2		78.2	26.6	142	134	106	32	5.7	1.2
3		141.0	30.3	152	136	112	15	5.6	1.3
Average		79.9	28.4	147	135	109	23	5.3	1.1
12 E 1	1957	30.4	22.7	139	133	105	32	5.1	2.9
2		25.2	21.5	---	134	---	21	5.0	2.5
3		78.9	23.1	134	133	101	20	4.4	2.1
Average		44.8	22.4	137	133	103	25	4.8	2.5

Average of all in-place densities = 143 pcf

Average of all Standard Proctor densities = 135 pcf

Average in-place density = 106 percent of average Standard Proctor

Table 10. Data From Taylor County Experimental Road.

Sample No.	Layer	Color	Texture	PRA Class	Gravel %	Sand %	Silt %	Clay %	LL	PL	PI	Dust Ratio
87 A 1	1"	Dk Yel Br	Gy Cl Lm	A-2-4(0)	46	22	19	13	21	15	6	0.73
	2"	Dk Yel Br	Gy Lm	A-2-4(0)	40	25	23	12	23	17	6	0.72
87 A 2	1"	Dk Yel Br	Gy Cl Lm	A-2-4(0)	53	19	18	10	21	17	4	0.70
87 A 1	Swept	Lt Br Gr	Gy Cl Lm	A-1-a(0)	71	14	9	6	19	15	4	0.65
87 A 2	Swept	Lt Br Gr	Gy Cl Lm	A-1-b(0)	68	15	10	7	18	15	3	0.65

Table 11. Calcium Chloride Content Data From Taylor County Experimental Road.

Sample No.	Layer[a]	$CaCl_2$[b] Content % Cl Basis	Average[c] $CaCl_2$ Content %	Water Content %
87 A 1	1	0.17	0.14	3.4
	2	0.17		3.6
	3	0.08		10.7
87 A 2	1	0.15	0.12	4.1
	2	0.06		6.9

[a]Layer numbers represent layers of material one inch thick. Layer 1 is the top 1 inch of material. Layer 2 is the 2nd inch of material, etc.

[b]Chlorine content determined by Mohr's method and expressed as calcium chloride.

[c]This value is the numerical average of all layers. The lower layer included subgrade material.

Table 12. Density Data From Linn County, 1958.

Road	Construction Year	Density Values In-place (sand-cone) pcf	Density Values Standard Proctor pcf	Percent of Std. Proctor	Float Material lbs. per linear ft.	Optimum Moisture Percent
57 A 1	1954	130	137	95	18.0	6.3
2		159	135	118	19.2	7.5
Average					18.6	
57 B 1	1955	154	139	111	39.4	8.2
2		143	138	104	23.2	6.8
3		---	140	---	12.8	6.0
Average					25.1	
57 C 1	1956	141	135	104	15.6	7.0
2		140	135	104	19.2	7.8
3		138	138	100	21.2	6.9
Average					18.7	
57 D 1	1957	150	138	109	31.2	7.5
2		138	137	101	36.8	8.0
3		140	137	102	42.8	7.2
Average					36.9	

Average of all in-place densities = 143 pcf

Average of all (except 57 B 3) Standard Proctor densities = 137 pcf

Average value of in-place density = 104 percent of standard

Table 13. Composite Sample Data From Linn County.

Sample	Year	Color	Texture	PRA Class	Gravel	Sand	Silt	Clay	LL	PL	PI	Dust Ratio
57 A 1	1954	Lt Yel Br	Gy Sa Lm	A-1-b(0)	38	35	16	11	16	13	3	0.57
2		Gry Br	Gy Sa	A-1-b(0)	38	56	3	3	16	13	3	0.58
57 B 1	1955	Lt Yel Br	Gy Lm	A-1-b(0)	58	19	16	7	19	14	5	0.70
2		Dk Yel Br	Gy Lm	A-2-4(0)	49	25	16	10	19	14	5	0.68
3		Dk Yel Br	Gy Sa Lm	A-1-b(0)	52	28	13	7	15	13	2	0.56
57 C 1	1956	Dk Yel Br	Gy Cl	A-2-4(0)	38	31	17	14	19	15	4	0.67
2		Lt Yel Br	Gy Cl Lm	A-2-4(0)	45	27	15	13	18	13	5	0.68
3		Lt Yel Br	Gy Sa Cl Lm	A-1-b(0)	49	26	14	11	18	13	5	0.66
57 D 1	1957	Lt Yel Br	Gy Cl Lm	A-2-4(0)	44	23	21	12	19	12	7	0.77
2		Lt Yel Br	Gy Cl Lm	A-2-4(0)	49	20	18	13	22	14	8	0.79
3		Lt Yel Br	Gy Lm	A-2-4(0)	50	24	18	8	18	13	5	0.72

Table 14. Swept Sample Data From Linn County.

Sample No.	Year Constd.	Color	Texture	PRA Class	Gravel %	Sand %	Silt %	Clay %	LL	PL	PI	Dust Ratio No. 200 / No. 40
57 A 1	1954	Lt Yel Br	Gy Sa Lm	A-1-a(0)	68	22	6	4	15	12	3	0.59
2		Lt Br Gry	Gy Sa Lm	A-1-a(0)	59	27	8	6	14	12	2	0.50
57 B 1	1955	Lt Gry Br	Gy Sa Lm	A-1-a(0)	68	22	7	3	-	NP	-	0.59
2		Lt Gry Br	Gy Sa Lm	A-1-a(0)	71	22	5	2	-	NP	-	0.51
3		Lt Gry Br	Gy Lm Sa	A-1-a(0)	69	25	4	2	-	NP	-	0.35
57 C 1	1956	Lt Yel Br	Gy Sa Lm	A-1-a(0)	71	22	4	3	-	NP	-	0.49
2		Lt Gry	Gy Sa Lm	A-1-b(0)	54	24	13	9	14	13	1	0.61
3		Gry	Gy Sa Lm	A-1-a(0)	62	25	7	6	15	13	2	0.54
57 D 1	1957	Lt Yel Br	Gy Sa Lm	A-1-b(0)	59	24	12	5	15	12	3	0.68
2		Lt Yel Br	Gy Sa Lm	A-1-b(0)	60	23	11	6	16	14	2	0.71
3		Lt Br Gry	Gy Sa Lm	A-1-b(0)	55	24	14	7	18	14	4	0.75

Table 15. 1" Depth Sample Data From Linn County.

