

**SOME ISSUES CONCERNING THE
AUTOMATIC MEASURING OF
CONCRETE WORKABILITY DURING
MIXING TIME**

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Aggregates & Materials Processing Laboratory

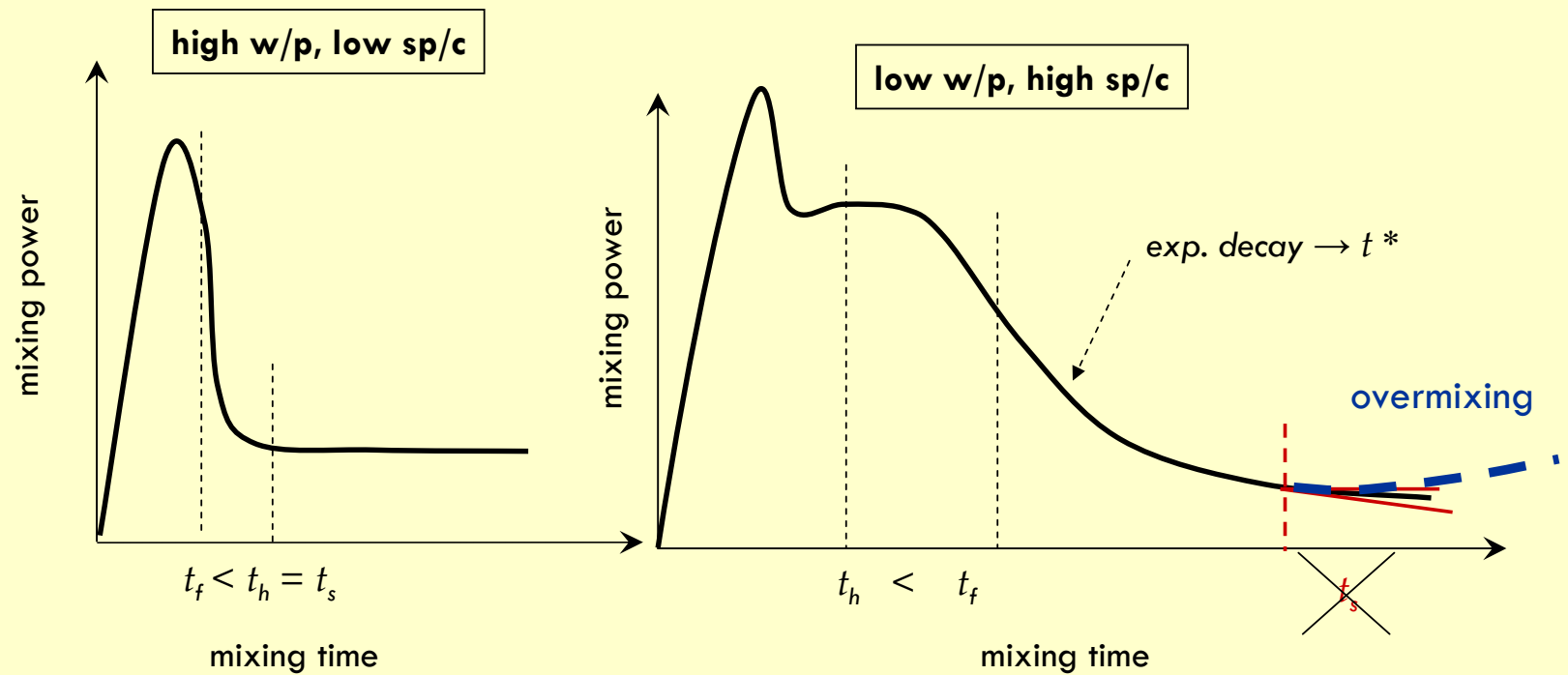
Basic principles of in-mixer sensors

- | | | |
|-----------------|---|------------------------|
| • Power curve | stabilization level
before stabilization | WATTMETER
MIXOMETER |
| • Drag force | under mixing
mixer stopped | VISCOPROBE, MFM
... |
| • Composition | water content
air entrained ... | Moister meters |
| • Other methods | | |

Power curve (or torque)

Ordinary concrete

SCC ...



