Present and Future Work Items of the ICAO Pavement Sub-Group

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ICAO Pavement Sub-group Work Statement

- Total Re-write of Part 3-Pavements - estimated completion date end of 2015

- Unpaved Surface Requirements - Aerodrome Manual - Part 1 - Runways

- Revised ICAO Overload Guidance for Annex 14

- New ACN/PCN Procedure - Multi-Layered Linear Elastic Method

- Summary
PCN definition- A number expressing the bearing strength of a pavement for ‘unrestricted operations’. What is meant by ‘unrestricted’?

- Revised section 1.1.2.1- The term unrestricted operations in the definition of PCN does not mean unlimited operations. Unrestricted refers to the relationship of PCN to the ACN, and it is permissible for an aircraft to operate without weight restriction (subject to tire pressure limitations) when the PCN is greater than or equal to the ACN. The term unlimited operations does not take into account pavement life. The PCN to be reported is such that, the pavement strength is sufficient for the current and future traffic analyzed, and should be re-evaluated if traffic changes significantly.

Current PCN guidance in ICAO Aerodrome Design Manual- Part 3 Pavements states “the airport authority can use any method of his choice to determine the load rating of his pavement.”

- New section 1.1.2.5- State may lack expertise in this area or wish to incorporate a standard methodology for performing the technical evaluation of their pavements. PSG has proposed the FAA COMFAA program as initial guidance in calculating PCN rating.
Clarification was needed to determine the difference between the “using aircraft” PCN and technical PCN. Additionally, clarification of what PCN to report for a runway was added.

- Revised section 3.6.4.9e- For pavements of varying cross section and subgrade strength it may be difficult to arrive at a single PCN value to report. A decision must be made whether to report the lowest PCN or a higher PCN which would not restrict traffic. This is at the discretion of the airport authority and may depend on the frequency of operations of heavier aircraft that would be permitted by reporting a higher PCN, where the weaker pavement section is located, or if increased maintenance may be necessary.
ICAO ACN Calculator

New ACN calculator part of revision to Part 3- scaled down version of COMFAA

Ability to determine ACN’s at intermediate weights. FAA to safeguard software and provide master copy to ICAO
Revised Table A5-1 in Part 3- Appendix 5

Table A5-1. ACNs for several aircraft types on rigid and flexible pavements

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>All-up mass (kg)</th>
<th>Load on one main gear leg (%)</th>
<th>Tire Pressure (MPa)</th>
<th>ACN FOR RIGID PAVEMENT SUBGRADES - MN/m²</th>
<th>ACN FOR FLEXIBLE PAVEMENT SUBGRADES - CBR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>High 150</td>
<td>Median 80</td>
<td>Low 40</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>A300 B2</td>
<td>142,000</td>
<td>88,000</td>
<td>47.0</td>
<td>1.28</td>
<td>38</td>
</tr>
<tr>
<td>A300 B4</td>
<td>165,000</td>
<td>90,000</td>
<td>47.0</td>
<td>1.46</td>
<td>48</td>
</tr>
<tr>
<td>A300-600 B4</td>
<td>165,000</td>
<td>92,000</td>
<td>47.5</td>
<td>1.28</td>
<td>46</td>
</tr>
<tr>
<td>A300-600R B4</td>
<td>172,600</td>
<td>90,000</td>
<td>47.5</td>
<td>1.34</td>
<td>50</td>
</tr>
<tr>
<td>A300-500R B4/F</td>
<td>172,600</td>
<td>90,000</td>
<td>47.5</td>
<td>1.34</td>
<td>50</td>
</tr>
</tbody>
</table>

- Aircraft updated from original 1983 database. Older versions such as Concorde removed and most recent models such as 787, A350 and A380 added

- ACN values updated based on 2007 acceptance by ICAO of new 4 and 6 wheel alpha factors

- Aircraft in table now based on minimum weight of 40 tonnes and 70 or more passengers
Revised Table A1-1 in Part 3- Appendix 1

Aircraft updated to match Table A5-1. Wheel arrangement nomenclature matches current industry standard based on FAA Order 5300.7