Sample No.	Year Constd.	Color	Texture	PRA Class	Gravel %	Sand %	Silt %	Clay %	LL	PL	PI	Dust Ratio
57 A 1	1954	Lt Yel Br	Gy Cl Lm	A-2-4(0)	46	26	16	12	18	13	5	0.68
2		Lt Yel Br	Gy Cl Lm	A-2-4(0)	41	26	20	13	16	12	4	0.66
57 B 1	1955	Lt. Br Gry	Gy Sa Lm	A-1-b(0)	54	24	16	6	16	14	2	0.66
2		Dk Yel Br	Gy Lm	A-2-4(0)	45	26	18	11	22	14	8	0.69
3		Lt Br Gry	Gy Sa Lm	A-1-b(0)	52	25	14	9	17	14	3	0.64
57 C 1	1956	Lt Yel Br	Gy Sa Cl Lm	A-2-4(0)	39	30	18	13	17	13	4	0.67
2		Lt. Yel Br	Gy Sa Cl Lm	A-1-b(0)	44	31	13	12	17	13	4	0.67
3		Lt Yel Br	Gy Sa Lm	A-2-4(0)	41	33	15	11	16	13	3	0.64
57 D 1	1957	Lt Yel Br	Gy Cl Lm	A-2-4(0)	46	25	18	11	19	13	6	0.78
2		Lt Yel Br	Gy Cl Lm	A-2-4(0)	51	21	17	11	21	14	7	0.78
3		Lt Yel Br	Gy Cl Lm	A-2-4(0)	47	20	21	12	22	14	8	0.80

Table 16. 2" Depth Data From Linn County

Sample No.	Year	Color	Texture	PRA Class	Gravel %	Sand %	Silt %	Clay %	LL	PL	PI	Dust Ratio
57 B 1	1955	Lt Br Gry	Gy Sa Lm	A-1-b(0)	54	24	16	6	16	14	2	0.67
2		Dk Yel Br	Gy Sa Lm	A-2-4(0)	57	24	11	8	20	13	7	0.65
57 C 1	1956	Lt Yel Br	Gy Sa Lm	A-2-4(0)	39	30	16	15	17	13	4	0.66
2		Mod Yel Br	Gy Sa Lm	A-1-b(0)	46	31	12	11	17	13	4	0.66
3		Lt Yel Br	Gy Sa Lm	A-1-b(0)	44	33	13	10	16	13	3	0.59
57 D 1	1957	Lt Yel Br	Gy Lm	A-2-4(0)	45	24	20	10	20	14	6	0.78
2		Lt Yel Br	Gy Cl Lm	A-2-4(0)	48	20	19	13	22	15	7	0.82

Table 17. 3" Depth Sample Data From Linn County.

Sample No.	Year	Color	Texture	PRA Class	Gravel %	Sand %	Silt %	Clay %	LL	PL	PI	DR
57 B* -	1955											
2		Dk Yel Br	Gy Cl Lm	A-2-4(0)	55	20	13	12	22	13	9	0.74
57 C 1	1956	Lt Yel Br	Gy Sa Lm	A-2-4(0)	37	34	17	12	16	13	3	0.62
2		Lt Yel Br	Gy Sa Cl Lm	A-2-4(0)	41	33	13	13	20	14	6	0.67
3		Dk Yel Br	Gy Sa Lm	A-2-4(0)	47	27	16	10	18	14	4	0.65

* 3" & 4" Depth.

Table 18. 5" & 6" Depth Sample Data From Linn County.

Sample No.	Year	Color	Texture	PRA Class	Gravel %	Sand %	Silt %	Clay %	LL	PL	PI	DR
57 B - 2	1955	Dk Yel Br	Gy Lm	A-2-4(0)	45	23	21	11	22	15	7	0.73

Table 19. Calcium Chloride Content Data From the Linn County Experimental Road.

Sample No.	Layer[a]	$CaCl_2$[b] Content % Cl Basis	Average[c] $CaCl_2$ Content %	Water Content %
57 A 1	1	0.11	0.19	4.2
	2	0.26		11.4
57 A 2	1	0.13	0.13	3.9
	2	0.22		5.5
57 B 1	1	0.13	0.15	1.8
	2	0.09		2.4
	3	0.23		17.1
57 B 2	1	0.30	0.12	2.6
	2	0.13		2.6
	3,4	0.09		3.3
	5,6	0.04		3.5
	7	0.05		17.6
57 B 3	1	0.04	0.04	4.1
	2	0.04		10.5
57 C 1	1	0.42	0.19	3.1
	2	0.17		2.6
	3	0.08		3.6
	4	0.07		14.0
57 C 2	1	0.25	0.14	2.8
	2	0.19		3.2
	3	0.07		3.3
	4	0.05		9.7
57 C 3	1	0.19	0.08	3.1
	2	0.06		2.7
	3	0.04		3.5
	4	0.04		8.9

Table 19. cont'd.

Sample No.	Layer[a]	$CaCl_2$[b] Content % Cl Basis	Average[c] $CaCl_2$ Content %	Water Content %
57 D 1	1	0.20	0.17	3.4
	2	0.14		4.0
	3	nil		7.6
57 D 2	1	0.28	0.27	3.8
	2	0.26		4.3
57 D 3	1	0.31	0.13	4.1
	2	0.03		6.3
	3	0.06		5.9

[a]Layer numbers represent layers one inch thick. Layer 1 is the top one inch of material. Layer 2 is the 2nd inch of material, etc.

[b]Chlorine content determined by Mohr's method and expressed as calcium chloride.

[c]This value is a numerical average computed from values for all layers.

Table 20. Average Percentages of Calcium Chloride Content Found at Various Depths in Linn County Roads Tabulated Under The Year The Road Was Constructed.

	1954	1955	1956	1957
1"	0.12	0.16	0.29	0.36
2"	0.24	0.09	0.14	0.14
3"		0.16	0.06	0.03
4"		0.09	0.05	
5"		0.04		
6"		0.04		
7"		0.05		

Appendix B

Specifications from

Hamilton County

Appendix B

Specifications from Hamilton County

DIVISION 3

Stabilized Surfacing Constructed on various Secondary Roads.

SEC. 1 Project 1961-3 From N¼ Cor. Sec. 17-88-26 East 1.00 Mile to N¼ Cor. Sec. 16-88-26.
Class C Gravel 394 Tons
Class A Crushed Stone 394 Tons
Sodium Chloride 12 Tons
Calcium Chloride 5.77 Tons

Project 1961-5 From W¼ Cor. Sec. 5-88-25 East & South 3.00 Miles to W¼ Cor. Sec. 10-88-25.
Class C Gravel 2358 Tons
Class A Crushed Stone 2358 Tons
Sodium Chloride 36 Tons
Calcium Chloride 17.31 Tons

Project 1961-7 From W¼¼ Cor. N. Line Sec. 28-87-26 East 4.75 Miles to NW Cor. Sec. 29-87-25.
Class C Gravel 2988 Tons
Class A Crushed Stone 2988 Tons
Sodium Chloride 57 Tons
Calcium Chloride 27.41 Tons

Project 1961-22 From E¼¼ Cor. N. Line Sec. 31-87-26 East 1.25 Miles to NW Cor. Sec. 33-87-26.
Class C Gravel 754 Tons
Class A Crushed Stone 754 Tons
Sodium Chloride 15 Tons
Calcium Chloride 7.21 Tons

SEC. 2

Project 1961-21 From NW Cor. Sec. 35-87-23 North 6.00 Miles to NW Cor Sec. 35-88-23.
Class A Crushed Stone 4500 Tons
Sodium Chloride 26 Tons
Calcium Chloride 50.9 Tons

DIVISION III Stabilized Surfacing construction on various secondary roads.

