Effects of Special Aggregate on Bridge Deck Overlay Frictional Properties

Final Report

Iowa Highway Research Board
Project HR-205

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Highway Division
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EFFECTS OF SPECIAL AGGREGATE ON BRIDGE DECK OVERLAY FRICTIONAL PROPERTIES

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ABSTRACT

The Iowa DOT has been using the "Iowa Method" thin bonded low-slump dense Portland Cement Concrete (PCC) bridge deck overlay for rehabilitation of delaminated decks since 1963. In time, continued use of studded tires will wear away the transverse grooved texture.

The objective of this research was to evaluate the benefit of incorporating a hard durable aggregate into a dense PCC overlay to provide frictional property longevity. The project included three overlays on I-35 near Ankeny. The texture and friction properties of two overlays, one constructed with crushed granite and the other with crushed quartzite coarse aggregate, were compared to an overlay constructed with locally available crushed limestone.

There were no construction problems resulting from the use of crushed granite or quartzite. There was no significant frictional property benefit from the crushed granite or crushed quartzite through six years.

INTRODUCTION

Bridge deck deterioration is one of the most extensive problems in the highway field. Many decks in Iowa were designed with the top reinforcing steel uncoated and within 2 inches of the surface. The top steel in some bridges had as little as 1/2 inch of cover in some areas. Initially, the portland cement being a strong base chemically, inhibits corrosion. Without chloride ions there would be no deterioration of the PCC encased steel.

The use of sodium chloride deicing material to provide a safe winter driving surface allows the chloride ion to infiltrate the concrete. When the chloride content of the concrete around the reinforcing steel exceeds the "threshold value", which is about 1.5 pounds per cubic yard, the protective property is destroyed. The steel then corrodes and the corrosion product has greater volume than the steel. This expansive force causes delamination and/or spalling of the concrete above the top layer of steel. These decks then require some form of rehabilitation.

The predominate solution to this problem in Iowa is a thin bonded dense P.C. Concrete overlay known as the "Iowa Method" overlay. This rehabilitation system was initiated in 1963 and is now included in section 2413 of the Iowa DOT Standard Specifications. With the national problem of obsolete or substandard bridges and insufficient funds to meet the needs, the desirable result from restoration would be 50 years of additional service. With this aim, a class 2 or better durability coarse aggregate is specified for the high quality, low-slump concrete.

Frictional properties of the bridge deck are very important to highway safety, consequently the effective life of the overlay may be dependent upon surface friction rather than concrete deterioration. The frictional properties of the bridge deck is dependent upon surface texture and aggregate characteristics.

The Iowa DOT specifies a transverse grooved texture to provide the desired friction. The grooves are imparted to the PCC surface by hand using a steel comb. It is very difficult to obtain the specified depth of groove in the dense low-slump concrete. The transverse groove becomes worn away, especially if there is heavy studded tire use, leaving surface friction dependent upon the aggregate characteristics.

An aggregate frictional property classification has been established by the Iowa DOT with Type 1 having the best frictional properties and Type 5 having the poorest frictional properties. The majority of crushed limestone quarried in Iowa is Type 4 or Type 5 with a limited production of Type 3, mainly in northeast Iowa.

OBJECTIVE

The objective of this research is to evaluate the benefit of incorporating a hard durable aggregate in a dense P.C. Concrete bridge deck overlay to provide frictional property longevity.

PROJECT DESCRIPTION AND LOCATION

The project involved the construction of bridge deck overlays using crushed granite, crushed quartzite and crushed limestone as the coarse aggregate in

the concrete overlay. The crushed limestone was the locally available aggregate that would normally have been used in central Iowa. The Iowa DOT frictional classification of this crushed limestone is Type 4 with the crushed granite and crushed quartzite in the Type 2 classification.

