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MICHIGAN'S EXPERIENCE IN THE USE OF WHITE-PIGMENTED MEMBRANE CURING COMPOUNDS

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SYNOPSIS

Michigan, in 1949, adopted specifications for white-pigmented curing compounds in an attempt to minimize temperature cracking in concrete pavements built during the spring and summer months. Previous laboratory studies and field tests had demonstrated the effectiveness and practicability of this type of curing.

At first there was some difficulty encountered in applying the compound with the spraying equipment then in use, which led to a modification of pump design by the manufacturer. It was found that most operational troubles were caused by: (1) inadequate stirring of the compound before and during application; and (2) failure to clean the spraying equipment properly after use.

Whiteness and hiding power are important properties of white-pigmented compounds. Michigan specified a minimum apparent reflectance of 70 percent relative to magnesium oxide for the former and 100 sq. ft. per gal. for the latter. The method of determining color by means of a spectrophotometer is described and details of other tests and application requirements are given in the Michigan specifications appended to the report.

As a result of more than 4 years of research and cooperative development, Michigan in 1949 adopted specifications for white-pigmented membranes as an alternate method of curing concrete pavements. The use of clear, or transparent, membrane curing compounds had been permitted since the spring of 1942, but a subsequent appraisal (*1*)[1] clearly revealed the need for controlling heat pickup in pavements cured by this method. The first full-scale use of white-pigmented compounds in Michigan was in July of 1949, and white compounds have been required on all membrane-cured concrete paving projects authorized since that time.

While it is still too early to make a statistical evaluation of their performance in actual service, the benefits to be derived from the use of white-pigmented compounds appear to be well established and there is a definite trend toward their preferment over the transparent type of membrane. New materials bring new problems, however, and it is the purpose of this paper not so much to present the case for white-pigmented compounds as to transmit experience gained in handling, specifying and testing these materials.

[1] Italicized figures in parentheses refer to the list of references at the end of the paper.

WHY USE WHITE-PIGMENTED COMPOUNDS?

That measures should be taken to prevent excessively high temperatures in immature concrete seems obvious, but it might be well to review briefly the basic reasons behind the use of white-pigmented curing compounds.

In the year A.D. 97 Sextus Junius Frontinus, Water Commissioner of Rome, wrote: "The proper time for masonry work is from the 1st of April to the 1st of November; but with this restriction: that the work be interrupted during the hottest part of the summer; —for the heat of the sun is no less destructive to masonry than is too violent frost." (*2*) Since that time, the wisdom of the Roman Commissioner's remarks has been demonstrated again and again in concrete construction experience.

It can be shown, both theoretically and experimentally, that membrane curing is entirely adequate from the standpoint of retaining sufficient water in the concrete to satisfy the hydration needs of the cement. A serious drawback to the method, however, has been the excessive temperature rise under both the bituminous and transparent types of membrane from absorption of the sun's radiant heat.

Gonnerman (*3*) reported to the Highway Research Board that the average crack interval was much shorter for pavements cured with bituminous membranes than for pavements cured by other methods. It was also observed that nearly all test sections of pavement poured in the morning had a tendency to crack more than those poured in the afternoon, irrespective of curing method. This experience has been repeated in Michigan. A survey of 29 projects built during 1946 and 1947, all of which were cured with clear membranes, showed that there were about three times as many cracked slabs in the morning pours as in the afternoon pours. The inference is that half of this premature cracking could have been prevented by effective temperature control.

The use of white or light-colored coatings, such as whitewash or cement, over bituminous membranes markedly reduced solar heat pickup. Later on, results obtained with white-pigmented membranes by the Bureau of Reclamation (*4*) were so encouraging that shading of fresh concrete was dispensed with when these compounds were used. Our own studies, referred to earlier, (*1*) verify the Bureau's findings.

Because of the practical advantages of the membrane curing method, Michigan has gone to the use of white compounds for this type of curing in an attempt to minimize temperature cracking. Problems in handling and application arose almost immediately, but were not insurmountable, as will appear forthwith.

HANDLING WHITE-PIGMENTED COMPOUNDS

Preliminary Field Tests—The first field application of white-pigmented compound in Michigan was on two successive 100-ft. slabs of an experimental pavement at Grand Ledge in September, 1946. An ordinary hand-operated orchard sprayer was used and no particular difficulty was encountered in getting down a uniform coat at the required coverage rate of 200 sq. ft. per gal.

