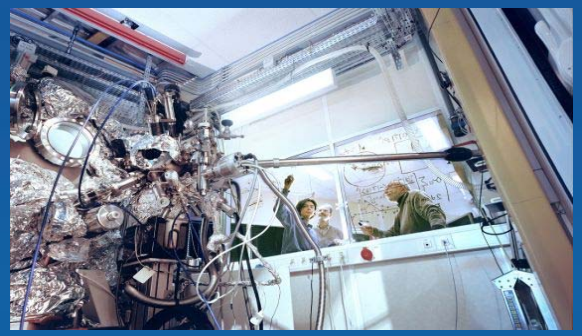
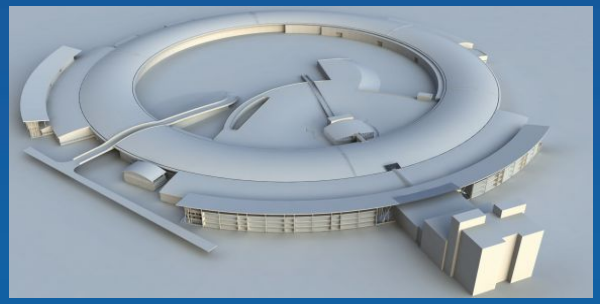
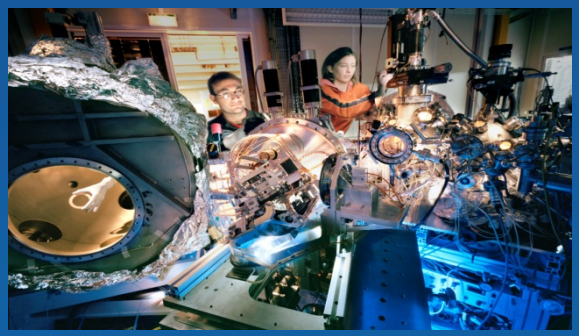
The concrete slab studies for the ESRF upgrade beamlines

Y.Dabin, L. Zhang, D. Martin,E. Bruas, P. Mackrill (ESRF)
Sh. Ghavamian (NECS*)







On behalf of all people working for the slab

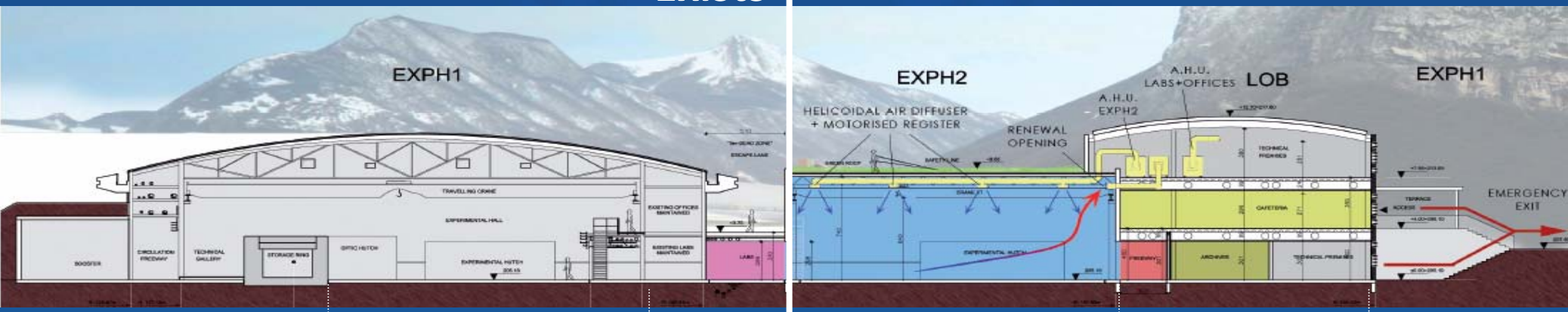
(*): NECS- Numerical Engineering and Consulting service, SCEAUX France

Slab design: Outline

- Specification definition
- Civil engineering: Call for competence
- ESRF: doing parallel engineering
- Selecting final solution
- Processing solution

Extending slab through a series of various species

Exists | **New**



BL Optics

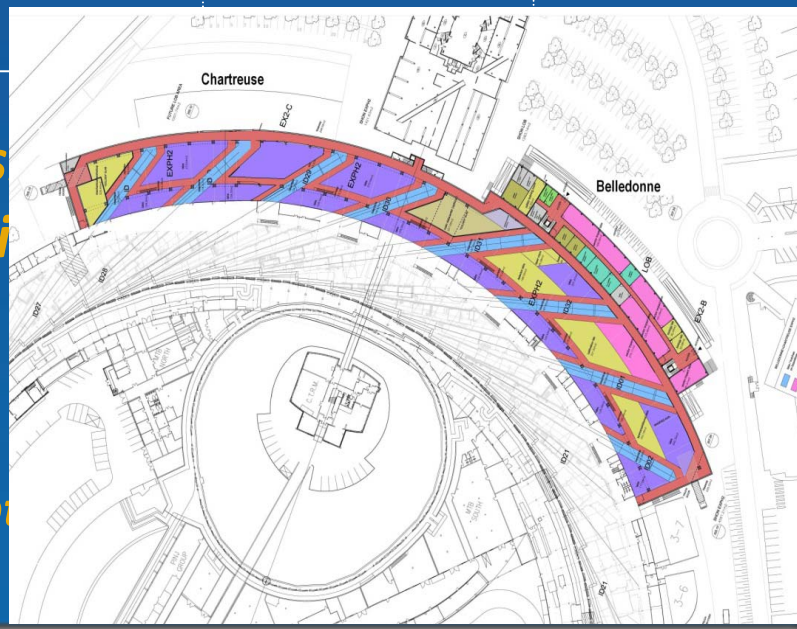
Last optic + sample

Segmented slabs

Designed in 1990
20 cm thick
Cracked but well repaired

Circulation Corridor
"dead zone" No opt

New s
experi



ESRF design principle: the basic

The ESRF world

- Spec. of performances
- Hold points
- Qualification

Contract

Civil engineering design world

- Translate spec. in civil engineering
- Design – arguments (demonstrate)
- Organise

The ESRF design principle: implementing

- *Vibration Stability*
- *Thermal aspects*
- *Permanent performances*
- *Slow - fast events*

Setup a specification close to scientific needs
… We are able to measure what we ask for

Organise competitive evaluation
And look at
•Technical arguments
•How data are handled
•Show some calculations

Make proposal

Quality of models
Small quantities: 200 nrd

Select a skilled engineering company
•able to understand features
•able to traduce in terms of civil engineering

INGEROP
GROUP 6
MASTER
SECHAUD & BOSSUYT
SETEC

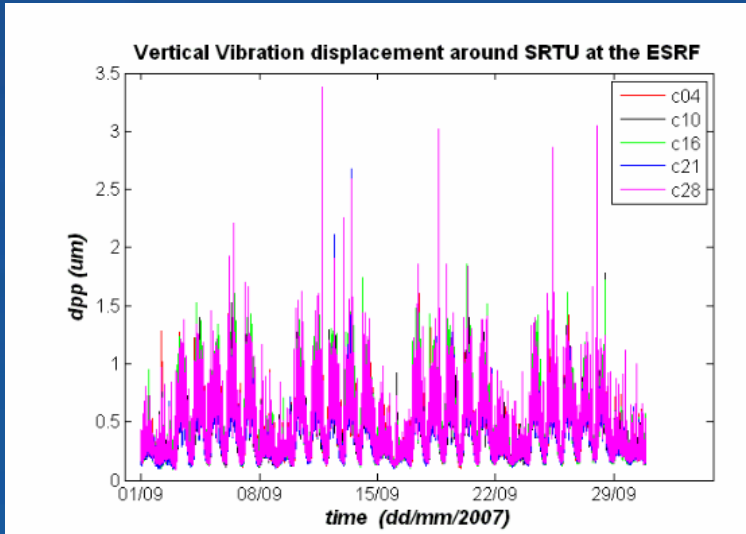
SECHAUD & Bossuyt
10 specialized companies regrouped together

