SOIL CEMENT ROADS IN IOWA

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It seems probably that ever since roads were first built, men have dreamed of having some magic material to mix with the natural soil on the road which would make hard durable surfaces. In this age of rapid advancement in highway construction in Iowa, we are still searching for ways of using the material already on the road, and for ways to improve the use of materials which have shown success in stabilizing soils. Programs of research and development of methods to stabilize soils for road construction, seems to be the most feasible approach to reducing the depletion rate of our dwindling aggregate sources, to providing suitable construction materials where aggregates are scarce, and to reducing the ever mounting costs of highway construction.

One of the more successful materials used for the stabilization of soils is portland cement. According to the 1950 Soil Cement Mixture Laboratory Handbook published by the Portland Cement Association (P.C.A.) patents for mixing soil and cement in mixers with large quantities of water and secret chemicals to produce roadways were issued as early as 1917.

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In 1924 the Iowa State Highway Commission in cooperation with the United States Bureau of Public Roads initiated a study on the effect of the treatment of earth roads by the admixtures of portland cement and hydrated lime. Two sections were constructed for study. One section was located on primary road Iowa 14 in Lucas County, and the other section on U. S. 34 in Mills County.

In 1933 and 1934 field experiments were tried in South Carolina. This was quickly followed by projects constructed to investigate this method of soil stabilization in South Carolina, South Dakota, Iowa, Ohio, California and Texas. Since those first recorded projects, the P.C.A. reports that 24,000 miles of soil-cement base has been constructed in the United States and Canada, plus millions of additional square yards in other parts of the world.

The first soil-cement primary road base construction in Iowa was in Wayne County. This project was completed in 1937 and ran from Allerton north 1.64 miles. At various times since 1937, eight other primary soil-cement projects have been completed. These projects, which were located mostly in the southern part of the state where aggregate is scarce, resulted in a total of 65.07 miles of soil-cement roads in Iowa.

There has also been completed in 1960 an experimental project in Webster County, HR-68, in which soil-cement and soil lime cement were used.

In the early efforts to stabilize soils with cement in the 1920's, the science of mixing two types of materials and the science of compacting materials was not very well developed. This factor plus an understandable lack of correlation between laboratory test data and field performance resulted in rather inconsistent stabilization of soils. However, starting with 1929 when the moisture-density relationship in soil compaction was developed real progress was made towards securing a more uniform stabilization of soils with cement.

By 1935 the P.C.A. felt that enough favorable information had been developed to warrant an intensive research program. Accordingly in 1935 they undertook the probelm of developing the basic relations of soil-cement mixtures. Since this first concentrated effort continual work has been conducted in the development of these relations and of correlations between laboratory tests and field performance.

At this time reliable criteria based on exhaustive laboratory tests, on field performance, and on exposure tests, has been developed by the P.C.A. and numerous other agencies.

The primary established requisite for producing soil-cement with satisfactory characteristics and service ability is that an adequate amount of portland cement be incorporated with the pulverized soil. Secondary established requisites are, (1) that proper amount of water be mixed uniformly with the soil-cement mixture, and (2) that the moistened soil-cement mixture be compacted to proper density before cement hydration.

It might be of value to very briefly review the tests and criteria that have been used in establishing the cement factors required to stabilize the soils on the various projects in Iowa.

In general, the primary basis of comparison of soil-cement mixtures is the cement content required to produce a mixture that will withstand the stresses incurred by weathering, which is simulated by the wet-dry and freeze-thaw tests. This resistance is measured by the soil-cement losses incurred during these tests.

Based on correlation studies of the data secured from these tests and field performance, the P.C.A. recommends the following criteria as a basis for establishment of cement factors for construction. This criteria was developed for general use in all sections of the country.

1. Soil-cement losses during 12 cycles of either the wet-dry test or freeze-thaw test shall conform to the following limits:

   Soil Groups A-1, A-2-4, A-2-5, and A-3, not over 14 per cent.

