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# Non-Destructive Technology Update

Federal Aviation Administration  
Airport Pavement Working Group Meeting  
April 17, 2013

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Significant Work. Extraordinary People. **SRA.**

## Outline

- **BAKFAA Background**
- **BAKFAA 1.0**
- **BAKFAA 2.0 Beta (New Features)**
- **F/HWD Round-Up Background**
- **Raw Data**
- **Excel Workbook Database**
- **Interactive Webpage Query System**
- **Future Work**

## BAKFAA Background

- **BAKFAA is a software program used to backcalculate FWD/HWD data with layered elastic analysis**
- **LEAF is the layered elastic analysis program and uses a downhill multidimensional simplex minimization methodology**
- **Since the original development, BAKFAA has been modified over time to read additional FWD/HWD file formats**
- **BAKFAA 2.0 represents the first major overhaul of the original programming**

# BAKFAA 1.0

FAA Backcalculation - C:\Program Files\BAKFAA\HFC\_011100\_1230 Sample.fwd

Layer Number	Young's Modulus	Poisson's Ratio	Interface Parameter (0 to 1.0)	Thickness inches	Layer Changeable
1	200,000	0.35	1.00	5.00	<input type="checkbox"/>
2	212,985	0.35	1.00	8.00	<input checked="" type="checkbox"/>
3	125,145	0.35	1.00	12.00	<input checked="" type="checkbox"/>
4	21,628	0.35	1.00	95.00	<input checked="" type="checkbox"/>
5	60,000	0.35	1.00	0.00	<input type="checkbox"/>
6	0	0.00	0.00	0.00	<input type="checkbox"/>
7	0	0.00	0.00	0.00	<input type="checkbox"/>
8	0	0.00	0.00	0.00	<input type="checkbox"/>
9	0	0.00	0.00	0.00	<input type="checkbox"/>
10	0	0.00	0.00	0.00	<input type="checkbox"/>

Sensor	1	2	3	4	5	6	7
Offset, in	-11.81	0.00	11.81	23.62	35.43	47.24	59.06
Defl, mils	19.56	26.66	20.35	12.82	7.85	5.07	3.47
Calc, mils	16.57	30.11	16.57	12.12	9.24	7.09	5.47

Plate Radius, in	5.91	Plate Load, lb	36,068
Function RMS, mils	2.5551	Iteration Number	53 (Done)

KUAB FWD File		
No	Distance	Load
1	860	35,517
2	860	11,904
3	860	23,913
4	860	36,068
Comment at 860 ft : HFI		
5	870	35,683
6	870	11,849
7	870	23,922
8	870	36,184
Comment at 870 ft : HFI		
9	880	35,387
10	880	11,917
11	880	23,750
12	880	36,016
Comment at 880 ft : HFI		
13	890	35,461
14	890	11,903
15	890	23,946
16	890	35,938
Comment at 890 ft : HFI		
17	860	35,500
18	860	11,895
19	860	23,801
20	860	36,002
Comment at 860 ft : HFI		
21	870	35,687
22	870	11,825

# BAKFAA 2.0 Beta New Features

FAA Backcalculation ...PDDX Files\Carl Brov1.1 PDDX IFAA Cycle 1.1.DDX

Layer Nbr	Young's Modulus, PSI	Poisson's Ratio	Interface Parameter (0 to 1.0)	Thickness, in	Layer Changeable
1	200,000	0.35	1.0000000	5.00	<input type="checkbox"/>
2	75,000	0.35	1.0000000	8.00	<input checked="" type="checkbox"/>
3	40,000	0.35	1.0000000	12.00	<input checked="" type="checkbox"/>
4	9,000	0.35	1.0000000	95.00	<input checked="" type="checkbox"/>
5	60,000	0.35	1.0000000	0.00	<input type="checkbox"/>
6	0	0.00	0.00	0.0000	<input type="checkbox"/>
7	0	0.00	0.00	0.0000	<input type="checkbox"/>
8	0	0.00	0.00	0.0000	<input type="checkbox"/>
9	0	0.00	0.00	0.0000	<input type="checkbox"/>
10	0	0.00	0.00	0.0000	<input type="checkbox"/>

Sensor	1	2	3	4	5	6	7	8	9
Offset, in	-12.0	0.0	8.0	12.0	16.0	20.0	24.0	30.0	3
Defln, mil	3.31	5.44	4.70	4.42	4.17	3.95	3.74	3.38	3
Calc, mil									

Loaded Deflection, mil	Unloaded Deflection, mil	Calculated J.T.E., %
5.44		

Units:  English  Metric

Buttons: Load FWD File, Convert to PDDX, Load Structure, Save Structure, Backcalculate, Stop Backcalculate, Show Output, Delete negative offset sensors

