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FUNDAMENTAL PRINCIPLES AND FACTORS EMBODIED IN THE MICHIGAN TEST ROAD

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Research Project 39 B-11 (2)
39 F-7 (2)

ROADS AND STREETS

Research Laboratory
Testing and Research Division
Report No. 14
May 1, 1941

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The Michigan Test Road previously mentioned in the November 1940 issue of Roads and Streets, has been completed. The project was constructed under regular contract and construction procedure using the Michigan State Highway Department 1940 plans and specifications with necessary supplementals. The test road is located on M-115 between Farwell and M-66 and consists of 17.6 miles of 22-foot width concrete pavement. The project is essentially divided into two sections, one for a study of design principles, and the other for the study of durability factors particularly in regards to scaling. This article constitutes a summary pertaining to the construction of the test road and illustrates the principles and factors embodied in the project.

DESIGN STUDY

The structural adequacy of a concrete pavement slab from the standpoint of strength and permanency is influenced by the features of design which determine its continuity and dimensions. The features which were given study in the design section of the Michigan Test Road were joints, cross-section dimensions and reinforcing.

Joints have been one of the most controversial subjects in the design of concrete pavements. Therefore, they were given considerable attention in the Michigan Test Road. Emphasis was placed upon joint spacing, expansion space and joint construction. Several different spacings of expansion joints from 120 feet to 2700 feet were used for various cross-sections

and various amounts of reinforcing steels. Correspondingly, various spacings of contraction joints from 10 to 60-foot intervals were used.

The proper spacing of joints will be determined by permissible maximum stress intensities induced by linear frictional restraint and flexural weight restraint.

Various types of expansion and contraction joints were installed to evaluate load transfer and the preservation of mutual elevation of slab ends. In this connection, a study of thickened slab ends at expansion joints, as well as the effectiveness of aggregate interlock at contraction joints will be studied. In this project a study of required expansion space for different spacings will also be made.

In regard to the design of the pavement slab itself, thought has been given to the study of reduced thickness on prepared subgrades, and equivalent uniform thickness versus the balanced cross-section. In this respect, four different types of cross-sections were set up for study on this project; namely, 9"-7"-9" Michigan State Highway Department standard cross-section; 8" uniform, the approximate equivalent of 9"-7"-9", 8"-6"-8" a reduced cross-section which might be used on subgrades of sufficient supporting value; and 7" uniform the approximate equivalent of the 8"-6"-8" cross-section.

In planning the Michigan Test Road, it was felt that a study of reinforcing steel should be included because of the many unanswered questions concerning its use among which are: (1) the amount of reinforcing steel required, (2) economics of reinforced pavement versus unreinforced pavement with adequate jointing and (3) the relation of plain uniform cross-section

to reinforced "balanced" cross-section. To this end, sections were constructed using 9"-7"-9", 8" and 7" uniform cross-section using plain concrete, and reinforced concrete with 60 pounds per hundred square feet and 37 pounds per hundred square feet.

For proper appraisal of the structural efficiency of the elements of design considered in this project, periodic visual examinations together with measurement of displacements and physical conditions must be made.

Throughout the entire project, special measuring devices and reference points have been installed including: (1) electrical strain gauges for measuring stresses, (2) thermocouples for temperature studies, (3) moisture cells for determining moisture content of concrete and subgrade soil, (4) reference monuments for detecting slab movement, (5) reference points for measuring changes in joint width, (6) elevation points for measuring changes in joint width, (7) meteorological station for obtaining complete record of weather conditions and (8) a traffic counter for recording vehicle movement over the test road.

Incidental with the construction of the Test Road, additional studies have been made which are of particular interest to the Michigan State Highway Department and pertinent to the improvement of concrete pavement construction. They are: stress curing of concrete, mechanical spreading of concrete and the use of various types of joint sealing materials.

The design section of the Michigan Test Road coincides in a general way with the Public Roads Administration's plans and procedure for construction of experimental roads which were submitted to various state highway organizations in 1940. The purpose of this experimental work is to study

the desired spacing of transverse expansion joints in concrete pavements and the amount of expansion space required per unit pavement length, and to study the efficiency of dummy contraction joints with and without dowels or other devices for the transfer of load.