WATTMETER

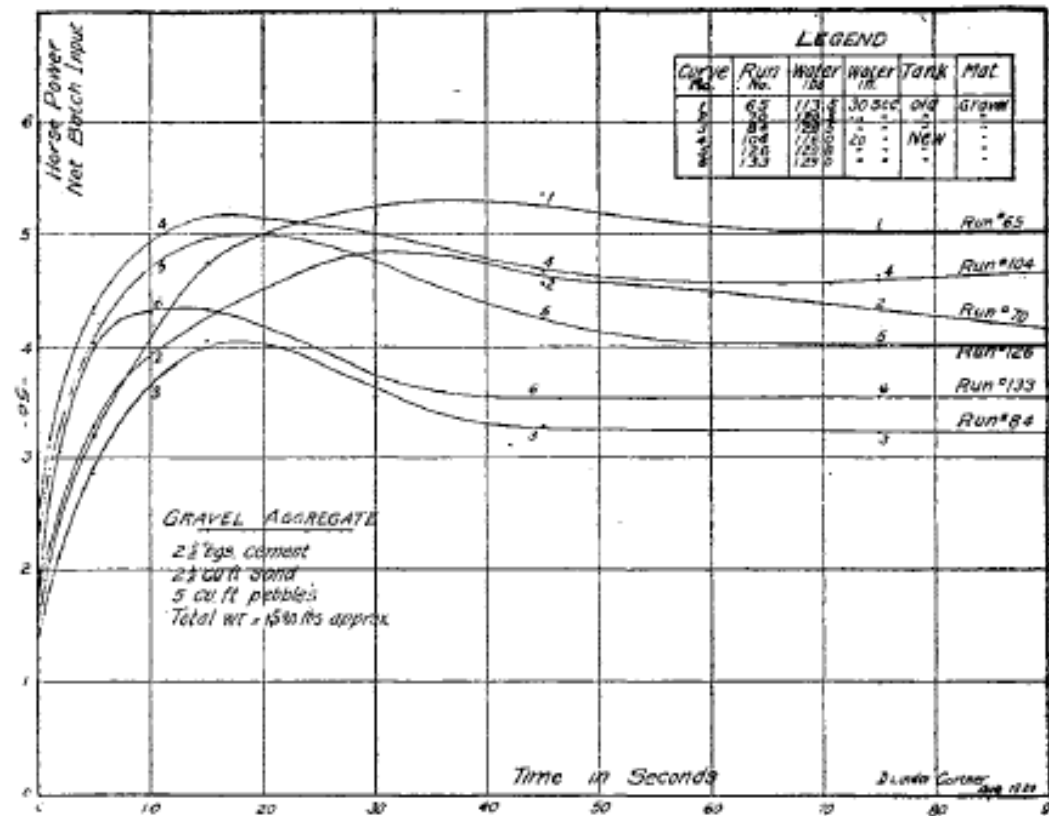


FIG. 5.—ELECTRICAL INPUT AND TIME OF MIX USING GRAVEL AGGREGATE.

