AIRPORT PAVEMENT WORKING GROUP MEETING, April 15, 16, 17 - 2013

ICAO-Pavement Subgroup update

New ACN calculation method, MLEA based

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Aircraft Classification Number (80's)

- Numerically, the ACN is two times the derived single wheel load (DSWL)
- The DSWL is obtained by equating the thickness given by the mathematical model for an aircraft LG to the thickness for a single wheel inflated at a standard tire pressure of 1.25 MPa. The DSWL is computed by using the Pre-MWHGL equation for 10 000 coverages and a contact pressure of 1.25 MPa
- For Flexible pavement, the mathematical model widely in use at this time (80's) was the Boussinesq solution for stresses and displacements in a homogeneous isotropic half-space under surface loading. The "CBR Design model" was then selected for ACN computation to allow the maximum correlation to world-wide pavement design methodology.
- What is today worldwide practice for pavement design and analysis?

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Aircraft Classification Number – NEW

- 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"

OBJECTIVES:

- To align the new ACN procedure with the current recommended practice for pavement design and analysis method, the multi-layered linear elastic analysis (ML²EA).
- Take advantage of the latest advanced methodology in pavement thickness design by keeping the current ACN-PCN structure unchanged (number, pavement type, subgrade code…).
- To develop a new and unique procedure (based on the ML²EA techniques) for PCN determination and publication which would be derived from the new ACNs of a traffic mix and the pavement characteristics.

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New Proposal Benefits

- Primary benefit to the airport owner is lower cost, and improved pavement management with optimal use of their pavement infrastructures and proper management of aircraft operating weights and frequencies.

- The mechanical approach will eliminate de facto the Alpha-factors (introduced to offset the overestimated damage produced by multi-wheel arrangement in the initial CBR equation)

- Current one-leg approach replaced by the full aircraft gear arrangement, allowing to accurately include gear proximity effect within the ACN calculation.

- Eliminate inconsistencies between pavement design and pavement strength reporting requirement and will encourage development of a whole program addressing both item on the same ML²EA system

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HOW TO ACHIEVE A NEW ACN?

- Keep the same procedure as today by replacing the CBR design procedure by the ML²EA procedure. By retaining the same appearance and simplicity of the current system, the changes would not be as substantial as they might otherwise appear to those who are unfamiliar with airfield pavement.
- The new procedure would require to:

  i. Define typical flexible structures (Surface and base AC layers thicknesses and modulus has to be fixed),
  ii. Define the new DSWL standard condition (1.5MPa suggested),
  iii. Define standard number of coverages of an aircraft landing gear (10,000?, 100,000?, other?),
  iv. Compute the DSWL (in ton) at standard conditions which gives the same pavement thickness (for the given design criteria) as required by the considered aircraft for the standard number of coverages
  v. Pavement thickness is computed by adjusting UGA (subbase) thickness so that CDF is equal to one (1)

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1st Computation Batch

- Compute Aircraft Classification Numbers (ACN) with new calculation method based on ML²EA computer programs **Alizé-LCPC** and **FAARFIELD V1.4 (Adapted for the purpose)**
- Compare computed values with current ACN
- Compare results derived from Alizé-LCPC and FAARFIELD
- The new ACN calculation method is based on the following steps:
    1. Compute the pavement thickness required by the aircraft
    2. Compute the new Derived Single Wheel Load (DSWL), at a standard tire pressure inflation of 1.5 MPa, that would require the same pavement thickness (SAC and BAC being fixed)
    3. Compute the ACN as two times the new DSWL (in Kgs)

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Hypotheses

- 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 structures are different for Alizé-LCPC and FAARFIELD:

Alizé-LCPC

6 .00 cm (2.36 in)	SAC	E = 1300.00 MPa
12.00 cm (4.72 in)	BAC	E = 2700.00 MPa
Variable thickness	UGA (Design layer)	E = variable
	Subgrade	

FAARFIELD

10.16 cm (4.00 in)	P-401 / P-403 HMA Surface	E = 1378.95 MPa
12.70 cm (5.00 in)	P-401 / P-403 St (flex)	E = 2757.90 MPa
Variable thickness	P-209 CrAg (Design layer)	E = variable
	Subgrade	

