FAA Airport Pavement Technology Program

Lia Ricalde

ICAO/ALACPA/FAA/ACI-LAC Seminar on Airfield Pavement Design

Bogotá, Colombia

September 13, 2005

Galaxy Scientific Corporation

Outline

- AC 150/5320-6D "Airport Pavement Design and Evaluation" with associated computer program for design.
- AC 150/5370-11A "Use of Nondestructive Testing in the Evaluation of Airport Pavements" with associated computer program for backcalculation.
- National Airport Pavement Test Facility (NAPTF) Overview.
- Engineering Brief EB-65 "Minimum Requirements to Widen Existing 150-ft. (45-m) Wide Runways for Airbus A380 Operations."
- 4- and 6-Wheel ACN's from full-scale test data.
- FEDFAA and NAPTF Rigid Pavement Test Results.

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Relevance of FAA Advisory Circulars

- In the U.S.A., for airport pavement construction projects at large airports to be eligible for Federal Government AIP funding (up to 90 percent of cost), the requirements of FAA advisory circulars must be met.

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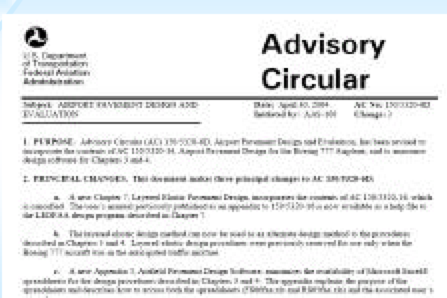
AC 150/5320-6D Change 3 – Design


Advisory Circular

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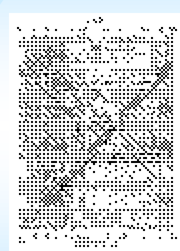
Newest Thickness Design Charts in the AC


A-300 Model B4 up to 350,000 lbs


B-747 up to 850,000 lbs

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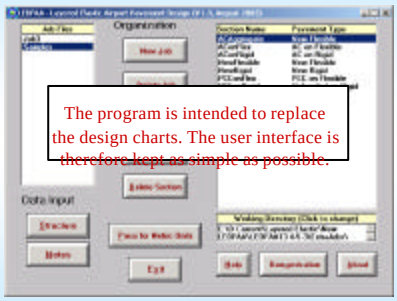
Design Charts are Based On:

- CBR method for new and overlaid flexible pavements.
- Westergaard edge stress for new rigid pavements.
- Westergaard edge stress plus empirical formulas for overlaid rigid pavements.
- Gradual development over a period of more than 30 years.

LEDFAA 1.3 Incorporated in the AC with Change 3

- LEDFAA is based on a layered elastic computational library program (called LEAF) included as an integral part of LEDFAA.
- LEAF has a completely new mathematical and program structure compared to other layered elastic programs (BISAR, JULEA, etc.).
- Source code is available for download with BAKFAA (see later).
- Comprehensive documentation available for download with BAKFAA.
- No restriction on public use.

LEDFAA 1.3 User Interface



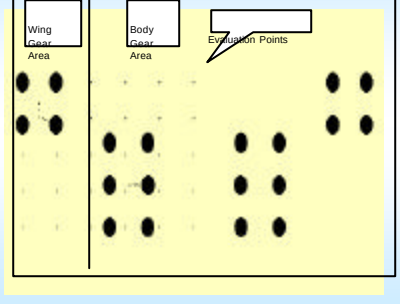
Significant Features of LEDFAA with Change 3

- A380-800, A380-800F, A340-500/600, and new large B-777 aircraft included.
- Allowed as an alternate design procedure to the design charts of chapters 3 and 4 of AC 150/5320-6D.
- Required for projects with mixes including 6-wheel aircraft and new aircraft not closely approximated by existing design charts.
- **Future aircraft will be added to LEDFAA - not as new design charts in chapters 3 and 4.**

LEDFAA 1.3 Flexible Thickness Design for Multiple Gears

- The B-747 nomographs in AC 150/5320-6D were produced with equivalent single wheel loads computed using 16 wheels.
- LEDFAA 1.2 (LEDNEW) computes subgrade strain for one four-wheel gear and then applies that strain to all sixteen wheels to compute CDF.
- LEDFAA 1.3 computes subgrade strain for all wheels in the main landing gear.
- **In this regard, LEDFAA 1.3 design philosophy is compatible with –6D but not with LEDFAA 1.2 or the ICAO ACN flexible methodology.**

Multiple-Gear Flexible Pavement ~~CDF Computation in LEDFAA~~ 1.3



Multiple-Gear Flexible Pavement CDF Computation in LEDFAA 1.3

- Compute the vertical strain in the subgrade over a grid under the wheels in response to the loads from all of the wheels in the main landing gears (16 for B-747 and 20 for A380):
  - Find the maximum strain in the **wing gear** area and find CDFs assuming a twin-gear aircraft.
  - Find the maximum strain in the **body gear** area and find CDFs assuming a twin-gear aircraft.

