Research Project Work Plan
for

Chip Seal Design and Specifications
SPR 777

Submitted by
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May 2014

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1.0 IDENTIFICATION

1.1 Organizations Sponsoring Research

Oregon Department of Transportation (ODOT)
Research Section
555 13th Street NE
Salem, OR 97301 Phone: (503) 986-2700
Federal Highway Administration (FHWA)
Washington, D.C. 20590

1.2 Principal Investigator(s)

Dr. Douglas Gransberg
Professor and Donald and Sharon Greenwood Chair of Construction Engineering
Department of Civil, Construction, and Environmental Engineering
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Co-Principal Investigator
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1.3 Technical Advisory Committee (TAC) Members

Possible Team members:
Jon Lazarus, Larry Ilg, Justin Moderie, Jim Huddleston, Oregon FHWA representative, Oregon DOT Maintenance Engineer

1.4 Friends of the Committee (if any)

Luci Moore, State Maintenance and Operations Engineer

ODOT Office of Maintenance

Phone: 503-986-3005

1.5 Research Coordinator

Jon Lazarus
ODOT Research Unit

Phone: 503-986-2852

1.6 Project Champion

Larry Ilg, Pavement Quality and Materials Engineer
ODOT Technical Services
Phone: 503-986-3072

2.0 SUMMARY OF STAFF, RESOURCES, AND EXPERIENCE

2.1 Staff

Dr. Doug Gransberg will serve as the Principal Investigator for this project for Iowa State University. He was the primary author of NCHRP Synthesis 372: Chip Seal Best Practices. He holds the Greenwood Endowed Chair in Construction Engineering at the ISU CC EE Department and brings over 20 years of research experience and 20 years of industry experience to the project. He is currently PI on the IaDOT "Asset Management Program Enhancement Plan Baseline Assessment. He has also served as PI/Co-PI on 53 funded research projects worth a total value of $4.5 million sponsored by National Cooperative Highway Research Program (NCHRP), the National Science Foundation (NSF), the Departments of Transportation in Oklahoma (ODOT), Texas (TxDOT), Washington (WSDOT), North Carolina (NCDOT), and several privately funded research institutes.

Dr. R. Christopher Williams will be the Co-Principal Investigator for Iowa State University. He is a Professor of Civil Engineering at Iowa State University with 14 years of research experience managing and directing research funded by governmental agencies and major corporations. This research experience is in addition to three years of research work experience for the Federal Highway Administration (FHWA) on staff research and in the capacity of a contracting officer's technical representative, directing research funded by the FHWA. Dr. Williams has more than 21 years of research experience in asphalt materials and pavement design. This experience includes the design and evaluation of asphalt mixtures, design and construction specification development for asphalt mixtures, fundamental characterization of asphalt materials and hot mix asphalt, and mechanistic-empirical pavement design. Dr. Williams' recent accomplishments include a substantial amount of work sustainability including the use of recycled asphalt shingles in asphalt mixtures, mixtures containing high amounts of recycled asphalt pavement, evaluation of warm mix asphalt technologies, development of a new warm mix asphalt technology from a food based biorefinery, and the development of bioasphalt and biopolymers. Dr. Williams directs the Asphalt Materials and Pavements Program under the Institute for Transportation at Iowa State University.

2.2 Resources

Iowa State University's Institute for Transportation (InTrans) is located in a 25,000 square-foot office suite in ISU's Research Park in Ames, Iowa. As Iowa State University's focal point for transportation-related research, education, and outreach, InTrans manages more than 14.2 million dollars annually in sponsored funding spread across more than 100 projects. Resources at the institute include over 45 faculty and professional/scientific staff, a mobile video monitoring laboratory, an asphalt laboratory (which is described in greater detail in the Facilities section), and a technical publications group. InTrans is fully equipped with the sophisticated computing facilities and support staff.

