Analysis of in-service PCC pavement responses from Denver International Airport

Dulce Rufino
ERES Consultants, A Division of ARA, Inc.

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Overview

- DIA project background
- Prediction of pavement parameters
  - Aircraft loading and wander
  - Pavement layer properties
  - Pavement temperature
  - Concrete joint characteristics
- Analysis of temperature curling
- Analysis of interface condition
- Conclusions
The Denver International Airport Instrumentation Project
Runway instrumentation

- Installed in the takeoff area of runway 34R–16L during construction
- Static and dynamic sensors collecting data under climatic and aircraft loading
Pavement structure

- Portland cement concrete: 18.75 ft
- Cement treated base: 8 in
- Lime stabilized subbase: 12 in
- Silty clay subgrade: 5 to 10 ft
- Direction of traffic: 20.00 ft

±17 in
Joint design

- Dowelled joint
  - Dowel bar
- Hinged joint
  - Tie bar
- Dummy joint
  - Aggregate interlock
## Position sensors

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>P38</td>
<td>P21</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>36 position sensors @ 1 ft</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>P18</td>
<td>P1</td>
</tr>
</tbody>
</table>

- P38 to P21: 3'6" 13'6" 10'
- P18 to P1: 36 position sensors @ 1 ft
H-bar sensors

Runway C

1

2

3

4

A

B

C

D
LVDT sensors

Gage: Depth (in)
G1: 9
G2: 26
G3: 38
G4: 50

MDD1
SDD11

MDD2
SDD12

MDD3
SDD13

MDD4
SDD14

MDD5
SDD15

MDD6
MDD7

MDD10
SDD16

MDD9
SDD17

SDD18
SDD19

Runway C
Depth of thermocouples

Depth (in)

- PCC slab
- Cement treated base
- Lime stabilized subbase
- Silty clay subgrade

- Slab B3
- Slab C3
DIA Database

DIA data is accessible through the Internet at http://www.airtech.tc.faa.gov/DENVER/

**Aircraft data:** event number, triggered sensor, complete record (793.4MB)

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Number</th>
<th>Size (MB)</th>
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<tbody>
<tr>
<td>B-727</td>
<td>2937</td>
<td>165.0</td>
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<tr>
<td>B-737</td>
<td>8168</td>
<td>426.0</td>
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<tr>
<td>B-747</td>
<td>144</td>
<td>7.6</td>
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<tr>
<td>B-757</td>
<td>1843</td>
<td>103.0</td>
</tr>
<tr>
<td>B-767</td>
<td>320</td>
<td>18.5</td>
</tr>
<tr>
<td>B-777</td>
<td>172</td>
<td>9.8</td>
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<tr>
<td>DC-10</td>
<td>389</td>
<td>23.0</td>
</tr>
<tr>
<td>MD-80</td>
<td>735</td>
<td>40.5</td>
</tr>
</tbody>
</table>

**Temperature data:** date, time, and temperature profile (14.5 MB)

**Displacement and strain data:** event number, number of peaks, interval time, start and end time, offset right and left, peak value and time

- **Displacement:** 50 LVDT’s (77.1 MB)
  10 SDD’s and 40 MDD’s

- **Strain:** 23 Carlson (45.2 MB)
  92 H-Bars (91.7 MB)

**Total:** ≈ 1 GB
Aircraft Location and Wander Analysis
Position sensors

36 position sensors @ 1 ft
## Methodology

<table>
<thead>
<tr>
<th>Case</th>
<th>Main gear</th>
<th>Number of position sensors triggered</th>
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<td>0</td>
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<td>2</td>
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<td>5</td>
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<td>4</td>
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<td>7</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

- **Triggered position sensor**
- **Non-triggered position sensor**
- **Undefined wheel position**
- **Defined wheel position**
Methodology (cont.)

\[ y = a \cdot x + b \]

\[ a = \frac{y_2 - y_1}{x_2 - x_1} \]

\[ b = y_1 - \left( \frac{y_2 - y_1}{x_2 - x_1} \right) \cdot x_1 \]

\[ x = \frac{y - y_1 + \left( \frac{y_2 - y_1}{x_2 - x_1} \right) \cdot x_1}{y_2 - y_1} \cdot (x_2 - x_1) \]
## Number of passes