LEDFAA 1.3 – Rigid Thickness Design for Multiple Gears

- Individual gears on multiple-gear aircraft such as the A380 are treated as belonging to separate aircraft:
  - Compute interior and edge stress for wing gear and treat as a dual-tandem twin-gear aircraft to calculate CDF.
  - Compute interior and edge stress for body gear and treat as a triple-dual-tandem twin-gear aircraft to calculate CDF

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  - National Airport Pavement Test Facility (NAPTF) Overview.
  - Engineering Brief 58 (EB 58) "Minimum Requirements to Widen Existing 150-ft. (45-m) Wide Runways for Airbus A380 Operations."
  - 4- and 6-Wheel ACNs from full-scale test data.
  - FEDFAA and NAPTF Rigid Pavement Test Results.

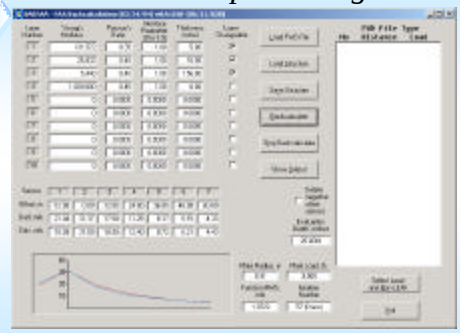
AC 150/5370-11A – Nondestructive Testing

- Covers only deflection measuring devices, primarily impulse (FWD/HWD).
- Available equipment and recommendations for setup, operation, plate size, load, etc.
- Objectives of NDT tests: joint efficiency, backcalculation, void detection, etc.
- Data analysis, primarily backcalculation and rehabilitation design. Compares available computer programs.

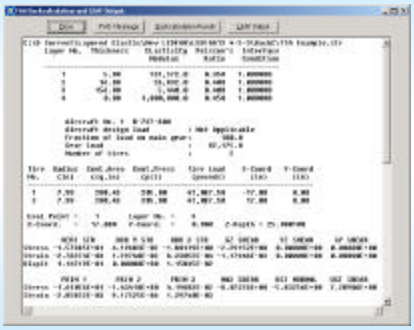
AC 150/5370-11A Data Analysis

- Comprehensive review of backcalculation closed-form methods and layered elastic iterative methods.
- Load and life evaluations from backcalculated values.
- Design of new pavements and overlaid pavements using backcalculated values in LEDFAA.
- Examples using BAKFAA.

BAKFAA Computer Program



BAKFAA Layered Elastic Response



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- 4- and 6-Wheel ACNs from full-scale test data.
- FEDFAA and NAPTF Rigid Pavement Test Results.

NAPTF Background

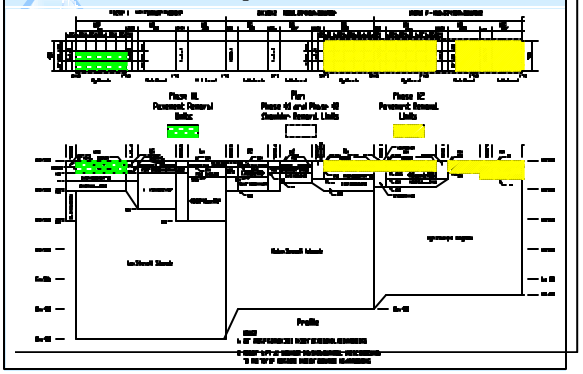
- For flexible pavements, the ACNs initially computed for B-777 (6-wheel gears appeared to be unreasonably high).
- The FAA had similar concerns about the existing CBR method for 6-wheel gears.
- Other theoretical models/methods not good enough to resolve the problem.
- Full-scale traffic test data to structural failure the only way.
- A380 also has 6-wheel body gears.