The next field trial of white membranes was on about 1500 lineal feet of 22-ft. concrete pavement north of Port Sanilac on US-25. The primary purpose of this test section was to provide an opportunity to observe the general visual effect and weathering characteristics of the white compound over an area sufficiently long to permit independent evaluation.

Spraying equipment used on the job was of the type furnished by the vendor of the compound to contractors for regular construction work, and is illustrated in Figure 1. This machine is entirely hand operated and was pulled forward on the forms after each transverse pass of the spray bar.

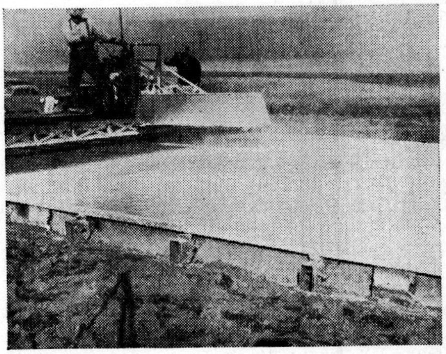

Figure 1. Distributor Used in Early Field Tests—Entire spray unit is being pulled by hand across the bridge.

At first a fairly uniform application was secured, but the spray nozzles soon became clogged, resulting in marked ridging as shown in Figure 2. It was discovered that the white pigment was filling the individual straining screens of the nozzles so these screens were removed as a temporary expedient and little trouble from clogging was experienced afterward. Also the spray bar was raised about 6 in., which further improved the spreading. In addition to these modifications, the curing compound was then applied by a double pass across the pavement using a more rapid rate of transverse travel and overlapping one-half the width of the path laid down by the spray bar on each pass. All of these changes resulted in a very uniform application and elimination of previous defects (Fig. 3).

The rate of coverage for the double pass was determined from a series of weighed panels placed in the path of the distributor and found to range between 163 and 209 sq. ft. per gal. with an average of 182. The white membrane weathered away rapidly and uniformly without mottling or other unsightly effects—so much so, that it was hard to pick out the experimental white section from the rest of the pavement less than 2 months after completion of the job.

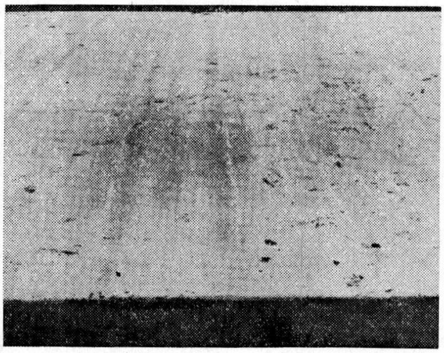

Figure 2. Ridging Effect Due to Clogging of Spray Nozzles—This picture was taken after removal of forms the following morning.

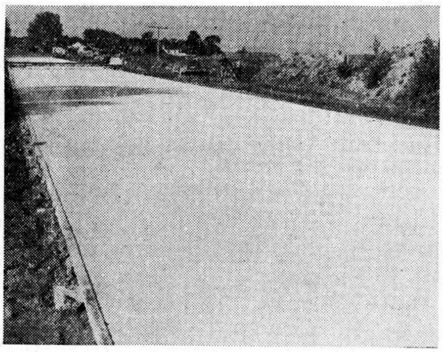

Figure 3. Application by Double Pass with Nozzle Screens Removed and Spray Bar Slightly Raised

White Compounds on Regular Construction—The two pilot tests just described cleared the way for full-scale trials on entire paving projects. Specifications were drawn up and included in the proposals for several projects to be paved in the 1949 construction season. The first of these projects to receive white membrane was 6.3 mi. of concrete widening and capping on US-131 south of Kalamazoo. Since nearly all of the application problems encountered so far arose shortly after construction began, a brief chronology of the curing phase of this project will bring out the facts of present interest.

The distributor used on the job was of the automatic type, having a continuous forward movement of the carriage on the forms and a single shielded spray nozzle traveling laterally across the pavement (see Fig. 4). The combined movements of carriage and nozzle produce a V-shaped application pattern, and the machine is geared so that the nozzle makes one transverse pass while the carriage is moving forward a distance equal to about one-half the width of the band laid down on each pass. In this way, each element of surface area receives a double application of curing compound. The material is pumped directly from the shipping drum which is placed on the carriage.

