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Performance Evaluation Of Composite Mixes Containing Rap Aggregates & Hydraulic Binder For Heavy Traffic Pavement
The RECYROUTE Project

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OUTLINE

- Introduction
- Materials: RCC mixes with fibers and RAP
- Laboratory characterisation & full scale test
- Calibration for pavement design & examples
- Conclusions

RCC: Roller Compacted Concrete
RAP: Reclaimed Asphalt Pavement

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Introduction

- Traditional technique RCC is recently taken in consideration:
  - Use of RAP as aggregates
  - Improving mechanical properties by adding steel fibres

- French National Research Agency (ANR) project **RECYROUTE**

  Development of an innovative material FRCC® (Fiber reinforced Rolled Compacted Concrete) mixed with RAP as long lasting composite material for heavy traffic pavements *(**continuous structure without joints**)*

- 7 Partners: 4 publics

  3 privates

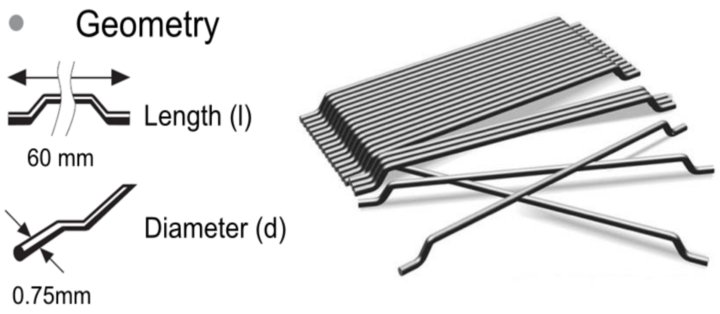
- Budget: 2.3 million €

RCC: Roller Compacted Concrete
RAP: Reclaimed Asphalt Pavement

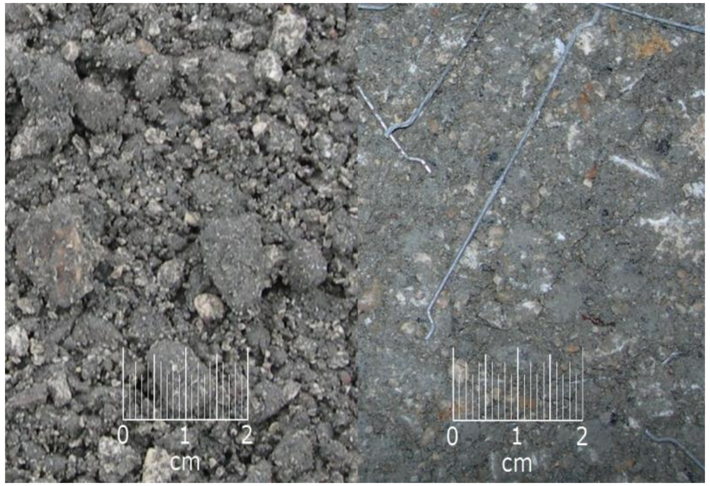
Materials

Material	***FRCC*** Haut-Lieu (hard limestone)	***FRCC*** Crain (soft limestone)	***FRCC*** RAP	***ERTALH (ref.)***
Sand 0/4	23%	23%	18%	-
Crushed Sand 0/6.3	35%	35%	-	25%
Gravel 6.3/14	30%	30%	-	-
RAP 0/14	-	-	70%	70%
Hyd. binder	12%	12%	12%	5%
Additive (Sika)	0.5%	0.5%	0.5%	-
Water content	6.1%	6.1%	6.2%	6.9%
Steel fibers	30kg/m^3	30kg/m^3	20kg/m^3	-

