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A New Mechanistic Design Procedure for Flexible Airfield Pavements

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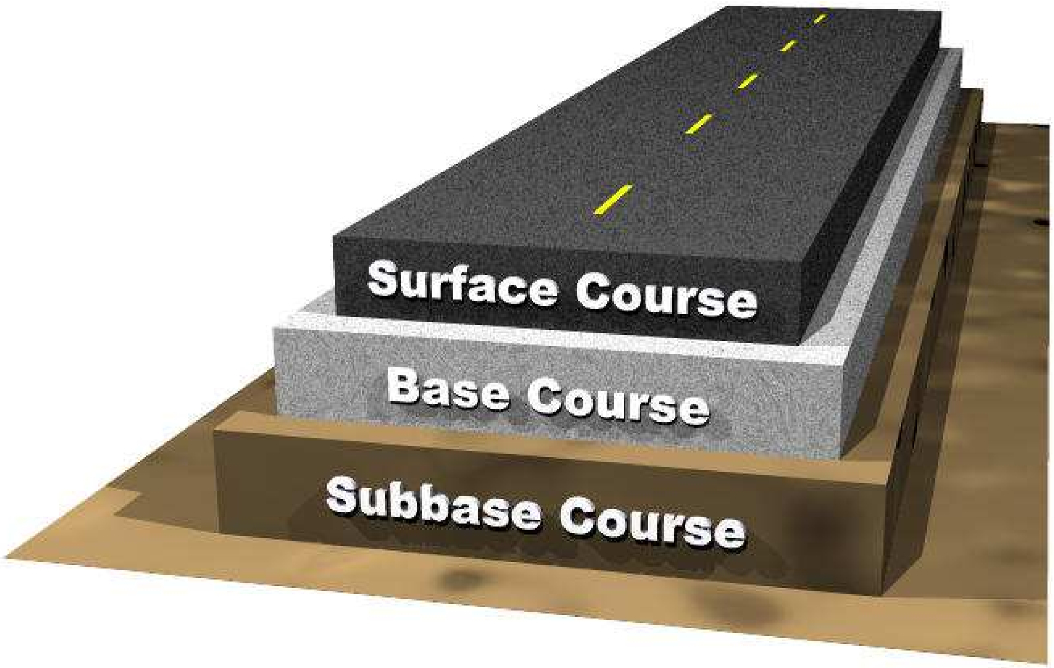
STS N°

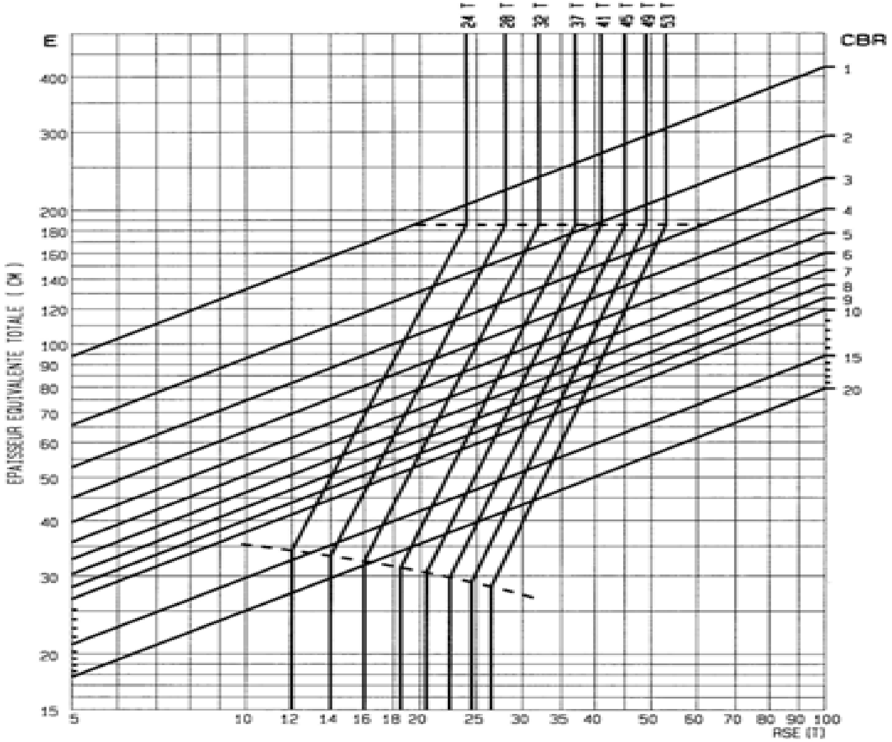
What is pavement design?

- Determination of the thickness of the layers constituting the pavement structure for a given traffic mix



A necessary revision

- Former empirical method (DCA software)
  - Inspired by the US Corps of Engineers design method
  - Based on the CBR method



A necessary revision

- Many limitations
  - No explicit consideration of asphalt material damage
  - CBR tests for soil's characterization
  - New materials not correctly considered
  - No modeling of binding conditions between layers
  - No consideration of temperature and speed
  - Not appropriate for new landing gear configurations

