# FWD (Falling Weight Deflectometer) Testing Guide

## General Description

To measure the response of a pavement layer or system to a dynamic load, MnROAD has used a device known as the Falling Weight Deflectometer or "FWD." Measurements with the FWD have been obtained both routinely (on a monthly or seasonal basis), and also for specific load test studies and sensor response verification.

The FWD device consists of a loading plate, weight package, geophone sensors, and data acquisition equipment. Mounted to a trailer, the equipment is designed to simulate the impulse load of a passing wheel. As the weight package is lifted (hydraulically) and dropped (free fall), the plate applies a dynamic load to the pavement; simultaneously geophone sensors (spaced at specific distances from the load plate) capture the resulting deflection basin. The deflection basin can be used to evaluate the structural capacity of the system as well as back-calculate the modulus of the underlying layers.

## Equipment

Since 1994, the standard FWD device used at MnROAD is the Dynatest Model 8000. Older versions of the operating control software were written in Microsoft DOS®. In 2008, a switch to Microsoft Windows® based control software was made. Output files are now in Microsoft Access® database file format.

Note that the location of the geophone sensors, relative to the center of the loading plate, has varied. Users need to verify the geophone sensor spacing for each FWD test before analyzing the data. As of May 2009 we have used 10 sensors and they are numbered and located at the following offsets:

| Sensor Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Distance (in) | 0 | 8 | 12 | 18 | 24 | 36 | 48 | 60 | 72 | -12 |

## Software

FWDWIN will be used for all MnROAD FWD testing for March 2008 and beyond. It uses Dynatest Control Center to operate the system. The MDB files (custom setup) were developed in conjunction with the Pavement Design Office so that both MnROAD and MnDOT State testing could be completed and put into a common database using loaders developed in 2007 (modified 2008). The FWD computers contain the

operating system parameters with sensor & load cell gains along with the infrared and air temperature calibration settings.

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## Data Collection Process

Most FWD testing at MnROAD consists of "routine" testing but sometimes we do "special" testing as requested. Typically the routine testing is put in the MnROAD database. Over the years MnROAD has been consistent in its FWD testing but has reduced some of its testing from the original studies in the 1990's.

HMA test cells: Testing on HMA test cells has always been done with the trailer facing west, regardless of the direction of travel in the particular lane being tested.

PCC test cells: Testing on PCC test cells was done with the trailer always facing west until April 1998. This resulted in the trailer facing in a direction opposite traffic loading in certain test cells. Since the direction of traffic loading has an impact on the development of transverse joint faulting, testing after April 1998 has been done with the trailer facing in the direction of traffic loading for all PCC test cells.
Each FWD device also collects GPS coordinates, which can be helpful in verification of test locations. As stated before, the location of the geophone sensors, relative to the center of the loading plate, has varied over time. Users of the data need to check the geophone sensor spacing for each FWD test before analyzing the data. As of May 2009, there are 10 sensors used and they are numbered and located as follows:

| Sensor Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Distance from center of load plate (in) | 0 | 8 | 12 | 18 | 24 | 36 | 48 | 60 | 72 | -12 |

Prior to 1996, load transfer efficiency testing of PCC transverse joints used different sensor spacing, due to the fact the FWD operator had to switch one of the geophone sensors to 12" behind the load plate.

Test Procedure:
At each test point, the following protocol is typically followed for the HMA, PCC and Composite cells:

- Pre-2008: Collect deflections for 3 drops at each load level of 6000, 9000, and 15000 lbs.
    - Load history data was collected on the 9000 lb load level.
- Post 2008: Collect deflections for 1 drop at each load level of 6000, 9000, 12000 lbs.
    - Load history collected only for specific research studies.

Aggregate surface cells and subsurface layers during construction:

- Collect deflections for 3 drops at each load level of 5000, 7000, and 9000 lbs.

The current detailed testing patterns for HMA and PCC test cells are described on the following pages.

