Meeting Minutes of the Technical Advisory Committee (TAC) of the Pooled-Fund Study TPF-5(039) Falling Weight Deflectometer (FWD) Calibration Centers and Operational Improvements

April 27 – 28, 2004
Albany, NY

Participants/Attendees

FHWA & Contractors
Eric Weaver, FHWA/TFHRC, 202-493-3153, eric.weaver@fhwa.dot.gov
Michael Moravec, FHWA/ERC, 410-962-5623, mike.moravec@fhwa.dot.gov
Lynne Irwin, Cornell University, 607-255-8033, lhi1@cornell.edu
David Orr, Cornell University, 607-255-8465, dpo3@cornell.edu
Daniel Atkins, Cornell University, 607-254-8734, dla33@cornell.edu

TAC Members
John Amestoy, MT DOT, 406-444-7651, jamestoy@state.mt.us
William Barstis, MS DOT, wbarstis@mdot.state.ms.us
David Bullock, MN DOT, 651-779-5542, dave.bullock@dot.state.mn.us
Doug Chalman, TX DOT, 512-465-7653, dchalman@dot.state.tx.us
January Corn, KS DOT, january.corn@ksdot.org
Steven Henrichs, ND DOT, shenrich@state.nd.us
Mohammed Hossain, NY DOT, mhossain@dot.state.ny.us
Andrew Johnson, SC DOT, johnsonam@dot.state.sc.us
Charles Kinne, WA DOT, kinnec@wsdot.wa.gov
Tommy Nantung, IN DOT, tnantung@indot.state.in.us
Jason Omundson, IA DOT, jason.omundson@dot.iowa.gov
Eric Prieve, CO DOT, eric.prieve@dot.state.co.us
David Wassel, PA DOT, 717-783-4824, dwassel@state.pa.us

Other Participants
Gary Frederick, NY DOT, GFREDERICK@dot.state.ny.us
Rick Bennett, NY DOT, RBENNETT@dot.state.ny.us
Wes Yang, NY DOT, wyang@dot.state.ny.us
Julian Bendana, NY DOT, jbendana@dot.state.ny.us
Chuck Stuber, NY DOT, cstuber@dot.state.ny.us

Introductions and Initial Discussions
After a welcome and introduction from the New York State Department of Transportation, the status of the pooled-fund study was discussed. The main goal was to review the funding of the project and the role of the TAC. Eric Weaver led the discussion, which included the following items.

- Initial Pooled-Fund meeting established objectives, scope and prioritized items for inclusion in the Statement of Work for a 5-year contract.

- The first 2 years of the contract includes the following tasks:
    - Task 1: Communication, Coordination and Reference Resources
    - Task 2: Modify Calibration Process
    - Task 3: Hardware and Software Upgrades and/or Development
    - Task 4: Calibration System Testing, Installation and Operator Materials/Training
      Task 5: Presentation and Reporting
- Three option years exist to perform additional tasks. One of the primary roles of the TAC is to help define these items.
- At the time of the meeting, the study had received $615k in commitments and $505k in obligations from 15 participating states. Therefore, the first 2 years of the contract are fully funded, however the option years will require more funding to cover the needs of the research.

Presentation of the History of FWD Calibration and Current Project Status
Lynne Irwin gave a history and led the subsequent discussion. The highlights of the presentation and discussion included:

HISTORY AND USE OF CURRENT CALIBRATION PROTOCOL

- Original SHRP project objective: Develop long-term plans for FWD calibration
- Original SHRP goals for calibration procedure:
    - Assure comparability between SHRP and State-owned FWDs
    - Create a calibration testing environment as similar as possible to field conditions
- Types of measurement errors associated with FWDs:
    - Seating – reduced by performing several unrecorded drops
    - Random – reduced by performing repeated drops and averaging the results
    - Systematic – goal of calibration to reduce systematic error to 0.3%
- Load cell calibration: done in a single step since the consequence of FWD load cell inaccuracy is relatively small for backcalculated moduli.
- A deflection reading in the range of 400 to 600 microns (16 to 24 mils) enables detection of the systematic error without it being masked by the random error
- Reference calibration of geophones: assures each sensor is random about the true reading
- Relative calibration is a statistical design that completes the geophone calibration. It assumes the overall average deflection in the calibration stand is a good estimate of truth.
- Beam movement: less than 2 microns is attributed to random noise. If the beam moves more than 2 microns, the reference calibration should be redone. The SHRP budget for FWD calibration did not allow for direct measurement of beam movement.

