Abridgment

Concrete Pavement Performance: A 23-Year Report

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In 1966 an experimental concrete pavement road was constructed in the eastern part of North Carolina. This test road included a control section and eight test sections with different design features. The purpose was to evaluate the relative merits of several types of surface and base course treatments. Pavement performance information was collected periodically. It is concluded that base type affects the performance of the concrete surface, and the current design equation underestimates the performance of the concrete pavement.

A test road of concrete pavement in eastern North Carolina was opened to traffic on December 1, 1967. Pavement condition was surveyed periodically. The results and findings of this study are summarized in this paper.

TEST SECTIONS

The experimental road is a 15.758-mi portion of I-95 from Mile Post 144.45 to 159.87.

The southbound lane, which serves as the control section, is 9-in. jointed plain concrete pavement (JPCP) with 30-ft joint spacing on a 4-in. coarse aggregate base course (ABC). The northbound lane was divided into eight sections designated as Sections A through H. Different features in each section are as follows:

Section A: 9-in. JPCP on 4-in. ABC, 30-ft skew joints (4 ft at 24 ft), 7,035 ft long;
Section B: 9-in. JPCP on 6-in. soil-cement base (SCB), 30-ft joints with dowels, 10,200 ft long;
Section C: 9-in. JPCP on 6-in. SCB, 30-ft joints, 10,200 ft long;
Section D: 9-in. JPCP on 4-in. ABC, 30-ft joints with dowels, 9,495.94 ft long;
Section E: 9-in. JPCP on 4-in. cement-treated base course (CTBC), 30-ft joints, 10,200 ft long;
Section F: 9-in. JPCP on 4-in. bituminous concrete base course (BCBC), 30-ft joints, 11,450.06 ft long;
Section G: 8-in. continuously reinforced concrete (CRC) with 0.6 percent steel and transverse No. 4 bar at 30-in. center to center on 4-in. ABC, 11,825.44 ft long; and
Section H: 8-in. jointed reinforced concrete (JRCP) with 8-in. mesh reinforcement on 4-in. ABC, 60-ft joints with dowels, 12,000 ft long.

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For all these sections, a 4-in. sand blanket was constructed under the shoulder. The sand layer, which extended from the base course to the ditch slope, is designed for subsurface drainage.

CONSTRUCTION NOTES

A few notes on construction:

1. The concrete was mixed in a central plant and placed in one layer using forms.
2. The longitudinal and transverse bars on the CRC section were assembled and tied on site.
3. Core samples revealed that pavement depth varied from 8.90 to 9.95 in. for the 9-in. pavement and 7.97 to 9.13 in. for the 8-in. pavement. Compression strength varied from 4,280 to 7,460 psi.

DATA COLLECTION

Data pertaining to performance were collected and recorded. Information collected was as follows.

Road Roughness

A Bureau of Public Roads (BPR) type roughometer was used to collect roughness data. Since 1988, a South Dakota Road Profilor (SDRP) has been used to acquire pavement roughness information. Results of roughness surveys are summarized in Tables 1 and 2.

Joint Faulting

Faulting development in all sections was measured in 1974, 1980, and 1988. The results are summarized in Table 3.

Skid Resistance

Locked-wheel skid resistance tests have been conducted along the outside travel lane since early 1970. Test results are inconsistent (see Table 4).

TABLE 1 Road Roughness Index in Inches per Mile

SECTION	FEB. 68	OCT. 68	FEB. 70	APR. 71	APR. 72	JAN. 74
			OUTSIDE LANE			
A	82	*	*	79	78	*
B	76	79	78	77	77	79
C	78	83	88	79	74	84
D	70	76	79	78	76	77
E	78	80	87	80	78	87
F	79	80	82	77	74	84
G	70	69	76	71	68	73
H	68	69	74	71	69	72
CONTROL	77	79	86	87	83	90
			MEDIAN LANE			
A	78	*	*	79	79	*
B	76	79	78	75	77	75
C	74	76	79	76	75	80
D	69	76	73	73	75	71
E	75	77	79	74	76	77
F	79	78	77	77	75	78
G	73	72	77	73	73	74
H	70	72	72	72	72	70
CONTROL	76	79	79	76	77	78

* NO READINGS TAKEN SINCE ONLY VERY SHORT PORTION OF SECTION IS OPEN TO TRAFFIC.

