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WALLACE STONE INVESTIGATION

PART II

1951 Condition Survey of Concrete Pavements and Bridges

Containing Wallace Bayport Crushed Limestone Aggregates

by

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1951 CONDITION SURVEY OF CONCRETE PAVEMENTS AND BRIDGES CONTAINING WALLACE CRUSHED LIMESTONE AGGREGATE

This is Part II of a comprehensive authorized investigation to determine the suitability of Wallace crushed limestone from Bay Port for highway construction purposes. Part I covered a study of scaling on the Main St. Bridges, Lansing UB-1 and UB-2 of 33-6-4 which was completed and reported on January 29, 1953, Research Laboratory Report No. 170. Part III was completed and reported on June 1, 1953 as Report No. 191, and covered a cooperative laboratory study of Wallace crushed limestone aggregate with the National Crushed Stone Association to determine the durability of Wallace stone under freeze-thaw action.

The purpose of Part II of the investigation was to make a field survey of existing highway pavements and bridges in which Wallace stone has been used, in order to evaluate performance of concrete in service.

This report presents pertinent information concerning the physical appearance of the pavement and bridge projects included in the field survey. The pavements and bridge condition surveys will be treated separately in this report.

PAVEMENTS

The pavement condition survey was completed in the fall of 1951 and included 68 projects totaling approximately 177 miles of pavement. The survey was made by Roy Fulton with the assistance of Aaron Hagenbuch. This mileage of pavement included all Wallace stone projects on state trunk lines accountable in the records dating back to the first pavements built in 1921.

The surface defects observed include pitting, popouts, hair checking, cracking, scaling, and spalling.

The concrete pavement projects include pavement constructed without and with air-entraining agents. The two types of pavement will be treated separately in the following text.

Non Air-entrained Concrete

The non air-entrained concrete pavement survey included 53 projects totaling approximately 136 miles of pavement all constructed during the period between 1921 and 1942. Of this number of projects, 18 with a total of 24.5 miles were constructed during the period 1921 to 1928 in which aggregates were proportioned by volume. Weight proportioning was introduced in 1928 and from then until 1942, 35 projects totaling 111.5 miles of pavement were constructed. Included in the latter group are two projects totaling 9.1 miles in which both natural aggregates and Wallace crushed stone were used.

Also included in the overall group of non air-entrained concrete projects are 8 which could not be evaluated because they were either resurfaced with bituminous material or replaced with new concrete. These 8 projects total 6.5 miles of pavement.

The records show that 6.0 sacks of cement per cubic yard were used from 1928 to and including projects completed in 1938. From 1938 to 1941, apparently no Wallace stone pavement projects were constructed. In 1941 the cement content was reduced to 5.5 sacks per cubic yard.

Table 1 has been prepared for reference from field and Department records. It summarizes as briefly as possible the construction data and physical defects as observed during the 1951 condition survey.

Scaling:- Scaling of the surface was carefully noted throughout the survey but, with few exceptions, it was found not to be abnormal for non air-entrained concrete projects.

Two projects, 74-1, C1 and 74-20, C1 totaling 1.6 miles, of years 1921 and 1924 respectively, were found to be 100 percent scaled and in generally poor physical condition.

Three later projects totaling 11.9 miles and including Project 74-27, C2 on M-53, built in 1941, and Projects 74-40, C1 and 74-40, C2, built concurrently on US-25 in 1942, contain light to heavy scaling throughout their respective lengths and are also in generally poor condition from the standpoint of scaling along joints and edges.

Figure 1 will serve to illustrate the typical scaling condition of these projects.

Construction records indicate that the soil conditions on Project 74-27, C2 were not good, requiring the installation of tile edge drain to intercept seepage, the excavation of frost heave material, and the placement of sand subbase. O. L. Stokstad reports cracking as occurring on granular subbase in the first day's run with a note that the project should be watched for progressive cracking and evidence of pavement roughening during winter frost heaving periods. Flexural strengths were 772 psi for seven days and 905 psi for 28 days.