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>All-up mass (kg)</th>
<th>Load on one main gear leg (%)</th>
<th>Wheel arrangement</th>
<th>Load on each leg (kg)</th>
<th>Tire pressure (MPa)</th>
<th>Wheel spacing (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A300 B2</td>
<td>142,900</td>
<td>47.0</td>
<td>2D</td>
<td>67,163</td>
<td>1.28</td>
<td>89</td>
</tr>
<tr>
<td>A300 B4</td>
<td>165,900</td>
<td>47.0</td>
<td>2D</td>
<td>77,973</td>
<td>1.46</td>
<td>93</td>
</tr>
<tr>
<td>A300-600 B4</td>
<td>165,900</td>
<td>47.5</td>
<td>2D</td>
<td>78,803</td>
<td>1.28</td>
<td>93</td>
</tr>
<tr>
<td>A300-600R B4</td>
<td>172,600</td>
<td>47.5</td>
<td>2D</td>
<td>81,985</td>
<td>1.34</td>
<td>93</td>
</tr>
<tr>
<td>A300-600R B4F</td>
<td>172,600</td>
<td>47.5</td>
<td>2D</td>
<td>81,985</td>
<td>1.34</td>
<td>93</td>
</tr>
<tr>
<td>A300-600R F4</td>
<td>171,400</td>
<td>47.5</td>
<td>2D</td>
<td>81,415</td>
<td>1.34</td>
<td>93</td>
</tr>
<tr>
<td>A310-200</td>
<td>142,900</td>
<td>46.6</td>
<td>2D</td>
<td>66,591</td>
<td>1.33</td>
<td>93</td>
</tr>
</tbody>
</table>
1. Updates to section 5.3-Surface Treatment of Runways
   a. Additional guidance on the pros and cons of grooving have been added
   b. Alternatives to grooving to achieve skid-resistance have been added. Details of the French bituminous concrete (BBA) and stone matrix asphalt (SMA) used in China for surface wearing courses have been added in a new section 5.3.8

2. Chapter 4- State Practices
   a. US practice pages in Part 3 will be replaced with references and web links to FAA advisory circulars (i.e. 150/5320-6E) and design software (i.e. Faarfield 1.4) currently being used for the design, evaluation and strength reporting of pavements. Nomographs will all be removed.
   b. United Kingdom and Canada state practice sections will be removed completely.

3. Miscellaneous
   a. Remove Appendix 2-Fortran Code, Appendix 3-French design graphs and Appendix 4-US background information.
   b. Minor re-wording of Chapters 6- Protection of Asphalt Pavements and Chapter 7- Structural Concerns for Culverts and Bridges
Strength- Runway Strip
5.3.22 Since the graded portion of a strip is provided to minimize the hazard to an aircraft running off the runway, it should be graded in such a manner as to prevent the collapse of the nose landing gear of the aircraft. The surface should be prepared in such a manner as to provide drag to an aircraft and below the surface, it should have sufficient bearing strength to avoid damage to the aircraft. To meet these divergent needs, the following guidelines are provided for preparing the strip. Aircraft manufacturers consider that a depth of 15 cm is the maximum depth to which the nose gear may sink without collapsing. Therefore, it is recommended that the soil at a depth of 15 cm below the finished strip surface be prepared to have a bearing strength of California Bearing Ratio (CBR) value of 15 to 20. The intention of this underlying prepared surface is to prevent the nose gear from sinking more than 15 cm. The top 15 cm may be of lesser strength which would facilitate deceleration of aircraft.

Strength- Runway End Safety Areas
5.4.13 A runway end safety area should be so prepared or constructed as to reduce the risk of damage to an aeroplane undershooting or overrunning the runway, enhance aeroplane deceleration, and facilitate the movement of rescue and fire fighting vehicles. See 5.3.22 for guidance on the minimum strength of the runway end safety area.

The new ICAO guidance will make reference to Part 3- Pavements for strength requirements. The current 15 cm of surface soft material for aircraft deceleration on overruns should not affect continued landing on an undershoot condition.

Strength- Runway Shoulders
5.2.10 A runway shoulder should be prepared or constructed so as to be capable, in the event of an aeroplane running off the runway, of supporting the aeroplane without inducing structural damage to the aeroplane and of supporting ground vehicles which may operate on the shoulder.