TABLE 2 Roughness Summary: IRI in Meters per Kilometer

SECTION	1988	1990	1991
A	1.86	1.91	2.04
B	2.03	2.06	2.18
C	1.83	1.86	1.97
D	1.90	1.92	2.11
E	2.03	2.07	2.12
F	1.89	1.85	1.99
G	1.54	1.45	1.59
H	1.70	1.69	1.79
CONTROL	1.94	1.98	2.61

TABLE 3 Average Joint Faulting in Inches

SECTIONS	MEDIAN LANE 1974	MEDIAN LANE 1980	OUTSIDE LANE 1974	OUTSIDE LANE 1980	OUTSIDE LANE 1988 (3)
A (1)	0.0	0.0	0.0	0.025	0.10
B	0.050	0.038	0.125	0.113	0.15
C	0.088	0.113	0.125	0.125	0.20
D	0.0	0.063	0.125	0.138	0.10
E	0.113	0.10	0.138	0.138	0.15
F	0.038	0.088	0.075	0.088	0.10
G (2)	-	-	-	-	-
H	0.038	0.075	0.125	0.150	0.15
CONTROL	0.039	0.094	0.141	0.189	0.194

NOTES: Ten joints were randomly selected from each section for measurements.
(1) Not open to traffic until late 1970's
(2) Continuously reinforced concrete pavement.
(3) Average of the first 18 joints from the Milepost.

TABLE 4 Average Skid Number

Section	1985	1986	1987
A	*	34	44
B	45	46	43
C	41	47	44
D	47	42	47
E	43	49	45
F	50	51	52
G	41	48	44
H	42	49	50
Control	44	45	45

* no data

Traffic Loading

Annual average daily traffic (AADT) data were used to estimate the truck traffic. The 18-kip equivalent single-axle load (ESAL) factors were applied to the estimated truck traffic to calculate the estimated loading.

On the basis of the given pavement structure, the design loading was backcalculated by using the 1972 AASHTO *Interim Guide for Design of Pavement Structures*.

TABLE 5 Surface Condition Summary

Sec	A	B	C	D	E	F	G	H	CONT.
1969	*	exc	F(m)	exc	F(l) S(l)	exc	exc	exc	exc
1970	*	exc	F(m)	exc	F(l) S(l)	exc	exc	exc	F(l)
1972	*	exc	F(m)	exc	F(l) S(l)	exc	exc	exc	F(l)
1973	*	exc	F(m)	exc	F(l) S(l)	exc	vg	exc	F(l)
1974	*	F(l)	F(m)	F(l)	F(m+)	F(l-)	vg	F(l)	F(m+)
1977	F(l)	F(l) C(l)	F(m)	F(l)	F(m+) S(l)	F(l)	vg	F(l)	F(m+)
1982	F(l)	F(l) C(l)	F(m) P(l)	F(l)	F(m+)	F(l)	vg	F(l) C(l-)	F(m+)
1983	F(l)	F(l)	F(m) C(l)		F(m+)	F(l)	vg	F(l) C(l-)	F(m+)
1984	F(l)	F(l) C(l)	F(m) C(m)	F(l)	F(m+)	F(l)	vg	F(l) C(l-)	F(m+) C(l)
1990	F(l) C(l-)	F(l) C(m) S(l)	F(m+) C(m+) P(l)	F(l) C(l-)	F(s) C(m)	F(l)	vg	F(l) C(l-)	F(s) C(m)

F : faulting
S : spalling
C : cracking
P : pumping
exc: excellent
vg : very good
* : section not open to traffic
l : low
m : medium
s : severe

Surface Condition

During every field investigation, subjective surveys of pavement surface condition were made. Only relational surface conditions were recorded. Results are summarized in Table 5.

