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, 2006
Denver, CO

Participants/Attendees:

FHWA & Contractors

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TAC and Other Participants

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Introductions and Initial Discussions:

Eric Weaver led the initial discussion and laid out the following as the main topics for the meeting:

- Study participation
- Financial status
- Progress to date
- Future work

There were no additional agenda items added for this meeting.

Critical points of study:

- Initial calibration procedure successful
- Nationwide trend toward mechanistic design

- Future funding of calibration centers – how?/who?
- Technical support for calibration centers

To date pooled-fund study funding:
(definitions: commitments = money promised, obligations = money paid).
A handout was provided illustrating the current commitments for the pooled-fund study on a state-by-state basis.

- California and Georgia recently contributed to the study
- The first of three option years in the contract begins in September 2006
- Currently $10k in bank and $95k promised for 2006
- All questions about commitments should go through Eric Weaver
- 100% federal dollars can be used for commitments and obligations w/o state matching funds. Although, states can use 80-20% funds or any other combinations if they wish.

  Q – Isn't future money needed to fund the calibration centers?
  A – in-place contract can be used for the term of the pooled-fund study; 2006-2009

Ninety days before the conclusion of the project, decisions on work items for the first option year must be made in order for the option year to be exercised. That date is June 8, 2006. The option year work items will be made during the second half of this meeting.

Eric Weaver will solicit other states to participate, though he encourages state-to-state solicitation.

- FWDUG may be a good list of contacts
- Research Directors of every state receive email from the pooled fund study website.
- Talk to FHWA division pavement and planning engineers

Technical support is approximately $40,000/year for the four SHRP/LTPP regional calibration centers. This includes technical support, quality assurance checks, a calibration center operator meeting, travel and reporting.

Presentation of the Current Project Status:
Lynne Irwin presented an overview of the past TAC meetings, reviewed the main goals of the project, and discussed the progress to date of the project. Following is a brief outline of the presentation.

Progress to date:

- Database of SHRP calibration procedure results for comparison to the new procedure
- FWDREFCL converted to VisualBasic 6
- USB data acquisition board (DAQ)
- PDDX file conversion tool for electronic transfer of data
- Multi-sensor calibration stands

Remaining Work in contract base period (9/2004-9/2006):

- Approval from COTR

- Distribute hardware/software and training for the 4 SHRP/LTPP calibration centers (PA, MN, TX and CO) (planned for late July, early August)
- Final Report

Types of measurement errors accounted for in the calibration procedure:

- Seating – do several unrecorded drops
- Random (repeatability) – reduced by averaging multiple drops
- Systematic (bias) – reduced by SHRP calibration and is the focus of the pooled-fund study

We want to reduce the systematic error to be less than the random error for all normal deflections encountered in the field.

The test pad should provide deflections in the 20±4 mils range at the 16 kip load level.

Reference Calibration objectives:

- Assure that each sensor is random about "truth" (e.g., the "correct reading")
    - This is fundamentally important for understanding the calibration procedure
- Requires an unbiased reference sensor and an unbiased calibration stand
- Earth gravity introduces a bias in the accelerometer readings, which is removed during subsequent data processing (similar to the "average zero" correction in the current procedure)
- Position in the stand, if significant, introduces a bias

Relative Calibration objectives:

- Collect large pool of data using all sensors
- Overall average of data collected is a good estimate of the correct deflection (if the reference calibration is unbiased)
- Overall Average (of all sensors)/Individual Sensor Avg = Cal Factor

Many problems encountered during calibration can be attributed to poor maintenance of the FWD. (Dave Bullock pointed out that in the past, the MnDOT center has had major electrical and RF interference issues. Center has recently relocated.)

Current calibrations take about 6 hours. Revised procedure takes less than two hours. (The goal set at the April 2005 meeting in Albany was to get it under three hours.)

