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MICHIGAN
STATE HIGHWAY DEPARTMENT

G. Donald Kennedy
State Highway Commissioner

Res. Report #20

MOVIE
OF
MICHIGAN TEST ROAD
PICTURES AND SCRIPT

Research Division
East Lansing, Michigan
August 26, 1941

MICHIGAN TEST ROAD

Pictures	Script
* Scene 1 Main title of picture 0 - 40	Music
Scene 2 - 3 Aerial views, intersection of test road and US-10 - long view, cut in of river 40 - 144 (156) Script 97 words Cut equivalent of 59 words. Cut to 26' - 16mm film	In May 1940, the administration of the Michigan State Highway Department realized the need for a comprehensive evaluation of modern theories of design and construction practices in concrete pavements. Therefore, it was decided to construct the Michigan Test Road an experimental concrete pavement project embodying certain controversial and developmental features which could be used as a study in establishing criteria for concrete pavement design and construction. The purpose of the test road is to establish certain fundamental principles in pavement design and to correlate laboratory studies with construction methods in order to develop more durable concrete pavements.
Scene 4 - 5 (A) Map of lower peninsula without M-115, then flash showing M-115. 144 - 166 (33) Script 33	The test road constructed on M-115, between US-10 and M-66, in Clare and Osceola counties, consists of 17.8 miles of 22 foot concrete pavement.

Scene 6

None

Scene 7 - 8

(A) View of test road location in background, then flash in design and durability project
166 - 181 (22)
Script 25

10.1 miles is devoted to the principles of design and construction, and 7.7 miles for the study of durability factors, particularly scaling.

Scene 9 - 10

Travel shots along the road showing grade, toptgraphy and curves.
181 - 231 (75)
Script 62
Cut equivalent of 13 words.
Cut to 17' - 16 mm. film.

The location of the Test Road is ideal from the standpoint of grade, aligment and average weather conditions. The maximum grade is 0.65 percent. The maximum degree of curvature is 45 minutes with approximate average curve length 3500 feet.
The length of the entire project of each test section is sufficient to reduce construction variables to a minimum for each feature investigated.

Scene 11

View showing subgrade operations 231 - 247 (24) Script 24	Except for a few thousand feet of clay underlying a 1 foot sand cushion, the test road was constructed on a uniform sand subgrade.

Scene 12 - 16

Title and road shot 247 - 260 (19) Script 46 Add footgge equivalent to 47 words. *Cut in additional 13' - 16 mm. film*	Design Project Design Features We will not consider the design project and later the durability project. In order to present the need and importance of the study of a design project, let us review the stresses in a concrete road and a history of the development of concrete pavement design. Concrete as a pavement material is subjected to various stress producing conditions such as temperature, moisture, traffic loads and subgrade changes.

Scene 17

(A) Pavement, no cracks, two expansion joints. ~~260 -~~ ? (15)	The various stress producing conditions are imposed upon a new slab immediately after curing period.

Scene 18

(A) Same view with sun and rain ~~260 - 290~~ (16)	Upon exposure to sun and rain, physical reactions take place in the slab causing linear movement.

Scene 19

(A) Same view with stress intensity

~~290 — 300~~ (14)

Linear changes of sufficient magnitude cause over stressing of the concrete at critical points.

Scene 20

(A) Cracked pavement

~~300 —~~ (15)

Continuous over stressing of new slabs results in subsequent transverse cracking midway between joints.

Scene 21

(A) Same view as 19 with stress at new point (15)

Further linear movement due to temperature and moisture eventually produces excessive stresses at intermediate points.

Scene 22

(A) Same view with cracks (15)

Ultimately transverse cracking will continue at the over-stressed points until equilibrium of slab conditions exist.

Scene 23

(A) Same view except shows blow-up (15)

Infiltration of earth into cracks depletes expansion space causing blow ups under extreme linear movement.

Scene 24

(A) View of pavement, scene 22 (14)

In addition to linear movement, pavement slabs are subject to stresses produced by warping.

Scene 25

(A) Same scene as 24, except shows sun and rain

(15)

Sun and rain produce differential temperature and moisture conditions between top and bottom of slab.

Scene 26

(A) Same scene as 25, showing convex warping of slab.

(16)

When temperature and moisture content of slab surface exceeds that of the bottom, convex warping occurs.