Building programme definition: the site cultural noise

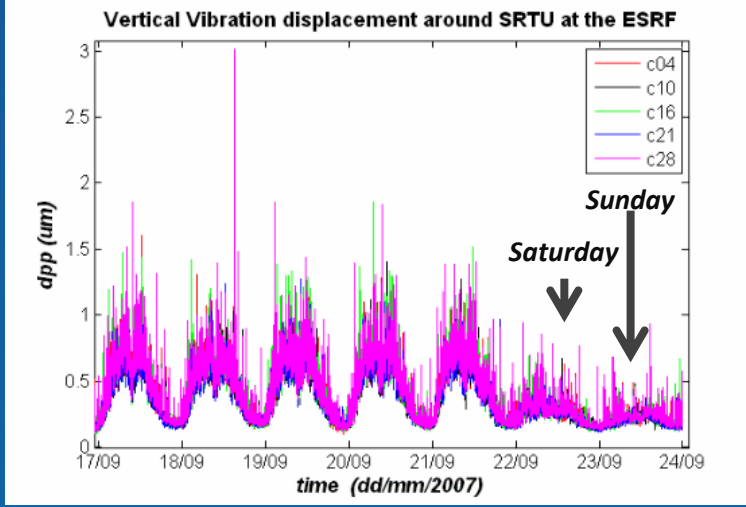
Explain why there are many parameters

Explain why what are vibration effects

The ESRF site from 13000 m



Over One month

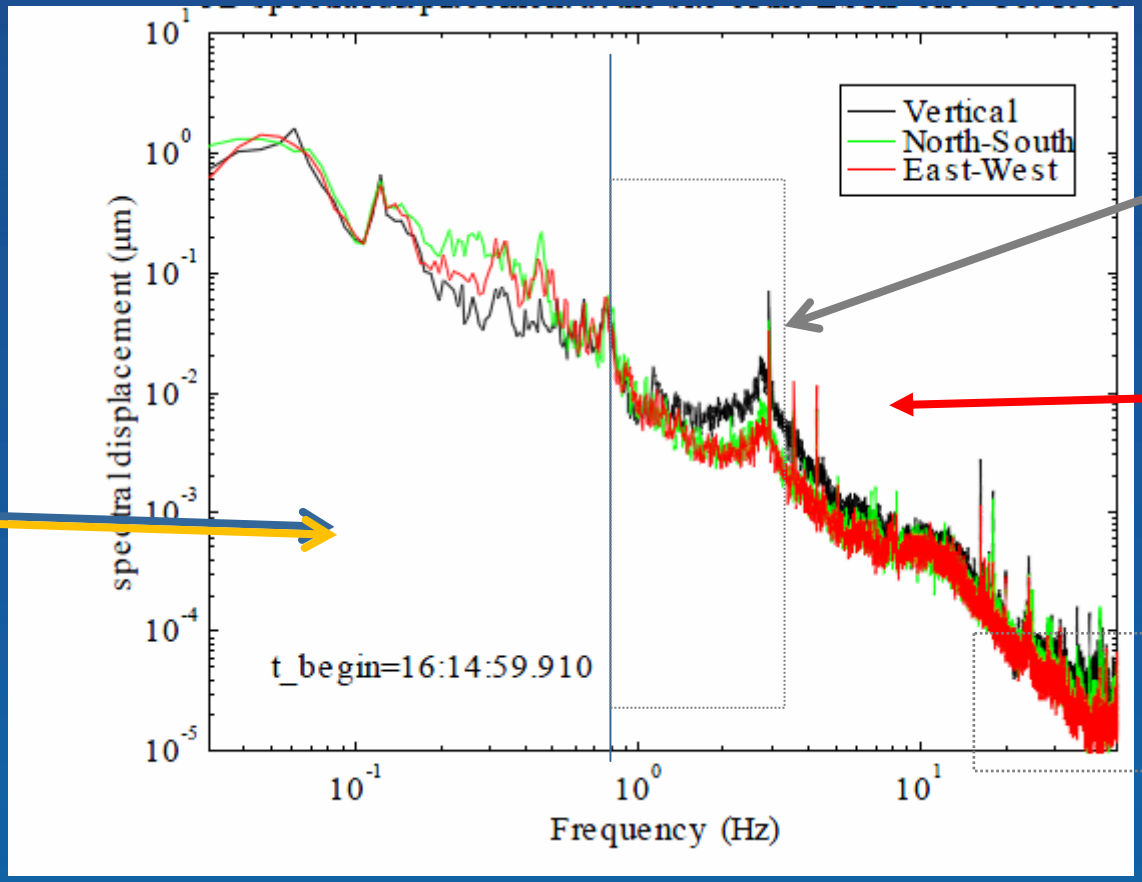


Over One week

Typical peak to peak displacement

Courtesy L. Zhang

Typical site vibration spectrum



Not really a pb
Because large spatial
Wavelength correlation

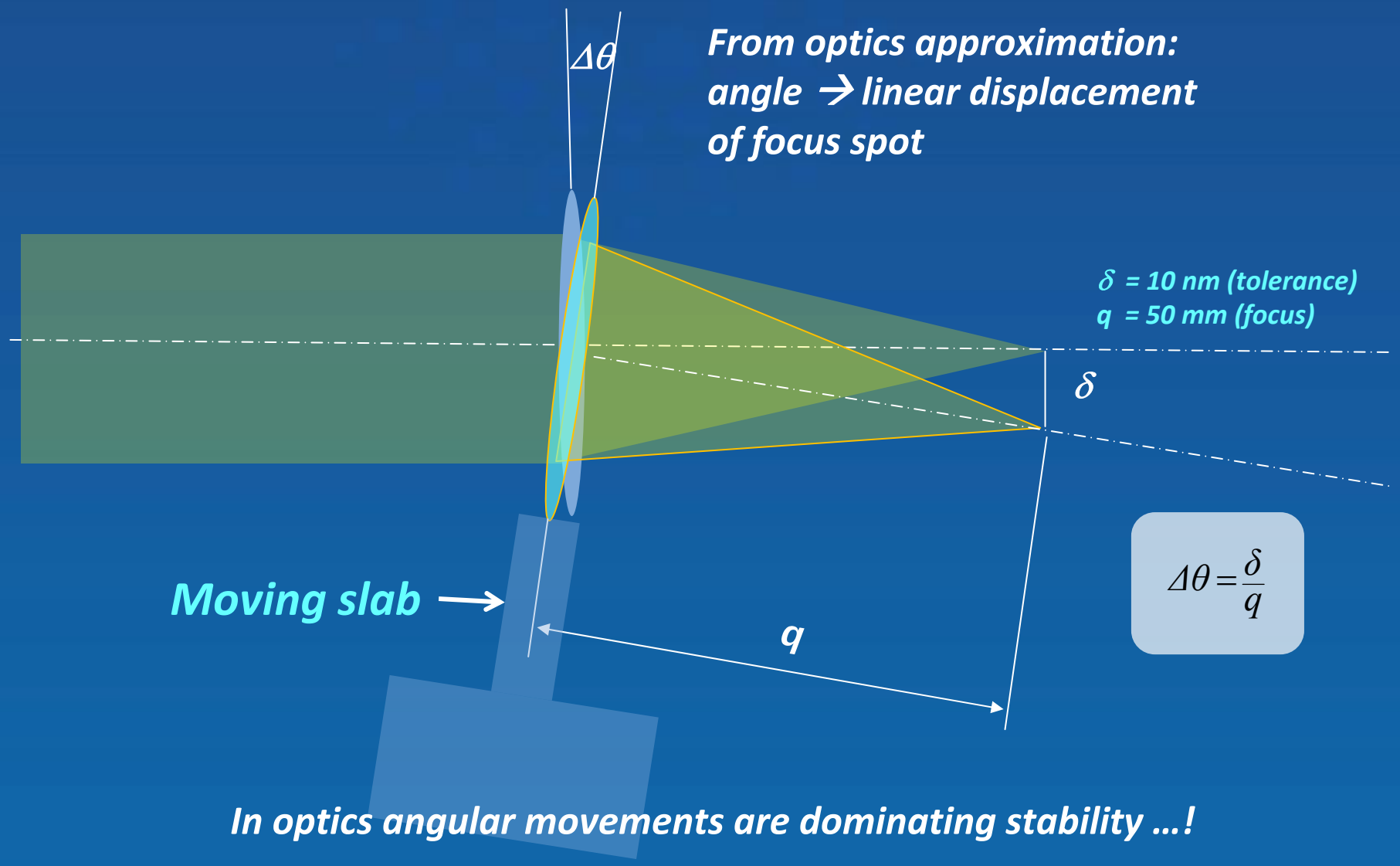
Stronger specifications for instruments In this area

Not considered to be a pb For instruments Feedback may solve

Not really a pb
Because low level

Ground vertical and horizontal spectral displacement

Optical property on angular measurement



From optics approximation: angle → linear displacement of focus spot

$$\Delta\theta = \frac{\delta}{q}$$

In optics angular movements are dominating stability …!