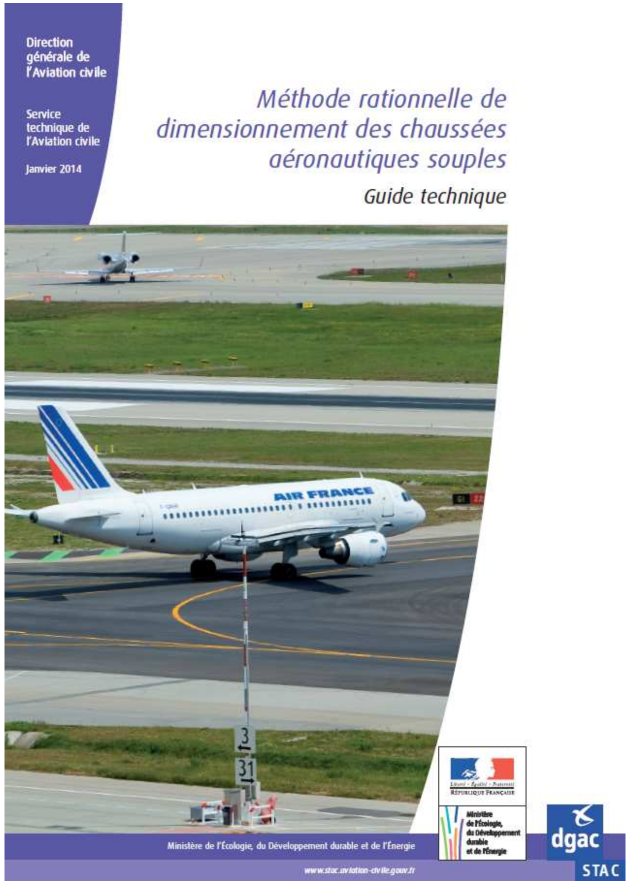
New methodology

- Based on a more rational approach
- Used in France for roads for more than 30 years
- Development of the airfield rational design method from the road rational design method
- Restricted to new flexible airfield pavement first

- Working group: STAC – ISFTTAR – CEREMA

Design manual

- Published in January 2014
- www.stac.aviation-civile.gouv.fr
- Available in English soon



Design guide
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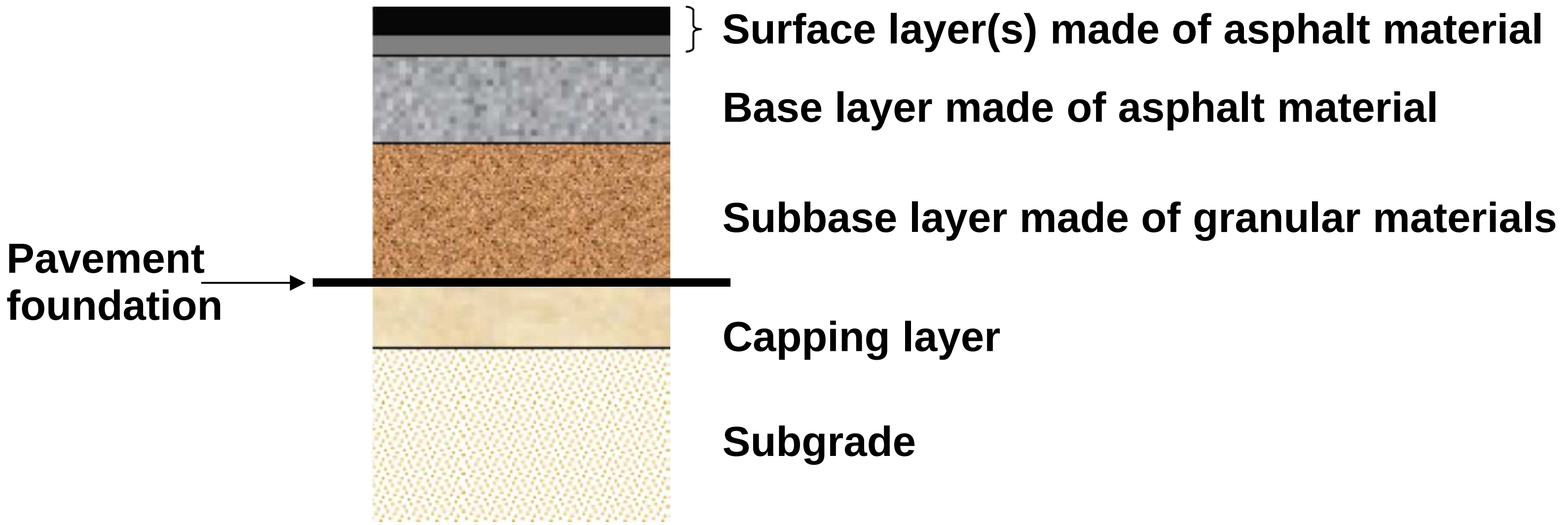
Scope of the guide

- New flexible pavements



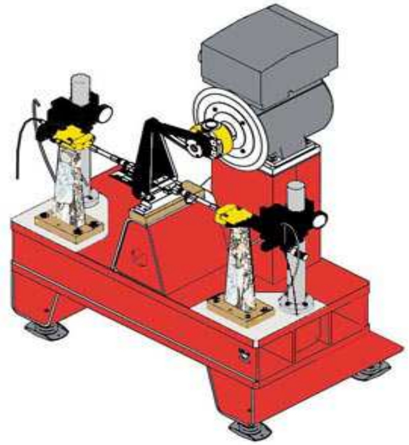
- Used for the design of all the sections of an airport: runways, taxiways and aprons

Calculation steps

- 1- Gathering of all the input data
- 2- Calculation of the strains and stresses
- 3- Determination of the damage (D=0 new pavement, D=1 pavement failed)
  - Without and with lateral wander
  - Cumulated over the design period
- 4- Iterations on the pavement layers thickness until D equals 1 (must comply with technological limits)
- 5- Freeze-thaw verification