Scene 27

(A) Unwarped slab in dry area.

(13)

The reverse is true when pavement slabs are exposed to continuous dry spells.

Scene 28

(A) Convex warping in dry area

(16)

Consequently concave warping results when the moisture content of the slab top is less than the bottom.

Scene 29

(A) Unwarped slab in cold area.

(16)

When the slab surface is cooled rapidly a temperature differentiation exists between the top and bottom.

Scene 30

(A) Warped slab in cold area

(13)

Such a condition causes contraction of the slab surface resulting in concave warping

Scene 30A

(A) View of slab with general cracking (18)
260 - 426 (240)
Script 225
Pauses for each scene.

The intensity of stresses caused by warping combined with other stresses may cause both longitudinal and transverse cracking.

Scene 31

(A) View of normal pavement
426 - 438 (18)
Script 15

Under vehicular traffic a pavement slab is subjected to a series of highly concentrated forces.

Scene 31A

(A) Same scene as 31, with truck (11)

These forces introduce flexural stresses in the slab of various intensities.

Scene 32

(A) View of truck showing stress intensities.
438 - 460 (33) (16)
Script 27

Both the moving wheel and impact forces resolve into destructive stresses unless adequate design is provided.

Scene 33

(A) View showing cracks in slab
460 - 470 (15)
Script 14

Repeated applications of these stresses ultimately result in pavement cracking at the critical positions.

Scene 34

(A) View of slab on fill section
470 - 477 (11)
Script 10

Improperly constructed subgrade in fill sections are subject to shrinkage. Consequently,

Scene 35

(A) View showing settling of subgrade.

Scene 36

(A) View with wheel on slab and stress intensities.

volumetric changes in the subgrade may act to alter the original conditions of slab support, thereby affecting any anticipated stress value.

Scene 37

(A) View of cracked slab.

477-499 (33)

Script 34

When this subgrade shrinkage destroys the uniform slab support, pavement failures result.

Scene 38

(A) View of cut section.

Also when small areas of unsuitable subgrade materials are not removed differential heaving will occur from high subgrade moisture content and freezing temperatures.

Scene 39

(A) Same view with heaving and stress arrows.

When unfavorable conditions exist, slab stresses of serious magnitude are introduced by such changes in the subgrade

Scene 40

(A) View showing cracked slab.

499 - 541 (63)

Script 63

Concrete pavement cannot withstand the combined stresses of differential heaving, temperature and superimposed loads and eventually failures over these areas take place.

Scene 41

(A) View of pavement badly cracked, with patches. Cut equivalent of 48 words. 541 - 597 (84) Script 36 ~~Cut equivalent to 48 words~~ Cut to 10' - 16 m.m. film	It has been shown how cracking may occur as the result of overstressing of the concrete by many causes. Investigation of pavements in service bear out the necessity of considering these factors in concrete pavement design.

Scene 42

(A) View of pavement properly designed. Road shot along test road. 597 - 617 (30) Script 29	However, a pavement properly designed and constructed should possess a uniform subgrade bearing capacity, adequate strength to overcome internal and external stresses, desirable surface characteristics, durability and permanency.

Scene 43

(A) Urban view showing 5 foot blocks 617 - 635 (27) Script 27	The evolution of concrete pavement design shows the methods of jointing and cross section used to control these stresses. This development dates back to 1893.

Scene 44

(A) View of pavement with two joints.	The first joints were small spaces between adjacent slabs filled with earth.

Scene 45

(A) Same view with steel plates. 635 - 651 (24)	Later joints with steel edge bars were designed to counteract damage by steel tire.

Script 25

Scene 46

(A) View of pavement with two tight joints	The transverse joint originally did not provide for expansion, but between 1900 and 1910 provisions for expansion appeared.

Scene 47

(A) Same view with expansion joints.

Scene 48

None

Scene 49

(A) Same view as 47, except with dowel bars.	In 1917, dowel bars were introduced for load transfer purposes.

Scene 50

(A) Same view as scene 47.	To overcome temperature stresses in a pavement slab,

Scene 51

(A) Same view as scene 50, except with groove midway between joints.	a weakened plane joint formed by grooving the surface

Scene 52

(A) Same view with crack at groove. 651 - 698 (70)	which caused the slab to crack for aggregate interlock.

