Water influence on skid resistance

Standardisation:
input of the HERMES programme

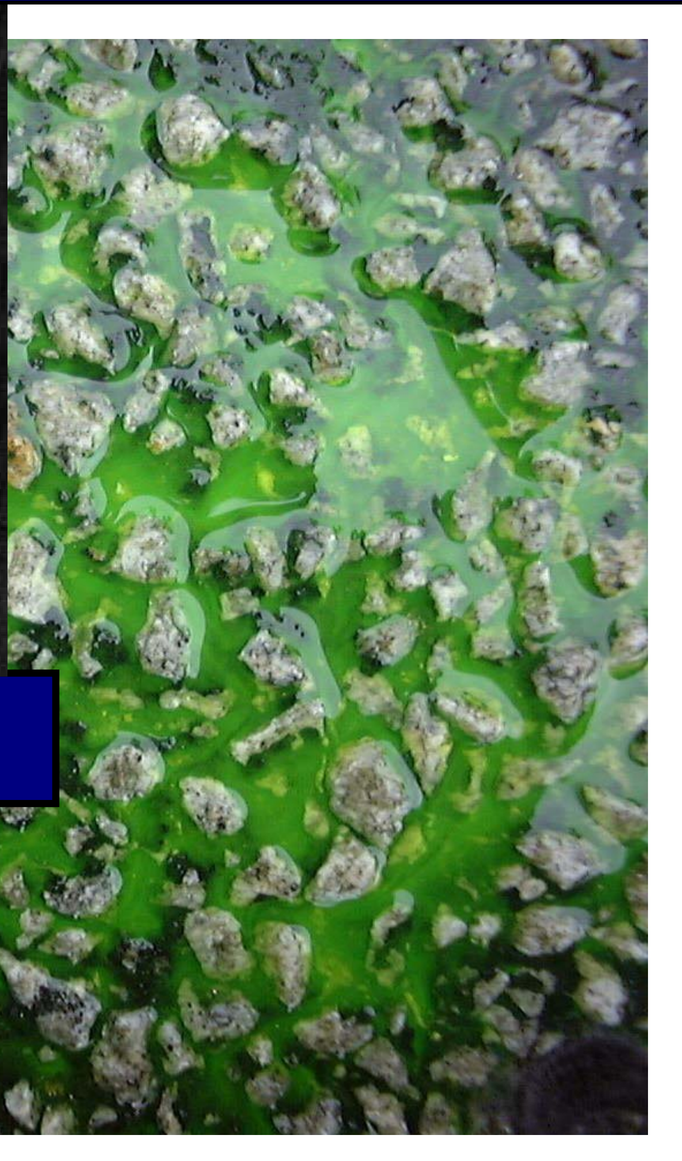
Michel Gothié
Research Director
LRPC de Lyon
France

Presentation outline

Water influence on skid resistance
- influence of the surface (texture, irregularities)
- influence of the tyre (compound, tread depth)
- input of VERT project and French research
  - on results
  - on modelling

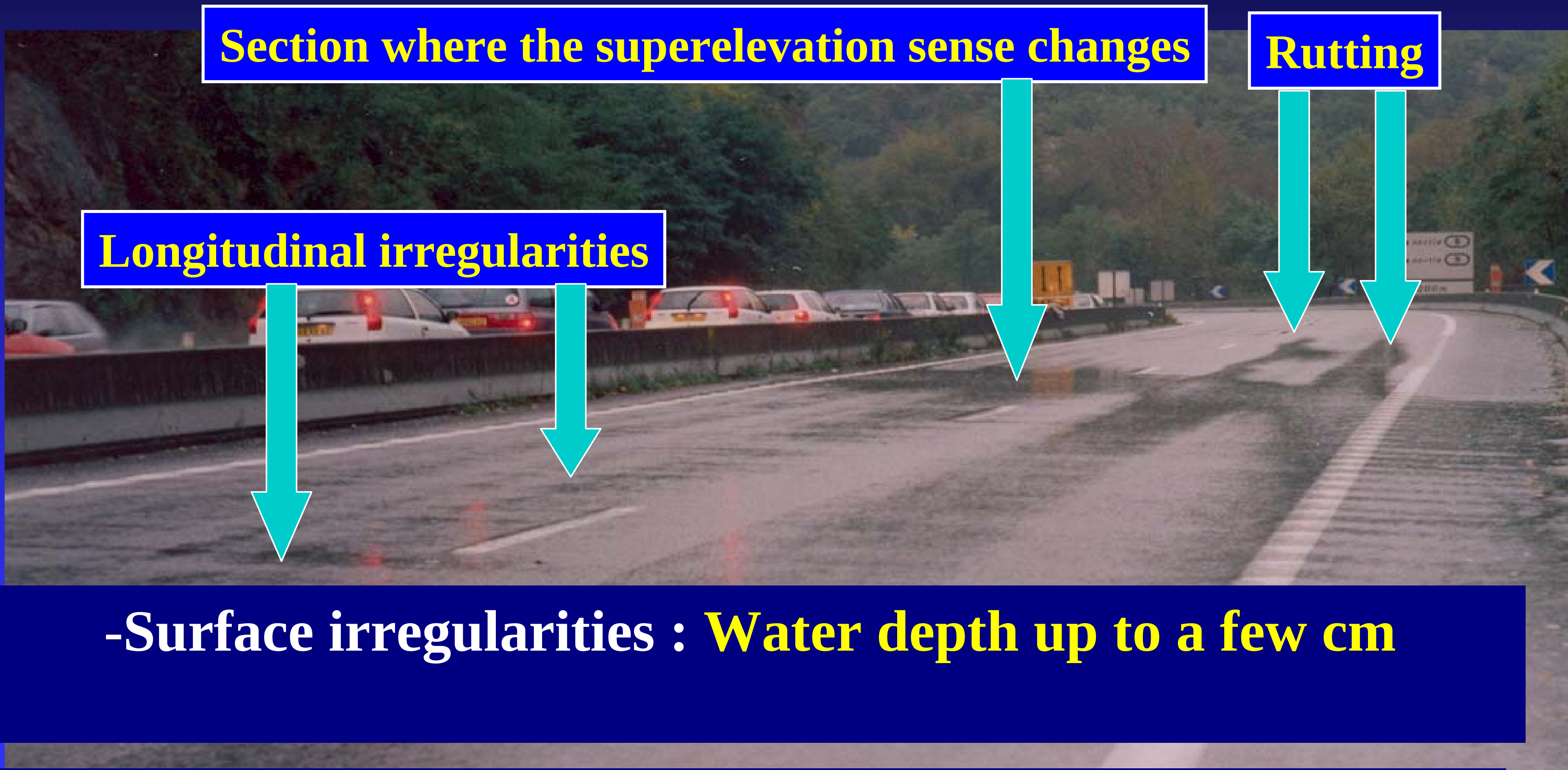
How to harmonise the skid resistance measurements
- standardisation aim
- input of HERMES project

Water has to be drained by the surface



And also by the tyre

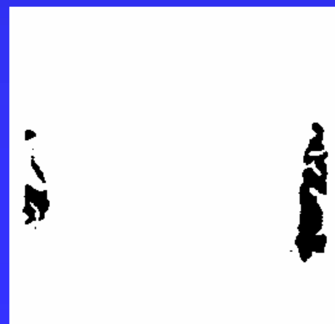
Water effect on road surface



-Surface irregularities : Water depth up to a few cm

- Without surface irregularities: the most probable situations
Water depth from 0.5 to 1 mm

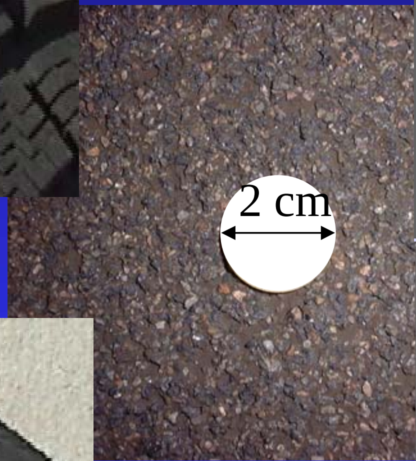
Tyre tread depth influence: 1 mm water depth

	50 km/h	70 km/h	90 km/h
New tyre (8 mm)			
Worn tyre 50%			
Worn tyre minimum (1.6 mm)			

