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Report #56

MICHIGAN

STATE HIGHWAY DEPARTMENT

LANSING

CHARLES M. ZIEGLER
STATE HIGHWAY COMMISSIONER

July 28, 1944

Mr. K. B. McLaughlin
Testing and Research Engineer
Michigan State Highway Department
Lansing, Michigan

Dear Mr. McLaughlin

In accordance with your request of July 10, in compliance with the wishes of H. C. Coons, Deputy Commissioner - Chief Engineer, a survey was made of several bituminous capped projects to determine the extent and seriousness of the blowups which were reported to be occurring at that time. The report submitted herewith presents the findings, conclusions and recommendations based on this survey and study.

In general nothing was found to be greatly alarmed about since most of the blowups were slight heaves in the bituminous surface due to extruding joint filler material and vertical displacement of bituminous patches or weakened areas in the concrete base especially at joints and cracks. The height of the heaves when observed was insufficient to affect traffic.

The report contains several recommendations which we believe are warranted by the study. We find that all of the recommendations are now being observed by the Department. In regard to the last recommendation on conditioning of bituminous capped surfaces, we note that the Maintenance Division, in their "Manual On Highway Maintenance", have made provisions for correcting bituminous capped surfaces with like material when it can be done economically through a local bituminous plant. We strongly recommend that emphasis be placed on this type of work whenever possible.

Yours very truly

E. A. Finney
Assistant Testing and Research
Engineer in charge of Research

EAF:EMM

MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles H. Ziegler
State Highway Commissioner

A STUDY OF

BLOWUPS ON BITUMINOUS CAPPED PAVEMENTS

Research Project 44 G-25

E. A. Finney

RESEARCH LABORATORY
TESTING AND RESEARCH DIVISION
JULY 20, 1944

CONTENTS

A STUDY OF BLOWUPS ON BITUMINOUS CAPPED CONCRETE PAVEMENTS

On July 12, 13, 18 and 24 surveys were made of several bituminous capped concrete projects on which there has been reported the development of blow-ups of sufficient importance to warrant attention. The blowups were noted to have occurred during the high temperature period of the early part of July. The survey covered all projects located on US 16 from Howell to Cooperesville; US 78 from Lansing to Charlotte; US 12 Galesburg to Kalamazoo; US 131 Kalamazoo to White Pigeon; US 112 White Pigeon to Niles; US 12 Benton Harbor east to Kalamazoo and on US 12 from Ann Arbor to Ypsilanti.

The results of the study have been presented by projects in the order that they occurred in the surveys, followed by a summary of factual information, conclusions and proposed recommendations for the prevention of future disturbances of this kind. The text is augmented by numerous illustrations and tabulated data with notes.

US 16, Between Fowlerville and Howell

On the bituminous capped project between Fowlerville and Howell there were observed on July 12, four heaved areas which were definitely caused by an eruption of a weak spot in the concrete base. A survey of the same location on July 24 revealed a total of twelve heaved areas of varying magnitude or an increase of eight since July 12. In all cases the heaved areas were similar in character in that the heaving was gradual and covered a distance of 2 to 4 feet in width with maximum heights varying from 1/2 to 2 inches. See Figures 1, 2, 3 and 4. In one instance the heave was caused by vertical displacement of a small segment of slab at a crack. There may be some heaves caused by extruding joint filler. Most of the heaves were caused

by vertical displacement of old bituminous patched areas which have no stability under lateral pressure. This fact was verified by Mr. Ryan, Maintenance Superintendent at Brighton, who stated that upon repairing some of these heaved areas they found underneath that the base material consisted of shattered pieces of concrete coated with bituminous patching material. The concrete project 47-14, C2 was laid in 1931, the surface was capped in 1934.

US 16, East Lansing M 78, West to Lansing

Eight slight surface heaves were observed on this project. They were all of the same type, being about 6 to 8 inches in width and approximately 1/2 inch high. From the appearance of the heaves it was quite obvious that they were caused by the extrusion of the old expansion joint filler in the concrete base. In driving over them they would produce the same effect as an extruded joint filler on a concrete pavement.

US 16, Clinton County Line West

No unusual disturbance of the bituminous surface was observed on this project.

US 16, Portland West to Grand Rapids

Five small surface heaves were observed on this stretch of bituminous capping. They were all of the type caused by extruding joint filler. See Figure 5. The majority of the heaves occurred in Kent County. They are listed in Table I.

It is understood that during construction of this project extensive concrete patching was necessary and that in this work expansion joints were

installed in which the extruding type of joint filler was used. The majority of heaved pieces occurred in this section since it had required the most extensive concrete patching.

US 16, Grand Rapids West to Coopersville

Six slight surface heaves due to extruding joint filler were observed on this project. They are listed in Table II. The average distance between heaves is 1782 feet. As illustrated in Figures 6 and 7 the heaves were about the same size, that is 6 to 7 inches in width and 1/2 to 3/4 inches in height, as those which had occurred on previous projects. They occurred most frequently in only one lane.

An examination of one joint filler heave on this project revealed that the expansion joint filler was extruded 1/2 inch above the old concrete pavement surface and that the expansion joint in the concrete base was about 3/4 inch wide. It is evident that expansion joints with extruding joint filler were inserted in the concrete patches and that during the joint cleaning operations the joints were not cleaned to a sufficient depth to eliminate extrusion or were entirely missed.

It is understood that an attempt is made to remove the old expansion joint filler to a depth of 1 1/2 inches. This is not a sufficient depth to prevent extrusion at new expansion joints containing the extrusion type of filler because this filler material will extrude several inches in one compression. See Figures 8 and 9.

US 12, Galesburg West to Comstock

On this stretch of bituminous capping there were observed twenty heaved areas. They were of a different type than those caused by extruding joint

filler in that the heaved surface extended over a greater area and the areas were more irregular in shape. They varied from 12 inches to 24 inches in width and 1/2 inch to 1 inch in height. The heaves occurred at both cracks and joints and it was apparent from their characteristic shape that they might be caused mainly by the pushing up of old bituminous patching material in the concrete base. It is understood that the bituminous capping was placed directly on the old concrete pavement without cleaning out the expansion joints or removing the weak bituminous patched areas and replacing them with concrete. See Table III.