The new ICAO guidance will make reference to Part 3- Pavements for strength requirements.
Typical un-surfaced shoulders and RESA will be at low CBR-natural soil conditions. Stronger cover material needs to be added to support subgrade.
Methodology: PCASE

Use PCASE modified CBR equation:

\[ t_{covered} = (0.1275 \times \log C + 0.087) \sqrt{P / 8.1 \times CBR - A / \pi} \]


- C: number of coverages
- P: ESWL. Function of gear type and thickness
- A: tire contact area.

Method assumes a single layer of cover material of higher CBR can be used to support natural soil. Soil strength determined from DCP testing.
Proposed Method for ICAO Un-surfaced Criteria

1.) Determine cover thickness requirement and CBR min for four subgrade types.

2.) 3 aircraft groups: regional, narrow body and widebody

3.) Assume minimum pass level of 10. Current 3” (7.6 cm) rut failure criteria assumes rolling load, no braking affects. FAA paved shoulder design based on 10 passes.

4.) Cover material similar to FAA P-154 subbase, CBR 20.

5.) Maintain existing shoulder surface grade by removing in situ soil to the required depth and replacing with required cover material.
<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Cover Material</th>
<th>Requirement-thickness (cm) and CBR min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBR 3</td>
<td>CBR 6</td>
</tr>
<tr>
<td>A320-200</td>
<td>15 (CBR 11)</td>
<td>10 (CBR 11)</td>
</tr>
<tr>
<td>737-800</td>
<td>18 (CBR 14)</td>
<td>13 (CBR 14)</td>
</tr>
<tr>
<td>737-900ER</td>
<td>18 (CBR 16)</td>
<td>13 (CBR 16)</td>
</tr>
<tr>
<td>747-400</td>
<td>25 (CBR 17)</td>
<td>18 (CBR 17)</td>
</tr>
<tr>
<td>A340-500</td>
<td>28 (CBR 22)</td>
<td>20 (CBR 22)</td>
</tr>
<tr>
<td>777-300ER</td>
<td>33 (CBR 20)</td>
<td>23 (CBR 20)</td>
</tr>
<tr>
<td>Dash 7</td>
<td>8 (CBR 5)</td>
<td>none</td>
</tr>
<tr>
<td>EMB 170</td>
<td>10 (CBR 8)</td>
<td>8 (CBR 8)</td>
</tr>
</tbody>
</table>
Proposal for ICAO Guidance

<table>
<thead>
<tr>
<th>Aircraft Group</th>
<th>Cover thickness required for subgrade type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBR 3</td>
</tr>
<tr>
<td>Group 1</td>
<td>4” (10 cm)</td>
</tr>
<tr>
<td>Group 2</td>
<td>7” (18 cm)</td>
</tr>
<tr>
<td>Group 3</td>
<td>12” (31 cm)</td>
</tr>
</tbody>
</table>

Group 1- Regional aircraft less than 30K (13.6 K kg) wheel loads

Group 2- Narrow body aircraft 30K-45K wheel loads

Group 3- Widebody aircraft > 50K (22.7 K kg) wheel loads

Conservative assumption of P-154 type cover material, CBR 20 min for all cases
FAA and ICAO Overload Criteria

Occasional minor aircraft overloading is acceptable with only limited loss of pavement life expectancy and relatively small acceleration of pavement deterioration. Those operations in which Magnitude and/or Frequency does not require a detailed technical analysis the following criteria is suggested.

- Flexible pavement
  ACN should not exceed 10% of the reported PCN

- Rigid pavement
  ACN should not exceed 5% of the reported PCN

Annual overload movements should not exceed ~5% of total annual aircraft movements

Overloads should not be allowed:
- If pavement is exhibiting signs of distress
- During periods of thaw
- When pavement/subgrade is weakened by water
Full-scale tests will consider:

- Percent overload based on PCN. Various overload levels up to 40-50% to be considered. Current ICAO overload guidance for flexible pavements only 10%.
- Percent overload based on CDF-.10, .50, 1.0
- Used pavement life expressed as cumulative damage factor (CDF). Effect of overload on pavement life to be compared against ACN/PCN ratio

Full-scale tests will consider:

- Dual, Dual tandem and 6 wheel gears
- Monitoring rutting will give indication of subbase failure due to overload
## Overload Tests for Flexible Pavement