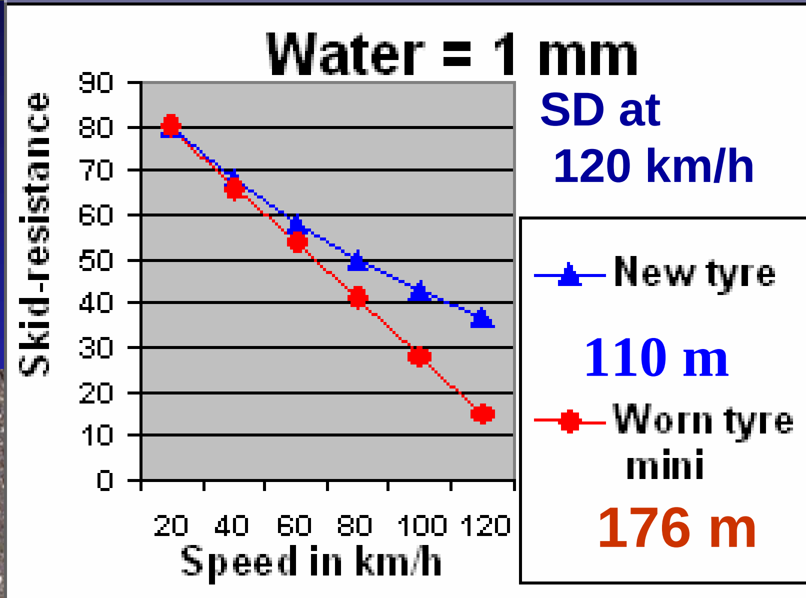
Tread depth influence

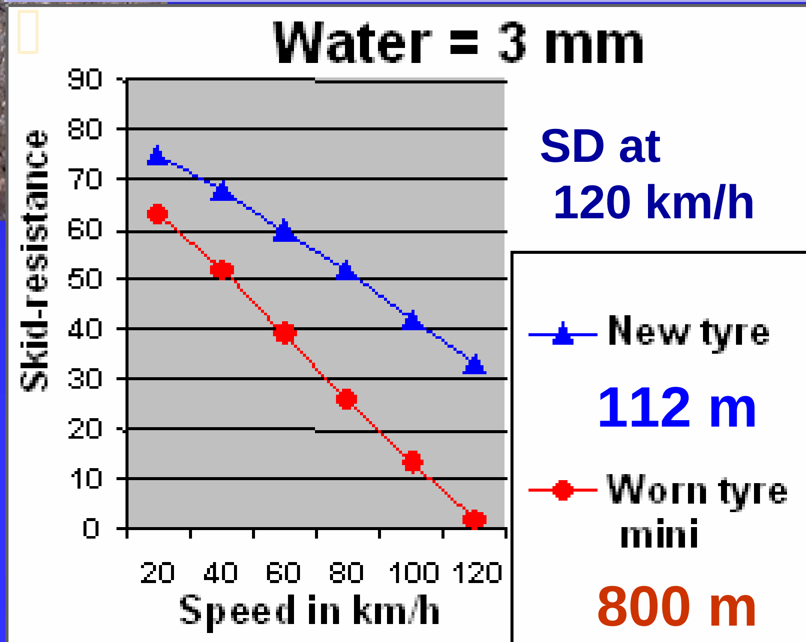
New tyre (8 mm)

Worn tyre (mini 1.6 mm)

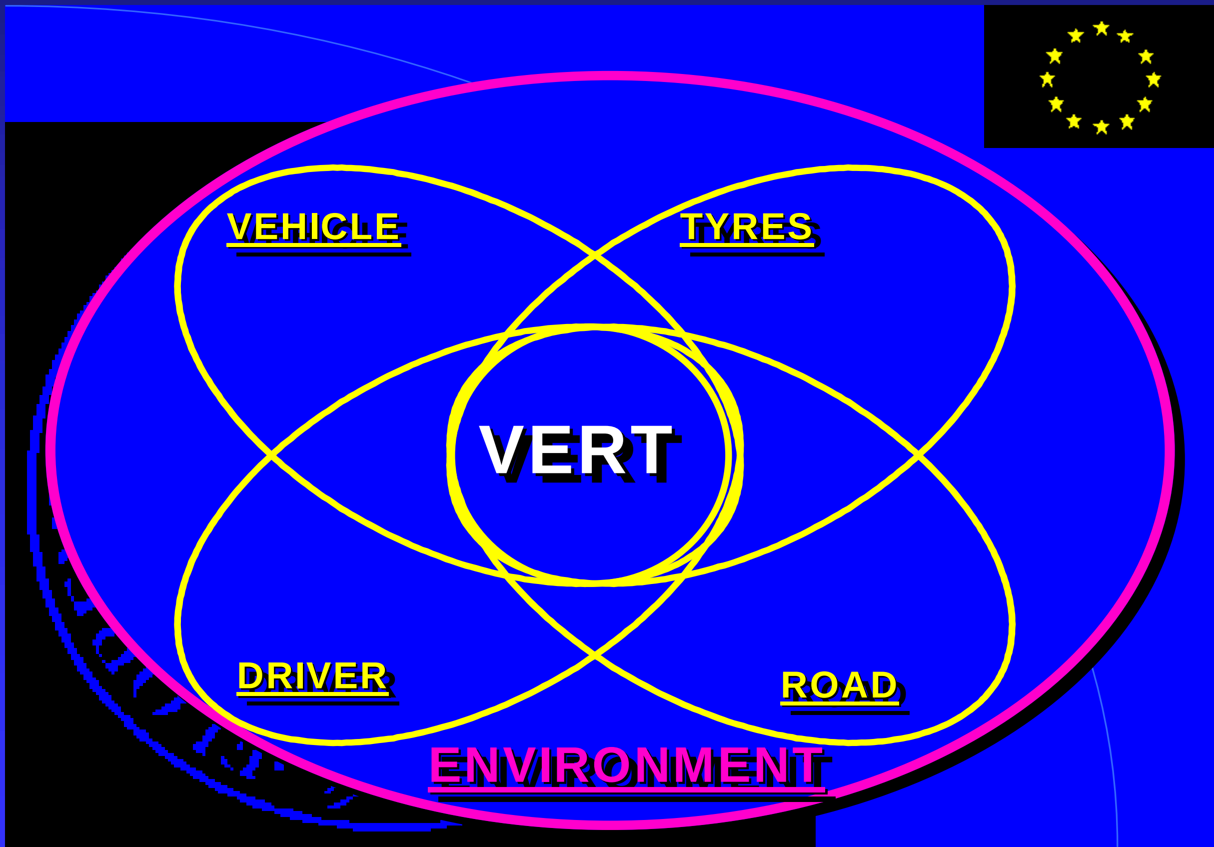


Harsh smooth surface (MTD 0.60 mm SFC=0.90)





Vehicle-Road-Tyre Interaction in Potential Dangerous Situations: Results of VERT Project



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VERT Project Partners

- **Pirelli Tyres** (IT, Tyre Manufacturer)
- **Nokian Tyres** (FI, Tyre Manufacturer)
- **Florence University** (IT, Education)
- **VTI** (SE, road/automotive consultancy)
- **TRL** (UK, Road Institute)
- **CRF** (IT, Car Manufacturer)
- **Darmstadt University** (DE, Education)
- **Porsche** (DE, Car Manufacturer)
- **Helsinki Univ. of Technology** (FI, Education)
- **CETE** (FR, Road Institute)

VERT Project (Nov.'97-Feb'01)
VEhicle-Road-Tyre interaction:

- **Development of an integrated full tyre-vehicle-driver model suitable for simulations of potentially dangerous conditions (presence of water, ice, snow, suddenly changing friction etc.)**