   Soil Groups A-2-6, A-2-7, A-4 and A-5, not over 10 per cent.

   Soil Groups A-6 and A-7, not over 7 per cent.

2. Compressive strengths should increase both with age and with increases in cement content in the ranges of cement content producing results that meet the above requirements.

It is suggested that these criteria should not be considered as irrevocable recommendations in that no deviations are made for variable climatic and soil conditions. The recommended criteria with some modifications as indicated by local experience are used in designing the soil-cement material in Iowa.

Past experience indicates the need for further correlation studies of laboratory test data and field performance in Iowa. In order to improve such correlations a research project will be conducted during this coming year in connection with 14.08 miles of soil-cement base to be constructed on Iowa 37 in Crawford, Harrison and Monona Counties, Project F-861(6). It is proposed that approximately 3.1 miles of the planned base construction be divided into test sections containing various cement contents. Special testing, both in the field and in the laboratory, will be undertaken to determine the characteristics of the soil-cement mixtures and their behavior under normal field conditions. The specific objectives of this project are to determine the suitability of soil-cement base construction using the fine-grained materials common to large areas of western Iowa and to correlate laboratory soil-cement design with field experience.

Besides using varying percentages of cement content (4-7-10-13) in a uniform 7 inch base on this project, the soil-cement mixture is required to be produced in a central mix plant. This, we hope, is another step toward securing a more uniform soil-cement mixture.

A sand-cement project on Iowa 21 in Iowa County is to be constructed in 1961. This is project F-505(7), and since both of these projects are being constructed by the same contractor, it is probable that a central mix plant, although not required, will also be used. Data secured will tend to give us a greater correlation between laboratory test data and field performance for sand-cement bases.

Both of these projects will be constructed with an inverted penetration surface course. On the Monona County, project F-861(2), it was observed that reflective cracking sometimes caused by shrinking in the soil-cement base has been minimized when the final hot mix surface course was not constructed until at a later date, usually the next construction season. For this reason the final hot mix surface course on both of these projects will be constructed later.

Procedures for conducting the wet-dry test are specified in ASTM Designation D 559-57, or AASHO Designation T 135-37. At the end of a 7-day storage period in an atmosphere of high humidity, a specimen is submerged in tap water at room temperature for 5 hours and then removed. The specimen is then placed in an oven at 160°F. for 42 hours. Following removal from the oven two firm strokes on all areas with a scratch brush are performed to remove all material loosened during the wetting and drying cycles. The foregoing procedures constitutes one 48 hour cycle. 12 cycles are required before losses are determined.

Procedures for conducting the freeze-thaw test are specified in ASTM Designation D 560-57, or AASHO Designation T-136-57. At the end of a 7-day storage period in an atmosphere of high humidity, water-saturated felt pads about one-fourth inch thick are placed between the specimen and the specimen carrier. This assembly is placed in a refrigerator with a constant temperature of not more than 10°F. for 24 hours. The assembly is then placed to thaw in a 100 per cent humidity moist room at a temperature of 70°F. for 23 hours. Free water is made available to the absorbent pads to permit the specimens to absorb water during the thawing period. The specimen is then brushed as in the wet-dry test. After 12 of these procedures, the soil-cement losses are determined. It has been recommended, that the scale occurring on some soil-cement which is not removed by the specified brushing procedures, be removed by a sharp-pointed instrument. This has not been the practice in our procedures.

The artificial weathering effects accomplished by the wet-dry and freeze-thaw tests are described in the 1959 Soil-Cement Laboratory Handbook published by the Portland Cement Association.

> "The wet-dry and the freeze-thaw tests were originally designed to determine whether the hardened soil-cement would stay hard or whether the material would soften from exposure to severe moisture variations and alternate freezing and thawing, conditions that have produced disastrous results in soil alone. The wet-dry test (alternate wetting and drying) is particularly severe on

soil-cement specimens molded with the use of soils that contain relatively high contents of silt and clay. The drying cycle sets up high shrinkage stresses in the specimens. These stresses are released when the wetting cycle starts, and high surface-expansion stresses are set up. Loosened material is then brushed off after the drying portion of each cycle.

