MICHIGAN
STATE HIGHWAY DEPARTMENT
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CONSTRUCTION

OF

MICHIGAN TEST ROAD

By

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The subject of research and findings is one of interest to scientist, engineer and the layman. The findings of research leads the scientist to newer fields of discovery, it leads the engineer to newer applications and it awakens the layman's interest in our development of a newer and better civilization. When I was assigned this paper by the Public Relations Division, I was asked if I could give a talk on some of the spectacular and mystical studies which the Research Division was making in its work. To be sure there are many interesting experiments which we are performing that might seem mystifying and uncanny, but this is true only because the field of research in the art of highway construction is adopting many of the newer methods of research recently developed in the fields of physics and chemistry.

It is not our purpose to be spectacular or mystifying, but rather to correlate certain observations to the end that definite basic relationships will provide for improved design and a more effective use of materials.

The important problems in highway engineering have been so insistent, that there is a tendency for highway administrators to demand from their technical staff answers to questions which the latter have not had ample opportunity to carry to final completion.

We have only half answers to many problems which are admittedly better than no answer at all. Research methods and organization of research groups in highway engineering has not been all

that is to be desired. Lack of appreciation of the benefits to be derived and lack of competent personnel may be the reasons for this status. But, recently, highway engineers have realized the inadequateness of the answers to certain basic problems and gradually new emphasis has been placed upon long range fact finding research projects.

The Michigan State Highway Department, over a period of years, has shown more than average interest in the value of research and has contributed valuable information to the art and science of highway building. However, the efforts have been more or less spasmodic with work only directed to the most urgent problems. In some cases, very important and valuable work has been initiated, but because no adequate organization existed which could make long range observations and establish definite conclusions, the original effort came to practically naught.

Credit must be given to the conscientious workers who made valuable contributions and it is not the intent to belittle their efforts, but rather to point out the necessity of long range programs - programs well planned, with adequate personnel, equipment and funds in order to derive the greatest good and to establish whole answers rather than half answers.

As the mileage of improved highways has increased, so has the number of half answers become more apparent. Half truth contradicting half truth with the result that too many unstandardized methods of design and construction have been used with no basic criterions available to sort the good from the bad.

The realization of this condition encouraged the administration of the Michigan State Highway Department to establish some means whereby a contribution could be made in research endeavor in order to find the whole answer where possible.

In 1939, a Research Division was instituted in Michigan State Highway Department charged with the responsibility of creating and carrying out a research program best suited to the needs of the highway engineering profession. Special emphasis was to be placed upon the design and construction of concrete pavements from the standpoint of strength, durability and economics.

It was realized that such a program must be a long range plan, the study of which should be made by an adequate staff specially trained in the field of highway research. Also, such an organization should have proper facilities away from the regular routine of highway interoffice business.

After a little over one year, the Research Division has put under way a comprehensive program including the study of primary problems pertaining to higher quality concrete and bituminous pavements as well as subgrade characteristics and soils stabilization. In regard to concrete pavements special importance is being placed upon such subjects as scaling, curing, design, including slab thickness, spacing of joints, joint design and concrete mix design. The changes in characteristics of binding medium and consequent development of specifications for binding material are being considered under bituminous pavements. Subgrade and soil studies include measurements of subgrade modulus, relation of characteristics of subgrade soil to supporting value and methods of soil stabilization.

The work is divided into several laboratory and field projects.

It would be difficult in the time allotted to cover all of these projects. Therefore, only the field projects, now under study, will be discussed at this time. As you perhaps know during the last year a test road known as the Michigan Test Road has been constructed by the Michigan State Highway Department on M-115 between Farwell and M-66. The road is 17.6 miles in length and 22 feet in width. It 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. A review of the construction of this test road will serve to illustrate the principles and factors being studied.

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.

The most desirable concrete pavement would eliminate all transverse expansion and contraction joints, but because of the nature of concrete, joints are a necessary evil. 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 steel. 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.

It was believed, by the planners of the Michigan Test Road, that on certain types of subgrades providing better than average support, reduced thickness of pavement might be used. Also, it has been argued that equivalent uniform thickness pavements are perhaps more satisfactory and economical than the balanced cross sections; for example, a joint strengthening whereas the thickened edge type cross section demands strengthening for a balanced section. It was hoped, in the planning of the Michigan Test Road, that some of these factors could be measured and some of the complex relations studied and simplified. Therefore, four different types of cross sections were set up in the study of 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 preceding cross section.