### ACN Criterion

<table>
<thead>
<tr>
<th>Gear Type</th>
<th>Overload</th>
<th>ACN</th>
<th>Wheel Load, lb (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>100% PCN</td>
<td>35.02</td>
<td>36,000 (16,330)</td>
</tr>
<tr>
<td>D</td>
<td>110% PCN</td>
<td>38.52</td>
<td>39,123 (17,745)</td>
</tr>
<tr>
<td>D</td>
<td>120% PCN</td>
<td>42.02</td>
<td>42,168 (19,127)</td>
</tr>
<tr>
<td>D</td>
<td>125% PCN</td>
<td>43.78</td>
<td>43,688 (19,816)</td>
</tr>
<tr>
<td>D</td>
<td>150% PCN</td>
<td>52.53</td>
<td>51,051 (23,156)</td>
</tr>
<tr>
<td>2D</td>
<td>110% PCN</td>
<td>38.52</td>
<td>35,423 (16,067)</td>
</tr>
<tr>
<td>2D</td>
<td>120% PCN</td>
<td>42.02</td>
<td>37,733 (17,115)</td>
</tr>
<tr>
<td>2D</td>
<td>125% PCN</td>
<td>43.78</td>
<td>38,837 (17,616)</td>
</tr>
<tr>
<td>2D</td>
<td>150% PCN</td>
<td>52.53</td>
<td>44,128 (20,016)</td>
</tr>
</tbody>
</table>

### CDF Criterion

<table>
<thead>
<tr>
<th>Gear Type</th>
<th>Overload</th>
<th>Wheel Load, lb (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>CDF = 0.10</td>
<td>45,481 (20,630)</td>
</tr>
<tr>
<td>D</td>
<td>CDF = 0.50</td>
<td>55,456 (25,154)</td>
</tr>
<tr>
<td>D</td>
<td>CDF = 1.00</td>
<td>61,334 (27,820)</td>
</tr>
<tr>
<td>2D</td>
<td>CDF = 0.10</td>
<td>39,663 (17,990)</td>
</tr>
<tr>
<td>2D</td>
<td>CDF = 0.50</td>
<td>48,688 (22,084)</td>
</tr>
<tr>
<td>2D</td>
<td>CDF = 1.00</td>
<td>53,378 (24,212)</td>
</tr>
</tbody>
</table>

- Pavement design thickness based on COMFAA-assumed design life of 27,000 passes. ACN criterion wheel loads as determined using COMFAA.
- CDF criterion wheel loads determined using Faarfield 1.4 and CDF overload.
1. Initial test load of 36,000 lb (16,330 kg) wheel load. Pavement is trafficked until rutting rate stabilizes.

2. Increase ACN by 10% overload increments—this determines wheel loading. Traffic until pavement stabilizes, but not more than 5% of lifetime traffic cycles (~1300 passes).

3. Return to 36,000 lb wheel load and traffic until pavement behavior stabilizes. Repeat with 10% increments until 150% loading is achieved or failure occurs. Overload failure will be evident by dramatic jump in rutting—indication of shear failure in lower pavement layers.
Worldwide Overload Guidance

Overload policy varies between countries—dependent on regulatory authority and not always follows ICAO criteria

- **Canadian overload**
  - Overload ratio for flexible pavements is computed based on subgrade strength required by aircraft and actual in-place subgrade strength. For concrete, ratio is based on stress induced in the slab and flexural design strength of slab of 400 psi.
  - Overload ratio determines the number of permitted operations. For example, ratio of 1.25-1.50 allows 300 operations between inspections.

- **Russian overload**
  - Overload ratio of PCN/ACN used to determine allowable departures per day
  - Flexible pavements: Ratio of .80-1.0 (25%) allows 20 dep/day, .70-.80 (40%) allows 5 dep/day
  - Rigid pavements: Ratio of .85-1.0 allows 10 dep/day, .80-.85 allows 2 dep/day

- **Australian overload**
  - The airport typically allows a pavement concession to the operator for the overload.
  - Pavement distress is monitored for a period of time, and if no resulting visual damage the PCN is set equal to the aircraft ACN. Amount of overload could exceed ICAO levels.
ICAO-PSG-Item.7

“The PSG agreed that the introduction of an ACN determination procedure more consistent with modern pavement design methods needs to be addressed quickly knowing that the development of such a procedure would take time. Thoughts toward this new approach will be carried on during the 2012-2015 work cycle. Incorporation of new methodology expected in 2018 timeframe.”