Dramix RC-80/60-BN steel fibres



before/after compaction

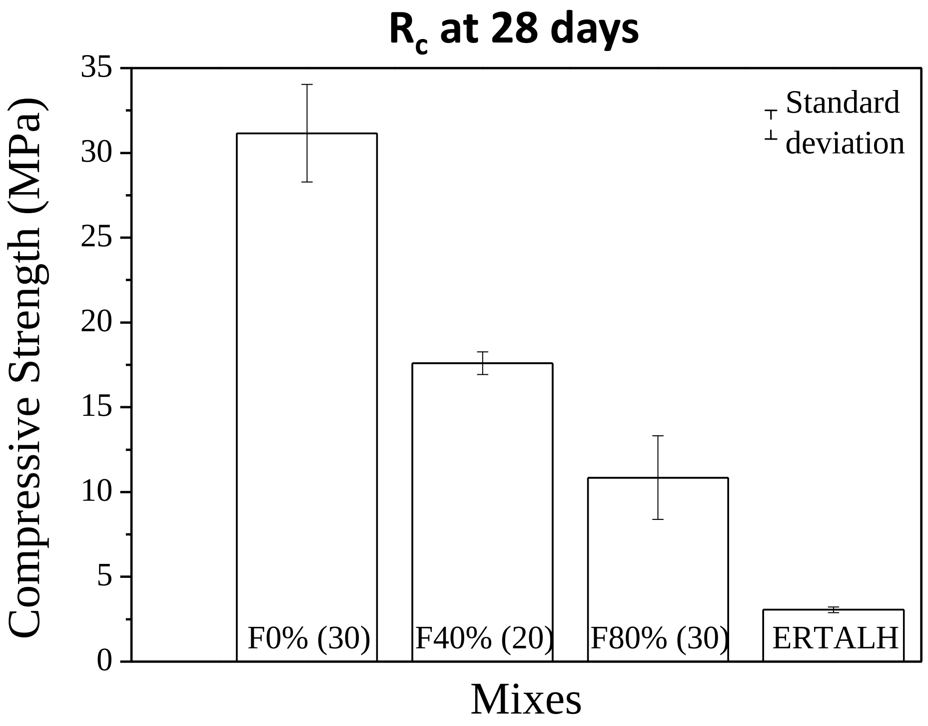


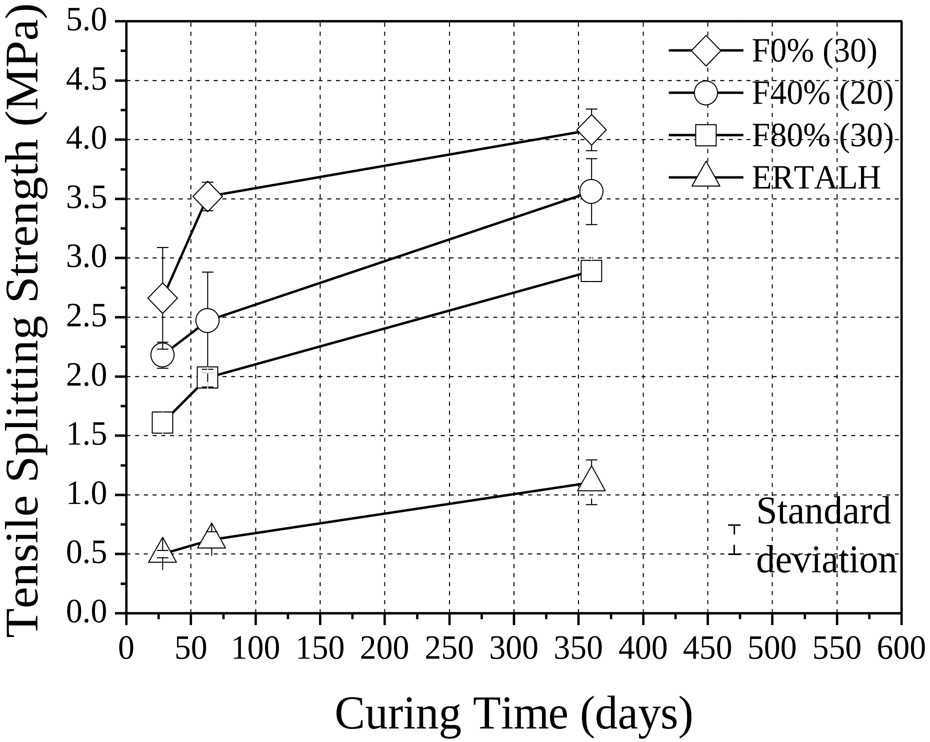
ERTALH: RAP aggregate treated with hydraulic binder, 70% RAP and without fibers