Ways to speed up process:

- Do reference calibration of all sensors simultaneously
- Eliminate manual entry of data
- Eliminate or reduce sensor rotation during relative calibration

Accomplishments:

- Calibration software (WinFWDCal) nearly finished

    - Using spreadsheet version with similar functionality to fine tune the procedure based on evaluations with the different equipment types.
- PDDX file conversion software nearly finished
    - Electronic transfer of data using thumb drive
- Purchased and implemented Keithley KUSB 3108 16-bit DAQ board
- Purchased and implemented Silicon Designs model 2220, +/- 5g accelerometer
- Using existing Vishay model #2310 signal conditioner

Problem encountered - Platter design for simultaneous deflection sensor calibration:

- Design provides good clearance for FWD (can get close to load plate)
- Results showed erratic roll and pitch causing data to be inconsistent and out of phase
- Had to go to a columnar design to avoid roll and pitch problem

Columnar stands for simultaneous deflection sensor calibration:

- Stiffness of stand is essential (to reduce significance of position)
- Sources of error include
    - Geophone error (this is what we are calibrating for)
    - Position in stand error
    - Set error (all sensors are in all sets, so no problem)
    - Unattributed error (should be quite small, less than 2 microns)
- Stand comparisons were discussed
    - Range of error due to position (stiff stands better)
    - Effect of hold down method (bolted to test pad better)
    - Effect of down pressure on stand (some human involvement reduces error)
- Several stand designs have been found to have less than 0.5 micron error due to position
    - The error is statistically significant in some cases, but not practically significant
    - These designs have an unattributed error less than 2 microns

The KUAB seismometer stand design has two columns of sensors:

- Shelf level and column errors analyzed
- Analysis of variance
    - Shelf level was not statistically significant
    - Column position statistically significant (solution is to interchange columns)

Reference calibration observations:

- Accelerometer
    - Unbiased device when correctly calibrated (use Earth gravity to calibrate)
    - Accuracy is 2 –3 microns (comparable to the LVDT/beam movement error in current procedure)
    - Locate accelerometer at mid-height of stand (to minimize error due to position)
    - Position in stand adds small bias (0.5 micron or less) when sensors are not rotated
    - Position in stand adds no bias if sensors are rotated (since all sensors are in all positions for an equal number of drops)
- Dynatest and JILS – rotate sensors top to bottom to correct for position
- KUAB – rotate sensors left to right to correct for column effect

Relative Calibration observations:

- 500-micron (20 mil) deflections hard to achieve
    - Locate the test point closer to the edge of the test pad (about 1 foot from edge)
    - Couple the stand directly to the test pad
- Full rotation of sensors eliminates stand-position bias

Tentative Protocol (subject to change)

- Continue to use the current load cell calibration procedure and hardware
    - May need to calibrate the reference load cell to 25,000 pounds (instead of 20,000 pounds) to accommodate the JILS static load level
- Perform reference and relative calibrations jointly in one procedure
    - Use the accelerometer as the reference device
    - Calibrate the accelerometer on the day of use
    - Multisensor stand for simultaneous deflection sensor calibration
    - Electronic transfer of data
- Reference calibration
    - 18 to 24 drops at a minimum of 3 drop heights (load levels) achieving 500±100 microns at the highest load level
    - Run two reference trials, one trial with the sensor 1 at the top of the stand and sensor 9 at the bottom of the stand, and the second trial with sensor 9 at the top of the stand and sensor 1 at the bottom (for Dynatest, JILS and Carl Bro)
    - Run two reference trials, rotating the stand 180 degrees (KUAB)
- Relative calibration
    - 40 drops without rotation in the stand at 500±100 microns deflections
    - Reverse sensors and repeat (same rotation as for reference calibration)
    - This will provide an overall pool of 720 observations for a 9-sensor system, versus 405 observations in the current procedure, and 80 observations per sensor, versus 45 currently, thereby strengthening the procedure with less time involvement
- Data Analysis
    - Transfer data from FWD electronically (using PDDX file format)
    - Software would compute interim gain factors for reference calibration and adjust relative calibration results internally (no need to enter interim gains in the FWD)
    - Software would compute the means ratios and calibration factors
    - Transfer final gain factors to the FWD computer electronically
        - Currently the FWDs do not have a means of reading the file, so manual entry of final gains will continue to be used, awaiting changes in the FWD data collection programs
- Quality Assurance
    - Downward accelerations should not exceed 4g's (software to check for this)
    - Compare the final gain factors to past calibration results
        - Historical calibration results will be distributed annually in a database
        - Accept results if the calibration factors have not changed by more than 1 percent from last calibration
        - Accept results if they are between 0.98 and 1.02

