basis, the other costs of the various sections can be compared by deducting the cost of the cement.

COST MINUS CEMENT

	Per Sq Yd	Per Mile
Route 5, Monteau County	$0 34	$4,350 00
Route 100, Franklin		
Road Mix	0 15	1,950 00
Machine Mix	0 27	3,450 00
Route 13, St Clair		
County	0 20	2,550 00

Part of the excess cost on Route 5, Monteau, has already been explained, however, another item is the character of the soil, the proper preparation of A-6 clay for treatment requiring considerable more manipulation than the readily friable A-4.

(2) The costs as given are reasonable and in the range of what one can expect to pay for a reliable base in the low cost program

(3) Some surface treatment to provide a wearing course is required before putting the road under traffic

(4) The results obtained do not appear to justify the extra cost of the machine mixing as carried on in this case

(5) In the processing it developed that by proper care and provision the objectionable conditions that develop on "turn-arounds" could be eliminated Another development in processing indicates that the use of gang plows in turning over the material during the disking and mixing operations is more effective in preparation of the material and in uniform mixing than the "Orchard Cultivators"

(6) With good organization it appears that a complete crew of men and equipment will complete, as an average, one quarter mile per working day

SOIL-CEMENT BASE, WAYNE COUNTY, IOWA

BY FRANK L DAVIS

Resident Engineer, Iowa State Highway Commission

During 1937, 1 64 miles of soil-cement stabilization base were built in Wayne County, Iowa by the State Highway Commission The section had been maintained with a traffic bound gravel surface since 1923

The new base course was built 26-ft wide, 4-in deep and with a finished crown of 5-in The material for the base was secured by scarifying the surface to the depth necessary to produce the required yardage of material About 60 per cent of the original gravel surfacing material was recovered and used

To make the final 4-in depth, 2127 cu yd. of material per mile were required from the road bed

Cement was mixed with the base material in the ratio of 1 to 10 by weight The optimum moisture content was found to be 11 per cent, which required the application of 5 09 gal of water per sq yd less the moisture contained in the material

The characteristics of the material in the base are given in Table 1

The job was done on contract by the road mix method

The base material was taken from the road bed with two No 11 auto patrols with scarifier attachments By removing half of the scarifier teeth and setting the rest to the correct depth below the scarifier block, it was possible to scarify to the full depth by running the scarifier block tight to the road surface The operation followed a heavy rain and by using one patrol to pull the other machine with the scarifier, the material was loosened to the full depth in one opera-

tion The material was then bladed into a windrow until all scarifier marks were removed from the sub-grade.

Pulverization was accomplished by two No 30 AC caterpillar tractors pulling a tandem and spring tooth harrow and a quack grass digger Some rolling was done to help flatten out the lumpy material.

After the material was pulverized it was placed into a windrow at one side of the road so that the water distributors would not travel too near the edge and cause settlements in the sub-grade.

TABLE 1

BASE MATERIAL

Sieve Size	Percentage Passing	Material Passing No 40 Sieve	
1 in	100 0	Liquid Limit	30 0
¾ in	98 0	Plastic Limit	14 8
⅜ in	91 3	Plasticity Index	15 2
No 4	82 1		
No 8	71 1		
No 10	68 8		
No 40	49 0		
No 60	42 6		
No 100	38 6		
No 270	35 3		
No 005	14 8		
No 001	7 6		

MIXING AND LAYING

Mat for Turning Equipment·

The first operation each day was to place a mat of 3 by 12-in fir plank over the end of the last day's run long enough for the mixing and rolling equipment

Spreading:

Following the placing of the mat, the header board from the last day's run was removed and the material between the header and windrow loosened from the sub-grade The windrow was then knocked down and spread uniformly over the sub-grade for the distance of the day's run The windrow was flattened for about 50 ft beyond this point to enable the equipment to be turned beyond the end of the run

A red flag was placed on each side of the road at the end of the day's run so that the point was clearly marked where each operation was to stop for the day

Applying Cement·

After the spreading of the material in the windrow the cement was placed

The cement was distributed with a Buckeye spreader attached to the rear end of a flat bottomed truck used for hauling the cement in bags The cement was applied in three widths of the spreader and in two layers After a few adjustments, on the first day's run, the machine was able to spread the cement uniformly at the required rate per square yard Considerable difficulty was encountered the first day as the contractor started dry mixing at the time he applied the cement which caused the mixture to become very loose and fluffy The Buckeye spreader, being traction driven, would sink deep into the loose material and cause trouble by stones and gravel getting into the drive chain and sticking the machine After the first day, the cement was spread on top of the material before dry mixing was started

Dry Mixing

Following application of cement, the material was uniformly dry mixed by the use of the quack grass digger, tandem disc and spring tooth harrow The quack grass digger which was a 10-ft McCormick Deering solid arm with large type open back shovels did an excellent job of mixing Shields should be used on the outside shovels of the quack grass digger to keep the mixed material from spreading beyond the trench in the sub-grade An extra set of shovels should be provided for this type of digger so that

they can be replaced and sharpened when dull Upon completion of the dry mixing the water was added