Laboratory characterisation

Tests	Objectives
Compressive Strength **(Rc)**	Classical mechanical properties for **concrete materials**
Compressive Modulus **(Ec)**	
Tensile Splitting Strength **(Rit)**	
Complex stiffness modulus **(E^*)**	Thermo-mechanical properties for **materials containing RAP**
Fatigue resistance **(σ_6 & b)**	

Example of laboratory tests





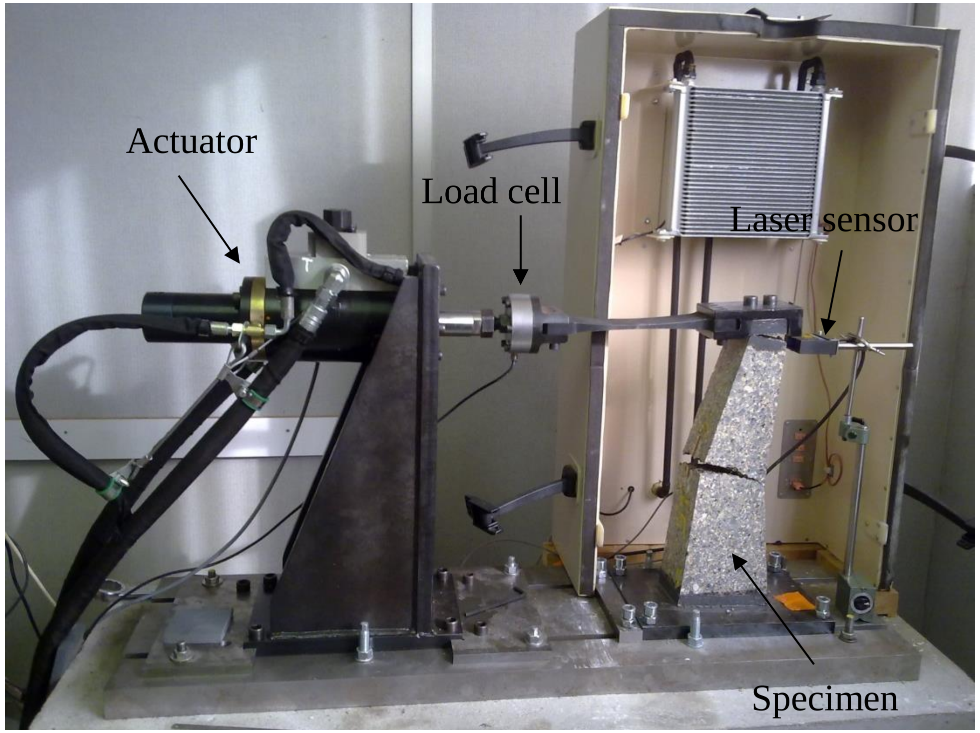
FRCC mix: **Fx%(yy)**

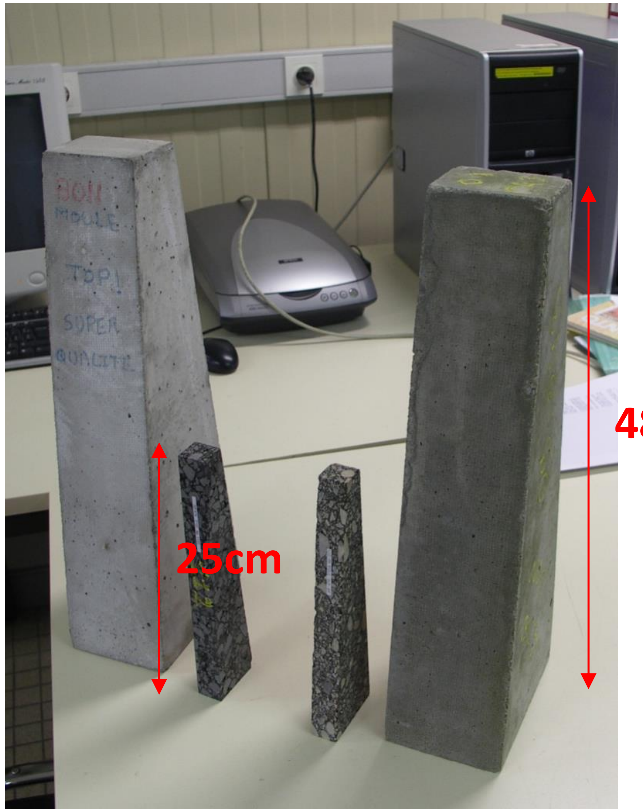
%RAP

Fibres content (kg/m^3)

Example of laboratory tests

Fatigue test





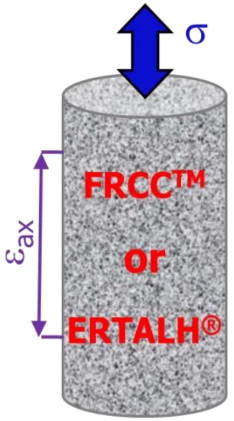
- Controlled force @ f = 50 Hz

- Controlled T = 10°C

Materials	-1/b	σ_6 (MPa)	σ_6 for design (MPa)
FRCC RAP	12.4	**2.50**	1.75
ERTALH	12.4	**1.17**	0.82