Input data

- Design life: 10 years (20 years for rigid pavements)
- Design temperature (equivalent temperature):
  - Oceanic, Mediterranean or continental climate: 15°C
  - Tropical climate: 28°C
- Risk coefficient r: to be set by the airport manager
  - 2.5% for high traffic, between 5 and 10% for low traffic
- Materials to be used and their fundamental properties:
  Complex modulus, fatigue resistance…



Input data

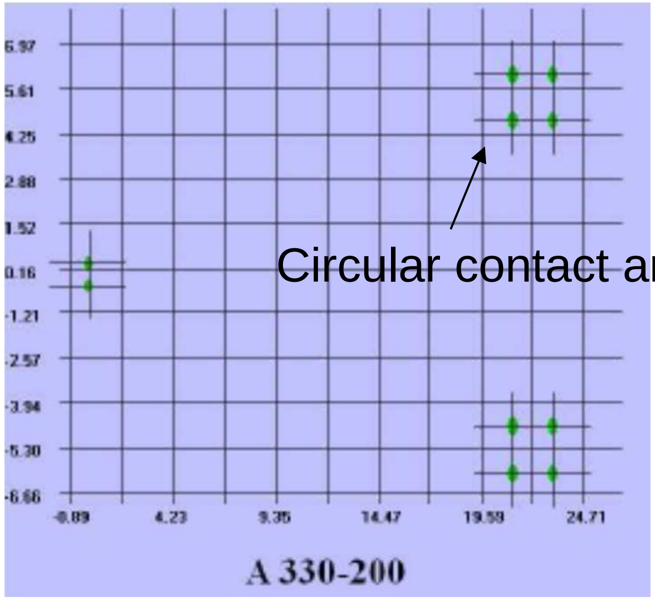
- Subgrade bearing capacity
  - Assessed using static or dynamic plate test

  - Elastic modulus (direct input of the design method)

Input data

- Traffic inputs:
  - Type of aircrafts
  - Number of passes (with distinction between take-offs and landings)
  - Landing gear configuration and loadings: coordinates of the wheels center, mass on each wheel, contact pressure (supposed to be equal to the tyre pressure)
  - Maximum ramp weight of the aircraft for take-offs
  - Maximum landing weight of the aircraft for landings

STAC's "Ficav" database

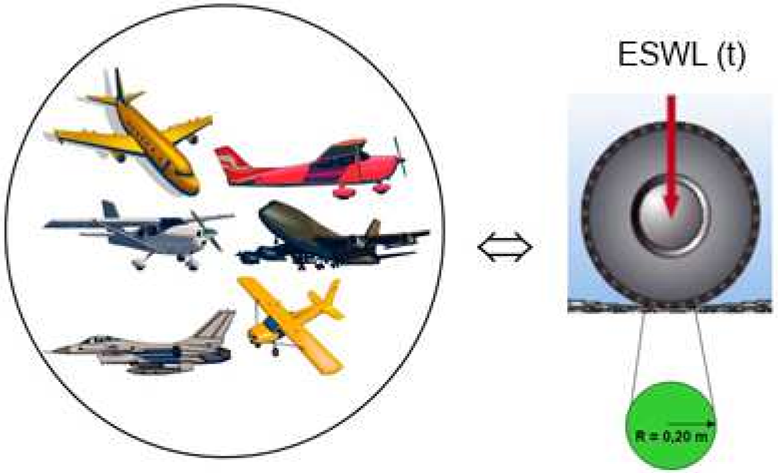


Input data

- Traffic aggressiveness quantified by the rational Equivalent Single Wheel Load (ESWL)

« The ESWL associated with an aircraft traffic mix and a pavement structure is the simple, non-wandered load (in tons) applied 10,000 times to the structure, with a footprint with a radius of 0.20 m, which produces the same value of fatigue damage of the asphalt concrete as the complete traffic mix »