Elaborate surveys have been made upon concrete pavements to determine the value of steel reinforcing in concrete pavements. The

results from such surveys have again opened up a controversial field in regards to the design of concrete pavements. Although the proponents of plain concrete pavements can present many plausible arguments, there are many unanswered questions. Among these unanswered questions are:

(1) Relation of plain uniform cross section to reinforced "balanced" cross section.

(2) Economics of reinforced cross sections of both types versus plain cross sections with adequate jointing.

(3) What is an adequate amount of reinforcing steel?

It was felt in planning the Michigan Test Road that inasmuch as the length of the project allowed for comparatively long stretches of both types of pavements to be constructed and observations could be made under identical conditions, perhaps some of the questions might be answered. To this end, sections were constructed using 9"-7"-9"; 8"-6"-8"; 8" and 7" uniform cross section using plain concrete, and reinforced concrete with 60 pounds per hundred square feet and 87 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.
8. A traffic counter for recording vehicle movement over the test road.

In the construction of an experimental road, certain incidental studies may be added which will not interfere with the plans and observations of the major items. A few incidental studies were introduced into the Michigan Test Road which were of interest to the Michigan State Highway Department and pertinent to the improvement of concrete slab construction. These sub-investigations comprised a study of various construction methods including; the stress curing of concrete, mechanical spreading of concrete and the use of various joint sealers.

Stress Curing: Eighteen hundred feet of concrete pavement was placed by the stress curing method of construction which eliminates steel reinforcement and transverse joints other than expansion. The slabs were laid in 100 foot lengths and the pre-stressing of the concrete accomplished by use of canvas covered rubber hose pressure cells inserted in the joint openings and expanded to exert pressures based on results of tests on representative specimens 7 by 9 by 14 inches cast throughout the period of construction of the stress curing section.

This pressure was maintained until the standard modulus of rupture beam tests reached the 7-day specification strength requirement of 550 pounds per square inch.

Mechanical Concrete Spreader: With the exception of 600 lineal feet, the concrete for the design project was placed and consolidated by means of a mechanical concrete spreader. Observations were made on the uniformity of distribution and placing of the concrete compared with and without spreader. Flexural strength tests on beams cast on the subgrade with and without concrete spreader and beams vibrated with internal vibrator will be reported for 7 and 28 day tests to determine characteristics of strength for each type of concrete placement. Preliminary conclusions relative to the concrete spreader indicate that the spreader is a valuable construction aid. Its use should allow much lower water content and requires less working of the concrete in finishing operations.

Joint Sealers: The finishing and spreading operations in the construction of a concrete pavement are very important in the development of the strength and durability of concrete slabs, yet there remains one other construction and design detail which may be of greater importance, namely, adequate and proper sealing of the joints. Probably many of our problems of pavement design would be simplified if more attention were given to this important item. Over a period of successive temperature changes causing repeated joint opening and closing cycles the possibility and occurrence of infiltration of foreign matter will be multiplied. When this partial filling of joint openings takes place the primary purpose of the joints will be defeated and the entrance of foreign

matter at transverse joints will reduce the effective width of the expansion joints, particularly in lengthy slabs, and subsequently high compression stresses will result which may not have been considered in the design. Equally important is the sealing of surface water from the subgrade.

Considerable attention has been given to this matter by the Michigan State Highway Department to the end that a seal of the asphalt oil latex type has been developed which shows promise of providing an adequate seal.

In this project all of the expansion joints were sealed with this material except a few in which other types of fillers were used. These types included poured rubber, premolded rubber and tar. A new type of expansion joint was also used which employs the poured filler of asphalt oil latex as a seal, completely sealing top, sides and bottom of joint. The details of this joint are shown in Figure . The contraction joints were observations will be made to determine the effectiveness of the various types of seals.

~~The second section~~ or 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 project was constructed under regular contract and construction procedure using the Michigan State Highway Department 1940 plans and specifications with necessary supplementals. The supplemental specifications covered details for all variables unusual to Michigan State Highway Department specifications. They 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 proprietary 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
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. The method is described as follows: "As soon as all excess moisture has disappeared and while it is still possible to produce a uniform surface of gutty texture, the pavement shall be given a final finish by dragging a strip of damp burlap over the full width of the pavement."

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.

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.