SEC. 1. Work and Materials under this section to be according to I.S.H.C. Standard Specifications For Construction Work Series 1960, where applicable and all Current Special Provisions, where applicable.

Note Special Provisions No. 3-1 attached.

Project 1961-3 Sec. 1 From N¼ Cor. Sec. 17-88-26 East 1.0 Mile to N¼ Cor. Sec. 16-88-26

Airport Road

Item		Approximate Quantities
1.	Class C Gravel	394 Tons
2.	Class A Crushed Stone	394 Tons
3.	Application only Sodium Chloride	12 Tons
4.	Scarifying, Pulverizing, Blending, Spreading & Compacting	1.00 Mile
5.	Application only Calcium Chloride Surface Treatment	5.77 Tons

Project 1961-5 Sec. 1 From W¼ Cor. Sec. 5-88-25 East and South 3.00 Miles to W¼ Cor. Sec. 10-88-25.

L-Road

Item		Approximate Quantities
1.	Class C Gravel	2358 Tons
2.	Class A Crushed Stone	2358 Tons
3.	Application only Sodium Chloride	36 Tons
4.	Scarifying, Pulverizing, Blending, Spreading & Compacting	3.00 Miles
5.	Application only Calcium Chloride Surface Treatment	17.31 Tons

Project 1961-7 Sec. 1 From W¼¼ Cor. N. Line Sec. 28-87-26 East 4.75 Miles to NW Cor. Sec. 29-87-25

5 Mile Road

Item		Approximate Quantities
1.	Class C Gravel	2988 Tons
2.	Class A Crushed Stone	2988 Tons
3.	Application only Sodium Chloride	57 Tons
4.	Scarifying, Pulverizing, Blending, Spreading & Compacting	4.75 Miles
5.	Application only Calcium Chloride Surface Treatment	27.41 Tons

Project 1961-22 Sec. 1 From E¼-¼ Cor. N. Line Sec. 31-87-26 East 1.25 Miles to NW Cor. Sec. 33-87-26.

Stratford Road

Item	Approximate Quantities
1. Class C Gravel	754 Tons
2. Class A Crushed Stone	754 Tons
3. Application Only Sodium Chloride	15 Tons
4. Scarifying, Pulverizing, Blending, Spreading & Compacting	1.25 Miles
5. Application Only Calcium Chloride Surface Treatment	7.21 Tons

SECTION 2

Work and materials under this section according to I.S.H.C. Sta. Specs. for Construction Work Series 1960 where applicable, and all Current Special Provisions, where applicable. Note Special Provisions No. 3-2 attached.

Project 1961-21 Sec. 2 From NW Cor. Sec. 35-87-23 North 6.00 Miles to NW Cor. Sec. 35-88-23.

6 Mile Road

Item	Approximate Quantities
1. Class A Crushed Stone	4500 Tons
2. Application Only Sodium Chloride	26 Tons
3. Application Only Calcium Chloride	10.5 Tons
4. Scarifying, Pulverizing, Blending, Spreading & Compacting	6.00 Miles
5. Application Only Calcium Chloride Surface Treatment	40.4 Tons

SPECIAL PROVISION NO. 3-1

Applicable to Div. 3 Sec. 1

1. Work to be done consists of stabilized surfacing on secondary roads shown on attached map and include Projects 1961-3, 5, 7, 22.

2. Additional granular materials for the work shall consist of Class C. Gravel and Class A Crushed Stone, meeting requirements set forth in Sec. 4120 Sta. Specs. They shall be applied at the following average rates per mile:

Project No.	Class C Gravel	Class A Stone
1961-3 Airport Road	394 Tons	394 Tons
1961-5 L-Road	786 Tons	786 Tons
1961-7 5 Mile Road	629 Tons	629 Tons
1961-22 Stratford Road	603 Tons	603 Tons

Actual application rates will vary, as designated by the Engineer through the length of each project.

3. Necessary binder will be obtained by scarification to an approximate average depth of 3 to 3.5 inches.

4. The additional granular material and the scarified material will be placed in windrow on the shoulder of the road in the same ratio as specified by the Engineer, for rate of application and depth of scarification. The subgrade will be bladed to remove irregularities and to obtain a uniform 6 inch crown on a 24 ft. width.

5. All materials shall be thoroughly pulverized and blended by road manipulation until all of the materials are combined so that individual characteristics of the various materials are not visible in the mixture.

6. After the materials are blended, or during the blending process, Sodium Chloride shall be added at the rate of 10 lbs. per ton of materials or 12 ton per mile. Total amount of blended aggregate and scarified material is approx. .2402 tons per mile.

7. After the materials have been mixed and the sodium chloride added, water shall be applied and mixed through the blended material in sufficient quantities to disolve the sodium chloride and to secure maximum density during compaction.

8. The contractor shall spread the material on the road to a width of 24 ft. and a depth of approx. 3.5 inches.

9. Compaction required must be uniform over the road and must equal or exceed 90% of Proctor Density as prescribed in Art. 4100.10 Standard Specifications.

10. Sodium Chloride will be furnished at no cost to the contractor and will be delivered to various road intersections on the individual projects. Contractors bid price for sodium chloride will include loading, hauling and spreading the sodium chloride.

11. Calcium Chloride will be furnished at no cost to the contractor in bulk form in hopper cars located as follows:

Project 1961-5 & 1961-3 Webster City, Iowa
Project 1961-7 & 1961-22 Stanhope, Iowa

Contractors bid price for calcium chloride will include loading & unloading, necessary water for solution, hauling to project and application on project. Application rate is 0.8 lb. per sq. yd. in solution 24 ft. wide. A 34% Calcium Chloride Concentration will be required for all solution applications.

12. Contractor shall furnish the gravel and crushed stone aggregates delivered on road.

13. Water added during construction of the surface and for the calcium chloride surface treatment will not be paid for as a separate item. Include this cost in other items bid.

14. Compaction equipment and procedures will be indentical through the length of the Project. Initial compaction shall be with a rubber tired roller.

15. Compaction shall be completed the same day the material is spread.

16. Contractor will designate to the Engineer the time of delivery of sodium and calcium chloride. Contractor will be responsible for all demurrage. The Engineer will require 7 days advance notice of the delivery date requested.

SPECIAL PROVISION NO. 3-2
Applicable to Div. 3 Sec. 2

1. Work to be done consists of stabilized surfacing on secondary roads shown on attached map. Project 1961-21

2. Additional granular material for the work shall consist of Class A Crushed Stone meeting requirements set forth in Sec. 4120 Sta. Specs. The stone shall be applied at an average rate per mile of 750 tons. Actual rate through the length of the project shall be as designated by the Engineer.