US 131, Schoolcraft South to County Line

This project contained twenty slight surface heaves varying in distance apart from 198 to 1584 feet or at an average distance of 631 feet. They were of the same general type as observed on the Galesburg job apparently caused by the vertical displacement of old bituminous patch material, extruding joint filler or by a general heaving of crushed concrete at a joint or crack. No violent blowups were observed. The survey data is presented in Table IV.

US 131, Constantine South to US 112

This is not a bituminous capped project, however a considerable number of blowups had occurred and they were logged. See Table V. Fourteen blowups had occurred on this project and they had been cleaned up and subsequently patched with bituminous material. The blowup areas were 2 to 3 feet in width. The spacing of blowups varied from 105 to 1584 feet with an average of 662 feet.

US 112, White Pigeon East to Nottaville

Thirty-five surface heaves were noted on this section of bituminous

capping. They varied in spacing from 106 to 2376 feet with an average distance of 770 feet. See Table VI. The majority of heaves extended completely across the pavement, the balance occured only in one lane. They averaged from 1 to 3 feet in width and 1/2 to 1 inch in height. An examination of one heave revealed the presence of a bituminous patch immediately underneath. See Figures 10 and 11. There was one bad heave (No. 10 in Table VI) which was caused by the vertical displacement of the concrete slab on one side of the joint only. See Figure 12. The slab was raised about 2 inches at the joint and extended back from the joint about 7 feet. A major blowup had occurred (No. 12 in Table VI) shortly after the surface was placed in 1942. This was repaired by the contractor.

The surface heaves at the time of survey were not of sufficient height to inconvenience traffic except for a slight jar equivalent to that which might be encountered on any concrete pavement with extruded joint filler or badly faulted joints.

I understand from Mr. Burgwald, Maintenance Superintendent, that this was the first time that these heaves had occurred on this project. Also he was of the opinion that the old concrete surface was not patched with concrete or that the joints were not cleaned out prior to applying bituminous capping. This fact was verified by the Construction Division.

US 112, Union East to M 205

This project extending from Union to M 205 contained six heaved areas. The distance between heaves varied from 528 to 5280 feet with an average of 3423 feet. See Table VII. The heaving was of the same type as that observed on the previous project.

US 12, Benton Harbor East

A survey was made of blowups occurring on the concrete pavement on project 11-2, US East of Benton Harbor. Sixteen blowups were observed on this project. A major portion of the blowups had been covered with a huge patch of bituminous material, as illustrated in Figure 15. This type of repair work is quite crude indeed and creates a sizable hump in the pavement.

At location No. 13, Table VIII a bad blowup occurred at a crack about three weeks prior to date of this survey. The concrete at the crack was badly shattered and pushed up. The adjacent slabs were raised for a distance of 12 feet on each side of blowup. At the time of observation the peak of blowup area was 4 to 5 inches above normal surface elevation. It was understood from an eye witness to the blowup that it was originally much worse and had subsided considerably. See Figure 14 for view of blowup. Pictures were taken of two other bad blowups Nos. 9 and 10 which are illustrated in Figures 17 and 18.

The spacing between blowups varied from 106 to 2450 feet with an average spacing of 864 feet. See Table VIII.

US 12, Paw Paw East to Kalamazoo

On the entire stretch of bituminous capping from Paw Paw to Kalamazoo there were observed forty-one heaved areas. They are listed in Tables II and I. The spacing of heaves varied from 264 to 7075 feet with an average value of 1510 feet. The heaved areas all had the same general characteristics as observed on previous projects.

US 12, Ann Arbor to Ypsilanti

On July 24 many surface heaves were noticed in the bituminous capping on US 12 between Ann Arbor and Ypsilanti. They were so frequent that it

was impractical to log them with the speedometer. It was observed that throughout the entire project there was a slight heave at practically every expansion joint on the north lane. These heaves were definitely caused by extruding joint filler. Thirty heaves of significant size were observed in the center and south lanes. These heaves were on the old pavement and appeared to be caused by extruding joint filler and vertical displacement of weak areas in the concrete base. In all cases the heaves were not high enough to inconvenience traffic. It is apparent that where the heaves caused by extruding joint filler have been subsequently ironed down by traffic there is structural failure of the surface along the heaved area. This failure is manifested by cracking and subsequent alligatoring immediately above the joint. Such places should be repaired as soon as possible to prevent further raveling of the surface.

M 17 from US 112 to Expressway

On this stretch of old Tecorse Road which was resurfaced with bituminous material recently there were no surface disfigurations of any kind throughout its entire length. The bituminous capping was laid in 1948.

SIGNIFICANT FACTS PERTAINING TO BLOWUPS

In addition to the factual data obtained from the survey, other information of significant importance in connection with the phenomena of surface heaves on bituminous capped projects and blowups on concrete pavements have been observed and studied.

It is significant to note that all of the blowups which were observed on the survey have occurred in pavements 16 years of age or older. In most cases the pavements are over 20 years old. See Table II. The pavements in

all cases were badly cracked, frequently patched with bituminous materials and the concrete at the cracks and joints had become badly disintegrated due to weathering and fatigue. It is quite obvious that concrete pavements in such condition can not withstand the high compressive forces which periodically occur during prolonged periods of unusually high temperatures. It has also been observed that without an exception a blowup will occur at a weakened crack or joint or at a badly disintegrated area between joints and cracks. Typical examples of types of blowup are illustrated in Figures 14 to 22 inclusive.

According to U. S. Weather Bureau data the temperature during the hot spell in which the blowups became prevalent was only 5 - 8 degrees above normal for this area and time of year. Also the relative humidity was average. See following table.

Date	Relative Humidity Percent	Temperature Degree F
July 5	34	86
July 6	38	90
July 7	34	89
July 8	33	90
July 9	48	86
July 10	45	89
July 11	46	89

It is believed that climatic conditions and the moisture content of concrete pavements prior to prolonged hot spells in which blowups occur in significant numbers are largely responsible for the excessive expansion which seems to take place during such periods. This matter will be investigated further.

It is understood from the Construction Division that on bituminous capped projects prior to 1942 the old concrete surfaces received no special repair treatment before applying capping. In 1942 the old concrete pavements were patched with concrete and expansion joints used. In 1943 the old concrete surface was patched with concrete but expansion joints were eliminated except for long patches of several hundred feet. It follows then that the type of treatment received by the concrete base prior to bituminous capping is reflected in the number and type of blowups experienced recently. Practically no surface heaves have occurred on pavements capped since 1943.

