Concrete Pavement Design for Airfields

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Outline

- Roads vs. Airfields
- Aircraft Landing Gear
- Brief History of Thickness Design
- Development of Design
- FAA (USA) Design Methods
- Australian Practice

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Roads

- Wheel loads about 2 to 3 tonnes
- Tyre pressures about 750kPa
- Trucks have quite similar wheel arrangements, are of the same width and generally track along a narrow part of the pavement
- Repetitions of the standard axle can be up to $10^8$
- Wheel loads are relatively close to the edge where moisture effects can be significant
Airfields (Defence Airfields & Civilian Airports)

- Wheel loads up to 29.5 tonnes for Airbus A340-600
- Tyre pressures up to 1600kPa and even as high as 3100 kPa on some fighter aircraft
- Wheel layout (or footprint) varies considerably between makes and models of aircraft
- Wander reduces as the aircraft lands on the runway and moves along the taxiway and across the apron to the aerobridge
- Repetitions can be in the range of about 10,000 to 100,000
- Wheel loads are remote from the edge of pavements and equilibrium moisture contents are considered to apply
- Ingestion of loose stones into jet engines can be catastrophic
SUPERIMPOSED FOOTPRINTS

B-747 (open contact areas) B-737 (shaded contact areas)
Brief History of Thickness Design

Based on US Army Corps of Engineers experience for military airfields by R S Rollings (2003)

1940

- B-17 and B-24 WW2 bombers had a single wheel on each main undercarriage leg with wheel loads up to 18 tonnes
- Larger bomber (B-29) proposed with dual wheels on each main leg and 70% heavier
- Design used Westergaard's (1926) equations for a wheel load in the centre of the slab – originally developed for roads
- Plate load tests (0.76m dam) used to determine modulus of subgrade reaction (k)
- Third point beam test used to measure flexural strength
1945 through early 1970s

- Larger aircraft (B-36) had single wheel loads of 34 tonnes
- 90 tonne wheel loads were contemplated but fortunately dual wheels used
- Strain measurements in model, test track and in-service pavements showed effective load transfer
- Westergaard’s 1948 equations for a single wheel at the edge of the slab were developed
- Pickett & Ray (1951) developed influence charts for 2 or more wheels in a group
- Kreger (1967) computerised the above solutions
1970s

- Westergaard analysis approach showing its limitations
- F-15E fighter had 2300 kPa tyre pressure and this was causing damage to some pavements
- The effect of complex 3 leg main gear on the commercial DC-10 and the military variant as an air refuelling tanker, the KC-10, was of concern
- The Westergaard models could not handle stabilised layers
DC-10 Series 30 & 40 Footprint
1980s onwards

- 1980s Layered elastic design used for concrete pavements as an alternative to Westergaard
- Late 1990s state of the art Finite Element modelling of pavements was being developed but military operational pressures put this on hold.
Development of Design

- Theoretical methods have evolved over time but have lagged behind the needs of the designer
- Considerable experience has been gained from observations of test sections, successful and unsuccessful pavements and the practice has been adapted as needed
- The importance of accumulated engineering experience over long periods and judgement has been a major factor in improving designs
Federal Aviation Administration (FAA)

- FAA is the controlling authority for civil aviation in USA
- Sets design standards for aircraft pavement design and other matters
  - Design using charts for individual aircraft with formulae for calculations are presented in Advisory Circulars (AC)
  - AC 150/5320-6D Parts 1 to 5 plus amendments
  - These AC cover Airport Pavement Design & Evaluation
FAA Spreadsheet Method

- R805FAA.xls
- [http://www.faa.gov/airports_airtraffic/airports/construction/design_software/](http://www.faa.gov/airports_airtraffic/airports/construction/design_software/)
- Method is same as previous one but spreadsheet has macros to automate calculation
- Input aircraft mix and annual departures for each aircraft and pavement profile
- Freeze thaw not generally applicable for Aust
- Spreadsheet based on critical aircraft and calculates equivalent departures for other aircraft in the mix
- Uses Imperial units only
- Need to understand FAA materials types (codes)
- Not to be used with aircraft with Triple Dual Tandem landing gear eg Airbus A-380 or Boeing 777
B-777 Triple Dual Tandem main gear
Layered Elastic Design Method