The wet-dry test is also rather severe on the one-size sand soil cement specimens. The wire brush with which they are brushed after the drying cycle acts as a severe abrading tool, not only removing material loosened by the alternate wetting and drying cycle but also loosening additional sand grains. This severe abrasion is considered when cement contents are selected for hardening soils, for instance, greater soil-cement losses are permitted for satisfactorily hardened sandy soil-cement mixtures than for satisfactorily hardened clay soil-cement mixtures.

The freeze-thaw test (alternate freezing and thawing) was devised to measure the hardening effect of portland cement on soils. The test not only shows how soil-cement reacts to the elements of weather, but of even more importance, it shows whether or not the cement has truly hardened the soil. Alternate freezing and thawing is particularly severe on soil-cement specimens molded with soils in the sand to silty clay loam textural range. In sandy soil-cement mixtures, the test definitely shows whether the cement is reacting favorably and has sufficient cementing power to overcome the expansion of water in the voids of the soil cement as the water freezes. In the loam, silt loam and silty clay loam soil-cement mixtures, the test shows:

1. Whether there is sufficient cement in the specimens to overcome the expansive force of the water freezing in the voids.
2. Whether there is sufficient cement in the specimens to overcome the formation of ice layers."

For sandy soils the Portland Cement Association now recommends the following short-cut test procedures:

"These procedures do not involve new tests or additional equipment. Instead, data and charts developed from previous tests of similar soils are utilized to eliminate some tests and greatly reduce the amount of work required. The only laboratory tests required are a grain-size analysis, a moisture-density test, and compressive-strength tests. Relatively small small soil samples are needed and all tests, except the 7-day compressive-strength tests, can be completed in one day.

While these procedures do not always give the minimum cement factor that can be used, they provide a safe cement factor generally close to that indicated by standard ASTM-AASHO wet-dry and freeze-thaw tests. The procedures are finding wide application by engineers and builders and may largely replace the standard tests as experience in their use is gained and the relationships are checked. Possibly the charts and procedures may be modified to conform to local conditions if needed."

During the ten year period from 1937 through 1947, seven projects involving 583,418 square yards or 41.02 miles of soil-cement bases, were constructed. In all but one of these projects, the material for the base course was secured from the existing road surface. In one case 600 tons of sand per mile was added to the road surface.

On these six projects, the base materials had P.R.A. classification of A-6 and A-7-6 except for one project in Monona County in which the material was classified A-4. Plastic indexes ranged from 9 to 25.

Cement contents as expressed in per cent of cement by volume in a given volume of compacted soil-cement mixture ranged from 7 to 12. Cement contents expressed in per cent of cement by weight of the weight of a given volume of compacted soil-cement mixture ranged from 5 to 11.7.

During the second ten years period from 1947 through 1957, two projects involving 24.05 miles of soil-cement base were constructed. The base materials on these projects and on the one exception in the previous ten year period were composed of non-plastic borrow materials with a P.R.A. classification of A-2-4. Cement contents ranged from 7 to 10 per cent by volume and 5.5 to 8.5 per cent by weight.

The curing specifications up until 1946 generally called for priming the base with a bituminous material on the morning of the day following completion of the compaction operation. The cure methods used on the Muscatine and Monona County projects constructed in 1946 was wet burlap followed by straw which was kept moist for seven days. In general all projects constructed since 1947 have required a moist cure within the first five day light hours without rain following the completion of the compaction operation. The wetting period was to be promptly followed with a prime coat of bituminous materials.

Designed base thicknesses on the first two projects was 4 and 5 inches respectively. The designed base thickness on all projects thereafter was 6 to 7 inches.

Due to the relatively low resistance of soil-cement to abrasion a double-inverted penetration bituminous mat was applied to the surface in all cases until 1954 when surface courses were changed to the dense graded machine mixed bituminous types.