3.0 PROBLEM STATEMENT

The Stage 2 document defines the problem as a need to “revisit” ODOT’s chip seal design methodology and specifications using common chip seal design methodologies found elsewhere in the US and internationally as a benchmark to identify potential approaches to improve the ODOT chip seal program. The crux of the issue revolves around the upcoming loss of experienced maintenance personnel and the current ODOT philosophy is that, “The technique used to apply chip seals is currently referred to as more of an ‘art’ than ‘science’ and is based on an experienced person conducting a visual inspection during the application and making adjustments in binder and/or aggregate (chip) rate.” Therefore, ODOT requires a rational chip seal design methodology based on quantitative measurements that can be successfully replicated by contractors in the field and which does not demand the current amount of professional judgment to be successful.

3.1 Background and Significance of Work

Chip seals are a key component to any pavement preservation program which seeks to “put the right treatment on the right road at the right time” (Galehouse et al. 2003). However, NCHRP Synthesis 342 (Gransberg and James 2005) concluded that research into chip design in the United States essentially stopped in 1969 when the Asphalt Institute adopted the McLeod method as its chip seal design methodology. NCHRP project 14-17 was funded to fill the gaps in the chip seal body-of-knowledge identified in the synthesis. However, the final report from that expanded study (Shuler et al. 2011) merely reiterated Synthesis 342 findings and best practices, failing to produce a rational chip seal design methodology discussed in the Stage 2 document.

NCHRP Synthesis 342 also found that there is an attitude found in many US public road agencies that treats chip seal as a commodity to be purchased in bulk rather than an important pavement preservation tool that requires a rational design approach based on sound engineering principles and a strong construction quality management effort to insure that it is properly installed, which exacerbates the problem of developing a strong chip seal program (Gransberg and James 2005). Therefore, the study concluded that American public road agencies will need to look abroad for the latest technical tools in the chip seal area, and New Zealand is one of those countries who have continuously invested in advancing the state-of-the-art in chip seal design and construction.

Dr. Gransberg, the proposed PI, has conducted funded chip seal research for the New Zealand Transport Agency (NZTA), and he found that chip seal design and construction practices have evolved over a number of years through research and monitoring performance in the field (Pidwerbesky et al. 2006). The seal design procedure is a rational system, based on the volumetric characteristics of the sealing aggregate, for calculating the amount of aggregate to spread and the quantity of binder required to hold it in place. There are a number of factors, such as the condition of surface on which the seal is to be placed, terrain, pavement geometry, etc. that influence the volume of voids in the seal and the rate at which these decrease under trafficking. Allowances are used in the seal design formula which increases or decrease the binder application rate as required calibrating the final design rates for variations encountered along the length of a given project.

In the NZTA design method, the substrate upon which a new seal is to be placed must be quantitatively characterized to calculate the binder application rates (TNZ1995). The rate varies as required along the length of the road and depends upon the size, shape and orientation of the aggregate particles, embedment of aggregate into the underlying pavement, texture of the surface onto which the seal is being applied, and absorption of binder into either the pavement or aggregates. The aim of the NZTA design process is for the residual binder to be ½ to 2/3 the mean depth of the aggregate (TNZ 2003). New Zealand mandates that pavement type selection be based on life cycle cost. A key factor in this economic analysis procedure is that a discount rate of 10% is mandated to discount all future benefits and costs to their present value. This effectively limits the use of structural asphalt pavements to those roads carrying over 25,000 AADT, and precludes the use of rigid (concrete) pavements. Thus, 95% of New Zealand's road network is unbound pavements, surfaced with chip seals, due to their low initial cost (Waters 2004). Field trials of high quality chip seals on private forestry roads have proven that high quality chip seals over granular pavements can carry extremely heavy loads (up to 16 tons per single axle) and high numbers of load repetitions (> 15 million ESAL) (Pidwerbesky and Arnold. 1996).

4.0 OBJECTIVES OF THE STUDY

Per the Stage 2 document, "the objective of this research is to document methods and report the performance of chip seals designed using different methodologies. Once quantified, the research will identify best practices that can be implemented."