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<thead>
<tr>
<th>Aircraft</th>
<th>Before filtering location</th>
<th>After filtering location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>W/ weight</td>
</tr>
<tr>
<td>B-727</td>
<td>2937</td>
<td>1266</td>
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<tr>
<td>B-737</td>
<td>8168</td>
<td>2234</td>
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<tr>
<td>B-747</td>
<td>144</td>
<td>4</td>
</tr>
<tr>
<td>B-757</td>
<td>1843</td>
<td>585</td>
</tr>
<tr>
<td>B-767</td>
<td>320</td>
<td>18</td>
</tr>
<tr>
<td>B-777</td>
<td>172</td>
<td>23</td>
</tr>
<tr>
<td>DC-10</td>
<td>389</td>
<td>114</td>
</tr>
<tr>
<td>MD-80</td>
<td>735</td>
<td>–</td>
</tr>
</tbody>
</table>
B-727 events

18 Position sensors @ 1'

- **Average:** 27.3 ft
- **Std deviation:** 2.5 ft

**ROW 2**

- **Average:** 27.6 ft
- **Std deviation:** 2.4 ft

**MIDDLE**

- **Average:** 27.9 ft
- **Std deviation:** 2.5 ft

- **Nose gear**
  - **Distance:** 8.4 ft

- **Center of main gear**
  - **Distance:** 28.1 ft

- **Runway**
  - Length: 17'
  - **3'6”**
  - **13'6”**
Wander and Pavement Design

- Aircraft path distribution

\[ f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-0.5 \left( \frac{x - \mu}{\sigma} \right)^2} \]

- Load location relative to the joints
B747 and B777

Wheel path distribution per in

x-coordinate (in)

Runway

Longitudinal joint
Backcalculation of Pavement Layer Properties
### Pavement evaluation at DIA

#### Runway C

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
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<td>C</td>
<td>D</td>
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<tr>
<td>2</td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Date:**
- 05/03/95
- 09/15/95
- 03/02/96
- 04/08/97
- 07/31/97
- 06/06/00

- 10 ft
- 30 ft
- 50 ft
- 70 ft
Comparison between different models

PCC slab (elastic layer and plate)

PCC slab (elastic layer and plate)
Bonded and unbonded

CTB (elastic layer and plate)
Factorial run performed with DIPLOMAT

**PCC slab (elastic layer and plate)**
- \( E = 1,000 \text{ to } 15,000 \text{ ksi (at 250 ksi)} \)
- \( \mu = 0.15 \)
- 18 in

**Subgrade**
- \( k = 50 \text{ to } 1,300 \text{ psi/in (at 2 psi/in)} \)

Total of \( 2 \times 35,682 \) cases

---

**PCC slab**
- \( E = 3,000 \text{ to } 15,000 \text{ ksi (at 250 ksi)} \)
- \( \mu = 0.15 \)
- 18 in

**CTB (elastic layer)**
- \( E = 1,000 \text{ to } 3,000 \text{ ksi (at 200 ksi)} \)
- \( \mu = 0.15 \)
- 8 in

**Subgrade**
- \( k = 50 \text{ to } 1,300 \text{ psi/in (at 2 psi/in)} \)

Total of \( 2 \times 48,576 \) cases
Slab modulus of elasticity for different models based on DIA

Cumulative frequency distribution (%)
Modulus of subgrade reaction for different models based on DIA

- 1PL
- 1EL
- 2EL-B
- 2EL-U

Cumulative frequency distribution (%)
Prediction of Pavement Temperature and Its Effect on Joint Behavior
## Data collection

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>T1-T8P2</td>
<td>B3</td>
<td>2016</td>
<td>2200</td>
<td>842</td>
<td>2690</td>
<td>1086</td>
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<tr>
<td></td>
<td>C3</td>
<td>2016</td>
<td>2409</td>
<td>376</td>
<td>2690</td>
<td>1086</td>
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<tr>
<td>T1-T22P10</td>
<td>B3</td>
<td>2016</td>
<td>2200</td>
<td>842</td>
<td>2690</td>
<td>1086</td>
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<td></td>
<td>C3</td>
<td>2016</td>
<td>2409</td>
<td>376</td>
<td>2690</td>
<td>1086</td>
</tr>
</tbody>
</table>

Collected combined data: **9,057**  
Annual data: **8,760**  
Total data: **43,800**
Prediction of pavement temperature using Integrated-Climatic Model (ICM)

Material properties:
- Thermal conductivity
- Heat capacity
- Emissivity factor
- Surface short-wave absorptivity

Climatic data:
- Air temperature
- Precipitation
- Percent sunshine
- Wind speed
- Radiation

Obtained from National Oceanic and Atmospheric Association (NOAA)
Measured versus predicted temperature differential