# MnROAD Lane and Test Point Descriptions

## MAINLINE

| | | |
|---|---|---|
| Cell 23 | Passing Lane | Cell 1 |
| "East End" | Driving Lane | "West End" |

## LOW VOLUME ROAD

| | | | | |
|---|---|---|---|---|
| East Low Volume Road Loop | Cell 54 | Outside Lane | Cell 24 | West Low Volume Road Loop |
| | "East End" | Inside Lane | "West End" | |
| | | | | |
| | Cell 40 | Inside Lane | Cell 33 | |
| | "East End" | Outside Lane | "West End" | |

## FARM LOOP

| | | | |
|---|---|---|---|
| PCC Slab | Eastbound Lane | | Gravel Curve |
| "East End" | Westbound Lane | | "West End" |

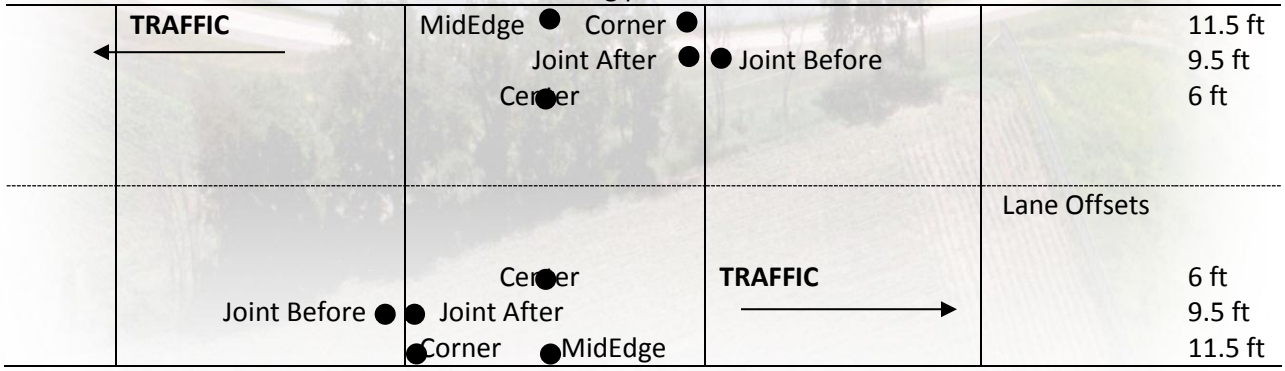
## HMA

1 - Use the marked test points – see the FWD test locations for test points for each cell.
2 - Always tested pointing the FWD West

| | | | |
|---|---|---|---|
| | ← OuterWheelPath → | | 9.5 ft |
| | ← Midlane → | | 6 ft |
| "East" | ← InnerWheelPath → | "West" | 2.5 ft |
| | ← InnerWheelPath → | Lane Offsets = | 2.5 ft |
| | ← Midlane → | | 6 ft |
| | ← OuterWheelPath → | | 9.5 ft |

## "Routine" PCC Locations

1 - Test the PCC slabs
2 - Use the panel number and points marked on test slab
3 - Always tested in the direction of traffic
4 – See FWD Test Locations for the current testing panel numbers for each cell.



