UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

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August 25, 2003

Pal Choudry
Research and Technology
Transfer Engineer
Federal Highway Administration
Illinois Division
3250 Executive Park Drive
Springfield, IL 62703

Subject: Progress in the project DTFH61-02-X-00029 between April 02, 2003 – August 20, 2003

Dear Mr. Choudry:

Significant progress has been made during summer of 2003 in several work areas of the FHWA research study entitled "Investigation of Aggregate Shape Effects on Hot Mix Performance Using an Image Analysis Approach." This is a 2-year pool-funded research project having as the participants the following states: Alabama, Georgia, Indiana, Minnesota, Mississippi, Missouri, Montana, and South Carolina, and the Central Federal Lands and Highways Division. This letter is intended to provide research progress to the FHWA project administrator and the project monitor, the FHWA Illinois Division for the period of April 02, 2003 – August 20, 2003.

A Mid-Year Research Progress Meeting took place at the University of Illinois on Tuesday, July 8th with attendance of the following individuals:

Pal Choudry, Project Monitor, FHWA, IL Division
John D'Angelo, FHWA, Turner-Fairbank Research Laboratory, Washington DC
Michael Peabody, Central Federal Lands and Highways, Colorado
Ron Walker, Indiana Department of Transportation
Jason Richter and David Nivell, Minnesota Department of Transportation
Bradley Bruce, Montana Department of Transportation
Sam Carpenter and Erol Tutumluer, University of Illinois.

A copy of the meeting agenda is given in Appendix 1. Overall, the July 8th meeting provided the project technical monitors and the state representatives in attendance an opportunity to evaluate the progress made in this pool-funded study. The meeting also facilitated discussions that generated valuable feedback/input for the successful completion of the study as well as directions for future research in the topic area. A handout package containing the meeting agenda and copies of research progress presentation slides from the meeting was distributed to all study partners for their information and review of the mid-year research progress in the project.

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The following is a short summary of the research progress made during summer of 2003:

1) A Surface Texture (ST) Index was developed for the imaging-based characterization of coarse aggregate surface properties to provide a quantifiable index for the aggregate smoothness and/or roughness. Aggregate surface texture or microtexture is a very important morphological property that has been known to affect hot mix asphalt rutting and surface friction performances. The new ST index successfully categorizes the degree of rough surfaced aggregate, such as basalt, in relation to smooth river gravel. The ST index analysis has been performed on all the NCAT and participating aggregate images thus far collected in this project.

2) Most of the missing aggregate materials, asphalt binders, and mix design information such as the job mix formulae have been collected from the participating states as summarized in Appendices 2 and 3. South Carolina and Indiana provided all the missing materials, binders, etc., and the mix design information for making laboratory hot mix samples. Mississippi DOT also decided to send an additional hot mix design and required materials that have just arrived for evaluation in the project.

3) Both the hardware and software components of the University of Illinois Aggregate Image Analyzer (UIAIA) were improved in functionality by a new black paint put on the conveyor belt and the new ST index added as a new virtual instrument (VI) used in aggregate image processing. This helped considerably the image processing of the somewhat darker colored Minnesota DOT aggregate samples, which could not have been processed earlier by the UIAIA.

In addition to the above-summarized items, considerable research progress has been also made in regular work items. This is according to the progress chart given in Appendix 5 detailing the 2 phases of the project, various task items to be accomplished in each phase, and the corresponding timelines scheduled for the successful completion of the project. Next progress will be described based on each phase and the individual task items in each phase as indicated in the chart.

PHASE I: Evaluation of Shape and Size Properties and Validation of the UIAIA

Work Items of Phase I

(1) Acquisition of NCAT Aggregate (March, 2002);

(2) Acquisition of Aggregate Samples from the Participating States (March 2002 – May 2002);

(3) Testing of Participating States' Aggregate Samples with UIAIA (March 2002 – March 2003);

(4) Testing of NCAT Aggregate Samples with UIAIA (May 2002 – May 2003);

(5) Image Processing for Shape Indices (August 2002 – August 2003).