Script (56)

Pauses between scenes 46 to 52 inclusive.

* Scene 53

(A) View of slab with no longitudinal joint.

698 - 705 (10)

Script 11

Longitudinal joints were not used originally and to overcome the irregular

* Scene 54

(A) Same view with longitudinal joint.

705 - 710 (7)

Script 7

crack formation a center joint was adopted.

Scene 55

(A) View of expansion joint, no dowel bars.

710 - 719 (13)

Script 14

Test road researches in 1922, brought out the need for strengthening slab edges.

Scene 56

(A) View showing thickened edge.

Thickened edge sections were found to be satisfactory for the increased strength required.

Scene 57

(A) View showing edge reinforced.

The same results were obtained by increasing the reinforcement along the joint.

Scene 58

(A) View showing dowel bars depicting load transfer.

719 - 745 (39)

Script 39

Load transfer with dowel bars also proved adequate to relieve high concentrated stresses.

* Scene 58A

(A) View showing distance spacing of joints

Prior to 1934, transverse joint spacing varied from 25 to 100 feet or more with joint widths 1/2 to 2 inches.

Scene 59 - 61

None

* Scene 62

(A) View of slab with thin edge - thick center

Beginning with the thick center - thin edge cross section, the concrete pavement developed into the

* Scene 63

(A) View of slab with uniform thickness

uniform cross section slab as the original cross section proved inadequate in theory and service behaviour.

* Scene 64

(A) View of slab with thickened edge.

745 - 791 (69)

Script 69

Finally in 1924, the thickened edge or balanced cross section was accepted as a standard.

Scene 65

View moving into test road at intersection US-10 and M-115.
791 - 817 (59)
Script 59

A study of these changes in design brought about many controversial issues, but results definitely showed that structural adequacy of a concrete pavement slab for strength and permanency is influenced by features of design which determine its continuity and dimensions.

Scene 66 - 68

Road travel shots
817 - 840 (34)
Script 58
Add equivalent of 24 words or 6½' - 16 m.m.

The Michigan Test Road, affords a large scale laboratory for the study of the proper dimensioning and construction of a concrete slab. The design features included are, spacing and design of joints, uniform slab thickness and balanced cross section, required reinforcing steel, relation of pavement cross section to subgrade bearing value and prestressing of concrete slabs during curing.

Scene 69 - 75

(A) View of bill board with all distances showing. Continue scenes 69 - 75 into one picture
840 - 884 (66)
cut to 2-1/2' - 16 mm. billboard
cut each length to 1-1/2' - 16 mm
Recapitulation about 3'

The expansion joint study included joint spacing at 120, 240, 480, 900, 1800 and 2700 foot intervals.

<u>Scene 76</u>

View of truss assembly 884 - 896 (18) Script 19	In general, where load transfer was included, the truss-assembly for holding dowel bars was used as standard construction.

<u>Scene 77 - 78</u>

View of corner bar in place. 896 - 907 (16)	A portion of the design project was constructed with thickened joint edges and 1-1/4" corner bars.

<u>Scene 81 - 86</u>

(A) Bill board with spacing lengths. 928 - 994 (99) Cut to 8' - 16 mm. Billboard Cut each length to 1-1/2' - 16 mm. Recapitulation 3'	Consistent with the spacing of expansion joints at specified intervals and varying amount of reinforcing steel, contraction joints have been constructed at 30, 20, 15 and 10 foot intervals.

<u>Scene 87</u>

View of standard dowel assembly for contraction joint.

994 - 1011 (25)

Script 20

In general, the contraction joints consisted of 3/4 diameter by 15 inch dowel bars held in place by truss-assembly.

<u>Scene 88</u>

View of dowel bars with parting strip. Contraction joint.

1011 - 1019 (12)

Script 13

Other types were installed for comparison as the dowel bar with parting strip,

<u>Scene 89</u>

View of dowel bars with divider plate. Contraction joint.

1019 - 1031 (18)

Script 16

and the dowel bar assembly with metal divider plate to give complete separation of the slabs.

<u>Scene 90</u>

View of keylode joint. Contraction joint.

1031 - 1044 (19)

Script 18

Also, the keylode joint with continuous plate dowel so constructed as to allow interlocking action of the concrete.