ESRF design key numbers

Permanent Vibration limit:

1 to 100 Hz

No noise amplification
< 1.5 µm p2p

No angular amplitude
< noise (15 nrd)

Slow/fast events:

Hourly daily
Seasonal yearly

Slab Slope < 200 nrd
Fork lift @ 10 m

Settlement: 250µm/year

ESRF project team…Making parallel calculations

The ESRF side

- Spec. of performances
- Hold point
- qualification

Our own way… as non specialists

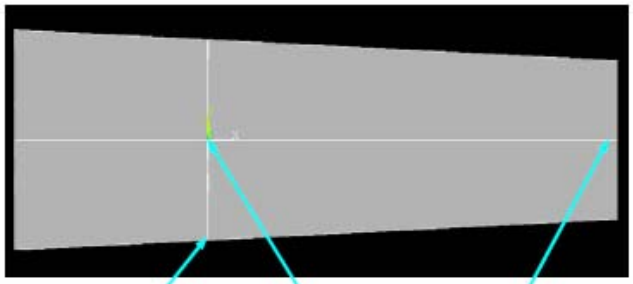
- Make our own model, calculate, identifying …..keys
- Measure thermal effects
- Set questions to Eng.

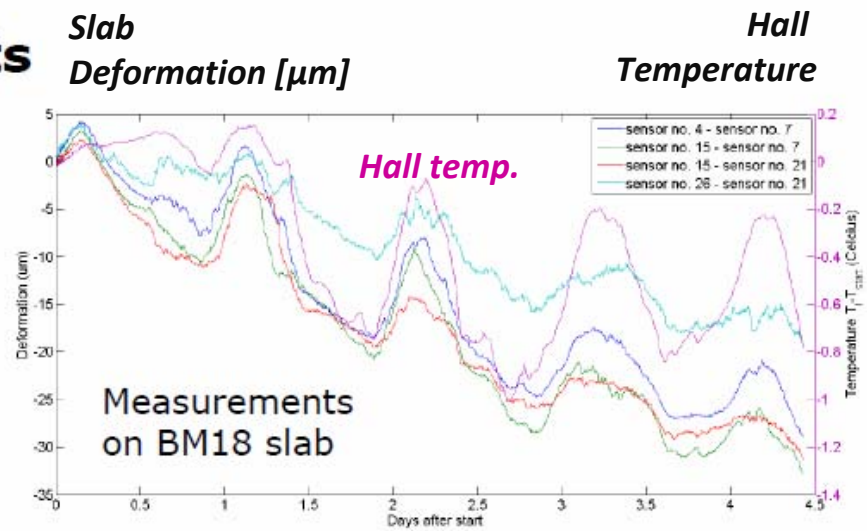
International evaluation panel: Soleil – Diamond – ALBA – PETRA III – (Megajoule)

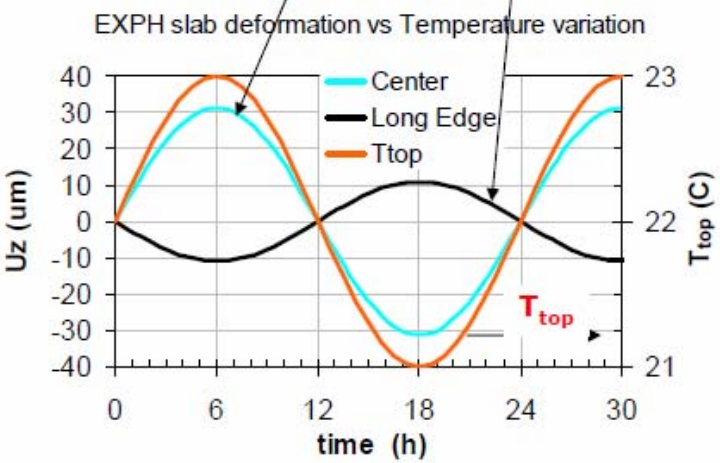
Ph. Eymard J. Kay L. Miralles F. Hermann

Present slab thermal deformation measurement

Temperature effects







- **FEA results**
  - dT(top-bottom)=±1 °C
  - dUz(**center**)=31 µm/°C
  - dUz(**long axis**)=11 µm/°C
- **Consistent with HLS measurements** (10µm for dT=±0.3 °C)

There is a daily thermal breath on existing slabs

Due to Exp. Hall Thermal breath 0,6 ° C

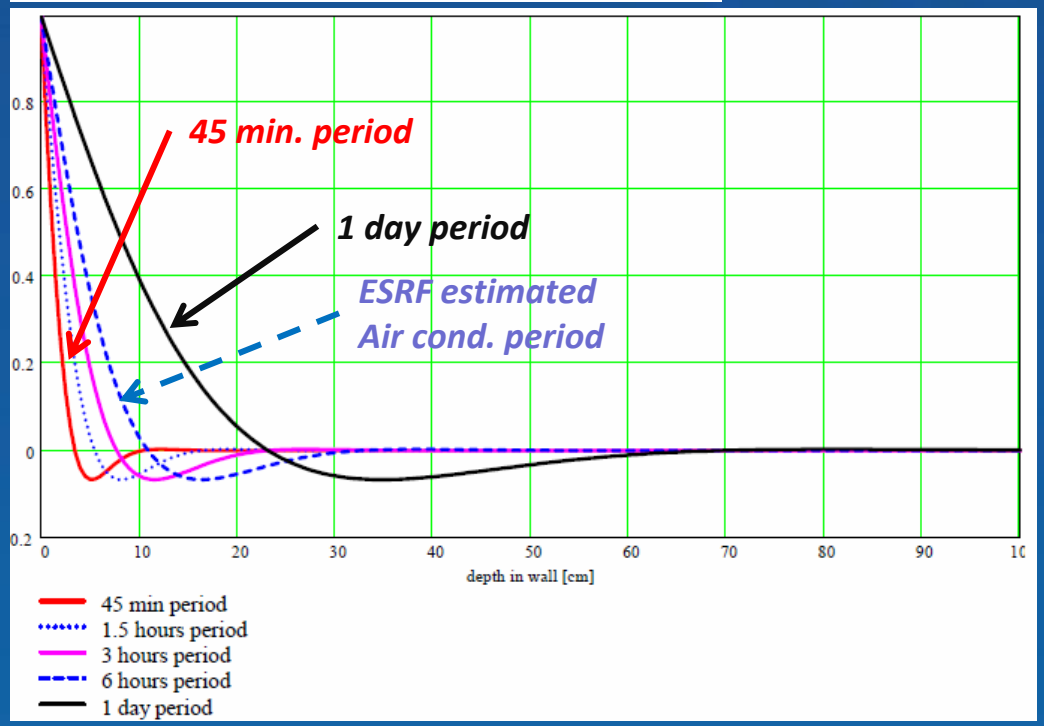
Courtesy L.Zhang D. Martin

Model of the thermal "skin depth"

Steady heat wave propagation in a concrete wall… starting from the heat wave equation

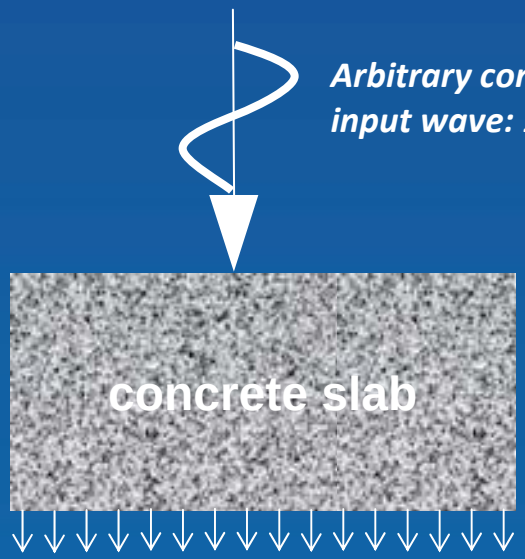
$$T(T_o, x, t, P) := T_o \cdot e^{-x \cdot \sqrt{\frac{\omega(P)}{2 \cdot a}}} \cdot \sin\left[(\omega(P)) \cdot t - x \cdot \sqrt{\frac{\omega(P)}{2 \cdot a}}\right]$$

$$a := \frac{K}{\rho \cdot C_p}$$



K = 1.75 [W/m. ° C]
ρ = 2300 [Kg / m3]
C_p = 1000 [J/Kg]

a = concrete diffusivity [m²/s]
P = input wave period [s]