N=9,057

Concrete thermal conductivity (CTC): 0.40 BTU/hr*ft*F
Heat capacity: 0.20 BTU/lb*F
Emissivity factor: 0.65
Surface short-wave absorvity: 0.65
Differential pavement temperature distribution

Concrete thermal conductivity (CTC): 0.40 BTU/hr-ft-F
Heat capacity: 0.20 BTU/lb-F
Emissivity factor: 0.65
Surface short-wave absorvity: 0.65
Concrete thermal conductivity (CTC): 0.40 BTU/hr·ft·F
Heat capacity: 0.20 BTU/lb·F
Emissivity factor: 0.65
Surface short-wave absorptivity: 0.65

Measured versus predicted average pavement temperature

N=9,057
Concrete thermal conductivity (CTC): 0.40 BTU/hr-ft·F
Heat capacity: 0.20 BTU/lb·F
Emissivity factor: 0.65
Surface short-wave absorvity: 0.65
### Joint gages

#### Gage (Depth)
Slab east, north (ft)

<table>
<thead>
<tr>
<th>Layer</th>
<th>Gage 1</th>
<th>Gage 2</th>
<th>Gage 3</th>
<th>Gage 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Dummy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Dummy</td>
<td>J903_R (17.7 in)</td>
<td>J897_R (17.1 in)</td>
<td>J898_R (16.8 in)</td>
</tr>
<tr>
<td>2</td>
<td>J904_R (9.6 in)</td>
<td>12.20 (ft)</td>
<td>J902_R (3.4 in)</td>
<td>J905_R (9.7 in)</td>
</tr>
<tr>
<td>1</td>
<td>Dummy</td>
<td>J900_R (17.5 in)</td>
<td></td>
<td>J906_R (17.7 in)</td>
</tr>
</tbody>
</table>

**Runway C**
Dummy joint opening by season

- **Spring**
  - Relative joint opening (mils)
  - Average pavement temperature (°F)

- **Summer**
  - Relative joint opening (mils)
  - Average pavement temperature (°F)

- **Fall**
  - Relative joint opening (mils)
  - Average pavement temperature (°F)

- **Winter**
  - Relative joint opening (mils)
  - Average pavement temperature (°F)
Load transfer efficiency

Date: Test #
05/03/95: 9, 32
09/16/95: 33
03/03/96: 10, 34
04/12/97: 31
08/01/97: 83

Note. 5 tests were performed for test # 9 at each position (total of 80).
LTE for doweled joints

Average pavement temperature (F)

LTE (%)
Predictions of LTE for dummy joints

LTE = 0.0112 x APT^2 + 0.0185 x APT + 6.3972  
R^2 = 0.9354

185 points
Frequency of predicted dummy joint LTE for seven years

Concrete thermal conductivity (CTC): 0.40 BTU/hr*ft*F
Heat capacity: 0.20 BTU/lb*F
Emissivity factor: 0.65
Surface short-wave absorptivity: 0.65
Effects of Temperature Curling on Airfield Pavement Responses
Theoretical analysis

- **Load:**
  - 36,000-lb single wheel
  - Size: 15-in. by 15-in.
  - Tire pressure: 160 psi

- **Temperature:**
  - Linear and nonlinear
  - 523 randomly selected cases

- $\text{E} = 5,000,000 \text{ psi}$
- $\alpha = 5.5 \times 10^{-6} \text{ in/in/}^\circ\text{F}$
- $\mu = 0.15$

- $k = 450 \text{ (psi/in)}$

**Diagram:**
- $L_x = 20 \text{ ft}$
- $L_y = 20 \text{ ft}$
- $y$
- $x$

- 18 in
Theoretical effect on stress

- Linear
- NonLinear
- Only Load
Theoretical effect on deflection and stress

CHANGE in deflection

CHANGE in stress

- Linear
- NonLinear
- Only Load

Temperature differential (°F)

Interior deflection (mils)

Edge deflection (mils)

Corner deflection (mils)

Interior bottom stress (psi)

Edge bottom stress (psi)

Corner top stress (psi)