  - The subgrade is defined by its **Young modulus E** through the equivalency
    E = 10 x CBR ~1500 x CBR (E in PSI)
    Other equivalencies could be explored
  - The design criterion is the **subgrade failure**

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Hypotheses (1/2)

- Aircraft data
  - Aircraft data (LG footprint, wheel load & pressure) used for computations is the same for both software

Aircraft	Maximum Taxi Weight (tons)	Tire pressure (MPa)
A320-100	68.4	1.24
A320-200	77.4	1.38
737-400	68.3	1.28
A321-100	85.4	1.39
A321-200	93.4	1.50
737-900	79.2	1.41
A330-200	233.9	1.42
A330-300	233.9	1.45
767-400ER	204.6	1.49
A340-300	277.4	1.42

Aircraft	Maximum Taxi Weight (tons)	Tire pressure (MPa)
777-200ER	298.5	1.41
777-300ER	352.4	1.55
747-400ER	414.1	1.59
A380-800	562.0	1.50
A380-800 BLG	562.0	1.50
A380-800 WLG	562.0	1.50
787-9	251.7	1.58
A350-900	268.9	1.66

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Hypotheses (2/2)

- Aircraft traffic
  - Pavement structures are designed for **36,500** aircraft passes (equivalent to 10 passes per day over 10 years)
  - **Aircraft lateral wandering** is not addressed (i.e. σ=0)
- DSWL
  - The new DSWL would be the single wheel load inflated at 1.5 MPa that produces the same strain at subgrade level in a multi-layer linear elastic system as the design gear,
  - The new DSWL is computed for the same traffic level as the aircraft i.e. at **36,500** passes
  - **Lateral wandering** is not addressed (fixed at σ=0)

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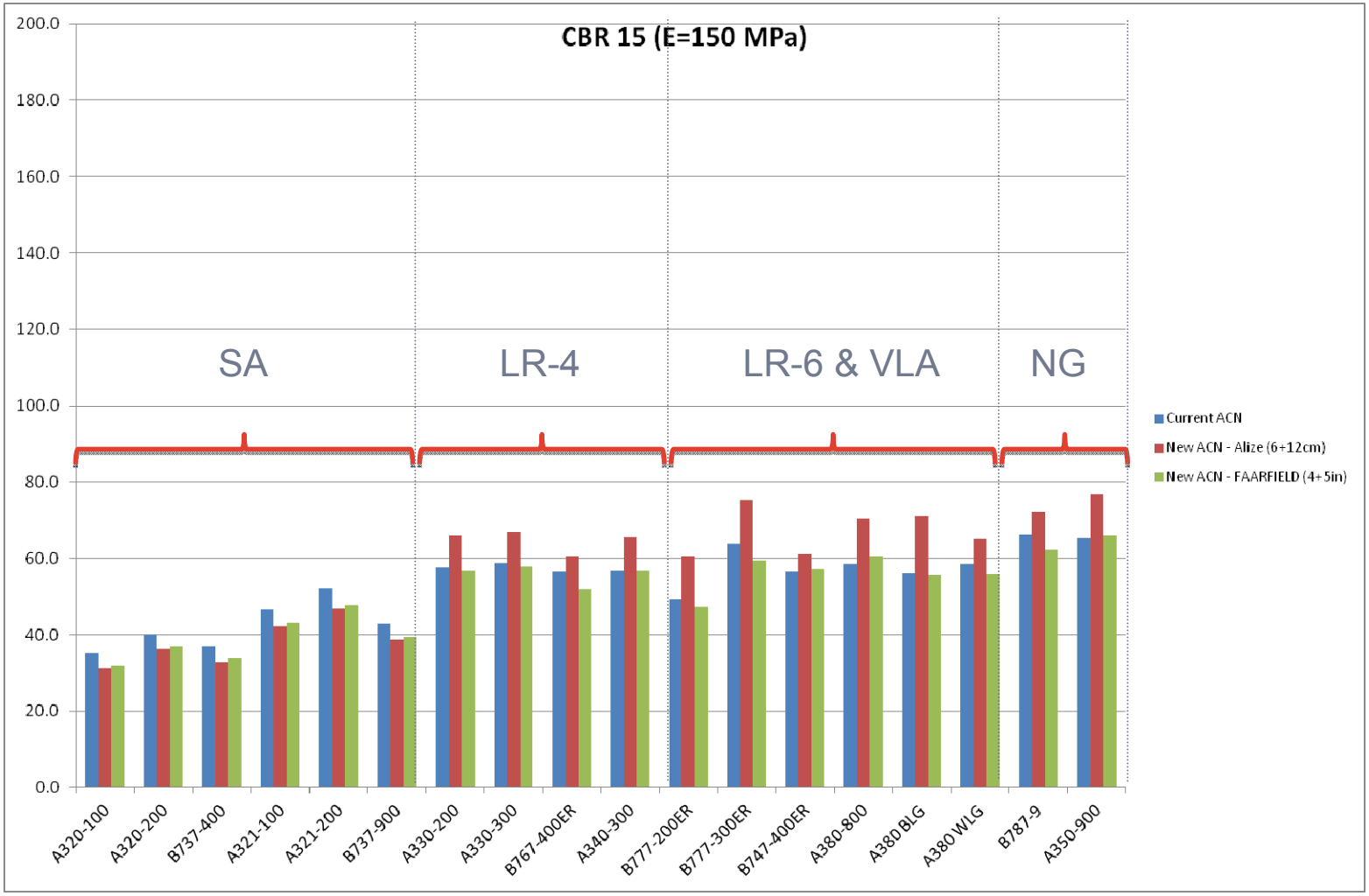
ACN comparison – CBR 15 (E=150 MPa)