Watering:

Water was obtained from a railroad reservoir two miles from the south end of the project A supply of 200-gal per min was provided by means of a portable pumping unit Gravity type distributors of 1040-gal capacity were mounted on Ford or Chevrolet truck chassis

The water was distributed over the dry mixed material as evenly as possible until 2 per cent above the optimum content had been added

Wet Mixing·

Mixing was continued as the water was added, until sufficient moisture showed uniformly distributed through the depth of the material It was often necessary to operate the mixing equipment in a zig-zag line of travel from one side of the road to the other to disperse wet streaks left by over-laps in the trips of the water distributors The same equipment was used for wet as for dry mixing It was often necessary during both the dry and wet mixing to blade the material in from the outside edges to prevent loss

In turning during the mixing and the rolling that followed, all equipment, as much as possible, was pulled upon the mat on the one end and past the red flags at the other Very little turning of the equipment should take place in the mixed material.

Preliminary Packing and Shaping·

Following the wet mixing, the mixture was rolled with a sheepsfoot roller until it was up to about $1\frac{1}{2}$-in from the surface at which time the motor patrols shaped the road to the proper width and crown The rolling continued after the shaping until the roller was about $\frac{3}{4}$-in. from the surface On account of the heat and large evaporation it was necessary to sprinkle with considerable water during this operation in order to keep sufficient moisture in the material

Final Packing and Shaping.

The final shaping was done with the auto patrols The material was bladed back and fourth over the surface of the base and to such depth that all compaction planes of the sheepsfoot were removed During this operation, a spike tooth farm harrow was used to help roughen any compaction planes missed by the blading When the final shaping was completed, a uniform mulch of the loose material was left over the base and compacted by a pneumatic roller It was often necessary to wet this mulch to provide enough moisture to bond it to the balance of the base The pneumatic rolling was continued until all material was rolled tightly into the base

Joining New Work to Completed Base·

After the header had been removed in the morning, the material was cleaned to the sub-grade for about 2-ft back from the joint During the wet mixing the material used for the joint was shoveled by hand against the end of the last day's run and hand tamped in place

The base usually thickens at this point, due to accumulation from the equipment pulling upon the mat in turning On final shaping, the mat was removed and blading operations carried over the joint When pneumatic rolling was about completed, the joint was given a final blading with the blade over the joint at an angle of about 60° with just enough pressure to clean the completed base and to cut the new base to the same level During the pneumatic rolling, the roller passed over the joint and turned on the section previously completed

Final Rolling and Finishing

Finally the base was given a smooth even surface with a smooth steel roller This roller had to be used with considerable caution if the surface was too wet, it picked up on the roller and if too dry, the best results could not be obtained

Header at End of Day's Run

The header was placed by hand after the steel roller left the base A line was struck across the base between the red flags, placed at the end of the section, and a trench about five to six inches in width was cut across the base to the subgrade Care was used to make the completed side vertical and straight and a 2 by 4-in header board was placed in the trench and staked in place against the completed base A small amount of mixed material which had been saved was wetted and tamped into the narrow space between the header board and the mixed base This completed the day's operations

CURING

The completed base was cured by priming with a TC-2 bitumen on the morning of the day following the completion of each day's run at the rate of 0 2-gal per sq yd

The first and second day's runs were not primed on the following day as intended The car of bitumen arrived three days late and the two day's base was kept wet by sprinkling with water five times each day until primed This delay in priming did not seem to cause any serious defects in the base

Upon completion of the soil-cement base, the shoulders of the roadway were treated by priming with SC-1 bitumen

PROGRESS

Operations on the soil-cement section was started July 25th, and completed Aug 10th, 1937

The removal of the material from the road bed and processing required three days

The mixing and laying of the base was completed in eight working days

Some rainy weather was encountered between the starting and completion dates However, only a few light showers were had on the days of operation

The temperature ranged from 90 to 102 deg F

The schedule of a typical day's operations is given in Table 2

TABLE 2

CONSTRUCTION OPERATIONS, ONE 14-HOUR DAY, 1100 FT

Operation	Time, hr
Spreading Windrow	0 50
Spreading Cement	2 75
Dry Mixing	1 25
Watering	2 50
Wet Mixing	4 25
Preliminary Packing	2 50
Preliminary Shaping	0 50
Final Packing	1 00
Final Shaping	0 50
Smooth Rolling	1 50
Header and Turning Mat	0 75

COSTS

The Contract prices were as follows

Item 1 Portland cement for base stabilization in place on road	$2 66 per bbl
Item 3 Water for wetting base mixture	$3 00 per 1000 gal
Item 4 Constructing soil-cement base	$0 68 per cu yd
Item 6 Primer bitumen TC-2 for base furnished and applied	$0 1413 per gal
Item 7 Primer bitumen MC-1 for shoulders and approaches, furnished and applied	$0 087 per gal.