Scene 90A

View showing placing and removing boards on subgrade.

1044 - 1060 (24)

Script 23

To facilitate the installation of joints, a board was placed on the subgrade which was removed following concrete placing and the joint installed.

Scene 91

General construction view.

1060 - 1070 (15)

Cut in paver scene of 6' - 16 mm.

Script 22

The adequate design of pavement cross section is important for proper stress distribution, therefore, various cross sections were included in the project.

* Scene 92 - 93

(A) View of thickened edge slab and uniform cross section.

1070 - 1095 (37)

Script 37

Four different types of cross sections were placed for study, namely, the 9-7-9 Michigan State Highway standard, and an 8-6-8 and their approximate equivalents, 8 inch and 7 inch uniform cross section respectively.

Scene 94

Construction view showing concrete on mesh.

1095 - 1102 (10)

Script ~~25~~ 24

Cut in 9' - 16mm.

Also, in the Michigan Test Road ~~In conjunction with joint spacing and slab cross section design, several~~ test sections were constructed ~~using 9-7-9, 8-6-8, 8 and 7-inch uniform consisting~~ of plain concrete and reinforced concrete with 37 and 60 pounds per hundred square feet.

Scene 95 - 101

Omitted.

* Scene 102 - 103

Title		Design Project
1102 - 1119	(25)	Construction Features
Script 25		Incidental studies of construction methods were included in the design project. They are mechanical spreading of concrete, tamping of forms, stress curing and joint sealers.

Scene 104

Screed pushing concrete, mechanical spreader and casting test molds.		A comparative study was made of hand spreading versus mechanical spreading of concrete. The spreader was designed to handle concrete for the full 22 foot width by means of a reversible 14 inch spiral screw. Flexural test specimens were cast in place on the subgrade for comparative study.
1119 - 1164	(67)	
Script 48		
Cut in screed and cut total length to 13'-16mm.		

Scene 105

View of hand tamping and mechanical tamping of forms.		Because of the heavy equipment used on the project a mechanical form tamper was used for comparative study with hand method of tamping forms on sandy subgrade.
1164 - 1182	(27)	
Script 27		

Scene 106

Travel shot along road. 1182 - 1193 (16) Script 17	An 1800 foot section of pavement was pre-stressed during curing, eliminating steel reinforcement and contraction joints.

Scene 107

Views installing premolded joint seal. 1193 - 1213 (30) Script 30	Several joint sealers having desirable characteristics were included for comparative study. One of the sealers a premolded rubber material was inserted into the top of the prepared concrete joint opening.

Scene 107A

Views applying Rai-Seal. 1213 - 1232 (28) Script 27	Rai-Seal, a commercial hot poured type of rubber compound which is melted at high temperature was used on one test section in the study of joint sealers.

Scene 108

Views applying asphalt latex. 1232 - 1257 (37) Script 35	Another sealer consisting of a mixture of SC asphaltic oil and rubber latex was included in the study. Hydrated lime was applied to the surface to accelerate hardening and to prevent pick up by traffic.

Scene 109

Views of installation of reference monuments and taking readings.

1257 - 1292 (52)

Script 52

After construction, the evaluation of the various designs and methods are being made by visual examinations, displacement and physical measurements. Permanent reference monuments were installed for measuring slab movement. A special telescopic instrument is used to determine increments of movement by sighting on cross hairs etched on glass plate and reference cap.

Scene 110

View showing method of taking readings with caliper.

1292 - 1302 (15)

Script 15

Reference points established on each side of joint are used for checking joint width changes.

Scene 111

View of level operations showing level and reference points.

1302 - 1312 (15)

Script 12

The vertical movement of slab ends is determined by precise level measurements.

Scene 112 - 113

None

Scene 114

Installation of thermocouples and taking reading with bridge. Moisture cells and reading with bridge.

1312 - 1345 (49)

Script 42

Thermocouples and moisture cells have been embedded in the fresh concrete and in the subgrade for obtaining temperature and moisture content in conjunction with displacement measurements. Measurements are determined by specially designed electrical bridges and determinations are made in conjunction with displacement measurements.

Scene 115

Installation of Carlson Electric Strain Meter, equipment and reading.

1345 - 1363 (27)

Script 23

Strain in the concrete is measured at the center of the slab with a Carlson Electric Strain Meter embedded in the fresh concrete.