Level of
stabilized power

Hatt 1921
Tests of Concrete Mixer

WATTMETER

STRONG

- Maintenance
 - No sensor in the mixer
- Cheap
- Well established

- OK for **VIBRATED** concrete

WEAK

- Rheology

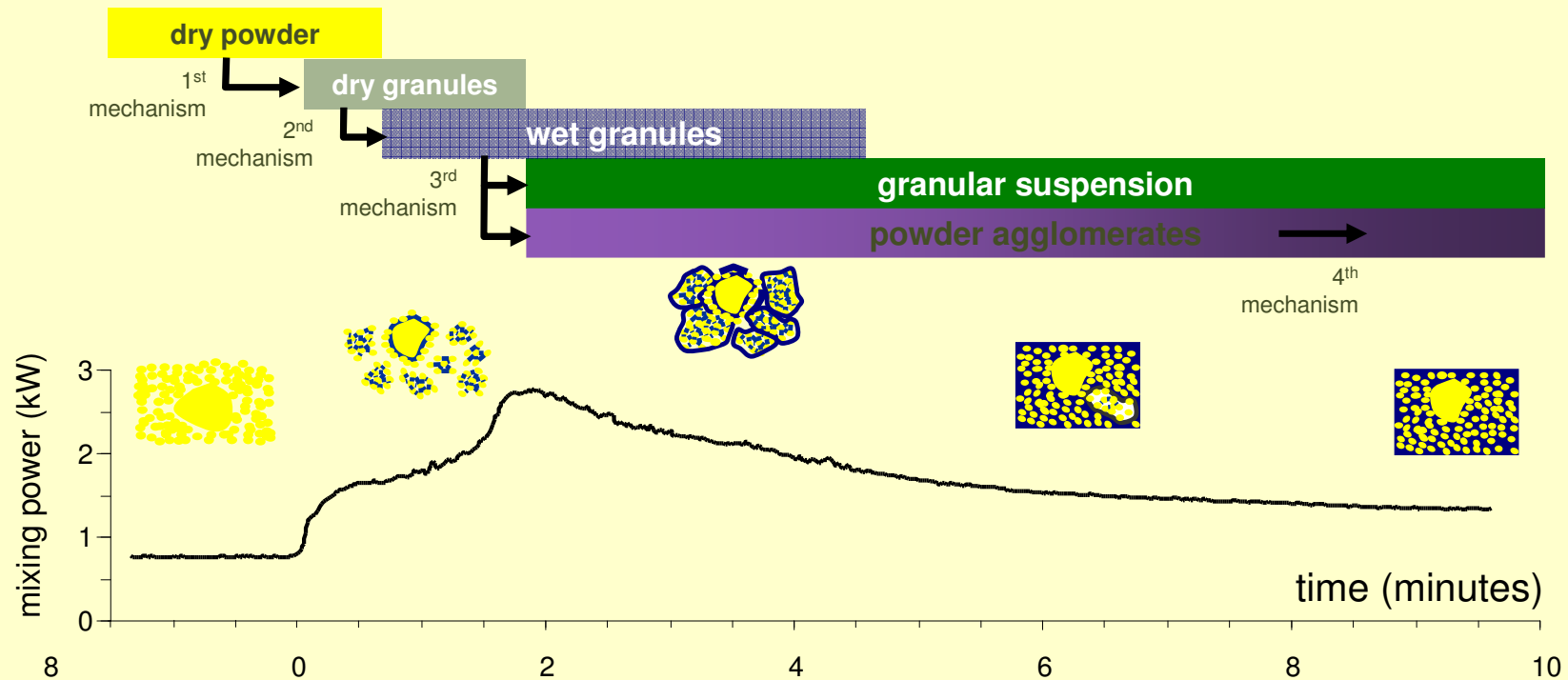
$$P = \begin{cases} P_{\text{Viscosity}} & \text{2 parameters 1 measure} \\ P_{\text{Wall Slip}} & \text{2 new parameters} \\ P_{\text{Crashing}} & \text{depends on wearing} \end{cases}$$

- For **SCC**
 - No stabilization
 - Small sensitivity

- For **DRY** concrete

MIXOMETER

MIXOMETER – mixing mechanisms

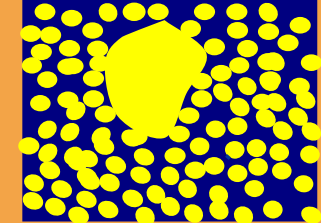
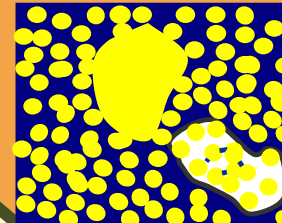
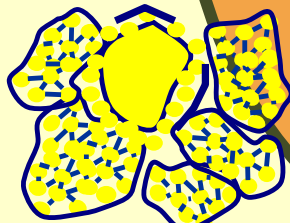
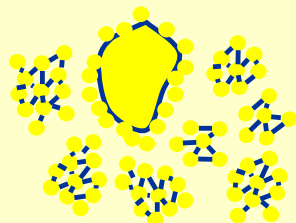
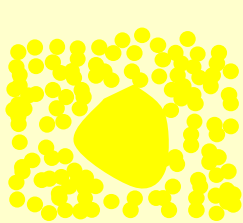
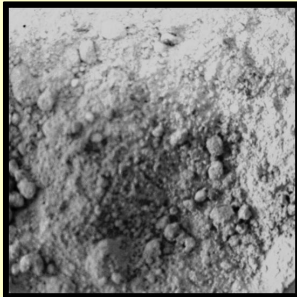


Cazacliu B., *In-mixer measurements to describe the mixture kinetics during concrete mixing*, Chemical Engineering Research and Development, Vol.86, 1423-1433, 2008

