TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): ____Maryland Department of Transportation____________

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *TPF-5(285)*	**Transportation Pooled Fund Program - Report Period:** ☐Quarter 1 (January 1 – March 31) ■Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 1 – December 31)

Project Title:
Standardizing Lightweight Deflectometer Measurements for QA and Modulus Determination in Unbound Bases and Subgrades

Name of Project Manager(s): Rodney Wynn	**Phone Number:** 443-572-5043	**E-Mail** RWynn@sha.state.md.us
Lead Agency Project ID: *TPF-5(285)*	**Other Project ID (i.e., contract #):**	**Project Start Date:** January/15/2014
Original Project End Date: December/15/2015	**Current Project End Date:** December/31/2015	**Number of Extensions:** 0

Project schedule status:

☐ On schedule ☐ On revised schedule ☐ Ahead of schedule ■ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$371,984	**$ 51,452.35**	**13.8%**

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
36,049.52 **9.7%**	**$ 36,049.52**	**13.8%**

Project Description:

Currently, compaction control using lightweight deflectometers (LWD) is being evaluated in a number of states and fully implemented for pavement construction quality assurance (QA) in some states and countries. However, there is no widely recognized standard for interpreting the stiffness data obtained during construction QA testing and then relating these measurements to the material properties required for pavement structural design.

The principal objective of this research is to provide a straightforward procedure for using LWD for modulus/stiffness-based compaction control that is suitable for practical implementation by field inspection personnel. This procedure must (1) fully account for the influence of moisture on LWD measurements, (2) include the effects of stress state on measured modulus and the differences between the LWD induced stress state and the stress states induced by design traffic loads, (and 3) be applicable to LWD testing of half-space conditions (i.e., subgrade) and finite thickness layered conditions (i.e., granular base layers). This procedure must also take into account details like plate size, plate rigidity, and plate contact stress distribution that influence the stiffness/modulus measurements reported by the LWD.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

The first progress meeting was arranged and held on July-1st-2014. The meeting discussed the significant progress in Task 1, 2, and 3 and the next immediate steps in the project. Appendix A presents the presentation slides for this online meeting.

The project is slightly behind schedule with respect to the work plan.
The progress with respect to each Task is as followed:

Task 1. Literature Review (3.3% of the total effort). Percent completion of Task 1: 100%

Over hundred papers and dozen comprehensive reports have been reviewed. A significant progress on the literature review has been made during this reporting period. The personnel will continue the review of the current and upcoming literature when deemed necessary.

Project personnel participating in these activities: Schwartz, Khosravifar, Afsharikia.

Task 2. Equipment Evaluation (2.4% of the total effort). Percent completion of Task 2: 100%

Available devices for in situ stiffness and moisture measurement were evaluated in order to determine the most appropriate pieces of equipment for more in-depth laboratory and field evaluation.

The LWD devices selected for further evaluation include: Zorn ZFG 3000, Dynatest 3031 LWD, Olson LWD-1. We will try to borrow the Zorn LWD from either SHA or Kessler Soils Engineering Products; our fallback position is to rent the Zorn LWD from Kessler. The Olson LWD-1 will be provided free of charge by Olson instruments company. The current plan is to rent the Dynatest LWD for this stage of the research.

The moisture content measurement devices selected for further evaluation include: Oven drying (according to ASTM D2216), the Speedy 2000 moisture device (http://www.humboldtmfg.com/speedy_moisture_tester_.html), and the Ohaus MB45 moisture analyzer (http://us.ohaus.com/en/home/products/product-families/MB45-US.aspx). The Ohaus MB45 is a particularly attractive device that combines a halogen heater with an integrated weighing scale to provide a portable small-scale device that functions similar to oven drying. Moisture contents measured using the MB45 and oven drying for flyash fill materials showed excellent agreement (B. Christopher, personal communication). Additional comparisons between MB45 and oven dried moisture contents will be made as part of the present study.

