

MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

RESEARCH ACTIVITIES
1939 - 1943

RESEARCH LABORATORY
TESTING AND RESEARCH DIVISION
EAST LANSING, MICHIGAN
May 1, 1943

PREFACE

This manuscript constitutes a report pertaining to the research organization and its function in the Michigan State Highway Department. It is intended that the report shall acquaint, those concerned, with the scope and character of the work being performed by the research organization, and to emphasize the importance of such work to the Department as well as to the entire highway industry.

The report includes a history of the research organization, the scope and status of the work under program, and the accomplishments of the organization since its creation in 1939.

PREFACE

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RESEARCH IN HIGHWAY DEPARTMENTS

Research has come to occupy an important place in the art and technique of highway building. For the adequate appraisal of new methods and for improvements in old as well as for the development of new materials, the highway administrator must have access to a group of engineers and scientists trained in the field of research.

"The highway administrator is dependent largely upon the work of his technical staff to secure the information on the various problems which confront him, so that in the end, the efficient research worker has an important position and the work that he does has such weight in determining policies which are put into effect. The research worker has in that way a direct voice and a direct control of the shaping of policies which determine the progress which we shall make in this public work in the United States. I cannot over emphasize the importance which I place upon the research staff within the various highway organizations of this country where they are capable and where they are supported with sufficient funds actually to produce results".

T. K. Macdonald

The important problems in the highway field have been so insistent that there has been a tendency for the highway administrator to demand from his technical staff answers to questions which they 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 to the administrative official carrying on a large program.

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 reasons for this. 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 evidence of 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 being directed to the most urgent problems.

Recently, the great number of half answers which were being used by the highway profession in the formation of policies in the design and construction of concrete and bituminous pavements, have become very large in number. Half truth contradicting half truth with a result that too many unstandardized methods of design and construction were used and 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 to answer some of the unanswered questions.

In August 1939, a separate Research Organization was established in the Michigan State Highway Department, charged with the responsibility of creating a highway research program best suited to the needs of the Department as well as to the engineering profession. Special emphasis was to be placed upon the design and construction of concrete pavements from the standpoint of strength, durability and economy.

THE RESEARCH ORGANIZATION

The purpose of the new organization was to carry on more effectively the research work previously done by the various Divisions and to investigate the specific technical problems arising within the Highway Department.

The Research Division was established at Michigan State College by mutual agreement between the State Board of Agriculture, the State Administrative Board and the State Highway Commissioner. The College authorities accorded to the Highway Department its facilities and certain space of the Civil Engineering Laboratories for pursuance of the research program.

The location of the research organization at Michigan State College is ideal for the promotion and carrying on of scientific investigations, thereby bringing about through mutual confidence the coordination of data and new knowledge as well as the correlation of effort to the end that highway engineering and the pursuance of its study shall be more effective and conclusive. In addition, the proximity of the research laboratory to Lansing has many advantages from the standpoint of conducting routine administrative functions and because of its accessibility to the staff and other personnel of the highway organization.

In April 1943, the Research Division and the Testing Division were combined thereby forming the present Testing and Research Division. This change was brought about by the Highway administration in keeping with a general retrenching program necessitated by war time conditions. The activities of the former research division were not changed by this union.

A memorandum of agreement between the Michigan State Highway De-

partment and Michigan State College stating the mutual benefits which may occur from such an enterprise was executed. It has been the policy of the research organization to adhere to the principles set forth in the Memorandum of Agreement.

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MEMORANDUM OF AGREEMENT
BETWEEN
MICHIGAN STATE HIGHWAY DEPARTMENT
AND
MICHIGAN STATE COLLEGE

It is recognized that the Michigan State College is an educational institution the object of which is to provide facilities for higher education, research and cooperative scientific enterprises.

It is recognized also that the Michigan State Highway Department is a governmental service organization the function of which is to provide for the construction, maintenance and safety of the public highways. To insure efficient administration and progress in highway engineering it is necessary that the Highway Department provide certain facilities for the scientific investigation of its problems and other instructional service facilities for the benefit of the general public. The two missions being in no sense antagonistic, but supplementary, it would seem the part of wise economy that these two agencies should avail themselves, of certain facilities of each other which would enhance the working out of their respective missions in serving the public interest.

Accepting the foregoing principles as fundamentally sound, the Michigan State College offers to the Michigan State Highway Department those facilities of plant and equipment which will enable the latter to carry on an active research program. The Michigan State College further offers such other facilities which will allow the Michigan State Highway Department to instruct the general public in its problems and further assist in the promotion of the general welfare. The Michigan State Highway Department in accepting the use of these facilities will endeavor to employ the same without interfering with student activities. And,

in acceptance of this offer the Michigan State Highway Department will strive to encourage and develop the importance of highway engineering research; to assist the Michigan State College in a cooperative manner in the promotion and carrying on of scientific investigation; to bring about through mutual confidence the coordination of data and new knowledge and the correlation of effort, to the end that highway engineering and the pursuance of its study shall be more effective and conclusive.

The detailed manner in which the coordination of facilities and efforts may be affected shall be determined by the respective administrators and officials of the two organizations.

It is understood that this agreement shall be effective for a period of one year and may be continued for an indefinite period by mutual agreement.

Murray D. Van Hogen
State Highway Commissioner

Robert E. Shaw
President, Michigan State College

Date September 18, 1939

Date September 16, 1939

Approved _____

Approved State Bd of Agriculture

Date _____

John A. Hanch, Sec.

Date Sept 18, 1939

FUNCTIONS OF THE RESEARCH ORGANIZATION

It is believed that a research organization in a highway department should be adequately staffed and equipped in order that it may perform the following functions -

1. To conduct experimental research pertaining to specific problems arising in the various engineering divisions of the Michigan State Highway Department.
2. To direct itself towards the solution of certain major problems of interest to the field of highway engineering in general.
3. To engage in cooperative research with other State Highway Departments and technical organizations interested in highway problems.
4. To take part and thereby representing the Department in the activities of the various engineering and technical societies.
5. To participate in developmental researches for the purpose of improving methods of highway design, construction methods and procedure, materials of construction and highway appurtenances.
6. To develop new materials for highway use.
7. To accumulate and dispense technical data and literature pertaining to outside research activities, construction practices, etc., for the convenience and benefit of other divisions of the Highway Department.
8. To prepare technical papers and reports for members of the Highway Department outside of the Research Division.
9. To act in an advisory capacity in regard to problems of mutual interest in the Department.

It has been the policy of the research organization of the Michigan State Highway Department to fulfill these functions to the best of its ability.

LABORATORY FACILITIES

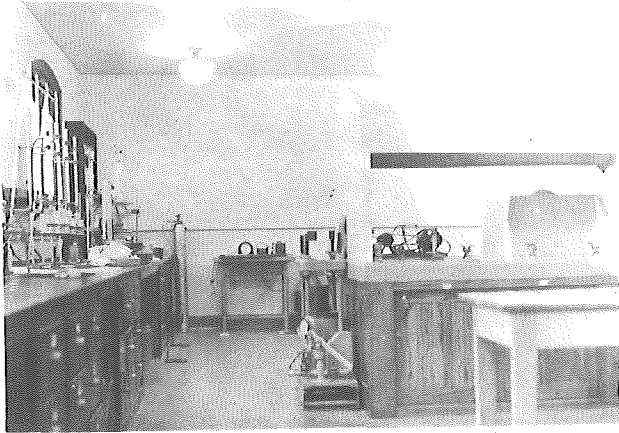
The research organization's office and laboratories are located in Olds Hall of Engineering on the Campus of Michigan State College. Laboratory activities are confined to two rooms, one of which is a large basement room properly conditioned and fully equipped to carry on research problems in the fields of cement, concrete, soils and miscellaneous experiments without interfering with college activities. The other room constitutes the bituminous laboratory of the Civil Engineering Department. A part of this laboratory is occupied by the Highway research personnel, for conducting bituminous research and problems of a chemical nature. A small office is provided for laboratory personnel to facilitate pursuance of their duties. The general administration office is located in Room 3, Olds Hall.

CEMENT AND CONCRETE LABORATORY

A fully equipped cement and concrete laboratory has been established in which it is possible to conduct the standard routine tests pertaining to cement analysis and concrete design. A large moist room is available for curing and storing concrete specimens. In conjunction with the large moist room a smaller moist cabinet is available for cement testing. It is possible to maintain the cement and concrete laboratory at a constant temperature and humidity.

PHYSICAL LABORATORY

The physical laboratory includes equipment and facilities for performing routine laboratory tests on aggregates and concrete specimens.



Bituminous and Chemical Laboratory

LABORATORY FACILITIES

ENGINEERING BUILDING
MICHIGAN STATE COLLEGE



General Research Laboratory



Soils Laboratory

In addition there are specially designed equipment such as a 50 ton hydraulic compression machine for all purpose compression testing, a 20" circular concrete cutting saw and grinding lap for cutting and preparing specimens for microscopic slides, a 10' diameter treadometer for conducting tests on different types of road mixtures, a fast freezing 3 cabinet refrigerating unit for freezing concrete specimens, and a sonic apparatus for determining the modulus of elasticity of concrete specimens.