Progress to Date in Phase I

Items (1) "Acquisition of NCAT Aggregate" and (2) "Acquisition of Aggregate Samples from the Participating States" have been completed. So far, all the aggregate samples requested have arrived with the exception of an additional hot mix aggregate samples from the State of Mississippi. As per the research scope of this project, of all the aggregate samples received, 14 coarse aggregate (retained on No.4 square opening sieve) samples from the National Center for Asphalt Technology (NCAT) and 45 (44 initially received plus one new sample from

Indiana) coarse aggregate samples from the participating states were selected as representatives for testing and image processing with the University of Illinois Aggregate Image Analyzer (UIAIA). As requested, coarse aggregate samples received are both light in color and sufficient for image testing and mixture design. For detailed information, please see Appendix 2 for aggregate samples from NCAT and Appendix 3 for aggregate samples from the participating states.

Item (3) "Testing of NCAT Aggregate Samples with the UIAIA" has been completed ahead of time. Depending on the average sizes and gradation results, anywhere from 300 to 2500 particles were selected for testing to establish a representative bag sample for each material. For materials having mainly smaller particles, a larger number of particles was typically needed to have anywhere from half a kilogram to 2 kilograms of aggregate by weight. Each aggregate sample was processed through the UIAIA system at least twice to verify the repeatability of the results. Only two of the samples had slightly darker particles, which could not be properly detected by the cameras and therefore were not image processed. In total, images of 15,000 particles from 14 samples were acquired and properly documented for image processing to later obtain their shape indices.

Item (4) for "Testing of Participating States' Aggregate Samples with the UIAIA", out of the 45 coarse aggregate samples listed in Appendix 3, processing of the 39 aggregate samples were completed ahead of the March 2003 schedule. Five samples were previously identified as too dark to be recognized by cameras of the UIAIA system. These 5 aggregate samples plus a new sample from the State of Indiana have been recently processed using the upgraded UIAIA system. So far, a total of approximately 45,000 images have been acquired from the 45 aggregate samples and properly documented for image processing to obtain their shape indices. In addition, the newly arriving aggregate samples from the Mississippi DOT will soon be worked on using the UIAIA for image acquisition and processing.

Item (5) "Image Processing for Shape Indices" is currently underway. For the images of the NCAT samples, both the image processing part and the analyses of shape indices for volume and weight (using specific gravities), flat and elongated ratio, angularity, gradation have been completed. The image processing and corresponding analyses of shape indices have also been completed for the acquired images of the 45 aggregate samples from the participating states. As the biggest contribution to this project during this period, surface texture analyses of all the aggregates have been also completed after successfully developing the surface texture (ST) index summer 2003. The ST index analysis has been performed on all the aggregate images thus far collected in the project.

The remaining Phase I research activities, which will be completed very soon, currently focus on obtaining all the missing information and materials from the participating states, processing of the newly arriving coarse aggregate materials using the UIAIA, and processing of the available and newly arriving aggregates for the imaging based indices. More specifically, the new aggregate materials received from the State of Mississippi still need to be processed using the UIAIA for volume and weight (using specific gravities), flat and elongated ratio, gradation, angularity, and surface texture. Further, we also contacted Georgia and Alabama to obtain missing binders, and mix design information that we should be receiving soon to finish Phase I of the study.

PHASE II: Evaluation of the Shape and Size Effects on Hot Mix Performance

Work Items of Phase II

(1) Preparation and Laboratory Testing of Asphalt Samples;

(2) NCAT Performance Data Collection;

(3) Laboratory and Field Data Analysis;

(4) Report Preparation.