4.1 Benefits

With the high price of asphalt products and ODOT's strong commitment to providing sustainable design solutions to the state's construction and maintenance projects, chip seals will replace thin asphalt overlays in much of the state's pavement preservation program. The result is a more cost effective treatment which minimizes the amount of virgin material required and greatly reduces the carbon footprint of the typical resurfacing job. In many cases, the chip seal's increased surface macrotexture will enhance safety by providing enhanced surface drainage to remove more water from the traveled way faster than hot mix asphalt surfaces.

5.0 IMPLEMENTATION

The recommendations from the outcomes from the project upon review and approval are likely to be incorporated in the ODOT design processes. This will include communication to the pavement designers and pavement material engineers. As appropriate, the recommendations will be reviewed for inclusion in the Pavement Design Guide and/or specifications. The outcomes of the project will also be communicated to local agencies and other partners as appropriate. Specifically, a performance-based specification, based on the NZTA TNZP/17 specification, will be developed for allowable macrotexture loss over 12 months. Additionally, specifications for roller linger time, minimum required rollers based on distributor output, and rolling patterns to ensure proper embedment and chip retention will be provided. Lastly, a material selection guideline for ensuring electrostatic compatibility of chip seal binder and aggregate will be developed for Oregon.

6.0 RESEARCH TASKS

6.1 Tasks

The proposed research will include five distinct tasks. These are detailed on the following pages.

Task 1-Literature Review and Assessment of Design Methods—Conduct a literature review to identify design methods and potential benefits of these design methods. The review will include the McLeod (1969), Hanson (1934), Kirby (1953), and Modified Kirby (Gransberg et al. 1998) methods as well as the NZTA method (TNZ 2005) and the Austroads (2004) method. Potential requirements and challenges with each proposed method will be identified in the same these were evaluated by Dr. Gransberg when he produced NCHRP Synthesis 342. The emphasis will be on adapting a method currently in use to the Oregon pavement preservation and maintenance program using local materials. The outcome, if possible, will be a method that minimizes the need for past experience to design and install a serviceable chip seal.

Estimated Duration: 6 months Cost: $15,000

Task 2-Identification of Field Projects—This task will identify potential field projects that can be used to assess the different design methods and testing equipment purchase. The research team will work with ODOT personnel to identify projects over two seasons and determine the number of case studies required for significance. The major requirement will be to find test sites where the existing pavement condition will not mask the results of the seals designed using the methods found in Task 1. Test sections will need to be on flat terrain, be straight sections with no planned turning movements, and rutting must be less ½ the mean least dimension of the aggregate that will be applied to the test section. The sections must have no patching, minimal crack sealing, and a traverse cross-section that drains as designed. The sections should have a reasonably uniform surface condition in the longitudinal direction.

Estimated Duration: 3 months Cost: $10,000

Task 3-Characterization of Existing Project Conditions—International design procedures require that the engineer to quantitatively characterize the substrate upon which the seal will be applied and from that binder and aggregate selection decisions are made. US design methods, like the Modified Kirby Method being using in Texas, usually results in a qualitative characterization to develop binder application rates and supports determination of the input characteristics for chip seal design. The NZTA design method, with which the research team has experience, requires surface macrotexture, pavement hardness, geometric inputs like grade and crown, rut measurements, traffic conditions, climatic conditions, turning movements, and superelevation as input values to determine aggregate gradation and binder application rate. International organizations characterize surface texture using the sand circle test (NZTA TNZT/3), which is similar to the ASTM E965 sand patch method, but more robust. Gransberg's research in Texas found that using a coarser sand with the sand circle and sand patch test, that the results had higher consistency compared to the same technician performing all the sand circles (Aktas et al. 2011). He also used the sand circle successfully in field testing in Oklahoma

(Pittenger et al. 2011). The UK Highways Agency uses a penetrometer to characterize surface hardness. Gransberg's Texas research could not identify a significant correlation when using this device with chip seal quality or durability. It is also imperative that rutting be measured across the transverse cross-section. Gransberg and Pittenger (2011) found that failing to identify that ruts were deeper than the mean least dimension of the aggregate led to premature flushing in the wheel paths with subsequent loss of skid resistance.