A more comprehensive description of the design phase of the Michigan Test Road will be found in the 1940 proceedings of the Highway Research Board.

DURABILITY STUDY

The durability section was constructed to make observations under service, of factors which had been determined by other investigators or in laboratory studies of the Research Division, that might be effective in the prevention of scaling. The purpose of this pavement was not only to make observations under service conditions but to afford a field laboratory to obtain accelerated action of chloride salts or ice on concrete pavements and the study of resultant action. The durability study project entails a length of approximately 7.7 miles. The location is ideal from a standpoint of average weather conditions in Michigan and the length is sufficient to reduce the variables of construction to a minimum for each factor investigated. The supplemental specifications covered details for all variables unusual to Michigan State Highway Department specifications. The included cements, admixtures, mix designs, methods of construction which preliminary laboratory studies indicated to possess characteristics favorable to the prevention of scaling.

The cements used included two brands of regular portland cement as normally used in the construction of concrete pavements in Michigan. Admixtures included the use of certain propietary materials known as Plastiment,

Pozzolith, Orvus and Vinsol Resin. Natural cement was also included, which was ground with and without the use of calcium stearate. Mix designs included the regular proportioning as determined by the material specifications and the mortar void design method of the Michigan State Highway Department, as well as the addition of fines supplementing the fine aggregates. These fines were added to increase the density and workability of the mix and a possible resultant reduction in scaling. Short sections were included to determine the relation of scaling to methods of curing.

The methods for finishing and curing of concrete studies on the project included the standard methods specified in the specifications of the Michigan State Highway Department.

The curing specifications include: (1) wetted earth, (2) wetted straw or hay, (3) ponding, (4) wetted burlap, (5) asphalt emulsion and (6) calcium chloride.

In addition to these methods, curing by cut-back asphalt was used on a section for study. The study of the curing methods was incorporated into the project only for the purpose of determining the relative resistance to scaling of the same concrete under various curing methods.

The final finishing operation specified in the Michigan State Highway Department standard specifications requires the use of a burlap drag.

In most cases, this method produces a satisfactory non-skid surface, but it is observed, under certain conditions, that an excess amount of fine material still remains upon the surface. All studies of scaling seem to indicate that this thin layer of material is the first to be displaced. Brooming the concrete with stiff brooms as a final finishing operation has been used by some highway engineers to reduce the amount of fine superficial material.

However, some engineers have contended that this method provided grooves for the concentration of salt solutions and a resultant unsatisfactory condition of aggravated scaling. Therefore, it was felt that a comparative study should be made of these two methods and obtain comparative data upon the two methods. Brooming was also included on certain sections of bituminous curing, since in the past, these methods of curing provided a rather slippery pavement for some time after construction, and it was hoped that a trial section of brooming would show how to overcome this difficulty if bituminous curing were allowed in the standard specifications.

The research information secured on the durability project divides itself into three groups. First, information obtained during construction; secondly, observations under service, and thirdly, special scaling study.

Construction Observations and Data: Observations and data obtained during construction are very important in the later interpretation of findings. Consequently, the observers were admonished to follow instructions closely and impressed with the importance of precise, unbiased and accurate analyses, observations and data. The information procured during this period consisted of the following items:

1. Soil surveys. Soil density and moisture content.
2. Meteorological observations including:
   a. Humidity
   b. Temperature
   c. Precipitation
   d. Wind movement
   e. Evaporation
3. Daily progress report including irregularities

4. Moisture content and temperature of concrete on special sections of curing.
5. Placing of concrete pavement.
6. Mechanical analysis of concrete to determine relative segregation.
7. Special observations relative to final finishing methods and curing.

Observations in Service: The relative value of the various factors may be prophesied by laboratory tests and observations during construction, but the ultimate conclusions must be determined by observations made under actual service conditions. Therefore, it is planned to make periodic visual examinations together with measurement of physical conditions as outlined in the above mentioned instructions. These observations will include continuation of measurements of moisture content, temperature of slab, but for the most part will be concentrated upon the study of surface scaling due to action of traffic and climatic conditions.

