Michigan
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Charles M. Ziegler
State Highway Commissioner

EVALUATION OF BITUMINOUS CONCRETE SURFACES ON STABILIZED GRAVEL BASE

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EVALUATION OF BITUMINOUS CONCRETE SURFACES ON STABILIZED GRAVEL BASE COURSE

Between 1934 and 1941 the Department constructed approximately 155 miles of Bituminous Concrete surfacing on stabilized gravel base courses. It is known that these pavements have, for the most part, been giving excellent service during the past years and it was the opinion of Messrs. W. W. McLaughlin and O. L. Stokstad that an evaluation study should be made of the projects for the purpose of correlating road service characteristics with design, traffic, soil, and economic factors.

At the request of Commissioner Charles M. Ziegler, Mr. A. C. Benkelman of the Bureau of Public Roads came to Michigan to inspect the pavement projects, discuss the proposed investigational work, and assist in setting up a research program. It was the opinion of those responsible for the project that Mr. Benkelman's background of experience in flexible pavement design and research would be of material help in connection with the proposed work.

At a meeting in Lansing on October 10, the following were present: W. W. McLaughlin, O. L. Stokstad, A. E. Matthews, E. A. Finney, H. C. Cash, Roy Lamond, Jack Schaub, A. C. Benkelman, Scott Baker, and Tom Humphries. Various phases of the investigation were discussed and it was the opinion of the group that the immediate objectives of the study should be as follows:

A. To determine the adequacy of present design with recommendations for changes, if necessary.

B. To determine the economy of such surfaces in relation to other pavement types for conditions imposed.

It was further agreed by the group that the scope of the investigation should include a conditions survey of each project, and determination of information relative to design, construction costs, maintenance costs, traffic volume, and soil characteristics. Riding qualities should also be determined and correlated with design and soil conditions.

It is the purpose of this report to describe briefly the scope of the project and the work completed and to present significant information gathered from the investigation for reference and study.

INVESTIGATIONAL PROCEDURE

Between October 11 and 14, a preliminary inspection trip was made by the above group over many of the projects selected for study to get better acquainted with the problem and thereby establish a definite procedure for conducting the investigation. At the conclusion of the trip, it was generally agreed that the investigation should proceed in accordance with the following program.

A. Field Study

1. Condition Survey of Projects. This survey should be as detailed as practical, showing location and limits of failed areas, as manifested by displacement, rutting, cracking, patches, etc. Soil conditions associated with above should be noted. Transverse profile to be determined at intervals to determine degree of rutting. Information to be recorded on regular pavement survey sheets. Data to be plotted in laboratory for reproduction and correlation with design features.

2. Roughometer Survey. Each project will be covered by Roughometer. Two runs will be made in each lane, one in center and the other in outside wheel track. Data to be correlated with condition survey and soil types.

3. Field Testing. Surface and base to be cored for thickness and to obtain samples for laboratory use. In-place density measurements to be made of base course and subgrade at center of lane and under wheel tracks.

B. Collection of Pertinent Information

1. Traffic Conditions. Determine type and characteristics of traffic from Planning and Traffic Division reports.

2. Maintenance Costs. Determine maintenance costs on surface from Maintenance Division.

3. General Design Considerations. Obtain pertinent design information such as age, type, dimensions of pavement components, prevailing soils, drainage, cut-fill sections, and construction costs. These to be obtained from plans and through the Design Office.

4. Weather Characteristics. Freezing index, rainfall-evaporation ratio for areas including surfaces under study.

C. Laboratory Studies

1. Special Tests. Examination of pavement samples for moisture content, grading, strength, bituminous content, and physical characteristics. Check with previous laboratory data from recovered samples.

2. Establish Condition Rating. Following method is suggested. Percentage of each to be determined from condition surveys.

a. No cracking
b. Partially cracked
c. Totally cracked
d. Smooth texture
e. Pitted
f. Displacement
g. Patched
h. Seal treatment

3. Correlation of Pavement Condition with Established Factors. Such factors as age, roughness, subbase soil, profile, thickness, traffic, condition rating, etc., as determined from above work will be included.