Project personnel participating in these activities: Schwartz, Khosravifar, Afsharikia.

Task 3. Model Refinement/Development (12.6% of the total effort). Percentage completion of Task 3: 52%

Existing resilient modulus constitutive models are being assessed using the data in literature (Andrei, 2003, and Nazarian et al 2013). A particular focus is the incorporation of partially saturated suction effects on resilient modulus.

A simplified dynamic model for LWD response was developed to evaluate whether the drop load in the Zorn LWD is dependent on the soil stiffness. This is an important question because the Zorn LWD assumes and does not measure the peak load value. Preliminary results suggest that the peak load is in fact dependent upon soil stiffness over the range of interest.

Project personnel participating in these activities: Schwartz, Khosravifar, Afsharikia.

Task 4. Controlled Trials (18.8% of the total effort). Percentage completion of Task 4: 8%

The sole source justification is approved and the requisition is processed for purchasing the triaxial resilient modulus test kit for UTM-100 from IPC-Global. The unit will be shipped early August according to the latest communications with Instrotek, the IPC-global representative in the US. The laboratory tests are on hold until the arrival of the unit.

The methodologies that have been used by other researchers and manufacturers to assess the LWD accuracy, calibration, and the effect of LWD's different configurations were investigated. Finally, the beam verification tester (BVT) developed by Hoffmann (2004) was selected to compare the static stiffness measured by the 3 different LWDs. Arrangements have been made with John Siekmeier of Minnesota DOT for borrowing their BVT and shipping it to the UMD laboratory.

Project personnel participating in these activities: Schwartz, Khosravifar, Afsharikia.

Task 5. Field Validation (53.7% of the total effort). Percentage completion of Task 5: 0%

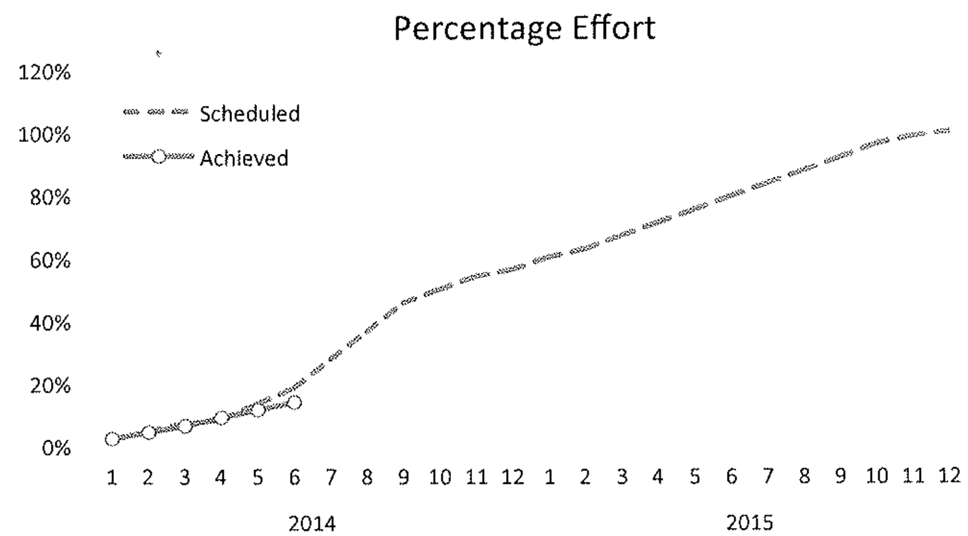
The initial round of field validation testing will focus on nearby projects in Maryland. A meeting will be scheduled with Dan Sajedi during the next reporting period to identify upcoming potential field projects in Maryland.

Task 6. Draft Test Specifications (3.3% of the total effort). Percentage completion of Task 6: 0%

No progress was made on this task during the reporting period.

Task 7. Workshop and Final Report (5.8% of the total effort). Percentage completion of Task 7: 0%

No progress was made on this task during the reporting period.