3. Necessary binder will be obtained by scarifying the existing roadbed to an approximate depth of 3.75 inches.

4. The additional granular material and the scarified material will be placed in windrow on the shoulder of the road in the same ratio as specified by the Engineer for rate of application and depth of scarification. The subgrade will be bladed to remove irregularities and to obtain a uniform 6 inch crown on the 24 ft. width.

5. All materials shall be thoroughly pulverized and blended by road manipulation until all of the materials are combined so that individual characteristics of the various materials are not visible in the mixture.

6. The type of chemical used and the method of use, will vary through the length of the project as follows:

1st. Mile-(South End) Sodium Chloride applied at rate of 10 lbs per ton of material or 13 ton per mile. Calcium Chloride surface treatment at rate of 0.8 lb. per sq. yd. in solution, 24 ft. wide.

2nd. Mile-Calcium Chloride applied in pellet form and mixed integrally with materials on road at rate of 8 lb. per ton of material or 10.5 tons per mile. Calcium Chloride surface treatment at rate of 0.8 lbs. per sq. yd. in solution, 24 ft. wide.

3rd. Mile-No chemical mixed integrally. Calcium Chloride surface treatment at rate of 1.6 lb. per sq. yd. in solution, 24 ft. wide.

4th. Mile-Sodium Chloride applied at rate of 10 lb. per ton or 13 ton per mile. Calcium Chloride surface treatment at rate of 0.8 lb. per sq. yd. in solution, 24 ft. wide.

5th. Mile-No chemical mixed integrally. Calcium chloride surface treatment at rate of 1.6 lb. per sq. yd. in solution, 24 ft. wide.

6th. Mile-(South Half) Armac T applied in solution and mixed with materials on road before laying materials down. No surface treatment on ¼ mile and calcium chloride on ¼ mile.

6th. Mile-(North Half) No chemical mixed integrally. No surface treatment.

7. Total amount of aggregate and scarified material is approximately 2622 tons per mile.

8. After materials have been mixed and chemicals added, water shall be applied and mixed through the blended material in sufficient quantities to disolve the chemical and to insure maximum density during compaction.

9. The contractor shall spread the material on the road to a width of 24 ft. and a depth of approximately 3.75 inches to 4 inches.

10. Compaction required must be uniform over the road and must equal or exceed 90% of Proctor Density as prescribed in Art. 4100.10 Sta. Specs.

11. Sodium Chloride will be furnished at no cost to the contractor and will be delivered to various road intersections in the area treated. Contractor's bid price for sodium chloride will include loading, hauling and spreading sodium chloride.

12. Calcium chloride will be furnished at no cost to the contractor in bulk form in hopper cars located at Ellsworth, Iowa. Contractor's bid price for calcium chloride will include loading, unloading, hauling and dry application mixed integrally in the 2nd. Mile and loading necessary water for solution, hauling, and application of solution on project for miles 1, 2, 3, 4, & 5. A 34% Calcium Chloride Concentration will be required for all solution applications.

13. Armac T will be furnished at no cost to the contractor at the job site.

14. Contractor shall furnish the crushed stone aggregate delivered on the road.

15. Water added during construction of the surface and for the calcium chloride surface treatment will not be paid for as a separate item. Include this cost in other items bid.

16. Compaction equipment and procedures will be identical through the length of the project. Initial compaction shall be with a rubber tired roller.

17. Compaction shall be completed the same day the material is spread.

18. Contractor will designate to the Engineer, time of delivery of Sodium and Calcium Chloride; contractor will be responsible for all demurrage. The Engineer will require 7 days advance notice of the delivery date requested.

Appendix C

Comments on the Hamilton County Experimental Roads

Appendix C

Comments on the Hamilton County Experimental Roads

The following comments and data on the five experimental roads in Hamilton County were obtained from County Engineer Wesley Smith and Assistant County Engineer Merle Easing.

Difficulties Found

The primary difficulties experienced were in chemical handling. The difficulties were traceable to either faulty equipment or to the lack of proper equipment. The calcium chloride presented problems in going into solution which were due to faulty seals on a recirculating pump. The sodium chloride was mostly spread with county equipment because an agricultural limestone spreader hired for the job was not always available when needed.

Excluding the 6-Mile experimental project, the crushed rock and gravel to be added were delivered two months before construction and were windrowed on the edges of the roads. Moisture accumulated under these windrows and caused the edges of the road-bed to soften. Due to the softness in these places it was difficult to get adequate compaction.

Mixing Procedure

The following stepwise mixing procedure was adopted and used on all roads:

(1) additional material spotted according to predetermined rates;

(2) additional material spread evenly across road;

(3) added material and old road bed scarified to a predetermined constant depth;

(4) windrowed all loose material;

(5) a part of the windrow taken at one time mixed with a Seaman Pulvi-mixer and an 8 foot disc with 24 inch blades until all materials were thoroughly pulverized and mixed.

The use of the disc in conjunction with the Seaman Pulvi-mixer allowed a greater amount of material to be mixed at one time.

Comments

In three or four locations, 300 to 400 feet long, sections showed evidence of too much binder material. All these sections were in the 6-mile road and on top of hills. At no other sections on the other ten miles of construction was there evidence of too much binder.

Ravelling was noted on the north mile of the 6-mile road. One-half of this mile was untreated, and one-half of it was treated with Armac-T. One-half of the Armac-T section was given a surface treatment of calcium chloride and one-half was left with no surface treatment. It was noted that the Armac-T section ravelled worse than the untreated section. Little difference was noted between the calcium chloride surface treated Armac-T section and the untreated Armac-T section.

Standard Proctor densities of the raw materials (no chemical added) for the 6-mile road ranged from 132 to 135 pcf. In-place density determinations on the finished surface ranged from 94 to 99 percent of standard Proctor and averaged about 97 percent.

Construction Costs

The costs associated with the construction of the 16 miles of stabilized roads in Hamilton County are given in Table 21. The 6-mile road costs were somewhat lower than the rest because of the amount of granular material in place before construction. If the 6-mile road is omitted the average cost of construction in the remaining 10 miles is $4292.00 per mile.

