DORE

INVESTIGATION INTO THE DETERIORATION OF THE CONCRETE ON ROUTE U.S. 206 BETWEEN MILEPOSTS 81 AND 95.

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Memorandum - Report

Bureau of Structures & Materials

Division of Research & Evaluation

NEW JERSEY DEPARTMENT OF TRANSPORTATION

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Investigation into the Deterioration of the Concrete on Route U.S. 206 between Mileposts 81 and 95.

SUMMARY

Route U.S. 206 between Gladstone and Netcong is a reinforced Portland Cement Concrete pavement, most of which is between 38 and 40 years old. Approximately 10 years ago an asphaltic overlay was put down over certain sections where the concrete had deteriorated. Occasionally a whitish powder is seen oozing out of cracks in this bituminous overlay, as appears on Figure II at the end of the Report. In addition, certain sections of the remaining concrete are experiencing rapid surface deterioration: see Figure III.

Eight cores were taken at four separate locations. These cores showed that the sampled concrete was sound, except in locations where deterioration had already started.

An analysis showed that the whitish powder oozing out of cracks in the asphaltic overlay was degraded cement.

A tannish stain, which formed around deteriorated areas of concrete and is visible on Figure I,* was analyzed and described by the Bureau of Testing, Division of Materials, as a 5 to 15 carbon chain aliphatic. Its presence and the possible connection with the deterioration of the concrete nearby, remain unexplainable.

Also unexplainable is a strip of roadway in excellent condition, directly adjacent to a badly deteriorated area illustrated in Figure III. The roadway in excellent condition was estimated to be approx. 34 years old, and therefore

* The figures and tables are at the end of the report.

only 5 years newer than the deteriorated concrete next to it -- hardly enough to explain the marked difference in appearance.

High concentrations of salt were found in the concrete core samples taken. These concentrations increased as the degree of deterioration of the concrete worsened.

The chloride content of the white powder, oozing out of the slits in the bituminous overlay, was almost 2-1/2 times greater than in the highest chloride-containing core. The cores, taken through the asphalt patches and/or overlays, showed evidence of this same white powder's presence at the interface between the asphalt and the underlying concrete. This indicates that the deterioration of the concrete is continuing underneath the various types of asphalt overlays and patches which have been applied on this road.

It also points up the need for moisture and salt barriers at the interface between asphalt and concrete in future installations. Any coating with good adhesion to both asphalt and concrete, in addition to low salt water permeability, should be satisfactory.

Details

The details have been broken down into 4 parts:

A - Statement of Problem

B - Background Information

C - Approach Used

D - Results Obtained

These four parts comprise the remainder of this report. The photographs shown and most of the analytical data listed, were obtained through the excellent aid and cooperation of Mr. Bob Wokoun and Mrs. Dorothy Andres of the Bureau of Testing, Division of Materials.

A. STATEMENT OF PROBLEM

Stretches of the Concrete Pavement, of Route U.S. 206 between Gladstone and Netcong, have undergone surface deteriorations. Both scaling and spalling of the concrete are evident.

Highway Department personnel in Region I report the appearance of a tannish ring-like stain developing around sections of concrete, just prior to spalling. This discoloration persists during and after deterioration, as shown in Figure I.

In certain areas, such as near milepost 94 where the concrete surface has received a bituminous overlay, small cracks are evident. A white powder is exuding from these cracks, per the example shown in Figure II.

B. BACKGROUND INFORMATION

A thorough knowledge of the composition and history of this roadway should help in diagnosing the present problems. To this effect Table I was compiled. First it was necessary to determine how the respective sampling sites or "Areas" were designated when they were originally constructed (see column 4: "Designation prior to 1952"). This has been cross-indexed with their present designation (see column 3: "Control Section"). The remaining portion of Table I gives data relative to the original construction - sources of ingredients, original 28-day compressive strengths and in certain cases the ratios of cement/sand/coarse aggregate.