Progress to Date in Phase II

Phase II of the research study involving laboratory asphalt sample preparation and testing took place at our Advanced Transportation Research and Engineering Laboratory (ATREL) in Rantoul, Illinois. As of August 20, 2003, in accordance with the project timetable (see Appendix 5), we have made progress in task item (1) "Preparation and Laboratory testing of Asphalt Samples." Appendix 4 lists asphalt mixture designs received from the participating states and the asphalt mix specimen preparation and testing progress in the laboratory. So far, out of the 10 participating states, we have prepared gyratory specimens for Federal Lands and Highways Division (NM mix), Federal Lands and Highways Division (OK mix), Montana ("Design 1 and 2") and Minnesota (Design 1 and Design 2). Test procedures for resilient modulus and permanent deformation properties were also decided and the laboratory equipment was set up to prepare samples. For the modulus and permanent deformation tests, samples were cut out of the gyratory specimens and tested for Federal Lands and Highways Division (NM mix), Federal Lands and Highways Division (OK mix), and Montana (Design 2), as indicated in Appendix 4.

As stated previously, many of the states have already sent us necessary mix design information and materials to make asphalt specimens in the laboratory; however, we still need to obtain information from Georgia as indicated in Appendix 3. Furthermore, three of the Alabama NCAT mix designs contain up to 3 of the image processed coarse aggregates in each mix. We are in the process of requesting related materials (asphalt binder and mixture designs) for making gyratory specimens for these Alabama NCAT mixes in the laboratory.

Asphalt mix samples are prepared in the laboratory for resilient modulus and performance testing strictly following the four major testing and analysis steps of the Superpave mixture design procedure:

(a) Selection of materials (aggregate, binders, modifiers, etc.);
(b) Selection of a design aggregate structure;
(c) Selection of the optimum design asphalt binder content;
(d) Evaluation of moisture sensitivity of the design asphalt mixture using AASHTO T283.

Note that the selections mentioned in these steps were already made and presented to us by the participating states for the job mix formulas received so far. For correlating better the laboratory testing results to mix performances from NCAT track test, a typical 7% field air void content was specified as the target air voids content for compacting asphalt specimens in the laboratory for resilient modulus and permanent deformation (rutting) tests.

The imaging based aggregate shape factors determined in Phase I will eventually be used to quantify the influences of particle shape on asphalt concrete mix performances and establish proper aggregate criteria.

For the Phase II work item "(2) NCAT Performance Data Collection," an NCAT study report (No. 2002-12, November 2002) has been obtained on "NCAT Test Track Design, Construction, and Performance." This report is currently used for obtaining field performance data for Phase II Items (3) and (4).

Again, I am happy report to you that we are on time with the scheduled tasks, we had a successful mid-year research progress meeting, and we are making good progress in the project. Should you have any questions, you can always contact me at (217) 333-8637 or send e-mail to tutumlue@uiuc.edu.

Sincerely,

Erol Tutumluer, Ph.D.
Associate Professor of Civil Engineering

Appendix 1. Mid-Year Research Progress Meeting Agenda

AGENDA

Mid-Year Research Progress Meeting

TPF-5(023): Pooled fund project DTFH61-02-X-00029
Investigation of Aggregate Shape Effects on Hot Mix
Performance Using An Image Analysis Approach

Tuesday, July 8, 2003

Grainger Library Room 329

09:30 – 12:00	Welcome and Introductions
	Project Overview
	Background on the University of Illinois Aggregate Image Analyzer (UIAIA) (short presentation + videotape)
	Development of A New Surface Texture Index Using the UIAIA
	Phase I Progress Update: Imaging Based Property Determination of Coarse Aggregates
12:00 – 1:00	Lunch – *Illini Union Ballroom*
1:00 – 1:30	UIAIA Laboratory Demonstration – *Newmark Civil Engineering Laboratory*

Grainger Library Room 329

1:30 – 4:00	Phase II Progress Update: Evaluation of Aggregate Shape & Size Effects on Hot Mix Performance
	Modulus and Permanent Deformation Testing of Asphalt Mixes
	Analysis of Performance Data & Effects of Imaging Based Indices on the Performance
	General Discussions & Directions for Future Research

Transportation to ATREL – Rantoul, Illinois

4:00 – 5:30	Tour of the Advanced Transportation Research & Engineering Laboratory (ATREL)
6:30	Dinner – Kennedy's Restaurant, Stone Creek Golf Course, Urbana