D. Pavement Projects included in Investigation

The projects considered in the investigation are listed in Table I. Their geographic location with respect to Michigan are shown in Figure 1 There are 33 projects in the study with an aggregate length of 154.5 miles.

E. Other Pavement Types to be Considered

The above investigational procedure will be applied to other types of low-cost construction, including bituminous surfaces on gravel base, such as bituminous aggregate, oil-aggregate, and seal coats.

BITUMINOUS CONCRETE ON GRAVEL SURFACE

This type of pavement consists in general of a two-course bituminous concrete surface on a stabilized gravel base. A typical cross section of this type of construction is shown in Figure 2 which is representative of the projects selected for study. Two types of construction are involved. Several of the projects were designed and constructed as gravel roads and maintained as such many years prior to the application of the

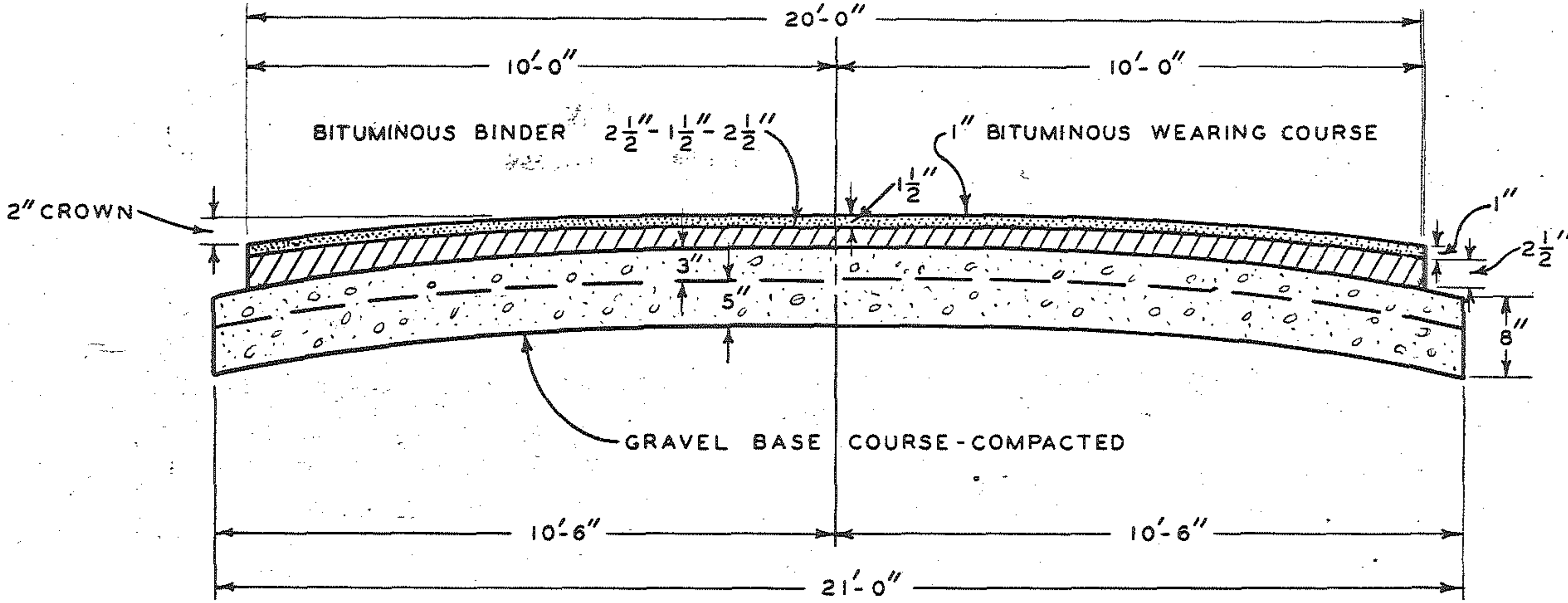
TABLE I

BITUMINOUS CONCRETE ON GRAVEL

Project	Location	Route	Length	Date Constructed
16-23, C 3	Wolverine S	US- 27	5	1936
69- 2, C 6	Wolverine	US- 27	2	1936
69- 2, C 7	Vanderbilt	US- 27	3.5	1936
59-34, C 1	Greenville W.	M- 57	3	1934
41-66, C 1	Greenville W.	M- 57	3	1934
39-27, C 2	Kalamazoo W.	M- 43	6	1934
80-19, C 2	Kalamazoo W.	M- 43	6	1934
83-12, C 1	Cadillac W.	M- 55	1	1935-36
83-13, C 4	Cadillac W.	M- 55	8	1935-36
83-13, C 5	Cadillac W.	M- 55	3	1935-36
83-13, C 6	Cadillac W.	M- 55	7	1935-36
51- 7, C 8	Manistee E.	M- 55	7	1936
51- 7, C 7	Manistee E.	M- 55	4.5	1936
51- 7, C 6	Manistee E.	M- 55	14	1936
65- 5, C 5	West Branch W.	M- 55	4	1936
65-19, C 2	West Branch W.	M- 55	2	1936
72-14, C 3	West Branch W.	M- 55	3.5	1936
17-41, C 3	Hulbert to Coline	M- 28	6	1937
17-41, C 4	Hulbert to Eckerman	M- 28	5	1937
17- 9, C 8	Strongs to Eckerman	M- 28	2.5	1940
17- 9, C 9	Strongs to Eckerman	M- 28	0.6	1940
17- 9, C10	Strongs to Rexford	M- 28	3.7	1940-41
17- 9, C11	Strongs to Rexford	M- 28	4	1940-41
48- 1, C 6	Newberry	M- 28	6	1935
48-19, C 2	Newberry	M- 28	3	1935
48- 4, C 2	Newberry	M- 28	3	1935
48-21, C 4	Newberry	M- 28	3.5	1936
62-32, C 3	Hesperia S.	M- 82	6.5	1936
62-32, C 3	Hesperia S.	M- 82	0.4	1936
43- 2, C 2	West from M-37	US- 10	9.5	1937
53-18, C 3	West from M-37	US- 10	2.5	1937
30-19, C 6	Osseo-Pittsford	M- 34	5.0	1935
28-26, C 3	Traverse City N.	M- 37	6.4	1935
10-16, C 3	Frankfort E.	M-115	4.3	1935
			154.4	


ISOTROPIC MAP
of the
NORMAL FREEZING INDEX
for
MICHIGAN
