MICHIGAN DEPARTMENT OF TRANSPORTATION
MDOT

CONCRETE SURFACE TEXTURING STUDY

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Testing and Research Section
Construction and Technology Division
Research Project 71C-0013 (Phase 2)
Research Report No. R-1423

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16. Abstract

Pavements with transversely tined texturing sometimes produce annoying traffic noise generated by the interaction of tires with the patterned tine marks on the pavement. In some cases abatement has required costly diamond-grinding to remove the noise-producing tine marks. An alternative artificial turf-drag texturing procedure has been developed.

This study compares the polishing characteristics of concrete surfaces textured by tining versus artificial turf-drag procedures. The study also investigates the polishing resistance of the fine and coarse aggregate, and the use of flyash in the concrete.

Wear track polishing tests indicate that the artificial turf-drag texture has somewhat higher polishing resistance than tining. Natural sand fine aggregate and crushed gravel in the concrete produce considerably higher polishing resistance than crushed limestone fine and coarse aggregate. The use of flyash in the concrete produced slightly higher resistance to polishing.

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EXECUTIVE SUMMARY

The use of transverse tining for texturing concrete pavements has, in some instances, resulted in excessive noise caused by vehicle tire interaction with the pavement surfaces. Attempts to vary the spacing and depths of the tining to reduce noise have met with varying degrees of success. In some cases, noise abatement of tined pavement surfaces has required expensive removal of the tining by diamond grinding.

An artificial turf drag procedure to texture new concrete pavement surfaces has been developed as an alternative to tining. Texturing that results from the use of an artificial turf drag has irregular score marks that do not generate the droning sounds generated by vehicle tires on a tined pavement surface.

This study compares the polishing characteristics of three types of concrete pavement finishing procedures – transverse artificial turf drag, transverse tining, and smooth troweling. The effects of crushed limestone fine aggregate versus natural sand fine aggregate in the concrete mixes, crushed limestone coarse aggregate versus crushed gravel in the mixes, and the use of flyash in the concrete mixes are also addressed. Test slabs were prepared and polished on the Michigan Department of Transportation (MDOT) wear track for four million wheel passes. Friction measurements were conducted with both the MDOT tester and a British Pendulum tester.

The results of the polishing tests indicate that the test slabs with transverse artificial turf drag texture, in combination with crushed gravel coarse aggregate and natural sand fine aggregate recorded the highest friction values after four million wheel passes of polishing on the wear track. Transverse tining texture, in combination with natural sand aggregate recorded slightly lower friction values.

Crushed limestone, as either coarse or fine aggregate in the concrete mix, resulted in moderately high initial friction values followed by significant polishing. At four million wheel passes, the polishing curve slopes plotted for the slabs containing crushed limestone coarse and fine aggregate indicated that the surfaces of test slabs containing crushed limestone had not yet reached a terminal polished condition. The six slabs containing crushed stone coarse and fine aggregates were subjected to extended wear track polishing for ten million wheel passes in an effort to determine a terminal polishing condition. However, at ten million wheel passes the slopes of the plotted polishing curves showed that additional polishing could be expected.

The smooth troweled surfaces recorded low friction values comparable to the control slab surfaces containing exposed control limestone. Flyash in the concrete was found to produce slightly higher polishing resistance in five of the six comparisons evaluated in the study, suggesting that flyash increases the hardness of the concrete paste.

ACTION PLAN

1. Construction and Technology Division

   A. Project completed, no further action necessary

2. Pavement Committee

   A. Approve Report R -1423

   B. Recommend use of artificial turf-drag as an alternative for texturing concrete pavement surfaces.

INTRODUCTION

In 1974, the MDOT circular wear track was constructed for the initial purpose of testing quarried carbonates and high-carbonate gravel for resistance to tire-polishing. Initially, quarried carbonates and high-carbonate gravel from selected sources were evaluated. Later investigations have included the effects of tire-polishing on glacial gravels, slags, blends, rock type constituents of glacial gravels, and fine aggregates, (1, 2, 3, 4, 5,). The wear track also has been used to evaluate the polishing characteristics of paving bricks and concrete pavers.

The results of the wear track tests on the gravel lithologies led to the development of the department's AWI (Aggregate Wear Index) specification for aggregates used in bituminous top course mixtures (8). Aggregate Wear Index numbers assigned to the aggregates are used in conjunction with Average Daily Traffic (ADT) values to design bituminous top course mixtures that will resist the anticipated amount of traffic polishing during the service life of the pavements. The AWI specification states that an aggregate for use in bituminous top course mixtures must record an AWI wear track test value of 260 or greater, modified by adjustments for ADT and crushed content of aggregates (6, 7, 8, 9, 10, 11).

This study, using the wear track for simulated traffic-polishing, was initiated to evaluate the polishing characteristics of a transverse artificial turf drag texturing treatment to be used as an alternative to transverse tining of concrete for new pavements.

OBJECTIVES OF THE STUDY

The study was structured to evaluate the polishing characteristics of the concrete surface textures and also to address the effects of aggregate types and the addition of flyash to the concrete mixes, as follows:

Objective No. 1

The first and main objective was to compare the polishing characteristics of an artificial turf drag concrete pavement surface texturing treatment with the tining treatment presently in use. Smooth troweled surfaces were included in the study to demonstrate the polishing characteristics of untextured concrete surfaces.

Objective No. 2

The second objective was to compare the polishing characteristics of textured concrete pavements containing crushed limestone fine aggregate versus natural sand fine aggregate in the concrete mix. For this objective, surfaces prepared by three procedures were compared - - smooth troweling, artificial turf drag, and tining.

Objective No. 3

The third objective was to compare the polishing characteristics of textured concrete pavements containing crushed limestone coarse aggregate versus crushed gravel coarse aggregate. For this objective, surfaces prepared by artificial turf drag were compared. The tining procedure was not used for this objective due to pulling of the coarse aggregate particles by the tining rake. The smooth troweling procedure was not included in this objective due to concealment of the coarse aggregate particles as a result of troweling.

Objective No. 4

The fourth objective was to compare the effect of adding flyash to the concrete mix. Flyash comparison mixes included slabs containing crushed limestone fine aggregate, natural sand fine aggregate, crushed limestone coarse aggregate, crushed gravel coarse aggregate, artificial turf drag, and tined textures.

PREPARATION AND TESTING OF SPECIMENS

Test Aggregates

The test aggregates used in this study were obtained from Michigan sources. The quarried limestone fine and coarse aggregate used in this study was obtained from the Inland No. 1 quarry, Aggregate source Index No. 75-005, located in the upper peninsula. Limestone from this quarry is used as a control aggregate in all wear track test series. The natural sand and crushed gravel used in this study were obtained from the New Hudson pit, Aggregate Source Index No. 63-048, located in the southeastern lower peninsula.

Test Slab Preparation and Testing

The test slabs were prepared in a total of nine concrete mixes. Mixes for comparison using flyash contained 15 percent Type F flyash. A detailed description of the test slab preparation and friction testing is presented in the appendix. Photographs show the emplacement of the concrete in wear track test forms, texturing, and appearance of the finished test slabs before and after wear track polishing. Also included in the appendix are photographs of the wear track and friction testing equipment.

As the standard protocol, the test slabs were polished on the wear track for a total of four million wheel passes, in increments of one-half million wheel passes. Initial friction measurements and subsequent measurements were obtained after each half-million wheel pass increment using the wear track friction tester. At four million wheel passes of polishing, the slopes of the polishing curves generated by the test slabs containing crushed limestone fine aggregate and 26A limestone coarse aggregate showed a continuous decrease. For additional information, wear track polishing of these test slabs was extended to 10 million wheel passes. At ten million wheel passes, the slopes of the polishing curves indicated that additional polishing could be expected.
British Pendulum tester measurements were obtained for the initial one-half million, and four million wheel pass increments to correlate the polishing with another method of friction measurement that is widely used to compare polishing resistance.