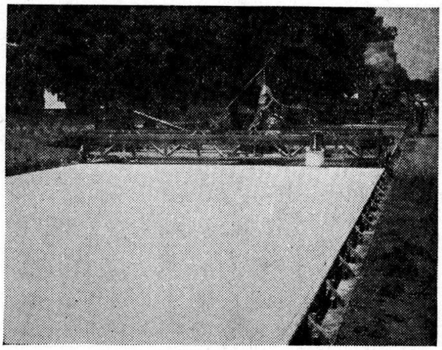

Figure 4. Automatic Distributor in Operation

At first, excellent coverage was obtained with the white-pigmented compound as shown in Figure 5. After a few days, however, it was learned that application troubles were developing. The chief trouble was described as the erosion of valve seats and cylinder walls of the reciprocating type of pump used on the distributor, making it difficult to maintain sufficient pressure for uniform distribution. The nozzle orifice was also enlarging rapidly from wear so that excessive amounts of material were used at normal operating pressures.

White compounds require a higher application pressure than the clear type. Whereas pressures of 50 to 100 psi. are normally sufficient for clear membrane compounds, contractors are now using 200 to 250 psi. for optimum results with the white-pigmented materials. When this particular job started, a pressure of 200 psi. was used and uniform coverage at the rate of 204 sq. ft. per gal. was attained. When the pump parts began to wear, however, the pressure was reduced by the contractor to 70–90 psi. which resulted in the banded pattern and light coverage rate of 306 sq. ft. per gal. shown in Figure 6. The pump manufacturer soon solved these problems by substituting porcelain-lined cast-iron cylinders for the bronze ones and producing a tungsten carbide orifice insert for the spray nozzle to replace the stainless steel insert formerly used.

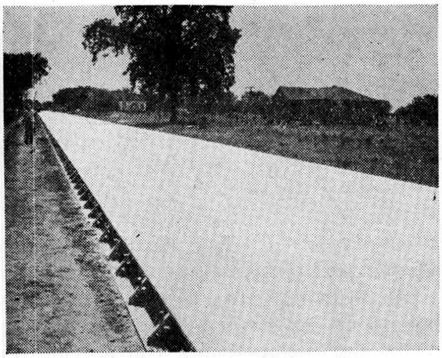

Figure 5. Uniform Coverage at the Rate of 204 sq. ft. per gal. with Pump Pressure of 200 p.s.i.

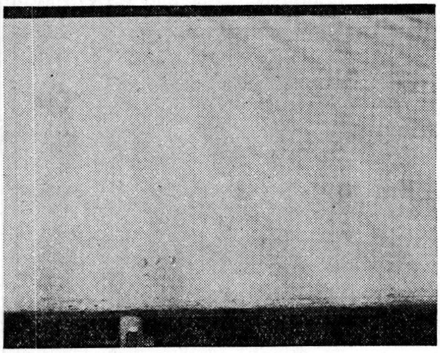

Figure 6. Closeup of Application Pattern with Pump Pressure Reduced to 70–90 p.s.i.—Coverage is non-uniform and too light (306 sq. ft. per gal.).

It is important that the entire circulating system of the distributor be thoroughly cleaned after each use. Residues from previous operations are very damaging to pump parts when the machine is again started up. A simple and effective method of cleaning this type of equipment is to circulate about 5 gal. of kerosene through the entire system several times by discharging the solvent from the spray nozzle into the original container.

Most of the difficulties in spraying white-pigmented compounds stem from inadequate stirring of the material in the drum before and during application. When the supernatant vehicle is pumped off first, there will be uneven distribution, waste of the residue (which may amount to $\frac{1}{4}$ to $\frac{1}{3}$ of the drum's contents), and damage to spraying equipment from pumping the high-solids material near the bottom. Our specifications require that the compound be shipped in drums equipped with internal agitators. These agitators should have stirring arms assembled in such a way that solids which have settled out will be brought up and thoroughly mixed with the vehicle. A V-shaped agitator with the apex of the V about half way down the side of the drum was definitely unsatisfactory. We have found that about 20 minutes of hand stirring is necessary before use. One contractor has greatly expedited this operation by making a chuck for a $\frac{3}{4}$-hp. electric drill to fit the agitator shaft, and this device does an effective stirring job in a few minutes. Still another gets good results by rotating the drum on two sets of supporting rollers turned by a washing machine motor. After shutdowns or overnight standing, the material in the drum should again be stirred thoroughly before use.