Construction records on Projects 74-40, C1 and C2 indicate a high percentage of thin and elongated particles (16.0 percent); also a considerable amount of edge drain was required due to water table being within 2.5 and 3.0 feet of grade. A large amount of frost heave and unsuitable subgrade material had to be removed.

Of the remaining 46 non air-entraining projects containing 100 percent Wallace coarse aggregate, 39 projects with a total of approximately 90.8 miles have experienced only light to medium scaling and are in generally good condition.

No scaling was observed on the remaining 13 projects totaling 36.1 miles. Scaling on the 39 projects is local in character, appearing in general at intersections, bridges, at joints, and along pavement edges. Typical conditions of light and heavy scaling are illustrated in Figures 2 and 3 respectively. Pictures showing similar types of scaling on gravel projects located in the Thumb area are presented in Figures 4 and 5.

Popouts:- Surface defects listed as popouts were observed on the projects surveyed. They were classified as "none", "few", or "numerous" per station. Seventeen projects were found to be entirely free of popouts. Popouts ranging from few to numerous per station were found on 25 projects. The popouts are no different than those experienced on many miles of gravel aggregate projects, and experience indicates such popouts cause no structural damage to the pavement. They cannot be detected except at slow speeds. Examples of popout surfaces are illustrated in Figures 6 and 7.

Cracking:- A study of the cracking in the various projects revealed that more cracking has occurred in the older pavements than in the newer ones. This may be due to the age, thickness, or subgrade conditions, or combinations of these. One of the older pavements was 7 inches uniform thickness and the transverse cracking was found at the rate of 8 transverse cracks per 100-ft. station. Sixteen of the projects had none or negligible cracking but all the rest had cracked at the rate of from 1 to 6 cracks per station.

By grouping the pavements in 10-year periods, it was found that the pavements from 1921 to 1930 inclusive averaged 3 cracks; those from 1931 to 1940 inclusive averaged 1.4 and those from 1941 to 1950 inclusive averaged less than 0.4 cracks per 100-ft. station.

All of the early pavements were laid on the subgrade as it occurred in the normal grading procedures while the recent pavemnts were laid on prepared sandy or gravelly subbases, and this factor will no doubt affect future cracking on these jobs. Many of the grades prior to the 1940's were relatively low, to the extent that there was no appreciable elevation of the pavement surface above the adjacent field levels. This was not conducive to good drainage at certain periods of the year, and no doubt would result in unstable foundation conditions.

Cracking often occurred at points where the grade changed from cut to fill sections and also in areas of frost heave or over fills underlaid by unstable subsurface materials. Longitudinal cracking particularly was heaviest over poor subgrades and in pavements cast before the centerline joints became standard practice.

Joint Deterioration: - Another defect noted on this survey was the joint condition. As a whole, most pavements showed joint distress in one form or another. Failures particularly noted were spalling, scaling, and faulting. Of these, spalling was the most serious. On 18 projects spalling had occurred at expansion joints and in two other cases scaling had started at the expansion joints. Twenty-two projects showed good expansion joints, 3 projects were reported fair with only an occasional joint spalled. Many of the joints have been well sealed, in which cases minor spalling has been concealed. However, several of the latter jobs also spalled at the joints.

In most cases where spalling occurred at expansion and contraction joints it also occurred along the longitudinal joint.

Occasionally a project was found where the concrete at the ends of the expansion and contraction joints failed as if by compression. The failure extended into the slab 3 or 4 inches and extended longitudinally from 3 inches to a foot.

Part Wallace Stone and Part Natural Aggregate

Two projects in the non air-entrained concrete group were found to contain natural aggregates as well as Wallace Stone. These projects afforded an excellent comparison of the performance of the two types of materials under identical traffic, weathering, and soil conditions. These projects are 32-6, C1 on M-142, constructed in 1927, and Project 32-36, C1 constructed in 1931. Both projects are now over 20 years old.