Example of laboratory tests

E* test

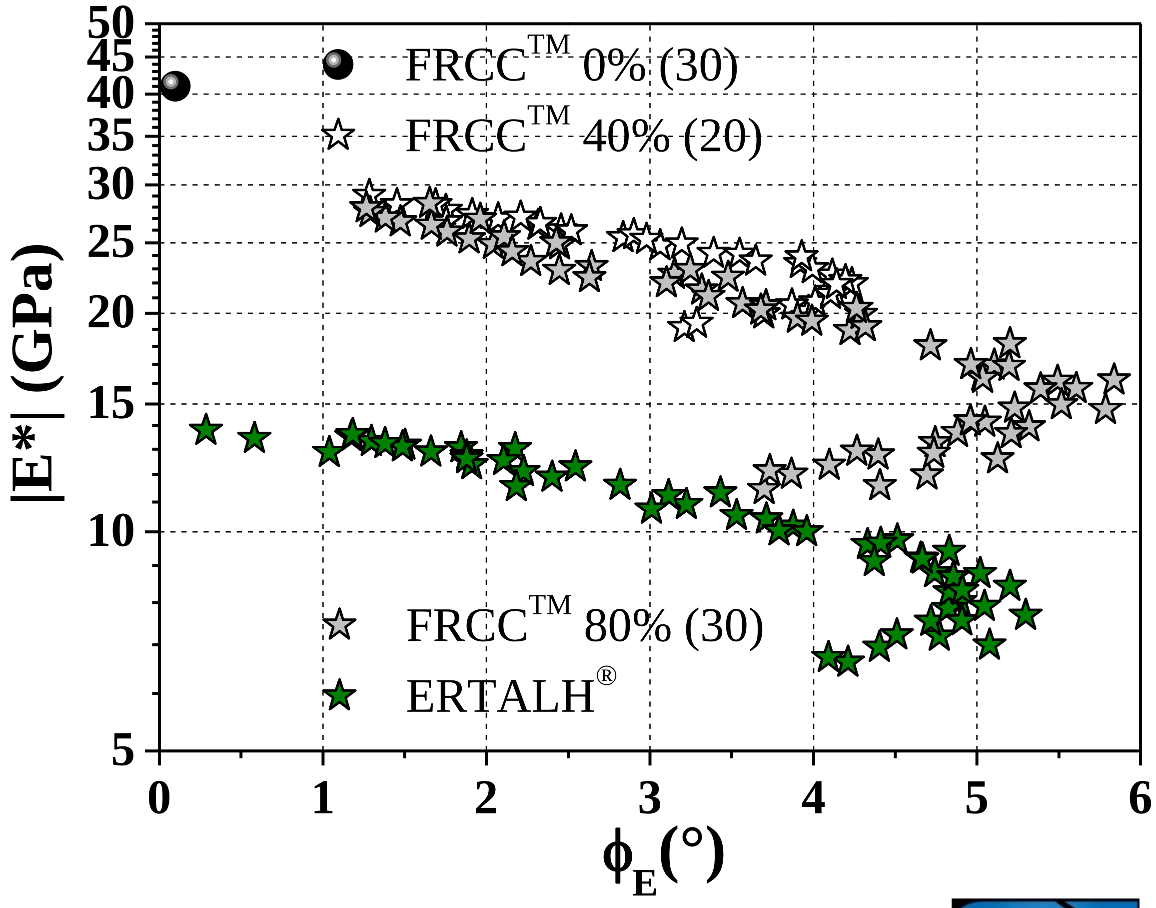


$$E^* = \frac{\sigma_0}{\varepsilon_{0ax}} e^{i\phi_{ax}}$$

$$= \left|E^*\right| e^{i\phi_E}$$

$\sigma = F/S = \sigma_0.e^{i(\omega t)}$

$\varepsilon_{ax} = \delta H/H = \varepsilon_{0ax}.e^{i(\omega t+\phi_{ax})}$



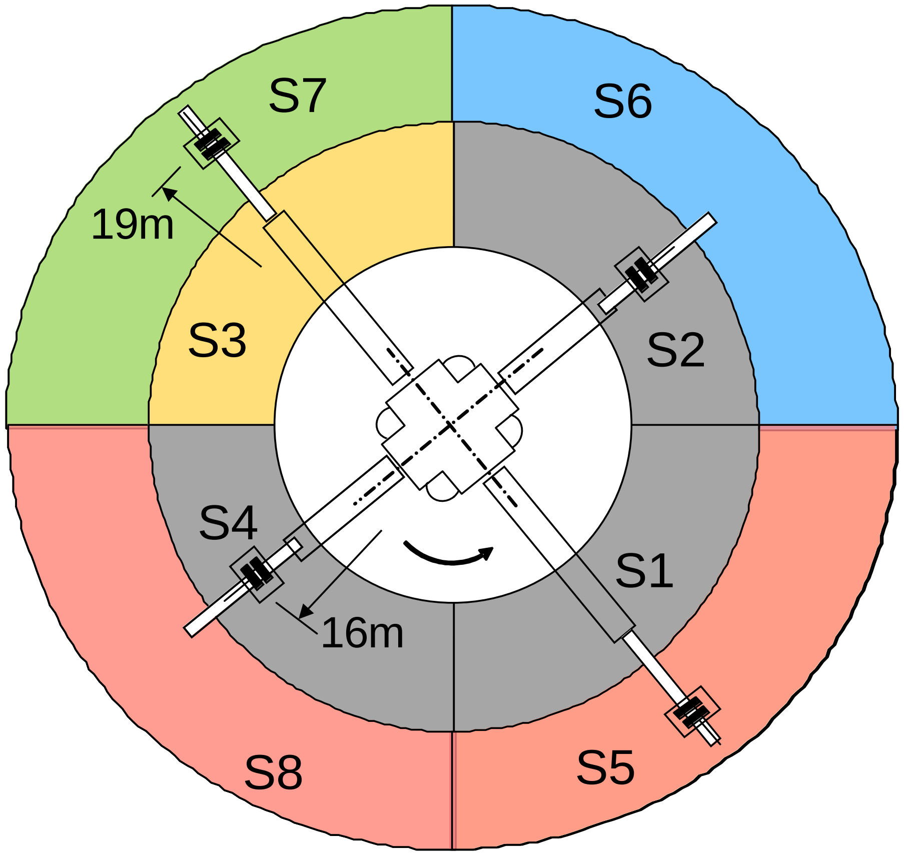
APT facility of the IFSTTAR

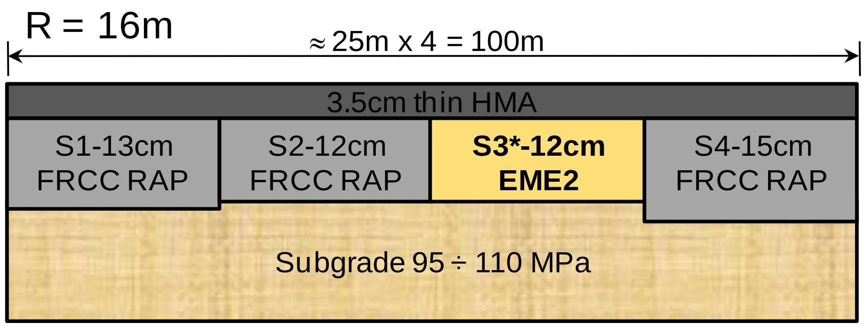
- Moving load in fatigue configuration: dual-wheel 65 kN
- Speed: up to 100 km/h (15 rounds/min.)
- Loading rate: up to 50 000 cycles/day