SUMMARY

Blowups or heaving of bituminous capped surfaces are caused by certain construction factors or inherent physical weaknesses of the concrete base which react in various ways when the pavement is subjected to abnormal compressive forces such as are known to occur under prolonged periods of high temperatures. The following reactions were observed to take place.

1. The extrusion of bituminous joint filler material from expansion joints.

2. The vertical displacement of bituminous patch material.

3. The vertical displacement of small areas of crushed or disintegrated concrete adjacent to cracks or joints which have been maintained in service by repeated applications of bituminous material and chips.

4. The crushing and subsequent vertical placement of weakened concrete adjacent to cracks and joints.

5. The partial crushing and subsequent vertical displacement of large sections of concrete slab adjacent to cracks or joints.

Practically all heaves due to physical weaknesses in the concrete base occurred on projects capped prior to 1942. It is understood that capped projects in that period received no special repair treatment prior to being capped. This would indicate that a careful repair operation is necessary prior to capping a concrete surface in order to prevent the occurrence of heaves.

With but one exception all of the bituminous capped projects surveyed had a considerable number of heaves caused by extruding expansion joint filler. This would indicate the promiscuous use of unapproved expansion joint filler during concrete patching operations or that these expansion joints were not properly cleaned out prior to applying bituminous surface.

Blowups seem to occur more frequently on projects constructed on heavy soils as compared to those built on granular well drained soil material.

Blowups seem to occur on only those concrete pavements which have attained an age sufficient for them to have developed structural weaknesses such as frequent cracking and disintegration of the concrete adjacent to joints and cracks.

The distance between heaves was found to vary from 105 feet to 10,500 feet with an average distance of 691 feet to 6,984 feet. It is apparent that the number of blowups occurring in the concrete base under a bituminous capping is dependent to a great extent upon the physical condition of the concrete surface at the time of capping and to the subgrade characteristics. It is important to note that blowups due to physical weakness of the base have not occurred on the projects capped in 1945. It is understood that these projects were patched with concrete with no expansion joints installed only in the case of long stretches of concrete pavement. This would indicate that provisions for expansion is not absolutely necessary when the concrete base has been properly patched with concrete and reconditioned to the extent that the concrete surface approaches the strength and continuity of a new concrete pavement and that the pavement is located on an ideal subgrade. In fact the provision of too much expansion space on bituminous capped projects may be undesirable in some cases because it is quite apparent that cracks will eventually develop in the bituminous surface over each crack or joint in the concrete base which has any appreciable lateral movement. Thus it may be desirable to maintain the concrete base under slight compression to insure prolonged structural stability of the bituminous capping.

The survey revealed no blowups or heaved areas on the bituminous capping projects which would constitute a serious traffic hazard at the time.

RECOMMENDATIONS

In order to eliminate surface heaving on future bituminous capped projects the following recommendations are offered, based on information obtained from the survey.

1. Provisions should be made to eliminate the use of extruding joint filler material from concrete patching work performed either by the Maintenance Division or by a contractor operating under a regular contract.

2. All joints in a concrete pavement to be capped should be carefully cleaned of existing extruding joint filler to a specified depth. The practice of allowing the surface mixture to fill up the area immediately above the remaining joint filler may be unwise since any further expansion and subsequent extrusion upward of the existing joint filler will only tend to heave the pavement. No data are available to substantiate this opinion, but nevertheless such a condition is possible and it may be the source of some of the heaving now taking place. Perhaps the joint should be covered with a supporting material which will both reinforce the surface at the joint and provide an expansion chamber underneath.

3. The future life of the bituminous surface is dependent upon the physical condition of its base. Therefore the old concrete base should be properly reconditioned by removing completely and filling with concrete all bituminous patched areas, all areas adjacent to cracks and joints which have been patched with bituminous material and chips although such areas appear sound and all areas which have developed complete structural failure as manifested by excessive cracking and any other areas in the concrete pavement of questionable soundness.

4. Until more conclusive data is available it may be advisable on certain projects to install an occasional expansion joint of the non-extruding type during patching operation as a factor of safety. The spacing of such joints may be several hundred feet apart depending upon reconditioning operations.

5. Reconditioning of Bituminous Surface: It was observed that when blowups occurred on the bituminous capped projects of sufficient magnitude to warrant immediate attention, the blowup areas were dug out and refilled with a soft bituminous mixture of the slow curing type such as an oil aggregate mixture. Such a treatment may suffice as an emergency measure but it is firmly believed that this type of surface should warrant a better treatment and that a higher type of maintenance should be provided for recapped surfaces in order to maintain the structural integrity of the surface. In this respect it would seem advisable to institute a practice of making a yearly check up of bituminous capped projects with the view of making recommendations for repairs and that the repairing of these surfaces should be done under prescribed high class construction methods involving the use of concrete patches in the base to replace blowup areas and the replaced surface material over these patches and at raveled areas in the surface should consist of a hot patch mixture comparable to the original surface material. Only in this manner can we hope to preserve the excellent wearing and riding qualities of a bituminous capped pavement at a minimum of maintenance cost.

APPENDIX

ILLUSTRATIONS AND TABLES

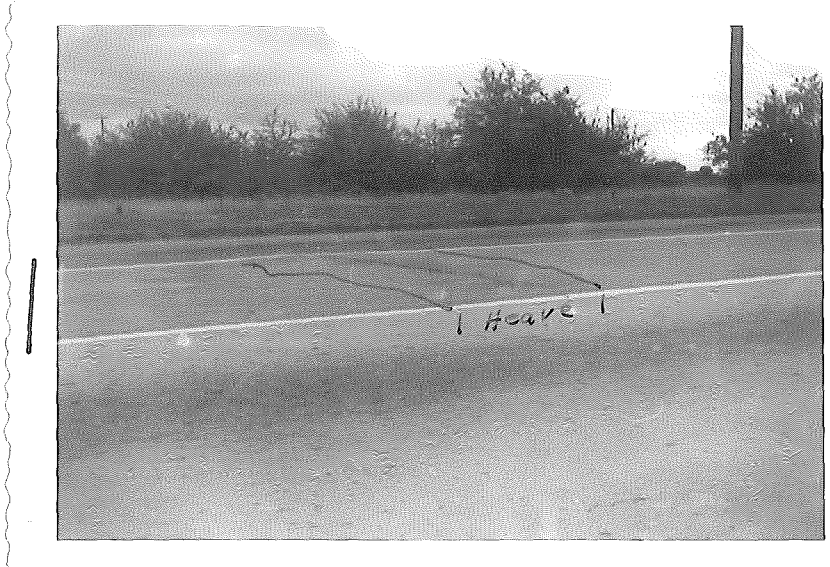

Figure 1. Heaving of bituminous surface center lane, US 16 Howell west, Project 47-14, C 5 & 6