With reference to Table 1, both projects are in excellent condition for their respective ages. Figures 8 and 9 show clearly the condition of the existing surfaces on Project 32-6, C1. Figure 8 shows the typical condition of the Wallace Stone portion of the project with very few popouts whereas in Figure 9, the adjacent natural aggregate surface from Cass City Sand & Gravel Co. has numerous popouts. A similar comparison is made for Project 32-36, C1. Figure 10 shows the typical condition of Wallace Stone surface and Figure 11 shows typical condition of concrete made with Oxford aggregates.

Air-Entrained Concrete Projects

The survey included 15 projects totalling 41.4 miles in which air-entrainment was used, starting in 1942. The projects and their conditions are listed in Table 1.

Only one of the 15 air-entrained concrete projects showed scaling in any appreciable amount. This project, 74-49, C1, located 4.5 miles west of Sandusky, was built in 1947. A study of field engineers' reports revealed that throughout this job the contractor had trouble with air-entraining cement which did not produce the desired air content in the concrete. This was checked from time to time and additional air-entraining agent was supplemented to bring the air content of the concrete up to requirements. Typical scaling on project 74-49, C1 may be seen in Figures 12 and 13. Several small areas of scaling were also noted on Project 74-49, C3; see Figures 14 and 15.

In Table 1, under air-entrained concrete projects, it may be noted that several projects have developed considerable spalling at joints. While this spalling may not necessarily be associated with aggregate performance, it is worthy of mention from a construction standpoint. Projects 32-52, C1 and 79-30, C4, constructed in 1942 with 20-foot contraction joints and 120-foot spacing of expansion joints, have developed spalling at both transverse and longitudinal joints. These projects were built under wartime conditions without steel reinforcement or load transfer devices. See Figures 16 to 19.

Considerable spalling at joints was also observed in Projects 32-52, C2 and 32-52, C3 built in 1947. Figures 20 and 21 are typical examples of joint spalling on Project 32-52, C2. The type of longitudinal spalling shown in Figure 21 is typical of that occurring on many miles of newer pavements in which premolded bituminous strip material is used to create the joint. Figures 22 to 25 illustrate the type of contraction joint spalling prevalent in Project 32-52, C3. Practically every joint had some degree of the type of joint edge breakage as illustrated in Figures 22 and 23, whereas about 75 percent of the transverse joints had corner spalling as illustrated in Figures 24 and 25.

Special Core Study

During the course of the field condition survey, it was decided to take cores from scaled and adjacent unscaled pavement areas for the purpose of examining them for differences in physical characteristics of the concrete which could be associated with the coarse aggregate. The projects included in the study ranged in age from 2 to 25 years.

Part of these cores were subjected to a stress of 2,000 psi, and the static modulus was measured from the deformation of the cores. The top 1/2 inch was cut from several of the cores from each project and after polishing the cut face, the air content was determined by means of the linear traverse method. All of the specimens were capped with neat cement and broken in compression. These results are arranged and summarized in Tables II and III.

With reference to data on non air-entrained concrete in Table II, the difference in quality of scaled and unscaled concrete is definitely indicated by difference in compressive strength and static modulus. In all cases the compressive strength properties of the Wallace Stone concrete can be considered as being very good.

In Table III the overall average of the data shows that the physical difference for scaled and unscaled air-entrained concrete is not so pronounced as in the case of standard concrete. This would indicate that scaling of air-entrained concrete is mostly confined to a surface condition whereas in the case of non air-entrained concrete, scaling reflects poor quality concrete throughout the depth of the pavement at the scaled area.

Projects listed in Table III deserving special consideration include M 32-52, C1; 74-41, C3; and FB of 32-23-13, C1. Cores 166, 167, and 168 from Project 32-52, C1 were taken from an area where excess Orvus was added to the mixer in powder form at the rate of 12.5 lb. to 40 gal. of water instead of 4.33 lb. which was the correct amount. The effect of the excess Orvus clearly shows up in the physical data. On Projects 74-41, C3, cores 193 to 198 were taken from a local area badly scaled, about 70 feet long. The quality of the concrete cores from both scaled and unscaled concrete was such as to indicate a significant departure from specifications.