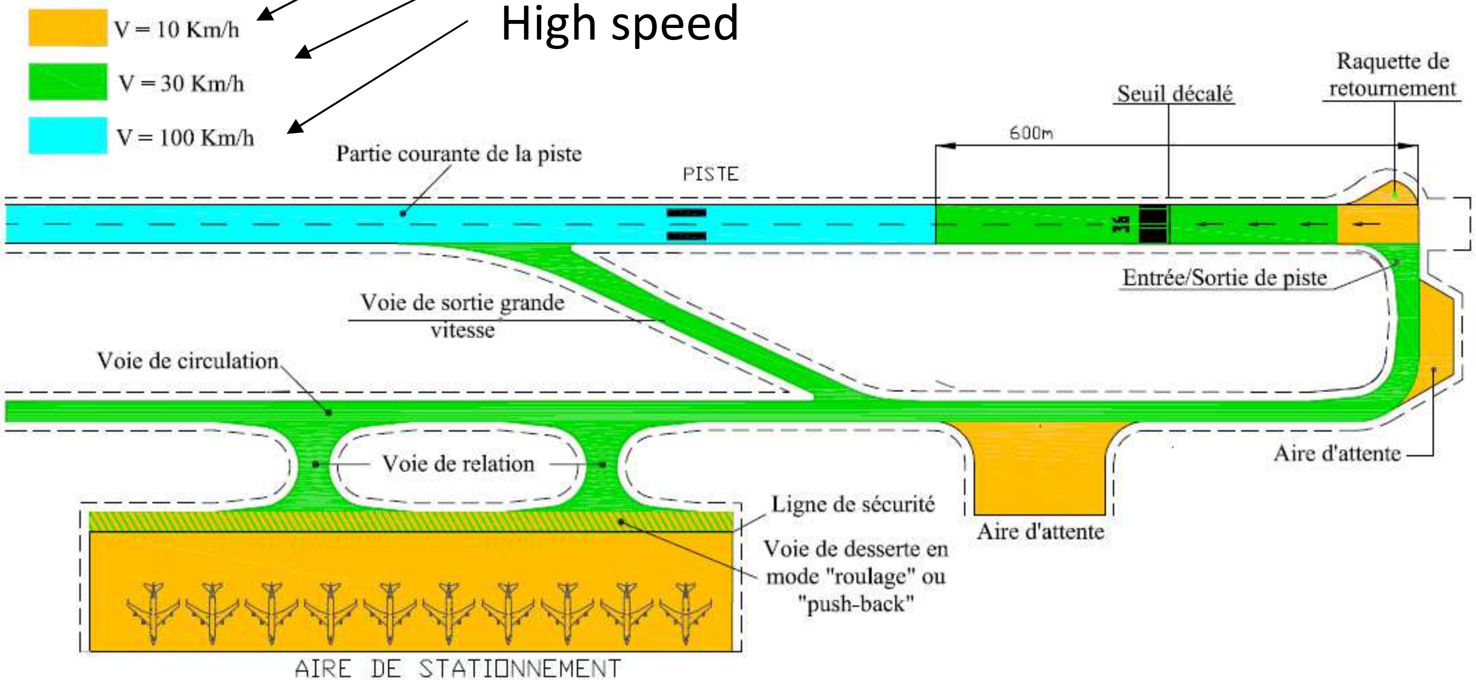
- Parameter used in the design process



Input data

Distinction of 3 types of section for the design:

Low speed
Intermediate speed
High speed



Input data

- Speed

Section considered	*Speed for calculations*
High speed section	100 km/h
Intermediate speed section	30 km/h
Low speed section	10 km/h*

* Fictitious value used for calculation

- Speed is related to the frequency of loading of asphalt materials (the higher the speed of loading, the higher the asphalt concrete modulus value)
- It is considered that:
  100 km/h ↔ 10 Hz and $f(Hz) = \frac{V(km/h)}{10}$

Input data

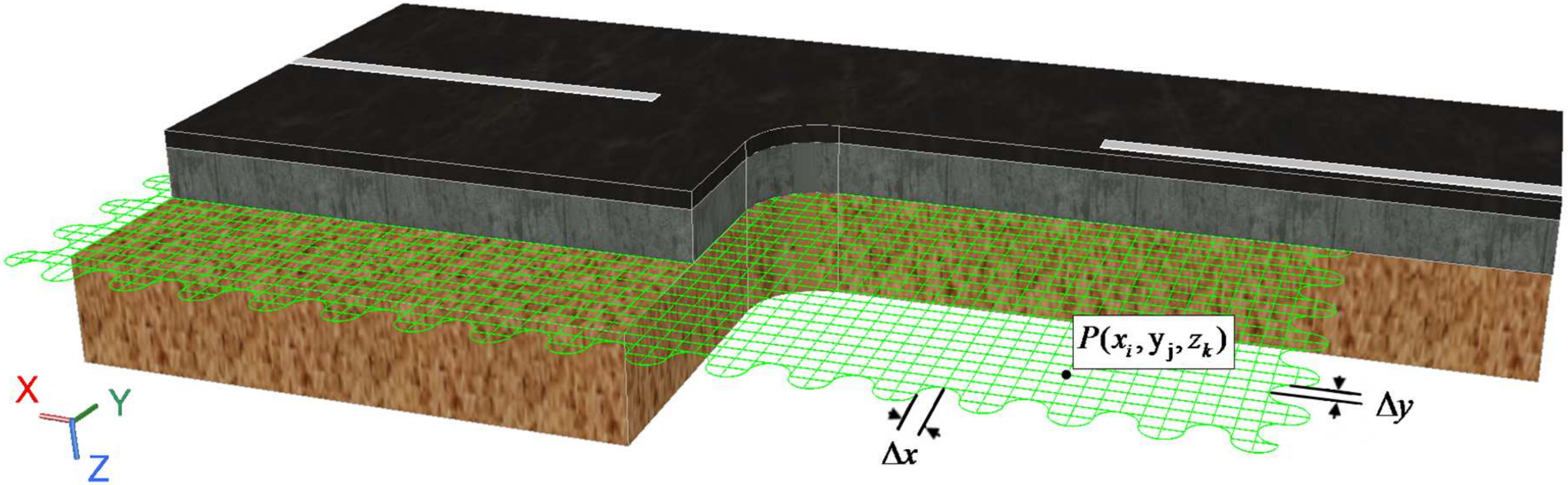
- Lateral wander

Section considered	***Lateral wander (standard deviation)***
High speed section	0.75 m
Intermediate speed section	0.5 m
Low speed section	0 m

- Lateral offsets from the runway centreline are taken into account
- Offsets distrubution is supposed to be Gaussian, centered and defined by its standard deviation S_{bal}