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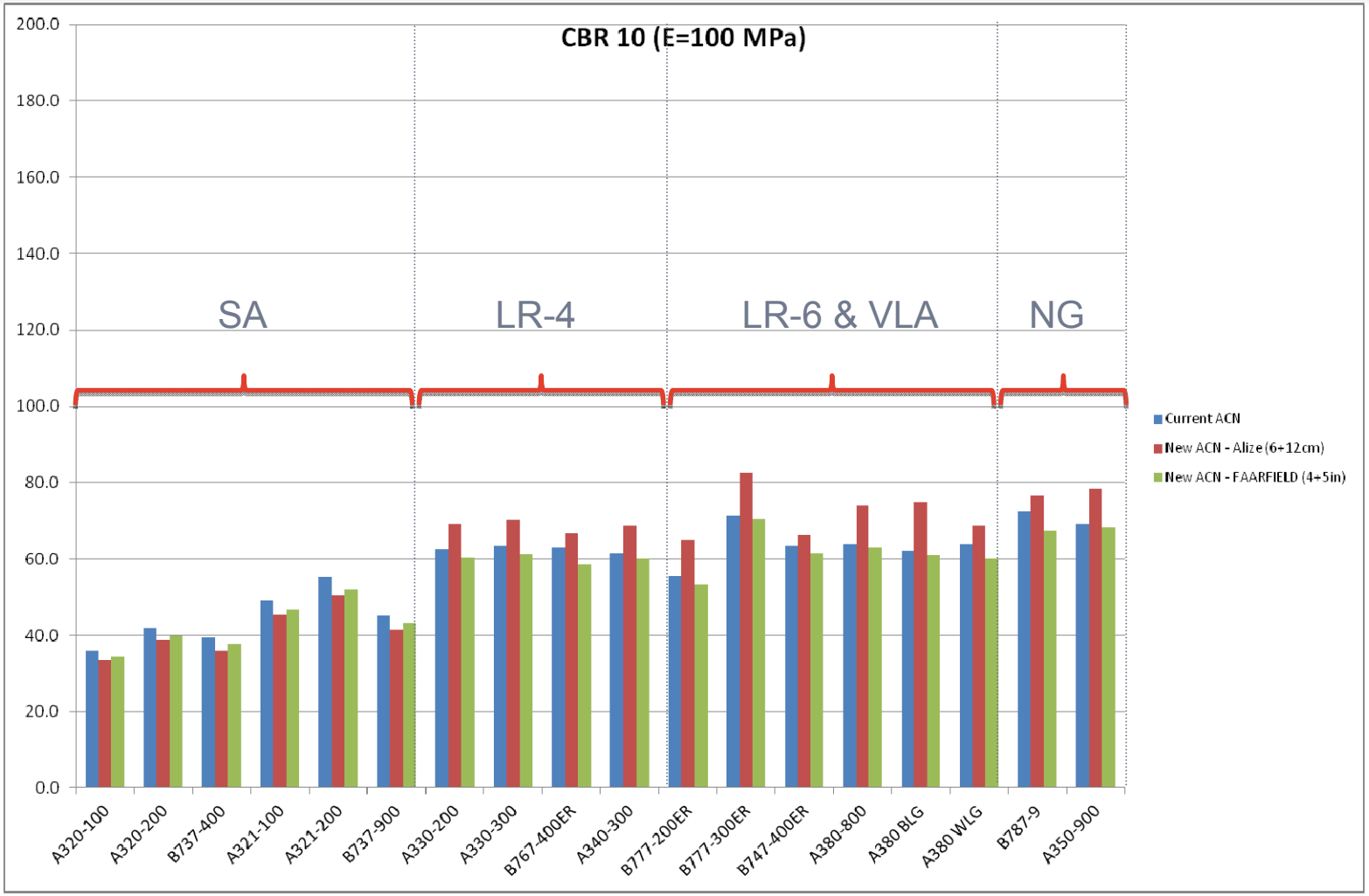
ACN comparison – CBR 10 (E=100 MPa)