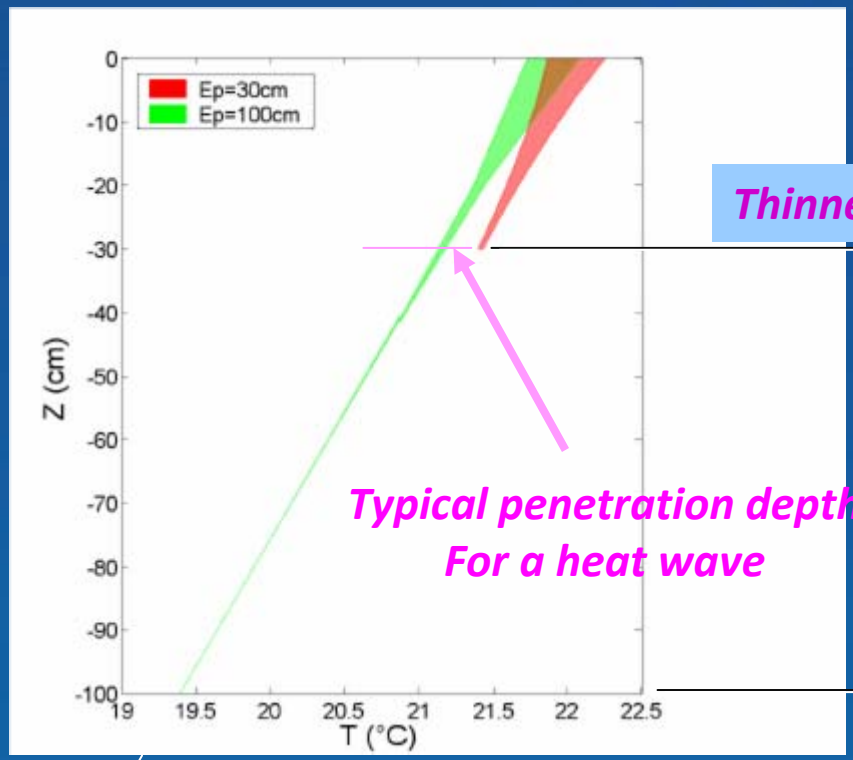
$\lambda = 2\sqrt{\pi a P}$ *is the thermal wavelength corresponding about to the decay*

The faster…the better !

Slab Thermal analysis: Thick or thin ?

Calculation of the thermal wave diffusion

Slab thickness



thickness

Thinner slab

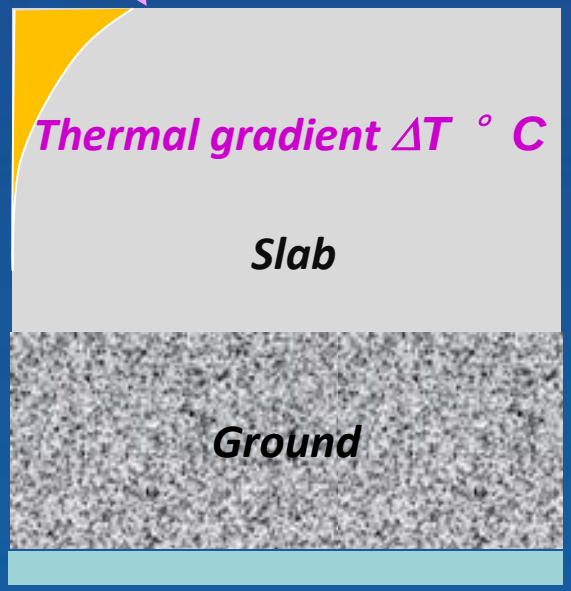
Typical penetration depth
For a heat wave