RESULTS OF WEAR TRACK POLISHING

Friction tester values obtained with the MDOT tester after four million wheel passes of polishing on the wear track are expressed as Aggregate Wear Index (AWI) numbers on a scale from zero to 1000 units, measured as pounds of initial peak force generated by the friction tester tire in contact with the test slab surface. On the scale, low numbers indicate low resistance to polishing and high numbers indicate high resistance to polishing. The readily polished control limestone usually records values of 170 to 200, whereas polish resistant sandstone surfaces record values around 500. The MDOT standard AWI of 260 is considered to be the minimum satisfactory value for bituminous top course aggregates.

The following tabulation contains a listing of the test slabs included in Wear Track Series No. 64. British Pendulum tester and MDOT friction tester values are both included.

Slab	Test Surface Type	Aggregate	Friction Nos.		
			Flyash In Mix	@ 4x10^6 WP	
				BPN	AWI
1	Exposed Aggregate	No. 3 Cr. Limestone	No	32	200.6
2	Exposed Aggregate	No. 3 Cr. Limestone	No	26	168.9
3	Smooth Troweled	2SS Cr. Ls. Fine Aggregate.	No	33	184.8
4	Transverse Tining	2SS Cr. Ls. Fine Aggregate.	No	43	287.8
5	Transverse Tining	2SS Cr. Ls. Fine Aggregate.	Yes	52	345.5
6	Transverse. Astroturf	2SS Cr. Ls. Fine Aggregate.	No	48	333.4
7	Transverse. Astroturf	2SS Cr. Ls. Fine Aggregate.	Yes	57	403.3
8	Transverse. Astroturf	26A Cr. Ls. +2SS Cr. Ls. F.A.	No	56	364.5
9	Transverse. Astroturf	26A Cr. Ls. +2SS Cr. Ls. F.A.	Yes	52	370.9
10	Smooth Troweled	2NS Sand Fine Aggregate.	No	31	220.5
11	Transverse Tining	2NS Sand Fine Aggregate.	No	49	408.1
12	Transverse Tining	2NS Sand Fine Aggregate.	Yes	44	421.1
13	Transverse. Astroturf	2NS Sand Fine Aggregate.	No	75	483.0
14	Transverse. Astroturf	2NS Sand Fine Aggregate.	Yes	63	469.4
15	Transverse. Astroturf	26A Cr. Grav.+2NS Sand F.A.	No	60	501.1
16	Transverse. Astroturf	26A Cr. Grav.+2NS Sand F.A.	Yes	64	507.6

Table 1. Results of Wear Track Series No. 64

Polishing curves showing the progress of the wear track polishing process are shown on page 6. The plots include the results of the extended polishing of the test slabs containing crushed limestone fine and coarse aggregates.

For a comparison of the AWI values, the following categories indicate the expected polishing resistance of an aggregate in bituminous top course pavement:

AWI	Expected Polishing Resistance
400	High to Very High
300 to 400	Intermediate to High
200 to 300	Low to Intermediate
<200	Very Low to Low

Analysis of the friction measurement data resulted in a linear correlation with an r^2 of 0.84 with an equation showing AWI = 7.6 13 * BPN – 20.097. Using the equation, an AWI value of 260, the standard minimum acceptable AWI value for use in bituminous top course mixtures, converts to a British Pendulum Number of 37. Some of the British Pendulum tester readings showed considerable deviations from those predicted by the correlation equation. The deviations indicate that the pendulum tester performance is affected by the surface irregularities typical of artificial turf drag and tined surfaces.

Test slab No. 1 containing the control limestone was not coated with curing compound, whereas test slabs No. 2 through 16 were coated with curing compound to simulate pavement construction practice. Test slab No. 2 containing the control limestone was coated for comparison with test slab No. 1 to evaluate the effect of curing compound on the polishing characteristics of exposed coarse aggregate on the wear track. Wear track test slabs are not normally coated with curing compound. The curing compound coating on test slab No. 2 caused a significant decrease in the initial friction value as compared to test slab No. 1. A similar decrease in the initial friction value attributed to the curing compound coating occurred on test slabs No. 3 and 4. Polishing curves on page 6 show that the effect of curing compound is transient, and disappears within the first 1.0 million wheel passes of tire-polishing on the wear track.

Detailed descriptions of the test slab preparation, including concrete mix designs, are included in the appendix. Photographs of the slabs before and after wear track polishing also are included in the appendix.

OBJECTIVE FINDINGS

Objective No. 1

The test slabs with transverse artificial turf drag and tined surface texture recorded moderately high to high final friction values. The test slabs with smooth troweled surface texture recorded low final friction values. These values are noted to be similar to the final friction values recorded by the exposed control limestone. The smooth surfaces, already at a low friction level before polishing on the wear track, did not record significant change by four million wheel passes.

Objective No. 2

The test slabs containing 2SS crushed limestone stone fine aggregate produced moderately high final friction values, whereas the test slabs containing 2NS natural sand recorded high final friction values. The slopes of the polishing curves on page 6 show that the test slabs containing crushed limestone fine aggregate had not yet reached a terminal polished condition after four million wheel passes on the wear track. Extended wear track polishing to 10 million wheel passes produced continued polishing. The slopes of the polishing curves indicate that additional polishing is predicted with further tire-polishing.

Objective No. 3

Test slabs prepared with the artificial turf drag surface texturing technique were used for comparison of concrete containing 26A crushed gravel versus 26A crushed limestone coarse aggregate. The test slabs containing 26A crushed gravel recorded high final friction, whereas the test slabs containing 26A crushed limestone recorded moderately high final friction values. As with the test slabs that contained only fine aggregate in the concrete mix, the polishing curves on page 6 show that the test slabs containing crushed limestone coarse aggregate had not yet reached a terminal polishing condition by four million wheel passes on the wear track. Extended wear track polishing to 10 million wheel passes showed continued polishing, with additional polishing predicted if exposed to further tire-polishing.

Objective No. 4

Comparison of the final friction values of the slabs containing flyash versus no flyash in the concrete mix indicates that the effect of flyash in the concrete slightly improved the polishing resistance of the test slab surface, suggesting that flyash increases the hardness of concrete paste.

CONCLUSIONS AND RECOMMENDATIONS

Both the transverse artificial turf drag and transverse tining surface texturing techniques produced surfaces that recorded moderately high to high final friction values. The surfaces of the test slabs containing crushed limestone fine aggregate or crushed limestone in the concrete mix recorded somewhat lower final friction values than the surfaces of the test slabs containing natural sand or crushed gravel in the concrete mix.

The final friction values of both texture types considerably exceeded the standard aggregate wear index (AWI) requirement of 260 used for acceptance of aggregates for use in bituminous top coarse pavements. However, the surfaces of concrete containing crushed limestone coarse or fine aggregate would be expected to develop additional polishing, as shown by the extended wear track polishing to 10 million wheel passes.

The results of the wear track polishing tests indicate that artificial turf texturing can produce a concrete pavement surface that is as polish-resistant as a tined surface. Observations made during preparation of the textured test slabs caution that both the tining and artificial turf drag procedures must be done at the proper time after placement of the concrete to achieve the desired surface texture. Also, failure to prevent clogging of the turf drag or tining rake will result in a an unsatisfactory, inconsistent final surface texture.