## PCC –Testing joint replacement panels / patches that replace a whole joint

1 - Test the PCC patches using the joint number marked on the pavement

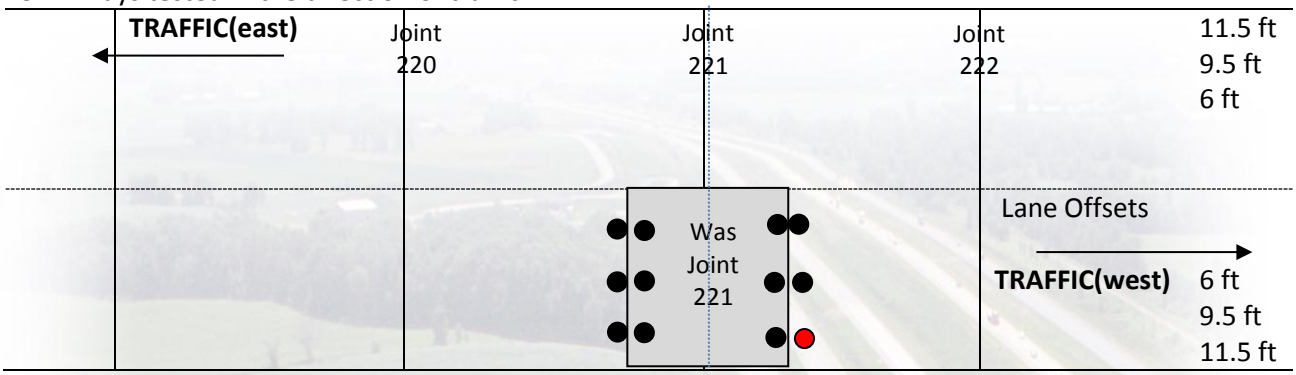
2 – Location is noted as the joint number along with the direction, E(ast) or W(est)

Example below (red) = 221W

3 – Position is defined as OWP, Center, IWP along with Joint Before or Joint After

Example below (red) = OWP-Joint After

3 - Always tested in the direction of traffic




## PCC –Testing longitudinal patches

1 - Test the PCC patch using the panel number with a "P" noting it's a patch

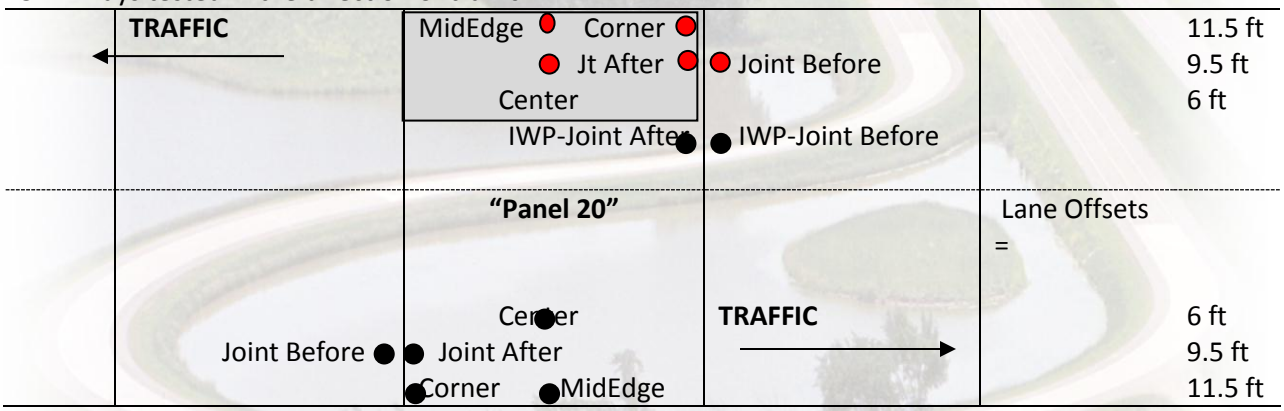
2 – Location is noted with the panel number along with a "P" for patch

Example below (in red) - "20P"

3 – If testing the original panel remaining use "20" for the panel number (shown in Black)

4 – Can test the Inside WheelPath at times

5 - Always tested in the direction of traffic




**2014 FWD Testing Plan**

MnROAD will follow the following plan for 2014. Testing frequency is determined by each cell and its age and can be tested more as needed. The terminology used in the testing includes "ES" Early Spring, "LS" Late Spring, "S" Summer, and "F" Fall.