The project, Polk I-IG-35-4(39)89--04-77, was located on I-35 near Ankeny. The overlay with crushed limestone used as a comparison was design 1678 southbound over the CRI & P (now the Northwestern) Railroad at milepost (MP) 88.2. The crushed granite coarse aggregate was used in design 1778 southbound across Four Mile Creek at MP 93.6. Design 1878 northbound across a local road at MP 94.6 was the deck overlay with the crushed quartzite. The traffic volume on this section of I-35 varies north and south of the Ankeny exits. The 1980 and 1984 one way average daily traffic (ADT) counts for the limestone overlay (MP 88.2) were 9,850 and 10,000 respectively. The one way ADT counts for the granite (MP 93.6) and quartzite (MP 94.6) overlays for 1980 and 1984 were 6,700 and 7,650 respectively. The percentage of trucks ranges from 15 to 20.

MATERIALS

The variable constituent in the concrete mix was the coarse aggregate. The crushed limestone was from the B. L. Anderson Quarry at Montour, Iowa. J. L. Shiely produced the crushed granite at the St. Cloud, Minnesota Quarry and the crushed quartzite was from New Ulm Quartzite of New Ulm, Minnesota. The typical gradations were:

Sieve Analysis
Percent Passing

Screen Size	Limestone	Granite	Quartzite
1/2"	100	100	100
3/8"	71	90	88
#4	8.1	16	13
#8	0.9	3.1	2.1
#200	0.6	0.9	1.1

Tests on physical properties yielded the following results:

Test Results

Test	Limestone	Granite	Quartzite
"A" Freeze & Thaw	2	1	1
Abrasion	34	22	19
Specific Gravity	2.69	2.81	2.65
Absorption	2.03	0.40	0.61
% Shale	0	0	0
% Coal	0	0	0
% Brown Chert	0	0	0
% White Chert	0	0	0
% Clay Lumps	0	0.6	0

The concrete sand was from the Martin-Marietta Pit at Johnston (near Des Moines) with the following gradation:

Screen Size	% Passing
3/8	100
#4	99
#8	88
#16	72
#30	46
#50	13
#100	2.8
#200	0.8

The cement was Type I from both the Penn-Dixie and Monarch plants in Des Moines.

The admixtures were CSC air entraining agent from Contractor Steel Corporation of Des Moines and Plastocrete 161 water reducer from Sika Corporation.

CONSTRUCTION

The successful bidder on this project (March 27, 1978, letting) was Waterloo Construction Company of Waterloo, Iowa. Construction of the three overlays was completed during July and August 1979. The concrete was produced through a volumetric Concrete Mobile Mixer. Tests of the concrete during construction yielded the following results:

Concrete Properties

Test	Limestone	Granite	Quartzite
Air	6.2 to 6.7%	6.2 to 6.8%	5.6 to 6.2%
Slump	1/2" to 3/4"	3/4" to 1.0"	1/2" to 3/4"
Wet Density (corrected to 6.0% air)	142.85 lb/cu.ft.	145.25 lb/cu.ft.	142.95 lb/cu. ft.

Prior to construction, it was suggested by some that the hard, sharp, angular characteristics of the granite and the quartzite would result in a harsh mix that would be difficult to finish. This was not the case. The Iowa DOT construction inspector noted four advantages of the mixtures containing the granite and quartzite:

1. The slump of the mix was more consistent than the mix containing limestone.
2. The surface finished easier than the mix containing limestone.

3. There was less difficulty in imparting the tined texture into the granite and quartzite mixes than the limestone mix.

4. The granite or quartzite mix could be easily worked after a 20 to 30 minute breakdown which is not typical of a mix containing limestone.

EVALUATION

The dry densities, air contents and densities corrected to 6.0% air were determined from cores obtained from the overlays on August 30, 1979.