Strains and stresses calculation

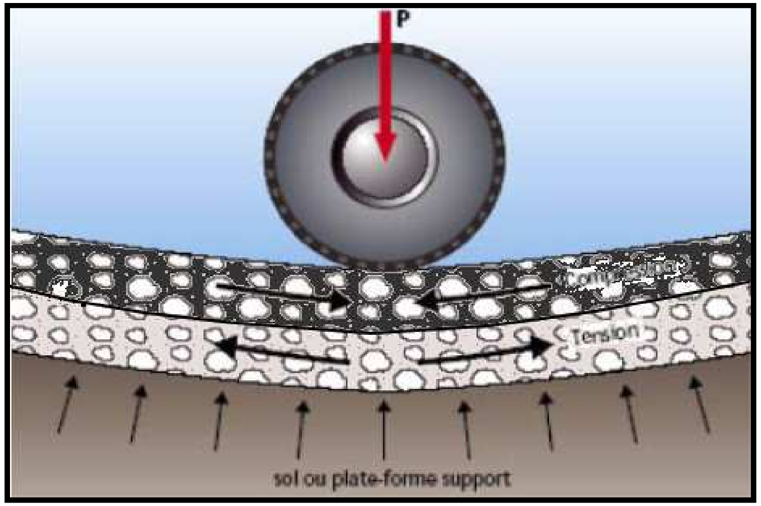
- Multi-layered semi-infinite elastic model (Burmister)
- Elastic modulus (E) and Poisson's ratio (ν) assigned to each layer



- Calculation at every node of the grid of the strains/stresses under each aircraft loading

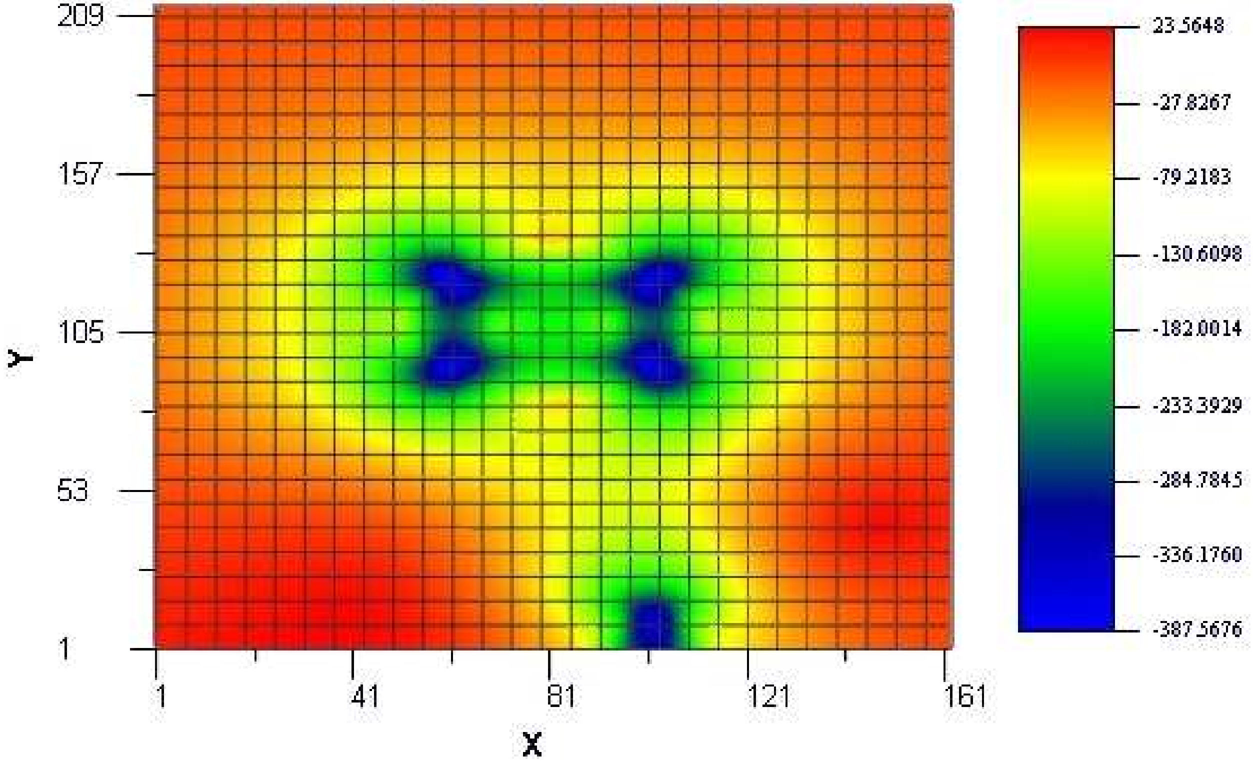
Strains and stresses calculation

- Calculations at two levels:
  - Horizontal extensions ε_t at the base of the asphalt materials (fatigue)
  - Vertical contractions ε_{zz} at the top of the unbound layer (permanent deformations)



Strains and stresses calculation

- Example of fatigue tensile strain calculation for an A330-300 aircraft



Failure model

- Wöhler failure model is used

$$N = \left(\frac{K}{\varepsilon_{max}} \right)^{\beta}$$

  - N the number of passes to failure
  - ε_{max} the maximum strain under an aircraft loading
  - $\beta > 1$, $b = -1/\beta$ slope of the fatigue line
  - K a constant of the material