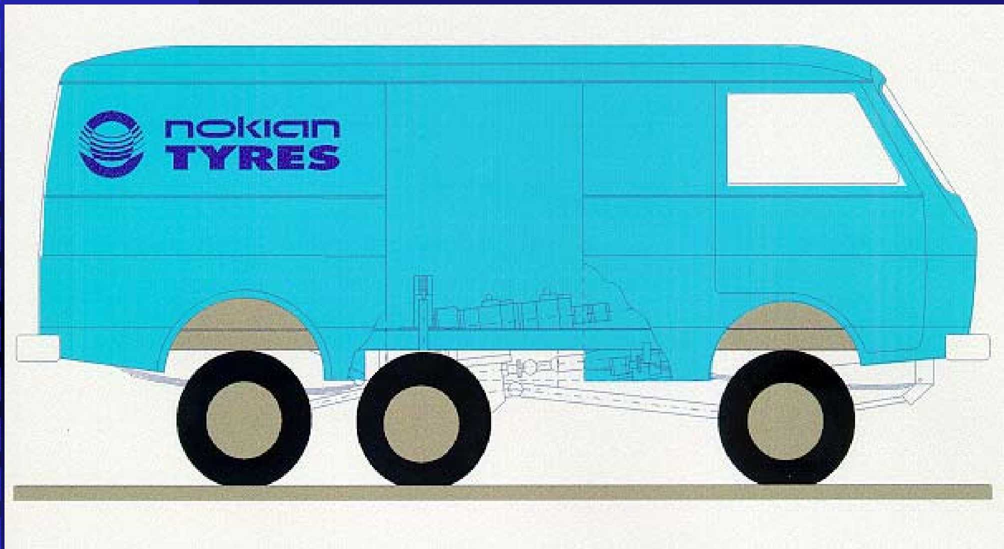
Devices available

Test sessions

Modelling activity

Simulations and classification of dangerous conditions

Development of new measuring devices: Nokian Tyres' vehicle



Development of new measuring devices: VTI's vehicle

Other measuring devices

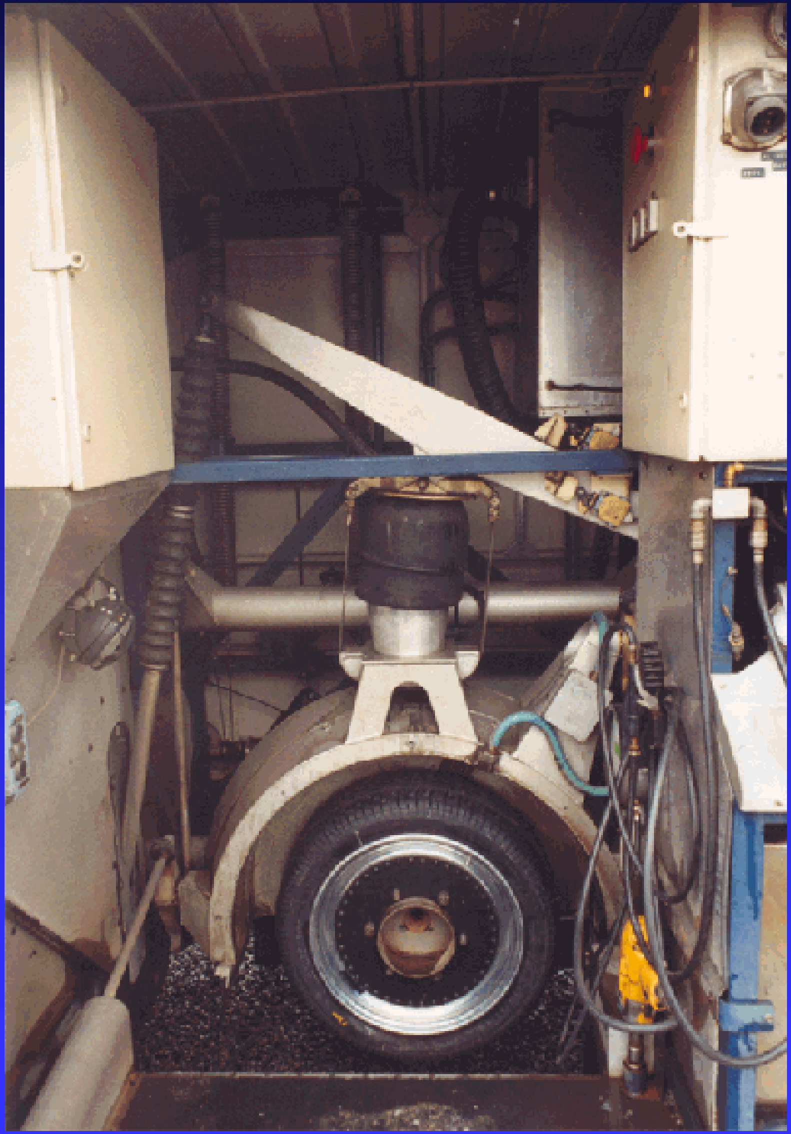
CETE Adhera device

Darmstadt trailer

TRL ASTM Trailer

Pirelli trailer

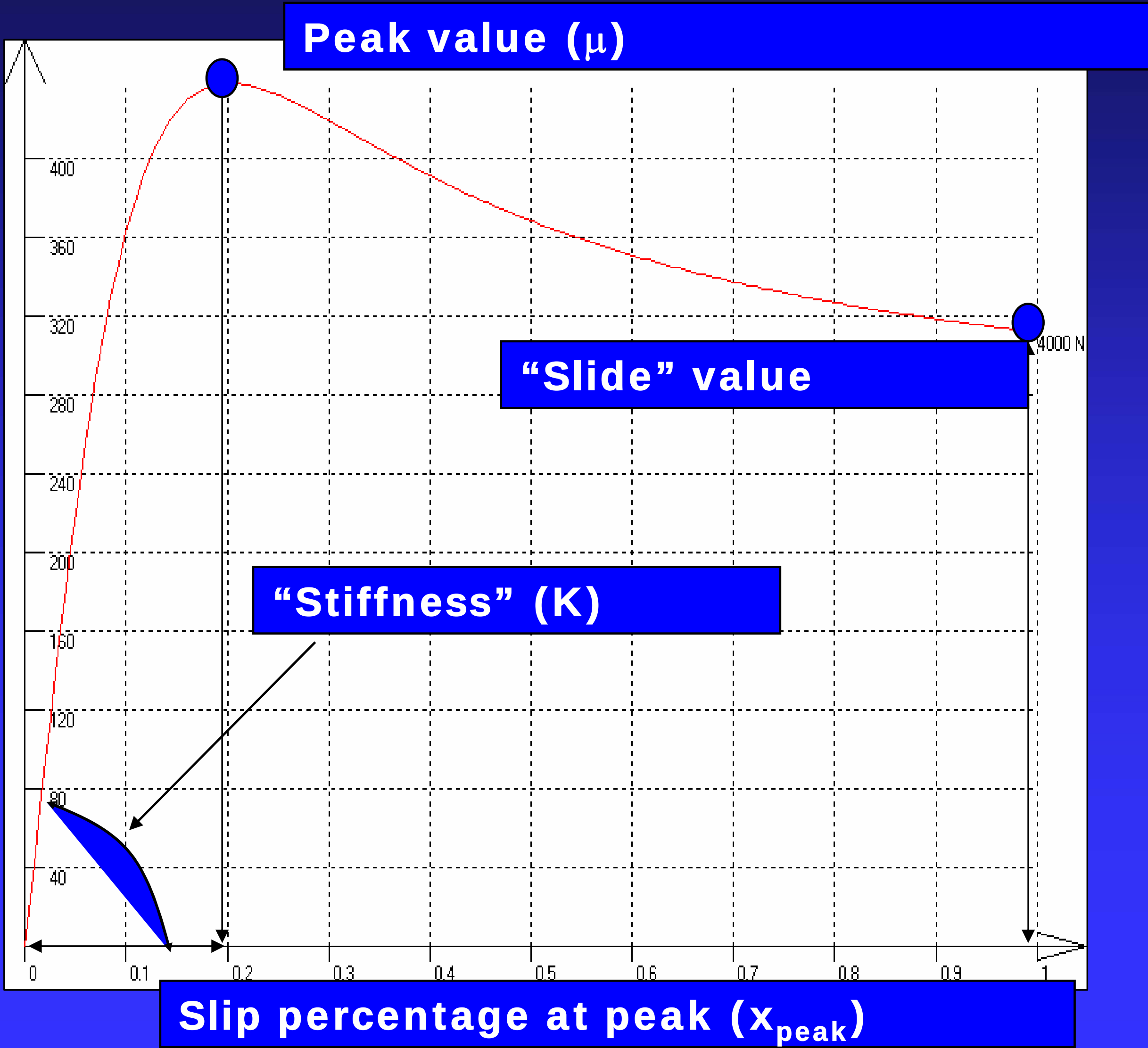
French Device used to measure BFC C 35



LFC = f(Slip %)
Speed from 20 to 100 km/h
Tyres from 145x13 to 245x19
Loads from 2000 N to 5000 N

VERT Tests

- **<u>Goal:</u> To understand the variations of tyre braking *performances* caused by:**
  - Tyre properties
    - Size & type
    - Tread depth
    - (Tread compound)
  - Testing conditions
    - Device
    - Surface
    - Speed



VERT Tests

- **Surfaces**
  - Wet / Dry asphalts (5 types); water layers: 1-8 mm
  - Snow (3 types)
  - Ice (4 types)
- **Speeds**
  - from 20 to 100 Km/h
- **Vertical loads**
  - from 2000 to 5000 N (2 or 3 loads each test)

VERT Tests

- **Tyres**
  - Summer:
    - 175/65 R 14 S
    - 195/65 R 15 S
    - 225/45 R 17 S
  - Winter:
    - 175/65 R 14 W (*)
    - 195/65 R 15 W (*)
    - 225/45 R 17 W

(*) with and without studs

99 800 readings were made during the test programme.

The French LCPC Nantes Centre

The two surfaces tested by CETE:

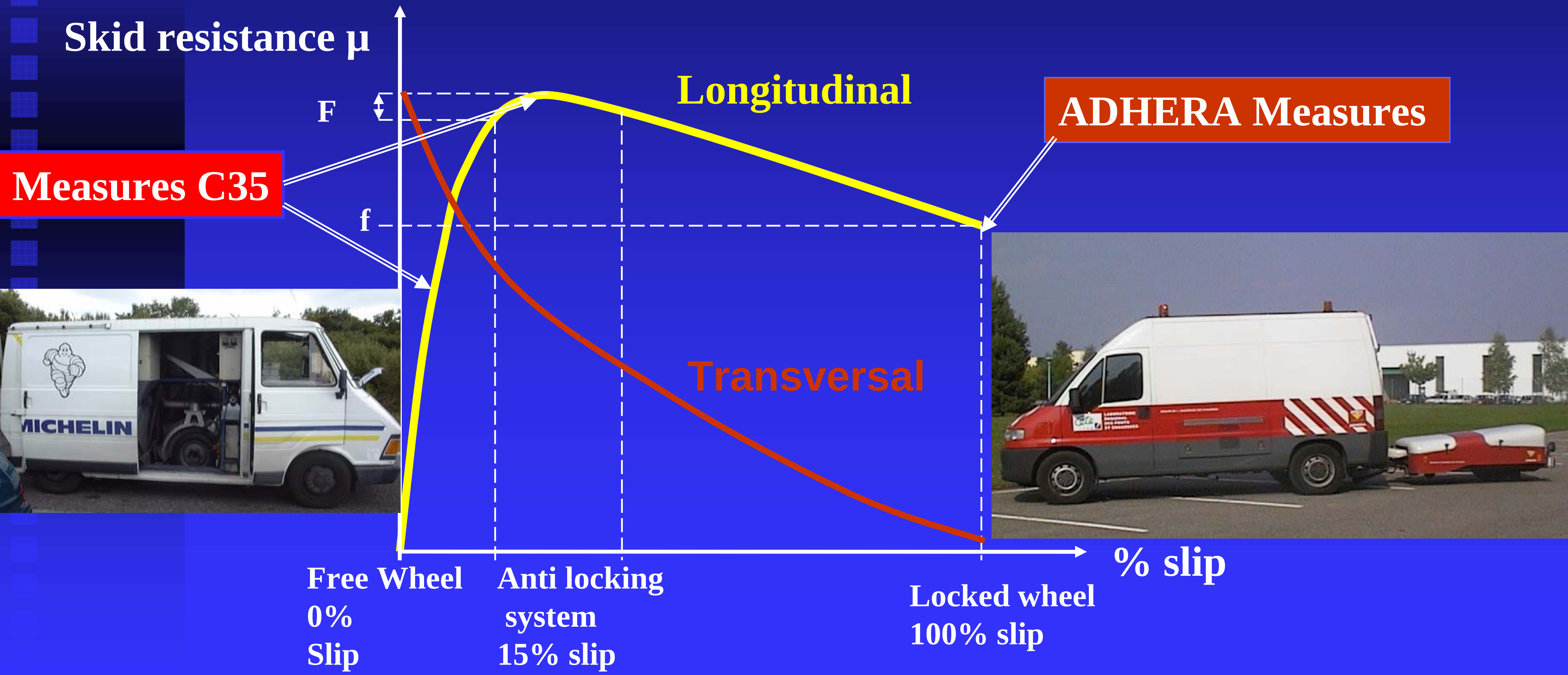
Asphalt Concrete 0/10:
- **ETD = 0.60 mm**
- **SFC = 0.67**