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APPENDIX

Concrete Surface Texturing Study

Research Project Number 71C-0013

This concrete surface texturing study involves using several different concrete mixtures in conjunction with three different texturing techniques to produce a total of sixteen test specimens. These specimens will be tested on the Michigan Department of Transportation, Construction and Technology Division, wear track test facility for accelerated polishing and skid resistance. The three texturing techniques employed for this study include a flat steel trowel finish, a transverse astroturf drag finish, and a transversely tined finish. A total of nine different concrete mixes were used, and are listed as follows with their respective batch weights:

Mix 1*		
2NS	ASI 19-058	64 lbs.
Cement	Type I	58 lbs.
Water		21 lbs.

Mix 2		
2SS	ASI 75-005	64 lbs.
Cement	Type I	58 lbs.
Water		21 lbs.

Mix 3		
2NS	ASI 63-048	64 lbs.
Cement	Type I	58 lbs.
Water		21 lbs.

* Standard wear track mix

Mix 4		
2SS	ASI 75-005	48 lbs.
26A	ASI 75-005	62 lbs.
Cement	Type I	21 lbs.
Water		12 lbs.

Mix 5		
2NS	ASI 63-048	48 lbs.
26A	ASI 63-048	62 lbs.
Cement	Type I	21 lbs.
Water		12 lbs.

Mix 6		
2SS	ASI 75-005	64 lbs.
Cement	Type I	47.6 lbs
Flyash	Class F	8.4 lbs.
Water		21 lbs.

Mix 7		
2NS	ASI 63-048	64 lbs.
Cement	Type I	47.6 lbs
Flyash	Class F	8.4 lbs.
Water		21 lbs.

Mix 8		
2SS	ASI 75-005	48 lbs.
26A	ASI 75-005	62 lbs.
Cement	Type I	17.8 lbs
Flyash	Class F	3.2 lbs.
Water		12 lbs.

Mix 9		
2NS	ASI 63-048	48 lbs.
26A	ASI 63-048	62 lbs.
Cement	Type I	17.8 lbs
Flyash	Class F	3.2 lbs.
Water		12 lbs.

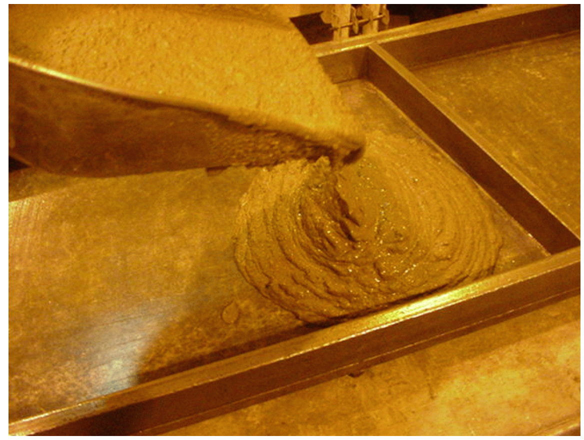
All aggregates were oven-dried. The specimen casting dates, as well as the mix type, and texturing method, are contained in the following table:

Concrete Surface Texturing Study					
			Texturing Technique		
Slab Number	***Date Cast***	***Mix Number***	***Smooth Troweled***	***Astroturf Drag***	***Transverse Tining***
1*	8-31-00	1			
2*	8-31-00	1			
3	9-05-00	2	Y		
4	9-05-00	2			Y
5	9-13-00	6			Y
6	9-05-00	2		Y	
7	9-13-00	6		Y	
8	9-07-00	4		Y	
9	9-14-00	8		Y	
10	9-06-00	3	Y		
11	9-06-00	3			Y
12	9-13-00	7			Y
13	9-06-00	3		Y	
14	9-13-00	7		Y	
15	9-07-00	5		Y	
16	9-14-00	9		Y	

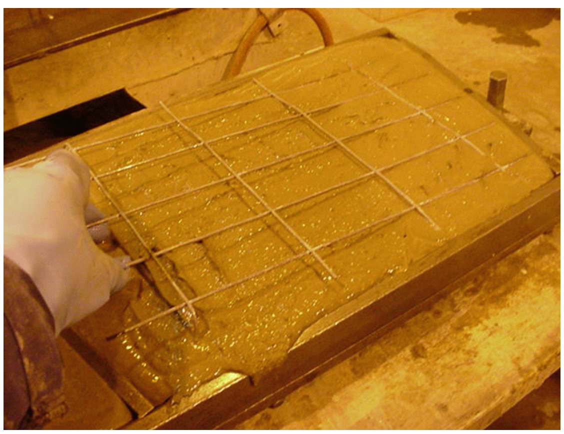
* Wear track control slabs - Inland Limestone, ASI 75-005

Each slab was cast in the wear track slab forms. The sand mixes were constructed in one layer. Once the form was filled with the concrete mixture it was vibrated for consolidation and wire mesh was placed approximately at mid height of the slab. The slabs were then struck off to remove the excess concrete. Each slab was then given a smooth finish with a steel trowel. The concrete mixes containing 26A aggregate were constructed in two layers. The concrete was first placed in the form to approximately the half way point. Wire mesh was then placed on this layer. The form was then slightly overfilled and consolidated by vibration. The slabs were struck off to remove the excess concrete and then each was given a smooth steel trowel finish.

Wear track slab forms



2NS concrete mixture being placed in form



Wire mesh is placed in the filled form

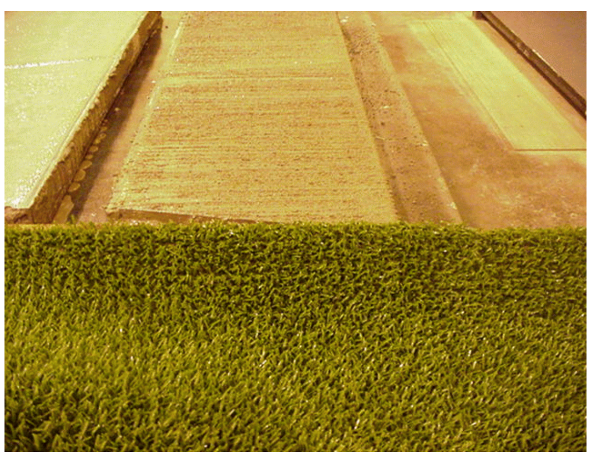
The excess concrete is struck off

26A concrete mixture being placed in form

Wire mesh is placed on the first layer of concrete

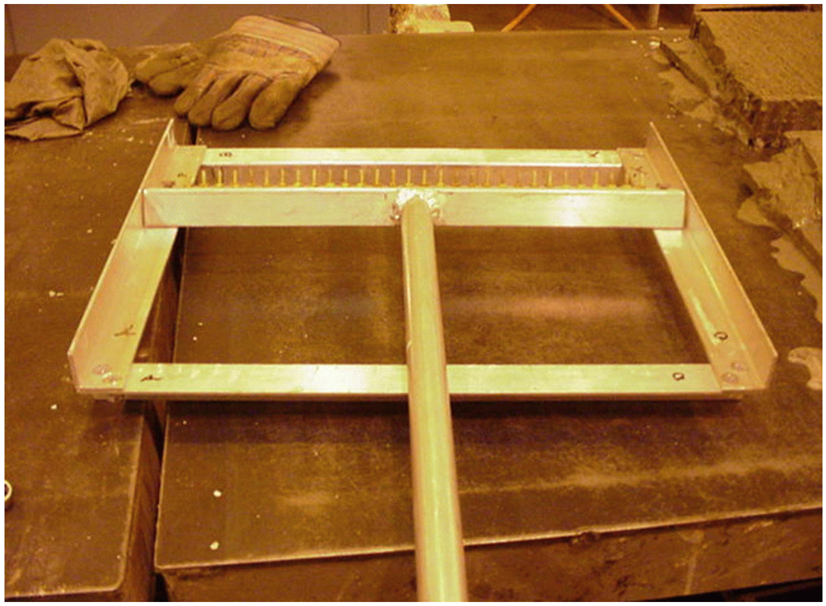
The remaining concrete is placed, consolidated, and struck off
The slabs are then given a smooth finish with a steel trowel

The slabs were left undisturbed to begin curing. They were periodically observed. When bleed water no longer appeared on the surface, and prior to initial set of the concrete, the slabs were given their final texture. The astroturf is dragged transversely across the surface of the slab to achieve the texture.