PROBLEMS ASSOCIATED WITH THE CURRENT CALIBRATION PROCEDURE:

- The DOS program developed for the current protocol is no longer compatible with ‘modern’ computers.
- The ISA bus is no longer an industry standard.
- The DAS-16G data acquisition board is no longer manufactured.

After the presentation, Prof. Irwin posed the following questions for discussion to the TAC:

1. Should we develop a 450 mm diameter load cell?

2. Should we develop a special high capacity load cell for HWD's?
3. Are there any special provisions that should be made to accommodate truck mounted FWD's? (The TAC felt there were no special provisions needed.)
4. How can we meet the current specifications when calibrating KUAB FWD's?
5. Should we modify our standard procedure to accommodate the JILS FWD? The large mass with small drop height does not allow enough time after mass is released for the system to settle properly. There can be too much noise in the data collected.
6. Is noise in the data at low drop heights a common problem for all types of FWD's?
7. How often do sensors fail to pass the linearity check (0.0020 std error)? Is the problem more common with certain types of FWD's?
8. What FWD calibration problems are ***NOT*** addressed by the approach discussed today
9. What should be the goal for the speed of calibration?
10. How many calibrations per year do center operators need to perform to remain proficient?

These issues were discussed during the meeting and the recommendations are summarized at the end of these minutes.

Presentation about the Building of the Cornell University Isolation Slab

David Orr presented the highlights of the installation of an isolation slab at the Cornell Local Roads Program laboratory. The goal was to provide some information on progress made by Cornell and also to illustrate some of the issues that need to be discussed when an isolation slab is installed. **Action Item #1: Eric Weaver post presentations on the pooled-fund web site by July 8, 2005.** Highlights of the presentation and discussion included:

- The design and construction of the isolation slab.
- How to determine optimal slab thickness vs. fatigue life. (A 5-inch thick slab provides the desired 400 – 600 microns of deflection. Less than 5 inches runs the risk of fatigue failure.)

Marketing ideas to promote the continued funding of the project:

Eric Weaver led a discussion on ways to get additional funding to cover all of the costs of the project including the future items in Task 6.

- Target the funding agencies, legislators, and upper management
- Use economic comparisons to illustrate the benefits and savings of a calibrated FWD
    - Eric requested case studies of FWD projects that support the cost/performance benefits including the scope and the nature of the project
    - Effect of FWD results on overlay design
    - Reduction in data variability due to regular calibration
    - Policy of requiring FWD analysis on all roads where the AADT exceeds a threshold
    - Use of the FWD analysis to predict remaining service life.
    - Agency cost vs. user cost
    - Suggest as a NCHRP study

- Explain role of FWD use with the new pavement design guide. Perhaps this could be coordinated with future M-E Design Guide Implementation Workshops.

Bill Barstis mentions that ARA is working with MS DOT to implement the M-E Design Guide, and that he is interested in using backcalculated M_r results from FWD measurements into their efforts.

Action Item #5: TAC send Eric Weaver ideas for projects or areas of practice where the cost benefit of FWD calibration could be demonstrated – by August 31 2005.

TAC Discussion of Project Status

Eric Weaver led a discussion of the project status. Highlights, questions, and ideas included the following.

- Should there be development of new calibration centers, so that some states do not have to travel as far?
    - UC Davis has expressed an interest in installing a calibration center
- What is the funding for new (and existing) calibration centers?
- Should the calibration procedure be expanded to include lightweight deflectometers?
- How about using a programmable shaker table to calibrate the geophones?
    - Valid for comparison using a generated wave
    - Texas DOT has done considerable work with geophones and shaker tables
    - Would eliminate the need for the beam and block

There was a question about how much error is acceptable in terms of FWD measurements. Lynne Irwin explained that he was involved in research that indicated very small errors in deflection measurements resulted in large errors in backcalculation results. These results were less sensitive to errors associated with load. Bill Barstis requested a copy of the paper resulting from Lynne's research.