Aerial View During Construction

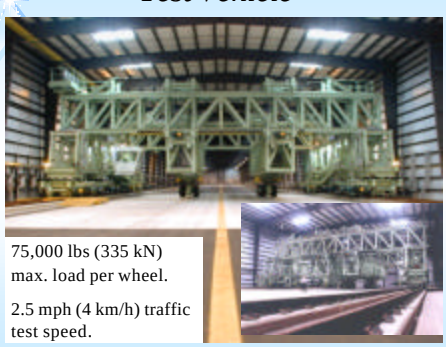
NAPTF Construction Cycles

- CC1 = original construction with three (3) rigid and six (6) flexible test items, all testing completed.
- CC2 = rigid test strip, single standing rigid slab and three (3) rigid pavements, all testing completed except overlay.
- CC3 = flexible pavement reconstruction with four (4) conventional test items, all testing completed.

PCC Removal and Replacement, Winter 2001/2002



Test Vehicle



75,000 lbs (335 kN) max. load per wheel.

2.5 mph (4 km/h) traffic test speed.

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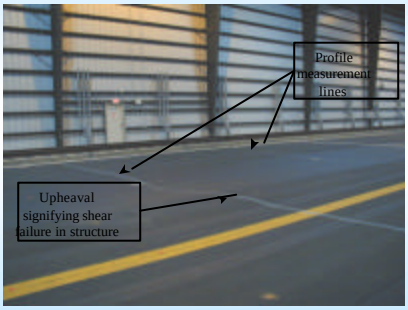
CC1 MFC Flexible Test Item Crushed Aggregate Base



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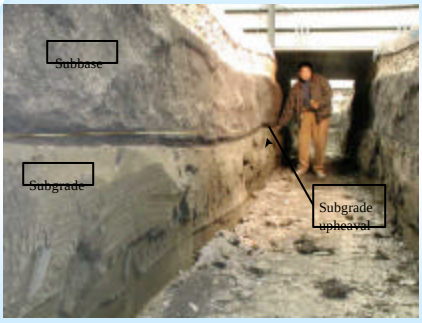
Trench in CC3 LFC2 Flexible



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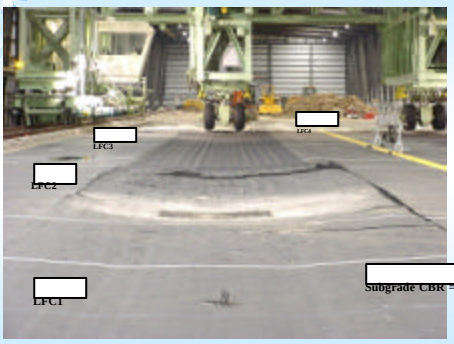
CC3 North, 6-Wheel Track



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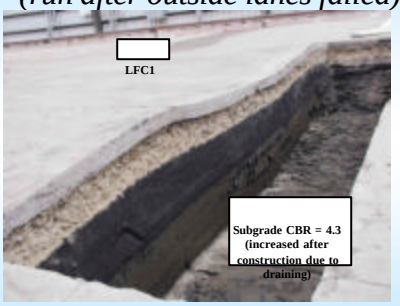
CC3 LFC1 Center Line, 6-Wheel Load, (run after outside lanes failed)



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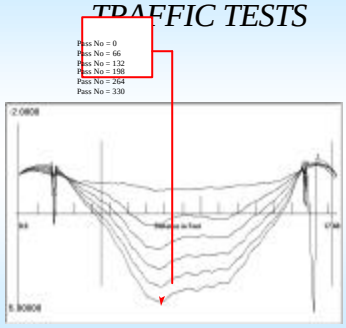
CC-3 PHASE-2: LFC-1 CL TRAFFIC TESTS



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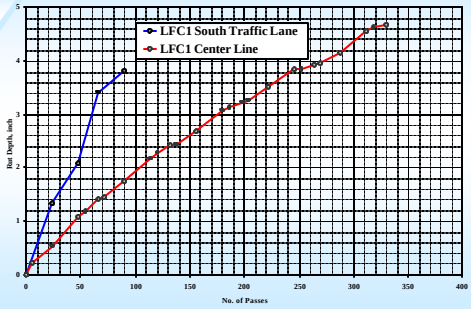
CC3 LFC1 6-Wheel Traffic Test Results



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CC3-LFC1 Traffic Results Summary

- A relatively small change in subgrade CBR can produce a very significant change in the magnitude and character of flexible pavement structural performance.
- Very large deformations can occur at, say, 5 passes, even when the life to the failure criterion is as large as 100 passes.
- This is the basis for the 240 coverage requirement in Engineering Brief No. 65, "Minimum Requirements to Widen Existing 150-Foot Wide Runways for Airbus A380 Operations."