SPECIFICATIONS FOR WHITE-PIGMENTED COMPOUNDS

The basic material requirements for clear membranes such as water retention, drying time, adherence to moist concrete, settlement, and reactivity with cement should, of course, be retained in specifications for white-pigmented compounds. Also such requirements as concern purchasing, sampling, and application should be retained. There are three additional details, however, which must be adequately specified in order to assure effective utilization of the white membrane idea—color or degree of whiteness, hiding power, and provision for adequate stirring.

Color—Color (and its associated property, heat absorption) is a very important factor in the evaluation of white-pigmented compounds. The data in Table 1 of a Bureau of Standards report by Cottony and Dill (5) illustrate the point and the table is reproduced here for convenience. Reference to this table shows that the lowest temperature rise occurred under glossy white paint. Since gloss aids reflection, it is a desirable property of

TABLE 1[a]
DAILY MEAN RISE IN TEMPERATURE IN DEGREES FAHRENHEIT OF TEST PANELS EXPOSED TO THE SUN

	Date (1939)				
	Aug. 2	Aug. 3	Aug. 1	July 31	Aug. 7
Panel inclination from horizontal *deg.*	90	90	60	45	30
	deg. F.	*deg. F.*	*deg. F.*	*deg. F.*	*deg. F.*
Black (lampblack)	20.9	21.0	37.4	46.3	48.5
Galvanized iron	16.1	15.3	28.1	32.0	37.7
Roofing shingle, Aluminum	19.4	20.2	34.1	40.7	41.6
Roofing shingle, green	19.5	20.7	33.3	41.3	43.4
Roofing shingle, red	21.5	23.1	37.2	44.8	46.0
Aluminum foil	9.8	8.3	15.0	17.3	19.7
White road-marking paint	12.3	12.1	19.7	22.9	24.7
Aluminum paint	14.6	14.5	24.4	29.0	29.3
Glossy white paint	8.9	7.9	12.1	13.0	15.5
Flat white paint	9.1	8.3	13.2	15.6	17.2
Ivory paint	10.2	9.3	14.9	16.8	19.2
Canary-yellow paint	10.9	10.4	16.7	19.2	21.6
Pearl-gray paint	13.3	13.7	20.3	24.3	25.6
Silver-gray paint	13.9	14.2	20.3	24.6	26.3
Light lead paint	15.1	15.2	22.9	27.4	29.7
Slate paint	16.8	17.1	26.7	32.4	35.4
Medium-green paint (trim color)	20.4	20.5	35.3	42.7	46.3

[a] Reproduced from Report BMS 64, Nat'l. Bur. of Standards (1941).

white membranes provided the gloss does not persist beyond the curing period to cause objectionable glare to drivers. A progressive increase in heat pickup under the various surfaces listed in the table may be noted as the color ranges from white through ivory, yellow, etc., to green, red, and black.

Surfaces which absorb heat most readily during the day generally radiate this heat most rapidly at night, so that temperature changes under these surfaces are not only wider, but also more abrupt than those under surfaces having higher reflective characteristics. Another interesting phenomenon observed by Cottony and Dill was the night radiation from their panels to a clear sky, which brought the panel temperatures down from 7 to 13 deg. F. below the ambient air temperature, the good heat radiators being the coolest.

From the facts just brought out, it follows that the white membrane should be as good a reflector as possible and, since whiteness is a general indicator of this property, the color should approach a perfect white as nearly as practicable. In Michigan a minimum apparent reflectance value of 70 percent relative to magnesium oxide has been adopted. This figure is purely arbitrary and represents a compromise between efficiency and cost of the compound. It has been possible to secure a good curing compound, quite white, and at reasonable cost with this specification.

Hiding Power—The significance of hiding power is more or less self-evident. It wouldn't be practical, of course, to demand the same degree of hiding power in a curing compound as in a high-quality paint. Our specifications require 100 sq. ft. per gal. as the minimum value for this property when the compound is applied over a black and white checkerboard. Although the specified rate of application to concrete for curing is 200 sq. ft. per gal., the color of the concrete surface is masked effectively by material meeting the specification requirement of 100 sq. ft. per gal. when it is properly applied. In this case, the conditions of the test are more rigorous than those encountered in actual practice.