CHANGE in deflection

Linear

NonLinear

Only Load
Aircraft weight used to normalize pavement response

<table>
<thead>
<tr>
<th>Aircraft type</th>
<th>Number of events</th>
<th>Average total weight (kips)</th>
<th>Std dev total weight (kips)</th>
<th>Average wheel weight (kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-727</td>
<td>523</td>
<td>160.5</td>
<td>10.9</td>
<td>38.1</td>
</tr>
<tr>
<td>B-737</td>
<td>382</td>
<td>109.8</td>
<td>9.0</td>
<td>26.1</td>
</tr>
<tr>
<td>B-757</td>
<td>132</td>
<td>192.3</td>
<td>11.6</td>
<td>45.7</td>
</tr>
<tr>
<td>DC-10</td>
<td>54</td>
<td>355.9</td>
<td>18.3</td>
<td>42.3</td>
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</table>
Selected LVDTs for a detailed measured deflection analysis

- Dummy joint
- Hinged joint
- Doweled joint

Aircraft travel

Runway C
Measured B-727 interior deflection

Temperature differential (°F)

Deflection (mils)

- MDD7
- MDD8
- MDD10
- SDD18
Measured B-727 dummy TJ deflection

Temperature differential (°F)

Deflection (mils)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

MDD6 MDD9 SDD16 SDD17 SDD19
Measured B-727 hinged LJ deflection

Temperature differential (°F)

Deflection (mils)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

MDD5  SDD15  SDD20
Measured B-727 corner deflection

Temperature differential (°F)

Deflection (mils)

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

-30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30

MDD4
SDD13
SDD14
### Summary of normalized mean deflections

<table>
<thead>
<tr>
<th>Location or load level</th>
<th>Aircraft</th>
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<tbody>
<tr>
<td></td>
<td>B727</td>
</tr>
<tr>
<td>Interior (mils)</td>
<td>6.9</td>
</tr>
<tr>
<td>TJ (mils)</td>
<td>13.6</td>
</tr>
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<td>LJ (mils)</td>
<td>8.3</td>
</tr>
<tr>
<td>Corner (mils)</td>
<td>15.7</td>
</tr>
<tr>
<td>Wheel Load (kips)</td>
<td>38.1</td>
</tr>
<tr>
<td>Gear Load (kips)</td>
<td>76.2</td>
</tr>
</tbody>
</table>
Selected strain gages

Runway C

<table>
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<th>Runway</th>
<th>Runway</th>
<th>Runway</th>
<th>Runway</th>
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<tbody>
<tr>
<td>D4</td>
<td>Dowedel joint</td>
<td>HB21</td>
<td>(11417) HB25</td>
</tr>
<tr>
<td>C4</td>
<td>Hingled joint</td>
<td>HB24</td>
<td>(4052) HB25</td>
</tr>
<tr>
<td>C3</td>
<td>Dummy joint</td>
<td>HB82</td>
<td>(2654) HB84</td>
</tr>
<tr>
<td>C2</td>
<td>Dummy joint</td>
<td>HB41</td>
<td>(2873)</td>
</tr>
<tr>
<td>C1</td>
<td>Dummy joint</td>
<td>HB51</td>
<td>(1180) HB52</td>
</tr>
<tr>
<td>D1</td>
<td>Dummy joint</td>
<td>HB56</td>
<td>(1081) HB58</td>
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HB52 HB58 HB61 (1081) HB71 (5754) (1923) (3111)
HB56 HB61 HB81 (6881) (4420) (9765) (11597)
HB3 HB29 HB3 HB29 (9077) (6742)
Measured B-727 TJ dummy strain

Tensile strain ($\mu\varepsilon$)

Temperature differential (°F)

-60 -50 -40 -30 -20 -10 0 10 20 30 40 50

HB19  HB84  HB21  HB5
Measured B-727 doweled TJ strain

Temperature differential (°F)

Tensile strain (µε)

-60 -50 -40 -30 -20 -10 0 10 20 30 40 50

HB3
HB29
HB25
HB26
### Summary of measured strains

<table>
<thead>
<tr>
<th>Location</th>
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<tr>
<td></td>
<td>B727</td>
<td>B737</td>
<td>B757</td>
<td>DC10</td>
</tr>
<tr>
<td>Interior (microns)</td>
<td>-14.8</td>
<td>-9.9</td>
<td>-11.9</td>
<td>-19.3</td>
</tr>
<tr>
<td>TJ dummy (microns)</td>
<td>-28.2</td>
<td>-21.4</td>
<td>-25.6</td>
<td>-30.9</td>
</tr>
<tr>
<td>TJ doweled (microns)</td>
<td>-23.2</td>
<td>-17.2</td>
<td>-21.4</td>
<td>-29.4</td>
</tr>
<tr>
<td>LJ (microns)</td>
<td>-26.3</td>
<td>-20.4</td>
<td>-17.8</td>
<td>-21.9</td>
</tr>
<tr>
<td>Wheel Load (kips)</td>
<td>38.1</td>
<td>26.1</td>
<td>22.8</td>
<td>42.3</td>
</tr>
<tr>
<td>Gear Load (kips)</td>
<td>76.2</td>
<td>52.9</td>
<td>91.3</td>
<td>169.1</td>
</tr>
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Analysis of Slab-base Interface Interaction
Sliding friction