Appendix 2. Aggregate Samples from NCAT

STATE	AGGREGATES	TYPE
Alabama	***Calera 67***	Limestone
	Calera 7	Limestone
	Calera 821	Limestone
	Calera 822	Limestone
	Calera 89	Limestone
	Calera 892	Limestone
	Jemison 1/2 Crushed gravel	Gravel
	Jemison 3/8 crushed gravel	Gravel
	Jemison Concrete sand	Sand
	Summit sandstone 8	Sandstone
	Summit sandstone sand	Sand
	Gadsden slag 78	Slag
	Gadsden slag 8910	Slag
Indiana	Indiana 1	Limestone
Georgia	***Columbus 6***	Granite
	Columbus 7	Granite
	Columbus 89	Granite
	Columbus M10	Granite
	Columbus W10	Granite
	Lithia springs 7	Granite
	Lithia springs 89	Granite
Mississippi	***Blain 1/2 crushed gravel***	Gravel
	Blain 3/4 crushed gravel	Gravel
	Blain coarse sand	Sand
	Blain 3/8 crushed gravel	Gravel
	Falco agricultural lime	Limestone
South Carolina	Blacksburg regular screens	Granite
	Blacksburg 67	Granite
	Blacksburg 78M	Granite
	Blacksburg manufactured sand	Sand
	Gray court #10 manufactured sand	Sand
	Gray court 6M	Granite
	Gray court 789	Granite
	Gray court regular screenings	Granite

Note: Samples in bold are the selected coarse aggregate samples for image analysis. For the NCAT aggregate samples, image testing and processing for shape indices have been completed.

Appendix 3. Materials and Mixture Designs from the Participating States

State No.	State	Mix No.
1	**Federal Lands and Highways Division (NM)**	1 mix
	**** 7/8" Rock***	
	**** Coarse Aggregate***	
	**** Intermediate Aggregate***	
	Asphalt Binder P6 58-34 (2)	
	Crushed Fines	
	Hydrated Lime	
2	**Federal Lands and Highways Division (OK)**	1 mix
	**** 1" Rock***	
	**** 1/2" Rock***	
	**** Screenings***	
	P6 70-28 Asphalt (2)	
	Sand	
	Stone Sand	
3	**Minnesota**	2 mixes
	Maple Grove Mix	
	**** Meridian St. Cloud 3/4" Unwashed Sand***	
	**** Meridian St. Cloud CA-50***	
	**** Meridian St. Cloud FA-3***	
	Barton Elk River #1 Washed Sand	
	Kraemer Burnsville Washed Sand	
	Meridian Washed Sand	
	Red Rock Mix	
	**** Barton Denmark BA-2***	
	****Kraemer Burnsville 9/16" Chip***	
	****Kraemer Burnsville Class 2***	
	Camas "Shiely" West Lakeland Washed Sand	
	Camas Nelson Man. Sand (Class D)	
	Mn/DOT 58-28 AC	
4	**Mississippi**	1 mix
	Dickerson Bowen Madison Mix	
	****Crushed Gravel (4 bags)***	
	****Crushed Limestone (2 bags)***	
	Agricultural Limestone	
	Asphalt Binder	
	Coarse Sand	
	Hydrated Lime	

5	**Missouri**	3 mixes
	Brickey's Mix	
	**** Brickeys 1"***	
	**** Brickeys 1/2"***	
	**** Brickeys 3/4"***	
	*** Brickeys 3/8"**	
	Burlington Mix	
	****1/2" Burlington***	
	**** 3/4" Joornagan, Joe Howard Qy***	
	****1/4" Chips Tower Rock***	
	1/2" Base	
	Clean Mix	
	****1 1/2" Clean Stone***	
	****1/2" Clean Stone***	
	****3/4" Clean Stone***	
	LOF	
	Man. Sand	
	MOR Life	
	PG 64-22 Asphalt	
	Screenings	
	TRSG Man. Sand	
6	**South Carolina**	3 mixes
	**** Blacksburg 67 (NCAT)***	
	**** Blacksburg 78M (NCAT)***	
	**** Gray Court 6M (NCAT)***	
	**** Gray Court 789***	
	**** Marlboro 67***	
	**** Marlboro 789***	
	Blacksburg Man. Sand	
	Blacksburg Regular Screening	
	Gray Court Regular Screenings	
	Asphalt binders for the 3 designs	
7	**Georgia**	3 mixes
	**** HMA 12 coarse aggregate***	
	**** Lithia Springs***	
	**** Handson and Candler Coarse aggregate***	
	M10 W10 Lime (binder)	
	Fine aggregate liquid AC lime (binder)	
	Binder	