Table 21. Construction Costs in Hamilton County

Project	Item	Cost, $	Length, miles	Cost $/mile
Airport Road	Contractor	3,010.58		
	Calcium chloride	300.57		
	Sodium chloride	176.00		
		3,487.15	1	3487
L-Road	Contractor	12,610.66		
	Calcium chloride	901.71		
	Sodium chloride	490.80		
		14,003.17	3	4668
5-Mile Road	Contractor	18,909.58		
	Calcium chloride	1,358.43		
	Sodium chloride	743.00		
		20,192.01	4 3/4	4251
6-Mile Road	Contractor	18,114.98		
	Calcium chloride	2,501.73		
	Sodium chloride	374.00		
		20,990.71	6	3498
Stratford Road	Contractor	4,636.86		
	Calcium chloride	378.69		
	Sodium chloride	225.00		
		5,240.55	1 1/4	4192
	Grand Total	63,913.59	16	3995

Appendix D

Data

from

Hamilton County

Table 22. Ranges in Mechanical Analysis Data From Hamilton County

Road	Texture	Range	Gravel %	Sand %	Silt %	Clay %	PI	Dust Ratio
6 mi. Rd.	Gy. Sa. Lm.	High	57.2	36.4	22.4	12.2	11	0.88
		Low	34.7	20.6	10.9	4.3	1	0.54
		Usual	41 - 52	22 - 33	12 - 18	6 - 10	3 - 8	0.62 - 0.73
L Road	Gy. Sa. Lm.	High	55.0	37.4	18.5	11.7	12	0.72
		Low	39.8	26.7	8.7	5.3	3	0.51
		Usual	44 - 51	28 - 33	11.5 - 15.5	7.7 - 10	6 - 8	0.63 - 0.67
5 mi. Rd.	Gy. Sa. Lm.	High	62.2	31.6	16.3	11.8	11	0.75
		Low	40.3	22.8	10.2	5.2	6	0.67
		Usual	49.5 - 54.5	25 - 29	10.5 - 11.5	7.8 - 8.8	8 - 10	0.70 - 0.75
Stratford	Gy. Sa. Lm.	High	56.0	36.0	17.4	6.8	9	0.68
		Low	39.8	25.8	11.2	6.4	6	0.60
		Usual	44 - 52	30 - 36	11 - 13.5	6.4 - 6.8	6 - 9	0.60 - 0.68
Airport	Gy. Sa. Lm.	High	59.4	34.4	13.4	9.8	10	0.68
		Low	43.5	25.2	10.0	6.2	5	0.62
		Usual	43 - 51	32 - 34.4	10 - 12.2	6.2 - 8.1	7 - 10	0.62 - 0.68

Table 23. Surface data, 6 mile road.

Location	Average Thickness in.	Float Mt. lb./sq. ft.	In-place Dry Density pcf
3 + 00	2.48	0.63	113.1
7 + 00	4.63	0.60	134.9
11 + 00	3.25	0.39	129.9
15 + 00	2.10	0.53	84.9*
19 + 00	3.82	0.65	122.7
23 + 00	2.08	0.51	137.8
27 + 00	2.95	0.75	137.8
31 + 00	2.75	0.62	141.6
35 + 00	2.71	0.40	136.3
39 + 00	3.31	0.51	133.5
43 + 00	3.23	1.01	139.7
47 + 00	2.52	0.86	134.3
51 + 00	3.54	0.70	100.0
55 + 00	3.37	0.69	138.9
59 + 00	3.15	0.64	134.9
63 + 00	2.03	0.50	132.3
67 + 00	2.89	0.40	135.1
71 + 00	1.95	0.43	129.8
75 + 00	2.65	0.38	136.8
85 + 00	1.35	0.33	129.5
89 + 00	2.81	0.42	133.6
93 + 00	1.87	0.34	133.4
97 + 00	4.32	0.44	133.9
101 + 00	2.58	0.30	138.0
105 + 00	2.73	0.20	132.2

Table 23 cont'd.

Location	Average Thickness, in.	Float Mtl. lb./sq. ft.	In-place Dry Density pcf
109 + 00	2.43	0.54	133.6
113 + 00	2.72	0.43	140.7
117 + 00	1.66	0.33	133.1
121 + 00	2.99	0.59	133.2
125 + 00	2.57	0.36	131.9
129 + 00	3.64	0.46	139.9
133 + 00	2.84	0.32	124.1
137 + 00	4.13	0.29	130.1
141 + 00	2.70	0.31	139.0
145 + 00	3.96	0.40	139.1
149 + 00	2.38	0.47	129.1
153 + 00	3.87	0.45	139.9
157 + 00	4.34	0.34	129.3
161 + 00	4.16	0.41	129.5
165 + 00	4.15	0.44	129.5
169 + 00	3.28	0.90	127.2
173 + 00	2.96	1.07	133.0
177 + 00	4.18	0.57	131.88
181 + 00	2.52	0.38	124.0
185 + 00	3.26	0.68	132.4
189 + 00	4.08	0.67	135.7
193 + 00	3.22	0.44	115.5*
197 + 00	6.96*	0.77	131.0
201 + 00	3.37	1.00	137.6
205 + 00	3.09	0.47	122.4

Table 23 cont'd.

Location	Average Thickness, in.	Float Mtl. lb./sq. ft.	In-place Dry Density pcf
209 + 00	3.14	0.69	130.2
214 + 00	3.44	0.46	134.8
217 + 00	4.02	0.77	133.8
221 + 00	2.15	0.45	121.7
225 + 00	3.56	0.70	133.3
229 + 00	3.00	0.77	114.2*
233 + 00	2.73	0.55	124.0
237 + 00	3.86	0.63	139.1
241 + 00	4.27	0.90	136.1
245 + 00	3.62	0.79	145.1
265 + 00	2.94	154	131.6
269 + 00	4.92	1.01	143.1*
273 + 00	3.87	1.90	139.0
277 + 00	3.27	0.79	142.0*
281 + 00	3.36	1.07	141.9*
285 + 00	5.02	0.56	138.0
289 + 00	5.19	0.56	131.0
293 + 00	5.36	0.48	134.0
297 + 00	3.53	0.50	129.5
301 + 00	3.92	0.59	134.6
305 + 00	4.58	0.61	132.7
309 + 00	4.14	0.69	136.2
313 + 00	4.58	0.61	122.6

* Unusual values

Table 24. Mechanical Analysis Data, 6 Mile Road.

Location	Gravel	Sand	Silt	Clay	Silt & Clay	Soil Passing # 40	Dust Ratio	LL	PL	PI
5 + 00	50.0	24.8	17.5	8.7	26.2	39.3	0.67	19	17	2
15 + 00	45.9	22.1	22.4	9.6	32.0	43.5	0.73	21	17	4
27 + 00	50.8	25.2	17.2	6.8	24.0	35.2	0.68	21	16	5
37 + 00	43.7	28.7	16.6	11.0	27.6	43.0	0.64	28	20	8
45 + 00	50.0	28.2	15.1	6.7	21.8	34.0	0.64	19	15	4
55 + 00	54.4	20.6	18.3	6.7	25.0	35.3	0.71	26	18	8
67 + 00	47.4	22.6	19.5	10.5	30.0	41.2	0.73	26	18	8
75 + 00	52.1	23.9	16.0	8.0	24.0	34.4	0.70	22	16	6
85 + 00	41.8	25.4	20.6	12.2	32.8	47.4	0.69	25	18	7
95 + 00	51.1	27.9	13.0	8.0	21.0	32.2	0.65	24	16	8
105 + 00	34.7	32.0	21.0	12.3	33.3	38.0	0.88	28	17	11
117 + 00	50.3	23.0	16.7	10.0	26.7	36.5	0.73	25	18	7
125 + 00	52.1	28.9	11.5	7.5	19.0	29.6	0.64	21	16	5
135 + 00	53.1	26.7	12.9	7.3	20.2	31.3	0.64	23	17	6
145 + 00	42.4	31.8	15.8	10.0	25.8	39.0	0.66	22	17	5
153 + 00	47.2	29.4	13.4	10.0	23.4	33.3	0.70	22	15	7
165 + 00	50.6	27.7	13.3	8.4	21.7	34.2	0.63	22	18	4

Table 24 cont'd.