Very Thin Asphalt Concrete 0/6:
- **ETD = 0.90 mm**
- **SFC = 0.62**

10 cm

Tyre-road skid resistance evolution during braking or

Relationship skid resistance/slip ratio



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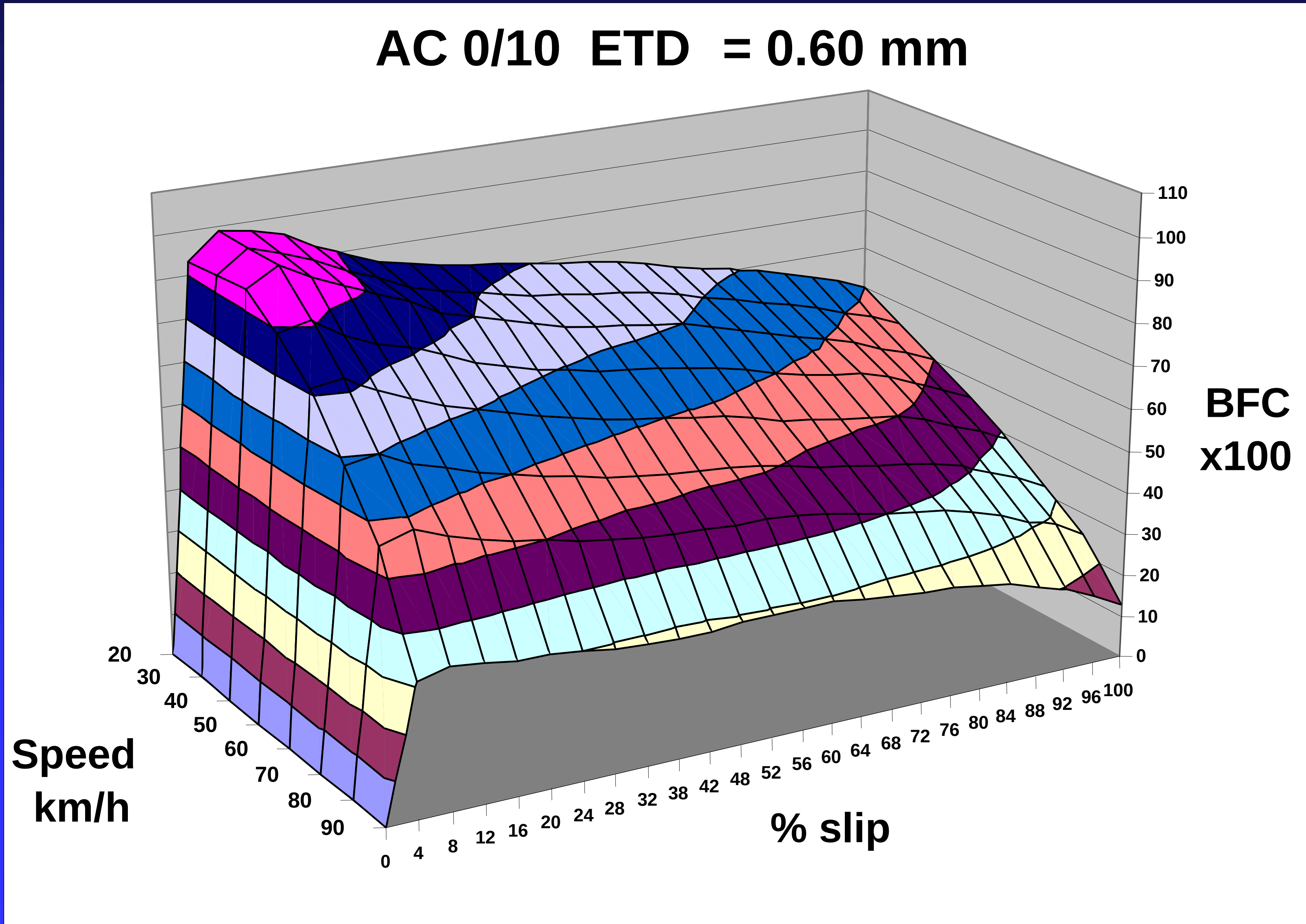
Raining consequences on tyre-road skid resistance