The Stage 2 document suggests purchasing a Dynamic Friction Tester (DFT) and Circular Track Meter (CTM). The work in Oklahoma used both pieces of test equipment, but found that the CTM does not add value to the test results because it requires that lanes be closed 5 to 6 times as long and it served to merely validate that the NZTA sand circle measurements were accurate. The sand circle testing equipment can be manufactured for less than $10.00, whereas the CTM costs over $36,000. Therefore, the research team recommends that the purchase of the CTM be eliminated from this project or at least postponed until after the research is complete. Elimination of the CTM will allow for the allocation of these monies towards a more complete and comprehensive field plan. If ODOT feels the need for the CTM, then the field work plan will be targeted to accommodate the available monies. The budget only includes the purchase of the DFT.

Estimated Duration: 3 months ***Cost: $45,000***

Task 4-Assessment of Field Projects Constructed with Different Chip Seal Designs—This task will assess the different chip seals constructed with the different design procedures. The researchers will replicate the experimental plan used successfully in the Texas and Oklahoma DOT projects. It will be based on a 12-month deterioration of macrotexture and microtexture. The macrotexture will be compared to the TNZP/17 performance specification. Specifically, New Zealand uses an equation to test the texture depth of its new chip seals after one year.

$$Td1 = 0.07\ ALD \log Yd + 0.9$$

where: T d1 = texture depth in one year (mm);
Yd = design life in years; and
ALD = average least dimension of the aggregate.

Microtexture will be measured using the DFT and failure criteria will be chosen based on current ODOT policy for minimum allowable skid numbers. It is anticipated that both tests will be conducted before application of the chip seal, with 30 days after construction, and then quarterly afterward. Additionally, the Montana DOT broom test will be conducted to measure chip seal retention in the field immediately after test site construction.

Laboratory testing will consist of Micro-Deval to measure soundness of the aggregate, determination of the angularity index using the Aggregate Imaging System (AIMS) which Gransberg and Pittenger (2011) correlated to skid numbers in Oklahoma. If the AIMS system is not available in Oregon, Dr. Pittenger has graciously offered to allow the team to use the AIMS system in the University of Oklahoma's asphalt laboratory. Lastly, electrostatic charge of the aggregate will be measured to ensure compatibility with the binder and determine if precoating is required.

Estimated duration: 12 months Cost: $90,000

Task 5-Final Report— A draft final report will be developed and submitted to ODOT for review. Following this review, a final report will be developed, incorporating the ODOT comments, to document the findings of the research. Note that the final report will include a proposed procedure for designing chip seals.

Estimated duration: 6 months Cost: $15,000

TOTAL ESTIMATED DURATION: 25 months TOTAL COST: $175,000

6.2 Reporting

All reports shall be produced in the standard ODOT Research Section report format provided to the Project Investigator by the Research Coordinator unless some other format is deemed to be more appropriate. The Project Investigator shall be responsible for submitting reports of professional-level written composition equivalent to the writing standards of peer-reviewed journals. These writing considerations include grammar, spelling, syntax, organization, and conciseness.

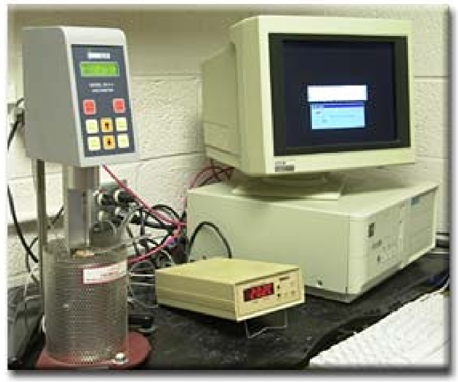
The Project Investigator, in consultation with the TAC and Research Coordinator, shall deliver to ODOT in electronic format the data produced during the project. The Project Investigator shall ensure the data is labeled and organized to facilitate future access. ODOT shall warehouse the data.