Contact friction

Before wheel load

After wheel load

FH
FRH
FW
FRW
Sliding friction

- Many theoretical and experimental studies
- Traditionally long slabs
- Recently short slabs

Contact friction

- Composite plate concept
- Intermediate levels of contact friction (Rollings, 1988)
- Design of UTW
- ISLAB2000
- Limited field studies
Multi-depth LVDT sensors

MDD2
MDD3
MDD4
MDD5
MDD6
MDD7
MDD8
MDD9

Gage: Depth (in)
G1: 9
G2: 26

Runway C
Daytime condition

G1-G2

PCC slab

CTB

Subbase

Subgrade

Anchorage
Nighttime condition

G1-G2

G1

G2

PCC slab

CTB

Subbase

Subgrade

Anchorage
Corner deflection versus temperature differential

Temperature differential (°F)

G1 (mils)

MDD4
Interface corner deflection versus temperature differential

Temperature differential (°F)

G1-G2 (mils)

MDD4
Interface TJ deflection versus temperature differential

Temperature differential (°F)

G1-G2 (mils)

-40 -30 -20 -10 0 10 20 30 40

MDD6
MDD9
Interface LJ deflection versus temperature differential

Temperature differential (°F)

G1-G2 (mils)

MDD5
Interface interior deflection versus temperature differential

Temperature differential (°F)

G1-G2 (mils)

+ MDD7
- MDD8
Selected paired strain gages

Runway C

<table>
<thead>
<tr>
<th>Doweled joint</th>
<th>Doweled joint</th>
<th>Doweled joint</th>
<th>Dummy joint</th>
<th>Dummy joint</th>
<th>Dummy joint</th>
<th>Doweled joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>HB20 HB16 HB45 HB24 HB25 HB26</td>
<td>HB22 HB21 HB10</td>
<td>HB41 HB7</td>
<td>HB42 HB19</td>
<td>HB59 HB58 HB71 HB78 HB81</td>
<td>HB1 HB56</td>
<td>HB14 HB27 HB29</td>
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<td>C2</td>
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</table>

Doweled joint

Dummy joint

Runway C
Interface condition

If $P_\varepsilon < 0$ Then:

$$P_{\varepsilon_T \text{corrected}} = P_{\varepsilon_T} - (d_T) \times \text{CSPD}$$
$$P_{\varepsilon_B \text{corrected}} = P_{\varepsilon_B} + (x) \times \text{CSPD}$$

If $P_\varepsilon > 0$ Then:

$$P_{\varepsilon_T \text{corrected}} = P_{\varepsilon_T} + (d_T) \times \text{CSPD}$$
$$P_{\varepsilon_B \text{corrected}} = P_{\varepsilon_B} + (x) \times \text{CSPD}$$

$$\text{CSPD} = \frac{|P_{\varepsilon_B}| + |P_{\varepsilon_T}|}{d_B - d_T}$$
Comparison between top and bottom slab at the slab interior

HB15 - Strain at the top (µε)

HB71 - Strain at the bottom (µε)
Comparison between top and bottom slab at the slab longitudinal hinged joint
Comparison between top and bottom slab at the slab dummy transverse joint

HB19 - Strain at the bottom (με)

HB42 - Strain at the top (με)
Comparison between top and bottom slab at the slab doweled transverse joint

HB16 - Strain at the top (\( \mu \varepsilon \))

HB25 - Strain at the bottom (\( \mu \varepsilon \))
Comparison between strain at the bottom of the slab and at the top of the base

- HB7 - Strain at the top (µε)
- HB10 - Strain at the top (µε) Dummy joint
- HB41 - Strain at the bottom (µε)
- HB21 - Strain at the bottom (µε)
Summary of temperature differential effect on measured interface parameter

\[
2\frac{\varepsilon_B}{(|\varepsilon_B| + |\varepsilon_I|)}
\]