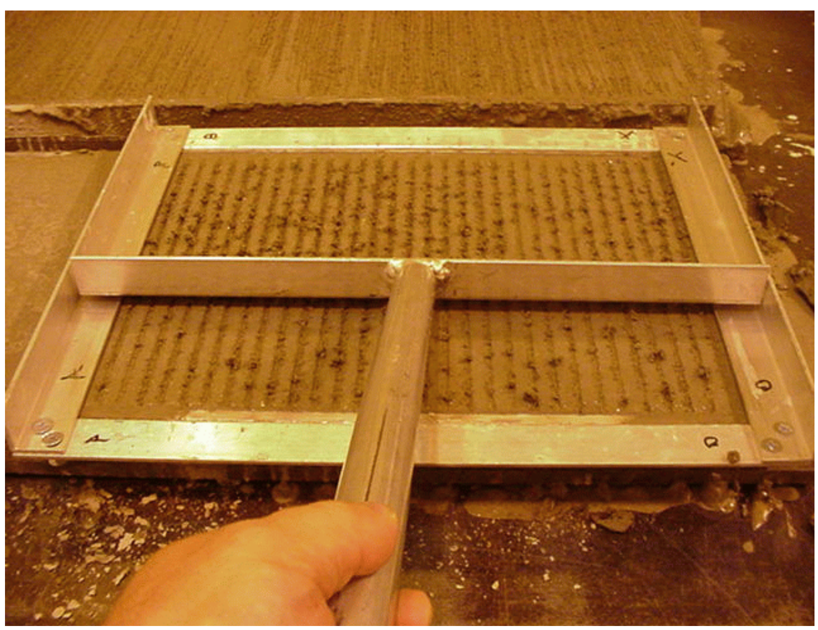


Transverse astroturf drag finish

A tining tool and jig were designed and built by Construction & Technology machine shop personnel to ensure consistency in tining depth, and orientation on the slab surface.

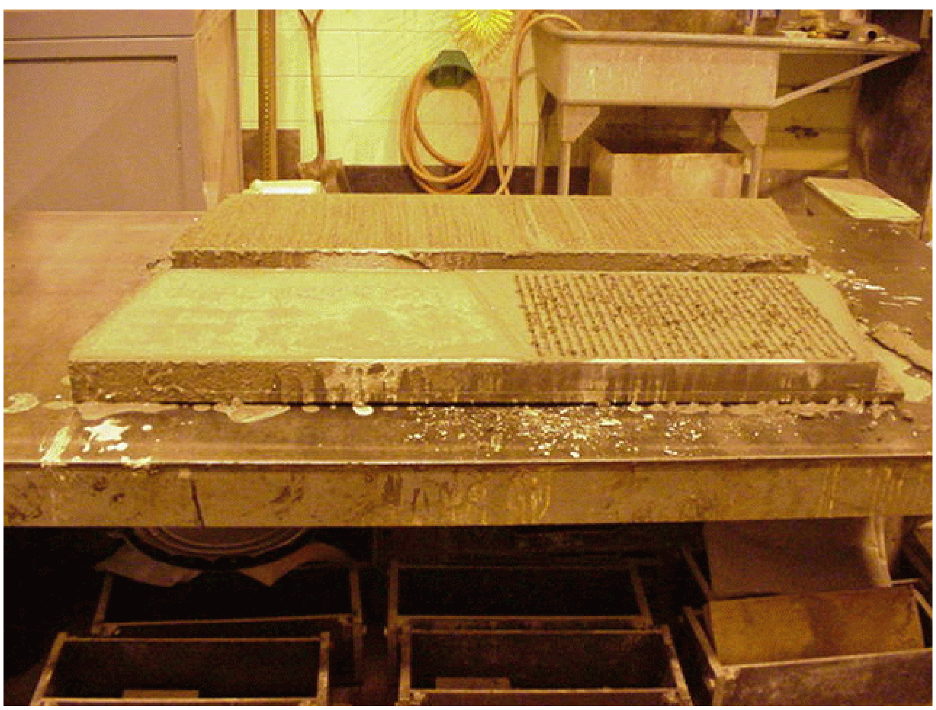


Tining tool and jig



Tining is achieved by placing the jig over the form and pulling the tining tool transversely across the slab surface

Transversely tined surface



Smooth trowel finish (bottom left), transversely tined finish (bottom right), astroturf drag finish (top)

The textured slabs were covered with polyethylene and allowed to cure overnight. Each slab specimen was stripped from the form after approximately twenty-four hours. The slabs were then immersed in lime saturated water for a minimum of seven days. After the seven-day immersion cure, the slabs were removed from the water, brushed off, and sprayed with fresh water to remove excess lime. Each specimen was allowed to air dry to a point where no surface moisture was present. At that point, *R.W. Meadows Sealtight Lin-Seal*™ *White,* white pigmented concrete curing compound was spray applied to slabs 2 through 16. Slab 1 will be the lone control slab for this wear track test series.

White pigmented curing compound (above) was spray applied (below) to slabs 2 through 16

Wear Track Series 064

The following photographs show each slab as they appeared just prior to being coated with white pigmented concrete curing compound, and after the curing compound was applied. These photographs are prior to the initial skid testing and subsequent accelerated polishing on the wear track.

Slabs 1 & 2

Control slabs 1and 2

Slab 2 (right) is coated with curing compound

Slab 3

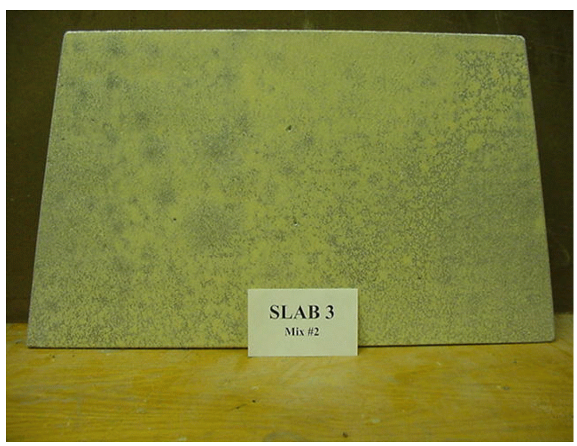
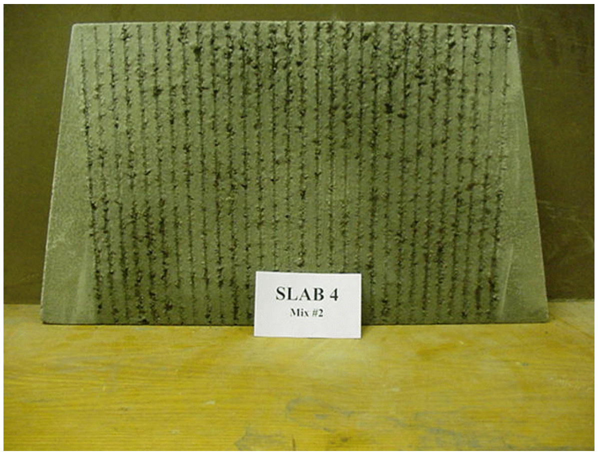


Photo at left shows slab 3 smooth trowel finish, at right is slab 3 with curing compound applied