The four cores (156 to 159 inclusive) taken from Project FB of 32-23-13, C1, are representative of transit mix concrete and were not included in the overall average of data from the cores representing scaled and unscaled concrete.

A comparison between the average results of two regular and two air-entrained concrete projects of 11 and 10-year ages, respectively, is made below.

Projects	Air Content		Compressive Strength		Static Modulus	
	Scaled	Unscaled	Scaled	Unscaled	Scaled	Unscaled
Regular:	(percent)		(psi.)		($X 10^6$ psi.)	
73-40, C2 & 74-27, C2	2.49	2.07	5434	8060	3.75	6.38
Air-Entrained:						
32-52, C1 & 79-30, C4	3.37	4.98	4975	5542	4.39	4.47

All four of these projects contained 5.5 sacks of cement per cubic yard of concrete. It is interesting to note that there is not much difference in air content between scaled and unscaled areas of the regular concrete projects but the scaled compressive strength is 32 percent lower than the unscaled concrete strengths. The static modulus of scaled regular concrete is 41 percent lower than the corresponding unscaled concrete.

In the two air-entrained projects, the results are somewhat different. There is only about 10 percent difference in compressive strengths between scaled and unscaled areas. The actual percentages of entrained air differ by about 1.6. The air-entrained concrete having a sound surface was 31 percent lower in compressive strength than the corresponding regular concrete.

Deterioration with Age

In 1939 a field condition survey of Wallace Stone pavements was made under similar circumstances by George Mansfield As a matter of interest the physical condition of several pavement projects listed in both the 1939 report by George Mansfield and the 1951 report by Fulton and Hagenbuch have been compared as noted in Table IV. Only the general physical conditions of the projects selected have been recorded.

It was found in general that the projects showing stress in 1939 had been either replaced or resurfaced at time of 1951 survey and the projects considered good or excellent by Mansfield are still in good condition but have experienced the normal physical change as may be expected on any pavement project. There is no indication of any abnormal change.

Comparison of two reports indicate that in general:

1. Projects in good condition at 1939 survey have remained in good condition with possible normal expected increase in popouts, cracking and scaling.

2. Projects that were noted as being under stress at the time of the 1939 survey have now to a large extent been replaced, patched or surface treated, or are in poor condition at the present time.

TABLE IV

COMPARISON OF PAVEMENT CONDITION AT VARIOUS AGES

Project	General Pavement Condition by Mansfield Report 1939	Age Years	General Pavement Condition by Fulton & Hagenbuch 1951	Age Years
01-14, C3	Good Condition	11	Good	22
32-18, C1	Fair	16	Badly cracked & patched	27
32-25, C1	Fair	14	Fair--some increase on cracking and spalling	25
32-31, C2	Good	9	Very Good	20
32-31, C4	Excellent	8	Very Good	19
32-31, C7	Excellent	6	Excellent	17
32-31, C8	Excellent	6	Very Good	17
32-31, C10	Excellent	6	Very Good	17
32-35, C1	Good	6	Good	17
73-40, C1	Fair	5	Very Good	16
32-19, C1 79-1, C1	Fair	18	Replaced by new pavement 1951	29
73-6, C1	Good	10	Good	21
73-7, C1	Fair	9	Good	20
79-32, C2	Fair	8	Very Good	11
79-37, C1	Good	10	Popouts have increased Condition fair	21
74-30, C1	Fair	15	Replaced in 1949 at 25 years	
32-7, C2	Fair	18	Resurfaced	

BRIDGE STRUCTURES

The bridge condition survey was made by E. A. Finney and M. Brown in October, 1951 and included a total of 20 structures in which Wallace Stone was used. The physical condition of such bridge features as abutments, wingwalls, piers, railings, wheelguards, sidewalks, and decks were observed and recorded. Photographs were taken to illustrate the various stages of concrete disintegration.