8	**Indiana**	2 mixes
	#23 Natural Sand, Interstate Sand & Gravel, Williamsport (2164)	
	QAFM-01 stone sand Newton County Stone, Kentland (2445)	
	**** #11 gravel Cowles Sand & Gravel, Williamsport (2164)***	
	Asphalt Binders for both designs	
	#23 Natural Sand Cowles Sand & Gravel, Kewanna (2432)	
	QA # 12 stone Vulcan Materials, Francisville (2461)	
	**** #11 gravel Cowles Sand & Gravel, Kewanna (2432)***	
9	**Alabama**	3 mixes
	**** Calera 7 (NCAT)***	
	**** Calera 89 (NCAT)***	
	**** Columbus 7 Granite 7 (NCAT)***	
	**** Jemison 1/2 crushed gravel (NCAT)***	
	**** Jemison 3/8 crushed gravel***	
	**** Summit sandstone 8 (NCAT)***	
	Calera 821	
	Calera 892	
	Columbus 89 Granite 89	
	Columbus M10 granite M10	
	Columbus W10 Granite W10	
	Jemison concrete sand natural sand	
	Summit sandstone sand	
10	**Montana**	2 mixes
	Crushed Fines	
	Washed Crushed Fines	
	****3/8 Inch Chips***	
	****Coarse Aggregate***	
	Fines	
	****Intermediate Aggregate***	
	****Coarse Aggregate***	
	Asphalt Binders for both designs	

Notes: Samples in bold are selected as coarse aggregate samples. Image testing and processing for samples beginning with a star have been completed.

Appendix 4. Progress In the Asphalt Testing Laboratory Study

Mixture Designs	ATREL Laboratory Research Progress		
	Gyratory Mix Preparation (3 specimens)	**Resilient Modulus Testing**	**Permanent Deformation Testing**
Federal Lands and Highways Division (NM)	Completed	Completed	Completed
Federal Lands and Highways Division (OK)	Completed	Completed	Completed
Minnesota Design 1	Completed		
Minnesota Design 2	Completed		
Mississippi			
Missouri Design 1			
Missouri Design 2			
Missouri Design 3			
South Carolina 1			
South Carolina 2			
South Carolina 3			
Georgia 1			
Georgia 2			
Georgia 3			
Indiana 1			
Indiana 2			
Alabama			
Montana Design 1	Completed		
Montana Design 2	Completed	Completed	Completed

Appendix 5. Timetable for the Pooled Fund Study on
"Investigation of Aggregate Shape Effects on Hot Mix Performance Using An Image Analysis Approach"

Task to Perform	Year 1				M Year 2			Report
	2002 March	2002 May	2002 August	2002 Nov.	2003 March	2003 May	2003 August	2003 Nov.
Phase 1		**Image Analysis**						
Acquisition of NCAT[1] Aggregates								
Acquisition of Aggregate Samples From Participating States								
Testing of NCAT Samples w/UI-AIA[2]								
Testing of Participating State Aggregate Samples with UI-AIA								
Image Processing for Shape Indices								
Phase 2					**Asphalt Mix Study**			
Preparation and Laboratory Testing of Asphalt Samples								
NCAT Performance Data Collection								
Laboratory and Field Data Analysis								
Report Preparation								

M : Proposed meeting schedule to discuss research progress and results

[1]: National Center for Asphalt Technology pavement test track facility

[2]: University of Illinois Aggregate Image Analyzer