Stirring—The importance of adequate stirring of the compound both before and during application cannot be overemphasized. Drums in which the material is shipped should contain efficient agitators. If the compound is not pumped directly from the shipping drum, the tank on the distributor should carry some sort of stirring apparatus to provide thorough mixing after interruptions, shutdowns, or overnight standing.

TESTING WHITE-PIGMENTED COMPOUNDS

Most of the tests for membrane curing compounds are familiar to highway engineers and concrete technicians. The tests in use by the Michigan State Highway Department follow ASTM procedures wherever possible or applicable and are described or referred to in the specifications in appendix 1 of this paper except that for color which is given below.

Some of the provisions in the specification are general performance requirements and are self-explanatory. An example of this type is the stipulation that the viscosity of the compound must be such that it can be applied in a uniform coat at temperatures down to 40 deg. F.

Whenever a new material is submitted for qualification under our specifications several laboratory observations not ordinarily included in routine acceptance tests are made in order to get some indication of field performance. Among these are sprayability, adhesion to moist concrete, reaction between curing compound and concrete, and settlement.

Color—The method of color determination in current use by the Department employs a spectrophotometer and has been described in a previous publication (*6*). Photographs of the apparatus set up for testing colored reflector buttons are shown in Figures 7 and 8. When testing white membranes the light source is located on the left of the target and at an angle of 45 deg. from the normal. Apparent luminous reflectance as defined in ASTM Method D 307 is obtained by measuring the comparative reflection of radiant energy by the sample and magnesium oxide standard at 20-millimicron intervals of wavelength of the incident light through the range of 400 to 700 millimicrons. The apparatus is set up for 45-deg. illumination with perpendicular viewing. The light source is a single G.E. No. 4560 sealed beam lamp operating at 28 volts with a maximum intensity of 600,000 candlepower at beam center.

Since reflection values at all wavelengths represent a ratio between unknown and standard, the only essential requirements for the illuminant are that its spectrum be continuous and its intensity sufficient to produce adequate galvanometer response at each wave length of the test. Computations follow the ASTM procedure for calculating the luminous apparent reflectance R_s in percent.

At the present time, a simplified color test unit is being assembled based on reflection measurements at three wavelength bands of the spectrum through the use of red, green and blue filters. This apparatus shows promise of giving very close approximations to the values attained in the longer method and should be accurate enough for routine acceptance tests.

Hiding Power—The test for hiding power is described in appendix 1, and follows the U. S. Bureau of Reclamation procedure. With experience it gives reproducible results and is easily performed. The checkerboard charts should be fastened to a rigid, non-absorbent backing of some kind—24 ga. metal sheet is satisfactory—to prevent curling of the cardboard before the sprayed film has dried. A good feature of this method is that the hiding

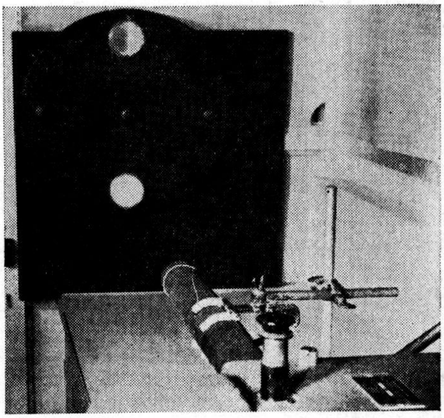

Figure 7. Target

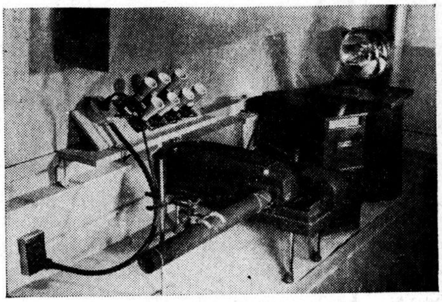

Figure 8. Spectrophotometric Assembly

power is determined directly from the weight of the dried film deposited on the checkerboards and is not affected by overspray or loss of volatile constituents during application.

CONCLUDING REMARKS

There are definite indications that white-pigmented compounds are doing the job for which they were intended. The problems encountered have not been serious and have been solved by mutual cooperation of equipment manufacturer, contractors, vendors of the compound, and the Highway Department. The pavements cured with white membranes are being watched closely and definite statistical data on performance will be secured as the list of projects grows.