Slab 4



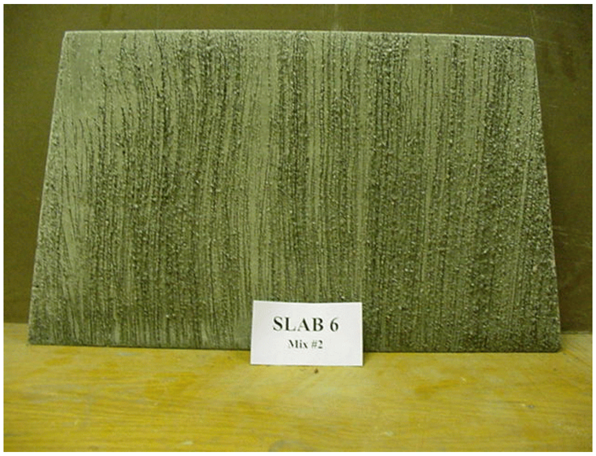
Slab 4 tined finish (left), and slab 4 with curing compound (right)

Slab 5

Tined surface texture on slab 5

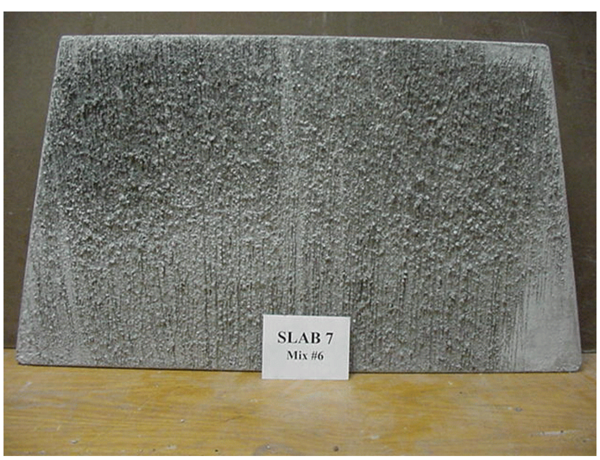
Slab 5 coated with curing compound

Slab 6



Slab 6 with astroturf drag finish (left) and coated with curing compound (right)

Slab 7



Slab 7 with transverse astroturf drag texture (left), and coated with white curing compound (right)

Slab 8

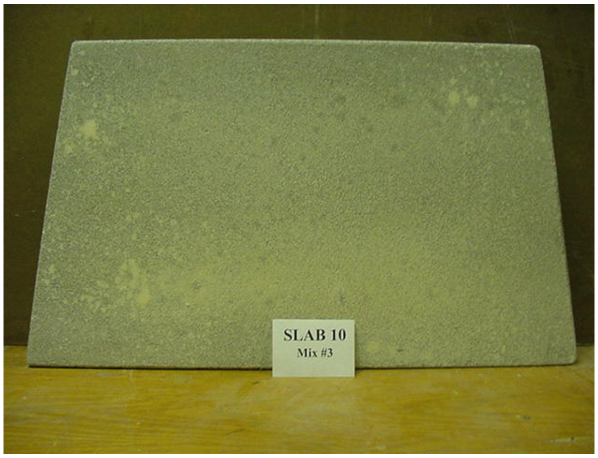
Slab 8 (left) with astroturf drag texture and coated with curing compound (right)

Slab 9

Astroturf drag texture on slab 9

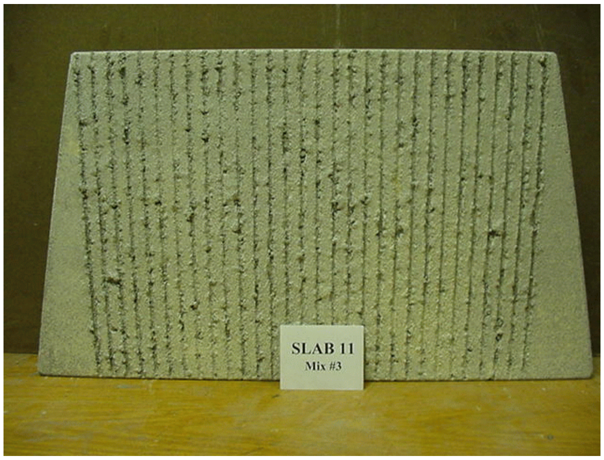
Slab 9 coated with curing compound

Slab 10



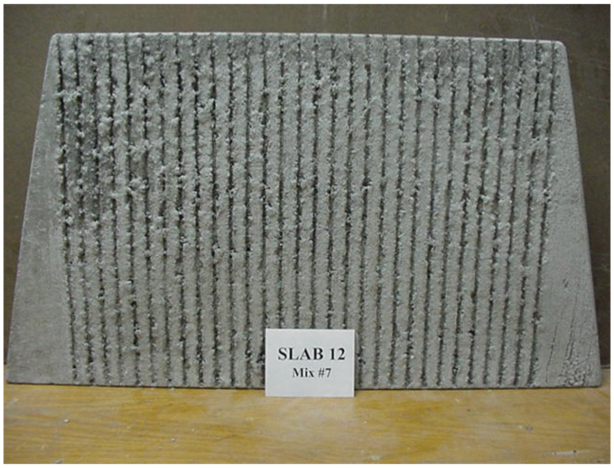
Slab10 has a smooth trowel finish (left). Slab 10 with white pigmented curing compound (right)

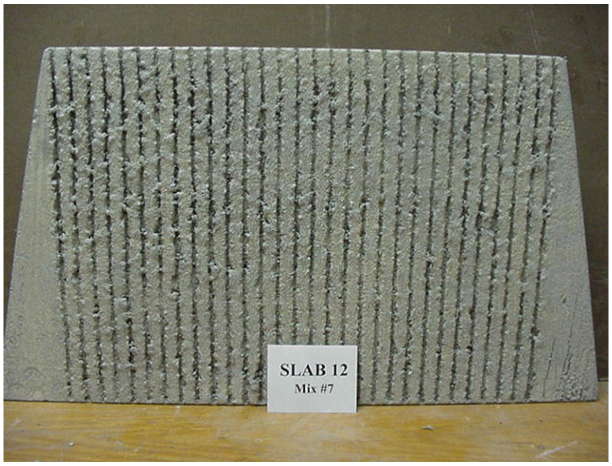
Slab 11



At left, slab 11 shows a tined surface texture, and at right, slab 11 with a coating of curing compound

<u>**Slab 12**</u>

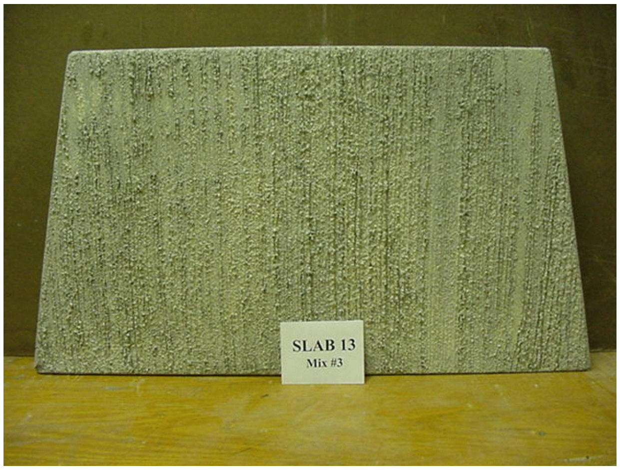




Slab 12 has a tined surface texture (left), and the same slab coated with white pigmented curing compound (right)