Iteration Tolerance: 0.0001, Evaluation Depth, in: 25.0001  
 Plate Radius, in: 5.91, Plate Load, lb: 13,507  
 Function RMS, mil: Func RMS, Iteration Number: Iter No

Buttons: Select All, Clear All, Select Load and Run LEAF, Help, Exit

Buttons: Approach, Depart, Batch Graph

PDDX File		
No	Distance	Load
1	5	13,507
2	5	26,831
3	5	13,620
4	5	26,849
5	11	13,461
6	11	26,758
7	11	13,357
8	11	26,652
9	16	27,038
10	21	13,598
11	21	26,621
12	21	13,607
13	21	26,512
14	21	13,342
15	21	26,587
16	26	13,753
17	26	26,580
18	32	13,565
19	32	26,573
20	32	13,244
21	32	26,492
22	37	13,639
23	37	27,034
24	37	13,754
25	37	26,822
26	37	13,599
27	37	26,887
28	42	13,336
29	42	26,564
30	48	13,712
31	48	26,198
32	48	14,027
33	48	26,161
34	53	13,415

# BAKFAA 2.0 Beta New Features

- Toggle allows user to use English or Metric Units
- Button allows user to convert a loaded FWD/HWD file into the PDDX file format
- Selecting multiple drop locations prior to clicking the backcalculate button allows for batch processing
- Select All and Clear All buttons added for easy batch testing of an entire file

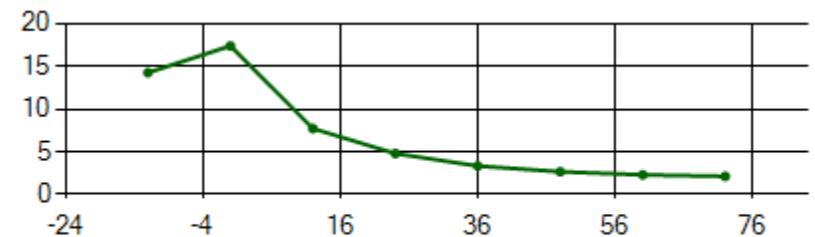
KUAB FWD File

No	Distance	Load
1	0	35,448
2	0	12,238
3	0	24,565
4	0	36,638
-- C Comment at 0 ft T:		
5	18	36,715
6	18	12,413
7	18	24,813
8	18	37,078
-- C Comment at 18 ft T:		
9	35	36,584
10	35	12,394
11	35	24,792
12	35	36,973
-- C Comment at 35 ft T:		
13	38	36,617
14	38	12,333
15	38	24,673
16	38	36,877
-- C Comment at 38 ft T:		
17	55	36,719
18	55	12,461
19	55	24,846
20	55	37,083
-- C Comment at 55 ft T:		
21	73	36,605
22	73	12,378
23	73	24,625
24	73	36,555
25	75	36,555
26	75	12,378
27	75	24,625

Select All      Clear All

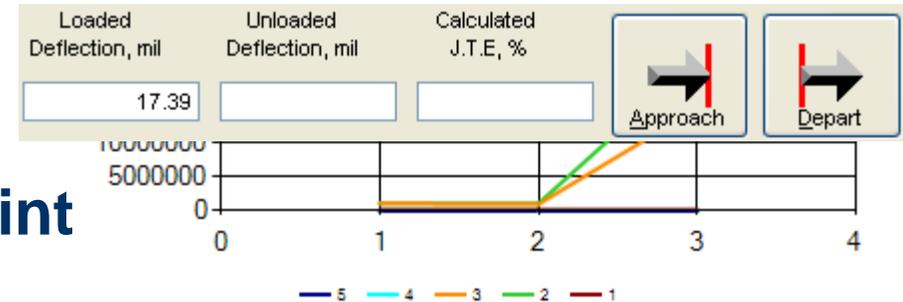
# BAKFAA 2.0 Beta New Features

- Help file has been added
- A user defined iteration tolerance affecting the termination criteria for the optimization algorithm
- Graph displays normally during backcalculation process but also shows a batch graph after calculations
- Users can now calculate joint transfer efficiency by approach or depart locations