Results From Cores

	Limestone	Granite	Quartzite
Dry Density	130.8 lb/cu.ft	137.0 lb/cu.ft	138.0 lb/cu.ft
Air Content	6.4%	5.5%	3.0%
Density Corrected to 6.0% Air	131.4 lb/cu.ft	136.3 lb/cu.ft	133.7 lb/cu.ft

The texture depth was determined by the silly putty test method at three locations in the driving lane on each deck overlay. The average texture depth for the three overlays in 1979 was:

	Limestone	Granite	Quartzite
Average Texture Depth, inches	0.046	0.040	0.036

The depth of the transverse grooves were measured in March 1986 using a tire tread depth gage. The groove depths of the limestone overlay are predominately 2/32" in the wheelpath (WP) with a maximum of 4/32". Between the wheelpaths (at the 1/4 point), which would be representative of the overlay as constructed, the groove depth is predominately 3/32" with a maximum of 5/32".

The granite overlay groove depths are predominately 1/32" in the WP with a maximum of 5/32". At the 1/4 point, the depths are predominately 2/32" with a maximum 5/32".

Groove depths on the quartzite overlay are predominately 1/32" or less in the WP with a maximum of 2/32". The 1/4 point measurements are predominately 1/32" to 2/32" with a maximum of 3/32".

The primary characteristic to be evaluated for this research was the frictional property. Friction testing has been conducted periodically using an ASTM E-274 test unit with an ASTM E-501 standard tread test tire at 40 mph. Friction Numbers (coefficient of friction times 100) have been obtained both in the WP and at the 1/4 point.

Friction Number Summary

Date	Limestone		Granite		Quartzite	
	¼point	WP	¼point	WP	¼point	WP
9-13-79		39		36		40
July 1980	39	32	37	31	40	36
9-8-81	47	42	51	42	53	40
6-2-82	47	44	48	39	49	49
6-13-84	49	44	49	39	53	46
5-17-85	47	39	46	35	50	40

DISCUSSION

Surface texture and frictional properties are closely related. To provide the safest driving conditions, high Friction Numbers are desirable. Iowa Specifications do not require a minimum friction number but specify a minimum texture depth. Unfortunately, the specified groove depth is not always

achieved on the Iowa deck overlays. The frictional properties will too soon be dependent upon the aggregate in the concrete.

As the groove depths achieved on the three deck overlays included in this research were for the most part near the minimum specification, the initial friction numbers may have been lower than a surface with greater groove depth. It would, however, benefit the research as the texture will be worn away in a shorter time and the Friction Numbers will become dependent upon the concrete and aggregate properties.

The average texture depth at time of construction ranged from 0.036 inches to 0.046 as measured with the Silly Putty test. The average texture depths and groove depths were greatest for the limestone aggregate overlay. The Iowa DOT inspector and the contractor said the workability of the granite and quartzite aggregate mixes was superior to the limestone mix. This should have allowed the texture to be imparted easier, but for some reason the groove depths were less.

No curing compound was used, but a linseed oil surface seal was applied soon after construction. The initial Friction Numbers ranged from 36 to 40. The friction in the WP dropped to 31 and 32 within one year. Two years after construction, the Friction Numbers increased 8 to 10 numbers to 40 to 42. This increase between one and two years may have resulted after the removal of the linseed oil seal residue. The most recent Friction Numbers obtained in 1985 ranged from 35 to 40. The Friction Number for the limestone overlay is 39 compared to 35 for the granite and 40 for the quartzite. These numbers are nearly the same as those obtained initially before the aggregate became

exposed. This would indicate that the friction is still primarily dependent upon the imparted texture rather than the special aggregate. Periodic friction testing and groove depth measurements will determine whether the special aggregate will be more effective than limestone in maintaining acceptable friction values.

CONCLUSION

This research on frictional properties of bridge deck overlays supports the following conclusions:

1. There were no construction problems that resulted from the use of crushed granite or crushed quartzite aggregate.
2. Friction tests do not indicate significant benefit from the crushed granite or crushed quartzite through six years.

RECOMMENDATIONS

It is recommended that periodic friction testing and groove depth measurements of these decks be continued through 15 years.

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