6.3 Safety and Related Training

Prior to accessing ODOT right-of-way (ROW), all personnel who will work on ODOT ROW shall complete safety training appropriate to the work to be performed within the ROW. The Project Investigator shall notify Project Coordinator in writing (email accepted) prior to the first day of work within the ROW that all project personnel who will access ODOT ROW have been trained. Until all ROW work is completed, the Project Investigator shall notify Project Coordinator in writing (email accepted) annually that an active safety training appropriate to the work to be performed within the ROW has been completed by all personnel who will work on ODOT ROW.

7.0 ASPHALT FACILITIES

The Iowa State University Asphalt Materials Laboratory is state of the art and contains research grade asphalt rheology equipment including Brookfield DV-II rotational viscometers, a TA Instruments CSA dynamic shear rheometer, a Cannon bending beam rheometer, a James Cox & Sons rolling thin film oven, an Applied Test Systems pressure aging vessel, and a Silverson L4RT-A high shear mill with two Glas-Col digital temperature controlled heating mantels capable of blending various additives/modifiers with asphalt binders. The ISU facilities contain all of the appropriate equipment including heating vessels, ovens, scales, and utensils. The next page shows some of the aforementioned equipment in the ISU facilities.

A Silverson Shear Mill for blending additives and polymers with asphalt binders and a Brookfield Rotational Viscometer for measuring the viscosity of asphalt blends

A James Cox & Sons Rolling Thin Film Oven for conducting short-term aging of asphalt binders with lignin and a Cannon Bending Beam Rheometer for characterizing the low temperature properties of asphalt binders

In addition to rheological test equipment, the asphalt materials laboratory also has performance testing capabilities for asphalt mixes. Compaction is performed using a Superpave Gyratory Compactor, the industry standard. Slabs can also be compacted using the linear kneading compactor. Slabs can be cut into beams and tested in the four point bending test. A universal testing machine contained within an environmental chamber allows for indirect tensile strength testing, dynamic modulus and flow number tests to be performed as well as a versatile control platform for the capabilities to set up new tests. The environmental chamber has the capabilities of low temperature tests such as the semi-circular bending test. The asphalt materials laboratory has the capabilities for AASHTO T-283 moisture conditioning using a vacuum pump, freezer and hot water bath equipment.

8.0 TIME SCHEDULE

This section specifies the time line for the project, listing the task headings and showing monthly and/or quarterly time blocks in which each task will be accomplished. Also shown are interim and final deliverables. (A sample matrix is shown on the following page.)

Task	**2014**		**2015**				**2016**		
	FY2015				**FY2016**				**17**
	Jul - Sep	Oct - Dec	Jan - Mar	Apr - Jun	Jul - Sep	Oct - Dec	Jan - Mar	Apr - Jun	Jul

1: Literature review						*																			
2: Identify field projects			*																						
3: Existing conditions						*																			
4: Field testing																					*				
5: Report																					R				F

*Deliverables
R - Draft report submitted for ODOT review.
F - Revised report submitted to ODOT for publication. End of contract.

9.0 BUDGET ESTIMATE

An itemized budget for the project is included here showing expenditures for each task by fiscal year and in total.

Task	FY15	FY16	Total
1: Literature review	$15,000		$15,000
2: Identify field projects	$10,000		$10,000
3: Existing conditions	$45,000		$45,000
4: Field testing	$30,000	$60,000	$90,000
5: Report		$15,000	$15,000
Total for tasks (Contract amount)			**$175,000**
ODOT support/management			
Total for ODOT			

The tasks are inclusive of all travel expenses incurred by the Institute for Transportation (InTrans).

A “blended” rate of Federal funds (SPR) and Oregon Department of Transportation (State) funds are used to finance the project.

10.0 REFERENCES

Aktaş, B., D.D. Gransberg, C. Riemer, and D. Pittenger, “Comparative Analysis of Macrotexture Measurement Tests for Pavement Preservation Treatments, *Transportation Research Record No.2209*, *Journal of the Transportation Research Board*, National Academies, 2011, pp. 34-40.

Arnold, G. and Pidwerbesky, B.D. Polymer-Modified Bitumens in Chip Seals for High Stress Conditions. *Proceedings Joint 18th ARRB Transport Research Conference and Transit NZ Land Transport Symposium*, Part 2, Christchurch, Sept. 1996, pp. 197-209.

