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CONSTRUCTION AND SUBSEQUENT STUDIES OF CONCRETE DURABILITY PROJECT MICHIGAN TEST ROAD

By

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During the construction season of 1940 a concrete pavement project was constructed in Michigan to determine the effect of known additives and admixtures on the concrete to resist scale. The durability project is located on M-115 West of Farwell in Clare County. The soil conditions for the 7.7 miles of pavement are ideal because of the uniformity of the free draining sand and the location geographically is representative of the average weather conditions in Michigan. Chemical additives and physical admixtures were incorporated in sections 1200 feet in length with the exception of two which are 2400 feet in length. All the standard practices of construction were adhered to in the matter of design using 22 foot width, 9 inch edge and 7 inch center cross section expansion joints spaced 120 feet, contraction joints spaced 60 feet and plane of weakness joints spaced at 30 feet. Between each section of concrete pavement where the mix was varied a 1200 foot section of standard concrete pavement was placed to obtain results between a standard and revised concrete mix under relatively similar construction conditions. During the placing of the concrete numerous and complete observations were made on the character of the concrete for the various admixtures and standard mixes. This included analysis of placing, workability, finishing, bleeding, laitance, slump, curing and complete weather observations.

Two types of finishing were used on standard concrete mixes, burlap drag and brooming. The brooming was found to be more effective when used at the proper time in removal of objectionable laitance. When brooming was performed from the center of the pavement to the outside edges a ridge was formed at the center line although not detrimental to the driving public other than from appearance. To overcome this irregular formation, brooming was attempted in one pass from edge to edge and also in a longitudinal direction and effected a neater surface. Broom finish of concrete pavement, done properly, from edge to edge is more desirable than using the burlap drag.

Eleven methods of curing, each on a 120 foot section of pavement, were used to ascertain the relative value of curing as affecting the durability of concrete. These included, asphalt emulsion and cut-back asphalt applied immediately following the finishing, asphalt emulsion applied after an initial 24 hour burlap cure, wet straw, wet earth, ponding, double burlap, paper, 2% calcium chloride admixture, rite-cure and paper following a 24 hour burlap cure. In this section the curing was performed with great care and more thoroughly than that conducted in the remainder of the project. Some methods were advantageous from a construction viewpoint in initial application and subsequent care as paper, emulsion, cut-back, calcium chloride and rite-cure. The final analysis of resistance to scale is the paramount issue with ease of application and economics being secondary. The results of the scaling study hereinafter discussed will determine the relative value of the curing methods.

Chemical additives used in the concrete mix as a part of the cement or added to the batch were incorporated in the standard concrete mix. Among them were pozzolith, plastiment, vinsol resin interground with cement, orvus, natural cement with a grinding aid and natural cement without grinding aid. Pozzolith was added at the rate of 2 pounds per sack of cement; plastiment at 1 pound per sack of cement; vinsol resin at 0.0375 pound per sack of cement; orvus at 0.015 pound per sack of cement; natural cement with and without grinding aid at the rate of 1 part natural to 5 parts of portland cement.

With pozzolith the workability was fair to poor, caused poor finishing, bleeding was noticeable and at air temperature of 50°F the concrete mix did not set to permit the removal of forms for eighteen hours. With the exception that workability and finishing were fair the use of plastiment in concrete has a reaction very similar to concrete wherein the pozzolith additive was used.

Portland cement interground with vinsol resin was used with two brands of cement, each being placed in 2400 lineal feet of pavement whereas pozzolith and plastiment were placed in 1200 lineal feet of pavement. The workability was fair to good, varying with the weather conditions. High temperatures caused the concrete to react both in the workability and finishing processes, and tended toward a stickiness that resulted in a cohesiveness unlike standard concrete. Puddling of the concrete, straightedging and floating was more difficult and although the floats were steel shod, the difficulty was not entirely overcome.

Bleeding was noticeable at times but the concrete was entirely free of laitance or segregation of the constituents. Continued use of vinsol resin cement on this project acquainted the workers with its idiocyncracies and they adapted themselves to such a point that this type of concrete proved quite satisfactory for concrete pavement.

When orvus was used as an additive it was typically similar to vinsol resin in its reaction with the exception that workability, finishing and bleeding were better and no evidence of laitance or segregation. From the viewpoint of adaptability orvus would be preferred to vinsol resin. In both, the criterion of causing a drop in weight of 4 to 6 pounds per cubic foot in the concrete mix is necessary for effectiveness in aiding durability. The reaction of either to the numerous sources of aggregates prevalent in Michigan will vary. This can be easily controlled in the use of orvus as the quantity required is added at the mixer. Similarly, considerable difficulty might be encountered with vinsol resin interground with portland cement on the basis of one or two sources of aggregate and when being used in a third type may result in too low or too high a drop in weight. No corrective measures can be taken after the cement is milled.

The use of natural cement as an additive proved quite satisfactory from a workability standpoint, both the cement with and without grinding aid. Slight segregation was observed in both types. Natural cement without grinding aid showed traces of bleeding and laitance

and fair to good finishing properties whereas no bleeding or laitance was evident where natural cement with grinding aid was used but the finishing was relatively poor.

In addition to the additives, inert admixtures were used, namely silica dust and limestone dust at the rate of 15.45 pounds per sack of cement and a native Michigan sand graded from a #40 sieve with approximately 50% passing a #200 sieve at the rate of 50 pounds per sack of cement. Where these three admixtures were used, the workability was excellent, segregation slight and finishing good. There was no bleeding on the sections where silica dust and native sand was used and noticeable in the limestone dust admixture section. A trace of laitance developed on all three types but at rare intervals. From observations of the inert admixture concrete, it proved definitely that fines are essential for good concrete placement and workability. The native sand type made the most favorable impression.