# MnROAD FWD Test Locations (after Jan 2014)

## Asphalt Test Sections

| Roadway | Tests When | Cells | Routine Test Points |
|---|---|---|---|
| Mainline | 3 ES,LS,S | 1, 15, 16, 17, 18, 19, 20, 21, 23 | 10, 8, 6, 4, 2 |
| | | 2, 3, 4, 22 | 10, 8, 6, 4, 2 |
| | | 70 | 27, 21, 15, 12, 8 |
| Low Volume Road | 3 ES,LS,S | 24, 27, 31, 33, 34, 35, 86, 87, 88 | 10, 8, 6, 4, 2 |
| | | 77, 78, 79 | 5, 3, 1 |
| | | 28 | 8, 6, 4, 2 |

## Concrete Test Sections

| Mainline Cells | Tests Year | Routine Panels | Low Volume Road Cells | Tests Year | Routine Panels |
|---|---|---|---|---|---|
| 505 | 4 ES,LS,S,F | 20, 11, 5 | 36 | 1 LS | 31, 25, 19, 13, 6 |
| 605 | | 14, 12, 4 | 37 | | 41, 33, 25, 16, 8 |
| 305 | 1 F | 25, 22 | 38 | | 31, 25, 18, 12, 5 |
| 405 | | 34, 32 | 39 | 3 LS,S,F | 17, 12, 7, 6, 2 |
| 306 | 4 LS | 3, 8, 13 | 32 | 4 ES,LS,S,F | 41, 29, 20, 11, 2 |
| 406 | | 13, 6, 2 | 52 | 2 LS,F | 17, 14, 8, 5, 2 |
| 7 | 1 F | 19, 14, 9, 4, 0 | 53 | 1 LS | 6, 5, 4, 3, 1 |
| 8 | | 32, 25, 18, 11, 4 | 54 | 1 LS | 11, 7, 2 |
| 9 | | 28, 21, 14, 7, 0 | 85 | 2 LS,F | 14, 8, 4 |
| 160 | 4 ES,LS,S,F | 21, 12, 5, 3 | 89 | | 16, 7, 2 |
| 161 | | 35, 34, 26, 19 | 140 | 4 ES,LS,S,F | (4), 12, 20, 29 |
| 162 | | 33, 19, 7, 4 | 240 | | 52, 64, 77, (86) |
| 163 | | 36, 28, 18, 8 | | | |
| 96 (jts only) | 2 LS,F | Drive: 33, 29, 24, 17, 11, 8, 2<br>Pass: 33, 24, 11, 2 | | | |
| 70 | 2 LS,F | 27, 21, 15, 12, 8 | | | |
| 71 | | 15, 11, 9, 4, 1 | | | |
| 72 | | 36, 28, 25, 21, 16, 10, 5 | | | |
| 73 | | Look | | | |
| 12 | 1 F | 27, 19, 14, 7, 1 | Old Westbound | | |
| 613 | 4 ES,LS,S,F | 32,21,18,10,5 | 970-981 | 1 F | See Maps |
| 114 | 2 LS,F | 12, 4 | | | |
| 214 | | 17 | | | |
| 314 | | 35, 22 | | | |
| 414 | | 45 | | | |
| 514 | | 50 | | | |
| 614 | | 60, 58, 56 | | | |
| 714 | | 64 | | | |
| 814 | | 67 | | | |
| 914 | | 74 | | | |

Updated: 29-Jan-14

## Data Management

Data from FWD testing is loaded into several MnROAD Database tables shown below:

| FWD_CALIBRATION | FWD_DROP | FWD_HISTORY | FWD_SESSION | FWD_STATION |
|---|---|---|---|---|
| CALIBRATION_ID | DROP_ID | HISTORY_ID | SESSION_ID | STATION_ID |
| SESSION_ID | STATION_ID | DROP_ID FORCE_HISTORY | FACILITY_NAME | SESSION_ID |
| TRANSDUCER_ID | HISTORY | STRESS_HISTORY | SECTION_NAME | TEST_SEQUENCE |
| SN | STRESS_KPA | TIME_HISTORY | SECTION_START | SLAB_ID |
| TYPE | SEQUENCE_NO | DEFLECTION_1_HISTORY_MLS | SECTION_END | TEST_POSITION |
| REL_GAIN | DEFLECTION_1_MICRONS | DEFLECTION_2_HISTORY_MLS | LANE | STATION |
| ABS_GAIN | DEFLECTION_2_MICRONS | DEFLECTION_3_HISTORY_MLS | SESSION_DATE | STATION_OFFSET |
| PARAM1 | DEFLECTION_3_MICRONS | DEFLECTION_4_HISTORY_MLS | TRAILER_ID | STATION_DIRECTION |
| PARAM2 | DEFLECTION_4_MICRONS | DEFLECTION_5_HISTORY_MLS | PROGRAM_VERSION | STATION_UNIT |
| PARAM3 | DEFLECTION_5_MICRONS | DEFLECTION_6_HISTORY_MLS | OPERATOR | DATE_STATION |
| | DEFLECTION_6_MICRONS | DEFLECTION_7_HISTORY_MLS | ELECTRONICS_ID | TIME_STATION |
| | DEFLECTION_7_MICRONS | DEFLECTION_8_HISTORY_MLS | TEST_SETUP | PAVEMENT_TEMP_C |
| | DEFLECTION_8_MICRONS | DEFLECTION_9_HISTORY_MLS | UNITS | SURFACE_INFRARED_TEMP_C |
| | DEFLECTION_9_MICRONS | DEFLECTION_10_HISTORY_MLS | PAVEMENT _TYPE | AIR_TEMP_C |
| | DEFLECTION_10_MICRONS | | SMOOTHING | GPS_STATUS |
| | | | RADIUS_PLATE_MM | SATELITES |
| | | | SENSOR_OFFSET_X1_MM | LATITUDE |
| | | | SENSOR_OFFSET_X2_MM | LONGITUDE |
| | | | SENSOR_OFFSET_X3_MM | HEIGHT |
| | | | SENSOR_OFFSET_X4_MM | COMMENT_STATION |
| | | | SENSOR_OFFSET_X5_MM | UTC_HH24_MM_SS |
| | | | SENSOR_OFFSET_X6_MM | |
| | | | SENSOR_OFFSET_X7_MM | |
| | | | SENSOR_OFFSET_X8_MM | |
| | | | SENSOR_OFFSET_X9_MM | |
| | | | SENSOR_OFFSET_X10_MM | |
| | | | SENSOR_OFFSET_Y1_MM | |
| | | | SENSOR_OFFSET_Y2_MM | |
| | | | SENSOR_OFFSET_Y3_MM | |
| | | | SENSOR_OFFSET_Y4_MM | |
| | | | SENSOR_OFFSET_Y5_MM | |
| | | | SENSOR_OFFSET_Y6_MM | |
| | | | SENSOR_OFFSET_Y7_MM | |
| | | | SENSOR_OFFSET_Y8_MM | |
| | | | SENSOR_OFFSET_Y9_MM | |
| | | | SENSOR_OFFSET_Y10_MM | |
| | | | CREATED_DATE | |