Measured  
0.0001

Batch Graph



# BAKFAA 2.0 Beta New Features

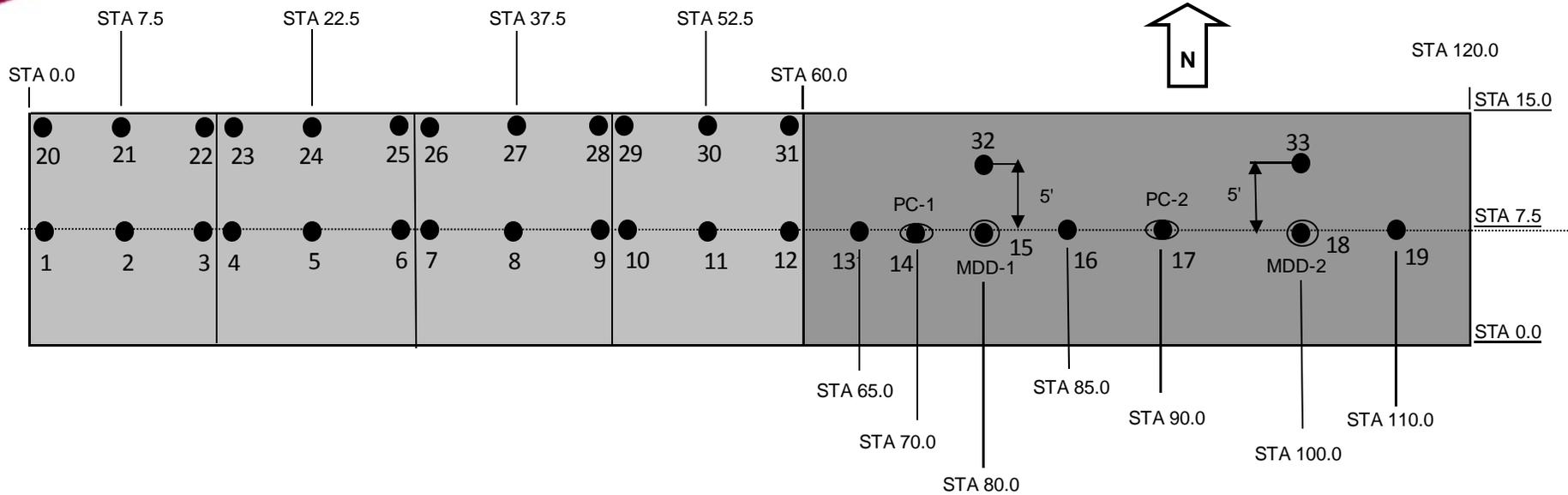
- Redesigned, moving from VB6 to VB.NET
- Backcalculation results can now be output as an Excel File
- LEAF is compatible in both BAKFAA & FAARFIELD
- Extended list of supported file formats

Equipment Manufacturer	Proprietary File Structure	Associated file extensions
Dynatest	R80	.fwd, .hwd
	F20,F25	.fwd, .F20, .F25
	FwdWin	.fwd, .txt
KUAB	KUAB	.fwd, .hwd
JILS	M3	.fwd, .hwd, .dat
	M5	.fwd, .hwd, .dat
Carl Bro	CarlBro	.txt, .fwd
PaveTest	PaveTest	.csv
AASHTO	PDDX	.ddx

## F/HWD Round-Up Background

- 1. Create an indoor, controlled pavement structure for F/HWD testing purposes**
- 2. Develop a testing plan for evaluating F/HWD vehicles**
- 3. Evaluate specifications and methodologies of various F/HWD equipment**
- 4. Examine what, if any differences are found between individual manufactures data and the effects that may have on data evaluation**
- 5. Provide industry with the testing data for more exhaustive analysis**