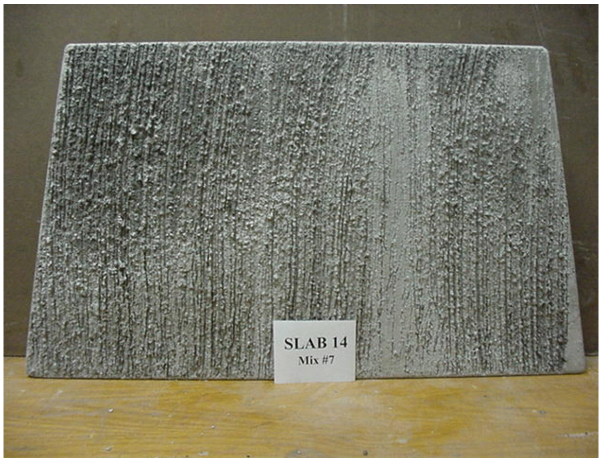
<u>**Slab 13**</u>

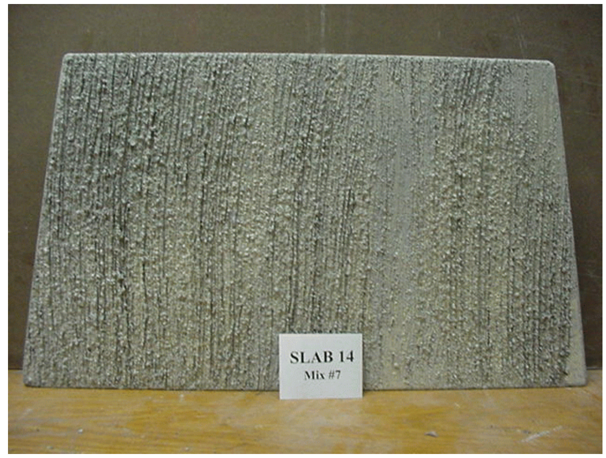
Slab 13 with astroturf drag texture



Slab 13 with white curing compound

Slab 14





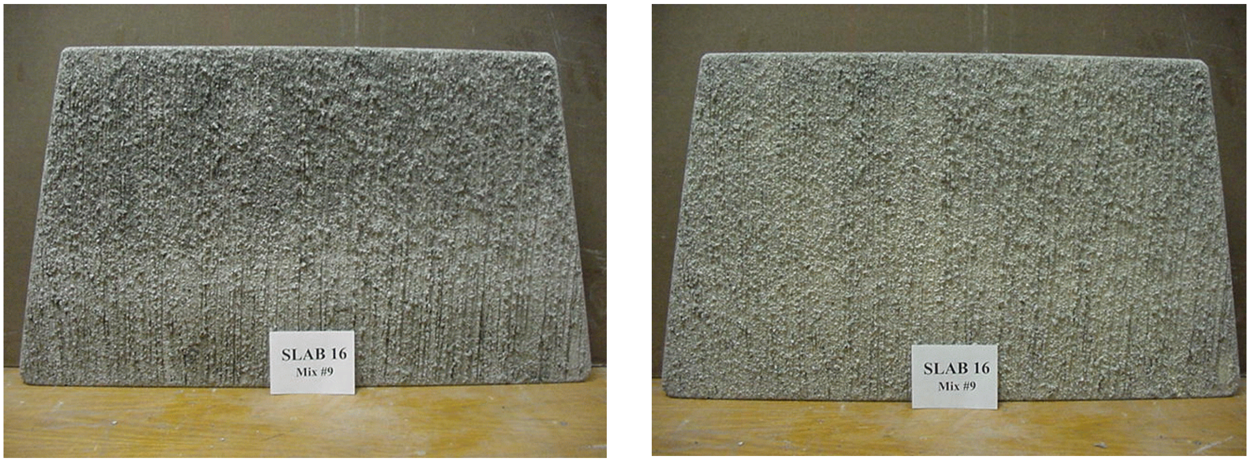
Slab 14 with astroturf drag texture

Slab 14 coated with curing compound

Slab 15

At left is slab 15 with an astroturf drag surface texture, and, at right, is slab 15 coated with curing compound

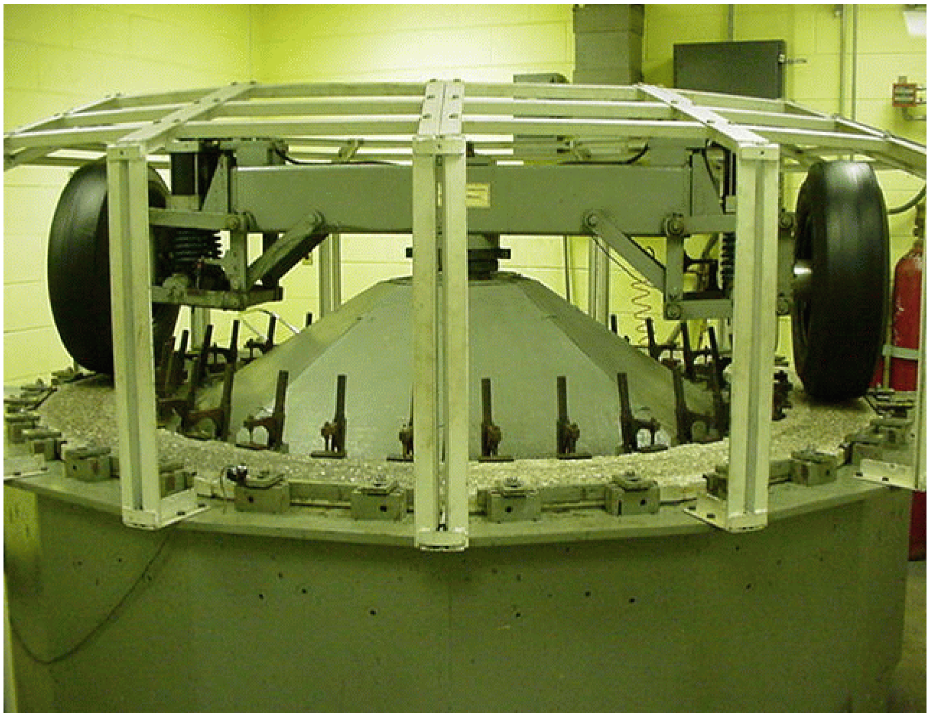
Slab 16



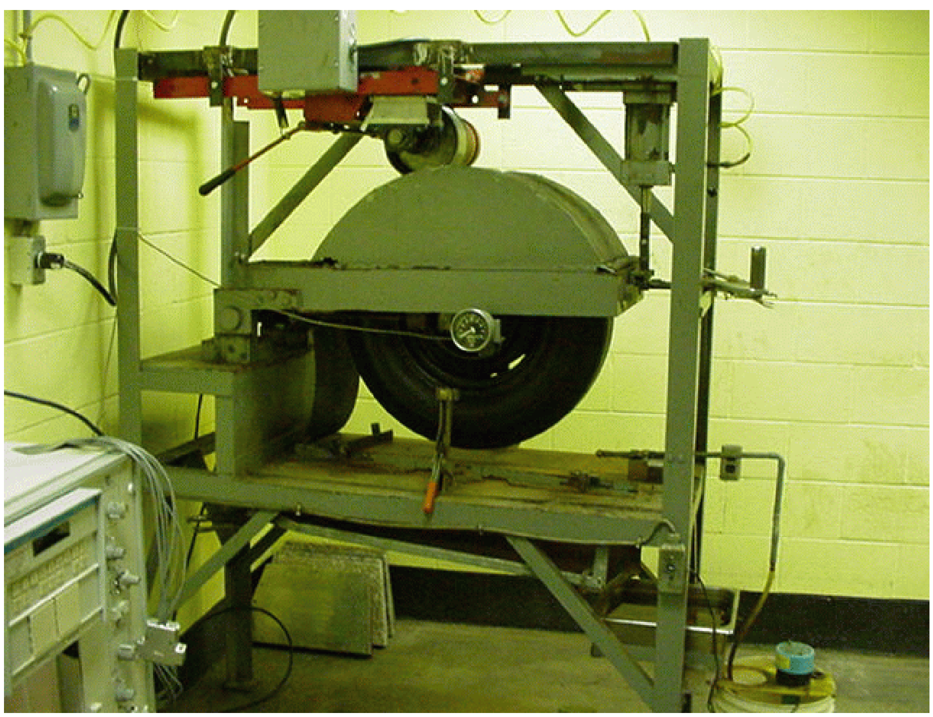
Astroturf drag finish on slab 16 (left), and slab 16 coated with curing compound (right)

Prior to skid testing, slabs 1 through 16 were tested by the British Pendulum test method. Each slab was again tested by this method after 0.5 million wheel passes, and four million wheel passes on the wear track Wear track testing progressed in the normal method, with slabs 1 through 16 being tested for skid resistance every 0.5 million wheel passes, until a total of four million wheel passes was reached.