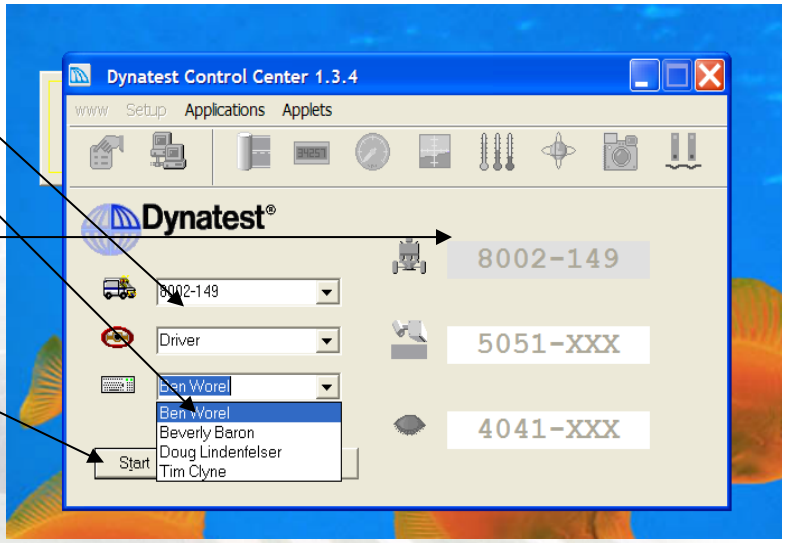
Data from the various FWD tables is then combined into the Data Product tables titled:

- AggCell xx Design x Fwd Drops.csv
- CompositeCell xx Design x Fwd Drops.csv
- HmaCell xx Design x Fwd Drops.csv
- PccCell xx Design x Fwd Drops.csv

## Data Collection Process – Operator Setup

### OPEN DYNATEST CONTROL CENTER

- Pick FWD Unit
- Pick/Enter FWD Operator
- Make sure FWD picture is highlighted/colored
  - May need to wait 10 seconds or so
- "Start" the program




### GPS ACTIVATION

The GPS system is poorly setup by Dynatest for our needs (Use the following to get the GPS to connect with the FWDWIN software we are using)

- Make sure the CP15 is fully powered up.
- Power up the GPS from the red button on the control box (also starts the trailer beacons).
- The GPS is controlled from the Setup then GPS settings in the Dynatest testing software. Here are the details for the settings:
- GPS location at MnROAD should be roughly 45N and 94W
- The GPS should be "embedded" to the CP15
- GPS Baud Rate is 4800
- GPS should be plugged into the CP15 processor on the trailer.

### FILL IN TESTING DESCRIPTION

Roadway

- **MnROAD**
- City of _____
- _____ County

District = **3**

Section/Cell = Cell #

- **33** not 033 (for MnROAD) or
- CSAH 33
- CR 3
- I 94

Start & End

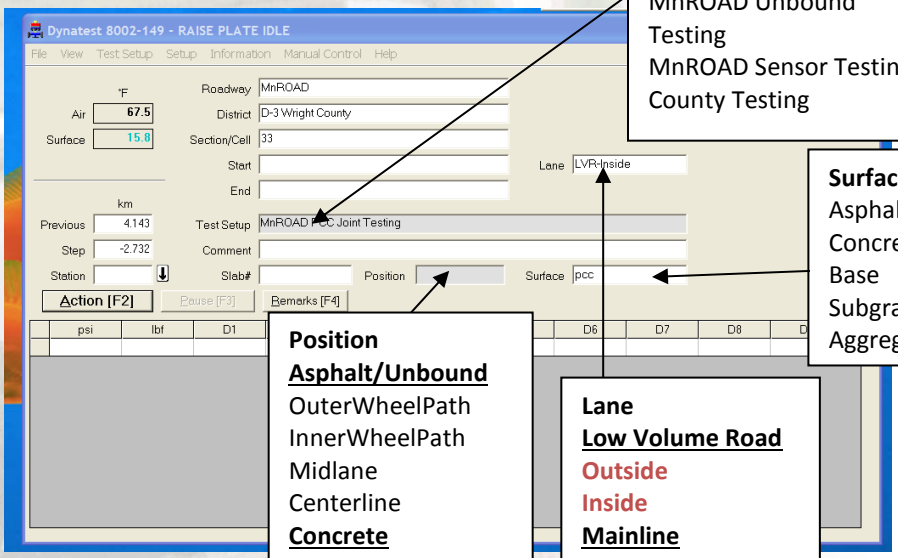
- Don't use for MnROAD
- County use where the DMI started or the points used for reference for testing.