Location	Gravel	Sand	Silt	Clay	Silt & Clay	Soil Passing # 40	Dust Ratio	LL	PL	PI
177 + 00	57.2	21.5	15.0	6.3	21.3	32.5	0.66	20	16	4
187 + 00	54.8	25.5	10.9	8.8	19.7	28.8	0.68	18	15	3
197 + 00	51.4	30.3	13.0	5.3	18.3	27.5	0.66	18	16	2
205 + 00	48.5	27.7	14.0	9.8	23.8	33.2	0.72	23	17	6
213 + 00	42.3	29.8	21.9	6.0	27.9	40.6	0.69	21	14	7
227 + 00	47.4	30.3	14.3	8.0	22.3	34.1	0.65	22	16	6
237 + 00	36.8	34.4	18.2	10.6	28.8	44.8	0.64	24	18	6
243 + 00	39.7	35.4	15.7	9.2	24.9	37.5	0.66	18	15	3
253 + 00	45.0	33.6	13.7	7.7	21.4	34.2	0.62	18	15	3
265 + 00	49.2	31.5	13.3	6.0	19.3	30.8	0.63	17	14	3
277 + 00	47.4	32.8	13.4	6.4	19.8	33.6	0.59	20	17	3
283 + 00	54.0	31.8	9.9	4.3	14.2	26.3	0.54	18	17	1
293 + 00	50.8	22.4	9.8	7.0	16.8	28.8	0.58	17	16	1
305 + 00	41.2	33.0	17.8	8.0	25.8	40.8	0.63	18	15	3
315 + 00	42.3	36.4	13.5	7.8	21.3	35.8	0.59	18	13	5

Table 25. Mechanical Analysis Data, L-Road.

Location	Gravel	Sand	Silt	Clay	Silt & Clay	Soil Passing # 40	Dust Ratio	LL	PL	PI
5 + 00	45.0	29.8	15.5	9.7	25.2	36.4	0.69	25	16	9
15 + 00	55.0	27.0	8.8	9.2	18.0	28.2	0.64	23	15	8
25 + 00	39.8	32.6	16.9	10.7	27.6	38.5	0.72	24	18	6
35 + 00	48.7	31.8	13.3	6.2	19.5	29.7	0.66	22	16	6
45 + 00	50.5	31.5	10.2	7.8	18.0	26.7	0.67	22	17	5
55 + 00	47.0	26.7	15.4	10.9	26.3	37.0	0.71	30	18	12
65 + 00	48.9	28.4	13.9	8.8	22.7	33.6	0.67	26	19	7
75 + 00	41.6	32.4	18.5	7.7	26.2	46.0	0.57	20	16	4
85 + 00	43.9	32.6	12.0	11.7	23.7	37.2	0.64	22	16	6
95 + 00	52.9	29.3	13.5	6.3	19.8	28.3	0.70	22	16	6
105 + 00	44.7	28.0	16.7	10.6	27.3	42.3	0.64	26	19	7
115 + 00	47.0	31.7	11.9	9.4	21.3	33.3	0.64	25	19	6
125 + 00	48.4	32.4	11.4	7.8	19.2	30.4	0.63	20	16	4
135 + 00	50.4	28.4	12.5	8.7	21.2	32.8	0.65	23	16	7
145 + 00	51.6	37.4	8.7	5.3	14.0	24.3	0.58	18	15	3
155 + 00	44.8	32.4	11.4	7.8	19.2	32.6	0.59	21	16	5

Table 26. Mechanical Analysis Data, 5-Mile Road.

Location	Gravel	Sand	Silt	Clay	Silt & Clay	Soil Passing # 40	Dust Ratio	LL	PL	PI
5 + 00	40.3	31.6	16.3	11.8	28.1	40.1	0.70	29	19	10
15 + 00	53.7	26.0	11.5	8.8	20.3	27.1	0.75	25	17	8
65 + 00	51.8	28.6	11.5	8.1	19.6	27.6	0.71	28	18	10
75 + 00	54.5	25.1	10.2	10.2	20.4	29.2	0.70	28	19	9
85 + 00	49.6	31.3	11.3	7.8	19.1	28.4	0.67	29	18	11
115 + 00	62.2	22.8	10.8	5.2	16.0	21.3	0.75	23	17	6

Table 27. Mechanical Analysis Data, Stratford Road.

Location	Gravel	Sand	Silt	Clay	Silt & Clay	Soil Passing # 40	Dust Ratio	LL	PL	PI
15 + 00	39.8	36.0	17.4	6.8	24.2	39.6	0.61	26	17	9
25 + 00	44.1	35.6	13.5	6.8	20.3	33.9	0.60	21	15	6
35 + 00	56.0	25.8	11.4	6.8	18.2	26.9	0.68	22	15	7
45 + 00	51.6	30.6	11.2	6.6	17.8	26.1	0.68	24	17	7
57 + 00	46.8	33.5	13.3	6.4	19.7	31.5	0.62	25	17	8

Table 28. Mechanical Analysis Data, Airport Road.

Location	Gravel	Sand	Silt	Clay	Silt & Clay	Soil Passing # 40	Dust Ratio	LL	PL	PI
5 + 00	43.5	33.3	13.4	9.8	23.2	34.0	0.68	26	17	9
15 + 00	--	--	--	--	--	--	--	32	22	10
25 + 00	50.7	32.3	11.1	6.2	17.3	26.3	0.66	22	17	5
35 + 00	45.3	34.4	12.2	8.1	20.3	32.6	0.62	26	18	8
45 + 00	59.4	25.2	10.0	6.4	16.4	26.3	0.62	24	17	7

Appendix E

Description of Experimental Road

in Franklin County

APPENDIX E

Construction of Experimental Sodium Chloride Stabilized

ROAD IN FRANKLIN COUNTY

The following data, concerning the construction of the experimental road in Franklin County was furnished by County Engineer W. H. Jorgenrud.

Salt stabilization has been used in Franklin County for some time and has been accepted as satisfactory for the purpose for which it is intended. The primary purpose for the use of salt stabilization in Franklin County is to reduce gravel loss. Salt stabilized material has been used in the past as a base for asphaltic concrete with good results. This road was constructed in 1961 with no plans for an asphalt surface. Traffic counts, made by the Highway Commission in 1957, at two points on the 5 miles were 57 and 35 vehicles per day. The road was graded in 1960 with all soil material coming from the roadside ditches or from local borrow. The soil materials were not selected.

The stabilized surface was constructed from a soil-aggregate-sodium chloride mix consisting of 2370 tons per mile of pit run gravel, crushed to a 3/4 inch maximum size limit with no specified gradation, 400 tons per mile of heavy dark glacial clay which is suitable for pottery and 10 tons of sodium chloride per mile. The stabilized section is 4 inches thick, 26 feet wide and has a 6 inch crown.