SOILS LABORATORY

The soils laboratory has all of the necessary apparatus for performing identification and classification tests as well as specially designed vibrating table and electrically driven proctor compaction machine for determining density and compaction of soil mixtures.

BITUMINOUS AND CHEMICAL LABORATORY

The bituminous and chemical laboratory has complete equipment for performing routine and special chemical tests on portland cements and bituminous materials including a Koppers Viscosimeter for determining viscosity in absolute units, a special apparatus for recovering slow-curing asphaltic materials from bituminous mixtures, and a photometer which may be used as a colorimeter and for determining the surface area of fine particles.

MISCELLANEOUS LABORATORY EQUIPMENT

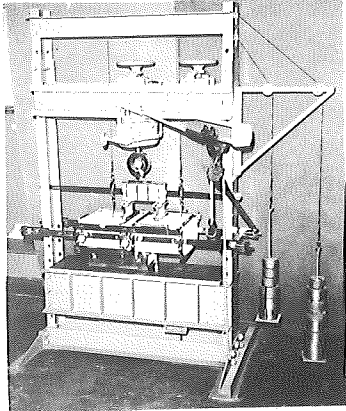
In conjunction with the laboratories there is a work shop well equipped with small tools, a lathe, drill press and grinder, a work shop is an important necessity in any research laboratory for repair work and for

developing new scientific equipment for research work. The College machine shops are always available for doing work too large or complicated for the laboratory work room. In addition to the desks, tables, and files in the separate laboratories modern office facilities are available to the staff.

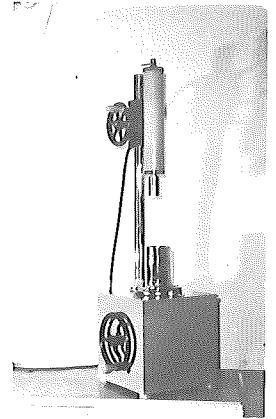
FIELD EQUIPMENT

Equipment available for field studies includes a panel truck, utility car and a mobile field laboratory. The mobile laboratory was designed to accommodate routine testing equipment relative to soils, soils stabilization, concrete and special equipment incidental to the Michigan Test Road and other field experiments. Associated with the Michigan Test Road are special equipment including an A-C bridge for determining moisture content of concrete and soils, a D-C bridge for measuring resistance ratios from Barlach electric strain gages incidental to measuring stresses in concrete slabs, measuring telescope for checking slab movements, complete assembly of recording meteorology and temperature equipment, apparatus for determining subgrade modulus and an assortment of miscellaneous equipment pertinent to field operations and sampling. A small field laboratory has been established on the Michigan Test Road Project for facilitating operations during the life of the project.

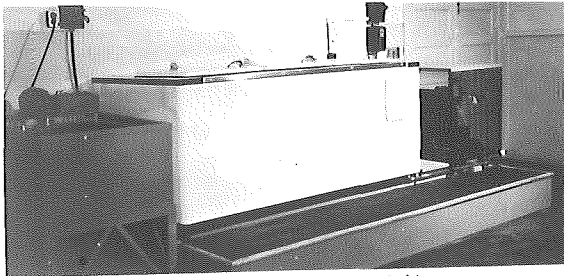
MODERN RESEARCH LABORATORY EQUIPMENT



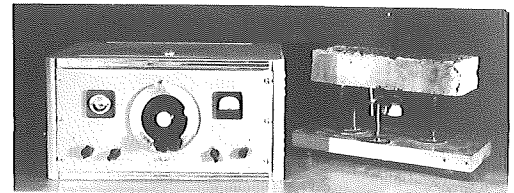
Hydraulic Testing Machine



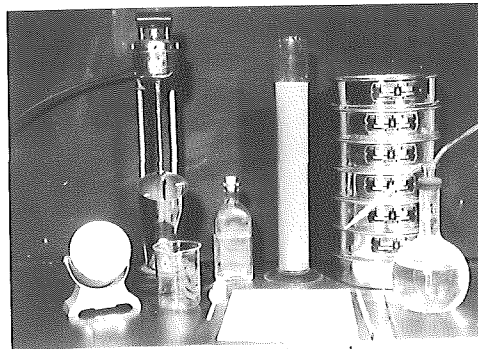
Proctor Apparatus
for Soil Testing



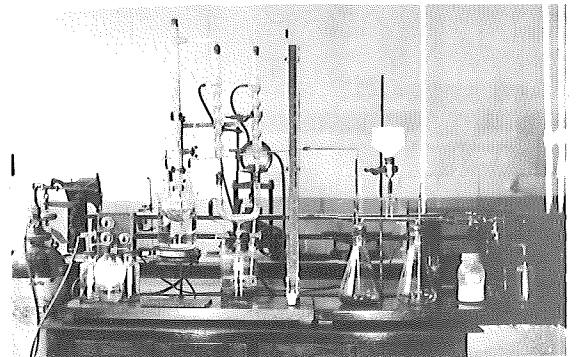
Freezing and Thawing Unit



Sonic Apparatus to Determine Young's Modulus

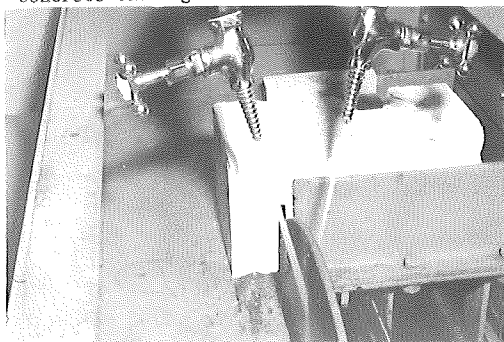


Soil Testing Apparatus

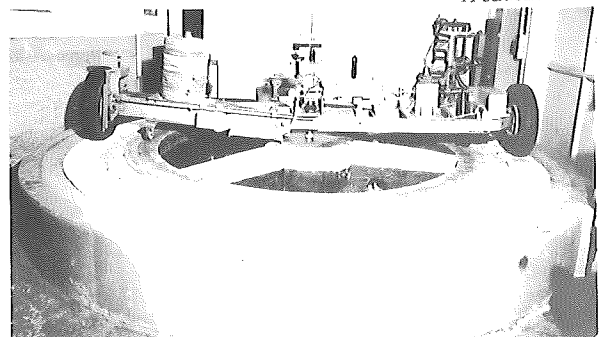


Bituminous Recovery Apparatus

Concrete Cutting Saw



Treadometer



PERSONNEL

The collection, organization and presentation of research data requires a staff of competent investigators. Such investigators must be sufficiently trained in the fundamentals of research to insure the proper degree of expertness, impartiality and precision in their work.

Inasmuch as modern highway research problems involve studies in the higher branches of physics, chemistry, engineering and mechanics, and because many modern methods of research analysis have been recently developed, it is necessary to employ men who are specialized in various fields of this higher learning.

Under normal operation conditions in 1941 the research organization consisted of 22 full time employees. Since January 1942 war activities has resulted in a reduction of staff personnel to nine persons.

The personnel of the present research organization includes a group of scientifically trained men possessing considerable practical research experience and scholastic achievement. A short biographical sketch of each member is given below: -

Finney, E.A. Assistant Testing and Research Engineer in charge of Research, B.S. (C.E.) Allegheny College 1923; M.S. in Highway Engineering, Iowa State College 1924; C.E. Iowa State College 1924; Staff member of Civil Engineering Department and Michigan Experiment Station, Michigan State College, 1925 to 1937. In Research and Testing Division, Michigan State Highway Department since 1937.

Rhodes, C.C. Chemical Research Engineer, B.S.E. (Ch.E.) M.S.E. - University of Michigan 1921-1922, Chief Chemist and Metallurgist, Surrroughs Adding Machine Company, 2 years. Research and Testing Division, Michigan State Highway Department, 1929 to present time.

Present, H.O. Technical Engineer, Graduate Civil Engineer, Institute of Engineers of Ways of Communication, Emperor Alex I., St. Petersburg, Russia, 1904, Engineer of Design and Construction, Russian Railways, 1904-1920, Private Engineering Practice 1920-1926, Russian Polytechnic Institute, Harbin, China, 1926-1929, Professor of Higher Mathematics, and Research Engineer, Department of Engineering, University of Michigan, 1929-1935, Research in Michigan State Highway Department 1935 to present time.

Tamm, Richard. Research Chemist, Doctor Chemical Engineering, Hannover Technical College, Germany, chemist in various manufacturing laboratories in Germany, 1901-1906; Chief Chemist Canadian Colliery Company, 1906-1912, Production Chemist, Benzene Chemical Company, 1912-1923, Chief Chemist, Baker Perkins Company 1923-1934, Consulting Practice 1934-1939, Research, Michigan State Highway Department 1939 to present time.

Burke, A.H. Physical Research Engineer, A.B. Battle Creek College, 1928, one year chemical research Battle Creek College, Research, Michigan State Highway Department, 1941 to present time.