MIXOMETER – mixing mechanisms

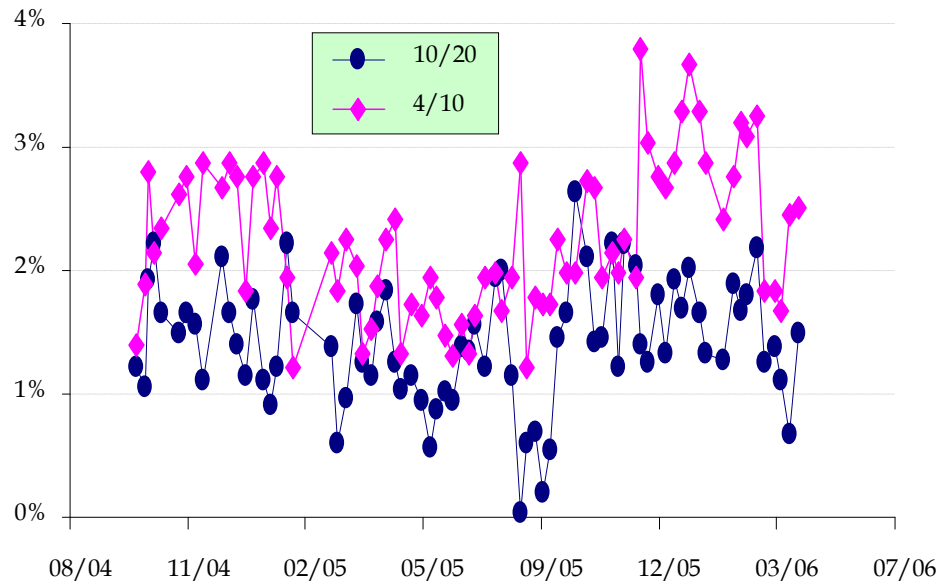
Wet powder

Uniform Concrete



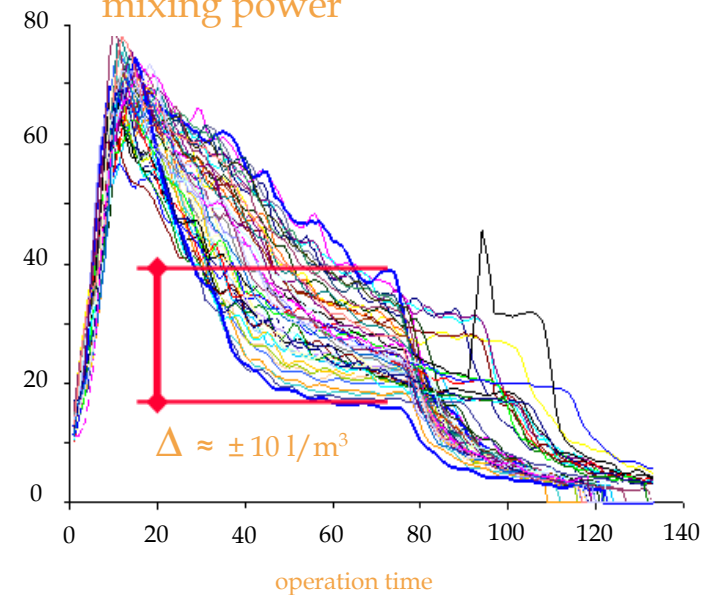
same concrete during 2 months

moisture



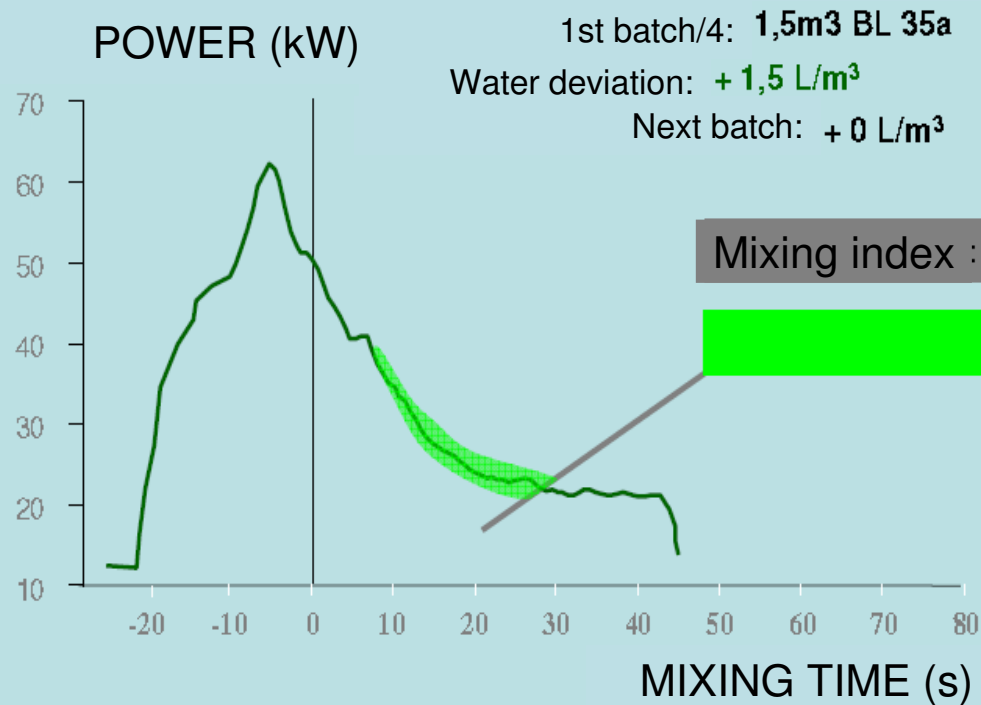
Aggregates moisture evolution
Measured by drying
RMC Plant