UMD personnel contact information:

1. Charles W. Schwartz- Principal Investigator, 301-405-1962, schwartz@umd.edu
2. Sadaf Khosravifar- GRA, 530-531-5030, sadafkh@umd.edu
3. Zahra Afsharikia- GRA, 202-747-4121, nafshari@umd.edu

Anticipated work next quarter:

- Continued monitoring and documentation of the literature.
- Acquiring (borrowing, renting, or purchasing) the selected moisture content and stiffness measurement devices for further evaluations. The procedures for evaluating and validating the devices and assessing their repeatability/reliability are described in the Project Work Plan.
- Task 3 and Task 4 will be the main focus of the next quarter.
  1. Parametric study using Hydrus-1 program. This study will evaluate how much drying can potentially occur within 24 hours after compaction on different soil types and under various climatic conditions.
  2. Evaluation of LWD devices using BVT.
  3. Laboratory resilient modulus testing.
  4. Soil box test.
- A meeting will be scheduled with Dan Sajedi during the next reporting period to identify upcoming potential field projects in Maryland.
- The Technical Advisory Committee will be polled for the potential field validation projects in each state (Task 5).

Significant Results:

I. **LWD device**: (1) LWD configuration (drop height, weight, buffer, plate diameter), (2) availability, type and location of sensors (w/wo load cell, accelerometer vs. geophone sensor type for deformation measurements, location of accelerometer or geophone to be on top of the soil or plate), and (3) assumptions and analysis formulas in calculation of modulus all have significant effects on the LWD measurements and reported results; many of these are documented in literature.

II. **Resilient modulus of soils:** The resilient modulus of soil in the field is dependent on several factors, especially the moisture at time of compaction and testing. Even though there is a great amount of information on the effect of moisture on resilient modulus of unbound material, most of the previous studies look at the long term and seasonal effects of moisture (and inevitably moisture at time of testing). Few studies differentiate the effect of moisture at time of compaction (which changes the structure of the soil) and at time of testing (which changes the amount of voids filled with water). In addition, the shortest time spans of moisture effects found in literature are on the order of days. However, QA testing is typically performed at most only few hours after compaction.

Task 4 and 5 will therefore focus on very short term changes in the moisture and the corresponding influence in modulus during the first 12 hours after compaction.

III. **Target modulus for LWD:** The differences between moisture at the time of compaction and testing, the presence of multiple materials in the zone of influence of LWD (multi-layer effect), the spatial nonlinearity of the soil modulus (due to spatial variation of effective stresses), and field spatial variability should be taken into account when setting the LWD target modulus.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

The work required to restore the MTS Teststar resilient modulus test system in the University of Maryland Pavement Materials Laboratory to adequate functioning condition has been evaluated. The estimated cost for is $42K+, which is prohibitively expensive and well beyond the budget allocated in the project for calibration and maintenance. The more effective approach is to add unbound resilient modulus test capabilities to our existing IPC UTM-100 asphalt testing system. The total cost for this upgrade is less than one-half the repair cost for the MTS Teststar system. An added benefit is that only one testing system will need to be maintained and calibrated moving forward. The project team therefore proposes to pursue this approach at no additional cost to the project. A detailed technical description of the unbound resilient modulus upgrade for the IPC UTM-100 is appended to this report.

Potential Implementation:

The use of LWDs for performance based construction quality assurance testing will not only result in a better product but also provide the quantitative engineering property values critical to better understanding the connection between pavement design and long term pavement performance. As the benefits of performance based quality assurance testing become more evident, more public agencies and private consultants are expected to acquire these tools and implement standardized procedures for their use. The products of this research will allow state DOT construction specifications to be modified to include LWDs as an option for construction quality assurance.