- Results are acceptable if *either* criterion is satisfied
- Provide certificate of calibration
- FWD should be calibrated annually
- Relative calibrations should be done monthly by owner

Points left for further discussion by TAC:

- Full rotation completely eliminates the bias due to position in the stand
- Should we offer two separate levels of calibration?
    - Level 1 - Full rotation
    - Level 2 - Simple (flip) rotation
    - FWD owner would choose which procedure to use

Questions, observations, and issues about progress to date

Q - Can the lower load levels be used for testing (i.e., 6,000 lbs) if not used during calibration?
A – A linearity check during reference calibration (i.e., the standard error of the adjustment factor) assures that the calibration factor is applicable over the full range of deflections seen in the field.

Q – Will equipment schematics be available with the draft report?
A – Yes.

Q – At what point in the procedure will it be determined that a sensor is worn out or failed?
A – Because the procedure goes so quickly, it will report sensor failure at the end, after relative calibration is completed. We are planning to do the data transfer from the FWD in one step at the end of the procedure. It could be done in two steps, once at the end of the reference calibration and then again at the end of the relative calibration. (We believe most FWD owners will want to continue to the end of the procedure, even if reference calibration flags a bad sensor.)
TAC comment - The TAC wants the procedure to work this way (i.e., two steps). This allows the FWD owner to substitute a new sensor and restart the procedure. Irwin agreed to make that procedural change.

The afternoon portion of the meeting shifted locations to the Colorado Department of Transportation facility:
Eric Prieve provided the TAC with a tour of the new Colorado Department of Transportation facility.

Presentation about JILS FWD Calibration:
Ed Trujillo discussed common problems, and their solutions, encountered when calibrating a JILS FWD.

- Vehicle preparation
    - Pre-calibration checklist
    - Exhaust system in good order

    - Hydraulic connections not leaking
    - Hydraulic pressure at correct levels
    - Air bags pressurized to correct level
    - Recommends annual replacement of rubber spring buffers
- Computer preparation
    - Uses a memory stick for reporting and data transfer instead of a printer and manual transcription
    - The file setup.par holds the gain factors and sensor channels
    - Sensor files must be in both the JCal and JTest directories
- Run a force calibration according to the JILS procedure after warm-ups, adjusting the force, adjusting the sensors, changing setup.par, and performing a relative calibration. Use 9,000, 12,000, 15,000, and 18,000 lbf load levels
- Calibration of load cells requires an initial static load of 250 to 300 bits (i.e., 2500 to 3000 pounds) before the three seating drops are applied
    - Static load is applied by pressurizing the air bags
    - Be sure to check for clipping of the peaks from the reference load cell at the highest load level

Q – How large a change in the calibration factors is allowed?
A – Contact JILS

Presentation about KUAB FWD Calibration:
Dave Wassel discussed common problems, and their solutions, encountered when calibrating a KUAB FWD.

- Vehicle Preparation
    - Pre-calibration checklist
    - General functionality
    - FWD operator must bring a spare parts kit, tools, and a voltmeter
- Seismometers must be statically calibrated before dynamic calibration
    - The LVDT is statically calibrated by a micrometer that is inside the seismometer casing
    - The LVDT must pass a linearity check
- Software
    - The *.ini file has all KUAB setup information
    - The DOS and Windows *.ini files are different and not compatible
    - Some KUABs use the DOS field program and some use the Windows program
- Load Cell calibrations
    - Duct tape is used to increase the vibration when the load is dropped, and trigger the data acquisition system (this will change with "about triggering" in the new calibration procedure)
- Seismometer calibrations
    - Difficulty getting load plate close enough to the beam
    - Maximum deflection usually around 9 mils at 16,000 lbf
    - Smaller deflections result in greater adjustments in the calibration factors from year to year
    - Drop sequence is performed manually