Two control sections, having no chemical treatment, were left. One extends from 1/4 mile north of the south end to 1/2 mile north of the south end of the project, the other extends from 1/4 mile south of Highway 3 to the railroad tracks.

A contract was let for hauling the materials onto the road, but the construction was done by county personnel with county equipment. The gravel and clay were placed in separate windrows on one side of the roadway and were then mixed. Mixing was with a blade grader and pulvi-mixers, one Seaman, and one Thrun which mounts on the front end of the blade grader.

The clay and gravel mixture was then spread evenly over the roadway, and the sodium chloride was spread with a truck spreader. The materials were then mixed in an air-dry state by windrowing and re-windrowing to the opposite side. (Some mixing difficulty was encountered during a previous project when water was added immediately after spreading the salt and large clay balls formed. Air dry mixing of the salt and soil materials before adding water has eliminated the difficulty.)

After being mixed finally the material was spread uniformly over the roadway, water was added if necessary, and compaction was with a rubber tire roller. The material was rolled until "hard", and no density checks were made.

The initial cost of salt stabilized roads in Franklin County varies primarily with haul distance, gravel costs, and clay costs. The cost of materials, hauling, and construction of this 5 mile project completed in 1961 was $22,000, or $4,400 per mile.

Appendix F

Data

from

Franklin County

Table 29. Ranges in Mechanical Analysis data from Franklin County.

SAMPLE	TEXTURE	RANGE	GRAV %	SAND %	SILT %	CLAY %	PI	DUST RATIO
Treated with NaCl	Gy.Sa.Lm	High	52.1	46.6	12.6	9.8	13	0.75
		Low	35.8	29.8	7.0	4.4	4	0.55
		Usual	44 - 49	35 - 39	8 - 11	5 - 8	4 - 9	0.60-0.70
Untreated	Gy.Sa.Lm	High	66.0	50.0	17.0	14.5	17	0.75
		Low	28.0	27.0	4.0	2.0	4	0.51
		Usual	43 - 53	34 - 44	55 - 11	3 - 6	7 - 12	0.56-0.62

Table 30. Mechanical analysis data from sodium chloride treated soil materials, Franklin County

Location	Gravel	Sand	Silt	Clay	Silt & Clay	Soil Passing #40	Dust Ratio	LL	PL	PI
5 + 00	47.3	37.9	8.5	6.3	14.8	24.0	0.62	21	17	4
15 + 00	48.5	33.5	11.3	6.7	18.0	24.0	0.75	23	15	8
25 + 00	44.2	39.2	10.6	6.0	16.6	25.7	0.64	22	16	6
35 + 00	44.6	38.6	10.5	6.3	16.8	26.8	0.63	22	15	7
45 + 00	44.0	38.7	11.3	6.0	17.3	24.8	0.70	21	15	6
55 + 00	47.7	35.1	11.1	6.1	17.2	25.2	0.68	22	14	8
65 + 00	-	-	-	-	-	-	-	24	15	9
75 + 00	35.8	46.6	12.6	5.0	17.6	33.4	0.53	20	16	4
85 + 00	42.7	41.5	10.4	5.4	15.8	27.3	0.58	22	14	8
95 + 00	46.0	39.2	9.0	5.8	14.8	23.4	0.63	22	17	5
105 + 00	44.3	38.1	11.3	6.3	17.6	27.2	0.65	20	16	4
115 + 00	43.9	40.6	9.1	6.4	15.5	25.2	0.61	20	15	5
125 + 00	45.0	38.0	10.6	6.4	17.0	27.4	0.62	20	16	4

Table 30. cont'd.

Location	Gravel	Sand	Silt	Clay	Silt & Clay	Soil Passing #40	Dust Ratio	LL	PL	PI
135 + 00	46.5	36.5	11.0	6.0	17.0	27.4	0.62	22	13	9
145 + 00	41.9	41.3	10.4	6.4	16.8	27.5	0.61	20	15	5
155 + 00	47.4	36.3	9.3	7.0	16.3	26.2	0.62	20	14	6
165 + 00	-	-	-	-	-	-	-	21	15	6
175 + 00	44.8	42.2	7.0	6.0	13.0	23.6	0.55	20	16	4
185 + 00	48.2	29.8	7.6	4.4	12.0	19.8	0.61	21	15	6
195 + 00	49.0	36.2	8.6	6.2	14.8	25.6	0.58	23	16	7
205 + 00	43.7	35.1	12.2	9.0	21.2	30.5	0.69	27	14	13
215 + 00	52.1	35.1	7.9	4.9	12.8	20.1	0.63	20	14	6
225 + 00	44.5	38.8	8.7	8.0	16.7	25.6	0.65	23	13	10
235 + 00	49.2	37.1	7.4	6.3	13.7	23.3	0.59	21	15	6
245 + 00	46.4	36.3	9.3	8.0	17.3	27.2	0.64	22	15	7
255 + 00	44.8	35.4	10.0	9.8	19.8	30.0	0.66	25	15	10

Table 31. Mechanical analysis data from untreated soil materials, Franklin County.

Location	Gravel	Sand	Silt	Clay	Silt & Clay	Soil Passing #40	Dust Ratio	LL	PL	PI
5 + 00	37.5	50.0	8.0	4.5	12.5	24.5	0.51	18.8	NP	-
15 + 00	53.0	32.0	9.8	5.2	15.0	25.7	0.58	22.2	13.0	9.2
25 + 00	-	-	-	-	-	-	-	19.6	12.2	7.4
35 + 00	47.5	40.5	8.0	4.0	12.0	20.6	0.58	21.0	14.3	6.7
45 + 00	48.5	40.5	6.5	4.5	11.0	18.8	0.58	19.3	9.7	9.6
55 + 00	50.3	37.2	9.5	3.0	12.5	18.5	0.67	21.8	13.8	8.0
65 + 00	57.0	34.5	5.5	3.0	8.5	13.7	0.62	19.9	15.8	4.1
75 + 00	50.0	41.0	5.67	3.33	9.0	17.5	0.51	21.3	14.5	6.8
85 + 00	65.5	27.0	-	-	-	-	-	21.3	13.8	7.5
105 + 00	28.0	40.5	17.0	14.5	31.5	44.1	0.71	27.3	10.6	16.7
115 + 00	42.0	42.5	9.50	6.0	15.5	27.6	0.56	18.9	9.2	9.7
125 + 00	53.0	39.0	5.0	3.0	8.0	15.0	0.53	17.9	11.6	6.3

Table 31. cont'd.