Research Engineer

Asst. Research Engr.

Chem. Res. Engr.

Chem. Res. Engr.

Phy. Res. Engr.

Chem. Res. Engr.

Phy. Res. Engr.

Mechanist

Phy. Res. Engr.

Phy. Res. Engr.

Phy. Res. Engr.

Lab. Aid.

Lab. Aid.

Steno. Clk.

Lab. Aid.

Lab. Aid.

Lab. Aid.

RESEARCH ORGANIZATION CHART

THE RESEARCH PROGRAM

The major problems receiving the immediate attention of the Research Laboratory are; concrete pavements including studies of sealing, curing, slab design, joints and concrete mix design; bituminous pavements with special emphasis on changes in characteristics of bituminous materials; soil stabilization embodying bituminous materials, portland cement and other binding agents; snow and ice control involving removal by mechanical and chemical methods and miscellaneous problems.

In October 1939, a research program consisting of eight major projects was submitted to the Administration for approval and for the establishment of a budget under which to operate. The program, as submitted, is presented in Table I, together with account numbers assigned by the Finance Division.

TABLE I
Original Research Program
October - 1939

<u>Account No.</u>	<u>Project Title</u>
82-19	Administration
82-19-1	Joint Testing
82-19-2	Concrete Sealing, curing and finishing
82-19-3	Pavement design
82-19-4	Concrete Mix Design
82-19-5	Bituminous Materials
82-19-6	Soil Stabilization and Subgrade
82-19-7	Snow and Ice Control
82-19-8	Miscellaneous

Later, when the program got under way, it was found necessary to assign the many separate investigations incidental to the master program, to their proper place under the appropriate projects and account numbers. Thus, the original research program has expanded as presented in Table II.

TABLE II
Current Research Program

<u>Account No.</u>	<u>Project No.</u>	<u>Project Title</u>
800		Administration
801	38 F - 1	Evaluation of Load Transfer Devices
802	39 B - 11	Durability of Concrete Pavements
		(a) Pavement Survey
		(b) The Michigan Test Road
		(c) Laboratory Studies
		(d) Miscellaneous Durability Projects
	42 B - 14	Membrane Curing of Pavements
	42 B - 15	Pouring Concrete at Low Temperatures
803	39 F - 7	Concrete Pavement Design
		(a) Subgrade Bearing Studies
804	38 B - 1	Concrete Proportioning and Grading of Aggregates
805	38 C - 1	Characteristics of Asphaltic Oils
806	38 E - 6	Soil Stabilization
		(a) Bituminous
		(b) Portland Cement
	42 E - 9	Turf Growth on Highway Shoulders and Airports
807	38 C - 8	Snow and Ice Control
808	38 C - 4	Concrete Pavement Joint Sealers
	42 C - 19	ReflectORIZED Sign Materials
	42 C - 20	Agrifil as a Mineral Filler

PART II

RESEARCH PROJECT ACTIVITIES

Part II has been prepared for the purpose of explaining, as briefly and simply as possible, the purpose, importance, scope and present status of the eight major research projects mentioned previously in Part I.

In addition, final reports pertaining to certain completed portions of the various projects, or the results of special investigations will be explained in their proper relationship to the research program.

PROJECT 1 - EVALUATION OF LOAD TRANSFER DEVICES

The evaluation of load transfer devices pertains to the study of the statics; elastic and plastic properties; strength characteristics and stress distribution in transverse joints composed of different types of load transfer devices.

The purpose of the study is to establish criteria for the evaluation of load transfer devices and joint assemblies, to determine proper spacing of same and to obtain data for writing specifications.

The importance of such a study is quite evident. There has been a feeling, for some time, among engineers that as long as expansion joints are required in concrete pavement slabs some type of load transfer device will be required to strengthen the free edges at such joints, especially to maintain the slabs at equal elevation. However, there has been a wide divergence of opinion as to how it should be accomplished and a decided lack of agreement on the fundamental structural requirements at such a joint when load transfer is used.

Load transfer devices have been used experimentally for a number of years but no definite criteria has been established for their use and design. Because there is such a diversity in the design and use of these devices, the situation seems to dictate the necessity for obtaining accurate information regarding other characteristics on individual units in concrete, as well as their characteristics in groups in a concrete slab.

The project has been planned to include the four following major studies -

1. Development and construction of a special hydraulic testing machine capable of not only testing joint units but equally adaptable to other tests requiring compressive forces.
2. Shear deflection tests on various types of load transfer devices to determine their mechanical characteristics. Also shear tests exemplifying load transfer at contraction joints.
3. The establishment of a proposed field installation test for joint unit assemblies and preparation of specifications for load transfer units, and joint unit assemblies.
4. Completion of data and necessary mathematical calculations incidental to the structural design of pavement slab edges at expansion joints.

Development of Hydraulic Testing Machine

Purpose: To design, and construct a compression machine capable of testing the various types of load transfer devices.

Scope: The testing machine was to be designed and constructed with the thought of using it for other laboratory tests involving the need for compressive forces.

Status: This part of the investigation has been completed.

Shear-Deflection Tests

Purpose: To study the characteristics of the various load transfer devices under laboratory shear-deflection tests in order to obtain data necessary for the successful design of expansion joints.

Scope: The study will include a review of the work of Hestergaard, Teller, Friberg, the previous work of the Michigan State Highway Department, as well as the laboratory studies included in the scope of the joint project.

Status: This work has been completed and written up in preliminary form.

The entire project on the evaluation of load transfer devices has been completed and written up in preliminary form. A formal report will be forthcoming in the near future. Progress reports have been submitted*

Special Reports

A paper was presented at the Highway Research Board meeting in 1940, entitled "The Theory and Design of Load Transfer Units in Concrete Pavements". Final Report No. 3.

PROJECT 2 - DURABILITY OF CONCRETE PAVEMENT

A survey study of all concrete pavements shows that a considerable percent of the surface is scaled in varying degrees. This condition has become more apparent as the use of chemical salts has increased for the removal of ice from pavements. Scaling has been common in most parts of the state, but, on a whole, the concrete is predominantly good. But, even so, the unsightliness of scaled areas and subsequent maintenance and the added possibility of further deterioration is of immediate concern to the highway engineer.

For this reason, a study of scaling, its causes and methods for prevention, has been incorporated into the research program under the title of "Durability of Concrete Pavements".

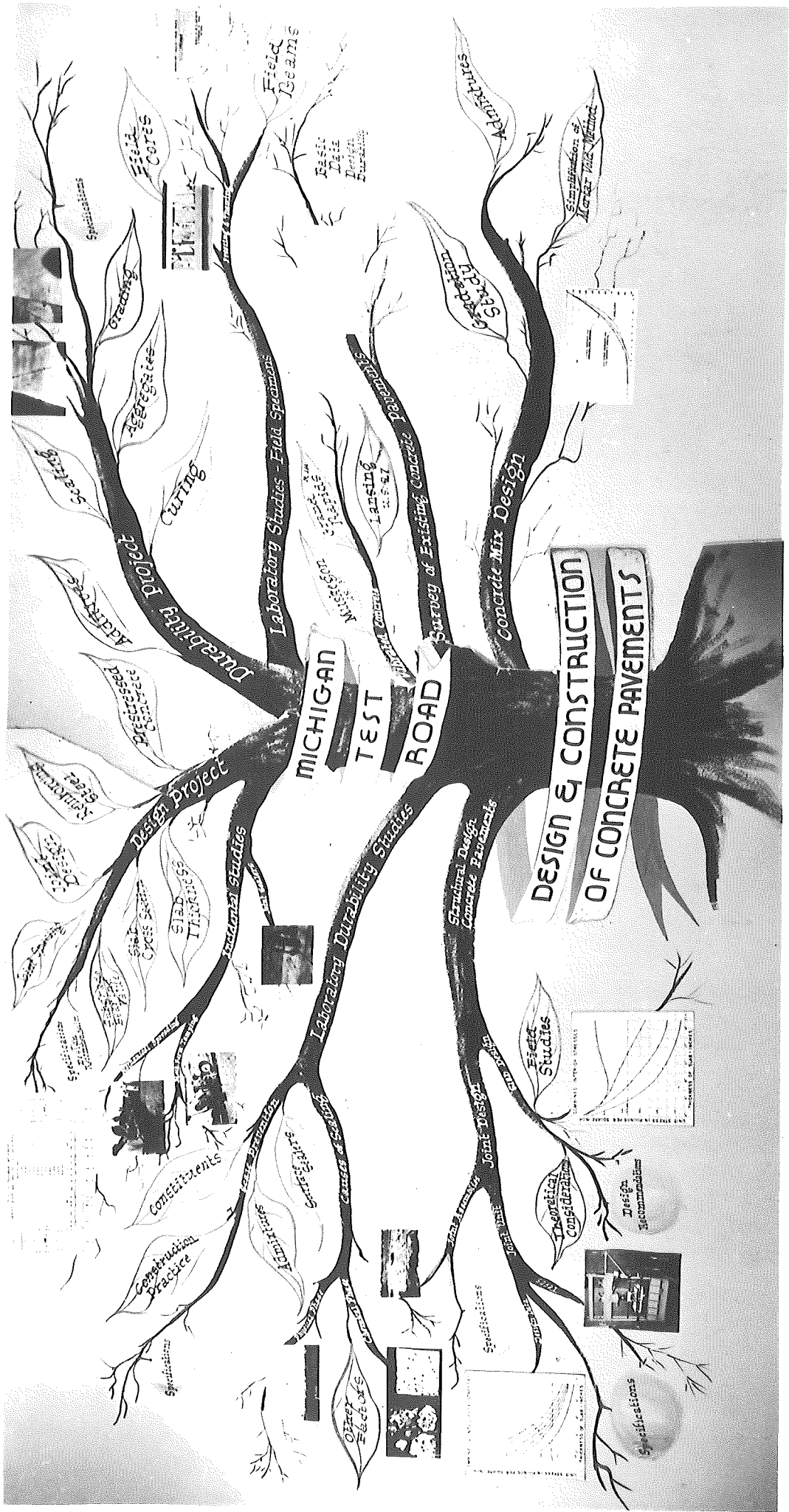
The durability project includes the following major parts:

1. Condition survey of existent pavements.
2. Durability project of the Michigan Test Road.
3. Laboratory durability studies.
4. Incidental studies.
5. Special Reports.