INCLUDING BITUMINOUS CONCRETE
ON GRAVEL PROJECTS
O-FREEZING INDEX REFERENCE POINTS
1400
1300
1200

Figure 1



TYPICAL CROSS SECTION
BITUMINOUS CONCRETE ON GRAVEL BASE

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Figure 2

bituminous concrete wearing course. In other cases, the gravel base course and bituminous concrete surface were designed and constructed in normal sequence as a bituminous concrete on gravel project.

DISCUSSION OF THE WORK

The work of the investigation so far has been directed towards the completion of condition surveys of all of the projects and the collection of factual information pertaining to construction and maintenance costs as well as traffic conditions and surface roughness. Parts A and B of the investigational procedure have been practically completed and the data therefrom have been summarized and presented in Table II for review and comparative study. Following is an account of the manner in which the information in Table II was obtained.

Condition Surveys

The condition surveys were made by personnel of the Soils Section of the Testing and Research Division under the general supervision of the Soils Engineer, O. L. Stokstad. The limits of different types of failures were defined on a set of standard plans for each project. From preliminary field surveys, it was agreed to classify the types of surface failures into ten different groups with an appropriate symbol established for each group. In the office the field condition survey information was plotted on a special plan sheet using the symbols. This plan sheet also contains the prevailing soil types under the base course. Examples of this plan sheet for two projects depicting a good surface and a bad surface are presented respectively in Figures 3 and 4.

From the condition plan sheet each project was given a condition rating in accordance with the percent of surface which was considered to be in either a good, fair, or bad condition. In establishing this rating, a good surface would be one that had not been sealed or was practically free of rutting, cracking and abnormal deterioration. A surface in the fair class would include a seal coat in good condition or an original surface where rotting and cracking had not progressed to the stage where immediate maintenance repairs were necessary to carry present traffic. All surfaces which had failed to the extent that they had to be rebuilt or patched due to either surface or base failure, or both, were classified as being bad.

