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EVALUATION OF SUBSURFACE ROAD DRAINAGE SYSTEMS

Final Report

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BY

VICTOR E. MOTTOLA
PROJECT ENGINEER

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16. Abstract

After nearly 10 years of measurements, the pavement sections with internal drainage (open graded layers) have out performed the control sections on both P.C.C. and bituminous pavements. All water which entered the pavement sections during rainfalls was drained within 10 - 12 hours after the rain stopped. Infiltration rates were approximately 3 - 4% of the total rainfall. There were no signs of faulting, pumping or rutting in any of the test pavements.

P.C.C. pavement life is now projected to be 35 - 40 years with internal drainage. Internally drainable pavement sections should provide a positive measure against water related pavement damage.

NJDOT specifications now require open graded drainage layers under all P.C. concrete pavements. On bituminous pavements, drainage layers are employed on a case by case basis. The final sections of Route I-78 and the last 22 miles of Route I-287 in New Jersey have been constructed using the drainage layer concept.

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ABSTRACT

After nearly 10 years of measurements, the pavement sections with internal drainage (open graded layers) have out performed the control sections on both P.C.C. and bituminous pavements.

All water which entered the pavement sections during rainfalls was drained within 10 - 12 hours after the rain stopped. Infiltration rates were approximately 3 - 4% of the total rainfall. There were no signs of faulting, pumping or rutting in any of the test pavements. P.C.C. pavement life is now projected to be 35 - 40 years with internal drainage.

Internally drainable pavement sections should provide a positive measure against water related pavement damage. NJDOT specifications require open graded drainage layers under all P.C. concrete pavements. The final sections of Route I-78 in New Jersey have been constructed with the drainage layer concept and the last 22 miles of Route I-287 contains open graded bases.

BACKGROUND

In the mid-1970's New Jersey began an extensive investigation into the causes of pavement distress in our state, the investigation included the effects of freeze and thaw of pavements and the permeability and bearing capacities of the base and subbase materials as then specified. This survey included pavements of both bituminous concrete and Portland cement concrete construction.

The initial phases of the study centered on visible forms of pavement distress. The most obvious causes of distress appeared to be water which was entering the pavement box from cracks, joints, and through deteriorated shoulders. The detrimental effects of water were most pronounced on Portland cement concrete (P.C.C.) pavements. P.C.C. pavements in New Jersey are constructed as expansion joint pavements with 78 foot slab lengths and 9 inch thicknesses. The joints are doweled and the slabs reinforced. The most evident problem in these pavements was pumping and the resultant damages due to pumping. On bituminous pavements, the effects of water were not as pronounced but nonetheless obvious.

The second phase of this initial investigation was an attempt to quantify moisture and frost conditions under the pavement. To accomplish this, frost and moisture tubes were installed in the pavements at 30 locations around the state. Moisture changes were monitored with a Troxler nuclear moisture depth probe while the frost depth penetration was measured with tubes filled with a methyl blue solution. This solution changes color on freezing.

Both frost depth and moisture conditions were monitored for approximately two years. The data was correlated with air and pavement surface temperatures to develop an equation to accurately predict maximum depth of frost for various subsurface moisture conditions.

It was concluded from this investigation that: (1) water was the largest contributor to distress in otherwise well designed and well-constructed pavements; (2) damage due to freezing was not a severe problem in New Jersey highways, however, the moisture measurements revealed that as the base and subbase materials thawed, they became saturated with a subsequent loss of bearing; and (3) once saturated, these materials remained in that state for long periods of time.

This was verified by permeability tests of all available bank run base and subbase materials, where average permeabilities of "drainable" materials averaged less than one foot per day.

MATERIAL DEVELOPMENT

New Jersey concluded that a system to quickly remove subsurface water would have to be incorporated if more durable pavements were to be designed. A literature search indicated that solutions proposed by Cedergren -- a drainage layer immediately beneath the lowest bound layer of pavements with longitudinal collector trenches -- seemed to be one of the most promising ideas on drainage of pavements. It is well known that a good base course material is one which contains both adequate drainage and adequate stability. However, the designs proposed by Cedergren, which consist of three quarters of an inch or five eighths of an inch stone immediately under the pavement, would have permeabilities in the order of 10,000 to 30,000 feet per day. It was felt that these excessively high permeability rates would make the base courses under the open graded layer prone to erosion, and that the drainage layers might also be unstable under construction traffic.

Therefore, New Jersey initiated a program to locate drainage layer material which could be used under both Portland cement concrete pavements and bituminous pavements and which would satisfy three basic requirements: First, the material had to be open enough to drain the free water in a reasonable amount of time and yet the flows had to be low enough to be laminar. This would prevent erosion of the underlying layers. Second, it had to be dense enough to support traffic; and, third, it had to possess filtration characteristics compatible with the base or subbase materials immediately under it, or some sort of filtering media or a barrier had to be placed. To achieve the first requirement drainage, rainfall intensity, and the estimated infiltration for New Jersey conditions was studied. Fifty percent of the free water in the base in 24 hours was selected as a limiting criteria to prevent freezing and pumping of the water from the pavements and excessive saturation of the underlying base courses. To meet this requirement, it was calculated that permeabilities of the drainage layers had to be in the order of about 1,000 feet per day. There were no bank run materials available that would meet this requirement. As an upper limit for permeability, 3,000 per day was selected from the results other researchers had concluded to be the lower limit of turbulent flow. After extensive laboratory work, which included developing a permeameter for testing permeabilities in the order of 1,000 - 3,000 feet per day and modifying Burmister equipment to compact the permeability and density samples, the following gradations for the nonstabilized open graded layer (NSOG) were selected:

SIEVE SIZE IN.	ALLOWABLE PERCENT PASSING
1 ½	100
1	95 - 100
½	60 - 80
#4	40 - 55
#8	5 - 25
#16	0 - 8
#50	0 - 5

Note that there are very few fines in this material. Materials meeting this gradation have a permeability range of 1,000 - 3,000 feet per day at a density of 115 - 125 pcf. Basically, the material is a blend of No. 9 and No. 57 stone. This material is blended at the quarry before shipping.