The major studies outlined above will be discussed separately including their purpose, scope and present status.

Condition Survey of Existent Concrete Pavements

Purpose: To determine by visual observation the amounts and degree of scaling prevalent on concrete roads in Michigan and to correlate information with the various factors incidental to the construction of the pavement slab.



Scope: Survey included all of the concrete pavements on the state trunkline system.

Status: The work at the present time consists of correlating the numerous factors with scaling. This work is in progress. Preliminary correlation studies have been completed.

Durability Project of the Michigan Test Road

Purpose: The performance of concrete under the severity of service cannot be predicated upon laboratory studies. Therefore, the purpose in constructing the durability project was to obtain a field laboratory to obtain accelerated action of chloride salts or ice on concrete pavement and to study the resultant action. Also, to evaluate the effect of variation of factors relative to construction and materials used in highway construction upon the durability of concrete pavements.

Scope: Embodied in the durability project are the following considerations:

1. The grading of aggregates with definite recognition of the material passing 200 mesh.
2. The comparative effect of various types of additives including, physical and chemical varieties as well as cement blends and cements produced with grinding aids.
3. Crushed limestone aggregates with special attention to finer fractions.
4. A study of finishing methods in relation to scaling.
5. A study of various curing methods in relation to scaling.
6. Accelerated scaling studies.

7. Comparative laboratory freezing and thawing tests on field specimens.
8. Special laboratory study of pavement cores taken from durability project including freezing and thawing, unit weight, void content, distribution of aggregate.
9. Factors incidental to construction which might be contributory to scaling.

Status: The first stage of the field and laboratory research work pertaining to the durability project of the Michigan Test Road has been completed. A progress report is being written for publication.

Laboratory Durability Study

As part of the general investigation of the durability of concrete pavements in Michigan, laboratory studies have been undertaken to supplement the field study and the durability field project of the Michigan Test Road.

The laboratory program has been divided into three main divisions devoted to the following work -

1. Preliminary work incidental to construction of Michigan Test Road.
2. The determination of causes of scaling.
3. A study of methods to prevent scale.

The above problems pertaining to the laboratory durability study will be discussed in the order given.

1. Preliminary work incidental to construction of Michigan Test Road.

Purpose: To evaluate, by certain laboratory methods, the characteristics of application and durability of the various cements, additives, aggregates and joint sealers offered to the Highway departments for the improvement of certain pavements. Also, to determine the characteristics of a

number of proprietary additives and methods of proper proportioning in concrete mixtures.

Scope: This work was done prior to the construction of the test road and included such problems as --

1. Comparative evaluation of several brands of Portland cement.
2. Comparative evaluation of several types of additives.
3. Design and proportioning of concrete mixtures containing additives.

Status: This work has been completed.

2. The Determination of Causes of Scaling

Purpose: To make a comprehensive study of the many factors considered to be contributory to scaling for the purpose of obtaining substantial data to enable us to approach the problem of prevention in a logical manner.

Scope: The study of causes of scaling has been divided into three phases, chemical physical and mechanical. Under chemical causes have been included --

1. Compilation of data pertinent to salt solutions involving a bibliographical study and a field study to determine the probable concentrations of salt solutions on pavement due to ice removal methods.
2. Scale formation on concrete as effected by chloride salts, involving such studies as the chemical reaction of chloride salts on the constituents of concrete and the formation and distribution of chemical products conducive to scaling.
3. The chemical action of chloride salts on neat cements, mortars and concrete under different test conditions.

The physical phase involves two main subjects -

1. The segregation and variation of constituents of concrete, such as bleeding when associated with mix design, physical characteristics of constituents, working of the concrete surface and interfacial relations between the constituents of concrete.
2. Variation in physical characteristics of concrete from top to bottom of slab, involving grading, amount of cement, density, absorption, porosity and coefficient of expansion.

Mechanical factors will be considered to include frost action, freezing and thawing and traffic conditions.

Status Parts 1 and 2 of the chemical phase have been temporarily completed pending further results from other phases of the problem. The study of chemical action of chloride salts on neat cements is practically completed and preparation has been made to continue with the study on mortars and concrete.

Studies 1 and 2 of the physical phase have been correlated with construction factors relative to the test road and that part has been completed. However, further laboratory studies are necessary to completely terminate the project.

The mechanical factors remain to be studied.

1. Scale Prevention Studies

Summary It is a recognized fact that scaling can be materially reduced by additives, and by the proper control of construction practices. Therefore, it is the purpose of this investigation to study the relative merits of the many proposed methods of scale prevention as a part of the whole subject of durability of concrete.

Scope: The scale prevention studies include the following subjects:

1. Improvement of characterization of constituents of concrete.
2. Improvement of construction practices involving mix design, construction operations and curing methods.
3. The use of admixtures or grinding aids.
4. The use of surface sealers.

Status: These four problems cannot be completely terminated until the durability project has been exhausted in all its phases. However, enough data has been accumulated, so far, to enable the Research Laboratory to present certain recommendations relevant to the subject.

Incidental Studies

The scope of the durability project has been enlarged to include those special studies which have some bearing upon the durability of concrete. For example, the stone sand problem, the question of plain concrete versus vibrated concrete as to durability and economy, the use of admixtures for scale prevention and others. During the last two years, three such problems have been given due consideration by the department, as well as special sealing studies and they are described under the heading "Incidental Studies".

Michigan Stone Sand - Project M 76-22. (II)

On the basis of results obtained from the sealing study conducted last winter on the durability portion of the Michigan Test Road, M-119

relative to the use of admixtures to improve the physical characteristics of stone sand concrete and its ability to resist scaling, it has been proposed to experiment further with the use of admixtures in stone sand concrete mixtures. Consequently, in the construction of a 0.417 mile of 28-42 foot concrete pavement in the City of Manistique with limestone aggregates, certain admixtures were added for comparative study of the resultant concrete mixtures and durability of the finished surface. This project was constructed in 1941.

The limestone aggregates, both coarse and fine, were obtained from the Inland Lime and Stone Company quarries located at Manistique. Orvus wetting agent paste admixture was added in specified amounts to the concrete throughout the entire project. In the north half of the pavement only, silica dust was added in addition to the orvus at the rate of 65 pounds per cubic yard of concrete.

The purpose of this work is an attempt at improving the objectionable characteristics of stone sand in concrete such as bleeding, difficult finishing and scaling by the addition of wetting agents and additional fines.

Throughout the construction of the pavement, the concrete operations were carefully watched and observations recorded for future comparison and study.

Final results from this study have been submitted in Report No. 37.

Orvus Admixture Used in Concrete - Project F R2 of 3-9-41, 01

In 1941, orvus was used as an admixture for scale prevention in the concrete which was used for constructing the sidewalks of bridge project

F 32 of 3-8-1, 01, at Plainwell, Michigan.

The application of the Orvus and construction procedure was similar to that of slab construction.

This project is under observation.

Vibratory Concrete - Project F 41-34, 06

The latest design of vibratory equipment was given a trial on project F 41-34, 06, near Grand Rapids, on east belt, K-115. The project was constructed in 1941.

In addition to vibratory and durability studies, certain factors relative to design and construction were included in the project such as -

1. Lane construction with concrete screw conveyor.
2. Uniform slab construction without reinforcement steel or load transfer at expansion and contraction joints.

A preliminary report (No. 38) has been prepared covering the research phase of this project.

Special Souling Studies

Accelerated souling studies have been conducted on four concrete projects to determine the relative effect of calcium chloride solution on different types of concrete, and to correlate laboratory studies with field observations under actual service. The four field projects include, the durability section of the Michigan Test Road, the Manistique stone sand project, a stamp sand project at Houghton, and a regular concrete

project at L'Anse.