Action Item #4: Lynne Irwin send Bill Barstis a copy Irwin, L. H., Yang, W. S., and Stubstad, R. N. "Deflection Reading Accuracy and Layer Thickness Accuracy in Backcalculation of Pavement Layer Moduli." Nondestructive Testing of Pavements and Backcalculation of Moduli, American Society for Testing and Materials, Philadelphia, PA, 1988 **by June 2005.**

There was a discussion about the value of the geophone time-history signal. Lynne indicated that his understanding is that the geophones re-zero themselves to reduce errors accumulated during the velocity to displacement integration process. Therefore signal existing after the first 25ms may not be of much value. How will signal integration errors affect the ability to utilize accelerometers for reference deflection devices?

Breakout Session

The TAC separated into two groups with the goal of prioritizing the Phase 2 (Task 6) objectives of the project. The combined TAC then reviewed the items and helped generate a final priority list. The results of the combined efforts are summarized below with a 1 being the highest priority and a 3 being the lowest.

Item #	Priority	Task 6 Items
1	1	Documentation by owner of FWD maintenance conducted prior to Calibration visit (more detailed and unified for all centers)
2	1	FWD reproducibility (multiple FWDs)
3	1	Long term funding mechanism for the calibration centers
4	1	Central help line or website for FWD/CC issues (part of calibration database?)
5	1	Calibration center repeatability (round-robin testing)
6	1	Calibration center operator training
7	1	Detailed FWD maintenance guide including a pre-calibration checklist and troubleshooting (details need to be applicable for all brands of FWDs)
8	1	Establish FWD calibration database
9	1	Certification of centers and center operators
10	1	Guidelines for on-site sensor replacement/verification in the field
11	1	Marketing video including a comparative worth statement for calibrated FWDs
12	1	What to do when the FWD does not pass calibration requirements (a guide for the cal. center)
13	1	Calibration of A/D board and signal conditioner
14	1	Training of the FWD operators that come to Cal. Ctr. Intended to ensure the operator knows what is expected of them when they arrive at the calibration center.
15	1	Computer based, just-in-time, training for FWD operators and center operators
16	1	Develop portable calibration/verification equipment (take the knowledge from tasks 1-5 and try to make it portable)
17	2	Relative calibration changes: stand with automatic down-pressure, shorter stand for seismometers, quicker procedure, ensure verticality

Item #	Priority	Task 6 Items
18	2	Modify concrete block design to allow easier access for some FWDs
19	2	Examine safety and ergonomics of calibration procedure
20	2	Indoor/Outdoor calibrations? (Temperature sensitivity issues)
21	2	Impact of non-calibrated FWDs on backcalculation
22	2	Build 18 inch (450 mm) diameter load cell
23	2	Look at whole time history (pulse length) in pavement analysis
24	2	Create maintenance videos for all types of FWDs
25	2	Information to setup all brands of FWDs for center operators to conduct calibration
26	2	Perform dynamic calibration of LVDT
27	2	Reduce distance to calibration center for SHAs
28	3	Calibrate the velocity transducers in velocity mode
29	3	Calibration of FWD accessories (IR temperature sensor, DMI, pavement temperature probe)
30	3	Encourage international participation
31	3	Investigate the use of a flush load cell design
32	3	Monitor the stabilization of sensors between drops
33	3	Develop reference test pads to calibrate FWDs in place
34	3	Dynamic analysis of calibration procedure
35	3	Inclusion of GPS and PDDX formats
36	3	Multipurpose calibration centers (expanding the scope)
37	3	Perform deflection sensor reference calibration verification with a shaker table
38	3	Use polynomial (non-linear) regression for gain setting

Item #	Priority	Task 6 Items
39	3	Backcalculate data from a series of FWD test over time to determine the effect of calibrations on the underlying materials parameters of the slab

During the breakout session, there were some additional items for future consideration:

- Effect of uneven surface on FWD data collection
- How critical is an "Independent" calibration vs. self-calibration if portable calibration equipment sets are developed?
- What are the effects of a split load plate vs. a solid load plate?
- Training for FWD Backcalculation and Temperature Correction (Computer based training?)
- Workshop on FWD Data for input to new mechanistic-empirical pavement design guide?