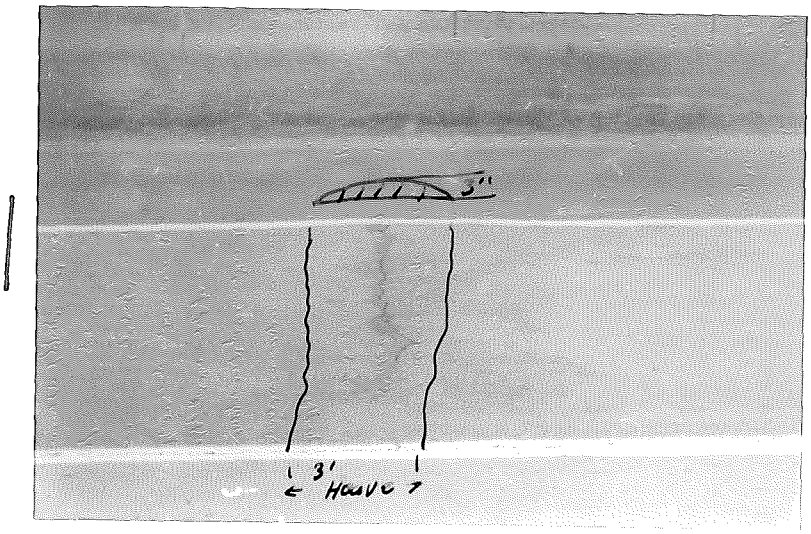

Figure 2. Close view of same heave as illustrated in Figure 1. Note characteristic crack in center of heaved area.

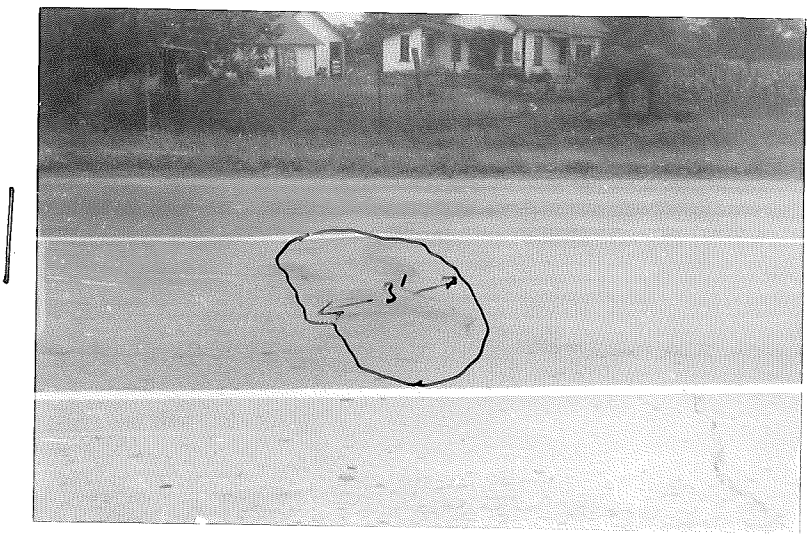

Figure 3. View of another heave of bituminous surface west of Howell. Project 47-14, C 5 & 6. Heave 3 feet wide, 1 inch high, center lane.

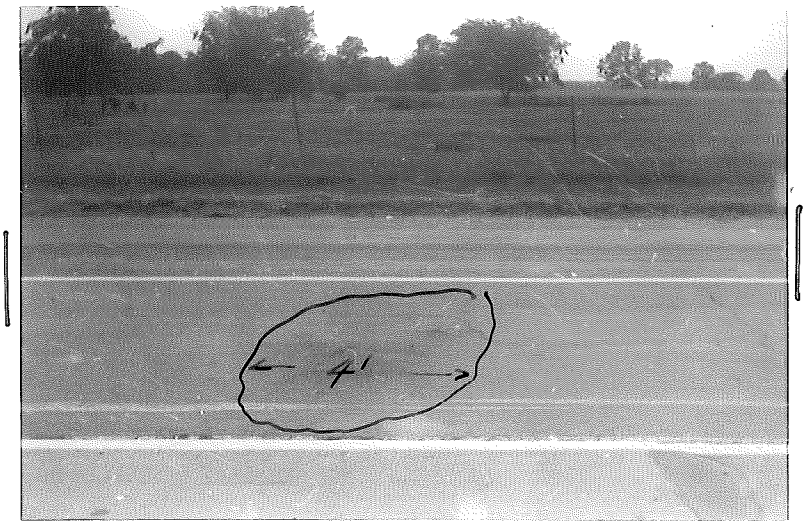

Figure 4. Circular heave area on Project 47-14 C 5 & 6 approximately 2 feet high, 4 feet in diameter. Center lane.

Figure 5. View of typical surface heave caused by extruding joint filler. Note area is narrow, and sharp with crack at ridge. The ends are partially ironed down by traffic, Project 41-13, C3.