InstroTek, Inc.
5908 Triangle Drive
Raleigh, NC 27617
919.875.8371 (t)
919.875.8328 (f)

Quote

Estimate #:	13466
Date:	3/10/2014
Terms:	Net 30
Contact:	Maurice Arbelaez
Delivery:	4-6 weeks

MA

Customer:

University of Maryland
Sadaf Khosravifar
Dept. of Civil and Environmental Engineer
1173 Glenn L. Martin Hall
College Park, MD 20742

Item	Qty	Description	Rate	Total
IPC-0002-1400	1.0	Universal Triaxial Cell (UTC)	11,000.00	**11,000.00T**
IPC-0002-2096	1.0	Servo valve cable	90.00	**90.00T**
Misc. IPC	1.0	RLC-1t (+/-6kN) w/IMACS ILC Assembly	1,968.60	**1,968.60T**
IPC-0361-1428	1.0	150mm UTM Extension Shaft	250.00	**250.00T**
IPC-0361-1437	1.0	65mm UTM Extension Shaft	100.00	**100.00T**
		AASHTO T307/TP46 Setup (Unbound Granular Testing)		
IPC-0002-3552	2.0	LVDT (+/-5mm) with in line conditioner (ILC)	1,150.00	**2,300.00T**
IPC-0002-1721	1.0	External axial LVDT mounting kit	375.00	**375.00T**
IPC-0002-1421	1.0	100mm diam. X 200mm bottom platen assembly	345.00	**345.00T**
IPC-0361-1427	1.0	100mm diam. top platen	260.00	**260.00T**
IPC-0002-1420	1.0	150mm diam. X 300mm bottom platen assembly	330.00	**330.00T**
IPC-0361-1426	1.0	150mm diam. top platen	300.00	**300.00T**
		AASHTO T-307 Accesories:		
IPC-0361-1711	1.0	Unbound Red Poly Specimen (100mm dia x 200mm tall)	400.00	**400.00T**
IPC-0438-0067	2.0	100mm Porous stone	25.00	**50.00T**
IPC-0438-0248	2.0	150mm Porous stone	80.00	**160.00T**
		Consumables: Universal Triaxial Cell		
IPC-0438-0066	4.0	100mm latex membrane, sleeve	14.50	**58.00T**
IPC-0438-0065	1.0	100mm Sealing Rings	4.00	**4.00T**
IPC-0438-0246	1.0	150mm latex membrane, sleeve (pkg 1)	38.50	**38.50T**
IPC-0438-0247	1.0	150mm Sealing Rings (pair)	16.00	**16.00T**
IPC-0150-0205	24.0	Sample Prep Filter Paper 100mm	1.00	**24.00T**
IPC-0150-0206	24.0	Sample Prep Filter Paper 150mm	1.00	**24.00T**

Subtotal	
Sales Tax (0.0%)	
Total	

InstroTek® Inc.

InstroTek, Inc.
5908 Triangle Drive
Raleigh, NC 27617
919.875.8371 (t)
919.875.8328 (f)

Quote

Estimate #:	13466
Date:	3/10/2014
Terms:	Net 30
Contact:	Maurice Arbelaez
Delivery:	4-6 weeks

MA

Customer:

University of Maryland
Sadaf Khosravifar
Dept. of Civil and Environmental Engineer
1173 Glenn L. Martin Hall
College Park, MD 20742

Item	Qty	Description	Rate	Total
				18,093.10
IPC-Installati...		IPC - Remote Installation Support	1,000.00	1,000.00T
IPC-P	1.0	Packing: Triaxial Cell	350.00	350.00T
Shipping	1.0	Air Freight Melbourne, Australia to College Park, MD (door to door service) Includes all import taxes, duties and delivery charges (estimate only; subject to change)	2,500.00	2,500.00T
		** Due to the age and the high capacity of the UTM-100, IPC Global cannot guarantee the safety of a 10kN load cell. Therefore the University must purchase the 10kN load cell at their own risk. Should there be a glitch in the system and the load cell is damaged IPC Global/InstroTek will not take any responsibility.**		

InstroTek® Inc.

Subtotal	$21,943.10
Sales Tax (0.0%)	$0.00
Total	$21,943.10