Several questions were raised in the discussions during the breakout sessions. The questions (and answers if applicable) and other statements following the breakout session are listed below.

- There was much discussion about where the future funding of the calibration centers might come from.
    - Use income generated from the calibrations as a funding source
    - Would DOTs pay for calibration?
    - Proposed possibility of a pooled-fund type of funding source
- What information should be reported about the calibrations?
- Development of a steel and spring structure to compare FWD response was discussed. The goal would be to have a device whose deflection properties would not change with repeated drops of the FWD mass, as pavements do.
- It is not recommended to bring all of the FWD manufacturers together for a discussion of the changes to the protocol, but rather keep up individual contacts.
- Would calibration centers be willing to provide FWD operator training? How about calibration center operators' training?
- Would a DVD or video be enough to prepare FWD operators for getting an FWD calibrated?
- It was agreed that 6 – 7 calibration centers across the U.S. would sufficiently cover the entire country
    - The calibration center at the DYNATEST facility in Florida is a possible source as well
- There is interest for a workshop about how FWD data will be used in conjunction with the new pavement design guide.
- A reference to the ASTM Standard for FWD Calibration should be incorporated into the Calibration Center QA Review memos to the calibration center operators and FHWA.

Answers to Outstanding Questions and Further Ideas

The following recommendations were made in response to Prof. Irwin's questions in the opening presentation.

1. How fast should the calibration procedure be completed? 3 hours or less
2. Do we need a 450 mm load cell?
    a. Federal Aviation has the only known FWD with a larger load plate. Not a high priority.
3. How to handle Heavy Weight Deflectometers (HWDs)? Would calibrating over the current range of loads be OK?
    a. Would the HWDs react the same without the weights? DYNATEST indicates that they do not foresee problems.
    b. Not many HWDs are seen at the calibration centers.
    c. The TAC agreed to place the development of a load cell for HWDs as an item for Task 6.
4. Should there be a modification to the calibration procedure to accommodate one particular manufacturer of FWDs?
    a. JILS modified their software to accommodate current calibration procedure.
    b. JILS uses two programs; one for the field and another for calibration.
    c. JILS are known to have problems at the 6,000 lb load level during calibration . This may be because the duration of time for the mass to fall is so short that the sensors have not had adequate time to stabilize, or that the calibration software picks a zero value from the signal generated during the ground rebound phase.
5. Calibration center operators have not had problems calibrating truck-mounted FWDs with the current setup and procedure.
6. It was suggested that the calibration protocol be changed to require 20 test points at four different load-levels between 6,000 lbs and 20,000 lbs.
7. It was also suggested that a range of deflections be specified for deflection calibration, allowing for the adjustment of load level to accommodate the required deflection.
8. How often do sensors fail the linearity check? Is it more frequent with certain types of FWDs?
    a. Seismometers fail more frequently.
    b. Flexibility in load-levels should help reduce linearity failure.
9. How many calibrations per year are needed to maintain center operator proficiency?
    a. 10 – 12 calibrations per year at a minimum.

TAC Selection and Future Meetings

Size of the TAC: It was decided that the TAC should be comprised of one representative from all participating agencies available to attend the meetings; rather than create a smaller working group.

Tentative Next Meeting: Sunday morning of the FWD Users Group meeting (Austin, TX, October 19, 2005).

The meeting would consist of a progress report/update for those members already attending the Users Group meeting; those members unable to attend would receive an update by email and meeting minutes.

A closed session of just the FHWA and TAC was held. Topics included:

1. Progress of the study with respect to the timeline in the contract
2. Their individual contributions, as reflected in the Fiscal Management Information System (FMIS)
3. Future participation; recommended annual commitments to address priority work items.
4. Participant satisfaction with study progress.
5. Participant interest in maintaining or hosting additional FWD calibration centers.

Meeting was adjourned at 12:00 Noon on April 28.