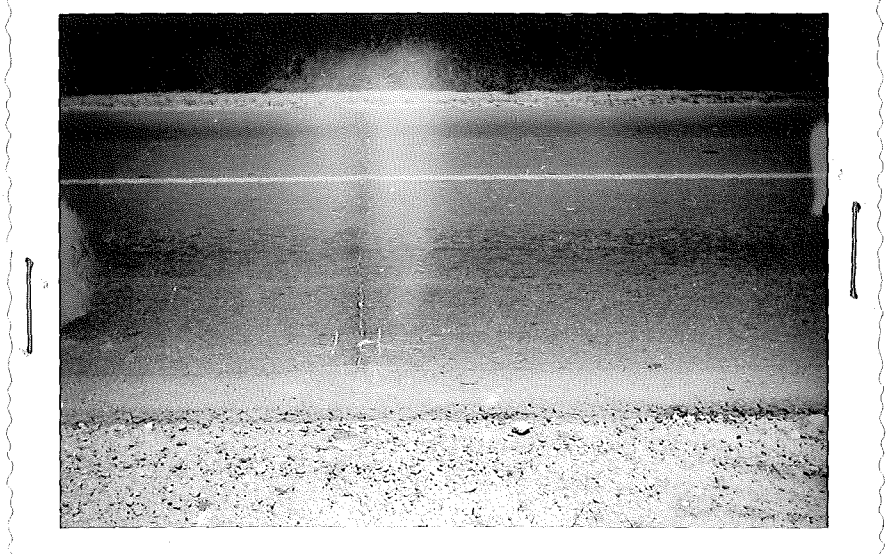

Figure 6. Heave due to extruding joint filler which extends entirely across pavement. Area is 6" wide and 1" high. Project 70-12, C2.

Figure 7. Another heave due to extruding joint filler on Project 70-12, C2.

Figure 7 A. A portion of heave in Figure 7 was removed to show extruding joint filler, Project 70-12, C2.

Figure 8. Extruding Joint Filler. US 16 - North Lane, East Lansing between Charles and Division Streets. Installed Fall 1943. Picture, May 8, 1944.

Figure 9. Close view of extruding joint filler as described in Figure 8.

Figure 10. Project 78-14, C1. White Pigeon East. Typical heave on this project. Area 24 inches wide 1 1/2 inches high, one side only.

Figure 11. Close view of heave in Figure 10. Note old bituminous patch underneath which under excessive compressive forces has pushed upward causing heaving of the surface course.

TABLE I
SURVEY OF BLOWUPS ON BITUMINOUS CAPPED PROJECTS
Portland West on US 16

Concrete Base - Project 34-8, C 3 & 4, 1926
Bituminous Capping - Project 34-8, C 8 & 9, 1943

Concrete Base - Project 41-18, C5, 1926
Bituminous Capping - Project 41-18, C7, 1942

No.	Speedometer Reading	Distance Feet	Lane L	Lane R	Description
	40.40				Beginning of bituminous capping
1	42.85		L	-	Heave due to joint filler, picture
	46.80				M 66 to Ionia
	49.05				Odessa Road
	51.10		L	-	Fresh patch 6' x 11'
	54.35				County road
	55.35				End bituminous capping, new concrete
	56.55				End concrete, start bituminous capping
	59.05				Kent County, end 34-8, beginning 41-18
	60.85				M 91
	62.10				M 50
2	64.80		-	R	Heave due to old joint filler
3	65.10	1584	L	R	Heave due to old joint filler
4	68.50	7392	-	R	Heave due to old joint filler
5	68.50	10560	-	R	Heave due to old joint filler
	69.70	7920			End

There was extensive concrete patchwork on section west of M 50 where extrusion type of expansion joint filler was used. The effect of using this material is reflected by the number of surface heaves occurring in this area.

Survey by E. A. Finney, July 12, 1944

Figure 21, Project 12-5, C5 (1923) US 27 North of Lansing. Blowup in west lane cleaned out ready for filling with bituminous material. No doubt such patches on bituminous capped projects are responsible for certain surface heaves.

Figure 22. Close view of Figure 21 showing how longitudinal edge bar was bent during blowup. This has been observed at blowup areas on other projects.

Figure 19. Project 53-24, C3 (1822) Bad blowup on US 16 near airport in center lanes on old slab. Note heaving and shattering of concrete at old expansion joint.

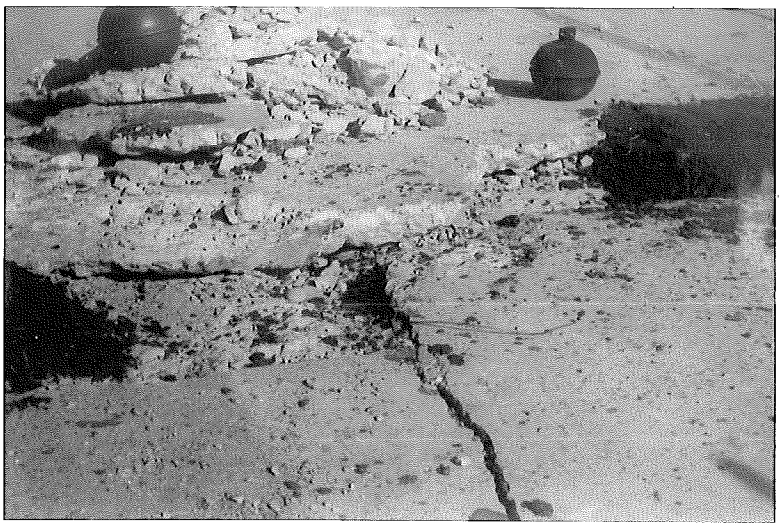

Figure 20. Project 53-24, C3. Close view of Figure 19 showing how left slab split horizontally and started to ride right slab.

Figure 17. Project 35-24, C5, (1922). Typical blowup area at a crack which has been maintained in service by tar and chips. Such areas are weak points in old pavements and are source of many heaves on bituminous capped projects.

Figure 18. 78-11, C1 (1929) M 60, Three Rivers at Carden and Michigan Streets. Slight blowup at expansion joint. Note crushing and slight heaving of concrete. Similar conditions are no doubt responsible for heaving of bituminous capped projects.

Figure 15. Project 11-3, CS, Benton Harbor East, Blowup No. 9. Note attempt of right slab to ride left slab. Right slab cracked back several feet. Difference in elevation about 2 inches.

Figure 16. Project 11-3, CS. Blowup No. 10 which was located a short distance from No. 9. In this case note uniform heaving of slabs on each side of crack. Blowup occurred in one lane only.

Figure 13. Project 11-3, C3 Benton Harbor East. Several old blowup areas were repaired by simply covering area with a huge patch of oil aggregate mixture without attempting to remove heaved concrete.

Figure 14. Fresh blowup which had occurred on Project 11-3, C3. Note typical crushing of concrete along crack. Bituminous material indicates that concrete along crack was in advanced stage of disintegration and could not sustain the abnormal compressive forces.