Scene 116

View showing reading by Berry Strain Gauge.

1363 - 1372 (13)

Script 13

Surface strain measurement is made by a Berry Strain Gauge at selected points.

Scene 117 - 118

View of subgrade equipment and closeup.		Subgrade bearing tests were made using three sizes of plates 10, 50 and 100 square inches in area to determine modulus of subgrade reaction "K".
1372 - 1390	(27)	
Script 25		

Scene 119

View of field office

Scene 120

View of anemometer and vane.

Scene 121

View of rain gauge

Scene 122

View of thermometer

1390 - 1413 (34)

Script 31

A meteorological station was established and contains continuous recording apparatus for wind movement, changes in air temperature, rain gauge and evaporation pans for precipitation and evaporation and a hygrometer for humidity.

Scene 123 - 124

None

Scene 125

View of traffic recorder.

1413 - 1422 (13)

Script 14

A continuous traffic flow record will be obtained throughout the duration of the project.

Scene 125 - A

Concrete section marker

1422 - 1434 (18)

Script 18

Cut pan on marker.

Concrete markers ~~appropriately identified~~ have been installed at ~~the beginning and end of~~ each test area.

Scene 126

Use part of scene 125-A or road scene.

1434 - 1443 (13)

Script 15

Features of design are not the only factors affecting the structural durability of concrete pavements.

* Scene 127

Title

1443 - 1466 (54)

Script 35

Durability Project

Factors affecting deterioration, scaling, combined physical, chemical and mechanical action as experienced in actual use can not be predicated upon laboratory studies. Consequently, a portion of the Michigan Test Road was constructed to this end.

Scene 128

None

Scene 129 - 132

View showing pavement with light, medium and heavy scale areas.

Close up of surface.

1466 - 1489 (34)

Script 34

Approximately 10 percent of the concrete pavements in Michigan have scaled in varying degrees. The unsightliness of scaled areas and the effect of disintegration on an adequately designed slab is of immediate concern to the engineer.

Scene 133 - 136

View of batch plant. View of straight edging and hand floating.

1489 - 1528 (56)

Script 52

Factors considered contributory to scale are grading and proportioning of aggregates, application of salts for ice removal and construction operations. Therefore, an effort was made to eliminate these factors in the concrete on the durability project by improvement of grading of aggregates, use of various admixtures and careful control of construction operation.

Scene 137

View showing the addition of fines to batch.

1528 - 1547 (28)

Script 25

The standard concrete mix was supplemented by adding 200 mesh fines to the fine aggregates to improve the density and workability of the concrete mixture.

Scene 138

(A) Ideal grading curve

1547 - 1559 (16)

Script 19

Coarse and fine aggregate, when graded to conform to the ideal grading curve will produce the most dense concrete.

Scene 139

(A) View showing standard grading curve superimposed over ideal curve.

1559 - 1570 (16)

Script 14

This condition is not obtained in actual practice, especially from the 50 sieve down.

Scene 140

Longitudinal float showing sloppy concrete.	The result is poor workability, bleeding and inferior concrete.
1570 - 1576 (9)	
Script 9	

Scene 141

None

Scene 142

(A) View of grading curves.	When natural fines, or mineral fillers were added to the standard mixture, the grading curve was improved at the lower end.
1576 - 1590 (21)	
Script 21	

Scene 143

View showing consistency of mixture.	The addition of the fines resulted in a concrete of good workability and consistency without segregation, laitance or bleeding.
1590 - 1605 (22)	
Script 19	

Scene 144 - A

(A) View of ingredients in standard mix.	Various additives were incorporated in the concrete mix to study their effect upon the character of the concrete. They include such proprietary materials as Pozzolith, Plastiment, a wetting agent called Orvus and Vinsol Resin ground with Portland cement as a grinding aid.
Scene 144 - B	
View of standard mix.	
Scene 145	
(A) View of ingredients plus additive.	
1605 - 1634 (43)	
Script 42	

Scene 146

View showing consistency of concrete.

1634 - 1646 (18)

Script 17

The additives produced different effects upon the concrete. In general, the workability was improved and bleeding eliminated.

Scene 147

(A) View of standard mix.

Cut out standard mix animation.

Scene 148

(A) View with natural cement.