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APPENDIX 1

Specifications[1] for Curing Concrete Pavement by Application of White Membrane Curing Compound

Michigan State Highway Department

SCOPE:

This specification covers the properties and use of white-pigmented membrane compounds for curing concrete pavements.

GENERAL REQUIREMENTS:

The white membrane curing compound shall consist of finely ground white pigment and vehicle, ready-mixed for immediate use without alteration. The pigment shall not settle out badly or cake in the container and the compound shall not thicken in storage to cause a change in consistency.

The compound shall be such that it can be used with safety under properly controlled conditions and shall conform to the following specific requirements:

SPECIFIC REQUIREMENTS:

Adhesion—The compound, when applied to a moist concrete surface at the specified coverage either prior to or subsequent to the time at which the concrete has attained its initial set, shall adhere firmly to the concrete surface for at least 7 days after application.

Color and Hiding Power—The compound, when applied to a new concrete surface at the specified coverage, shall present a uniformly white appearance and shall effectively obscure the original color of the concrete. After the compound has dried, it shall have an apparent daylight reflectance of not less than 70 percent relative to magnesium oxide. The compound shall have a hiding power of not less than 100 sq. ft. per gallon when tested as follows:

A 1-sq. ft. test area of a black and white checkerboard hiding power chart (type used in Federal Specifications TT-P-141a, Method 411.1) shall be cut into four equal rectangles, dried at 105 C. to 110 C. for 1 hour, cooled, and weighed. The sealing compound shall be sprayed on two of the rectangles in an amount that barely permits identifying a contrast between the black and white areas. On the other two rectangles the compound shall be applied in an amount slightly more than necessary to completely eliminate the contrast between the black and white areas. The coated rectangles shall then be dried at 105 C. to 110 C. for 3 hours, cooled, and weighed. The hiding power shall be computed from the following formula:

$$\text{Hiding power in sq. ft. per gal.} = \frac{W_g \times S}{W_d \times 100}$$

Where, W_g. = Weight per gallon of compound in grams,

S = Solids content of compound in per cent (Paragraphs 7 and 8, ASTM D 154 - 43), and

W_d. = Total weight of dried coatings on all four rectangles, in grams.

[1] Extract from 1950 Standard Specifications

Drying Properties—The compound shall become dry to touch within 4 hours when applied to the concrete under ordinary conditions and shall not be tacky or track off of the concrete when walked upon, nor impart a slippery surface to the pavement.

Viscosity—The compound shall be suitable for application at a minimum temperature of 40 F. and shall be sufficiently low in viscosity to result in an even, uniform coating.

Non-volatile Matter—The non-volatile matter in the white curing compound shall be not less than 60 percent by weight as determined by the current Method of Testing Oleoresinous Varnishes, A.S.T.M. Designation: D 154.

Reaction Between Curing Compound and Concrete—There shall be no evidence that new concrete surfaces are softened by reaction with the curing compound.

Weathering—The compound, when applied at the specified coverage on a new concrete surface and exposed outside to sunlight, shall remain as a continuous, unbroken film that provides an effective moisture seal for at least 7 days after application, without noticeable darkening or yellowing of the film.

Moisture Retention—The white curing compound when applied at the rate of not less than one gallon per 200 sq. ft. on mortar specimens in accordance with the tests prescribed in the current Method of Test for Water Retention Efficiency of Methods for Curing Concrete, A.S.T.M. Designation: C 156, shall provide a film which will cause at least 93 percent of the moisture in the specimens to be retained for a period of 3 days based on the moisture content of the specimens at the time of coating.

PACKING AND MARKING:

The curing compound shall be delivered to the job only in the manufacturer's original container which shall be legibly marked with the manufacturer's name, trade name and formula number of the material, and lot number with which test samples may be correlated. No designation shall be used to represent more than one formula.

Containers shall be clean steel drums equipped with mechanical agitators for thoroughly stirring the compound to a uniform consistency immediately before use.

SAMPLING AND TESTING:

When the curing compound is not supplied from stock which has been tested and approved by the Department, it shall be sampled and tested after delivery to the project. A sample shall consist of one quart of the curing compound for each batch or lot number represented in the shipment. Fourteen days may be required from time of sampling before results of tests are reported.

APPLICATION:

After finishing operations have been completed and immediately after the free water has left the surface, the surface of the slab shall be completely coated and sealed with a uniform layer of white membrane curing compound. The compound shall be applied in one or two applications as directed by the Engineer. When the compound is applied in two increments the second application shall follow the first application within 30 minutes.