Figure 12. Surface displacement caused by pushing up of concrete slab. Project 78-14, C1. This was the worse blowup area on project.

TABLE II

SURVEY OF BLOWUPS ON BITUMINOUS CAPPED PROJECTS

Grand Rapids West to Coopersville on US 16

Concrete Base Project 70-21, C2, 1925
Bituminous Capping Project 70, 21, C3, 1943

Concrete Base Project 70-12, C2, 1925
Bituminous Capping Project 70-12, C3, 1943

No.	Speedometer Reading	Distance Feet	Lane L	Lane R	Description
	894.25				Beginning bituminous capping, Project 70-21, C3
1	95.16	475	L	R	Heave due to old joint filler
	96.55	7400			End bituminous capping
	96.65	528			Beginning of bituminous capping
2	97.35	3700	L	R	Heave due to old joint filler
	97.50	795			End 70-21, C3 - Beginning 70-12, C3
3	900.90	18000	L	R	Heave due to old joint filler
4	01.10	1055	-	R	Heave due to old joint filler
5	01.50	2111	-	R	Heave due to old joint filler, picture
6	01.75	1320	L	R	Heave due to old joint filler, picture
	02.25	2640	L	R	End bituminous capping, Coopersville

Project 70-12, C3 average distance between blowups 1782 feet

Survey by F. A. Finney, July 14, 1944
P. V. Nelson
H. J. Koster

TABLE III
SURVEY OF BLOWUPS ON BITUMINOUS CAPPED PROJECTS
Galesburg East to Comstock US 12

Concrete Base - 39-18, C1-2, F -16, 1918
Bituminous Capping BMFA 21 (2) & 52(3), 1939

No.	Speedometer Reading	Distance Feet	Lane L	Lane R	Description
1	86.20		L	R	Surface heaves appeared to develop at
2	86.30	528	L	R	cracks and joints in old concrete base.
3	86.80	2640	L	R	The heaved areas varied from 12" to 24"
4	87.00	1056	L	R	in width and from 1/2 to 1" in height.
5	87.05	264	L	R	The heaves were gradual and not sharp
6	87.20	792	L	R	as was in the case of heaves caused by
7	87.35	792	L	R	extrusion of joint filler. The heaves
8	87.45	528	L	R	were apparently caused by the pushing
9	87.60	792	L	R	up of old bituminous patch material
10	87.65	264	-	R	which was used to repair disintegrated
11	87.70	264	-	R	portions of the old concrete. This is
12	87.80	528	-	R	true for the entire project.
13	88.15	1848	L	R	
14.	88.25	528	L	R	
15	88.35	528	L	R	
16	88.50	792	L	-	
17	88.90	2112	L	R	
18	89.10	1056	L	R	
19	89.70	5168	L	R	
20	89.80	528	L	R	
	89.90	528	L	R	End of bituminous capping

Minimum distance between blowups	264 feet
Maximum distance between blow ups	5168 feet
Average distance between blowups	977 feet

According to E. E. Blomgren, District Engineer, the old joint filler material was not removed from joints nor the old pavement patched with concrete. Capping applied to old surface as it existed.

Survey by E. A. Finney, July 18, 1944

TABLE III A

FREQUENCY OF BLOWUP OCCURRENCE

Galesburg West to Comstock

Distance in Feet	Frequency
264	5
528	7
792	4
945	1
1056	2
1850	1
2112	1
5188	1

TABLE IV
SURVEY OF BLOWUPS ON BITUMINOUS CAPPED PROJECTS
Schoolcraft South to County Line on US 131

Concrete Base 39-1, C1, 1920
Bituminous Capping on 39-1, C4, 1940

No.	Speedometer Reading	Distance Feet	Lane L	Lane R	Description
	08.25				Railroad Crossing
1	8.55	1584	L	R	
2	8.70	792	L	R	All heaves had same general characteristics which have been described in Table III and they are apparently caused by same conditions existing in old concrete base.
3	8.75	264	L	R	
4	9.00	1320	-	R	
5	9.15	792	L	R	
6	9.25	528	L	R	
7	9.35	528	L	R	
8	9.50	792	L	R	
9	9.65	792	L	-	
10	9.70	264	-	R	
11	9.80	528	L	R	
12	9.95	792	L	R	
13	10.10	792	L	R	
14	10.20	528	L	R	
15	10.40	1056	-	R	
16	10.45	264	L	R	
17	10.48	158	L	R	
18	10.55	370	L	R	
19	10.70	792	L	R	
20	10.86	792	L	R	
	11.00	792			County line end of project

Minimum distance between blowups	158 feet
Maximum distance between blowups	1584 feet
Average distance between blowups	691 feet

Survey by E. A. Finney, July 13, 1944
E. Dahlgren

TABLE IV A

FREQUENCY OF BLOWUP OCCURRENCES

Schoolcraft South to County Line on US 131

Distance in Feet	Frequency
158	1
264	3
370	1
528	4
792	9
1056	1
1320	1
1650	1

TABLE V

SURVEY OF BLOWUPS ON CONCRETE PAVEMENT

Constantine South to White Pigeon US131

Concrete Pavement 78-2-C5, 1924

No.	Speedometer Reading	Distance Feet	Lane L	Lane R	Description
	30.20				Beginning of project
1	30.22	105	L	R	
2	30.40	950	-	R	All blowups on this project had oc-
3	30.65	1320	L	R	curred prior to survey and they had
4	30.75	528	L	R	been cleaned out and patched with a
5	30.82	370	L	R	bituminous mixture. The patched
6	30.90	422	L	R	area varied in width from 3 to 4 feet.
7	31.20	1584	L	R	
8	31.35	792	L	R	
9	31.65	1584	L	R	
10	31.80	792	L	R	
11	31.82	105	L	R	
12	31.85	158	L	R	
13	32.10	1320	L	R	
14	32.35	1320	L	R	
	32.65	1584	L	R	End of Project

Minimum distance between blowups	105
Maximum distance between blowups	1584
Average distance between blowups	862

Soil - Marshan Loam

Survey by E. A. Finney, July 18, 1944
E. Dahlman
C. Burgwald

TABLE V A
FREQUENCY OF BLOWUP OCCURRENCE
Constantine South to White Pigeon, US 131

Distance between Blowups	Frequency
105	2
159	1
370	1
423	1
528	1
792	2
952	1
1320	3
1585	5