Lane = (pick from drop down) – See appendix

Test Setup = (pick from drop down)

- See next page for view

Comment = Use as needed




**Test Setup**
MnROAD HMA Testing
MNROAD PCC Testing
MnROAD Unbound Testing
MnROAD Sensor Testing
County Testing

**Surface**
Asphalt
Concrete
Base
Subgrade
Aggregate

**Position**
**Asphalt/Unbound**
OuterWheelPath
InnerWheelPath
Midlane
Centerline
**Concrete**
Center
Corner
MidEdge
Joint Before
Joint After
Sensor
OWP-Joint Before
OWP-Joint After

**Lane**
**Low Volume Road**
Outside
Inside
**Mainline**
Driving
Passing
**Farm Road**
Eastbound
Westbound
NA
**Old Westbound**
Driving
Passing

- Suggest that county testing use this for how they test.

Remark = Noted later in testing

Slab# =

- Enter Concrete Slab number
- Or if sensor testing enter sensor number  where the load plate is centered on (example 22LE100)
- Using PCC or Sensor Test Setups will also prompt you for this.

Position = (pick from drop down shown)

Surface = (pick from drop down shown)

- Specifications

## SETUP SCREEN WHEN "SET UP IS SELECTED"

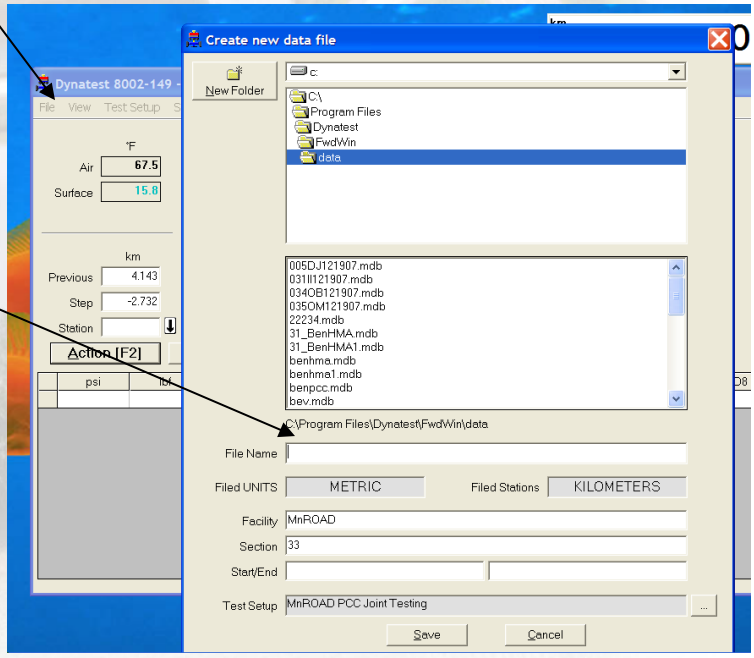
Note the following should already be pre-entered (you only need to scan them for a check)

- 3 drops for both HMA and PCC
- Loads set at 6,000, 9,000, 12,000 lbs.
- **Do not** collect load history data unless specifically requested by researcher.
- HMA only prompts "Station"
- PCC and Sensor prompts "Slab ID, Test Position"
- Sensor 10 added to the system May 2009 so no need to move any sensors anymore for PCC Joint Testing.  Sensor 10 will be located at -12 inch for all testing (both HMA and PCC).