- For granular material permanent deformations, $\varepsilon_{max} = \varepsilon_{zz}$ and

$$\begin{cases} K = 16000 \\ \beta = 4.5 \end{cases}$$

Failure model

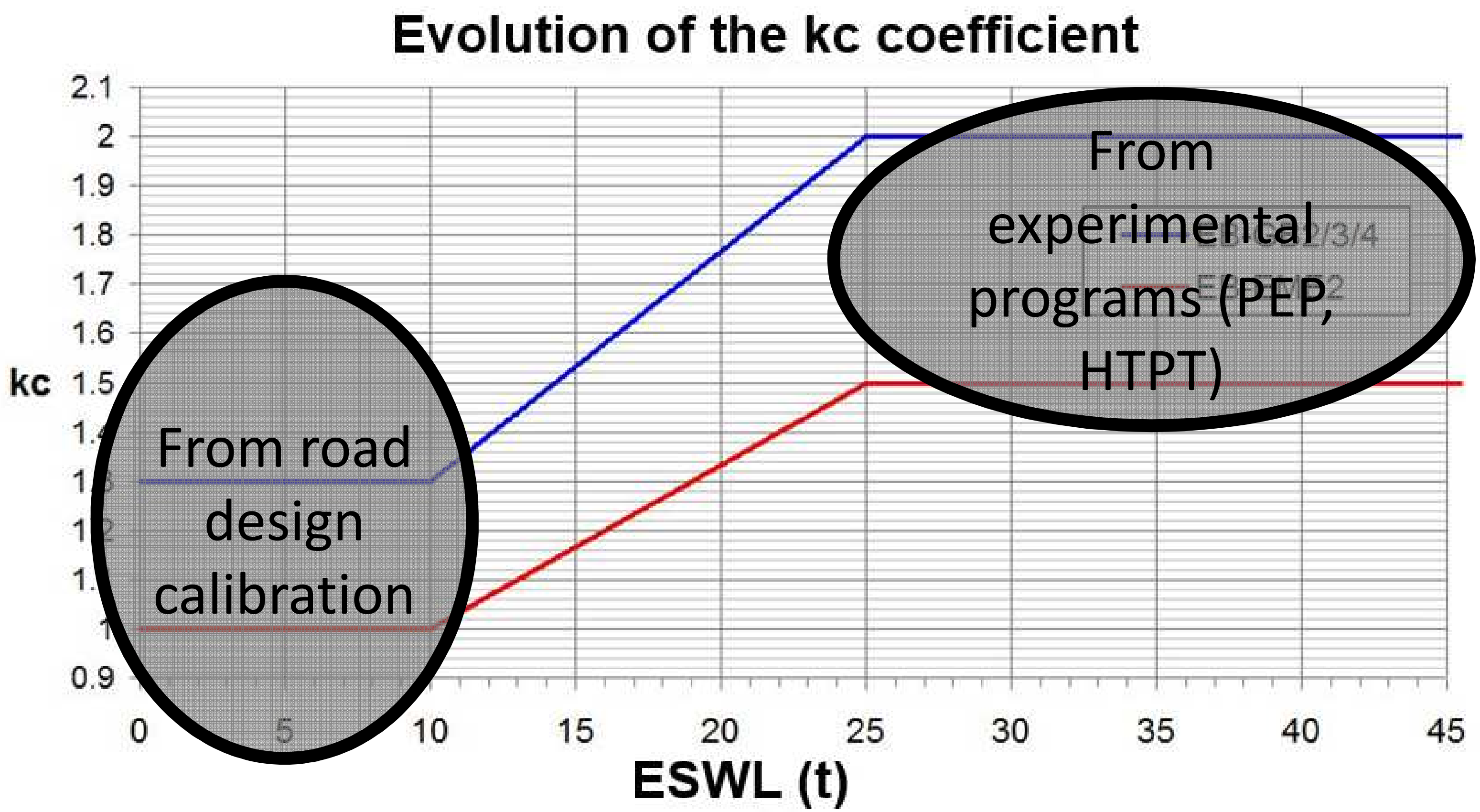
- For asphalt concrete fatigue, $\varepsilon_{max} = \varepsilon_t$ and

$$K = 10^{6/\beta} k_{\theta f} k_s k_r k_c \overline{\varepsilon}_6$$

- $\overline{\varepsilon}_6$: Fatigue resistance of the material
- $k_{\theta f}$: Transposition of the fatigue test performed at 10°C and 25Hz to the actual design temperature and frequency
- k_s: Local bearing capacity heterogeneities of a granular layer
- k_r: Scattering of the fatigue test results and of the layer thickness variation
- k_c: Shift factor