# F/HWD Round-Up Background



**RIGID PAVEMENT**

**FLEXIBLE PAVEMENT**

● Drop Location

**FWD- Testing Load Levels**

**9,000 lbs**

**12,000 lbs**

**16,000 lbs**

**HWD- Testing Load Levels**

**12,000 lbs**

**24,000 lbs**

**36,000 lbs**

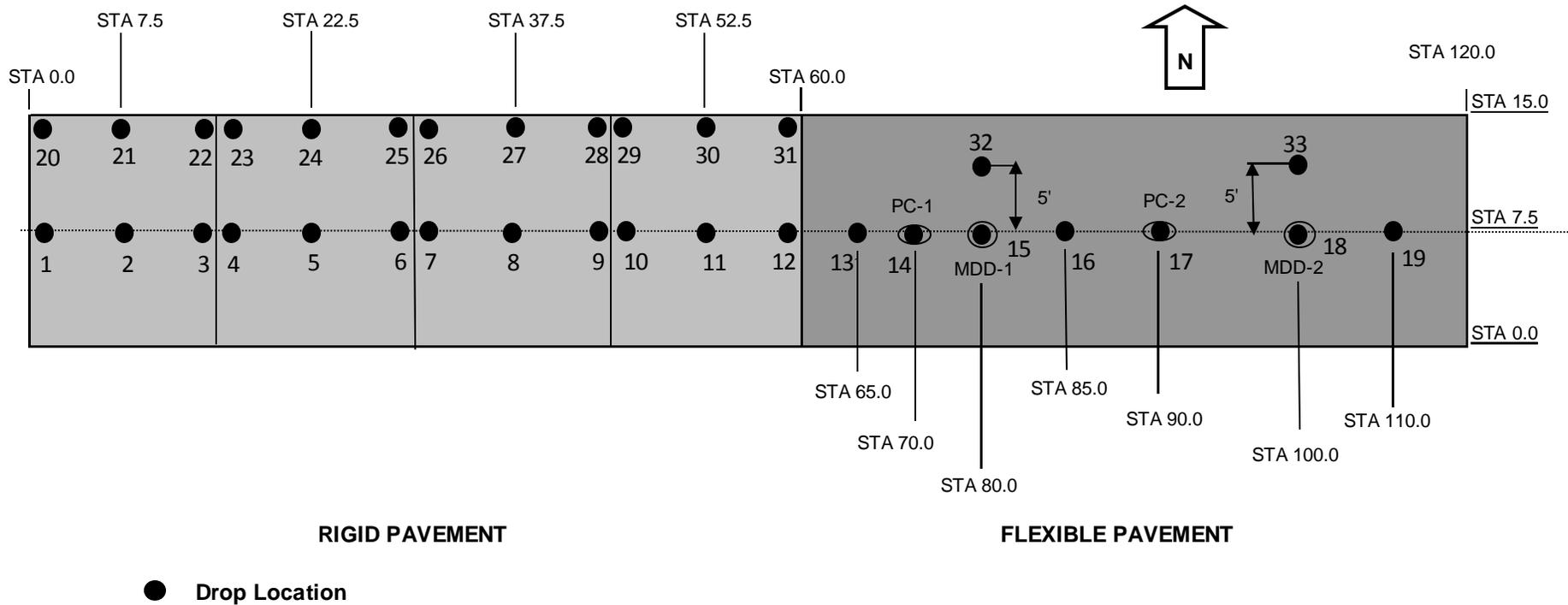
## Raw Data

- **Nearly 1,200 individual files collected from the F/HWD equipment**
- **Countless deflections and time histories data collected for each drop location**
- **Nearly 900 individual files collected from the embedded sensors**
- **With 49 embedded sensors that equals nearly 44,000 unique data collected**
- **Unprocessed deflection and time history files were published first**

## Excel Workbook Database

- **F/HWD equipment data sorted by participant and by drop**
- **Database data includes but is not limited to:**
  - Pavement Type Under Plate Load
  - Load
  - Deflection (at each sensor)
  - Time History
  - Pulse Width (at each sensor)
  - Peak Time (at each sensor)
  - Pavement and Air Temperature
  - Limited Embedded Sensor Responses

# Interactive Webpage Query System



# Interactive Webpage Query System

Home **Drop Data**

Select Manufacturer & Vehicle Direction for Drop Location 8

Select Manufacturer:

Choose Cycle & Vehicle Direction

(Cycle 1) West to East  
(Cycle 1) East to West  
(Cycle 2) West to East  
(Cycle 2) East to West

Selection  
(Cycle 1) West to East

ADD  
DELETE  
CLEAR

SEARCH

Direction	Drop Location	Drop Number	Pavement Type Under Plate	PCC Plate Position	Plate Diameter (in)	Load (lbs)	Deflection, Sensor Offset (0"), (mil)	Deflection, Sensor Offset (-12"), (mil)	Deflection, Sensor Offset (12"), (mil)	Deflection, Sensor Offset (24"), (mil)	Deflection, Sensor Offset (36"), (mil)	Deflection, Sensor Offset (48"), (mil)	Deflection, Sensor Offset (60"), (mil)
1	8	1	PCC	CENTER	5.91	36763	5.61	5.13	5.22	4.74	4.34	3.93	3.48
1	8	2	PCC	CENTER	5.91	12575	1.86	1.69	1.72	1.57	1.46	1.30	1.20
1	8	3	PCC	CENTER	5.91	24806	3.80	3.49	3.55	3.21	2.94	2.67	2.43
1	8	4	PCC	CENTER	5.91	37095	5.56	5.09	5.21	4.73	4.34	3.97	3.55

Export To Excel

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## Future Work

- **BAKFAA**
  - User Group Meeting (Address Comments and Suggestions)
  - Consider integration of AI
- **F/HWD Round-Up**
  - Process and publish embedded sensor data
  - Provide software and instructions need to view embedded sensor data
  - Examine analysis opportunities (i.e. – compare dynamic loading responses and F/HWD responses)

# Questions???

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