APT: Accelerated Pavement Testing

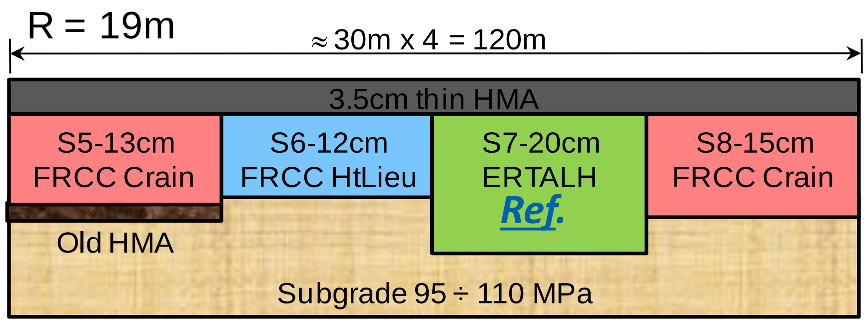
APT experiment

on selected formulations of FRCC & ERTALH





* S3 is the reference structure



2.15 million heavy loads (mainly at 65 kN)

EME2: high modulus asphalt (French reference material for heavy traffic)

Calibration of design model

based on fatigue criterion

For a hydraulic material :

$$\sigma_{t,max} \leq \sigma_{t,adm} = \sigma_6 \, Kc \, Kd \, Kr \, Ks \times \left(\frac{NE}{10^6} \right)^b$$

- $\sigma_{t,max}$: tensile stress (Alizé-LCPC)
- $\sigma_{t,adm}$: admissible value
- σ_6: fatigue resistance (laboratory fatigue tests)
- Kc: coef. of calibration : adjustment of model vs. real pavement performance, for rigid pavement Kc = 1.5
- Kd: coef. of discontinuity
- Kr: coef. of risk of failure, representing level of structural degradation of pavement at the considered time ’’t’
- Ks: coef. of security for low bearing capacity of subgrade (good bearing capacity →Ks = 1)
- NE: traffic at considered time « t »
- b: fatigue slope (laboratory fatigue tests)