Thick slab closer
To water table

Local temperature

Linear thermal gradient through the slab

Sinusoidal thermal wave

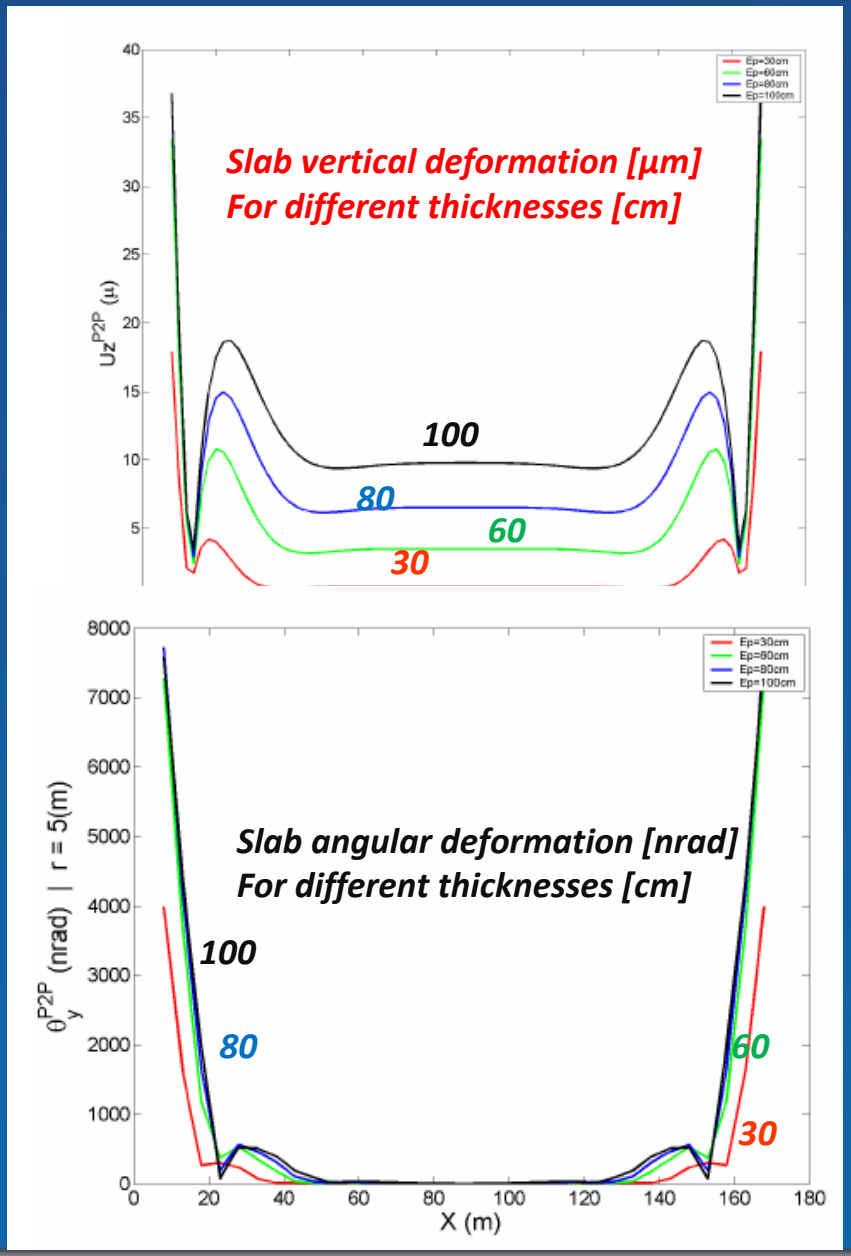


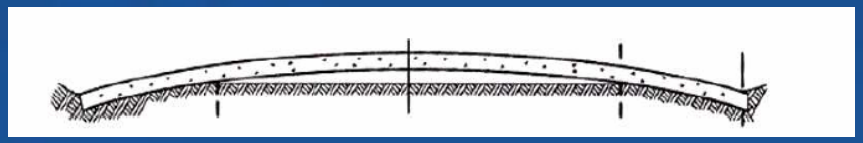
2.5 m

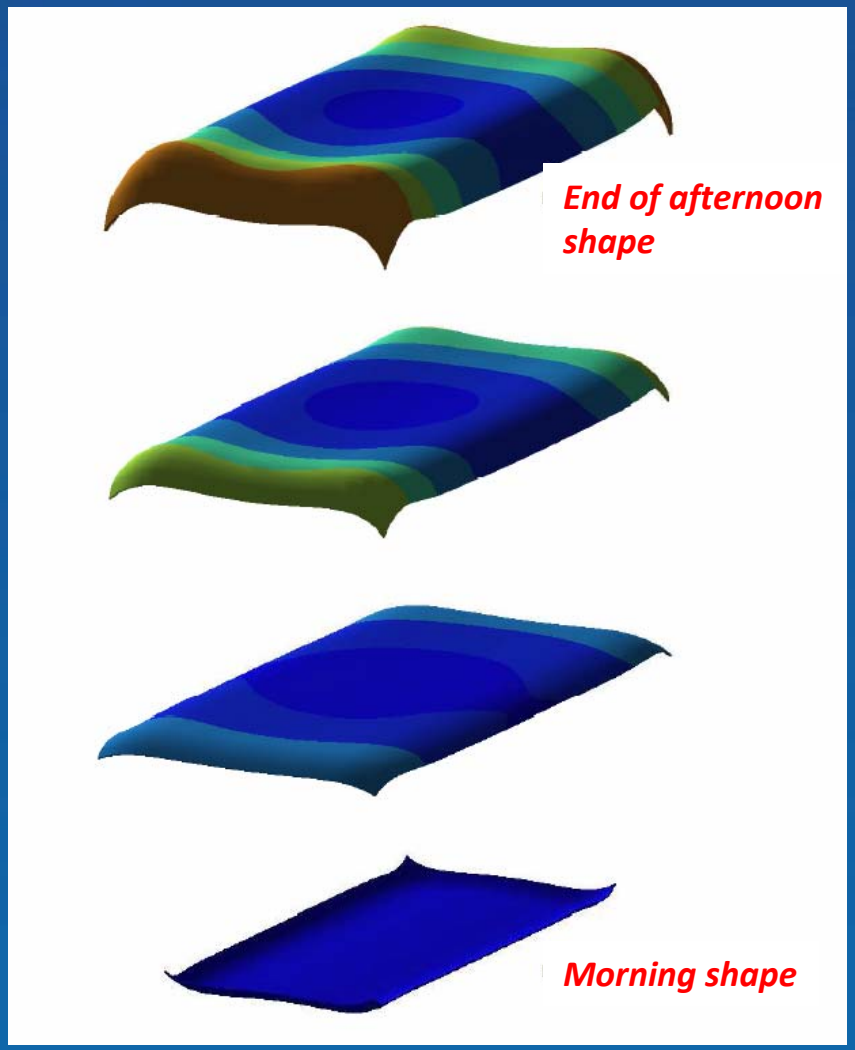
Water table

Courtesy: Shahrokh Ghavamian

Slab thermo-mechanical analysis: dynamic wave from top (air conditioning)