British Pendulum Tester



The Wear Track



The Skid Drop Tester

Wear Track Series 064 - British Pendulum Testing

Slab Number	*Mix Number*	*Texturing Method*	*British Pendulum Test Results*		
			0.0 Million Wheel Passes	0.5 Million Wheel Passes	4.0 Million Wheel Passes
1	1	None	79	42	32
2	1	None	20	23	26
3	2	Smooth Troweled	20	25	33
4	2	Transverse Tining	33	40	43
5	6	Transverse Tining	64	42	52
6	2	Astroturf Drag	53	40	48
7	6	Astroturf Drag	73	52	57
8	4	Astroturf Drag	56	43	56
9	8	Astroturf Drag	70	47	52
10	3	Smooth Troweled	55	23	31
11	3	Transverse Tining	63	40	49
12	7	Transverse Tining	58	42	44
13	3	Astroturf Drag	76	65	75
14	7	Astroturf Drag	68	51	63
15	5	Astroturf Drag	72	48	60
16	9	Astroturf Drag	83	52	64

Remarks: British Pendulum test results represent the average of five test drops on each slab, following ASTM E 303 Standard Method of Test for Surface Frictional Properties Using the British Pendulum Tester.

All specimens except slab number 1 are coated with Lin-Seal White curing compound.

Control limestone coarse aggregate, and 2SS stone sand fine aggregate are from Inland, ASI 75-005. Gravel 26A coarse aggregate and natural sand 2NS fine aggregate are from New Hudson, ASI 63-048.

Textured slabs were scored transversely with tines or astroturf.

Wear Track Series 064 - Friction Testing Summary				
Slab Number	***Mix Number***	***Texturing Method***	***Friction Test Results At 4 Million Wheel Passes***	
			British Pendulum Test	**Aggregate Wear Index (AWI)**
1	1	None	32	200.6
2	1	None	26	168.9
3	2	Smooth Troweled	33	184.8
4	2	Transverse Tining	43	287.8
5	6	Transverse Tining	52	345.5
6	2	Astroturf Drag	48	333.4
7	6	Astroturf Drag	57	403.3
	4	Astroturf Drag	56	364.5
9	8	Astroturf Drag	52	370.9
10	3	Smooth Troweled	31	220.5
11	3	Transverse Tining	49	408.1
12	7	Transverse Tining	44	421.2
13	3	Astroturf Drag	75	483.0
14	7	Astroturf Drag	63	469.4
15	5	Astroturf Drag	60	501.1
16	9	Astroturf Drag	64	507.6

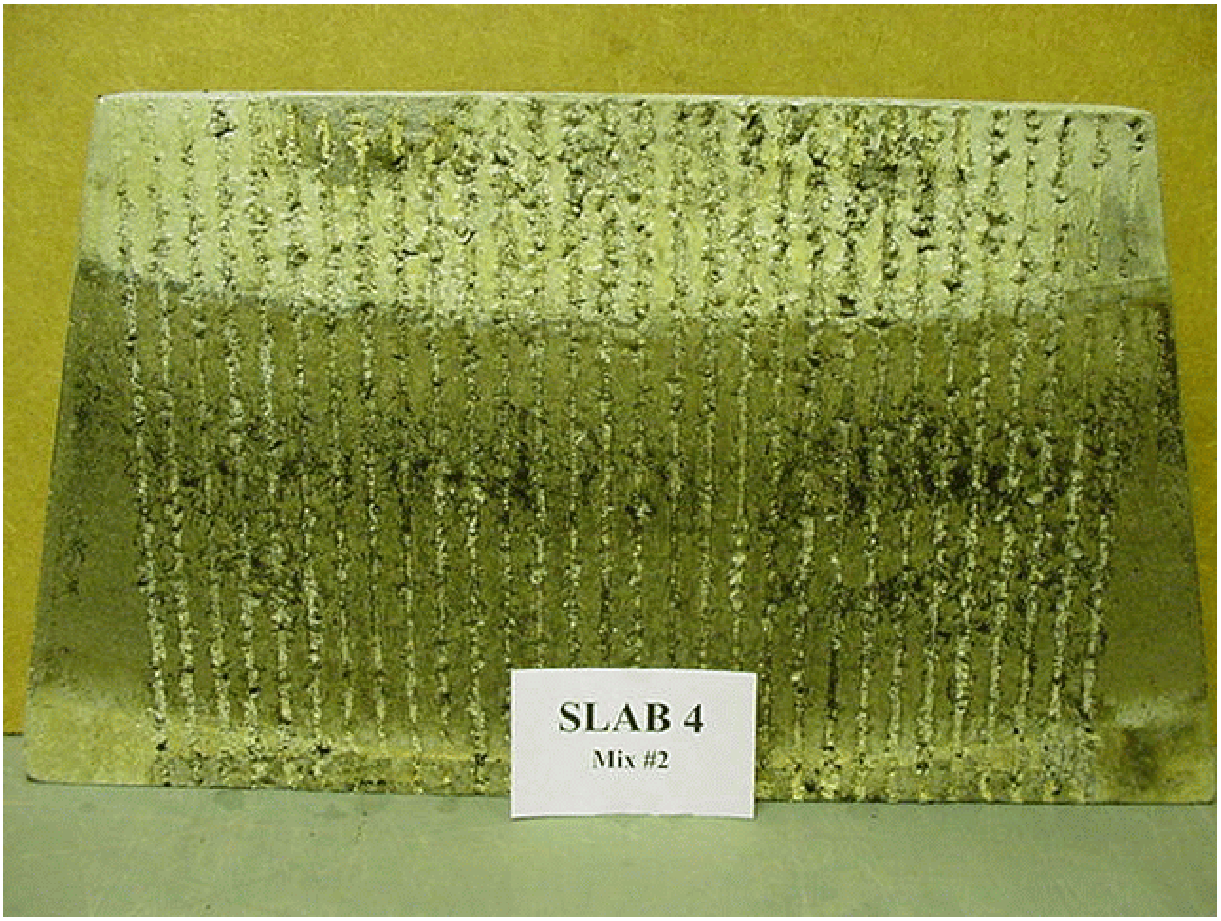
The following photographs document the condition of the slabs after four million wheel passes.