Certain sections of the durability project of the Michigan Test Road were subjected to a series of controlled calcium chloride treatments to determine the relative ability of the various concrete mixtures to resist scaling and disintegration. This study is augmented by extensive laboratory study.

The sections treated included the various curing studies, the concretes containing additives, blends of portland cement and natural cement, concrete containing added fines and limestone aggregate.

The data from two-year scaling studies has been obtained. The field data must be correlated with laboratory studies before a final report can be presented.

The three following scaling projects are located in the Upper Peninsula and, therefore, they are described under the activities of the Houghton Branch of the Research Division -

Manistique Stone Sand Project

Stamp Sand Project at Houghton

Regular Concrete Project at L'Anse

Membrane Curing Study

42-8-14

Purpose: To evaluate the various membrane curing compounds on market and to determine the relative merits of membrane curing as compared with standard methods. Also, to procure data for preparing adequate specifications pertinent to laboratory testing and field control.

Scope: The work shall include the following:

1. Establishment of suitable laboratory equipment for conducting the tests.

2. Evaluation of membrane curing compounds.
3. Evaluation of curing methods.
4. Development of specifications and test procedure.

Status: Tentative specifications have been established and several membrane compounds evaluated. Attention has centered largely on developing a suitable water retention test procedure. Work is in progress.

Pouring Concrete at Low Temperatures AS R - 15

Purpose: To determine the setting characteristics of neat cement and concrete under low temperature conditions with and without admixtures.

Scope: The work shall include laboratory studies under controlled conditions and field observations on regular construction projects.

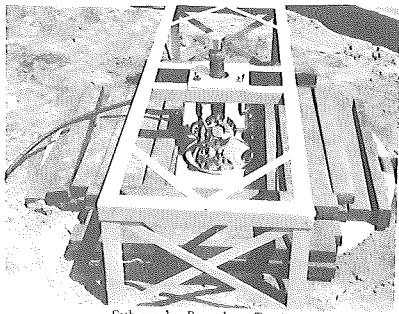
Status: The work has been completed. A formal report is being prepared.

Special Reports

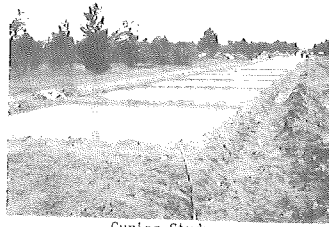
During the last two years, the Research Division has prepared several special reports pertaining to the durability of concrete or associated with the durability project of the Michigan Test Road. The reports completed are as follows:

1. Concrete Durability Studies. Final Report No. 11
2. The Manufacture of Stone Sand and Its Use In Concrete Mixtures. Final Report No. 15.
3. Report on Claims Presented by K. L. Thom Company Contractor on Michigan Test Road. Final Report No. 16.

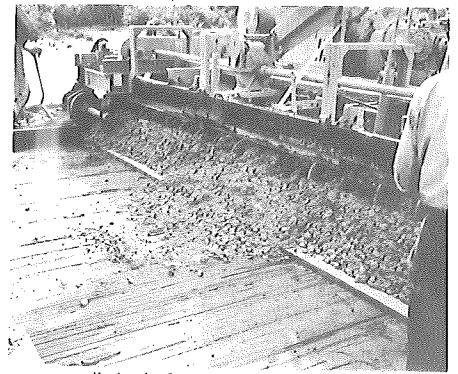
4. Pamphlet on Michigan Test Road. Final Report No. 21.
5. Comments on Concrete Sealing Studies. Final Report No. 24.
6. Accelerated Sealing Studies on Concrete Pavement.



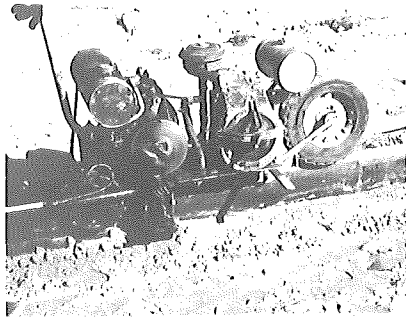
Subgrade Bearing Tests



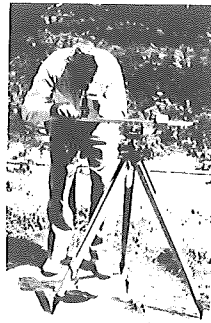
Curing Study



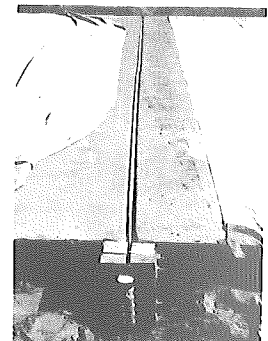
Mechanical Handling of Concrete



Mechanical Form Tamper



Slab Movement Measurements

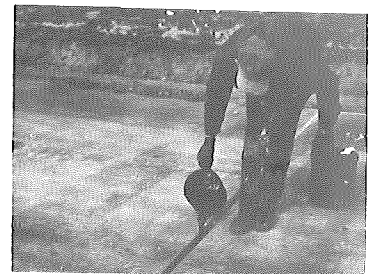


Pavement Slabs Prestressed During Curing

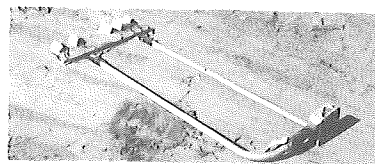


Analysis of Fresh Concrete

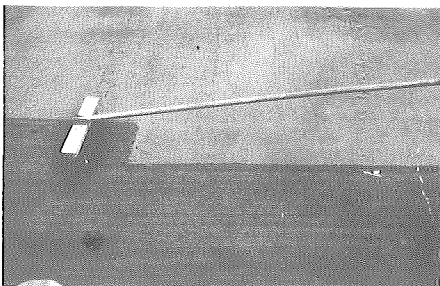
THE MICHIGAN TEST ROAD



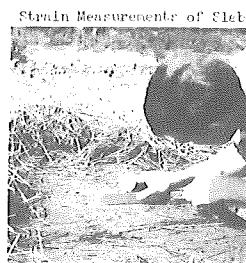
Joint Sealing Study



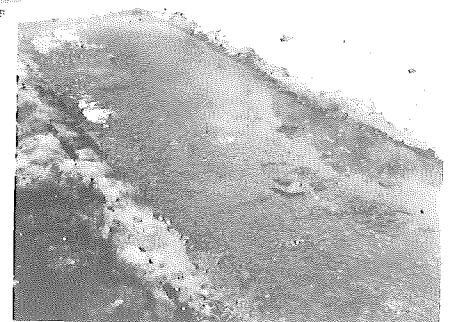
Moisture Cell and Thermocouple Assemblies



Brooming Operations



Strain Measurements of Slab



Scaling Studies

PROJECT 1 - CONCRETE PAVEMENT DESIGN

Purpose: To establish certain fundamental principles in concrete pavement design and to correlate certain laboratory studies with construction methods in order to develop more durable concrete pavements. The facts and relationships obtained shall be used for the improvement of the Michigan State Highway Department design and construction procedure.

In order to realize the purpose of the project, it was necessary to construct an experimental pavement incorporating the principles and factors incidental to design and construction. This experimental pavement is known as the design project of the Michigan Test Road.

The design project coincides in a general way with the Public Roads Administration's plans and procedure for construction of experimental roads which were submitted to the Department in 1940.

Scope: The important design studies considered with respect to modern practices are:

1. Spacing of expansion and contraction joints.
2. Expansion and contraction joint design.
3. Uniform slab thickness versus balanced cross sections.
4. Amount of reinforcing steel necessary.
5. Relation of pavement cross-section to subgrade supporting value.
6. Pavement cross-section thickness.
7. Prestressing of concrete slabs during curing.

Included in the scope of the design project were certain incidental construction features, such as -

1. Mechanical versus manual handling of concrete on subgrade.
2. Mechanical versus hand tamping of forms.
3. The use of different types of joint seals.

Importance: There is need, at the present time, of a comprehensive evaluation of modern theories of design and construction. This statement is clearly demonstrated in recent reports of technical writers on the subject.

The value of this study is further enhanced by increased beauty, safety, roadability, economic life and reduction of cost of construction and maintenance.

Furthermore, no study of this type has been carried on since the Bates Road Test in Illinois in 1922-23.

Status: It will take several years time before sufficient data will be accumulated from the design project of the test road to warrant making any definite conclusions relative to the design studies. However, the data will be compiled as received from the field and, no doubt, some definite trends relative to the various factors studied will be noted within a short time. This project is in progress continuously.

Special Reports: Several reports have been written on this project. They are listed below.

1. Investigational Concrete Pavement in Michigan, Final Report No. 4.
2. Value of Concrete Spreader in Concrete Pavement Construction, Final Report No. 9.
3. Construction of Michigan Test Road, Final Report No. 12.
4. Pamphlet on Michigan Test Road, Final Report No. 21.

