Design and Construction of Airport Concrete Pavement in JAPAN

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Summary of Airport Concrete Pavement

Tokyo International (Haneda) Airport (offshore extension project in 1980’s)
Summary of Airport Concrete Pavement

Tokyo International (Haneda) Airport
(Aprons are concrete pavement)
Summary of Airport Concrete Pavement

Kansai International Airport
(Aprons and ends of runways are concrete pavement)
Summary of Airport Concrete Pavement

Fukuoka Airport
(Aprons and a part of taxiway are concrete pavement)
Summary of Concrete Pavement

Asphalt pavement is used at
  runway
  taxiway
  apron for small aircraft

Concrete pavement is used at
  apron
  taxiway for large traffic
  end of runway (a few of large airports)

Pavement type is selected based on many factors such as
  objective of facilities
  initial cost (concrete > asphalt in JAPAN)
  easiness of rehabilitation
  construction condition etc…
Type of Concrete Pavement

NC - Non-Reinforced (Plain) Concrete Pavement
Almost all apron in JAPAN are NC Pavement

CRC - Continuously Reinforced Concrete Pavement
Reinforced with longitudinal steel
No transverse joint
Used in NARITA International Airport

PPC - Precast Prestressed Concrete Pavement
PRC - Precast Reinforced Concrete Pavement
Constructed in midnight -> Opened in morning
Used as rehabilitation work in busy airports
Type of Concrete Pavement

NC - Non-Reinforced (Plain) Concrete Pavement
   Thickness: 37 – 45cm (for Code E and F aircraft)
   Maximum joint spacing: 8.5m
   Flexural strength of concrete: 5N/mm²

Diagram:
- Concrete Slab
- Asphalt
- Stabilized Base
- Subbase
- Dowel bar or Tie bar
Type of Concrete Pavement

CRC - Continuously Reinforced Concrete Pavement
Thickness: 30 – 35cm (for Code E and F aircraft)
Expansion joint spacing: about 200m
Reinforcement ratio: 0.65% (longitudinal)
0.09% (transverse)

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Transverse reinforcing steel bar
Crack (less than 0.5mm in width)
Longitudinal reinforcing steel bar
Type of Concrete Pavement

PPC - Precast Prestressed Concrete Pavement
Thickness: 24cm (for Code E and F aircraft)
Slab size: 15m x 7.5m (10m x 2.5m x 3 slabs)
PC cable: $\phi 12.7$mm @150 mm (longitudinal)
$\phi 23.0$mm @500 mm (transverse)
PPC Lift-Up

Soon after construction

Uneven settlement

Lift up and grouting

PPC slabs can be lifted up by the jacks and the void beneath PPC slabs is grouted.

-> Lift-up is used for rehabilitation of an apron on reclaimed land.
PPC Lift-Up

PPC is “flexible concrete slab”, Lift-up can be done.
Lift-up jacks are controlled by personal computer.
Type of Concrete Pavement

PRC - Precast Reinforced Concrete Pavement
- Thickness: 24cm (for Code E and F aircraft)
- Slab size: 15m x 2.5m
- Flexural strength of concrete: 6.4N/mm²
- Reinforcing steel bar: D13 @ 75mm (upper)
  - D16 @ 75mm (lower)
Cotter joint
PRC

Construction
Design of Concrete Pavement
Design of NC Pavement

Empirical Design Method (till 2008)
Slab thickness is designed based on loading stress.
\[ \sigma < \frac{f}{a} \]
\( \sigma \) : loading stress at bottom of slab due to aircraft load
\( f \) : design flexural strength of concrete
\( a \) : safety factor
\( (=1.7 \text{ to } 2.2, \text{ depending on traffic volume}) \)

Mechanistic-Empirical Design Method (after 2008)
Slab thickness is designed based on fatigue degree due to loading stress and thermal stress.
\( FD = \sum \left( \frac{N_d}{N_f} \right) \)
\( N_d \) : design number of load repetition
\( N_f \) : number of failure
Empirical Design of NC Pavement

\[ f = 5.0 \text{N/mm}^2 \text{ and safety factor} = 2.0 \text{ then} \]
\[ \sigma \text{ due to aircraft load must be less than} 2.5 \text{N/mm}^2 \]

Relationship between slab thickness and \( \sigma \) due to B747-400 landing gear in case \( K=70 \text{MN/m}^3 \)

Safety factor considers “effect of load repetition” and “thermal stress at the bottom of slab due to daily temperature change”.
Mechanistic-Empirical Design of NC Pavement

Loading stress:
loading stress at center of slab
due to aircraft gear load is calculated by FEM.