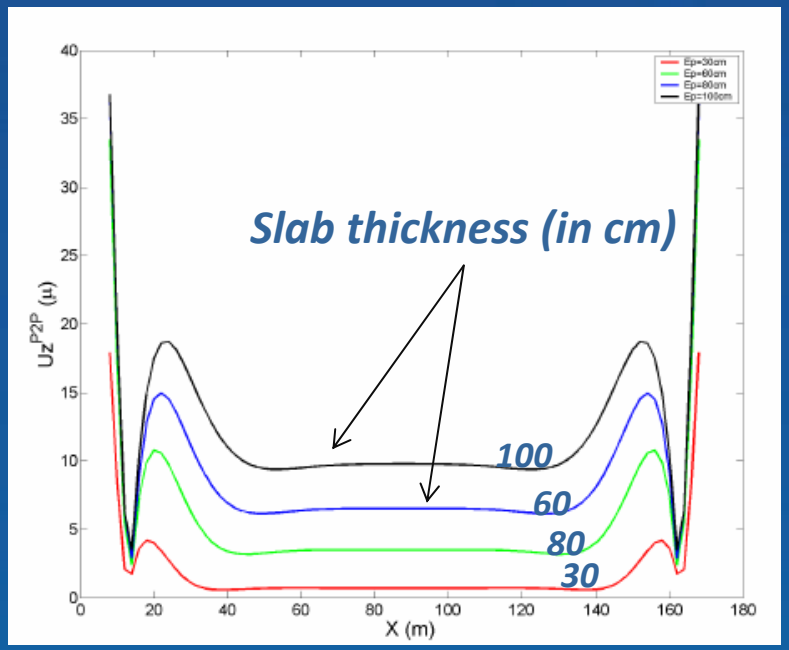




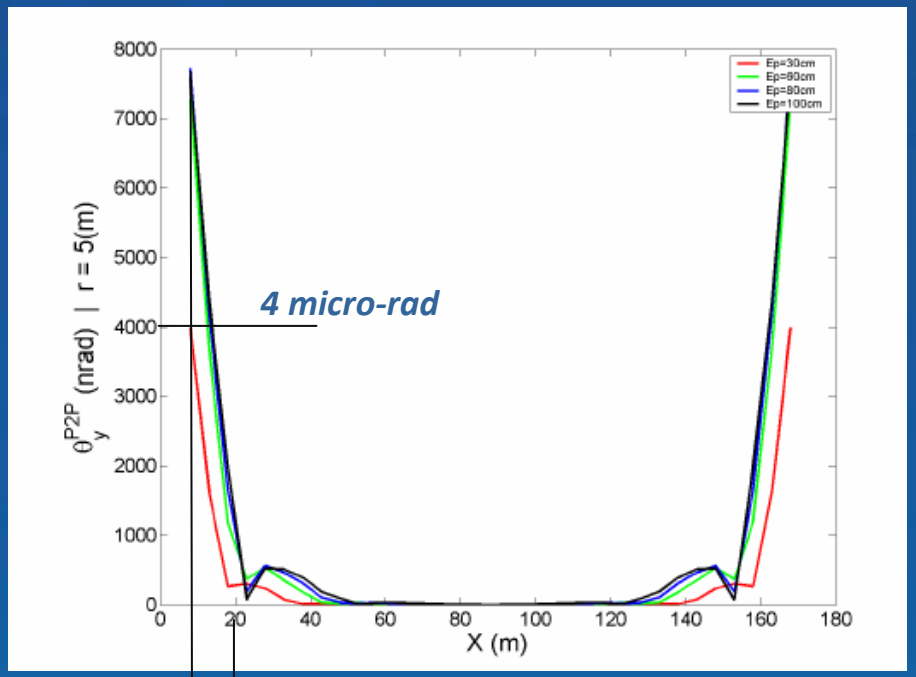
Courtesy Shahrokh Ghavamian

Response to thermal waves: ±1 ° C over 24H

Thermal deflection in microns



Thermal slope in nano-radians



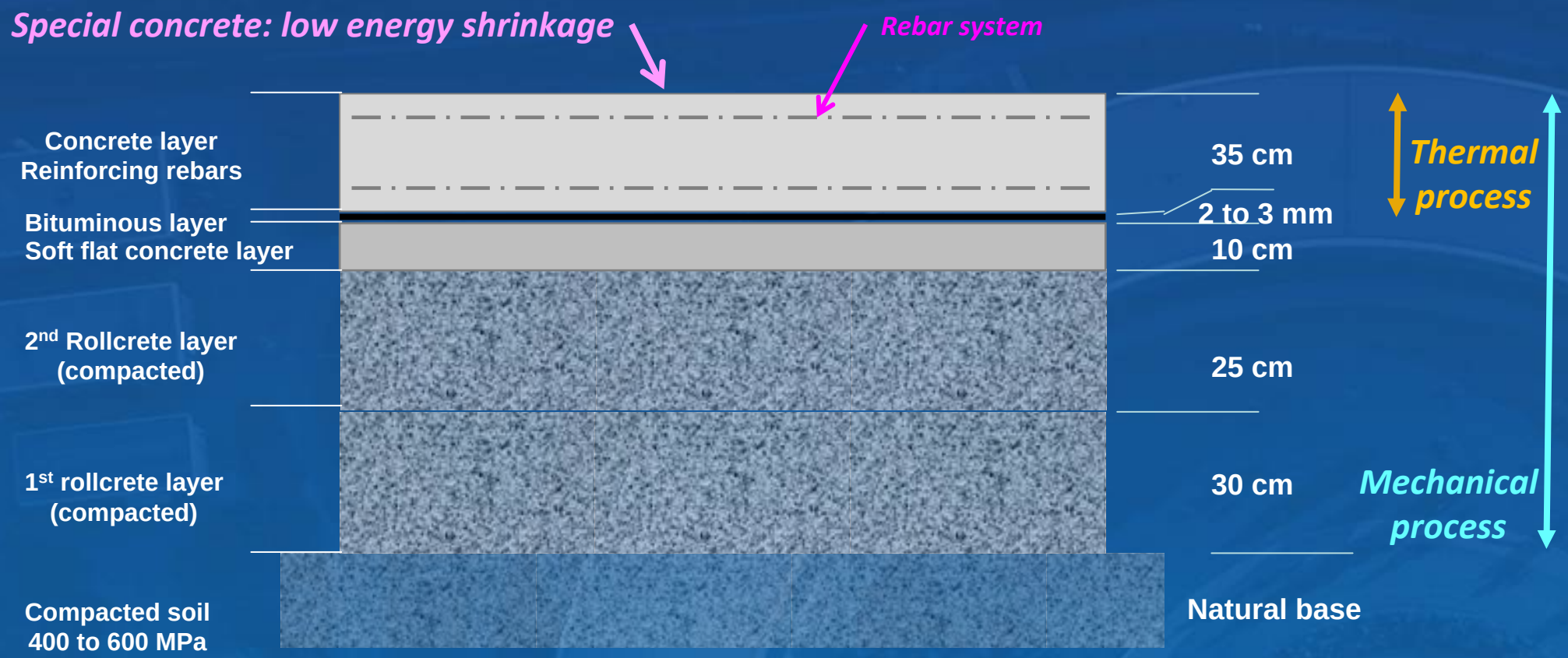
Plot along median of 160 m slab

10 m deformed area

Other issue ! → Air conditioning is linked to the slab thickness: ±0.25 ° C goal

Courtesy Sh Ghavamian

Then the ESRF slab solution is…



…Also thermal hydratation shrinkage history

A proto slab 3 x 15 m is realised: test protocols !

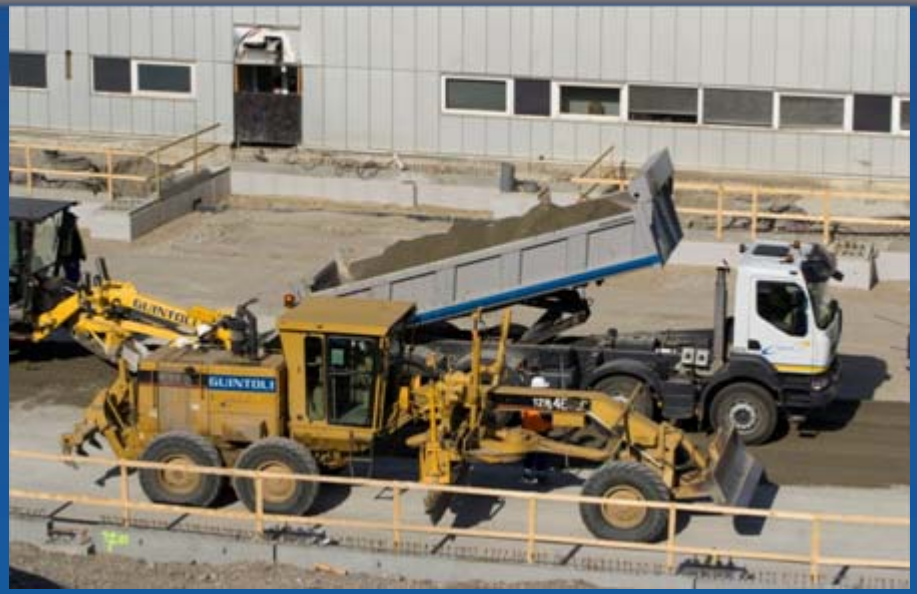
HLS probes
Laser tracker network
3 month history
Strain gauge inside

Quality record at the pouring

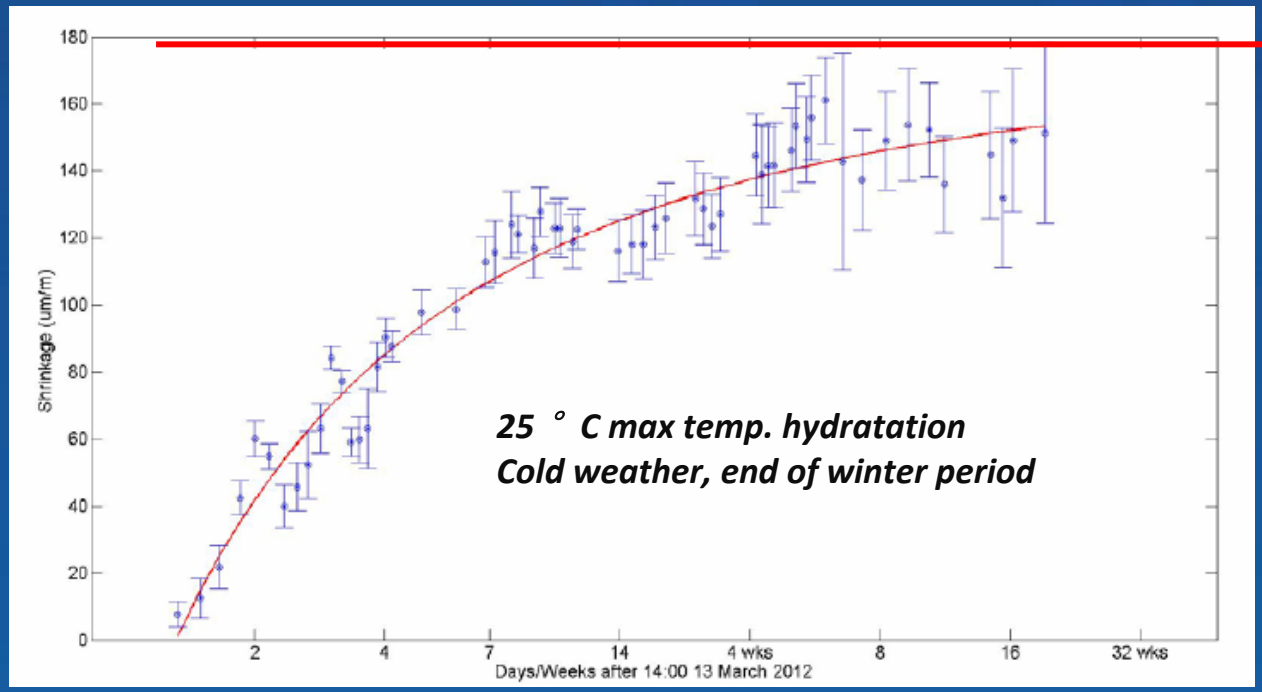
1st: rollcrete	*→ poor mixing – removed once*
Soft lean concrete layer	*→ not horizontal*
Bituminous layer	*→ peeling under footprint- changed*

Concrete pouring is a long complex chain
Concrete cracking is measured with the ring test: 100% constrained