- FWD Time History Files
    - Seismometer time histories used to check for beam movement
    - FWD load cell time histories used to detect load cell malfunctions
- Standard error of the adjustment factor is approximately 0.0020
- The setscrews used to hold the seismometers on the stand strip easily

Demonstration of the current reference calibration procedure:
Daniel Atkins and Ed Trujillo performed a demonstration reference calibration using the Colorado DOT JILS FWD.

- The reference calibration (9 sensors) took about 20 minutes
- The deflection sensors were loaded in the stand from the top down with sensor one in the top position and sensor nine in the bottom position.
- Accelerometer s/n 278 was used
- The accelerometer was calibrated during the demonstration

Future funding options:
Eric Weaver led the discussion about future funding options for calibration center support and the pooled-fund study.

- A handout was provided with some potential ideas for future funding sources
    1. Continuation of pooled-fund study
    2. Establishment of mechanisms through state highway agencies to allow calibration center to charge a fee for calibration and apply that fee to the needs of the calibration center
    3. Transfer of control of the calibration center support and certification to a central agency, such as AASHTO
    4. Establishment of an independent organization to provide oversight for pavement monitoring equipment such as FWDs, road profilers, and skid testers

There was some discussion about these options and the following others were raised:

- Incorporate the FWDUG to manage the calibration center support and certification
    - As an all volunteer organization, the incorporation of the FWDUG would take a significant amount of work
    - The concept would require the commitment of a significant amount of time for management
    - Other potential support partners mentioned include NIST, TRB, and NCHRP. NCHRP charges an 8 percent administration fee to manage pooled-fund studies
    - The non-profit organization could hire someone to take the management burden off the board of directors.
    - **Action Item 1: Doug Chalman, who is the current FWDUG Chairman, agreed to raise the proposal during the 2006 Annual meeting in Helena.**

- Tie calibration of FWD to design work
    - FHWA mandate that design work on Federal Aid projects be done using a calibrated FWD
    - Office of Pavement Technology (FHWA) would be first resource for information on that option.

Q - Can FWD work be looked at along the same lines as material testing?
A – Material testing is for acceptance, FWD provides preliminary analysis data, so they are not in the same category

Q - If the pooled-fund study was sufficiently funded, could a contract be made to support the centers?
A – Yes, as is the case with the current contract. However, pooled-fund studies are not meant to provide a service and they are meant to be limited to discrete time periods.

- An example, inconsistent with the statement above, is the pooled-fund for the SuperPave center in Indiana, which is state-run (managed) and has continued for a long period of time
- It was suggested that more information about the demand for the calibration centers should be garnered through:
    - Questionnaire to all fifty states being created to solicit funding for the future of calibration centers
    - A synthesis statement has been submitted to NCHRP about FWD usage. If approved, then they will manage the survey
    - Issue a survey through AASHTO
    - Use the listserv for State Research Directors (all fifty states and the Canadian providences)
- TAC favors the continuation of the pooled-fund study for calibration center support and certification because of ease with which states can contribute and the lack of effort to administer the program.

TAC brainstorming of Task 6 activities
Each member of the TAC was asked to identify their top three priorities for the option years of the contract. The list of Task 6 ideas generated at the TAC meeting in 2004 in Albany, NY was referenced while new ideas were also welcome. Voting tallies are listed in table 1 with further discussion following.