Concrete slab
Elastic spring as base
Thermal stress:
thermal stress at center of slab is calculated by equation based on long term observation

\[ \sigma_t = \beta \frac{E \alpha \theta}{2(1-\nu)} \]

- \( \beta : -0.772h + 0.854 \)
- \( h : \) slab thickness (m)
- \( E : \) elastic modulus of concrete (N/mm²)
- \( \alpha : \) coefficient of thermal expansion (1/oC)
- \( \theta : \) temperature difference between top and bottom of slab (°C)
- \( \nu : \) poisson’s ratio of concrete
Mechanistic-Empirical Design of NC Pavement

**Number of failure:**

Number of failure is calculated by total stress and fatigue failure criteria

\[
\log N_f = \frac{1.19614 - \sigma / f_{bd,h}}{0.08672}
\]

- \( N_f \): Number of failure
- \( \sigma \): Total stress (=loading stress and thermal stress, N/mm\(^2\))
- \( f_{bd,h} \): Flexural strength with design slab thickness \( h \) (N/mm\(^2\))

**Fatigue failure criteria**

\[
\log \frac{N_d}{N_f} = 0.8
\]

\( FD = \frac{N_d}{N_f} \)
- \( FD < 1.0 \): OK
- \( FD > 1.0 \): Redesign

\[ \text{Log } N_d \quad \text{Log } N_f \]
Fatigue degree have to be calculated in transverse direction because gear location and lateral deviation of each aircraft is different.
Construction of Concrete Pavement
Materials

Cement:
- Portland cement
- Blast-furnace slag cement are used usually.

Aggregate:
- Maximum aggregate size: 40mm

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>(%)</th>
</tr>
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<tbody>
<tr>
<td>53</td>
<td>100</td>
</tr>
<tr>
<td>37.5</td>
<td>95-100</td>
</tr>
<tr>
<td>19</td>
<td>50-100</td>
</tr>
<tr>
<td>2.36</td>
<td>20-60</td>
</tr>
<tr>
<td>0.075</td>
<td>0-15</td>
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</tbody>
</table>
Mix Design

Standard of mixture
Design flexural strength : 5.0 N/mm² (28 day)
Slump : 2.5 ± 1 cm
Air : 4.5 ± 1.5 %
W/C : less than 50% (generally about 40%)

Cement per unit volume
C = 300-350kg/m³ is better.
C<300 kg/m³ -> Bloom finishing may be difficult.
C>350 kg/m³ -> Initial crack may occur.

Water per unit volume
W = 130-140kg/m³ is better.
W<120 kg/m³ -> Const. may be difficult in summer.
Mix Design

Flexural strength test (test piece size : 15x15x53 cm)
1. Average strength in 3 test pieces shall be greater than design strength.
2. Each strength shall be greater than 0.85*design strength.

<table>
<thead>
<tr>
<th>Coefficient of Variation</th>
<th>10%</th>
<th>12.5%</th>
<th>15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overdesign Factor</td>
<td>1.21</td>
<td>1.36</td>
<td>1.55</td>
</tr>
<tr>
<td>Target Strength</td>
<td>6.05N/mm²</td>
<td>6.80N/mm²</td>
<td>7.75N/mm²</td>
</tr>
<tr>
<td>when Design Strength is 5N/mm²</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Construction

Quality control item for subgrade
water content
degree of compaction
Plate loading test

Quality control item for concrete
Slump
Air
Temperature
Flexural strength

optimum value
1time / 1day
98%
1time / 2000m²
design $K_{75}$
1time / 2000m²

1time / 1 day or 150m³
Construction

Transfer from concrete plant (in case of slump < 2.5cm)
Dump truck should be used.
Paving should be started within 1 hour.

Vibrator
Inner vibrator shall be used in case slab thickness is larger than 30cm.

Mesh steel
Mesh steel is inserted at (slab thickness/4+2)cm depth from surface of slab.

Curing
Initial curing : membrane curing
After curing : mat curing
Curing term : 70% of target flexural strength
Slip Form Paving

“Slip form paver” does not require any steel set forms.

Merit: large construction area per day
Demerit: need to pay attention to concrete mixture specification (slump, air).
Concrete Bonded Overlay

Thin concrete layer is constructed on existing slab in case existing slab is sound and slope and height have to be modified.
Concrete Bonded Overlay

Bonded strength between new and old layer
1.6 N/mm² tensile strength is needed.

Surface treating
1. Water Jet + Shot Blast
2. Shot Blast + Glue Soaking
3. Other ? (1.6 N/mm² tensile is needed)

Concrete mixture of new layer
Usual concrete mixture for airport concrete pavement except for maximum aggregate size (40mm -> 20mm)

Overlay thickness
Minimum 5cm
Concrete Bonded Overlay

Example of concrete bonded overlay in New Chitose Airport.

Slope modification by concrete bonded overlay

New Concrete Slab
Concrete Bonded Overlay

Surface treating by Water Jet (WJ)
Concrete Bonded Overlay

Surface treating by Shot Blast (SB)
Concrete Bonded Overlay

Surface treating by Shot Blast + Glue Soaking

Shot Blast

Glue Soaking