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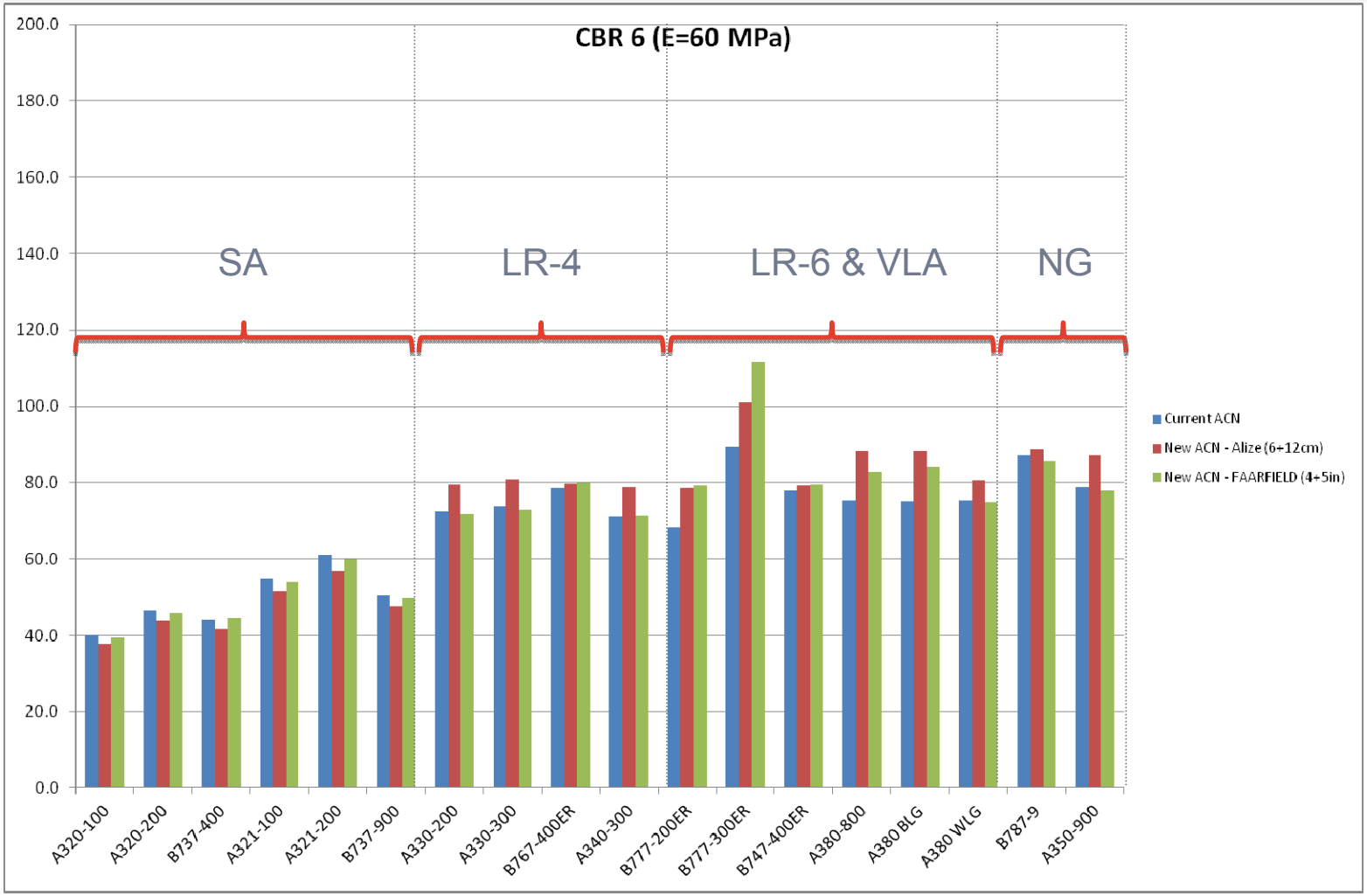
ACN comparison – CBR 6 (E=60 MPa)