<table>
<thead>
<tr>
<th></th>
<th>Negative</th>
<th>Combined</th>
<th>Positive</th>
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<tbody>
<tr>
<td>Interior (15-71)</td>
<td>-0.82</td>
<td>-0.81</td>
<td>-0.80</td>
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<tr>
<td>Hinged (59-58)</td>
<td>-0.84</td>
<td>-0.83</td>
<td>-0.82</td>
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<tr>
<td>Dummy (42-19)</td>
<td>-0.85</td>
<td>-0.84</td>
<td>-0.83</td>
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<tr>
<td>Doweled (16-25)</td>
<td>-0.86</td>
<td>-0.85</td>
<td>-0.84</td>
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</tbody>
</table>
Effect of load location on measured interface parameter

Cumulative frequency distribution (%)

2\(\varepsilon_B/(|\varepsilon_B| + |\varepsilon_T|)\)

- Interior
- Doweled joint
- Dummy joint
- Hinged joint

Legend:
- Hinged
- Doweled
- Dummy
- Interior
Measured versus predicted responses

LTE_x = 85%

LTE_y = f(T)

C

D

Hinged

Doweled

Line_{n}

Dummy

Dummy

x

y

Runway C

\[ f(T) \]
Selected gages for a detailed analysis

- HB82
- HB84
- D3
- MDD5
- MDD7
- HB41
- MDD10
- HB8
- MDD4
- SDD16
- MDD6
- MDD9
Measured and predicted B-727 interior strain (HB41)

Cumulative frequency distribution (number of events)

Strain (µε)

Measured
Unbonded
Bonded
Measured and predicted B-727 transverse joint strain (HB84)

Cumulative frequency distribution (number of events)

Strain (µε)

-70
-60
-50
-40
-30
-20
-10
0
100
200
300
400
0
100
200
300
400

Measured
Unbonded
Bonded
Measured and predicted DC-10 longitudinal joint strain (HB8)

Cumulative frequency distribution (number of events)
Summary of comparison between measured and predicted tensile strains ($\mu\varepsilon$)

- B-727
- B-737
- B-757
- DC-10

Interior (HB41)

LJ (HB8)

TJ (HB82)

TJ (HB84)

bonded  measured  unbonded
Measured and predicted B-727 interior deflection (MDD10)

Deflection (mils)

Cumulative frequency distribution (number of events)
Measured and predicted B-727 TJ dummy deflection (MDD6)

- Measured
- Unbonded
- Bonded

Deflection (mils)

Cumulative frequency distribution (number of events)
Measured and predicted DC-10 hinged LJ (MDD5)

Deflection (mils)

Cumulative frequency distribution (number of events)
Measured and predicted DC-10 corner deflection (MDD4)

Deflection (mils)

Cumulative frequency distribution (number of events)
Summary of comparison between measured and predicted deflection (mils)

Interior (MDD10)

LJ (MDD5)

Corner (MDD4)

TJ (MDD6)

<table>
<thead>
<tr>
<th></th>
<th>B-727</th>
<th>B-737</th>
<th>B-757</th>
<th>DC-10</th>
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<tbody>
<tr>
<td>bonded</td>
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<tr>
<td>measured</td>
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<tr>
<td>unbonded</td>
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</tbody>
</table>

bonded  measured  unbonded
Wander Analysis

- Normal distribution
- B-777 and DC-10 had similar distributions
- Gear path distribution
- Interaction between gear type and joint location

Backcalculation

- Adequate properties

Pavement Temperature

- ICM evaluation
- Joint opening
- LTE
Temperature versus pavement response

- **Theoretical analysis**
  - Effect of temperature distribution and type of response

- **Analysis of measured responses**
  - Change in strain
    - Interior *(strong correlation)*
    - TJ dummy joint *(strong correlation)*
    - TJ doweled joint *(some correlation)*
    - LJ hinged joint *(no correlation)*
  - Deflection
    - Interior *(some correlation)*
    - TJ dummy joint *(strong correlation)*
    - LJ hinged joint *(no correlation)*
    - Corner *(some correlation)*
  - Effect of load magnitude

- **Design implications**
  - Total or stress range?
  - Which stress component causes failure?
Interface condition

- Gap analysis
  - Temperature differential and location
  - EBITD

- Paired strain analysis
  - Location: interior, TJ and LJ
  - Interface parameter and slab-base contact

- Measured versus predicted responses
  - Strain
    - Interior (bonded)
    - TJ dummy joint (partial)
    - LJ hinged joint (unbonded)
  - Deflection
    - Interior (bonded)
    - TJ dummy joint (bonded)
    - LJ hinged joint (bonded)
    - Corner (partial)
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