Setting the Rollcrete layer over a compacted soil



Prototype slab shrinkage

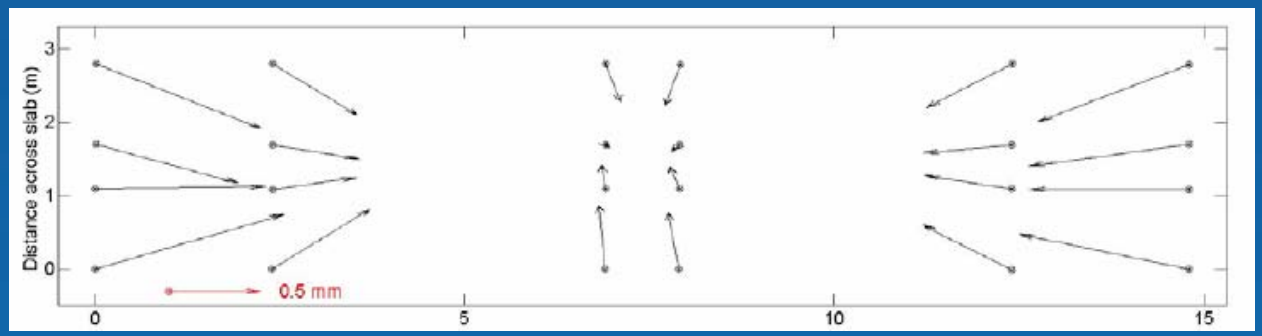


200 to 300 ppm

Shrinkage level
Within which no cracks occurs

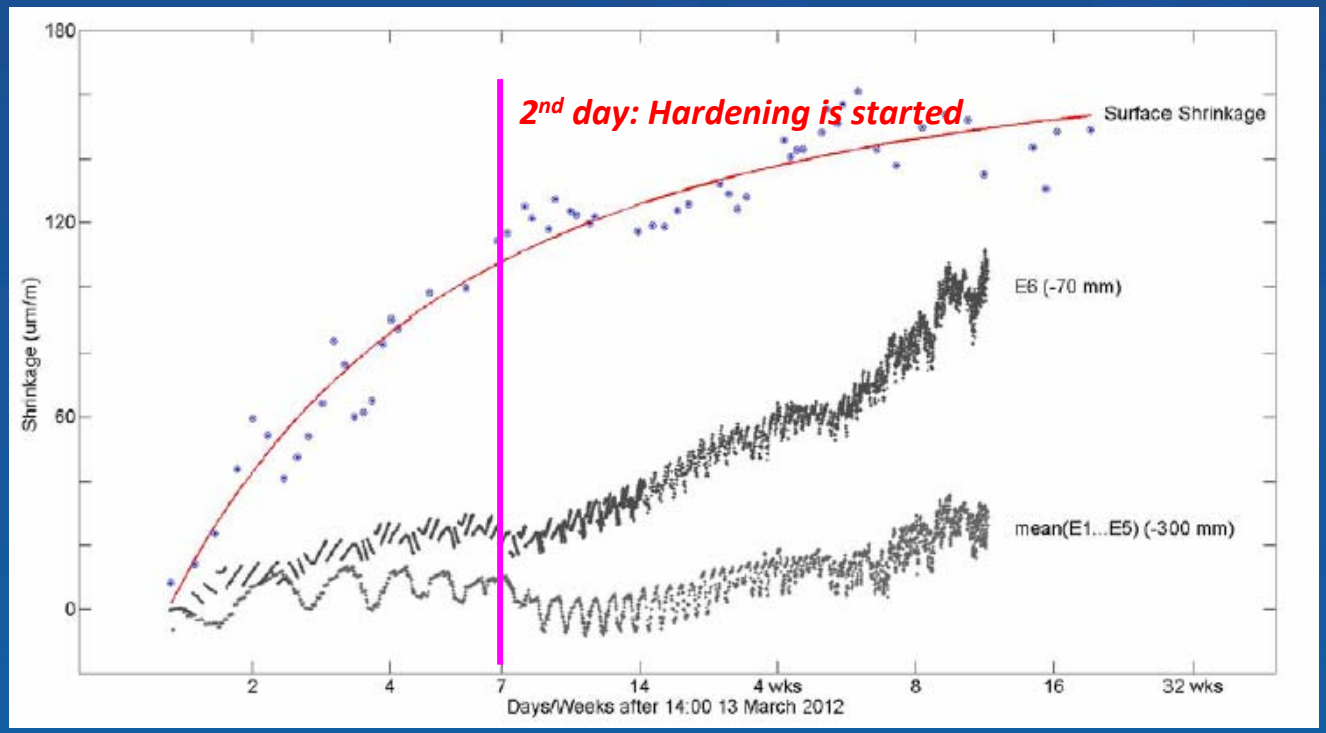
Low water content concrete
Fast chemical reaction
Highly viscous
Difficult to pump

Shrinkage deformation (corrected with temperature variation) **over 19 weeks**
Period March to July 2012



Total
Shrinkage
Proto slab 15 x 3 m²

Hardening Set up process

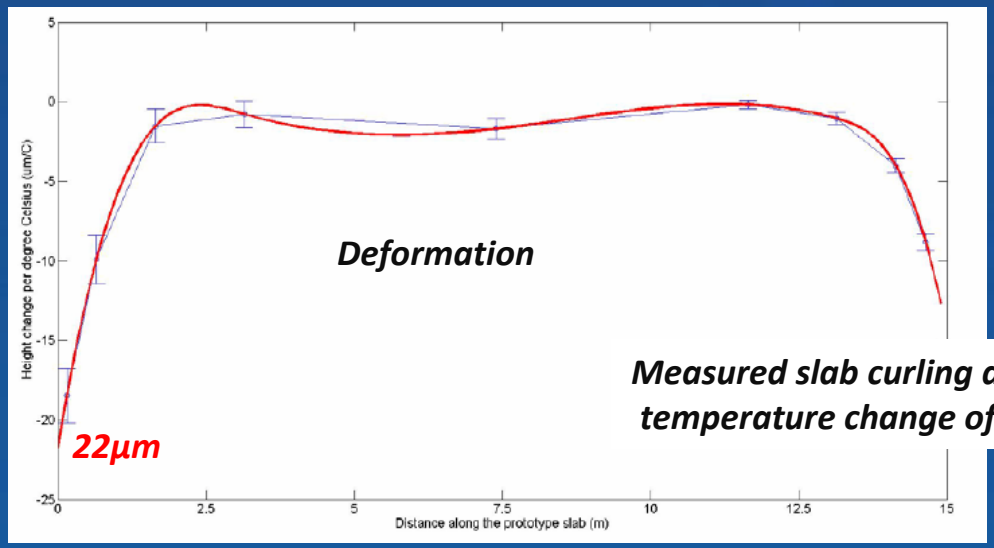


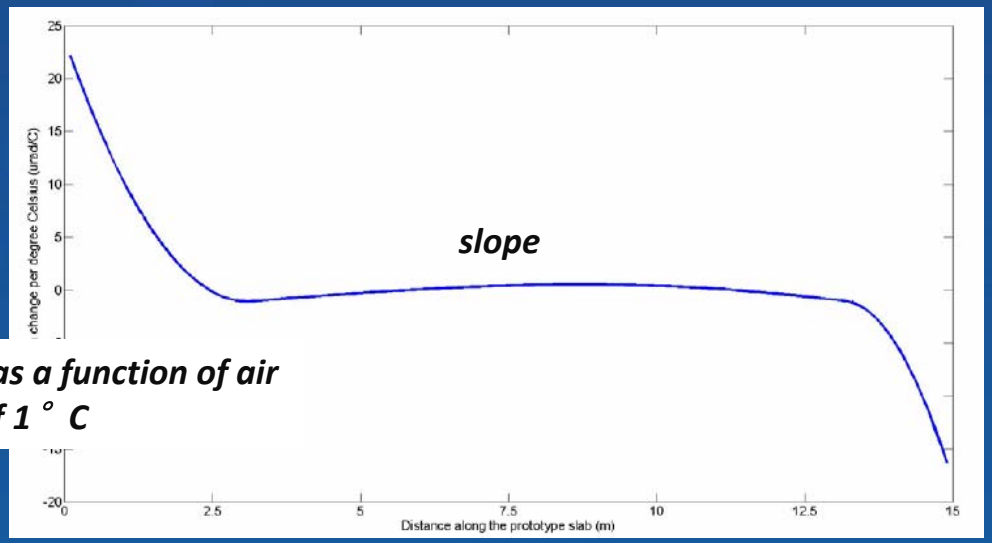
Concrete with
No cracks means:

Golden rule: managing the shrinkage such that

$E_p = 15\ GPa$ (hydratation Young modulus)
$\sigma_c = 4.5\ Mpa$
Then:
$\varepsilon_c = 300\ ppm$ ⟷ *Fulfilled if T ° C hydratation ⩽ 35 ° C*