TABLE VI
SURVEY OF BITUMINOUS CAPPED PROJECTS
White Pigeon West to Mottville US112

Concrete Base Project 75-14, C1, 1925
Bituminous Capping Project 75-14, C4, 1942

No.	Speedometer Reading	Distance Feet	Lane L	Lane R	Description
	45.10				Beginning of Project BR at White Pigeon
1	45.20	528	L	R	Heave at crack or joint
2	45.35	792	L	R	Heave at crack or joint
3	45.40	264	L	R	Heave at crack or joint
4	45.45	264	L	R	Heave at crack or joint
5	45.60	792	L	R	Heave at crack
6	45.70	528	L	R	Heave at crack
7	45.85	792	L	R	Heave at crack, picture
8	46.05	1056	L	R	Heave at patch or crack
9	46.10	264	L	R	Heave at patch or crack
10	46.25	792	L	R	Slab heaved at crack, picture
11	46.40	792	L	-	Slab heaved at crack
12	46.75	1848	L	R	Heave occurred shortly after pavement was laid
13	46.90	792	-	R	Heave at crack or joint
14	46.95	264	L	-	Heave at crack or joint
15	47.05	528	-	R	Heave at crack or joint
16	47.08	158	L	R	Heave at crack
17	47.35	1425	L	R	Heave at crack
18	47.38	158	L	R	Heave at crack
19	47.40	105	L	R	Heave at crack
20	47.45	264	L	R	Patch
21	47.55	528	L	R	Heave at crack or joint
22	47.75	1056	L	R	Heave at crack or joint
23	47.85	528	L	R	Heave at crack at joint
24	47.95	528	L	R	Heave at crack or joint
25	48.10	737	L	-	Heave at crack or joint
26	48.25	792	L	R	Heave at crack or joint
27	48.35	528	L	-	Heave at crack or joint
28	48.45	528	L	R	Heave at crack or joint
29	48.55	528	L	-	Heave at crack or joint
30	48.80	264	L	R	Heave at crack or joint
31	48.85	1320	L	R	Heave at crack or joint
32	48.95	528	L	R	Heave at crack
33	49.25	1584	L	R	Heave at crack
34	49.55	1584	L	-	Heave at crack
35	50.00	2376	-	R	Heave at crack
	50.35	1848			End of project Mottville

Minimum distance between blowups 106 feet
Maximum distance between blowups 2376 feet
Average distance between blowups 770 feet

Heaving apparently due to pushing up of old bituminous patch material at cracks and joints

Soil - Fox Sandy Loam

Survey by E. A. Finney
E. Dahlman
C. Burgwald

TABLE VI A

SURVEY OF BITUMINOUS CAPPED PROJECTS

White Pigeon West to Mottsville US 112

Frequency of Blowup Occurrence

Distance in Feet	Frequency
106	1
158	2
264	6
528	10
792	8
1056	2
1320	1
1426	1
1584	2
1848	2
2576	1

TABLE VII
SURVEY OF BLOWUPS ON BITUMINOUS RECAPPED PROJECTS
Union West on US 112

Concrete Base, Project 14-15, C2, 1923
Bituminous Capping, Project 14-15, C8 & 7, 1942

No.	Speedometer Reading	Distance Feet	Lane L	Lane R	Description
	66.80				Beginning of Project
1	82.80	8280	L	R	Heave at crack or joint
2	87.25	2375	L	R	Heave at crack or joint
3	89.05	4230	L	R	Heave at crack or joint
4	89.15	528	L	R	Heave at crack or joint
5	89.80	3360	L	R	Heave at crack or joint
6	70.55	3430	L	R	Heave at crack or joint
	71.34	4170			End of Project at M 205

Minimum distance between blowups 528
Maximum distance between blowups 5280
Average distance between blowups 3425

Heaving due to pushing up of old bituminous patching material at cracks and joints.

Survey by E. A. Finney, July 18, 1944
E. Eshleman

TABLE VII A
SURVEY OF BLOWUPS ON BITUMINOUS RECAPPED PROJECTS
Union Test on US 112
Frequency of Occurrence

Distance between Blowups	Frequency
528	1
2575	1
3430	1
3960	1
4170	1
4230	1
5280	1

TABLE VIII
SURVEY OF BLOWUPS ON CONCRETE PAVEMENT
Benton Harbor East on US 12

Concrete Pavement, Project 11-B, CS, 1924

No.	Speedometer Reading	Distance Feet	Lane L	Lane R	Description
	17.90				Beginning of project
1	18.00	528	L	R	Covered by bituminous patch
2	18.20	1056	L	R	Covered by bituminous patch
3	18.35	792	L	R	Covered by bituminous patch
4	18.40	264	L	R	Covered by bituminous patch
5	18.53	686	L	R	Covered by bituminous patch, picture
6	18.75	1162	L	R	Covered by bituminous patch
7	18.88	686	L	R	Covered by bituminous patch
8	19.20	1690	L	R	Covered by bituminous patch
9	19.50	1584	L	R	Covered by bituminous patch
10	19.52	105	L	-	Covered by bituminous patch
11	19.60	422	L	-	Covered by bituminous patch
12	19.65	264	L	R	Bad blowup at crack, pictures
13	19.70	264	L	R	Crushed concrete removed
14	20.20	2640	L	R	Crushed concrete removed
15	20.29	475	L	R	Crushed concrete removed
16	20.51	1162	L	R	Crushed concrete removed
	20.97	2429			End of project

Minimum distance between blowups 106
Maximum distance between blowups 2480
Average distance between blowups 954

Concrete badly cracked and patched with bituminous material at weak places.