From this table we can conclude:

1. The concrete involved is between 38 and 40 years old.
2. Class B Concrete was used.
3. No air-entrainment was employed (New Jersey did not start using air entrainers until the late forties).
4. The twenty-eight-day compressive strengths of the original concrete varied between 4300 and 5700 psi.

It may be noted that portions of the road under study are in excellent condition, as sbown in Figure III. This picture was taken standing at Area #1 and looking south. Note the abrupt end of scaling and spalling and the beginning of a perfectly sound stretch of concrete, just slightly above the middle portion of the snapshot. Messrs. Englishman and Wodell seem to recall that this pavement was installed approximately 5 years after that shown in the foreground of the picture.

A marked contrast would seem to exist then between 2 lengths of pavement, one approximately 34 years old and the other 39 years old. Further knowledge of the history of these 2 pavements would be necessary, before any intelligent discussion of this apparent incongruity could take place. Such a study might also shed further light on the basic causes of deterioration in the other sections of pavement discussed in this report.

C. APPROACH USED

An inspection of the area involved was made by Mr. Bob Wokoun of Materials and Mr. Mark Swaab of Research and Evaluation, under the leadership and direction of Mr. Herb Englishman. Mr. Walt Wodell and Mr. Joe Galayda of Region I accompanied us.

Mr. Ray Bilinski and his field group were requested to take cores at four locations. A sample of white dust was collected from a fifth location. These samples, which it took 2 days to collect, resulted in a total of 8 concrete cores, 4 bituminous caps and 1 sample of white dust. These were sent to the Materials Laboratory for chemical and physical testing.

This test work was designed to answer three (3) main questions:

1. How badly deteriorated is the concrete pavement?
2. What is the nature of the white dust exuding from cracks in the bituminous overlay?
3. What is the nature of the stain appearing as a ring around an area, just prior to scaling and spalling?

D. RESULTS OBTAINED

(a) Integrity and Strength of Cores

Of the eight cores taken, 2 were badly cracked: D8293C and D8298C. All the remaining six had respectable compressive strengths; in fact, in four instances, these were higher than the original.*

Mrs. Dorothy Andres of the Materials Lab reported that "the three cores with bituminous overlay, when cap was removed, showed a considerable amount of white powdery material adjacent to the cap. Assuming the loose surface material had been removed prior to patching, the concrete had continued deteriorating below the bituminous overlay. This condition existed roughly 1/2" or more into the core."

(b) Chemical Analyses

All analyses were preformed on samples obtained from the top surface of each core, being careful not to include aggregate.

The last two columns of Table II show the chloride analysis of both the concrete cores and the bituminous caps. First the accumulation of chlorides or salts in the concrete is at least ten times greater than in the asphalt.

This points up two (2) facts:

1. Asphàltic overlays or patches afford the underlying concrete little protection from penetration by salts.
2. Asphalt and salt are not very compatible - the asphalt allows most of the salt to pass through, retaining only a small percentage.

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* Table II shows the compressive strengths of the cored samples. As can be seen, these cores are not of the conventional size, since ASTM C 192-65 specifies a cylinder with a length equal to twice the diameter. These results, however, are meaningful for the purposes of rough comparison suitable for this report.

The last two (2) columns of Table II also show that cores taken from areas where the concrete was badly spalled and scaled contain higher concentrations of chlorides than cores taken from areas of sound concrete. Finally, the chloride content of the white powder, oozing out of slits in the bituminous overlay, was almost 2-1/2 times greater than in the highest chloride-containing core. If we assume then that this white powder is degraded cement (to be elaborated upon in the next few paragraphs), we find increasing concentrations of salt present, as the degree of deterioration of the concrete worsens.

Table III shows the chemical analyses of the cement portion of the samples. It is difficult to interpret these results too closely without knowing the original analyses of the cements used, along with the sand-to-cement ratios. Dorothy Andres of the Materials Lab attempted to derive the cement/sand ratio by using the SO_3 analysis and working backwards. Mrs. Andres derived a series of ratios ranging from 1:2 to 1:1. This seems to agree fairly well with the few ratios we were able to obtain from the records on this pavement, 1:1.91, 1:1.61 and 1:1.75 (See Table I). However, too little at this point is known about the original cement composition to assume what an initial analysis would look like. Nonetheless certain important items of information can be obtained from Table III.