OBJECTIVES:
- To align the new ACN procedure with the current practice for pavement design and analysis, multi-layered linear elastic systems such as Faarfield.
- Attempt to keep the current ACN-PCN structure unchanged (number, pavement type, subgrade code…).
- Develop a new and unique procedure for PCN determination using the same linear elastic methods.

BENEFITS:
- Eliminate inconsistency between new pavement design and pavement ratings which are based on different analysis methods.
- Alpha factors and thickness equivalency factors would no longer be needed.
Details of the New Method

Retaining the same appearance and simplicity of the current system is important, less impact on the airport authority and their willingness to accept a new methodology.

The new procedure would require the following steps and parameters:

i. Define typical flexible reference structures (Surface and base asphalt layer thicknesses and moduli have to be fixed),

ii. Define the new DSWL standard condition (1.5MPa suggested),

iii. Define standard number of coverages of an aircraft landing gear (36,500 for initial evaluation-i.e. 10 coverages per day over 10 yrs)

iv. Compute the DSWL (in kg) at standard conditions which gives the same pavement thickness as the aircraft used for the ACN computation.

v. Pavement thickness is computed by adjusting (subbase) thickness only, such that CDF is equal to 1.0
Historical Definition of ACN- 1980’s

Using linear elastic techniques we are now dealing with equal subgrade strains or possibly equal subgrade stress levels.

Load at Max CG = DSWL

Airplane Operating Tire Pressure ?? psi

Defined Tire Pressure 181 psi (1.25 Mpa)

Equal Deflection

Compute DSWL so subgrade deflection is equal
Reference Structures for the ACN Calculation

- **Pavement structure**
  - Surface layer and base layer are fixed, only the subbase layer is adjusted to reach a CDF of 1 (for a fixed number of passes)
  - Pavement subbase thickness is determined for each aircraft. DSWL is then computed at the same thickness with \( ACN = 2 \times DSWL \):

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Surface Configuration</th>
<th>Young Modulus E (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.16 cm (4.00 in)</td>
<td>P-401 / P-403 HMA Surface</td>
<td>1378.95</td>
</tr>
<tr>
<td>12.70 cm (5.00 in)</td>
<td>P-401 / P-403 St (flex)</td>
<td>2757.90</td>
</tr>
<tr>
<td>Variable thickness</td>
<td>P-209 CrAg (Design layer)</td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td>E = variable</td>
<td></td>
</tr>
</tbody>
</table>

- The subgrade is defined by its Young modulus \( E \) through the equivalency
  \[
  E = 10 \times \text{CBR} \sim 1500 \times \text{CBR} \quad (E \text{ in PSI})
  \]

- The design criterion is the subgrade failure
Preliminary ACN Results – CBR 10 (E=100 MPa)

CBR 10 (E=100 MPa)

D 2D 3D and NLA Next Gen

Current ACN
New ACN - Alt1 (6+12 cm)
New ACN - FAA/FEFD (4+5 cm)
Preliminary ACN Results – CBR 3 (E=30 MPa)
Summary and Future Work

• For D type aircraft the results derived from Alizé-LCPC and FAARFIELD correlate quite well across all subgrade strengths

• For 2D and 3D aircraft, the difference between Alizé-LCPC and FAARFIELD become quite significant
  • For high subgrade strengths, FAARFIELD is close to current aircraft ACN’s (typically lower) while Alizé-LCPC leads to higher ACNs;
  • For low subgrade strengths both are significantly higher than current ACNs

Future Work

• Incorporate the Alize method of looking at multi-axle loading. Faarfield uses a pass/coverage approach whereas Alize uses a multi-peak integration approach. This will effect the CDF computation significantly and the ACN computation slightly.

• Rigid pavements need to be addressed- currently assumed not to be as discrepant as the flexible pavement failure models

• Consider different reference structures and coverage levels for ACN determination
Preguntas?

Muchas Gracias!