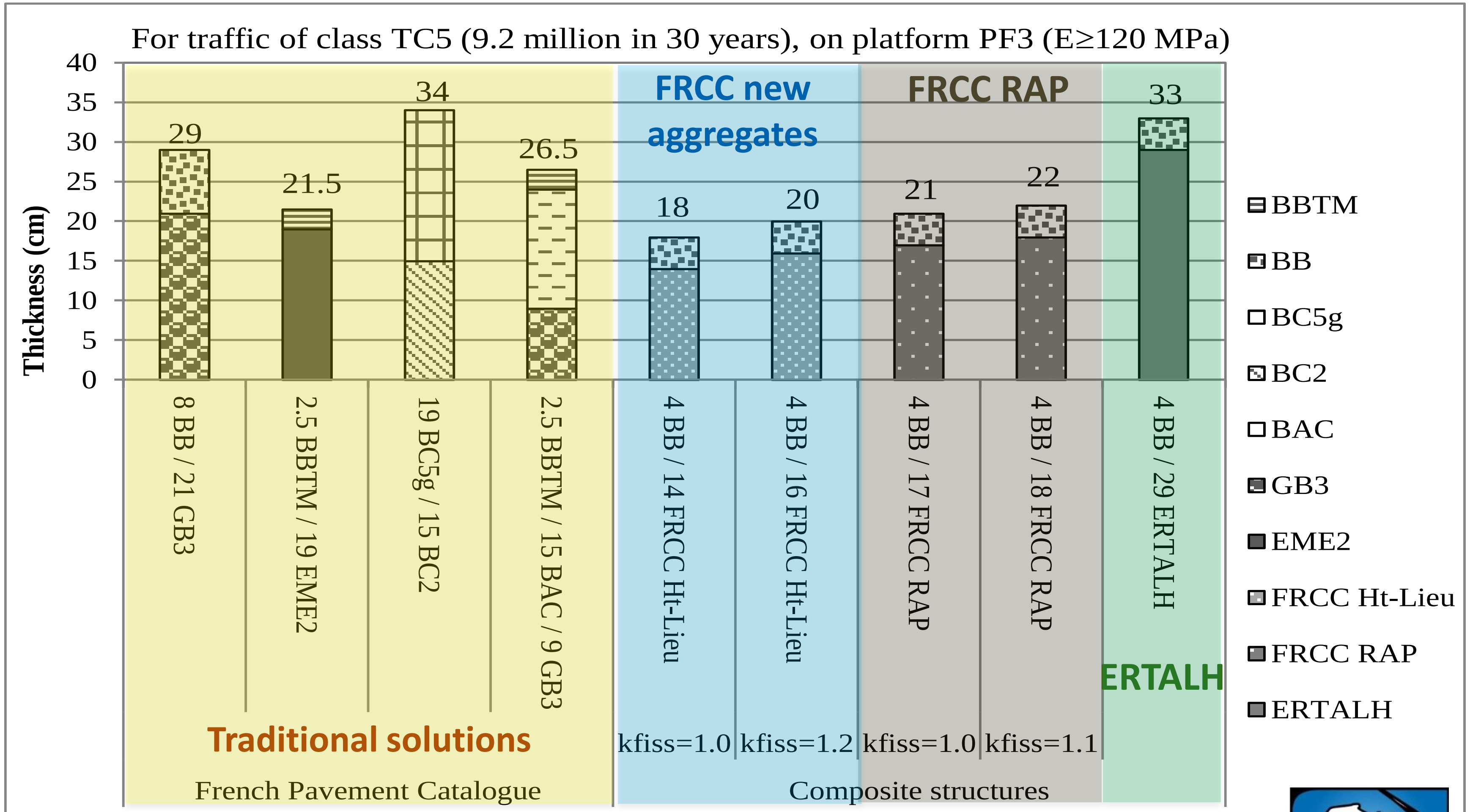
Two additional factors

- Harmonization between APT results & Real Pavement →$K_{harmonization}$

- Effect of hypothetic wide transverse cracking on FRCC pavement → K_{fiss}

Examples of pavement design

Comparison FRCC & ERTALH with traditional solutions



TM and BB: very thin bituminous surface layer and the normal one
dowelled concrete slabs
undation lean concrete
continuously reinforced concrete pavement (CRCP)
B3: base asphalt concrete

Conclusions

- Lab tests showed that the mechanical properties of both FRCC and ERTALH decrease (Rc, Rt, E*, σ_6) with high RAP content.
  Viscous properties are observed as well.

- Full-scale pavement structures were constructed and tested under heavy loads of the IFSTTAR traffic simulator. This APT test showed encouraging behavior of FRCC™ structures, despite low thicknesses of materials used in the base layer (12-15cm) and good behavior for the ref. ERTALH® in 20cm.

- Pavement design of FRCC structures shows similar thickness to high modulus asphalt pavement (EME2) used in France, but significant reduction of thickness compared to classical bituminous pavement (GB3) and concrete pavement structures as well.

- Perspectives: heavy duty pavements (harbors or industrial platforms)

Thank you for your attention!

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