Deformations and slopes of the prototype slab

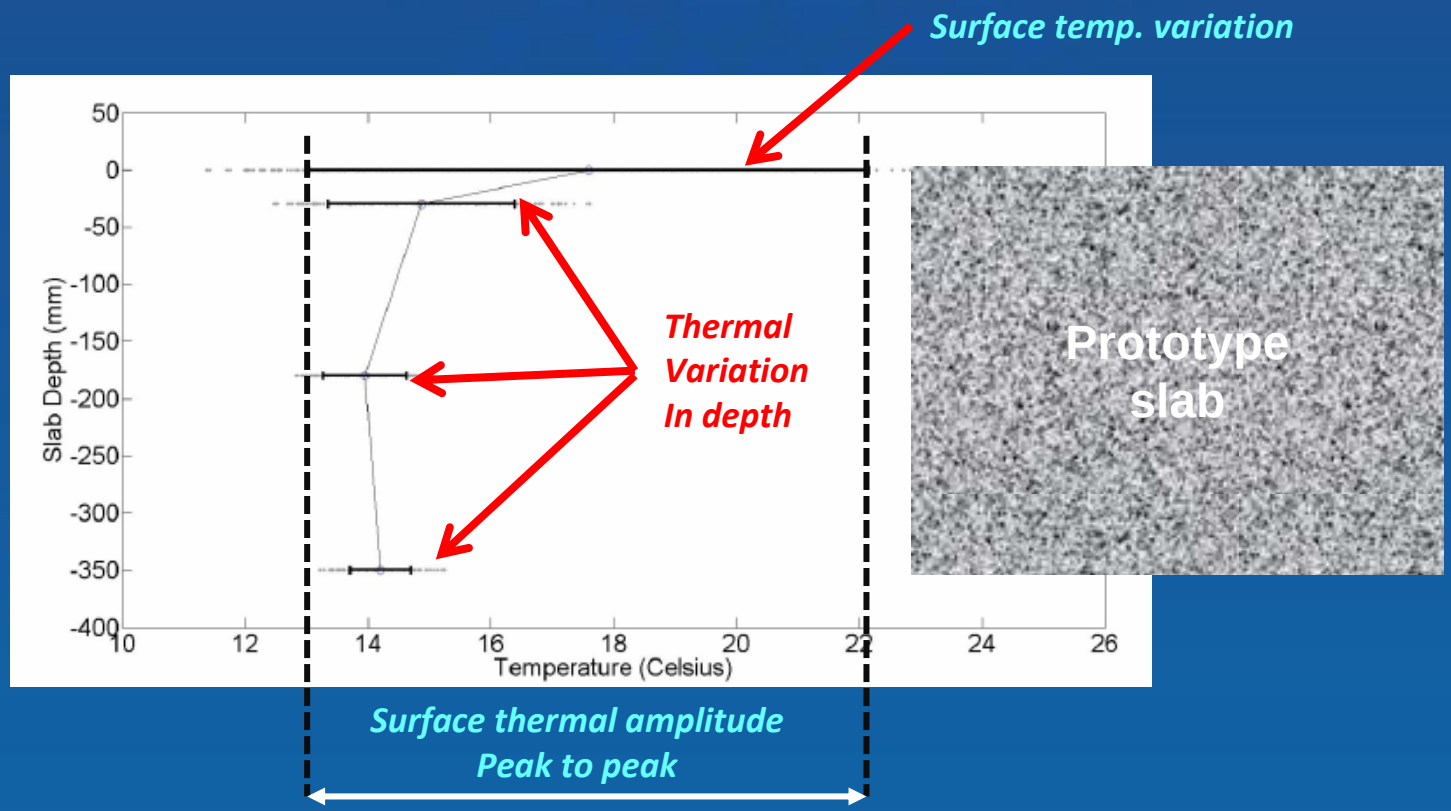




Measured slab curling as a function of air temperature change of 1 ° C

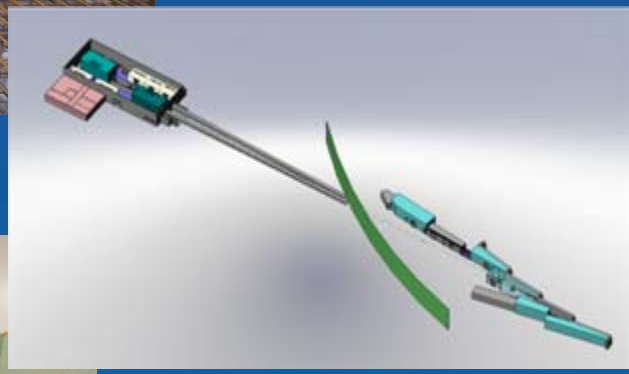
Thermal waves propagation

Record on prototype slab from embedded thermo-couples



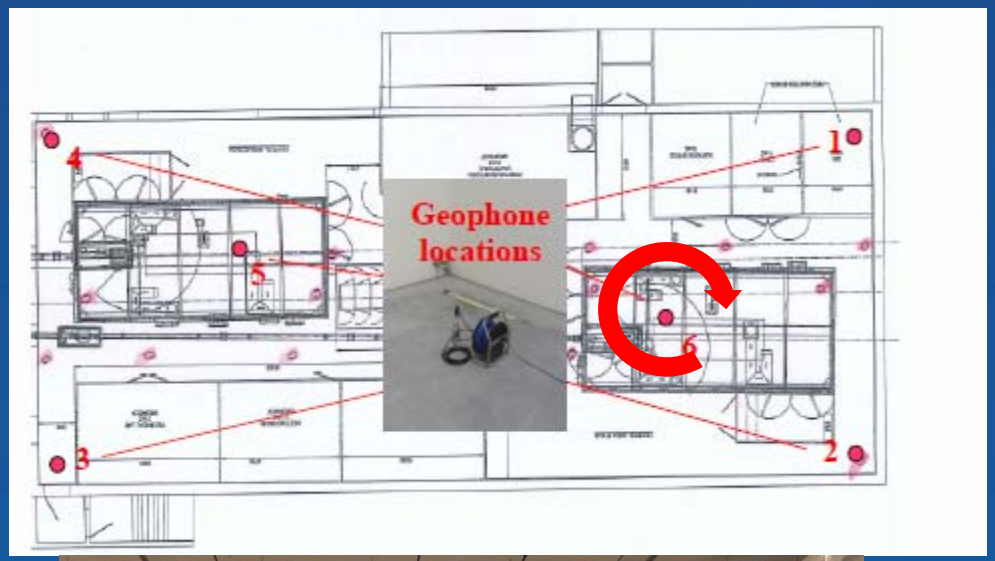
6 months later, setting the ID16 slab

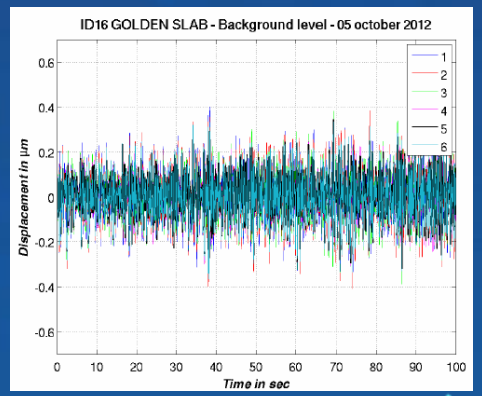
The concrete pouring Is associated with a cautious vibration head through the rebar's

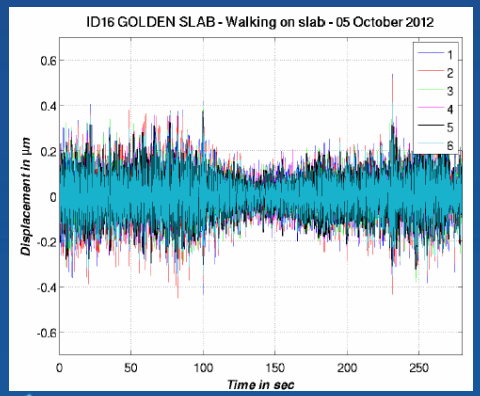


Final surface aspect is Flattened with the "helicopter" during 6 hours

First records on ID16 slab Pedestrian walking around the probe







Not recorded at the same time

Recorded: 5th October 2012

Location		1	2	3	4	5	6
Background level	µm p2p	**0.79**	**0.79**	**0.73**	**0.61**	**0.62**	**0.70**
Pedestrian Walking Around geophone	µm p2p	**0.97**	**0.95**	**0.76**	**0.66**	**0.68**	**0.76**

Peak to peak displacement on ID16 slab

Courtesy L.Zhang – M.Lesourd

In Conclusion:

- *3 years effort*

- *The slab seems going on the right side presently*

- *Fundamental good understanding between teams*

  ESRF: demander as " non-specialist" , but used to practice modelling

  Supplier: competent, but not used to so exotic performances

- *Everyone seems having gained good experience*

Thank you for your attention !