In general there was very little variation in the construction details and procedures used during the first ten year period. These were the projects where base material was secured from the existing road bed.

The roadways were shaped to the desired crown and profile with care being exercised during this operation to get uniform distribution across the base width of any loose surfacing material. Following this procedure the road beds were scarified and bladed to the desired depth and this material pulverized to a specified degree of fineness. Usually 75 to 80 per cent of the soil particles were required to pass a #4 sieve. Generally cross-sections of windrowed material would be checked to determine if the desired amount of soil was available for the base.

The pulverized material would be spread uniformly on the surface by means of trucks with spreader boxes.

Pulverization of the soil and mixing of the soil and cement was usually accomplished by use of one or more types of machinery. Discs, gang plows, cultivators, harrows, drags, patrols and rotary machines were used. As you would guess from the equipment used, these procedures were called the "farming method".

Water was generally added to the mixed material by gravity-fed spray bars on tank trucks and distribution accomplished with the same equipment as used for blending. When the optimum amount of water had been applied to the materials as determined by the educated eye and feel of the inspector, compaction of the base was started. The ability of the inspector to judge optimum moisture condition was then checked by moisture samples.

Compaction of the base, except for the top 1 to 1½ inches was accomplished with tamping type rollers. Shaping and final compaction of the top 1 to 1½ inches was carried out by the use of rubber and steel rollers.

Very little change occurred in construction details or procedures during the second ten year period.

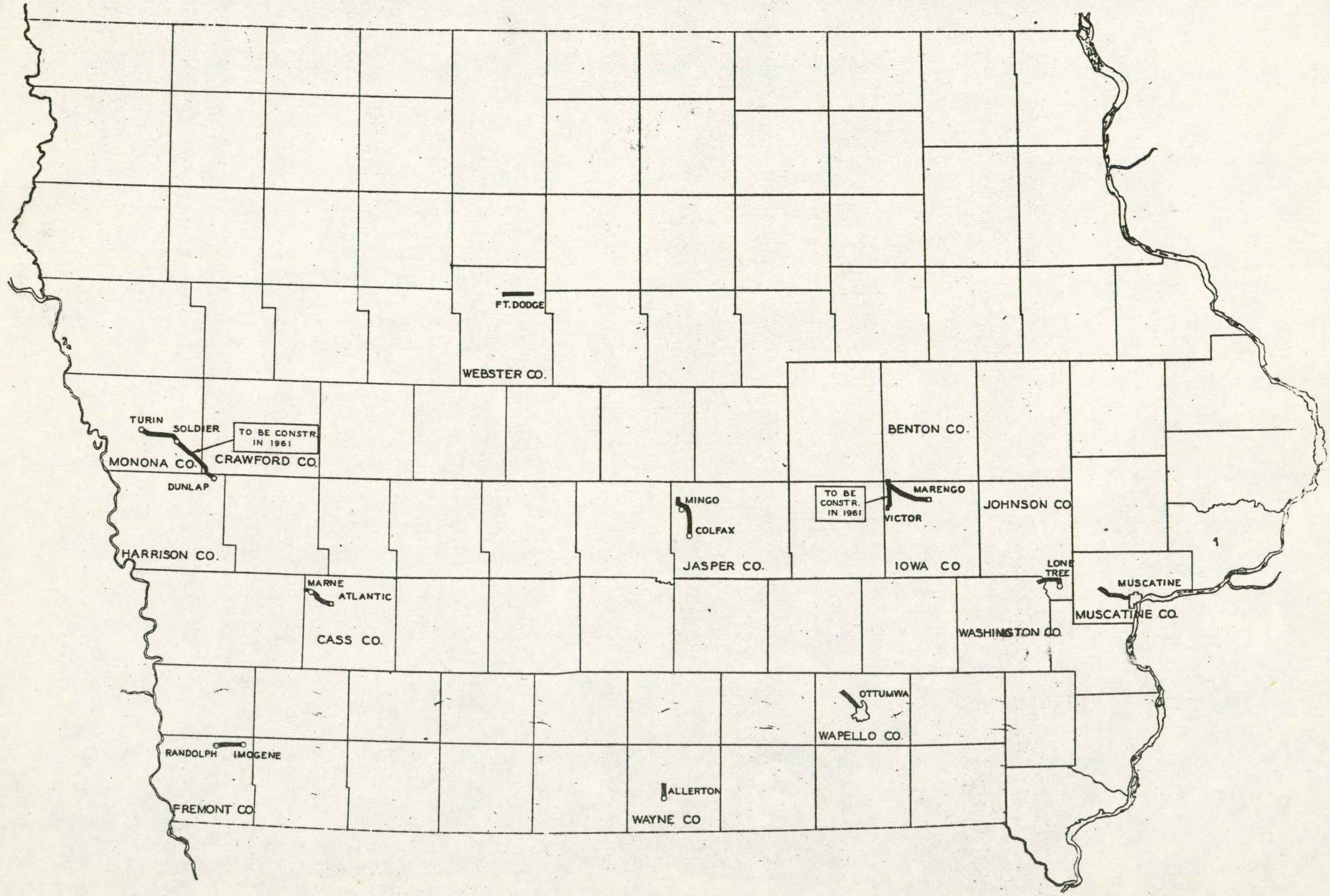
The use of borrow for the source of base materials led to the practice of subgrade preparation as you know it from use on all types of base construction now.