- Program LEDFAA
- Can select either imperial or metric units
- Mandatory to use this method with Triple Dual Tandem landing gear such as A-380 or B-777 in aircraft mix
- Covered by Chapter 7 of AC 150/5320-6D Change 3
- No user manual but drop down help menus

http://www.faa.gov/airports_airtraffic/airports/construction/design_software/
Finite Element Method

- Proposed FAA method not yet approved for design use
- Program FAARFIELD Version 1.302 made available as a Beta version for evaluation or research
- A number of extensive reports are available on the software and its development

http://www.faa.gov/airports_airtraffic/airports/construction/design_software/
AIRCRAFT PAVEMENT ANALYSIS AND DESIGN PROGRAMS

USER MANUAL

JANUARY 1983

AERODROME AND ROAD ENGINEERING BRANCH
Program CONCC

- Originally used on mainframe computer, then on PC
- Only available as compiled Fortran
- Original code now lost
- Uses “fixed format” Fortran – right adjusted, integers & floating point formats must be adhered to
- Careful attention to input data
- Determines thickness for given concrete strength & k value
- Can consider 10 aircraft in the traffic mix
- Simulates “influence chart” method within 10% for 4 wheel gear
- Each leg is limited to 8 wheels
- Antonov An-124 (10 wheels per leg) cannot be directly simulated
Brisbane Airport

Pavements comprised the following

• 400mm plain concrete
• 150mm crushed rock base (well graded to prevent pumping)
• 1500mm sand
• Subgrade of mangrove clay
Jointing

- Longitudinal joints are usually dowelled and formed
- Transverse joints are generally sawn to 0.25 x pavement thickness
- Keyed joints and tied joints are no longer used
- Temporary protection of sawn joints to prevent entry of construction debris
- Isolation joints are used at drains and structures and are commonly 20mm wide with compressible filler with sealant at the top
- In the past slabs up to 7.5 m have been prone to cracking and spalling with loose concrete fragments on the surface
- Slab sizes are now generally 5 to 6m
Concrete

- 40mm maximum size aggregate used in mix
- This gives better aggregate interlock at sawn joints
- Aggregates must be high quality, sound, durable & unweathered
- Minimum cement content 360 kg per cubic metre
- Strength specified as flexural (beam) tests - 4.5 to 4.8 MPa
- Beams must be 150mm square section
- Only rarely is compressive strength testing used and then 150mm diameter cylinders are required
- Water cement ratio 0.45 maximum
- Slump 50mm maximum
Joint Sealing

• Taxiways and Runway ends may have narrow unsealed joints
• On Aprons, where surface activity is high, joints are more likely to be sealed
• Initial saw cut widened to about 10mm for the sealant
• Sealants are silicone, polysulphide or polyurethane
• Self expanding cork is no longer used
Reinforcement & Dowels

Reinforcement

• Pavements are predominantly plain (unreinforced) concrete
• Mesh reinforcement is used in odd shaped (outside 1.25 : 1 ratio) or where pits or footings for light towers etc occur in a panel or where mismatched joints occur
• For 400mm thick slab – SL 82 at 130mm cover

Dowels

• For 400mm thick slab – R36 dowels at 375mm ctrs and 500mm long
Spalling at grated drain – inadequate isolation joint
An example of good joint detailing
PCA Procedure (AIRpav 2000)

- Assumptions
  - Westergaard Analysis
  - Center Loading (+25%)
  - Engineer Selects Stress Ratio
  - Gear Rotation
- ICAO Standard
  - PCN Calculation
Maximum Stress Gear Positions
PCA & AIRpave Program

- Portland Cement Assoc (PCA) in USA has transferred rights to PCA Eng Bulletin EB050P *Design of Airport Pavement* by Robert Packard (1973, reprinted 1995) to American Concrete Pavement Assoc (ACPA) – [www.pavement.com](http://www.pavement.com)
- Program AIRpave 2000 Version 1.2 (2001) is available from ACPA – it is understood to be an update of the 1968 PCA program