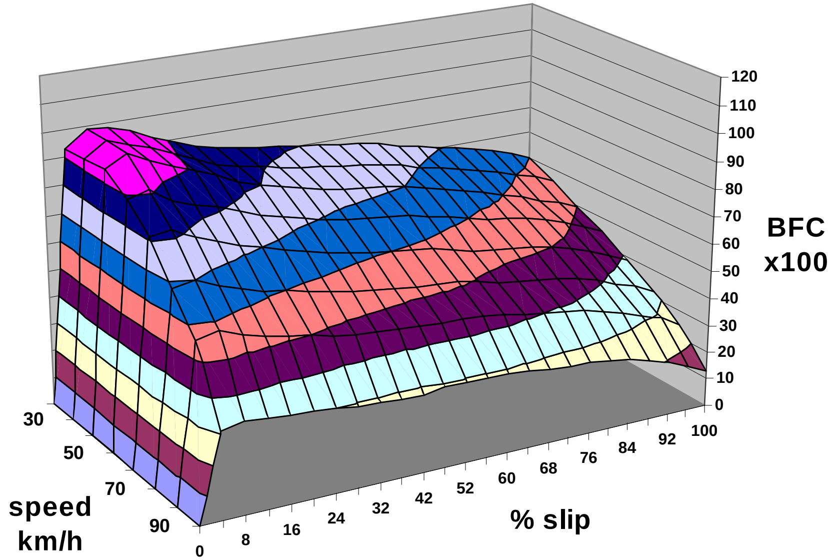
water depth = 1 mm; tread depth = 2 mm



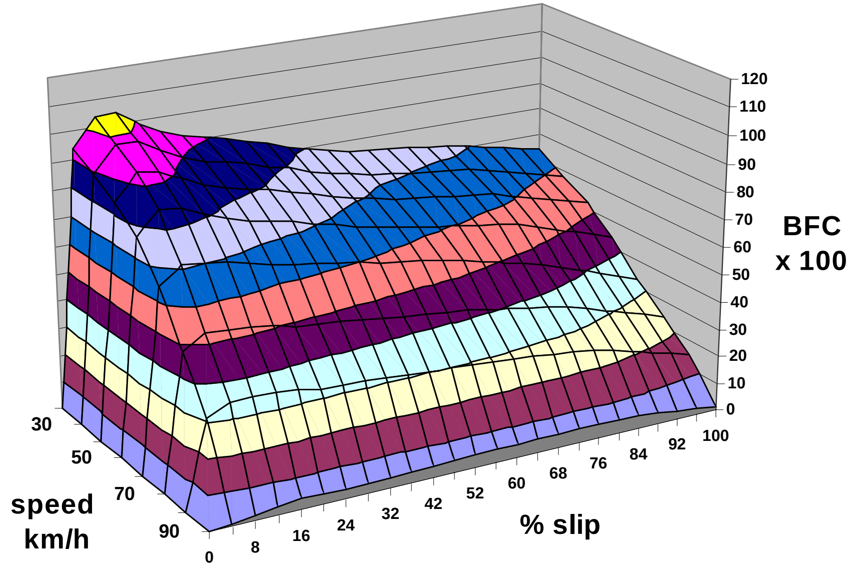
1 mm water depth 3 mm

Tyre with 2 mm tread depth

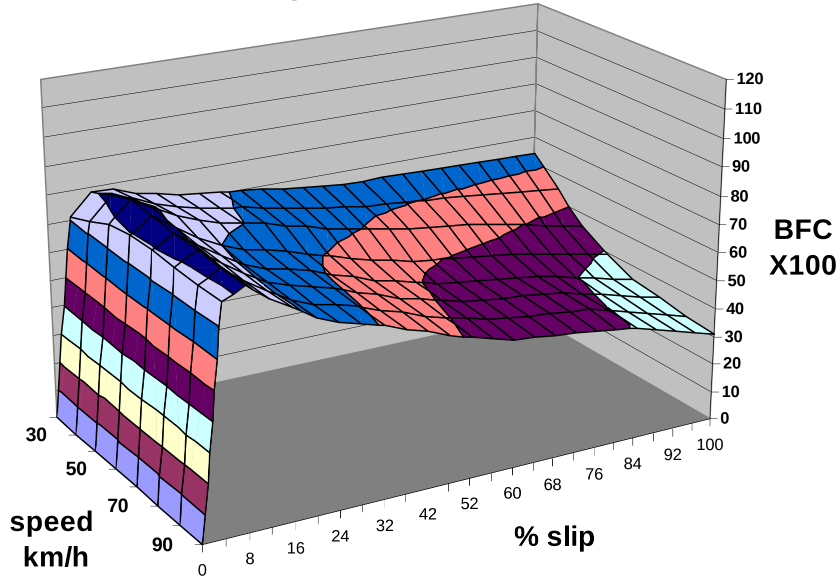
AC 0/10 ETD = 0.60 mm



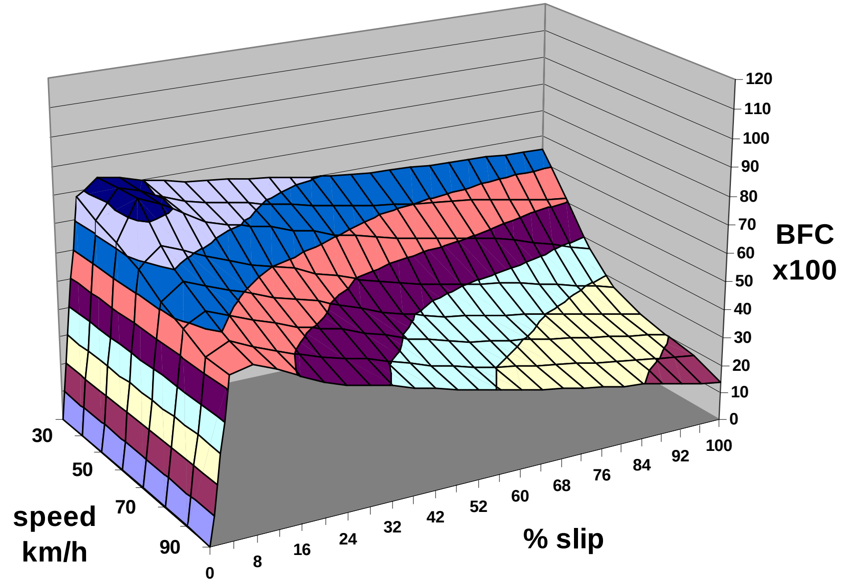
AC 0/10 ETD = 0.60 mm



VTAC 0/6 ETD = 0.90 mm



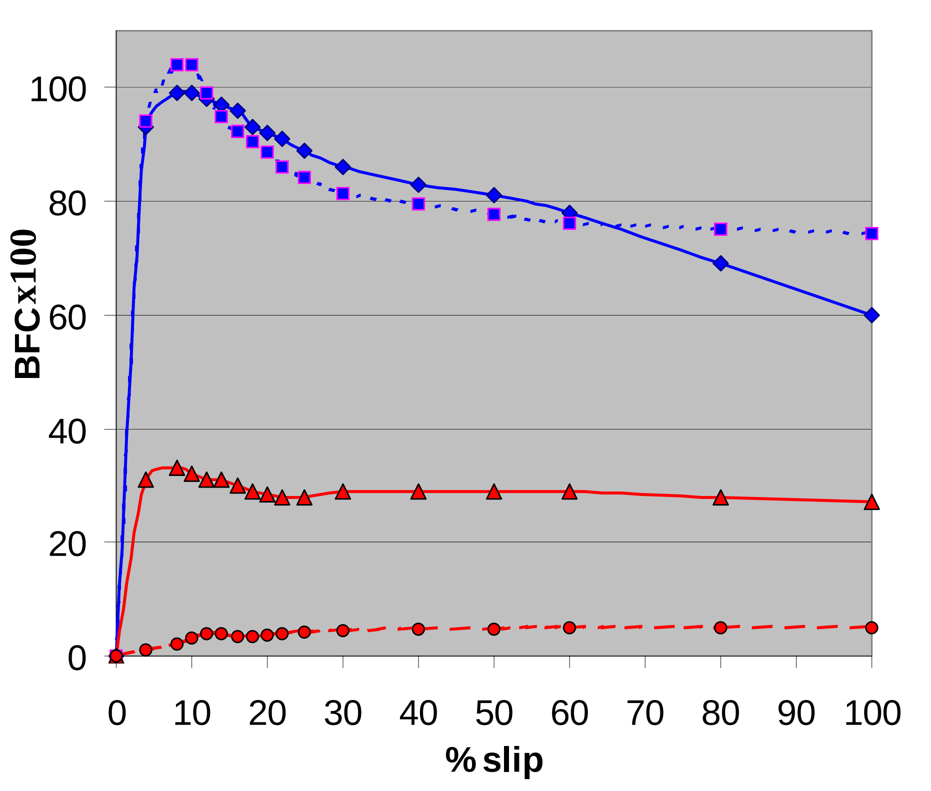
VTAC 0/6 ETD = 0.90 mm

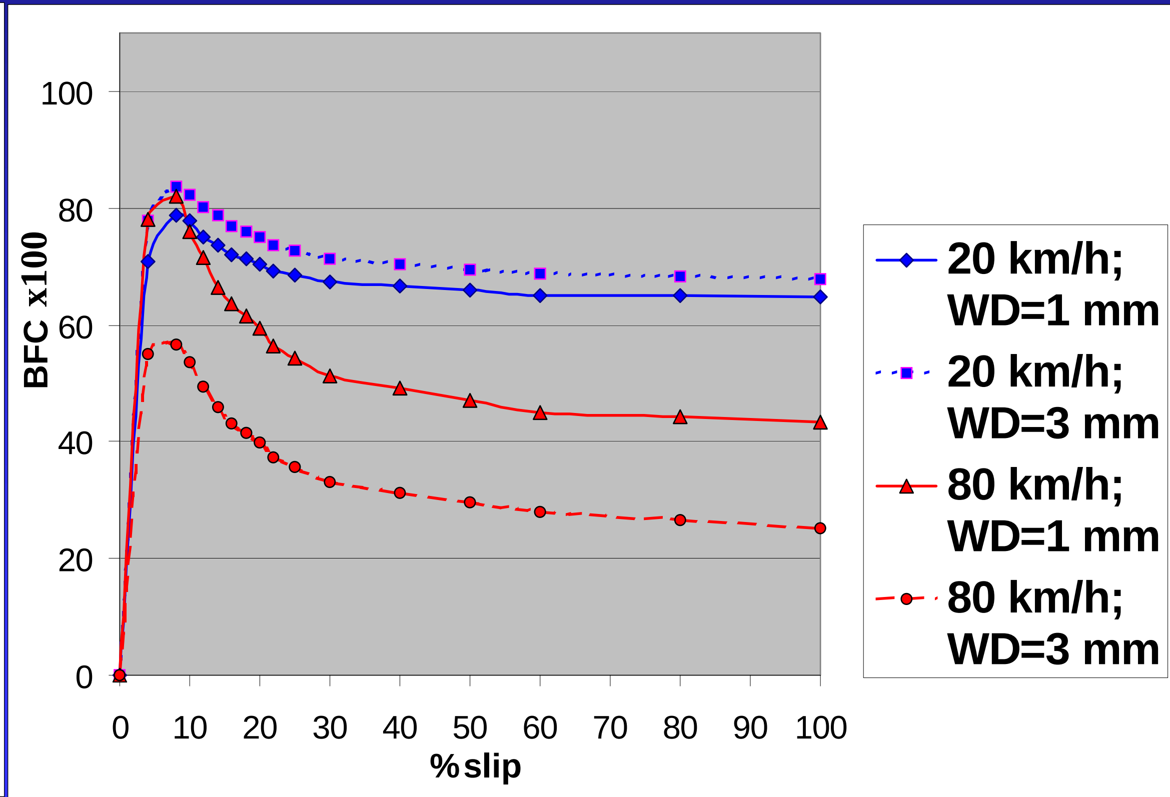


Water depth influence : (tyre 195x65R15; TD = 2 mm)

AC 0/10
ETD = 0.60 mm
SFC = 0.67

VTAC 0/6
ETD = 0.90 mm
SFC = 0.62





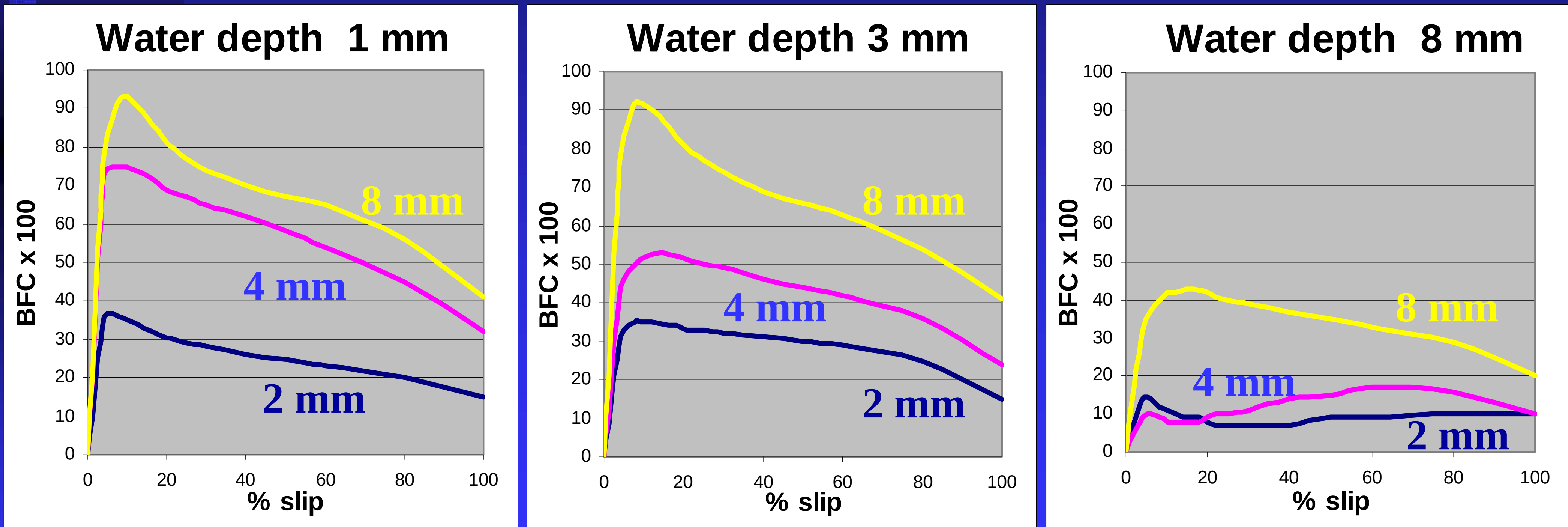
Summer tyres

Winter tyres new and worn

Water depth influence

AC 0/10 (ETD = 0.60 mm SFC = 0.67)