PROJECT 4 - CONCRETE PROPORTIONING AND GRADINGS OF AGGREGATE

Purpose: The purpose of this study is two-fold. First, to design concrete mixtures according to the mortar void theory, using various additives as preliminary work to the durability project of the Michigan Test Road. Second, an attempt to design a practical and economical concrete mix that would show improvement in resistance to scaling as compared to some of our present day pavements.

Scope: The project is comprised of five main problems, namely:

1. The design of concrete mixtures by mortar void method when additives are to be used in the mixture. A preliminary study to durability project of test road.
2. A gradation study of concrete aggregates and cement as related to scaling and durability of concrete.
3. A physical study of the physical characteristics of mortars and concrete in which certain factors have been varied.
4. A study of physical characteristics of different concrete mixtures after mixing and placing.
5. The simplification of mortar void method of concrete design.

Importance: In one respect, this subject is a part of the durability project, however, it is of such significant importance from another standpoint that it has been set up as a separate project. It is significant that our present specification requirements are not all that they should be with respect to gradation of fine and coarse aggregates, especially where workability and durability are concerned. Also, it is important that we consider several possible changes in gradations and thus open up

local material sources for the manufacturing of more economical concrete. The mortar void method of concrete design as used by the Department should be thoroughly studied in all its phases and simplified so that it can be understood and applied by all engineers, who are interested in concrete design problems.

Status Part one of this project program has been completed. The balance of the project program was dropped because men were not available for assignment to the work. Preliminary report No. 32 has been prepared.

PROJECT 5 - BITUMINOUS MATERIALS

Purpose: This is a continuation of a bituminous research program initiated in 1935. The purpose being to determine the changes in characteristics of slow curing asphalts before and after weathering with the idea of perfecting a laboratory test whereby it would be possible to distinguish between bituminous materials possessing good or undesirable weathering qualities before they were incorporated in the bituminous mixture.

Scope: The scope of the investigation included five important phases of the subject of durability of bituminous materials, namely:

1. The viscosity-temperature relationship of bituminous materials before and after weathering.
2. Physical and chemical surface phenomena as related to durability.
3. Effect of change in constituents upon durability.
4. Changes in characteristics of slow-curing asphalts after weathering under service conditions. This study embraces sixteen test projects established over a period of years from which samples are taken each year for laboratory study.
5. Condition survey of existing bituminous surfaces using slow-curing oils as a binder. Samples were taken from the various surfaces for correlation with laboratory studies. The studies of changes in characteristics of asphaltic cements has not been undertaken.

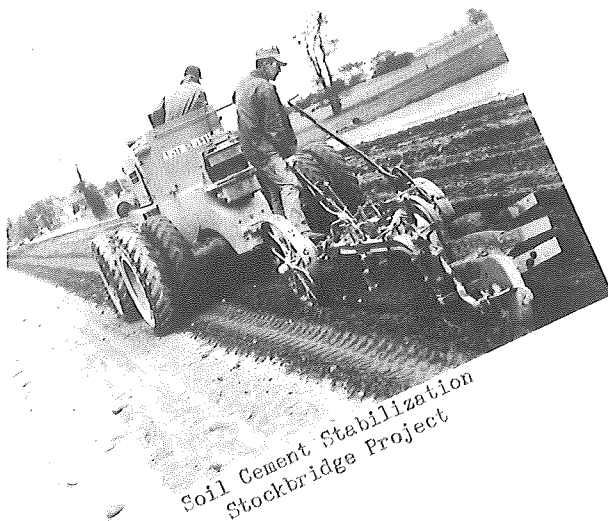
Importance: The urgent need for continued research in bituminous materials is evident because of the rapid growth of bituminous surfaces in Michigan, especially of the oil-aggregate type which produce definite maintenance problems involving stockpiling and repairs. The undesirable variation in characteristics of the bituminous materials from the various

refineries, as well as the failure of current specifications to predict service behavior of the bituminous material makes it doubly important that better laboratory control must be devised to insure durable and lasting surfaces.

Status: Parts 1 and 5 of this project have been completed. Only certain phases of parts 2 and 3 have been touched upon. Part 4 is continuous in that each fall a survey is made of the test sections, samples taken, recovery of the bitumen made and subsequent studies conducted on the recovered bitumen.

Special Reports: The following reports have been prepared:

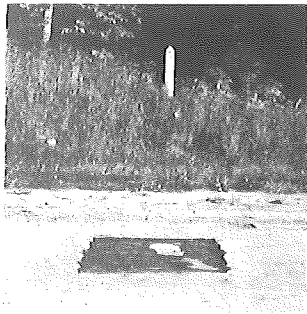
1. Changes in Characteristics of Slow-Curing Asphaltic Oils. Final Report No. 6.
2. Proposed Specifications for Slow-Curing Liquid Asphalts. Final Report No. 17.



Soil Cement Stabilization
Stockbridge Project

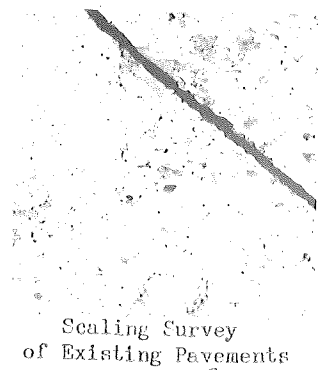


Sand-Bituminous Stabilization
Grayling Project

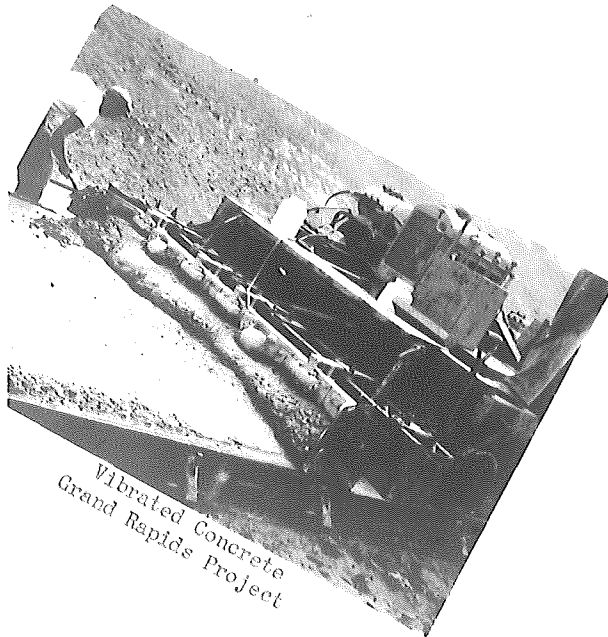


Weathering of Asphaltic
Oils in Service

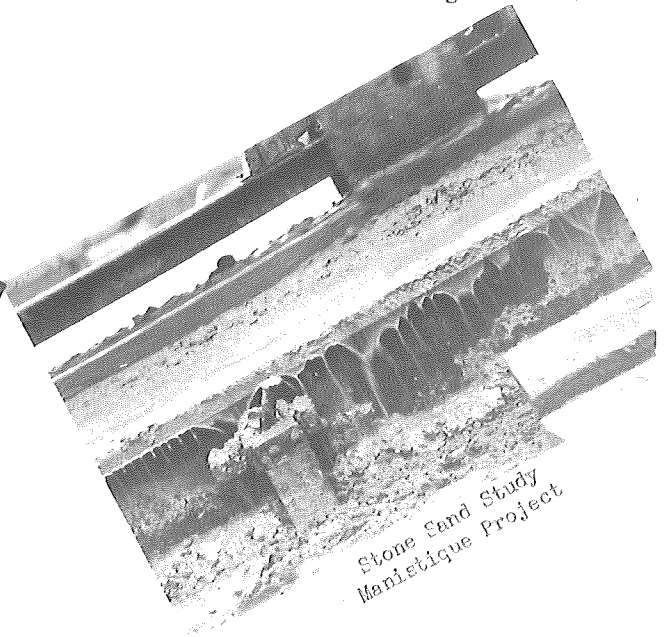
OTHER FIELD STUDIES



Scaling Survey
of Existing Pavements



Vibrated Concrete
Grand Rapids Project



Stone Sand Study
Manistique Project

PROJECT 6 - SOIL STABILIZATION AND SUPERPADE

Purpose: To construct soil-cement and bituminous stabilized road surfaces using existing roadway material, new material and Portland cement to produce a low-cost light-traffic surface. The purpose being to determine the feasibility of constructing such roads with existing surfacing materials, or with suitable local materials, and to develop specifications for the use of the Michigan State Highway Department in construction of such types of roads.

Scope: This project included the construction, in 1941, of two soil stabilized roadway surfaces as follows:

1. Soil cement construction on M-92, Stockbridge north, length 3.02 miles, project # 33-50, C1.
2. Soil cement construction on M-72, Grayling east, length 1.57 miles, project # 20-20, C2.
3. Bituminous stabilization on M-72, Grayling east, length 4.5 miles, project # 20-20, C2.

Importance: Many types of stabilized roads are being developed and it is important to the Michigan State Highway Department to know which are best suited to Michigan conditions. From an economic standpoint, it is important to know the relative cost of this type of construction as compared to other types of light-traffic surfaces. Also, it is desirable to know if this type of construction is satisfactory for certain localities where prepared aggregates are not available.