Because of the difficulties encountered which resulted from improper distribution of moisture in the soil-cement materials, a trend in the first period towards the use of pressure spray bars became a must on these projects. Also, the use of pugmill type machine in which a measured amount of water is blended with the material has practically become a standard method.

It is exceedingly difficult to evaluate the soil-cement projects built in Iowa with our present day increased traffic volume and axle loads. Our present methods of correction of subgrades, our selection of soils and materials, our construction methods, our design, all contribute toward building better roads.

The data gathered from our latest experimental projects, together with past experience and information from other sources, will be and are valuable in the designing and construction of future cement treated bases.

MAP OF SOIL-CEMENT ROADS IN IOWA
1961



SOIL-CEMENT ROADS IN IOWA

County	Project	Rt.	Location	Year Const.	Miles	Depth Inches	Base Width Feet	Approx. Square Yards	1950 Survey Distressed Areas Square Yards	Percentage
Wayne	FN-91B	Ia. 14	Allerton, North	1937	1.64	4	26	25,016	4	0.02
Cass	FN-447	Ia. 83	Near Marne	1938	2.50	5	26	38,113	6084	16.00
Wapello	FN-598D	Ia. 15	Ottumwa, N.W.	1940	4.07	7	24	57,476	1018	1.80
Muscatine	FA-820(2)	Ia. 22	Near Muscatine	1946	10.89	6	24	153,289	240	0.16
Monona	F-861(2)	US 37	Soldier to Turin	1946	9.05	6	24	126,800	2025	1.60
Fremont	F-864(3)	Ia.184	Imogene west	1947	6.80	6	24	96,500	254	0.26
Johnson-Washington	F-956(1)	Ia. 22	Lone Tree to 218	1947	6.07	6	24	86,224	300	0.35
Benton-Iowa	P-1058	Ia.212	Marengo, N.W.	1954	12.79	7	24	180,008		
Jasper	F-772(7)	Ia.117	Colfax to Ia. 64	1957	11.26	7	23'6"	155,962		
Webster	HR-68	Sec.	U.S. 169 East	1960	4.00	6 - 8	24	56,320		
Iowa	F-505(7)	Ia. 21	U.S. 6, N. to Ia. 212	1961	7.33	7	24'6"	105,787		
Crawford-Harrison-Monona	F-861(6)	Ia. 37	Dunlap to Soldier	1961	12.89	7	23'6"	178,539		
			TOTAL		89.29			1,260,034		