Special Scaling Study: During the actual service life of the pavement and for a period of 3 to 5 years, it is planned to study or observe certain sections of the project under the action of ice and salts in an accelerated manner.

The correlation of the observations made during construction and actual service together with the test information of the special scaling study should enable the Research Division to evaluate the many factors and determine their relative importance under the conditions imposed.

In conducting the scaling study definite pavement sections 120 feet in length were chosen with respect to the various concrete mixtures and surface

treatments involved in the construction of the pavement. In each section two areas were dyked off, each area being 3 feet wide and 12 feet long. The dyked areas were established along the east edge of the pavement and parallel to it. Safety precautions were maintained day and night to warn traffic of the presence of the test areas and to prevent accidents.

Two different types of accelerated test methods were employed. In test area "A", a 10 percent solution of calcium chloride of 1/4 inch minimum depth was applied and allowed to remain in place 5 days. At the end of this period, the solution was removed, the panel flushed and water applied to a depth of 1/4 inch. After the water had frozen, the ice was melted by an application of 5 pounds of flake calcium chloride per area. When the ice was decomposed, it was removed from the test area, the surface was flushed and allowed to rest one day before completing the next cycle.

Test area "B" received a different treatment. Water was applied to the test area and allowed to freeze over night. The following morning the ice was melted by distributing calcium chloride over the area at the rate of 5 pounds per area. When the ice was decomposed it was removed from the test area and the surface was flushed. Fresh water was applied to the test area and the freezing and thawing cycle repeated. On the basis of the quantity of water resulting from the melted ice in each test area, it was calculated that 5 pounds of flake calcium chloride would be sufficient to produce a 10 percent solution.

It is proposed to carry on these tests for several years to determine what effect age has on the ability of concrete to resist freezing, thawing and calcium chloride treatments. To this end, no calcium chloride has been applied to the durability section of the Test Road. Each winter the test

areas will be established in the same section and adjacent to the previous test areas.

The first of the series of scaling studies which were conducted during the past winter have been completed. The results obtained so far indicate that certain treatments of the concrete or its ingredients will tend to influence the ability of the concrete pavement to resist scaling caused by the application of calcium chloride for ice removal. Preliminary conclusions tend to show that the ability of concrete to resist scaling caused by the action of chloride salts can be materially improved by the addition of certain additives. This is particularly true of Orvus, Vinsol Resin and Calcium Chloride.

The value of these studies to the Michigan State Highway Department will depend entirely upon the manner in which the findings are applied to current and standardized practice. It is hoped as soon as definite conclusions are obtained they will be transmitted to the various divisions concerned and if feasible, the recommendations will be incorporated in the specifications. In some cases, it will be necessary to construct only a few projects including these changes and obtain further substantiating data as to the effectiveness of the newer practice. It is hoped that the facts and relationships finally obtained from both the design and durability sections will assist in obtaining the whole answer to many controversial issues and will serve to aid the Michigan State Highway Department, as well as other highway organizations in the development and improvement of concrete pavements.

Titles of Pictures attached to original article

1. Mechanical Handling of Concrete

2. Subgrade Modulus Study
   Equipment set up to determine bearing value of subgrade

3. Expansion Joint Study
   Method of measuring joint opening

4. Slab Movement Study
   Measuring Slab Movement

5. Electric strain meter assembly for measuring stresses in pavement slab

6. Slab Movement Study
   Thermocouples and moisture cells for determining changes in temperature and moisture content

7. Finishing and Curing Studies
   Study included ponding, wetted earth, wetted straw, wetted burlap, calcium chloride, and water-proof membranes.

8. Finishing and Curing Studies
   Brooming of surface

9. Concrete Scaling Study
   Accelerated scaling of concrete in test panel, size of panel 3' x 12'

10. Concrete Scaling Study
    Unscaled concrete in test panel.