Status: All work has been completed and a progress report submitted. The three projects are under observation to determine behavior under normal service conditions.

Special Reports: The following reports have been prepared:

1. Construction of Experimental Soil-Cement Stabilization Road Surface - Stockbridge. Report No. 29.

2. Graveling Cement and Bituminous Soil Stabilization Projects. Report No. 30.

TURF GROWTH ON HIGHWAY SHOULDERS AND AIRPORTS
PROJECT 42 8 9

Purpose: To develop specifications pertaining to the construction of highway shoulders and airport landing fields which will possess adequate stability to support traffic and contain proper characteristics to encourage durable turf growth under abnormal conditions.

Scope: The proposed study will consist of two parts; the first comprising a survey and field study of grass growth on the shoulders of existing highways in Michigan while the second part will embrace a study of grass culture under controlled conditions at Michigan State College in cooperation with the Soils Department of the College.

Importance: The esthetic and economic aspects of modern highway construction as well as the prospect of future maintenance of airport landing fields by the Highway Department has created a great need for information pertaining to grass culture on compacted soils and heavily traveled areas.

Status: This study is now in the process of development and organization for the years program.

PROJECT 7 - SNOW AND ICE CONTROL

Purpose: The snow and ice problem on highways has reached a stage of real importance in highway transportation. Therefore, it is believed that serious consideration should be given to introducing modern methods into removing or preventing ice formation on pavements. It was proposed to attack this problem from a scientific standpoint in an attempt to find out better, modern and economical methods to overcome this serious traffic hazard.

Scope: This problem is only in the outline form, taking into consideration such phases as -

1. Survey of ice conditions in Michigan.
2. Physics of snow and ice.
3. General considerations in ice removal.
4. Comprehensive study of ice removal methods.

Importance: Michigan, because of its unusual topographic location, with respect to the Great Lakes, is subjected to frequent snow and sleet storms which interrupt the normal functions of the Michigan highway system. They also cause many traffic accidents, excessive maintenance costs and reduction in traffic movement. Therefore, any studies which will reveal methods which will improve these conditions should be worthy of consideration by the Department.

Status: This project has not progressed very far due to lack of personnel. However, some work was done last winter on snow mechanics and thought has been given to developing special ice prevention material. Plans are being made for extensive work on this project for the coming winter.

PROJECT 8 - MISCELLANEOUS STUDIES

This project was established to take care of the miscellaneous research studies which would be requested by certain administrative officials and division heads of the Highway Department, or would not fall under the category of the other seven projects. The research studies so far requested will be discussed separately.

COMPLETED STUDIES

Guard Rail Post Preservative Treatment Investigation

This investigation was requested by former State Highway Commissioner, Murrey D. Van Wagener. It constituted a study of proprietary wood preservative known as Protect-O-Post. The investigation embraced wood preservatives in general, evaluations of approved methods of treatment with preservatives, and analyses of service records of Michigan guard rail posts now in use. This study has been completed and preliminary report No. 1 prepared.

Paint Study for Bridges Maintenance Division

Requested by the Bridge Division to act as an observer on a comparative paint study which they were conducting. Observations completed and reported. Preliminary Report No. 22.

Effect of Various Axle Loadings on Highway Pavements

At the request of Mr. L. W. Hillard, of the Bridge Division, a study was made relative to the maximum axle load that shall be permitted upon the highway in respect to present design limitations. The study has been completed and final report No. 25 submitted to the Bridge Division.

The Design and Construction of Flight Strips

At the request of the Planning Committee, sub-committee on flight strips, a study has been made of flight strip construction in Michigan. This work has been completed and report 25A has been presented.

Manufactured Stone Sand and Its Uses in Concrete Mixtures

At the request of H. C. Coons, Deputy Commissioner and Chief Engineer, a study was made of the advisability of using stone sand in concrete construction. The purpose of the study was to establish future departmental policies in regard to the use of stone sand as a fine aggregate in concrete construction. Report No. 15 submitted.

Slow Curing Liquid Asphalt Specifications

At the request of J. G. Schaub, Construction Engineer, a summarization of results of bituminous researches on slow curing asphalts was made for the purpose of setting up new specification requirements as a means of obtaining a more uniform product and a product which will have a slow rate of hardening in the road surface. Report No. 17 submitted.

Selected Bibliography on Airport Construction for National Defense

This bibliography was prepared at the request of the sub-committee on flight strips under the direction of the Engineering Committee of the Michigan State Highway Department for the purpose of procuring information concerning the design and construction of flight strips and to compile this information for distribution to those members of the department responsible for the development of a flight strip program. Report No. 28 submitted.

The Design and Construction of Flight Strips

In continuation of the study of flight strips a manual was prepared containing the basic information on flight strip construction to assist the design department in working out the details of a sound program of flight strip development. Report No. 28 submitted.

Limestone Dust in Mortar

This study fulfilled a request by the Testing Division for information concerning the effects of limestone dust in the physical properties of concrete. Report No. 32 submitted.

Color Treatment of Concrete Pavement for Camouflage Purposes

At the request of H. C. Coons, Deputy Commissioner and Chief Engineer, a study was made concerning the practicability of coloring concrete pavement slabs during construction for camouflage purposes at the Willow Run Bomber Plant. Report No. 36 submitted.

Discoloration Phenomenon in Beaded Reflectorized Highway Sign Materials

At the request of the Maintenance Division an investigation was made concerning the abnormal discoloration of highway signs on I-76 between Charlotte and Battle Creek. Report No. 40 submitted.

Curing of Concrete by Calcium Chloride Integral Mixed

A report to the Testing Division concerning the experiences observed on the Michigan Test Road when calcium chloride was mixed in the concrete for curing purposes. Report No. 30 submitted.

STUDIES IN PROGRESS

A Cooperative Study of ReflectORIZED Materials for Highway Signs

At the request of the former Traffic and Safety Division a comparative study was made of several types of reflectORIZED highway sign materials. This study is still in progress. A progress report No. 38 has been submitted.

A Study of Agri-fil and its Use in Bituminous Mixtures

At the request of Mr. J. G. Schaub, Construction Engineer, a study was made of Agri-fil to determine its merits as a mineral filler in bituminous mixtures. The study is in progress.

Study of Asphalt-latex Joint Seal Material for Bridge Expansion Joints

A cooperative project with the Bridge Division on the use of asphalt-latex joint seal material for bridge maintenance. The work has been completed but periodic inspection of the various installations will be continued.

Joint Sealer Investigation

This study embodies a major long range research program devoted to the development and evaluation of joint sealers. The following progress reports have been submitted.

- a. Field Study of Joint Sealers. Report No. 2.
- b. Specifications covering joint sealers submitted to Testing Division.

PART III

MISCELLANEOUS ACTIVITIES

The research organization has had the opportunity to take part in several activities of significant importance to the Michigan State Highway Department from a public relation standpoint. These activities are in keeping with the functions and policies of the research organization outlined in Part I.

The several activities which have engaged the attention of the research organization pertain to cooperation in schools and conferences of an educational nature, the participation in the activities of engineering societies, the dissemination of information valuable to the engineering profession and the establishment of a branch research laboratory at the Michigan College of Mining and Technology at Houghton, Michigan. These various activities will be discussed briefly in Part III.

EDUCATIONAL ACTIVITIES

It has been proven from past experience in the Department that special schools and conferences are desirable from time to time to bring to certain members of the Highway personnel the modern concepts in highway engineering practice. With this in mind, the Research Organization has taken active part in the following educational activities.

Soils School at Michigan State College

In March 1941, an Engineering Conference in soils for engineers was held at Michigan State College. This soils school was organized in cooperation with the Civil Engineering Department, at Michigan State College for the purpose of giving practicing engineers, and especially engineers of the Highway Department an opportunity to become better acquainted with the subject of soils as related to modern highway engineering practices. The school consisted of lectures, discussions and demonstrations. Proceedings of the conference have been published.

Conference with Officials and Representatives of the Portland Cement Association and Cement Manufacturers and members of the Michigan State Highway Department

This conference was held for the express purpose of explaining to the group, the scope and principles relative to concrete pavement construction contained in the Michigan Test Road, as well as to discuss and exemplify the work of the Highway Department in their attempt to solve the scaling problem. The conference was held on the Campus in the Engineering Building. Members of the Engineering staff of the College were invited to attend.

Central Snow Conference

The Central Snow Conference is an international organization composed of a group of men interested in snow and snow problems. At the first meeting of the Central Snow Conference which was held at Michigan in December 1941, the research laboratory of the Highway Department was invited to cooperate in preparing a program for the conference pertaining to standards, techniques, and methods of application of knowledge of the character of snow in relation to highway transportation.

The proceedings of this conference were published in 1942.

Farmer's Week Activities

The research laboratory has participated in two Michigan State College Farmer's Week programs by preparing extensive exhibits to acquaint the visitors with the research activities of the Highway Department and how they are eventually benefited by the fruit of such efforts.