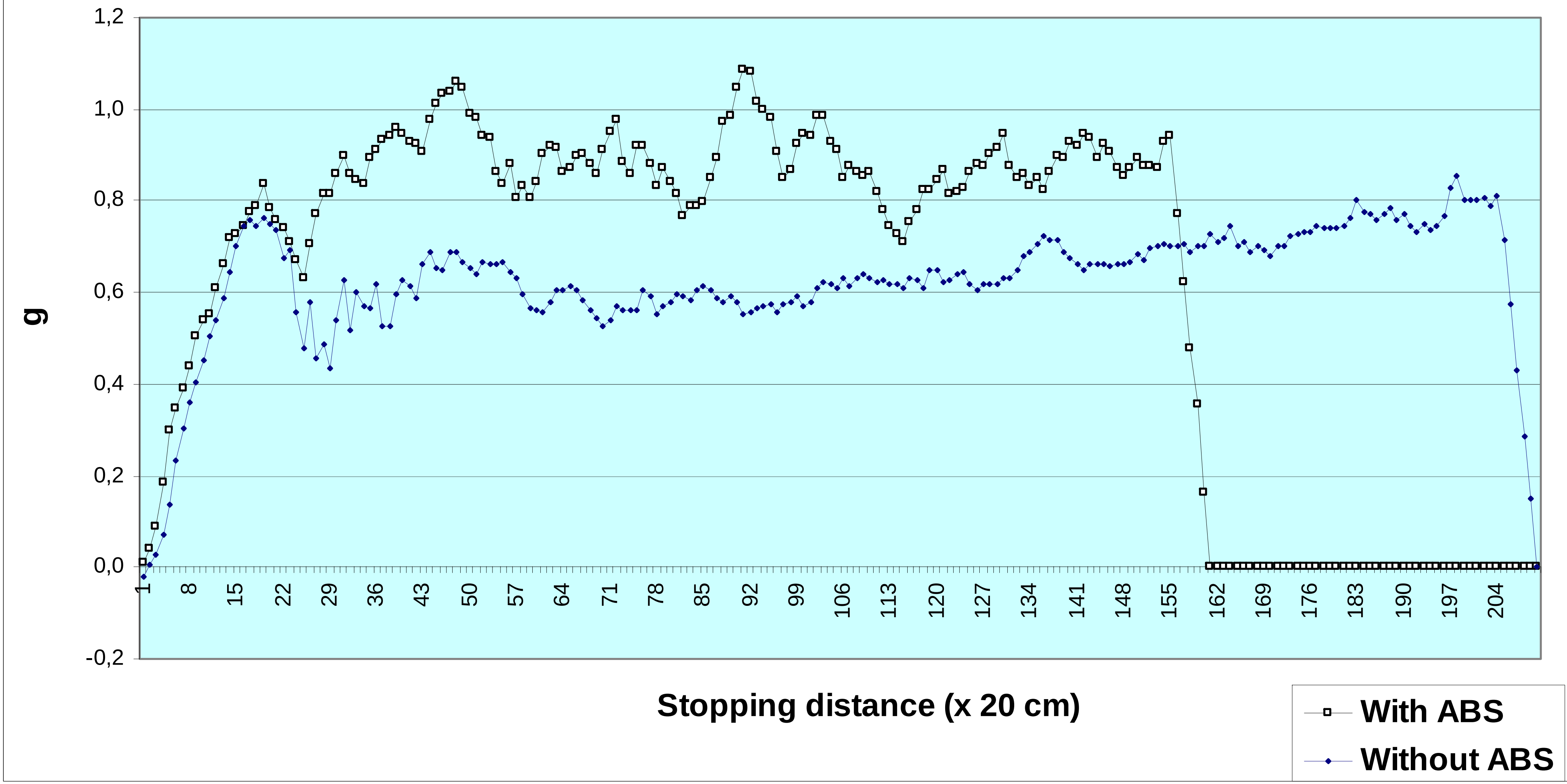
Summer tyre 195x65R15 with 3 tread depth levels: 8, 4 and 2 mm



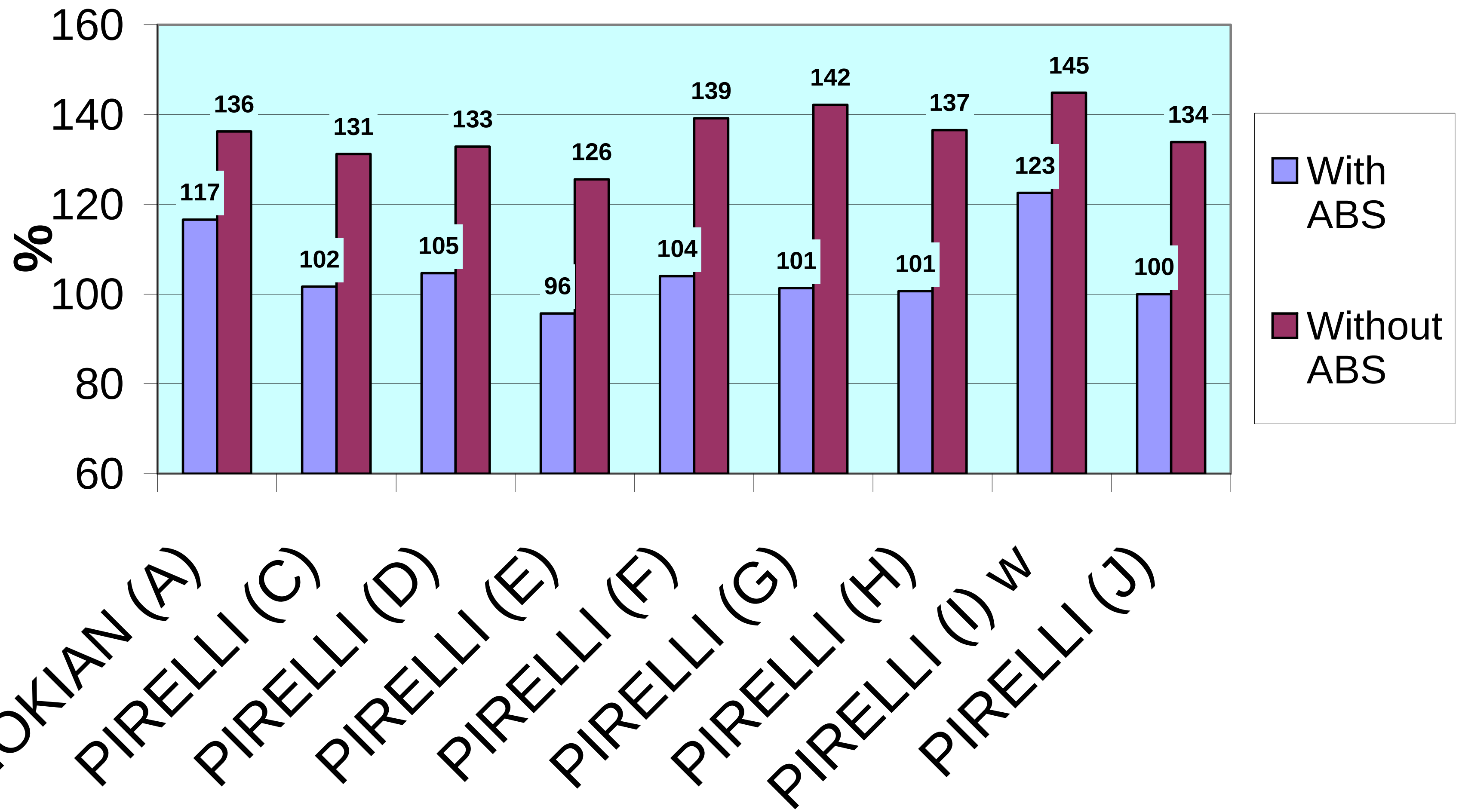
Special equipped passenger car; test tyres; test track

Stopping distance measured on wet surface

Tyre C - Deceleration*(-1) : (with ABS and without ABS)



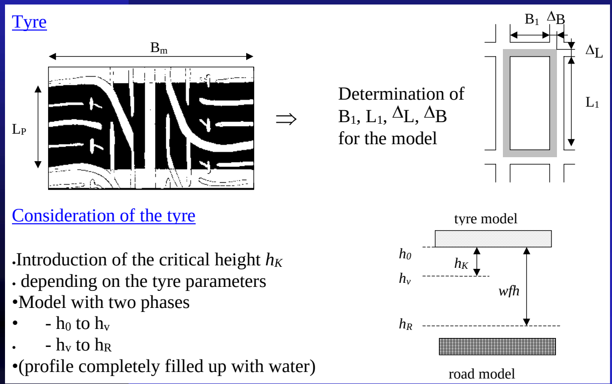
Stopping distance on wet pavement in % (base 100 Pirelli J with ABS)

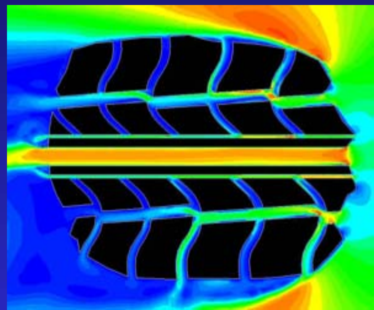


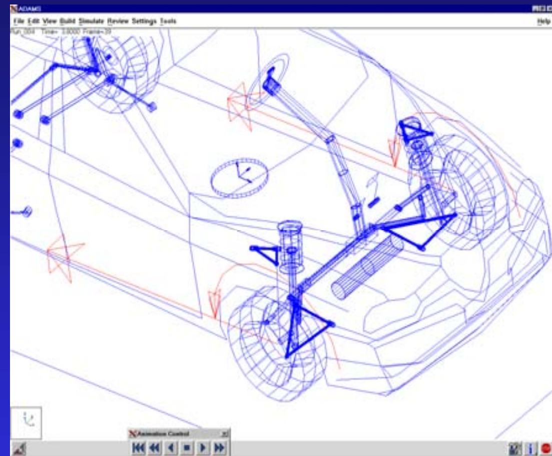
$$\mu_{moy} = \frac{M.\left[\frac{V_2^2 - V_1^2}{2d}\right] - M.\left[A + B.\left(\frac{V_1 + V_2}{2}\right)^2\right]}{\sum F_z}$$

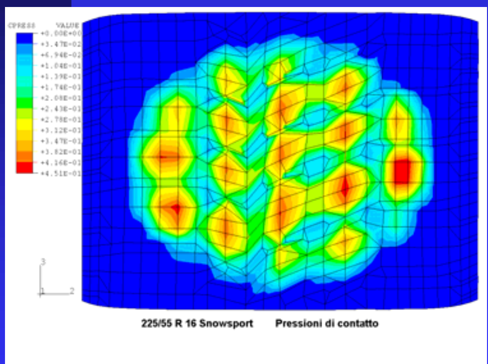
d: braking distance
V1: speed at the beginning
V2: speed at the end
M: vehicle masse
Fz: vertical load supported by each wheel
A and B: parameters linked to the vehicle