FINAL SURVEY

The final survey was performed in November 1991. A 300-ft segment within each test section was randomly selected, and the number of cracks was counted. The sample was compared with the whole section visually to ensure that it was representative.

RESULTS AND FINDINGS

The results indicated that some test sections are showing signs of minor deficiency. However, all sections are structurally sound.

The actual loading of 12.3 million ESALs on the design lane is more than twice the design loading of 5.5 million ESALs for the unstabilized base and 1.5 times the design loading of 8 million ESALs for the stabilized base. Although some sections are in better condition than others, none of the test sections is in bad condition. This indicates that the pavement outperformed the prediction model.

Soil samples indicate that subgrade soils are predominantly A-6 soils. Traffic loading for all sections except Section A, which was opened to traffic 7 years later than the other sections, is essentially the same. There is no evidence to suggest that the northbound and southbound lanes carried different traffic loadings. Under these conditions, it is reasonable to assume that the difference in performance of the various sections is due to different treatments.

Pavement Surface Condition

In summary, the pavement in all sections outperformed the performance model. CRC pavement outperformed all other designs. As a matter of fact, this section of CRC outperformed any other CRC projects in North Carolina. The BCBC section (F) also performed well. Both Sections D and H are still in good condition. These two doweled sections, which have the same type of base as the control section, performed better than the control section.

Performance of the control and Section E is at the same level. Sections B and C (soil-cement base) are the worst-performing designs. Section B, which was constructed with dowels, is somewhat better than Section C (without dowels).

Section A was opened to traffic 7 years later than all other sections. Therefore no direct comparison can be carried out. On the basis of data collected, this section's performance is similar to that of the control section.

Roughness

From the latest International Roughness Index (IRI) data, Section G has the best ride quality. Sections H, C, and F

follow. Sections D and E are on the next level, and Section B is the worst.

Load Transfer

Regardless of the base material, sections with dowels outperform the same base without dowels. Providing load transfer devices reduces joint faulting, hence improves ride quality.

Base Material

Concrete pavement with an asphalt base outperforms that with any other type of base. Aggregate bases are next in performance, and cement-treated aggregate bases are next to the last. Soil-cement bases are the worst.

CONCLUSIONS AND RECOMMENDATIONS

On the basis of this project, it is concluded that

1. Having transverse tie bars on the CRC provides reinforcement in the transverse direction and hence eliminates the punch-out problem.
2. JPCP on SCB performs poorly.
3. CTBC may provide a strong, nonerodible base that fulfills the functions of a base as defined by Yoder and Witczak (*1*). Wu and Hearne (*2*) found that concrete slabs actually lift up and separate from an econocrete base as the surface temperature changes. Curling of concrete slabs on stiff CTBC results in loss of uniform support and shortened fatigue life. Therefore, relative stiffness should be considered in the selection of base material for a concrete pavement.
4. BCBC is the best of all base materials tested in this project. Nonerodibility and flexibility contribute to the good performance.
5. A sand blanket provides an outlet for trapped water and hence eliminates this destructive factor. Pavement drainage design should be an integral part of the pavement structural design procedure.
6. Providing load transfer at joints reduces faulting and vertical movement at the joint. It therefore decreases pumping problems and improves ride quality.
7. Long joint spacing provides a better ride quality.
8. The current pavement performance model underestimates concrete pavement performance. Development of a model that is calibrated with North Carolina data is essential.
9. Over the years, IRI values show deterioration of the pavement surface condition. Considering its low cost of operation and its safety, the SDRP could be the primary source of objective pavement condition information to support the Pavement Management System.

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REFERENCES

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