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Why Engineering Brief # 65

- Standard FAA guidance says that the A380 requires a 200 foot (60m) runway and that the outer 50 feet (15m) of a 200 foot (60m) runway must be 0.7T of full pavement.
- Airports were asking for **temporary** relief from this requirement due to time restraints and cost.

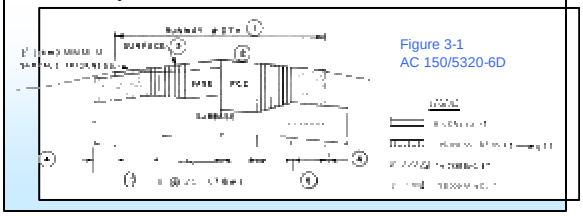
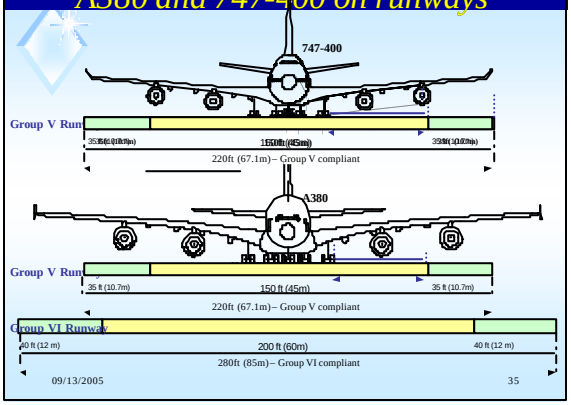


Figure 3-1
AC 150/5320-6D

A380 and 747-400 on runways



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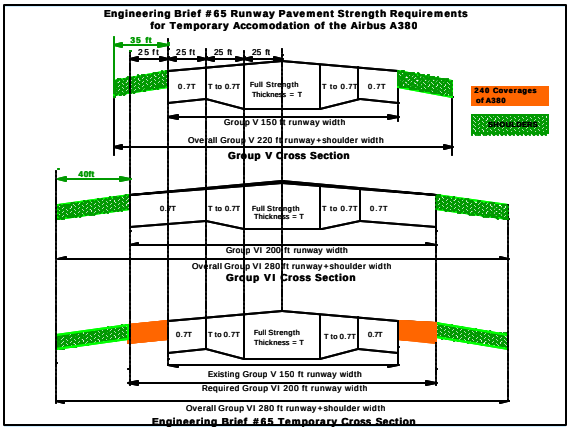

Summary of EB65

- Minimum Design of outer 50 feet (15m) each side of 200-foot (60m) runway must accommodate a total of 240 coverages of A380 (from NAPTF results).
- Asphalt surface must be 5 inches (127mm) or greater of ACC (P-401 or high quality State DOT mix). Normal requirement for wide-body aircraft.
- Grading, Marking and Lighting must meet current design standards
- New shoulders must be provided for 200-foot (60m) runway
- Slides on EB65 courtesy of Rodney Joel.

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Summary of NAPTF Flexible Pavement Full-Scale Test Results

Wheel Configuration	Test Item	Wheel Load, lbs	Repetitions to Failure	Coverages to Failure	Design Thickness in	Design Thickness cm	Subgrade CBR
6-Wheel	CC3-LFC1	55,000	90	57.3	29	73.7	3.72
	CC3-LFC2	55,000	**1,584**	**1,009**	37	94.0	4.38
	CC3-LFC3	65,000	20,000	12,739	47	119.4	4.38
	CC1-MFC	45,000	13,000	8,280	25	63.5	7.45
4-Wheel	CC3-LFC1	55,000	**132**	**55.9**	29	73.7	4.32
	CC3-LFC2	55,000	**2,970**	**1,258**	37	94.0	4.32
	CC3-LFC3	65,000	40,000*	16,968	47	119.4	4.32
	CC1-MFC	45,000	12,000	**5,825**	25	63.5	7.34
	CC1-MFS	45,000	19,000	9,223	18.5	47.0	7.43

* Extrapolated from rut depth curve

Bold = corrected values

Computation of Alpha Factor

- Pass/Coverage ratios calculated from surface coverages in test wander pattern:
  - 4-Wheel = 2.36 for CC3 and 2.06 for CC1
  - 6-Wheel = 1.57
- Subgrade CBR = trench measurements.
- Total structure thicknesses are known.
- Contact area = 265 square inches.
- Compute Alpha using COMFAA.