A bituminous stabilized open graded material (BSOG) for use under bituminous pavements was also developed. The material consists of No. 8 stone with some larger stone added to cut down on material costs.

SIEVE SIZE, IN.	ALLOWABLE PERCENT PASSING
1	100
3/4	95 - 100
1 /2	85 - 100
3/8	60 - 90
#4	15 - 25
#8	2 - 10
#16	2 - 5
#200	*

*Add 2% (by weight of total mix) mineral filler.

Mineral filler is added to stiffen the asphalt, which generally runs about 3%. The BSOG has permeability values of 1,000 - 1,500 feet per day and a density of 122 - 127 pcf depending on the stone sources. BSOG material is produced at a conventional asphalt plant.

To ascertain the load-carrying capability of the open graded drainage layers, material samples were sent to the Corps of Engineers Waterways Experiment station in Vicksburg where gyratory shear and repeated load triaxial tests were run. Results indicated that both the BSOG and NSOG drainage materials had bearing capacities similar to a dense graded aggregate base and were assigned a structural number of about .15.

Additionally, to study both the structural and drainage capabilities of the materials, two test tracks were constructed at the University of Illinois. The first was constructed with a Portland cement concrete pavement and the other with a bituminous pavement. Each contained five sections of drainable materials and a control section. A wheel to simulate traffic loads was run on the track for approximately one half million repetitions. On the test tracks the sections were subjected to periodic flooding with water to simulate heavy rainfalls. The results indicated that the materials would perform well under traffic.

Large scale flume tests were performed in-house to study the effects of turbulent flow, and to determine the flow rates for pipe sizing. These tests, in addition to several trial field applications, indicated that both the NSOG and BSOG would provide a good construction material from both drainage and structural viewpoints. These early tests provided the basis for materials and construction specifications for internally drainable pavements.

Basically, the internally drainable pavement section consists of a drainage layer immediately beneath the lowest bound layer of the pavement section which is connected to longitudinal drains (with pipes) extending the full-length of the pavement. The drains are either daylighted or connected to available inlet structures. It is important to note here that the system and materials are designed to accommodate only roof infiltration, i.e., water which permeates from the pavement surface.

CONSTRUCTION OF DRAINABLE PAVEMENTS

New Jersey constructed two full-scale internally drainable pavements to study the performance of internally drained pavements, one on Route I-676 in Camden, which contains a Portland cement pavement, and a bituminous concrete section on Route I-195 near the Jersey Shore. Both of these pavements include several separate test sections.

The construction procedure for internally drainable pavements is conventional up to and including the level of the subbase. The next operation is a trenching operation for placing the longitudinal drains. Filter cloth is placed to encapsulate all the trenches. No. 8 or No. 57 crushed, stone is used in the drains as a backfill for a 6" pipe.

After completion of the longitudinal drains, the open graded layers are placed over the subbase and connected at the longitudinal drains. Both NSOG and BSOG materials are constructed using conventional asphalt pavers. NSOG material is compacted with a vibratory roller while monitoring density with a nuclear gauge and a density control strip. BSOG material is allowed to cool to approximately 210 - 230°F before compaction. This permits the material to stiffen slightly and prevents edge shoving. BSOG is compacted with both a three-wheel and tandem roller. Density is controlled with a nuclear gauge.

The pavement surface courses are placed conventionally over the open graded material, however, it is important that only tracked pavers be used on the NSOG to prevent excessive rutting of the unstabilized open graded layer.

PAVEMENT PERFORMANCE

The two experimental pavements were completed in 1980 and have been monitored extensively.

In 1985, the volume on I-676 was as high as 43,000 vehicles a day including 25% trucks. The volume on I-195 was 15,000 vehicles per day.

The following were used to measure pavement performance on the sections:

- Pavement serviceability index (PSI)
- Benkleman beam deflections
- Joint faulting on the P.C.C. pavement
- Rutting on the bituminous pavement
- Frost penetration
- Soil moisture content
- Rainfall and outflow

FINDINGS

After nearly 10 years of measurements, the pavement sections with internal drainage (open graded layers) have out performed the control sections on both P.C.C. and bituminous pavements.

All water which entered the pavement sections during rainfalls was drained within 10 - 12 hours after the rain stopped. Infiltration rates were approximately 3 - 4% of the total rainfall. There were no signs of faulting, pumping or rutting in any of the test pavements.

IMPLEMENTATION

P.C.C. pavement life is now projected to be 35 - 40 years with internal drainage. NJDOT specifications require open graded drainage layers under all P.C. concrete pavements. On bituminous pavements, drainage layers are employed on a case by case basis. The final sections of Route I-78 and the last 22 miles of Route I-287 in New Jersey have been constructed with P.C.C. pavement using the the drainage layer concept.