Failure model

- Shift factor k_c: difference between lab and the field



Damage calculation

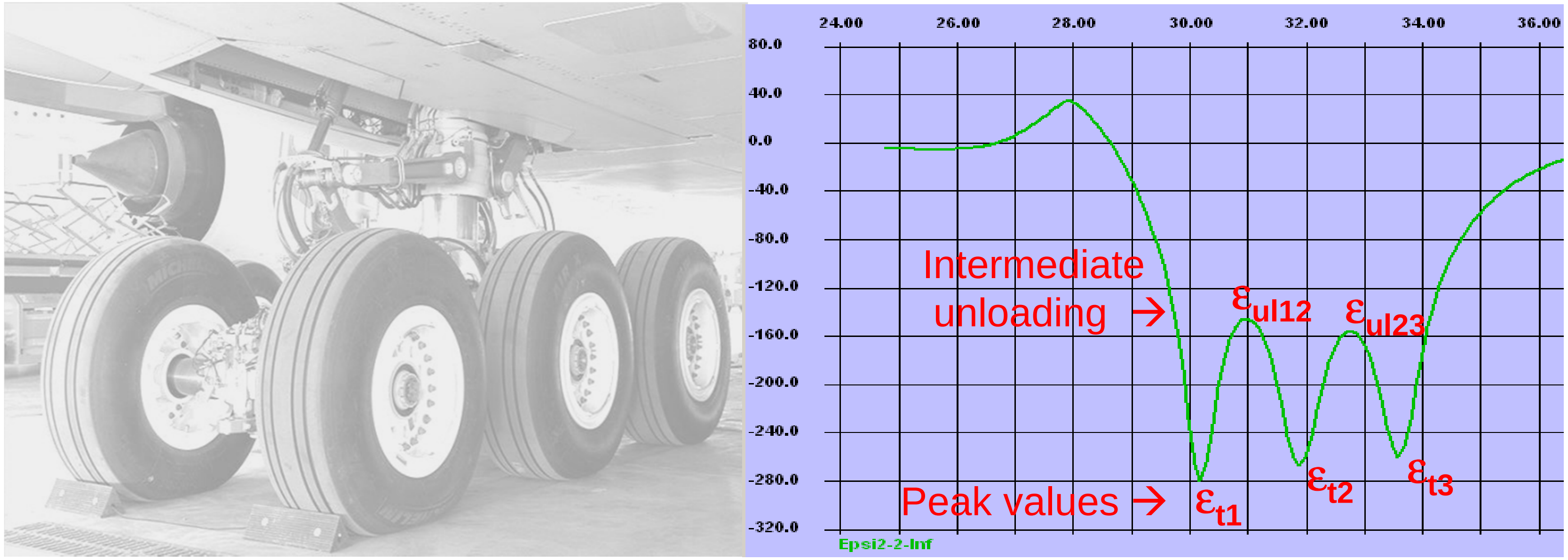
- Elementary damage: $\Delta D = \dfrac{1}{N}$

- Additivity of damage, Miner's rule:

$$D = \sum_i n_i \Delta D_i = \sum_i \frac{n_i}{N(\varepsilon_{\max i})}$$

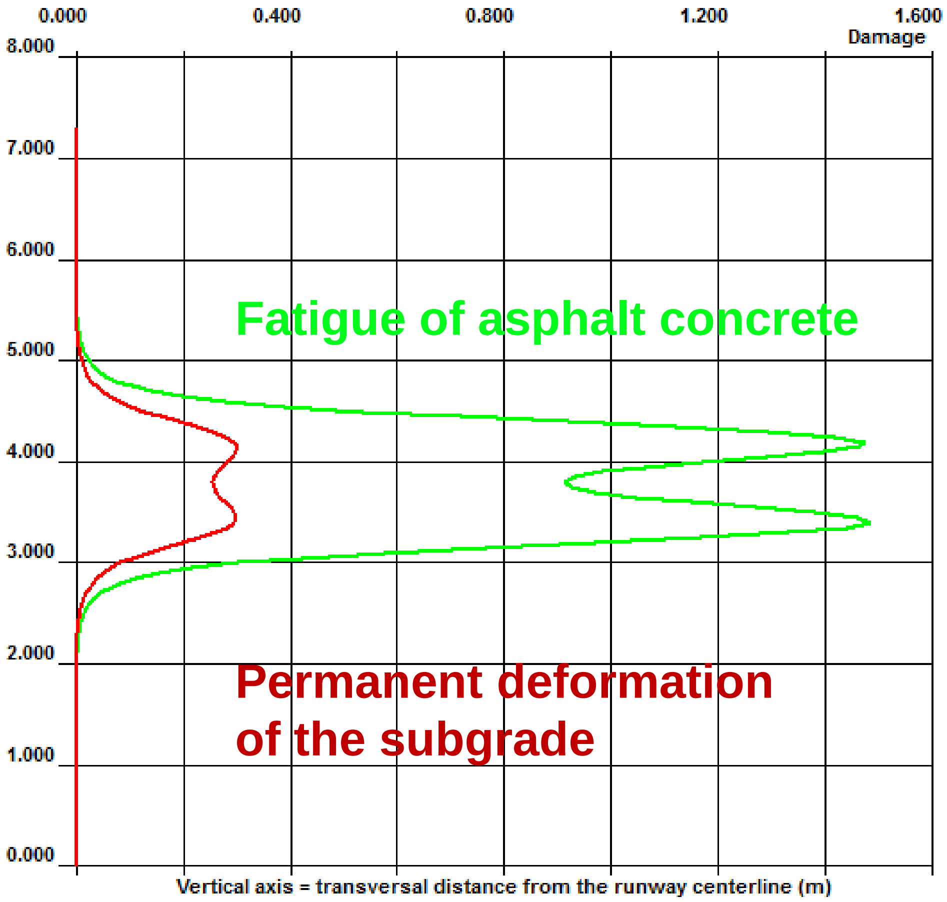
ni: number of passes for aircraft i

Damage calculation

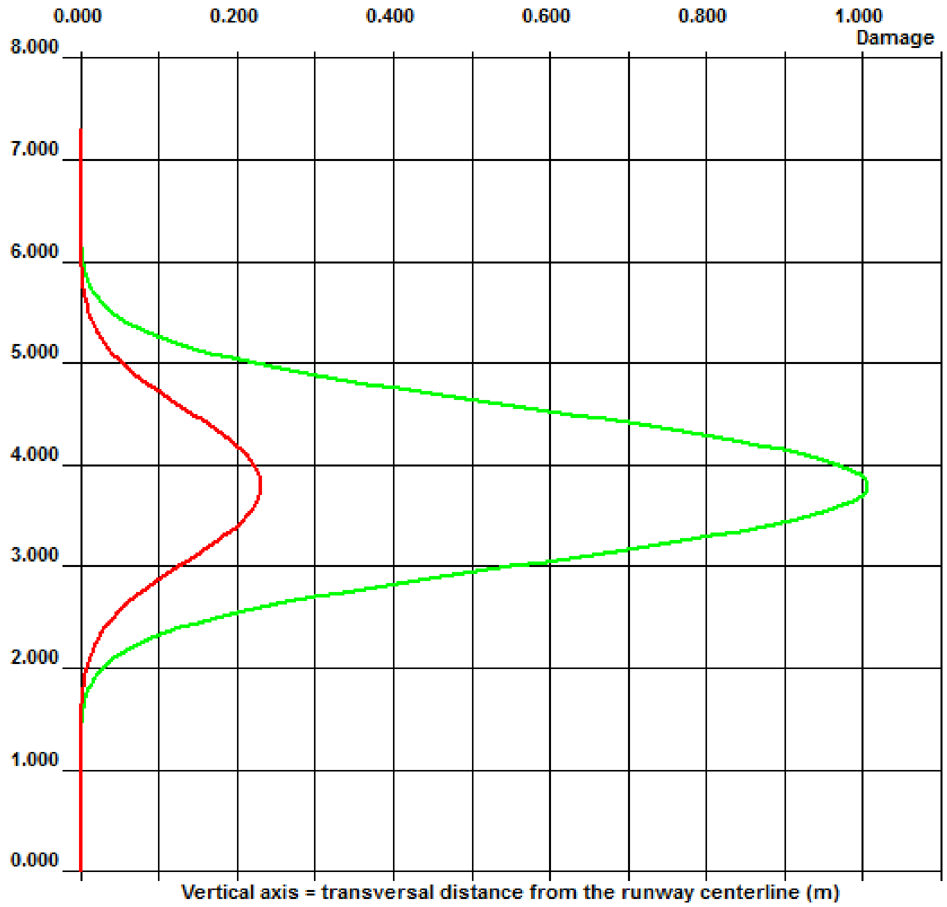


- Calculation using the time history strain profile

$$D_{tridem} = \frac{1}{K^{\beta}} \left(\varepsilon_{t1}^{\beta} - \varepsilon_{ul12}^{\beta} + \varepsilon_{t2}^{\beta} - \varepsilon_{ul23}^{\beta} + \varepsilon_{t3}^{\beta} \right)$$



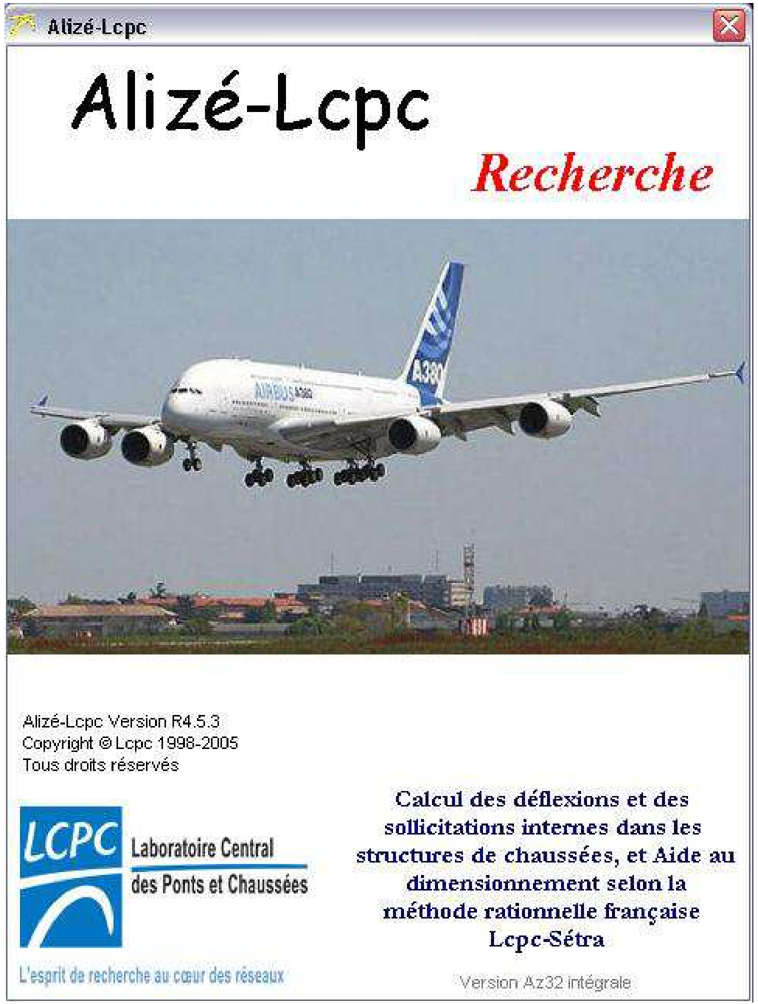
Without wander



With wander

Alizé-Airfield Pavement Software

- **Alizé-Airfield Pavement:** Developed as a module of Alizé-Lcpc software
- Available soon (2014)
- Distributed by the company ITECH



Validation of the method

- Validation by a committee of experts:
  - Main French public works companies
  - Airport managers
  - Aircraft manufacturers

- Validation based on more than 50 case studies (with various contexts)

Next steps

Pavement overlay

- Flexible on flexible (underway)
- Other cases (flexible on rigid…)

- New rigid pavement design (project starting)

- ACN/PCN methodology to be revised

Any questions ??

Thank you for your attention

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