Slab 1

Slab 2

Slab 3

Slab 4



Slab 5

Slab 6

Slab 7

Slab 8

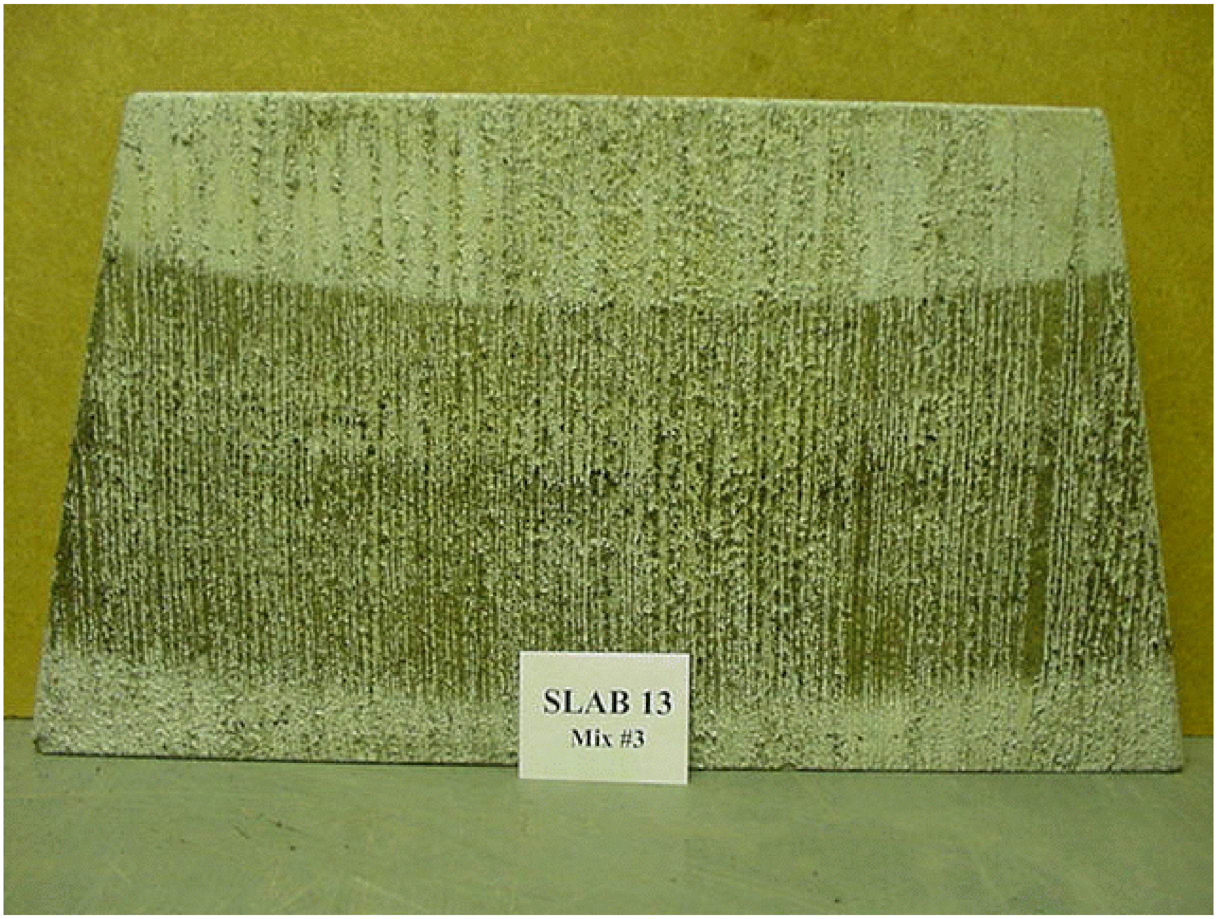
Slab 9

Slab 10

Slab 11

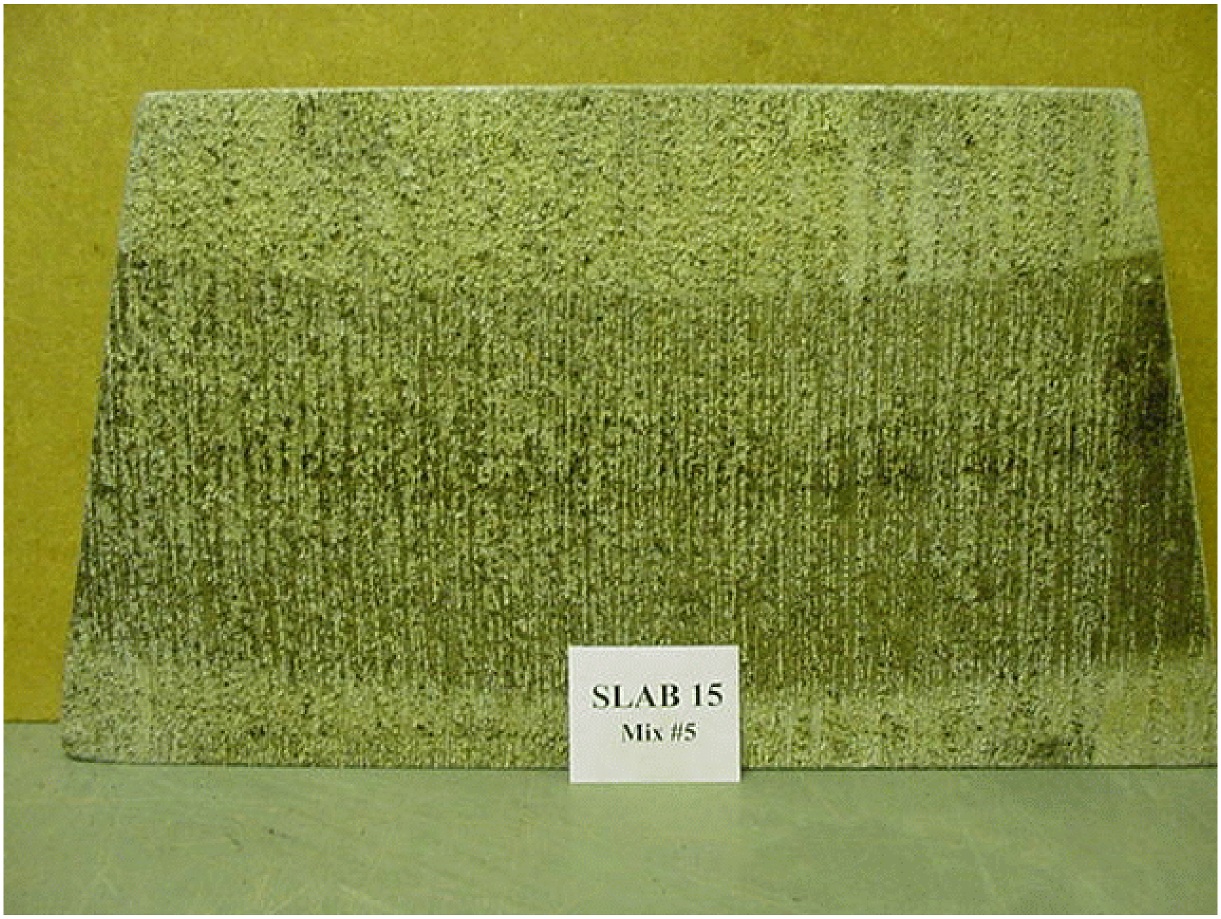
Slab 12

Slab 13



Slab 14

Slab 15



Slab 16

Conclusions

- Overall, the transverse astroturf drag texture resulted in the highest skid numbers. This held true regardless of the type of aggregates used in the concrete mixture. Both the tined textured slabs, and the astroturf textured slabs had skid numbers well above the 260 AWI standard used in normal wear track testing.

- The tining technique used to texture the transversely tined slabs tended to damage the slab surface and did not represent the actual tining method that is used in actual concrete construction. The tining tool was inserted into the slab surface and then pulled through the concrete, resulting in the tearing of the surface, and a rather inconsistent surface.

- Both texturing methods are very susceptible to proper timing after the concrete is placed. Waiting too long will not allow the tines or astroturf to penetrate the surface resulting in an unsatisfactory final surface texture.

- With the astroturf texturing method, great care must be taken to ensure that the strands of the astroturf do not get clogged with the paste from the concrete surface being textured. This would result in an unsatisfactory final surface texture.

- The slabs with the transverse astroturf drag texture appeared to pond more water during the skid testing than the tined slabs. This assumption is based strictly on visual observation and no scientific method was used to measure the amount of water on the surface of the slabs.