Location	Gravel	Sand	Silt	Clay	Silt & Clay	Soil Passing #40	Dust Ratio	LL	PL	PI
135 + 00	51.0	36.0	10.0	3.0	13.0	21.4	0.61	19.9	10.3	9.6
145 + 00	39.0	44.0	11.0	6.0	17.0	30.1	0.56	19.2	11.8	7.4
155 + 00	46.0	41.5	8.5	4.0	12.5	21.5	0.59	18.8	10.8	8.0
165 + 00	-	-	-	-	-	-	-	-	-	-
175 + 00	51.0	34.0	10.0	5.0	16.0	23.4	0.68	22.3	7.0	15.3
185 + 00	55.5	34.0	10.0	5.0	15.0	20.0	0.75	19.3	9.6	9.7
195 + 00	43.0	42.5	8.5	6.0	14.5	23.4	0.62	20.9	10.4	10.5
205 + 00	66.0	28.0	4.0	2.0	6.0	10.4	0.57	15.1	NP	-
215 + 00	48.0	41.5	7.0	3.5	10.5	18.8	0.56	18.6	8.8	9.8
225 + 00	46.0	41.5	7.5	5.0	12.5	22.3	0.56	20.3	8.3	12.0
235 + 00	50.0	31.0	15.0	4.0	19.0	26.9	0.71	20.1	11.9	8.2
245 + 00	43.0	39.0	10.0	8.0	18.0	29.3	0.61	22.8	15.1	7.7
255 + 00	50.0	37.0	8.0	5.0	13.0	21.4	0.61	18.9	7.9	11.0

Location	Float Material Thickness	In-place lbs/sq.ft.	Dry density pcf
5 + 00	5.53	1.04	-
15 + 00	3.69	1.53	-
25 + 00	5.83	2.24	135.9
35 + 00	3.46	1.41	133.3
45 + 00	5.32	1.06	136.9
55 + 00	3.75	1.16	132.0
65 + 00	4.48	1.45	140.3
75 + 00	5.12	1.55	136.0
85 + 00	4.66	1.09	132.1
95 + 00	4.79	1.64	132.3
105 + 00	4.84	1.48	134.7
115 + 00	4.84	1.03	133.8
125 + 00	6.53	0.71	151.7*
135 + 00	3.89	1.29	132.0
145 + 00	5.12	1.19	-
155 + 00	5.21	1.16	-
165 + 00	4.65	0.71	-
175 + 00	3.92	1.01	-
185 + 00	4.09	1.13	-
195 + 00	4.41	0.64	-
205 + 00	4.27	0.92	-
215 + 00	3.51	-	-

*Abnormal Value

Table 33. CBR values of untreated materials.

Location	Dry CBR 0.2" pen %	Soaked CBR 0.2" pen %	Moisture Content at Molding %	Moisture Content after Soaking %	Moisture Content Increase %	PI
5 + 00	3.3	6.1	10.6	-	-	-
15 + 00	3.1	6.0	10.0	11.0	1.0	9.2
25 + 00	4.6	5.2	10.0	10.8	0.8	7.4
35 + 00	3.1	8.0	10.9	12.0	1.1	6.7
45 + 00	3.0	7.1	9.6	-	-	9.6
55 + 00	4.3	5.7	9.4	10.4	1.0	8.0
65 + 00	5.3	16.3	9.8	10.9	1.1	4.1
75 + 00	3.7	5.8	10.1	-	-	6.8
85 + 00	6.7	8.7	10.3	-	-	9.4
95 + 00	9.3	13.8	9.9	11.2	1.3	7.5
105 + 00	5.5	6.0	10.6	12.1	1.5	16.7
115 + 00	7.3	9.5	10.8	11.9	1.1	9.7
125 + 00	4.3	8.8	10.3	11.0	0.8	6.3
135 + 00	2.8	4.9	10.0	11.7	1.7	9.6
145 + 00	3.3	4.5	9.5	11.0	1.5	7.4
155 + 00	3.2	3.8	9.6	11.4	1.8	8.0
175 + 00	2.7	6.5	10.4	12.5	2.1	15.3
185 + 00	3.2	5.9	9.9	11.2	1.3	9.7
195 + 00	2.5	4.3	10.7	11.8	1.1	10.5
205 + 00	34.8*	40.7*	10.3	12.1	1.8	NP
215 + 00	4.5	8.2	10.2	11.4	1.2	9.8
225 + 00	3.5	5.8	9.8	10.6	1.2	12.0
235 + 00	2.9	4.2	9.6	10.7	1.1	8.2
245 + 00	5.7	7.8	10.6	12.1	1.5	7.7
255 + 00	2.9	4.1	10.7	11.9	1.2	11.0

*Abnormal Values

Table 34. Moisture content variations within CBR specimens after soaking. Untreated material, Franklin County.

Location	Condition	Moisture Content at the height of					
		0"	1"	2"	3"	4"	5"
135 + 00	Dry	10.07	10.44	9.75	3.35	10.59	9.49
	Soaked	11.58	9.96	9.83	26.18	10.23	10.08
155 + 00	Dry	10.70	10.27	9.79	10.01	9.62	11.79
	Soaked	15.16	13.72	10.96	5.93	12.83	9.46
185 + 00	Dry	10.81	10.74	10.03	8.68	10.30	10.57
	Soaked	18.05	9.43	7.60	8.37	10.41	11.62
195 + 00	Dry	8.88	8.31	9.73	6.52	9.16	11.31
	Soaked	14.16	13.27	11.80	10.57	12.56	10.69
215 + 00	Dry	11.69	9.41	10.56	10.01	9.20	10.32
	Soaked	11.57	10.91	9.38	9.57	9.47	9.05
225 + 00	Dry	14.23	12.23	10.43	11.65	12.72	13.42
	Soaked	19.90	13.35	11.81	12.81	11.30	9.94
245 + 00	Dry	10.71	10.63	10.04	10.35	-	13.33
	Soaked	12.84	10.39	13.01	11.80	11.31	10.09

Appendix G

Surface tension data of sodium chloride and calcium chloride solutions

Table 35. Surface tension data for 0.5% chemical content in stabilized soils.

Moisture Content of the soil %	Chemical in Solution %	NaCl content mols/kg	$CaCl_2$ content mols/kg	Surface Tension NaCl Solution dynes/cm	Surface Tension $CaCl_2$ Solution dynes/cm
0	∞	∞	∞		
1	50.0	8.56	4.51	86.73	88.72
2	25.0	4.28	2.25	79.75	79.84
3	16.667	2.85	1.50	77.42	76.96
4	12.500	2.14	1.13	76.26	75.64
5	10.000	1.71	0.90	75.55	74.83
6	8.333	1.43	0.75	75.10	74.32
7	7.142	1.22	0.64	74.74	73.95
8	6.250	1.07	0.56	74.51	73.66
9	5.555	0.95	0.50	74.32	73.49
10	5.000	0.86	0.45	74.16	73.33
11	4.545	0.78	0.41	74.04	73.20
12	4.167	0.71	0.38	73.92	73.16
13	3.846	0.66	0.35	73.83	73.03
14	3.571	0.61	0.32	73.75	72.94
15	3.333	0.57	0.30	73.69	72.88
16	3.125	0.53	0.28	73.63	72.83
17	2.941	0.50	0.26	73.57	72.77
18	2.778	0.48	0.25	73.55	72.74