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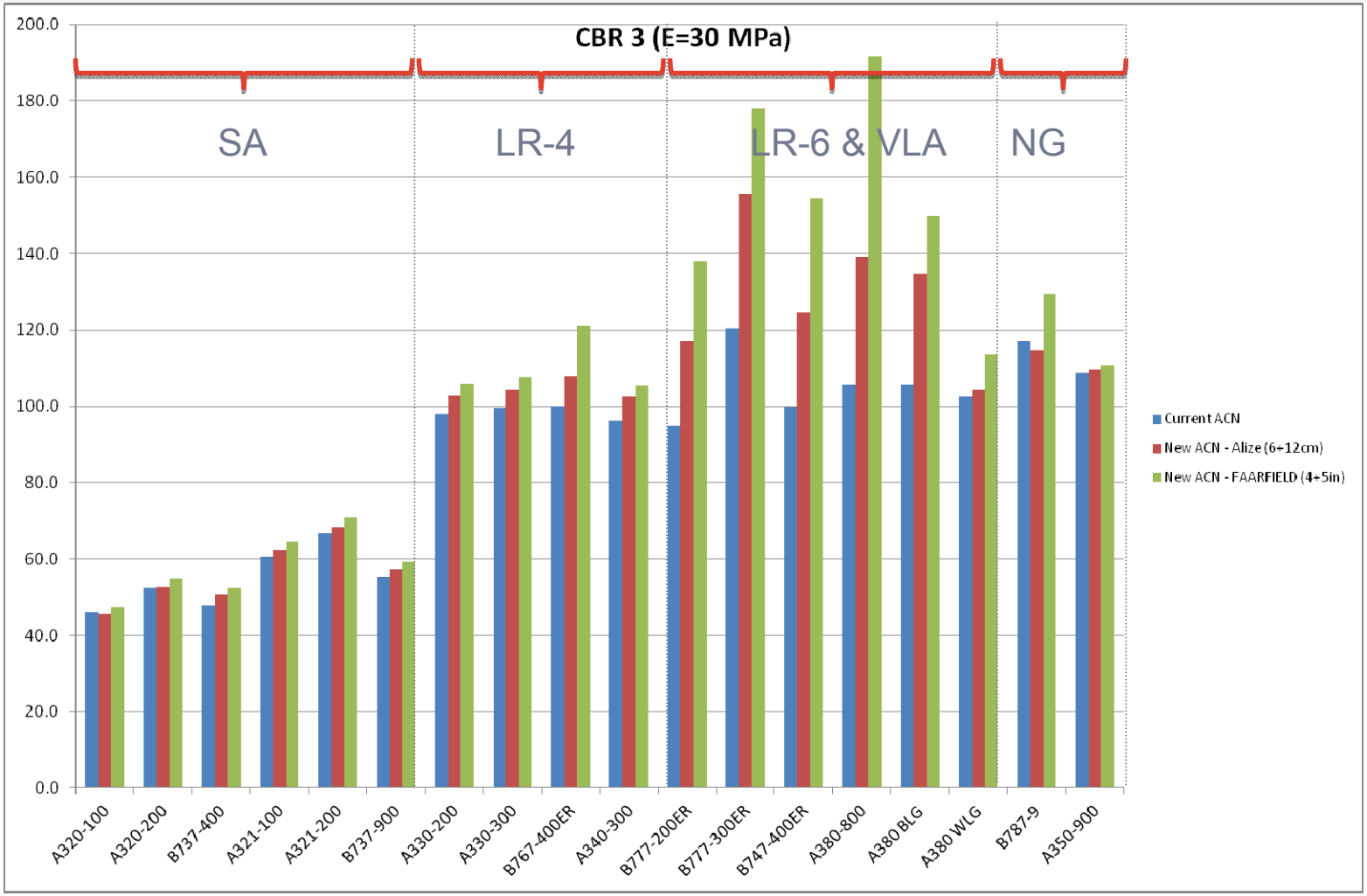
ACN comparison – CBR 3 (E=30 MPa)