CBR Equations

Pre-MWHGL equation:

$$t = a\sqrt{\frac{P}{8.1\,CBR} - \frac{A}{p}}$$

t = Total Thickness
P = ESWL

Post-MWHGL equation:

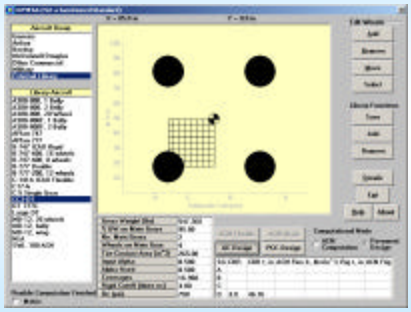
$$t = \alpha\,(A_c)^{0.5}\,[-0.0481 - 1.1562\,(\log CBR/P) - 0.6414\,(\log CBR/P)^2 - 0.473\,(\log CBR/P)^3]$$

$$a = \frac{t}{\sqrt{\frac{P}{8.1\,CBR} - \frac{A}{p}}}$$

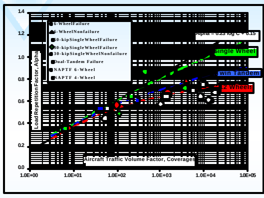
OR

Solve the Post-MWHGL equation for α

Change the Input Alpha until the design thickness is equal to the test structure thickness.

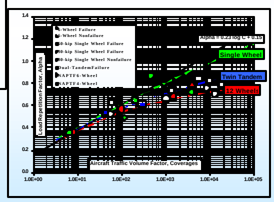


NAPTF and MWHGL Alpha Factor Results



No structure conversions and C5-A as two 6-wheel gears

NAPTF structures converted to equivalent MWHGL structures (SQS = 1.6 x CA) and C5-A as two 6-wheel gears



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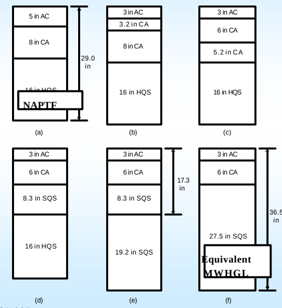
Procedure for Converting NAPTF Structures to Equivalent MWHGL Structures (Example)



Steps:

(a) real structure, 29.0 in.
(b) convert 2 in. AC to 3.2 in. CA (E.F. 1.6)
(c) add 3.2 in. CA to exist. 8 in. CA = 11.2 in. CA
(d) convert 5.2 in. CA to 8.3 in. SQS (E.F. 1.6)
(e) convert 16 in. HQS to 19.2 in. SQS (E.F. 1.2)
(f) equivalent MWHGL structure, 36.5 in.

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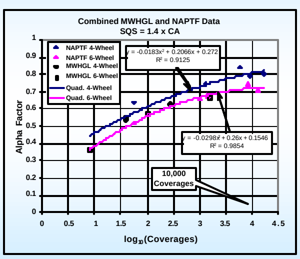
4- and 6-Wheel Alpha Factors for Base-to-Subbase Equivalency = 1.4



Alpha factor quadratic curve fit intercepts at 10,000 coverages:

4-wheel a = 0.8060

6-wheel a = 0.7178

From MWHGL report:

4-wheel a = 0.825

6-wheel a = 0.788

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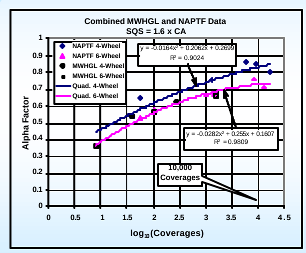
4- and 6-Wheel Alpha Factors for Base-to-Subbase Equivalency = 1.6



Alpha factor quadratic curve fit intercepts at 10,000 coverages:

4-wheel a = 0.832

6-wheel a = 0.7295

From MWHGL report:

4-wheel a = 0.825

6-wheel a = 0.788

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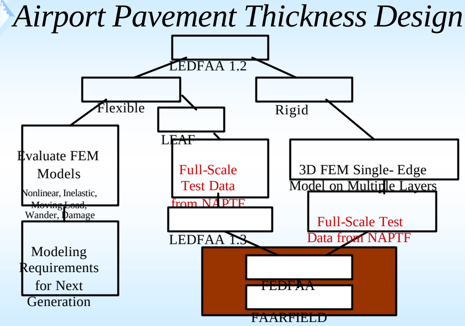
Development of FAA Standards for Airport Pavement Thickness Design


LEDFAA 1.2
Flexible
Rigid
LEAF
Evaluate FEM Models
Nonlinear, Inelastic, Moving Load, Wander, Damage
Full-Scale Test Data from NAPTF
3D FEM Single- Edge Model on Multiple Layers
LEDFAA 1.3
Full-Scale Test Data from NAPTF
Modeling Requirements for Next Generation
FEDFAA
FAARFIELD

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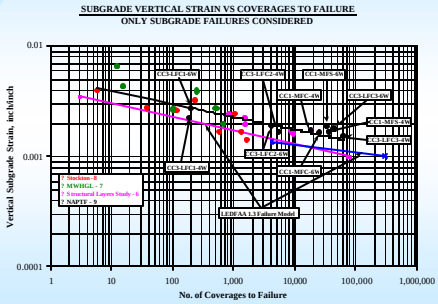
LEDFAA Flexible Failure Model
For All Available Full-Scale Test Data Points



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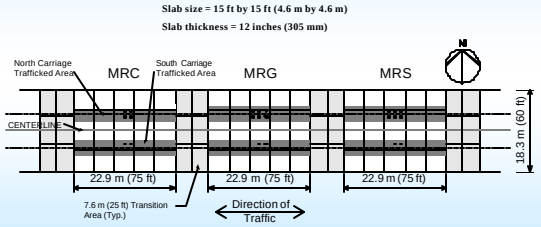
NAPTF Rigid Pavement CC2 Traffic Test Item Layout



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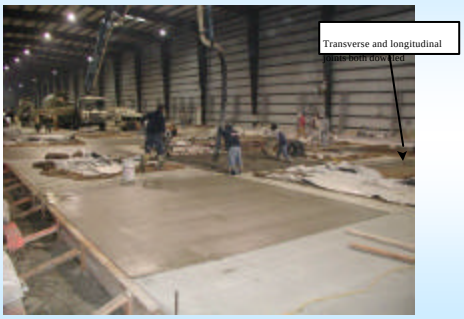
Placing Concrete in Checkerboard Pattern



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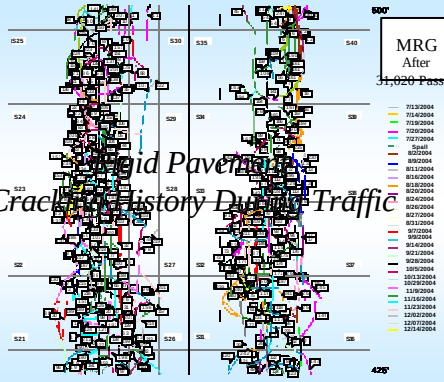
Rigid Pavement Cracking History During Traffic



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CC2 Test Items - Results

- Full-scale traffic testing began on 4/27/04.
- Trafficking ended 12/10/04.
- Passes completed:

		Passes Completed			
Test Item	Gear Type	Apr-Jun 2004	Jul-Sep 2004	Oct-Dec 2004	Total
MRC - North	4-wheel	12675	0	0	12675
MRC - South	4-wheel	5405	0	0	5405
MRG - North	6-wheel	0	21186	9834	31020
MRG - South	4-wheel	0	21162	9834	30996
MRS - North	6-wheel	0	20262	0	20262
MRS - South	4-wheel	0	21162	9834	30996

- Top-down cracking has not been eliminated, but bottom-up longitudinal cracks have occurred in the lane receiving loading from both lines of tires.

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Achievements – New Computer Programs and Full-Scale Test Data

- Savings from reduced thickness requirements.
- Savings from avoidance of pavement strengthening.
- Guidance for ICAO ACN for six-wheel gears.
- Guidance for runway shoulder conversion for Group 6 aircraft (FAA Engineering Brief 65)

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Our Website
http://www.airporttech.tc.faa.gov
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