The cost data for the project are given in Table 3

THE FINISHED BASE

Measurements of density, thickness and water content were made on each day's run at 100-ft intervals before the prime coat was applied Table 4 gives the typical results

Two Proctor density tests were made on composite samples taken at the time of completion of wet mixing as follows

(1) Density 110 0 at 13 6 per cent water
(2) Density 123 8 at 11 5 per cent water

such equipment as was recommended and the project was completed without any changes in the set-up

It became apparent that with additional equipment and different methods for cement spreading better progress could have been made, better results would have been obtained and operation costs reduced

Recommendations for operations and equipment on soil-cement base stabilization are as follows

1 The mat for turning on completed base should be full width of base and 30 to 35 ft in length with a covering of dirt over the planks to prevent breakage and hold them in place All equipment should turn entirely upon the mat

TABLE 3

COST FOR SOIL-CEMENT STABILIZED BASE

Items	Costs for Project	Costs Per Mile	Cost Per Sq Yd of 4" Base	Cost of Sq Yd Per Inch of Base Depth
Cement in Place	$6,315 51	$3,848 79	$0 2523	$0 0631
Water for Mixture	450 30	274 42	0 0180	0 0045
Constructing Base	2,372 52	1,445 86	0 0948	0 0237
Prime TC-2 Curing	707 33	431 06	0 0282	0 0070
Prime MC-1 Shoulders	308 05	187 73	0 0123	0 0031
Total All Items	$10,153 71	$6,187 86	$0 4056	$0 1014

TABLE 4

	Thickness of Base, in	Density, lb per cu ft	Water %
Minimum	4 25	92 0	9 4
Average	5 04	105 8	14 5
Maximum	6 50	117 2	23 8

RECOMMENDATIONS

As this project was the first soil-cement base to be laid in the state very little information was available as to what type of equipment should be used and how many units of each type would be necessary to do the work in a satisfactory manner

The contractor accordingly furnished

2 The handling of cement in bulk with proper facilities for weighing and hauling with end dump trucks to feed the cement spreader This should save labor and expense and speed up the operation

3 As wet and dry mixing time seems to be the largest factor in the day's operation plenty of equipment should be used for this operation At least two quack grass diggers equipped with large type shovels should be used as this machine is fast and gives a very thorough mixture

4 The tandem farm disc should be replaced with quack grass diggers or their equivalent as it has a tendency to ride

out of the material and does not mix to the bottom of the base

5 Water should be applied with power driven distributors properly tachometered whenever possible At least all water distributors should have spray bar length control and adjustable valves so that the spread of water can be controlled at all times and under all conditions

6. Rolling with sheepsfoot rollers should be completed while the base mixture is at the optimum moisture content

Enough rollers should be used so that the required density is reached in 2 to 2½ hours

7 During the initial compacting, or sheepsfoot rolling, only tractors of the track laying type should be used for operating the rollers Pneumatic tires should not be used at this stage as they compact the base unevenly

8 For final compaction the pneumatic roller should be operated by pneumatic tired tractors as a uniform surface, free from tracks, is desired Where track laying tractors are used, track marks are left in the base and extra rolling and blading are required to remove them

One pneumatic roller will take care of about 1500 ft per day The job should be equipped with two rollers of this type as this final compaction is important to the finish of the base In case of extra footage or breakdown of roller, the additional machine would be available to complete the day's run

9 For removing compaction planes on final shaping and packing, a fine spike tooth harrow should be used This type of harrow should have more and finer teeth than the common farm harrow so as not to leave too large ridges in the top mixture

10 Where bitumen is used for curing, it appears advisable to give the completed base one or two light applications of water before priming The first application should be about five hours after the base has been completed and the second 5 hours later, with about the same lapse of time before the prime coat is applied

FINISHED ROAD

The soil-cement stabilized base was surfaced with a bituminous wearing mat of inverted penetration type, 22 ft wide applied in two courses The binder was SC-7 bitumen applied at 0 3 gal. per sq yd for each course Crushed lime stone was applied at 30 lb per sq yd for each of the two courses

EXPERIMENTAL SOIL-CEMENT ROAD IN WISCONSIN

By Guy H Larson

Senior Assistant Engineer of Materials

An experimental soil-cement stabilization project was undertaken in Wisconsin during the fall of 1936, and early summer of 1937 The project consisted of a 3 3-mile section, located on State Highway 13, immediately north of Friendship in Adams County, 1 65 miles were built in 1936 and the project was completed in 1937. The work was done by county forces at the expense and under the supervision of the State Highway Commission of Wisconsin, working in cooperation with the Portland Cement Association, who also conducted the preliminary tests and designed the proportions.

The region is an old glacial lake bed and while the sandy soil deposited by the lake waters lent itself to some easy manipulation during construction, it also presented some unexpected problems during the preliminary tests The soil was graded largely between the 30 and 100-mesh sieves and appeared very uniform throughout the project A limited num-