First the white powder seen oozing forth from small cracks in the bituminous overlay is definitely cementitious. This product contains more carbonate as represented by the CO_2 analysis and less lime (Cao) than the cores tested. If we theorize that water and salt have decomposed the original cement by a typical dissolution* process, this would account for the presence of the powder at the interface of the concrete and the asphalt (See Figure IV). The movement from heavy truck traffic could break this powder up further and pump it to the surface, as seen in Figure II. Such a lime-rich material, when pumped to the surface and exposed to water and CO_2 (from the air and vehicle exhausts), could then react as follows:

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

Some of the calcium hydroxide $Ca(OH)_2$, being partially soluble (1.7 gms per liter), could wash out, leaving a mixture lean in lime content. The remaining calcium hydroxide could react with CO_2 to give insoluble Calcium Carbonate, showing up in the analysis as increased CO_2 .

It was of additional interest to note that the cores exposed to the air (in the next-to-last column from the right, in Table III) analyzed higher in carbonate and lower in lime than their counterparts shielded by their asphalt "caps", from contact with the air and the vehicular exhaust gases.

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* This dissolution is basically a hydrolytic decomposition of concrete, initiated by the partial solubility of Calcium hydroxide ($Ca(OH)_2$) in water. The products of the hydration of cement are stable only in an environment containing a certain minimum concentration of calcium hydroxide. As the $Ca(OH)_2$ present is dissolved by the water attack, the calcium silicates, aluminates and ferrites present in hydrated cement, slowly decompose, releasing large quantities of lime. This process is closely associated with the phenomenon of efflorescence, which is occasionally observed on concrete structures.

Two attempts were made to identify the tannish stain that appears prior to scaling and spalling. A portion of Core #D8294C was extracted in benzol for approximately 18 hours. The resultant solution, after being concentrated and put through the I.R. Spectrum, was identified as an aliphatic hydrocarbon, with a carbon length of 5 to 15. One of the possibilities falling into this category would be gasoline (chain length 6-12). However, it is difficult to relate the presence of gasoline to a tannish stain which forms around a concrete area shortly before it deteriorates.

Figure I (left) Showing Tannish Stain (@ Milepost 95) which forms around an area of concrete prior to deterioration and persists after the concrete has scaled and spalled.

Figure II (right) Whitish Powder which has been oozing out of cracks in the Bituminous Overlay.

Figure III (left) - Taken @ Milepost 95 on U.S. 206 looking South, showing excellent stretch of Road directly adjacent to pavement with marked deterioration.

Figure IV (below) - This picture was taken immediately after drilling a core @ Milepost 95 on U.S. 206. Note the clusters of whitish material near the Asphalt-Concrete Interface.

TABLE I BACKGROUND INFORMATION

U.S. 206

rea #	Specific Location	Control Section	Designation Prior to 1952	Construction Year	Contractor	Cement	Sand	Coarse Aggregate	Compressive Strength of 28-Day Cores, psi	Ratio Cement: Sand: Coarse Aggregate	Other Commen
I	Milepost 95, near utility pole RU 1173 Slab 726	* 1417 (020)	Route 31 - Section 2	1929	J.W. Heller	Vulcanite Dragon	Hodg- son	Stone Mercer Co.	5516 (47 days)	- -	- -
II	Milepost 94 50 feet south of pole #26 on westerly side (south bound)	1417	Route 31 - Section 2	"	"	"	"	"	"	- -	- -
III	Apx. 500 ft. South of M.P 87 4.5 ft. north of Pole	1417	Route 31 - Section 5	1930	S.J. Groves	Edison	Gallo Bros.	Gallo 50/50 1-1/2"+3/4"	5677	- -	- -
IV	9 feet south of Pole 651 M.P.89	1417	Route 31 - Section 1	1928/ 1929	Lulelle + Pfeffer	Edison	Morris Plains	Stone Mercer Co.	***4279	(1928) 1-1.91 - 3.5 (1929) 1-1.61 -3.5	9"Rein Conc. 3/8 Rd deform bars
V	Milepost 81	**1811	Route 31 - Section 6	1930	- -	Edison Keystone	Morris Co.	50/50 1-1/2"+3/4"	5161 (11 samples)	1-1.75 - 3.5	9"Rein Concre Wire Mesh