Predominant Subgrade Soil

The predominant soil types for each project have been listed in Table II by series and texture for convenience in analyzing the physical condition of the respective projects. Each project has small areas of bad acting soils not listed in Table II which, however, must be taken into consideration in the final analysis because most of the percentage of bad surface in the condition rating can be traced to these areas.

Surface and Base

The thickness of the surface and the gravel base was taken from the plans for each project. Most of the projects have a 2-1/2-in. bituminous concrete surface with an 8-in. compacted gravel base. A few projects have less than 8 inches of base and in some cases this may be the reason for failure. The actual thickness by field tests has not been determined yet and may very well show a difference from the original design thickness.

Surface Roughness

The surface roughness values were obtained at the 1/8 point and 3/8 point of each lane. These points are considered to be approximately under each wheel track. The average of the roughness values in inches per mile for each lane are presented in the summary in Table II. Roughness values were obtained by means of the Department's Roughometer. Some projects do not have roughness values for the 3/8 point. In such cases roughness measurements were taken before it was definitely decided to take measurements at both positions and additional roughness determinations have not been made.

Freezing Index

A map (Figure 1) was prepared showing isotropic lines of the normal freezing index over Michigan. This map was made using all available reference points obtained from the East Lansing Weather Station. The normal freezing index at each point was computed and with these reference points, the isotropic lines were drawn. Most projects were long enough to have different freezing indexes at the ends. In such cases the average normal freezing index over the project was taken from the map and recorded in Table II.

Traffic Conditions

Traffic volume has been broken down into three classes of vehicles: passenger, commercial, and tractor-trailer combinations. The values presented in Table II were furnished by the Planning and Traffic Division. They are based on three years - 1936, 1941, and 1949 - adjusted to give an estimated average 24-hour weekday traffic count over the past 14 years. By means of these traffic data augmented by appropriate vehicle weights it has been possible to arrive at a traffic weight factor for each project in terms of tons per mile per day. It was felt that such a factor could be successfully correlated with surface performance and cost data.

Surface Cost Data

The cost of the original surface was obtained by summarizing the individual costs of surface and base for each project as found in project cost records. All other project construction costs, such as grading, drainage and appurtenances were excluded because the cost of such work varies greatly from project to project depending upon general construction conditions and should not be reflected in the cost of the surface.

Maintenance Cost Data

Maintenance costs were obtained through the help of the Finance Division and include only those costs directly associated with the repair and maintenance of the bituminous surface. Because of the Department's system of keeping maintenance costs by sections, and in certain cases a maintenance section may include several projects of different types, it is very difficult to separate maintenance costs by individual projects or surface types. Consequently, it has been necessary to prorate maintenance costs on a basis of percentage of section covered by the project. Thus, it will be found in Table II that maintenance costs on some projects are identical. Furthermore, maintenance costs were available for only nine years. Average maintenance costs per year are based on these nine year values.

Annual Cost of Pavement Type

The annual cost of the surface was determined from the following equation:

$$C = \frac{I + (I - S) + M}{L1}$$

where

C = annual cost per mile of surface,

I = original cost of surface, including only stabilized gravel base and bituminous concrete surface with incidental construction items to surface and base course,

S = salvage value of surface at end of service life which, in this case, will be considered equal to 25% of original cost (I) (this is equal to approximate original cost of base course),

M = total normal maintenance cost during service life plus periodical maintenance costs, the latter to include two complete single seal jobs within the service life of the pavement, at the cost of 17 cents per sq. yard,

L = service life of pavement in years - in this case taken as 20 years - and

l = length of individual project in miles.

In this equation the term $\frac{I - S}{L}$ is equal to the annual depreciation of the surface without interest.

Comparative Cost on a Ton Mile Basis

In an attempt to correlate traffic, performance, and annual cost for each project, and eventually projects with different types of surface, the annual cost for each project has been divided by the value representing the weight factor of the traffic which the surface carries. The performance of the different projects will be evaluated on this basis. Cost data computed in this manner are given in Table II. The ton miles were determined by applying the following vehicle weight factors. These values were obtained from the Planning and Traffic Division.

Passenger cars	average 1-1/2 tons
Commercial	average 4.2 tons
Tractor-Trailer combinations	average 16.25 tons