Austroads. *Austroads Provisional Sprayed Seal Design Method*. Austroads, Sydney, Australia, 2004.

Galehouse, L., J.S. Moulthrop, and R.G. Hicks. Principles for Pavement Preservation: Definitions, Benefits, Issues and Barriers, *TR News*, September/October 2003, pp.4-9.

Gransberg, D.D., “Correlating Chip Seal Performance and Construction Methods,” *Transportation Research Record 1958, Journal of the Transportation Research Board*, National Academies, August 2006, pp. 54-58.
Gransberg, D.D., and D.M.B. James. *Chip Seal Best Practices*, National Cooperative Highway Research Program Synthesis 342, Transportation Research Board, National Academies, Washington, D.C, 2005.
Gransberg, D.D., S. Senadheera, and I. Karaca. Analysis of Statewide Seal Coat Constructability Review, Texas Department of Transportation Research Report TX- 98/0-1787-1R, Texas Tech University, Lubbock, Texas, 1998.
Gransberg, D.D., S. Senadheera, and I. Karaca. Calculating Roller Requirements for Chip Seal Projects, *Journal of Construction Engineering and Management,* ASCE, Vol. 130 No. 3, 2004, pp. 1-7.
Hicks, R.G., S.B. Seeds, and D.G. Peshkin, *Selecting a Preventive Maintenance Treatment for Flexible Pavements*, Report FHWA-IF-00-027, Foundation for Pavement Preservation and Federal Highway Administration, Washington, D.C., 2000, 87 pp.
Kearby, J.P. Tests and Theories on Penetration Surfaces, *Proceedings, Highway Research Board*, Volume 32, 1953.
McLeod N. W. “A General Method of Design for Seal Coats and Surface Treatments,” *Proceedings of the Association of Asphalt Paving Technologists,* Vol. 38, St. Paul, Minnesota, 1969.
Minnesota Seal Coat Handbook, MD/RC-2006-34, Minnesota Department of Transportation, Maplewood.
Pidwerbesky, B.D. and Pollard, J.S. The Design and Performance of Sprayed Seal Coats for Unbound Granular Pavements Carrying Heavy Logging Trucks. *Transportation Research Record: Journal of the Transportation Research Board, No. 1291*, National Research Council, Washington, D.C., 1991, pp. 66-71.
Pidwerbesky, B.D., D.D. Gransberg, R. Stemprok, and J. Waters, *Road Surface Texture Measurement Using Digital Image Processing and Information Theory,* Land Transport New Zealand Research Report 290, June, 2006.
Pittenger,D.M., D.D. Gransberg, M. Zaman and C. Riemer, ”Life Cycle Cost-Based Pavement Preservation Treatment Design,” *Transportation Research Record No. 2235, Journal of the Transportation Research Board* National Academies, 2011, pp. 28-35.
Roque, R., D. Anderson, and M. Thompson, “Effect of Material, Design, and Construction Variables on Seal-Coat Performance,” *Transportation Research Record 1300*, Transportation Research Board, National Research Council, Washington, D.C., 1991, pp. 108–115.
Shuler, S., Lord, A., Epps-Martin, A., and Hoyt, D. “Manual for Emulsion-Based Chip Seals for Pavement Preservation,” NCHRP Report No. 680, Washington, D.C. 2011.
Transit New Zealand (TNZ), C*hipsealing in New Zealand.* Transit New Zealand, Wellington, N.Z., 2005, pp. 84-86.
Transit New Zealand.(TNZ) *Specification for Improvement of Pavement Macrotexture*, TNZ P26, Wellington, New Zealand, 2003.
Transit New Zealand.(TNZ). *Specification for Resealing, TNZ P4*, Wellington, New Zealand, 1995.
Waters, J. **Retexturing Polished Surfaces Using the Watercutting Process,** *Fulton Hogan Ultra-High Pressure Watercutter* **CD ROM, Fulton Hogan, Ltd., Christchurch, New Zealand, 2004**