Item #3: Long-term funding mechanism – investigate and recommend options
Item #9: Certification of centers and center operators

- Develop a quality assurance procedure
- Conduct certification of centers and center operators
- Benefits of annual FWD calibration
    - Detection of failed equipment and components
    - Accurate measurements used for design can save money and/or determine correct layer thickness

Table 1: Priority Task Voting Tallies

Item #	Brief Description	Votes
3	Long-term funding mechanism for calibration center support	16
9	Certification of centers and center operators	11
6 & 15	Calibration center operator training	6
16	Develop portable calibration/verification equipment	4
7	Detailed FWD maintenance guide	2
11	Marketing video including a cost/benefit statement for FWD calibration	2
12	Calibration center operator's guide for calibration failure options	2
21	Impact of non-calibrated FWD on backcalculation	2
2	FWD reproducibility	1
13	Calibration of A/D board and signal conditioner	1
27	Reduce distance to calibration centers for state highway agencies	1
New	Backcalculation workshop	1

Item #2: FWD reproducibility

- Reproducibility is defined as the ability to produce similar results with different FWDs or the same FWD at a different location
- Texas has studied this extensively and developed an alternative calibration procedure to improve the reproducibility of their fleet
- The changing characteristics of pavement under continued loading test creates difficulties when trying to compare one FWD to another

Voting results were combined into three general categories and prioritized

1. Technical Support: item #6, #9, #12, #13, #15, #27
2. Center Funding: item #2, #6, #7, #11, #12, #13, #15, #16, #21, and BC Workshop
3. Product development: item #3, #11, #21, #27

A brainstorming session followed to determine the activities that fall under the role of technical support.

- Hardware purchase and production
- Reference load cell calibrations
- A/D board calibration
- Software support
- Calibration center operator training
- Telephone support, e-mail communications
- Hardware maintenance
- Documentation
- Peer information exchange
- Installation of new centers
- Database of past calibrations update and periodic reissue
- Maintain a resource and vendor list
- PDDX conversion (liaison with FWD manufacturers)

Action Item #2: Eric Weaver will categorize and organize the technical support items and ask the TAC for feedback. July 31, 2006

Action Item #3: Eric Weaver will determine an estimate of annual costs associated with the maintenance and certification of the calibration centers. Cornell will develop equipment cost estimates. July 31, 2006.

Action Item #4: Eric Weaver will research how obligations are handled by the FHWA District Offices and report back at the FWDUG meeting in 2006.

Action Item #5: Eric Weaver will draft a letter and make phone calls requesting additional funding or new funding for calibration center support. The TAC will provide Eric with appropriate contacts. June 30, 2006

Action Item #6: Cornell will determine which states have used the calibration centers from 1993 through 2004 and provide Eric with the list. June 15, 2006

Action Item #7: Eric Weaver and Tommy Nantung will develop a questionnaire to be passed out through the listserv used by state research directors. June 30, 2006

Action Item #8: Tommy Nantung, John Amestoy, and Doug Chalman agreed to provide Eric Weaver with testimonials about how calibrated FWDs have benefited their states. July 15, 2006

Action Item #9: Eric Weaver will ask Cheryl Richter to schedule a box session at the TRB meeting in January 2007 to report on the new FWD calibration procedures and other efforts of the pooled-fund study, other State Highway Agencies and the FHWA. May 15, 2006

Miscellaneous Items:

- Software name – TAC voted to keep the current software name of WinFWDCal
- Main purpose of the pooled-fund study, under the 2004-2006 base period, is to update the calibration procedure. The main objective under the option years (2007-2009) of the pooled-fund contract is to establish long-term support mechanism for the calibration centers.

  Q – If there is no long-term funding of the calibration centers, what could happen?
  A – Centers would either close or support themselves

  Q - Can the interpretation of FWD data in pavement design be included in an NHI training course?
  A – Not likely. NHI offered such a course for several years in the mid-1990's, but it was dropped due to lack of interest from the states. It was difficult to get enough people for the course in any single state. Regional workshops on data interpretation may be more feasible. Perhaps the FWDUG could offer something along those lines?

The open meeting adjourned at 10:15 AM on April 28, 2006.

A closed session of the TAC was held following the open meeting.

The next meeting will occur Sunday, September 17, 2006 from 9:00 am – 11:30 am in conjunction with the FWD User Group Meeting. As was the case last year, this meeting is intended for those TAC members already planning to attend the FWD User Group Annual Meeting and no study funds will be used to pay for TAC members travel, lodging or per diem.