Natural cement with and without beef tallow as a grinding aid was blended with Portland cement at the rate of 1 sack of natural to 5 sacks of Portland cement, on the 6 bag batch basis.

Scene 149

View of concrete operations.

Cut in 10' - 16 mm. of scenes 148 and 149 combined.

Scene 150

Views showing bleeding and surface texture. Limestone aggregates.

1683 - 1727 (66)

Script 33

Cut to 9' - 16 mm.

Limestone, coarse and fine aggregates are in disfavor because of poor workability, excessive bleeding, difficult finishing and scaling characteristics. A section of concrete containing limestone aggregates with and without limestone dust were included for study.

Scene 151

None

Scene 152

View showing brooming operations followed by view of burlap drag.

1727 - 1771 (66)

Script 46

Cut brooming 5' - 16 mm.

The use of stiff brooms to remove laitance is recommended by some engineers to overcome scaling. Consequently, brooming versus burlap finishing was included to obtain more comparative data as to the merits of the two methods. The methods were studied both with and without bituminous curing.

Scene 153

View showing burlap curing, citu-minous curing.

1771 - 1803 (48)

Script 45

The factor of curing relative to durability was considered by including a comparative study of several methods under field conditions. The curing methods employed were wetted burlap, asphalt emulsion, cut-back asphalt, wetted straw, paper curing, wetted earth, ponding, calcium chloride integral and transparent membrane.

Scene 154

Laboratory views of Dunagan method.

1803 - 1830 (40)

Script 40

Incidental to construction operations, visual and physical evaluation was made of the various concrete mixtures. Segregation was studied on samples selected throughout the depth of the pavement by means of the Dunagan method for determining the constituents of fresh concrete.

Scene 155

View of setting time apparatus.

1830 - 1847 (25)

Script 20

A comparison of setting time was made on the various concrete mixtures by means of the Burggraf time penetration method.

Scene 156

View making field specimens.

1847 - 1872 (37)

Script 25

Cut out 3' - 16 mm.

Test specimens representative of the various concrete mixtures were prepared in the field for future laboratory tests on compression, flexure and freezing and thawing.

Scene 157

View of freezing equipment.

1872 - 1953 (91)

Script 67

Cut out 6' - 16 mm.

In the laboratory, the specimens were subjected to freezing and thawing test cycles in equipment designed for that particular purpose. The concrete specimens were placed in rubber boots containing water. These were immersed in a glycerine solution in the freezer at a temperature of 20 degrees below zero. Following complete freezing of the concrete specimens they were placed in a constant temperature bath at 70 degrees fahrenheit.

Scene 158

View of sonic apparatus.

1953 - 1983 (45)

Script 42

The break-down of the freezing and thawing specimens was determined by the sonic method. The change in modulus of elasticity of the specimen due to freezing and thawing is detected by noting the change in natural vibration frequency of the specimen.

Scene 159

View of flexural testing machine.
1963 - 1995 (45)
Script 32
Cut out 3' - 16 mm.

The compression strength as well as the flexural strength was determined for the various concrete mixtures for comparative study. A special third point loading machine was designed for testing the flexural strength.

Scene 160

Winter views along test road.
1995 - 2019 (39)
Script 30
Cut out 2' - 16 mm.

Throughout both projects periodic visual and physical measurements will be made over a period of years. During the winter months special scaling studies will be conducted on the durability project.

Scene 161

Views showing scaling structure panels.
2019 - 2080 (61)
Script 63

The various concretes will be subjected to accelerated cycles of freezing and thawing by two methods. In one 3 by 12 foot panel water is frozen and the ice decomposed with a 10 percent application of calcium chloride and the cycle repeated daily. In the second method a 10 percent calcium chloride solution is placed in an adjacent panel and solution renewed weekly.

Scene 162

Aeroplane and travel shots to conclude picture.

2060 - 2106 (69)

Script 70

The value of the design and durability studies will depend entirely upon the manner in which the findings are applied to current and standard practice. It is hoped that the facts and relationships finally obtained from both the design and durability projects will assist in obtaining the whole answer to many controversial issues, and will serve to aid the Michigan State Highway Department, as well as other highway organizations in the development and improvement of concrete pavements.

Scene 163

2106 - 2146 (60)

Cut to fit reading of sign.

Scene 164

END