Note county testing should either have the program enter STA as a point location or have the distance DMI set to collect distance from the noted start location (C/L of a roadway)

## OPEN A DATA FILE

- File "New" file
- Keep the location of the file as the default location
- ICON on desktop for easy access later on
- C:\Program Files\Dynatest\FwdWin\data directory
- MnROAD File Naming (12 digits)
    - 3-digit cell number
    - 3-digit C/L Offset
        - OWP (HMA-OWP)
        - IWP (HMA-IWP)
        - MDL (HMA-midlane)
        - EDG (PCC Edge)
        - JTS (PCC Joints)
        - CEN (PCC Center)
        - SEN (Sensor Test)
    - 1-digit Lane
        - D=Driving, P=Passing



        - I=Inside, O=Outside
        - E=East, W=West, N=North, S=South
        - S=Shoulder
    - 6-digit Date
        - Month-Day-Year
        - 040108 for April 1, 2008
    - Example for testing a HMA in the outerwheel path driving lane, for cell 22 on April 1, 2008 = 022OWPD040108.mdb
        - Note the mdb extension will be added by the computer software.
- For other testing including counties use the following.
    - Instead of the 3-digit cell number enter in the name of the facility – Example of "Clay County" or "Interstate94" then use the offset, lane, date format above. Example "ClayCountyOWPE05212009".
- The facility-Section should already be entered if you filled in the section information before opening a file.
- "Save" the file
    - Data will be collected as the equipment tests (don't need to save before ending testing)

## CONDUCT THE TESTING

- PCC Testing see maps developed for each cell
    - **Subsections will be tested as individual cells** (i.e., cell 306, 406)
    - Can also test other non-standard panels but the FWDSCAN will note non-standard testing was done.
- HMA Testing see charts for test points
    - Only test on the test points
- Hit F2 or use the mouse to on "ACTION [F2]" to start a test
- Close a file using the same process you used to open a file but use "File Close"
- Open a new file for new cell or pass or close out the program if you're done.

## START OF EACH DAY

- Pickup the flash drive for your FWD unit.
- Pickup a daily log to document what you tested that day.
- Determine the cells that need to be tested from the list.
- Talk to the other FWD operators so you're not testing the same cells that day.

## END OF EACH DAY

Move data to flash drive

- Go to the Data Directory (use the ICON on the front)
- Select the data files (Highlight all the files or use "Contol-A")
- Copy the data files (Control-C)
- Paste the data files to your jump stick (Control-V)
- Leave the flash drive at MnROAD in the FWD area (MnROAD personnel will move the files onto the R:\drive for loading into the database)

Check off the files collected that day on the written FWD log

- Use your initials to check off the cell(s) tested

Leave the cell check off list in the FWD data area at MnROAD.

- Forms are provided at MnROAD.

## For more information:

For more information about MnROAD and the Road Research program at MnDOT:

Ben Worel
Office of Materials & Road Research
Phone: 651-366-5522
Email: ben.worel@state.mn.us

www.mndot.gov/mnroad

MnROAD FWD FIELD DATA COLLECTION Documentation

**Startup Checks**

- ❑ Infrared Sensors
- ❑ Sensor Spacings
- ❑ Loadings (heights)
- ❑ Buffer Warm-ups
- ❑ GPS Working

**Final Checks**

- ❑ Copy Data to Flash Drive
- ❑ Check off cells tested in the FWD Log
- ❑ Leave this sheet and the Flash Drive at MnROAD

| | |
|---|---|
| **Date:** | |
| **FWD Unit:** | |
| **Operator:** | |
| **Odometer:** | |

**Filename**

| Cell (3 digits) | Offset (3 digits) | Lane (1 digit) | Date (6 digits) |
|---|---|---|---|
| **001** = Cell 1<br>**033** = Cell 33<br>**114** = Cell 114 | HMA [**OWP, MDL, SEN**]<br>PCC [**EDG, JTS, CEN, SEN**] | Mainline = **D**(riving) or **P**(assing)<br>LVR = **I**(nside) or **O**(utside)<br>Farm = **E**(ast) or **W**(est) | March 21, 2009<br>**032109** |

| Cell | Offset | Lane | Edits/Comments |
|---|---|---|---|
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MnROAD is a state of the art cold weather pavement and transportation testing facility located in Minnesota