The compound shall be applied in a continuous uniform film by means of mechanical pressure sprayer equipment at the rate directed by the Engineer but not less than one gallon per 200 sq. ft. of surface. The equipment for applying the compound shall provide for adequate stirring of the compound during application and must be approved by the Engineer before work is started. Should the method of applying the compound not produce a uniform film, its use shall be discontinued and the curing shall be done by one of the other approved methods as specified in Article 4.14.03-t of the 1950 Standard Specifications.

If the compound is too thick for satisfactory application during cold weather the material may be warmed in a water bath at temperatures not over 100 F. Thinning with solvents will not be permitted.

If rain falls on the newly coated pavement before the film has dried sufficiently to resist damage, or if the film is damaged in any other way, the Contractor will be required to apply a new coat of material to the affected areas equal in curing value to that specified for the original coat. The treated surface shall be protected by the Contractor from injury for a period of at least 7 days. All traffic, either foot or otherwise, will be considered as injurious to the film of the applied compound. A minimum of foot traffic will be permitted on the dried film as necessary to properly carry on the work provided any damage to the film is immediately repaired by the application of a second coat of the compound. Immediately after the forms are removed, the entire area of the sides of the slab shall be coated with the curing compound at the rate specified for the pavement surface, except where honeycombed areas are to be pointed. Such areas shall be covered with wetted burlap until the pointing has been completed, at which time they shall be cured as specified herein. Hand-spray equipment will be permitted for the application of the curing compound over the sides of the slab.

The Contractor shall provide on the project sufficient burlap or cotton coverings for the protection of the pavement in case of rain or breakdown of the spray equipment. If hair checking develops before the curing compound can be applied, the procedure as specified herein shall be modified in that preliminary curing with wetted burlap or cotton coverings, as specified under Article 4.14.03-t of the 1950 Standard Specifications, shall be performed before the curing compound is applied.

The Contractor shall assume all liabilities for and protect the Department from any damages or claims arising from the use of materials or processes described herein.

BASIS OF PAYMENT:

Curing by the application of white membrane curing compounds will not be paid for separately but shall be considered as included in the contract unit price for "Concrete Pavement."

DEPARTMENT OF MAINTENANCE

REX M. WHITTON, Chairman

MINNESOTA PRACTICES ON SALVAGING OLD PAVEMENTS BY RESURFACING

O. L. KIPP, *Assistant Commissioner and Chief Engineer* AND C. K. PREUS, *Assistant Engineer of Materials and Research, Minnesota Department of Highways*

SYNOPSIS

The earlier efforts at resurfacing of old concrete pavements in Minnesota were started in 1936 as special projects by the Maintenance Division of the Minnesota Highway Department. The primary objective of these early jobs was to secure improvement of the riding quality of the pavements and to retard progressive surface deterioration of the concrete. The methods employed in these and later jobs included both plant mix and road-mix mats, generally about 1 to 2 in. in thickness. Some widening of 18-ft. pavements was done using a minimum of base under the widening. Most of these earlier jobs served well for many years considering the relatively light construction, although the thinner mats began to wear through or crack and scale off in spots after a few years under heavy traffic.

The first full scale construction project for pavement rehabilitation was built in 1938 involving double-tracking a 12-mi. heavy traffic road. The existing 18-ft. pavement was utilized through most of its length for one roadway, being widened six feet on one side and resurfaced with asphaltic concrete. Following World War II a program of rehabilitation of some 600 mi. of too-narrow 18-ft. pavements was initiated. To date about 183 mi. have been reconstructed while 55 mi. are currently under contract.

The resurfacing of these projects has in most cases consisted of two courses totaling about 3-in. in thickness where placed directly on the concrete. Other treatment has been used on pavements which had been badly broken, cracked or distorted or had shown pumping tendencies or severe surface disintegration. On such slabs a gravel lift or base course of about 5-in. minimum thickness was placed before the bituminous covering was placed. In some of these cases the upper two inches of the lift was stabilized with bituminous material before placement of a single course 1½-in. wearing surface. In other cases the lift was primed and covered with two courses of about 1½-in. thickness each. Indications to date are that the surfaces placed on gravel lifts are retaining their smoothness better and showing less cracking than those placed directly on the concrete even though the latter were the better areas of the slab at the time of reconstruction.