In addition to the above mentioned additives and admixtures a study of manufactured limestone sand and crushed limestone was made. The material came from a source extensively used in Michigan concrete pavement construction and invariably resulted in a high percentage of scaled surface. The use of limestone dust was made in one section to be analyzed against a section of standard mix. In both sections the workability, segregation and finishing was poor and developed extensive bleeding and laitance. The limestone dust aided the workability slightly but had no remedial effect on the bleeding or laitance.

To determine the effectiveness of the various concrete mixes as to their relative resistance to the action of calcium chloride, accelerated tests were conducted during the winter of the first year of the pavements life. Two methods of attack were used on panels 3 feet by 12 feet along the outside edge of the slab. In one panel the concrete was subject to water being frozen overnight and the ice formation decomposed with 10% of calcium chloride by weights the following morning.

Immediately following decomposition the ice was removed and the surface of the concrete flushed with clear water and the cycle repeated. This method was continuous for five daily cycles and the ice permitted to remain undisturbed over the weekend. The second accelerated test was performed by applying a 10% calcium chloride solution in an adjacent panel on the concrete surface which remained in place five days. Following this period the solution was removed, panel flushed and clear water applied for a freezing cycle over the weekend. The ice was decomposed, removed, surface flushed and the successive weekly cycle of 10% calcium chloride solution applied.

Very interesting results were obtained from this study of concrete pavement mixes and their resistance to scale. Theories of increased density of concrete providing increased durability were discounted. The incorporation of air voids or the reverse method gave satisfactory results. Table I lists the various concrete mixes, their constituents and behaviour under the two methods of test.

Cement	Admixture	Finish	Curing	Freeze-Thaw Cycles	Freeze-Thaw % Scale	$CaCl_2$ Solution Cycles	$CaCl_2$ Solution % Scale
Petoskey	None	Broom	Wet Straw	28	94.5	5	100.0
"	"	"	Asp. Emulsion	25	92.0	6	22.0
"	"	"	Asp. Cut-Back	33	83.0	7	42.0
"	"	Burlap	24-hr. burlap& Asp Emulsion	27	61.0	6	42.0
"	"	"	Wet Straw	27	19.0	6	6.0
"	"	"	24-hr. burlap & paper	28	Trace	6	Trace
"	"	"	Wet earth	28	33.0	6	1.4
"	"	"	Ponding	28	28.0	6	Trace
"	"	"	Double burlap	24	14.0	6	Trace
"	"	"	Paper	28	3.0	6	0.0
"	"	"	$CaCl_2$ integral	24	16.7	6	Trace
"	"	"	Rite-Cure	28	0.0	6	0.0
"	"	"	Wet Straw	33	61.0	7	11.2
"	"	"	Wet Straw	13	100.0	3	100.0
Aetna	None	"	Wet Straw	27	56.0	6	33.0
"	"	"	Wet Straw	21	100.0	5	100.0
Petoskey	2% Pozzolith	"	" "	33	1.4	7	0.0
"	1% Plastiment	"	" "	33	22.2	7	0.0
"	Orvus	"	" "	33	0.0	7	0.0
Aetna	"	"	" "	33	Trace	7	Trace
Petoskey	Vinsol Resin	"	" "	33	0.0	7	Trace
Aetna	" "	"	" "	33	0.0	7	0.0
Petoskey	Natural Cement	"	" "	29	Trace	7	6.0
"	" " & Grinding Aie	"	" "	33	Trace	7	0.0
"	Silica Dust	"	" "	30	70.0	7	17.0
"	Limestone Dust	"	" "	27	94.4	7	59.0
"	Native Sand	"	" "	21	100.0	3	100.0
"	Limestone Agg.& Limestone Dust	"	" "	5	100.0	3	100.0
"	Limestone Agg. Std.	"	" "	22	100.0	5	100.0

Table I - Accelerated Weathering Tests

The results definitely determine for themselves the satisfactory means of increasing resistance to scale and possible permanent elimination. These tests are all preliminary and must be considered as such. Annual accelerated weathering tests will be conducted until definite final conclusions are obtained.

From Table I positive statements can be made on certain factors. (1) Brooming has no effect on resistance to scale compared to burlap finishing. (2) Asphalt curing methods only delay scale action, intensity about the same; (3) Curing properly performed decreases the intensity of scale development and with rite-cure eliminates it entirely and to a negligable degree with paper curing. It must be remembered that this curing study was made under ideal conditions and not truly representative of job conditions; (4) Pozzolith reduces scale to a monor quantity whereas plastiment had no more effect on degree of scale than a good curing condition; (5) Orvus and vinsol resin definitely eliminate the reaction of calcium chloride to concrete and is recommended for use extensively; (6) Natural cement with a grinding aid gave as good results as either orvus or vinsol resin but straight natural cement developed some scale; (7) The inert admixtures had no effect on reducing of scale but rather seemed to accelerate the action compared with standard concrete; (8) Limestone dust added to limestone aggregate and stone sand hastened surface deterioration in comparison to a standard mix of similar materials.

Supplementing the field tests of durability of concrete, freezing and thawing tests were conducted in the laboratory on specimens molded on the project during construction. Cylinders were cast 4 inches in diameter and 16 inches in length and beams 3 inches by 6 inches by 15 inches. These specimens were used in the freeze-thaw weathering tests on comparable curing conditions and age of specimens. The breakdown was determined by the dynamic method of determining Modulus of Elasticity (E). Although at this time the results are not complete, certain conclusions can be drawn from the data to date.