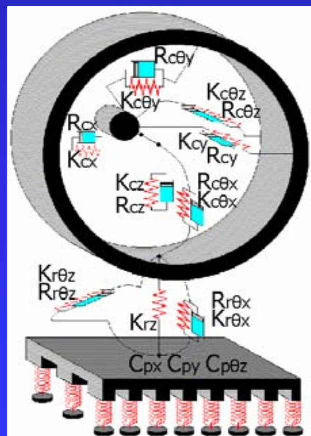
VERT Modelling



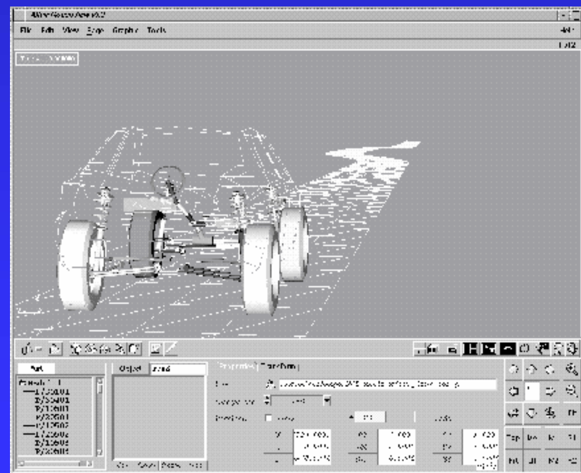




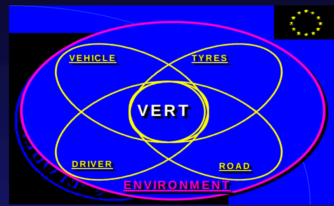




P3DT MODEL



Developed models in VERT



Model to predict the available skid resistance

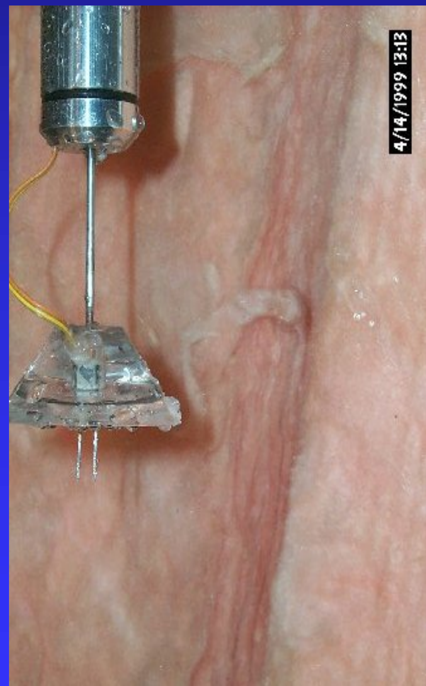
- based on real measurement (one surface, one speed, one tyre, one water depth)
- predict the skid resistance which will be available on this surface in different conditions

μ locked model | **μ max. model**

$$CF = b_0 + \frac{b_1}{1 + b_2 . e^{(b_3 + b_4 . V)}}$$

The b coefficients depend on water depth, texture and tyre

The “Limnimetre”



The rainfall artificial system


Low


Medium


High

Developed models in VERT

➢ **Proposed model for water depth above aggregates calculation**

$$h = 0.26 * (ETD)^{0.4} \frac{(I * L)^{0.4}}{P^{0.3}} - (ETD) + 0.30$$

I = rainfall intensity
L= flow length
P= most important slope

➢ **Model to estimate the maximum water depth**

$$h_1 = 10^{((L_{Me}/20)-5,8)} + h$$

L_{Me} megatexture indicator in dB

Conclusions (VERT): Correlations between braking test data and testing conditions

- On wet Asphalt
  - Important statistical amount of information
  - Definitely clear effect of speed, water film thickness, tread thickness
  - Peak and slide values easier to investigate than stiffness and slip-% at peak
- Snow/Ice:
  - Not linear/ simple relations with the testing conditions
  - Weak/ not evident influence of the speed
  - Dramatic influence of the surface and the tyre behaviour

Conclusions: rain effect on skid-resistance

- Even on low rainfall intensity it is possible to find on a road surface some high water thickness (1 to 3 mm)

- At high speed, tyre (tread) and macrotexture functions are very important to eliminate this water and keep an acceptable skid resistance level. Between medium (WD 1mm, New tyre, ETD>0.9 mm) and bad conditions (WD 3 mm, Worn tyre, ETD<0.6 mm) stopping distances (locked wheel) can be multiplied by 7!

- Water depths on road surfaces by rainy time is depending of rain intensity, slope, flow length and macrotexture. To predict water depth and skid resistance some models exist. But,

- These water depths are more over depending of surfaces irregularities as superelevation sense changes, rutting or megatexture.

HERMES

2001 - 2004

*H*armonization of *E*uropean *R*outine and Research *M*easuring *E*quipment for *S*kid Resistance of Roads and Runways

PIACR
SC Committee C1

1992 experiment
PIARC report Paris 1995

IFI

IRFI

ASTM standard
E1960-98

European standard project
EFI - SRI – prEN 13036-2

ASTM standard
E2100-00

HERMES

HERMES working group

- BRRC — Belgium
- DRI — Denmark
- CEDEX — Spain
- DWW — Netherlands
- LCPC — France
- TRL — Great-Britain

HERMES

HERMES main objective

Apply and improve, if possible, the CEN standard for calibration/verification of skid resistance measurements European devices in using the EFI concept

PIARC simplified Model

$$EFI = A + B*F*EXP[(S - 30)/Sp]$$

With:

- ▷ A and B device used depending
- ▷ F, friction coefficient measured
- ▷ S, slip speed used during measurement
- ▷ $Sp = 57 + 56*MPD$ or $Sp = 43 + 70*MTD$

Experiments organised during the HERMES project

- 23-25/10/01: Great Britain: 4 devices
- 29-31/10/01; Netherlands: 3 devices
- 20-22/11/01: Spain: 4 devices
- 19-21/03/02: Belgium: 5 devices + 3
- 26-28/03/02: France: 5 devices
- 23-25/04/02: Netherlands: 5 devices + 2
- 01-03/10/02: Great-Britain: 4 devices + 1
- 08-10/10/02: Belgium: 4 devies + 1
- 15-17/10/02: France: 6 devices

FEHRL

IMAG (F)

ADHERA (F)

HERMES

ODOLIOGRAPH (B)

SKIDOMETRE (NL)

SCRIM (SP)

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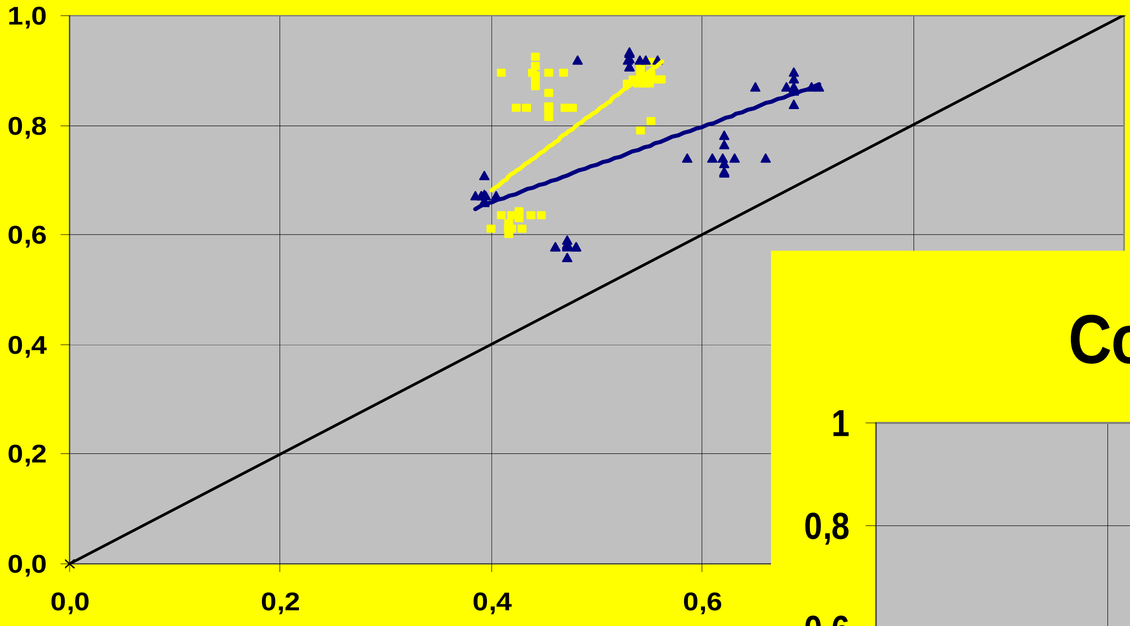
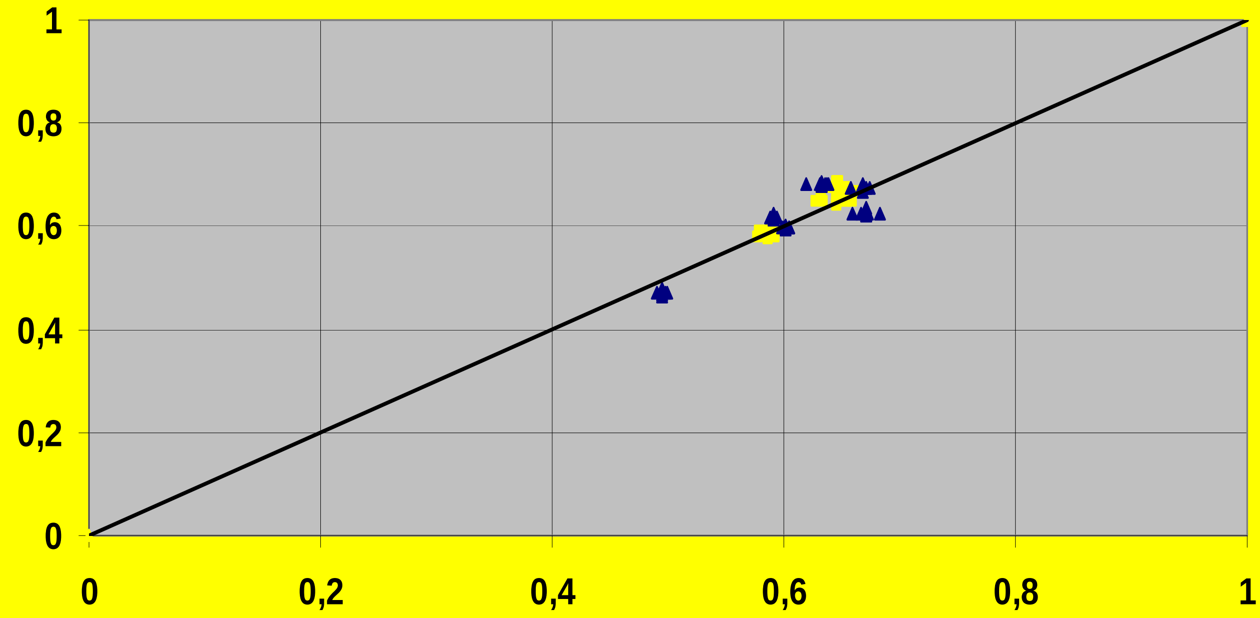
EFI interest:

Direct comparison

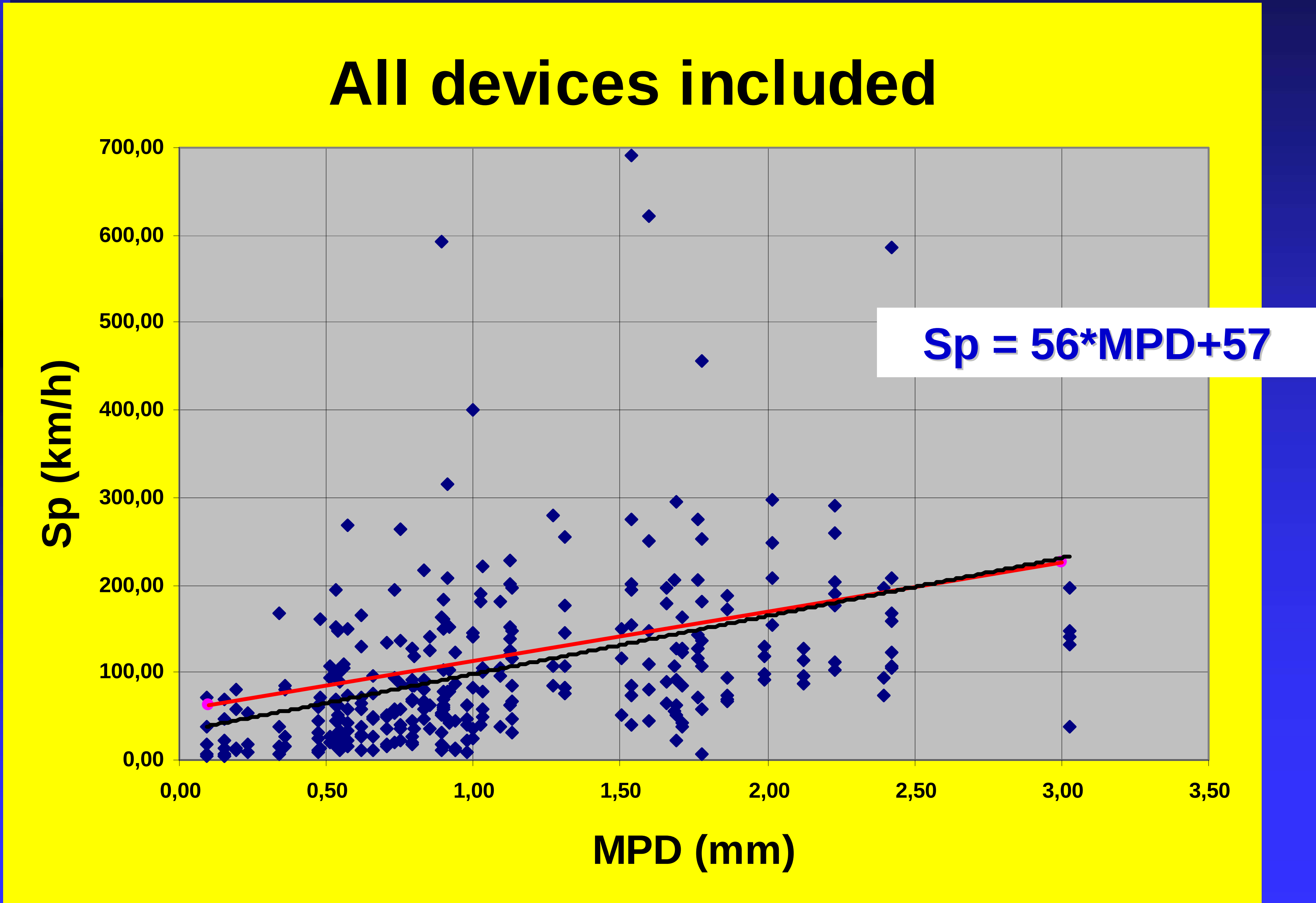


Comparison between spanish SCRIM and french ADHERA

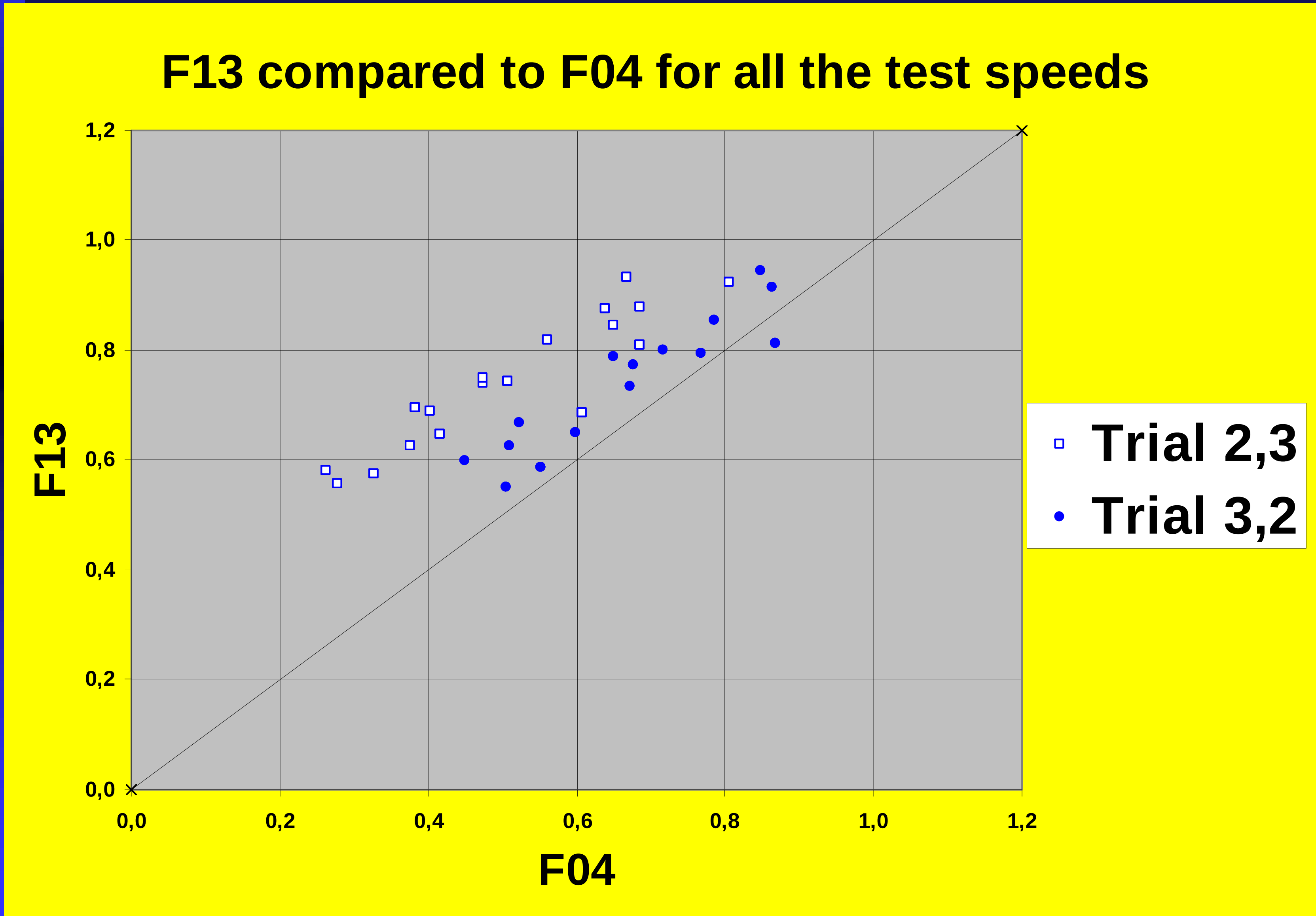
Comparison based on EFI



Sp = f(MPD)


All devices included
Sp = 56*MPD+57
Sp (km/h)
700,00
600,00
500,00
400,00
300,00
200,00
100,00
0,00
0,00
0,50
1,00
1,50
2,00
2,50
3,00
3,50
MPD (mm)

Difficulty linked with the devices stability



HERMES

Main results:

- HERMES confirmed the EFI interest
- PIARC model is not enough accurate
- The texture influence on friction seems not enough taken into account by MPD (develop other models for Sp than Sp = a+b(MPD) or $a(MPD)^b$)
- The participating devices not enough controlled before the tests
- It appears necessary to set out references for such tests
    - references surfaces (first overview)
    - reference device (first specifications written)

HERMES

Short term (less than 4 years):

- Propose a temporary method to allow the device results comparison to a common scale; this method would be used in a first EN standard series;
- Propose a harmonised procedure to verify the devices quality;
- Apply this method and this procedure in real conditions to increase the EFI accuracy
- Launch a feasibility study for reference surfaces.

HERMES

For long term (more than 8 years):

- Progressively replace the existing devices by the reference device;
- Adapt or improve the European calibration procedure;
- Develop a new EN standard (descriptive) for a test method based on the reference device

The end

Thank you for your attention