Student Interests

The research program is of such a nature that it has been possible to handle part-time employment for students either through the N.Y.A. or through Civil Service of the State.

The facilities of the research laboratory have always been available to students interested in research problems. Several students in the Engineering Division have taken advantage of these facilities.

College Personnel

The Engineering Division, as well as other departments on the Michigan State College Campus such as Chemistry, Physics, Soils, Geology and Forestry have been familiarized with the work of the research organization and have even cooperated in problems of mutual interest.

ASSOCIATION WITH TECHNICAL SOCIETIES

To keep abreast of the constantly expanding field of research and its relationship to highway problems, it is imperative that an association is maintained with technical societies to obtain authoritative information on properties and tests of materials and to have available latest data on researches which involve the efforts of hundreds of engineers and the expenditures of large sums yearly. In return we can be of service by sharing experience and knowledge on similar problems, by participating in programs of research, by constructive criticism of standards and by helping promote the use of quality specifications and standard tests.

Association is maintained with the following technical societies:

American Association of State Highway Officials

Highway Research Board

American Society of Civil Engineers

American Society of Testing Materials

America Road Builders Association

American Concrete Institute

Mississippi Valley Conference of State Highway Officials

American Chemical Society

Asphalt Paving Technologists

Cooperative exchange of research information is maintained with the Division of Tests of Public Roads Administration, the Portland Cement Association, Calcium Chloride Association, Natural Sand and Gravel Association, National Slag Association, National Crushed Stone Association, Wire

Reinforcing Institute, Nail Steel Bar Association, Asphalt Institute.

Contact has been maintained with various engineering conferences such as the Michigan Highway Conference, Houghton Highway Conference, Montana Bituminous Conference and Purdue Soil Mechanics Conference.

ESTABLISHMENT OF BRANCH RESEARCH DIVISION LABORATORY
AT MICHIGAN COLLEGE OF MINING AND TECHNOLOGY
Houghton, Michigan

In March 1941, at the request of Grover C. Dillman, President of the Michigan College of Mining and Technology, State Highway Commissioner, U. Donald Kennedy, instructed the Research Division to proceed with the establishment of a cooperative research project between the Michigan College of Mining and Technology and the State Highway Department. The Research Division to assume the responsibility for the general direction of the work.

It was understood that the branch research laboratory would be established at Houghton for the purpose of using the laboratory facilities of the College for convenience in investigating the problems of immediate concern to the construction of highways in the Upper Peninsula.

After considerable delay in obtaining and training a man to assume the responsibility for this particular project, the project was started in December 1941 under the following program.

The program was prepared on the basis of suggested projects recommended by the Testing Division and the current activities of the Research Division in the Upper Peninsula.

The research program consists of three major projects as follows:

1. Field sealing studies on concrete pavements.
2. Concrete materials investigation.
3. Stabilized base course investigation.

The major studies listed above will be discussed in the order presented.

FIELD SCALING STUDIES ON CONCRETE PAVEMENTS

Accelerated scaling studies were made on certain concrete pavements to supplement similar scaling studies on the Michigan Test Road as well as laboratory studies being conducted at East Lansing.

The field scaling projects include a comparative study of calcium chloride salt versus natural freezing and thawing, the effect of calcium chloride on concrete containing steep sand and the effect of calcium chloride on stone sand with and without silica dust and containing arvus.

Investigation of Calcium Chloride Salt versus Natural Freezing and Thawing of Water on Concrete Pavement

Purpose: To conduct comparative scaling studies on a concrete slab not previously treated with calcium chloride to determine in what degree calcium chloride or natural freezing and thawing are inductive to scaling of concrete surfaces.

Scope: Scaling panels similar to those used on the Test Road were installed on US-41, Beraga County near L'Anse. The pavement was constructed in 1941 using Champion Sand and Gravel.

Status: This work has been completed.

Investigation of Calcium Chloride on Steep Sand Fine Aggregate Concrete Pavement

Purpose: To determine the resistance to scale of concrete pavement containing steep sand as a fine aggregate.

Scope: Scaling panel was established on pavement surface containing steep sand. The scaling panel is on US-41 about 8 miles north of Hancock toward Calumet, station 440+00.

Status: Work has been completed

Investigation of Calcium Chloride on Stone Sand Fine Aggregate Concrete
With and Without Silica Dust and Containing Orvus

Purpose: To determine the relative resistance to scaling of stone sand concrete pavement with and without silica dust as a mineral filler and containing Orvus.

Scope: Scaling panels were installed on stone sand project in the City of Manistique. Project # 75-26, CR. Panels at station 53+00 right (Orvus and silica dust). Station 54+15 left (Orvus only).

Status: This work has been completed.

CONCRETE MATERIALS INVESTIGATION

It was proposed to make a comprehensive study of local mine wastes to determine their suitability for use in highway construction. The study includes both stamp sand and crushed mine rock.

Study of Stamp Sand as Fine Aggregate for Concrete

Purpose: To determine the suitability of stamp sand, ground and reground for use in concrete mixtures. This will entail field and laboratory studies on the aggregate separately and in concrete specimens.

Status: This study is in progress. To date, the work has consisted of collection of samples and running routine laboratory tests on materials from different sources.

Study of Crushed Mine Rock as Coarse Aggregate for Concrete

Purpose: To determine the suitability of crushed mine rock for use as coarse aggregate in concrete mixtures. This will entail field and laboratory studies on the aggregate separately and in concrete specimens.

Status: This study is in progress in conjunction with the stamp sand investigation.

STABILIZED BASE COURSE INVESTIGATION

Purpose: A study to determine the suitability of stamp sand for bituminous or portland cement stabilized base courses. The study will consist of two parts -

1. Bituminous stabilization studies
2. Cement stabilization studies

It was proposed to conduct laboratory studies on these materials for the purpose of developing proper mix design and prepare specifications for base or surface construction.

Status: This phase of the program has not been started.

At the present time the Houghton Project is dormant because of lack of personnel to carry on the work. A progress report was submitted covering the work up to July 1942. Report No. 34.

REPORTS AND ARTICLES

The reports prepared by the research laboratory have been summarized in the following pages. The summary represents the final reports which have been completed by the research laboratory and submitted to individuals or organizations both inside or outside of the Highway Department during the last three years.

Copies of these reports are on file in the research laboratory.

<u>No.</u>	<u>Date</u>	<u>Title</u>
1.	7-40	Research Activities of the Michigan State Highway Department
2.	10-40	Field Study of Joint Sealers
3.	11-40	Michigan Test Road
4.	12-40	Investigational Concrete Pavement in Michigan
5.	12-40	Load Transfer at Concrete Pavement Joints
6.	12-40	Changes in Characteristics of Slow Curing Asphaltic Oils
7.	1-41	Activities of Research Division
8.	1-41	Summary, Michigan Test Road
9.	1-41	Value of Concrete Spreader in Concrete Pavement Construction
10.	1-41	Pavement Joints and Their Functions
11.	2-41	Concrete Durability Studies
12.	2-41	Construction of Michigan Test Road
13.	3-41	Natural Conditions affecting Performance of Soils
14.	5-41	Fundamental Principles and Factors Involved in Michigan Test Road

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15.	5-41	Report on Manufactured Stone Sand and Its Use in Concrete Mixtures
16.	5-41	Report on Claims Presented by E.L. Tison Company, Projects F 18-20, C4 and F 57-37, C6
17.	7-41	Proposal Specifications for Slow Curing Liquid Asphalt
18.	7-41	Construction and Subsequent Studies of Concrete Durability Project, Michigan Test Road
19.	8-41	The Library-Laboratory Research
20.	8-41	Movie Script of Michigan Test Road
21.	9-41	Pamphlet on Michigan Test Road
22.	11-41	Research Activities of Michigan State Highway Department
23.	12-41	General Observations on Concrete Sealing
24.	12-41	Comments on Concrete Sealing Studies
25.	2-42	Effect of Various Axle Loadings on Highway Pavements
26.	2-42	Selected Bibliography on Airport Construction for National Defense
26-A.	3-42	The Design and Construction of Flight Strips
27.	4-42	Summary of Research Projects
28.	4-42	Agri-Fil as a Mineral Filler for Bituminous Mixtures
29.	4-42	Construction of Experimental Soil-Cement Stabilization Road Surfaces, Stockbridge
30.	4-42	Curing of Concrete by Calcium Chloride Integral Mixed
31.	5-42	Graveling Cement and Bituminous Soil Stabilization Projects

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32.	6-42	Limestone Dust in Mortar
33.	7-42	Research Laboratory Report for Biennium 1940-42
34.	7-42	Progress Report on Houghton Project, December 1941 - July 1942
35.	7-42	Report on Research Laboratory Activities to Engineering Division, Michigan State College
36.	7-42	Color Treatment of Concrete Pavements for Camouflage Purposes
37.	8-42	Accelerated Scaling Studies on Concrete Pavement Surfaces
38.	11-42	ReflectORIZED Sign Material Study
39.	11-42	Digest of the Michigan Test Road
40.	1-43	Discoloration Phenomenon in Beaded ReflectORIZED Highway Sign Materials