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Comments

- For D (SA) aircraft results derived from Alizé-LCPC and FAARFIELD correlate quite well
- For 2D (LR) and 3D (LR & VLA) aircraft, the difference between Alizé-LCPC and FAARFIELD become quite significative
  - For high subgrade strengths, FAARFIELD is close to current ACN while Alizé-LCPC lead to higher ACNs;
  - For low subgrade strengths, the gap between Alizé-LCPC and FAARFIELD is of less importance
- For 3D aircraft, both Alizé-LCPC and FAARFIELD values exceed significantly current ACN values on medium and low subgrade strengths

	Average difference between ACNs from Alizé-LCPC and FAARFIELD (as % of lowest value)			
	E=150 MPa	E=100 MPa	E=60 MPa	E=30 MPa
2-wheels	2.3 %	3.3 %	5.1 %	3.5 %
4-wheels	14.8 %	13.4 %	7.1 %	8.4 %
6-wheels	27.3 %	20.5 %	5.5 %	14.6 %

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Preliminaries Findings

- No or marginal surface and base AC thickness effect: The AC thickness variations are compensated by UGA layer, giving similar equivalent pavement thicknesses and DSWLs when computations are based on the subgrade failure criteria,
- 2-wheels and 4-wheels aircraft give coherent results compared to current ACN values.
- 6-wheel gear assembly gives higher DSWLs (thus ACNs), in particular on low subgrade strength,
- Comparison between the 787-9 and A350-900 illustrate pretty well the combined effect of individual wheel-loads, which prevails on high subgrade strength, and the gear geometry effect which prevails on low subgrade strength,
- The gear proximity effect are revealed when comparing results on A380 full MLG and either its BLG or WLG treated independently. NAPTF test findings on gear interaction could ease for a rational justification of this issue.

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Future works

- Significant discrepancies we have in some cases between current ACNs and ALIZE/FAARFIELD or between ALIZE and FAARFIELD should trigger deeper investigation on:
  1. The fundamental differences between ALIZE-lcpc and FAARFIELD (Fatigue low, P-to-C ratio etc...). This should help explaining the 3D gear type results,
  2. The gear interaction effect for complex aircraft LG arrangement,
  3. The equivalency factors between US material and others
  4. Make the method valid for the largest aircraft types from ~ 6t to 600t+

- Think about a future integrated computer programme (part of a PMS) which would be based on ML²EA. Pavement design, ACN, PCN and overload operations would be handle by this single tool.
- Test other soil fatigue law (Shell, APSDS...)

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