Four of the bridges examined were constructed in 1928-1929 at which time concrete was proportioned volumetrically. The remaining 16 projects built between 1938 and 1950 were made of concrete designed according to the Department's mortar voids method. Air-entraining cement was used in 7 of the structures built since 1946. A summary of information obtained from the condition survey has been presented in Table V. Coded information on fine aggregate and cement used in surveyed structures will be found respectively in Tables VI and VII at end of report.

Results of Survey

The worst condition of concrete was found in the Court Street Bridge, Saginaw B1 & X1 of 73-20-22, C1. This structure was built in 1938. The decks and approaches have been completely covered with bituminous concrete but the north and south walk and curb sections are in varying degrees of disintegration. In some instances, disintegration is so bad that the steel reinforcement is showing. The fact that many badly disintegrated areas lie adjacent to perfectly good areas leads one to question the control exercised in the manufacture and placing of the concrete. See Figure 26. Transit mix concrete was used. Tops of piers which scaled badly due to salt drippings from the deck have been repaired as illustrated in Figure 27.

Two other structures, built in 1940 and 1941, exhibited a considerable amount of sporadic scaling. One structure, B3 of 25-19-3, C1 located in Flint had considerable deep scaling in the deck and slight scaling on sidewalks and wheel guards. This may be seen in Figure 28. The other structure, B1 of 56-1-3, C1 on M-18 North of Bradley had considerable scaling in deck and localized disintegration of concrete at east end of north abutment. See Figures 29 and 30.

An interesting pitting occurrence was observed on Bridge B1 of 32-23-13, C1 at Sebewaing. The deck and approaches were constructed with transit mix air-entrained concrete. The deck was in excellent condition with the exception of one panel in the S. E. corner. This deck panel had started to pit abnormally as shown in Figure 31. The air content of cores taken from the pitted panel and an adjacent good panel are presented below.

	Pitted Panel	Good Area
Air content, percent	1.95 - 3.01	5.97 - 8.66

It was further observed that the approaches had started to scale considerably in spots. Wallace stone was also used in their construction.

Further, very fine map cracking was noted all over the structure. At the time of examination, they were very fine as shown in Figure 32.

One other structure worthy of special mention is Bridge B1 of 34-13-8, C1 on M-44 at Belding. This structure was built in 1950 with air-entraining cement. Slight pitting and scaling has occurred on both sides of the deck area extending to a distance of approximately 7 feet in from sidewalks. See Figure 33. This condition has obviously been encouraged by allowing salt-laden snow and ice to remain in the gutter area. Considerable fine map cracking was also noted both on the deck section as well as on the curb and sidewalk sections. See Figures 34 and 35.

With but one exception, the balance of the structures examined which were built entirely of Wallace stone experienced pitting or scaling in varying degrees either on the decks alone, or including decks, wheel guards and walks. The exception was Bridge B6 of 74-11-1, C2 on US-25 North of Richmond which was in perfect condition throughout.

In all structures examined, the substructure elements were found to be in excellent condition. In three cases, the decks had been resurfaced with bituminous materials. Pictures showing typical examples of pitting and scaling encountered throughout the survey are shown in Figures 36 to 41.

In the course of the survey, several bridge structures were encountered in which only certain elements were made of Wallace Stone -- for example, retaining walls, piers, abutments, sidewalks and decks. In all cases, the concrete in these elements was in excellent condition.

Observations on Bridges Made with Aggregate from Other Sources

Observations made in this survey and on other occasions clearly demonstrate that the concrete weaknesses found associated with Wallace Stone are just as prevalent in structures made with some gravel aggregates. This fact may be readily seen by referring to Research Laboratory Report No. 110R titled "Deterioration and Restoration of Concrete Bridges on State Trunkline System", and to the photographs in this report shown in Figures 42 to 46.

CONCLUSION

From the results of this condition survey of pavements and bridges constructed with Wallace crushed stone, it is concluded that under approved construction practices, concrete made with Wallace crushed stone coarse aggregate is not inferior in service performance to concrete made with natural aggregates meeting current MSHD specifications in the A class.