* Extends from line between Somerset and Morris counties to Musconetcong River, Mileposts 83.4 to 96.4

** Extends from Junction 202 Bedminster to Somerset - Morris County line, Mileposts 78.8 to 83.4

*** Also had strength figures of 1928 - 3781 and 1929- 4494 psi

TABLE I

TABLE II DESCRIPTION OF SAMPLES TAKEN

Area #	Core No.	Description	Bituminous Cap	Height	Diameter	Compressive Strength/psi	Chlorides At Top Surface of Concrete Core, ppm	Chlorides in Bituminou Cap
I								
	D8293C	Directly over Bituminous Patch	Yes	Sample Fell Apart		- -	864	50
	D8294C	Adjacent to D8293C, to include stain	No	9.45"	6.20"	6945	944	- -
	D8295C	Over sound concrete 1 foot away from D8294C	No	9.35"	6.20"	6785	334	- -
II								
	D8296C	Directly over slit in Bituminous overlay, from which white dust is exuding	Yes	8.40"	7.70"	3555	758	74
	D8297C	Sound area with no slits 3 feet away from D8296C	Yes	8.00"	7.70"	6025	678	62

(continued)

TABLE II

TABLE II DESCRIPTION OF SAMPLES TAKEN (Continuation)

ea #	Core No.	Description	Bituminous Cap	Height	Diameter	Compressive Strength/psi	Chlorides At Top Surface of Concrete Core ppm	Chlorides in Bituminous Cap
II								
	D8298C	Over Surface crack in concrete surrounded by stain	No	9.30"	7.70"	Sample contained V-shaped crack	706	- -
IV								
	- -	Sample of white powder oozing to surface of bituminous concrete	- - --	- -	- -	- -	2250	- -
V								
	D8300C	Directly over deep bituminous patch (portion of reinforcing bar is showing)	Yes (Lost in transit from field to materials lab)	7.00"	7.70"	6610	664	- -
	D8299C	Over sound concrete, a few feet away from D8300C.	No	9.05"	7.70"	5125	556	- --

TABLE II (continuation)

TABLE III - CHEMICAL ANALYSES OF FIELD SAMPLES

Constituents Analyzed	Arithmetic Mean of all eight cores	Range for Values for all eight cores Max. - Min.	Average of three cores having bituminous caps (when brought into lab) 8293/6/7	Average of remaining five cores without bituminous caps (when brought into lab) 8294/5/8/9 and 8300	White powder oozing to surface
Ignition Loss%	16.03	13.14 - 18.9	17.56	15.27	15.10
CO_2	4.60	1.23 - 9.24	3.33	5.37	13.50
H_2O (By difference)	11.53	6.82 - 15.74	14.23	9.91	1.60
SiO_2	53.66	47.36 - 62.36	50.19	55.75	60.98
$Al_2 O_3$	4.5	3.26 - 5.96	4.38	4.50	5.11
$Fe_2 O_3$	1.88	1.37 - 3.44	1.64	1.95	1.97
Ca O	21.07	17.96 - 25.14	23.18	19.81	14.93
MgO	1.61	1.21 - 2.11	1.85	1.47	1.34
$Na_2 O$	.31	.09 - .78	.13	.43	.30
K_2O	.33	.08 - 1.67	.16	.44	.22
SO_3	.75	.62 - .90	.78	.74	.65