Survey by E. A. Finney, July 18, 1944
E. Dehlman

TABLE VIII A
SURVEY OF BLOWUPS ON CONCRETE PAVEMENT
Benton Harbor East on US 12
Frequency of Occurrence

Distance between Blowups	Frequency
198	1
264	1
423	1
475	1
528	1
687	2
792	1
1056	1
1155	2
1582	1
1650	1
2459	1
2640	1

TABLE IX

SURVEY OF BLOWUPS ON BITUMINOUS RECAPPED PROJECTS

Paw Paw East on US 12

Concrete Base Project 80-15, C1, 1922

Bituminous Recapping Project 80-16, C5 & 4, 1942

No.	Speedometer Reading	Distance Feet	Lane L	Lane R	Description
	49.27				Beginning of project
1	51.15	9928	-	R	Heave at crack or joint
2	51.20	264	L	R	Heave at crack or joint
3	51.30	528	L	R	Heave at crack or joint
4	51.67	1954	-	R	Heave at crack or joint
5	51.90	1214	L	R	Heave at crack or joint
6	52.00	528	L	R	Heave at crack or joint
7	52.45	2376	-	R	Heave at crack or joint
8	52.65	1056	L	R	Heave at crack or joint
9	53.00	1848	L	R	Heave at crack or joint
10	53.10	528	L	R	Heave at crack or joint
	53.20	528			End of Project

Minimum distance between blowups 264

Maximum distance between blowups 1955

Average distance between blowups 1955

Survey by E. A. Finney, July 18, 1944

E. Dahlman

Table IX A
Survey of Blowups on Bituminous Recapped Projects
Paw Paw East on US 12
Frequency of Occurrence

Distance between Blowups	Frequency
264	1
528	4
995	1
1056	1
1230	1
1848	1
1955	1
2475	1

TABLE X

SURVEY OF BLOWUPS ON BITUMINOUS RECAPPED PROJECTS

Paw Paw East on US 12

Concrete Base Project 80-8, C2, 1928
Bituminous Recapping Project 80-8, C5, 1942

Concrete Base Project 59-12, C1, 1928
Bituminous Capping Project 59-12, C5, 1942

No.	Speedometer Reading	Distance Feet	Lane L	Lane R	Description
	54.20				Beginning of Project
1	52.52	1690	L	R	Heave at crack or joint
2	55.85	666	L	R	Heave at crack or joint
3	53.77	675	L	R	Heave at crack or joint
4	55.11	7075	L	R	Heave at crack
	55.30				Kalamazoo County Line P.C.P. 80-8, P.C.P. 59-12
5	55.50	2059	L	R	Heave at crack or joint
6	55.78	1479	L	R	Heave at crack or joint
6	55.78	1478	L	R	Heave at crack or joint
7	55.85	370	L	-	Heave at crack or joint
8	56.20	1848	L	R	Heave at crack or joint
9	56.25	264	L	R	Heave at series of several short cracks
10	56.47	1162	L	R	Heave at crack or joint
11	56.55	422	L	R	Heave at crack or joint
	56.70				Grade Crossing
12	56.81	1373	L	R	Heave at crack or joint
13	57.10	1531	L	R	Heave at crack or joint
14	57.50	2112	-	R	Heave at crack or joint
15	57.88	2006	L	R	Heave at crack or joint
16	58.00	634	L	R	Heave at crack or joint
17	58.08	422	-	R	Heave at crack or joint
18	58.20	634	L	R	Heave at crack or joint
19	58.38	845	L	R	Heave at crack or joint
20	58.45	475	L	-	Heave at crack or joint
21	58.65	1056	L	R	Heave at crack or joint
22	58.88	1214	L	R	Heave at crack or joint
23	59.08	1056	L	R	Heave at crack or joint
24	59.60	2745	L	R	Several small blowups at cracked area
25	59.68	422	L	-	Heave at crack or joint
26	59.75	370	L	R	Heave at crack or joint
27	60.38	5328	L	R	Heave at crack or joint
28	60.45	370	L	R	Heave at crack or joint
29	60.65	1056	L	R	Heave at crack
30	60.75	528	L	R	Heave at crack or joint
31	60.80	264	L	R	Heave at crack or joint
	61.00	1056	L	R	End of Project

Minimum distance between blowups 264
Maximum distance between blowups 7075
Average distance between blowups 1247

Survey by E. A. Finney, July 18, 1944
E. Buhlman

TABLE I A
SURVEY OF BLOWUPS ON BITUMINOUS RECAPPED PAVEMENTS
Paw Paw East on US 12
Frequency of Blowup Occurrence

Distance between Blowups	Frequency
264	2
370	3
422	3
475	1
528	1
634	3
687	1
845	1
1056	4
1162	1
1320	1
1372	1
1480	1
1532	1
1690	1
1848	1
2006	1
2060	1
2112	1
2745	1
5325	1
7080	1

TABLE XI
SUMMARY OF PROJECT AND BLOWUP DATA

Route	Project No.	Location	Year Built	Age	Year Capped	No. Blowups or Heaves	*Type of Blowup	Length in Miles	Blowup Spacing		
									Minimum	Maximum	Average
US 16	47-14, C2	Fowlerville - Howell	1921	23	1934	4	A	5.3	-	-	-
US 16	33-24, C6	East Lansing - Lansing	1921	23	1945	8	B	2.0	-	-	-
US 16	34-9, C3-4	Portland West	1926	18	1945	1	B	3.4	-	-	-
	41-13, C3	Portland West	1926	18	1942	4	B	13.9	1,584	10,560	6,864
US 16	70-21, C2	Grand Rapids - Coopersville	1925	19	1945	2	B	3.2	-	-	-
	70-12, C2	Grand Rapids - Coopersville	1925	21	1945	4	B	4.8	1,055	2,111	1,495
US 12	39-18, C1-2	Galesburg to Comstock	1919	25	1939	20	A	6.9	264	3,168	977
US 131	39-1, C1	Schoolcraft to County Line, S	1920	24	1940	20	A	5.9	158	1,584	691
US 131	78-2, C3	Constantine South to White Pigeon	1924	20	None	14	-	2.6	105	1,584	862
US 112	78-14, C1	White Pigeon to Mottsville	1923	21	1942	38	A	6.4	106	2,376	770
US 112	14-15, C2	Union West	1923	21	1942	5	A	6.3	528	5,280	5,425
US 12	11-3, C1-3	Benton Harbor East	1924	20	None	16	-	5.1	106	2,459	954
US 12	80-16, C1	Paw Paw East	1922	22	1942	10	-	5.2	264	1,355	1,586
US 12	80-8, C2	Paw Paw - Kalamazoo	1928	16	1942	4	A	2.1	264	7,075	1,247
	39-12, C2	Paw Paw - Kalamazoo	1928	16	1942	27	A	8.3			

* Type A. Apparently caused by blowups in concrete base

* Type B. Caused by extruding joint filler.