TABLE VI

FINE AGGREGATE CODE

Code No.	Manufacturer
0008	American Agg. Corp.; Kalamazoo; 39-01
0011	American Agg. Corp.; Oxford; 63-04
0012	Anderson Sand and Gravel Co.; Vassar; 79-21
0035	Baker, J. H. and Sons; Sullivan Pit; 00-00
0038	Baker, J. H. and Sons; Farver Pit; 32-23
0076	Brodie, Mrs. I. C.; Port Sanilac; 74-18
0105	Cass City Sand and Gravel Co.; Cass City; 79-11
0106	Cass City and Tuscola Sand and Gravel Co., Cass City; 00-00
0132	Cheney Gravel Co.; Holt; 33-57
0183	Eckfield, Wm., Saginaw Bay Shore Sand; 00-00
0207	Farver, Clarence and Sons; Elkton; 32-23
0242	Gordon Pit; Near Croswell; 00-00
0285	Hackett Pitt; Jackson; 00-00
0291	Hastings Sand and Gravel Co.; Hastings; 00-00
0327	Inland Lime and Stone Co.; Port Inland; 75-05
0387	Kelly Island Lime and Transport Co.; St. Clair River; 00-00
0452	McBride Pit Local; North of Sandusky; 00-00
0465	Milbrook Gravel Co.; Milbrook; 00-00
0569	Pickett, Harry; Price Pit; Bay Shore; 15-15
0572	Postma Gravel Co.; Grand Rapids; 41-12
0576	Poritt Pit; Richmondville, Sec. 28, T 13 N, R 13 E; 00-00
0590	Rocks Sand and Gravel Co.; Grand Rapids; 41-19
0614	Schwaderer, E. B.; Carmody Pit, N. W. of New Greenleaf, 00-00
0619	Shenk Gravel Co.; Durand; 76-01
0753	Ward Sand and Gravel Co.; Oxford; 63-06
1050	Combination of 0105 and 0753
1066	Combination of 0207 and 0569
9999	No Record

TABLE VII

CEMENT CODE

Code No.	Manufacturer
001	Aetna, Aetna Cement Co., Bay City, Michigan
002	Aetna Vinsol Resin; Aetna Cement Co., Bay City, Michigan
005	Aetna; Aetna Cement Co., Fenton, Michigan
019	Huron; Huron Portland Cement Co., Alpena, Michigan
020	Huron, Adm. Orvus; Huron Portland Cement Co., Alpena Michigan
022	Huron VR; Huron Portland Cement Co., Alpena, Michigan
030	Medusa VR; Medusa Cement Co., Manitowoc, Wisconsin
032	Michigan; Michigan Cement Co., Chelsea, Michigan
036	Newaygo; Newaygo Portland Cement Co., Newaygo, Michigan
037	New Egyptian; Peerless Portland Cement Co., Fenton, Michigan
038	New Egyptian; Peerless Portland Cement Co., Port Huron, Michigan
039	Peerless VR; Peerless Portland Cement Co., Port Huron, Michigan
040	Peerless Egyptian; Peerless Portland Cement Co., Port Huron, Michigan
041	Peerless, Adm. Orvus; Peerless Portland Cement Co., Detroit, Michigan
042	Peerless VR; Peerless Portland Cement Co., Detroit, Michigan
043	Peerless; Peerless Portland Cement Co., Detroit, Michigan
045	Peninsular VR; Consolidated Cement Co., Cement City, Michigan
048	Petoskey; Petoskey Portland Cement Co., Petoskey, Michigan
064	Universal; Universal Atlas Cement Co., Buffington, Indiana
076	Wolverine; Wolverine Cement Co., Coldwater, Michigan
085	Wyandotte; Huron Portland Cement Co.
103	Combination of 001 and 019
134	Combination of 005 and 085
157	Combination of 019 and 037
159	Combination of 019 and 040