mixing power



Power measurement for batches
of a same mix-design
RMC Plant

MIXOMETER



Estimates:

- The time needed to finish the mixing
- The deviation in water content (or consistency)

Patent
Skako / IFSTTAR

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MIXOMETER

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- Rheology

$$P = \begin{cases} P_{\text{Viscosity}} \\ P_{\text{Wall Slip}} \\ P_{\text{Crashing}} \end{cases}$$

2 parameters 1 measure

2 new parameters

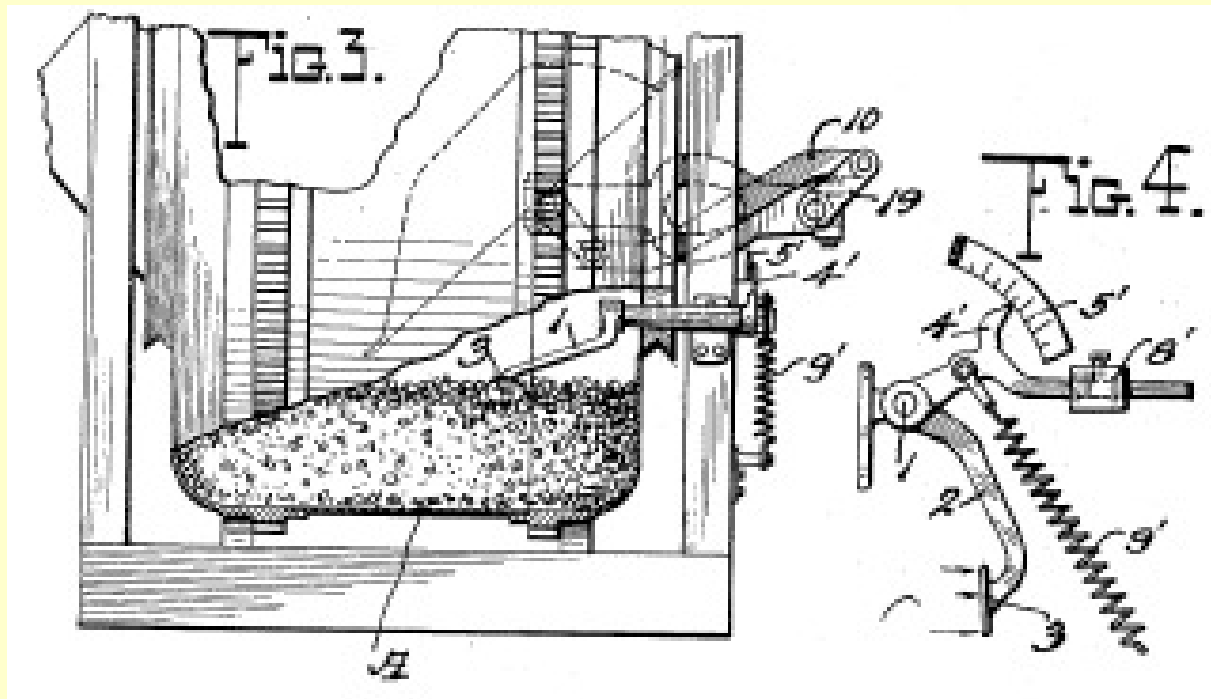
depends on wearing

- For **SCC**
 - No stabilization
 - Small sensitivity

- For **DRY** concrete

DRAG FORCE

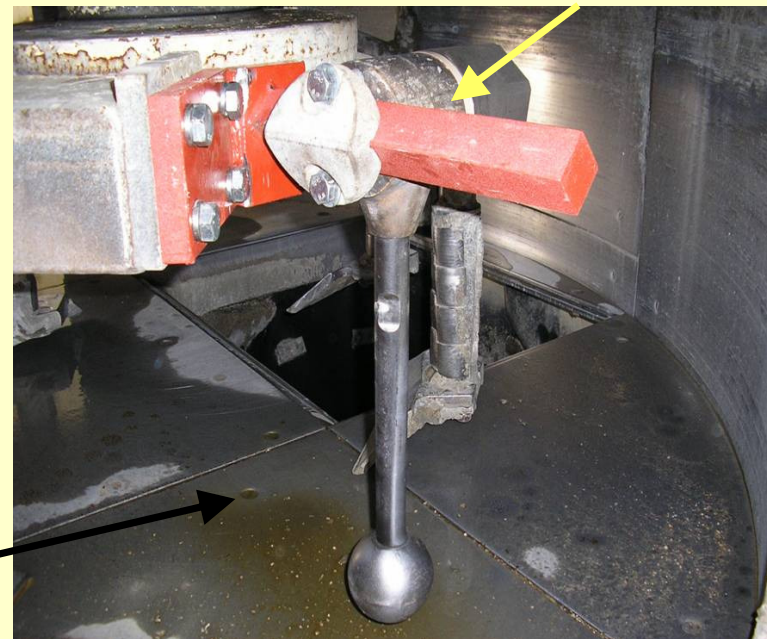
Drag force



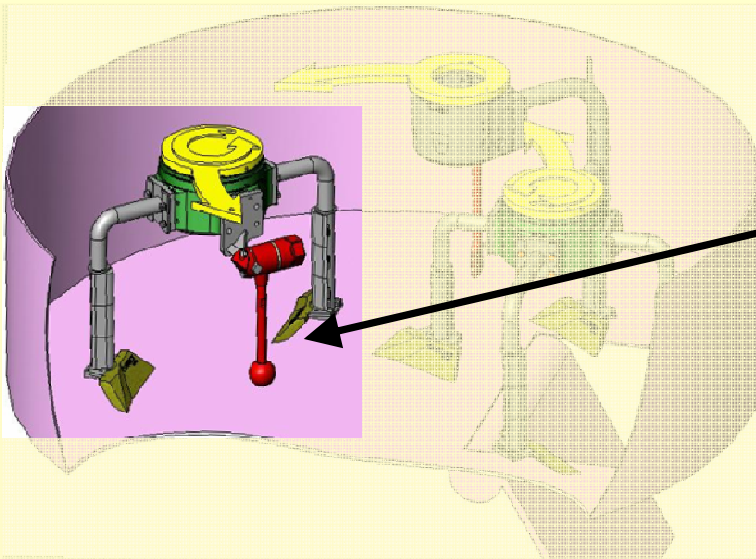
LICHTENBERG 1926 - method of and apparatus for determining the consistency of concrete

VISCOPROBE

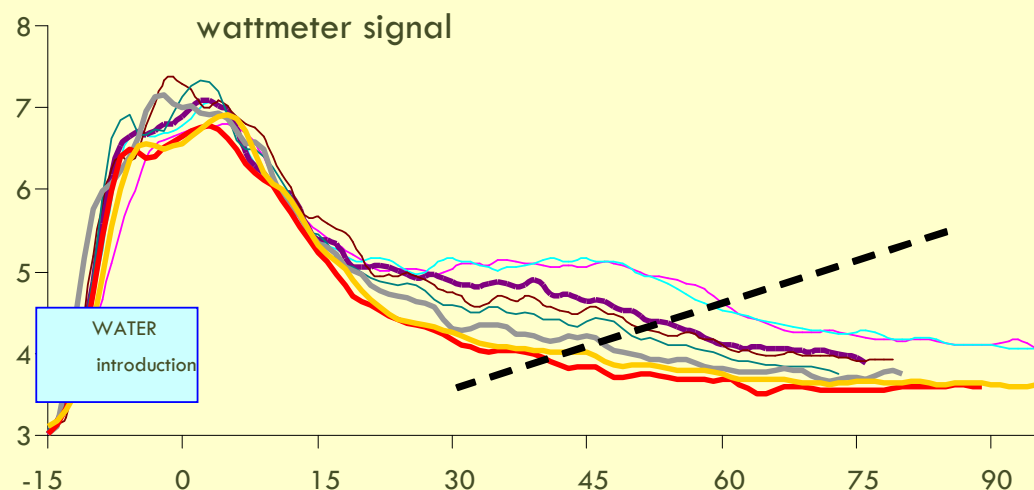
strain gauge



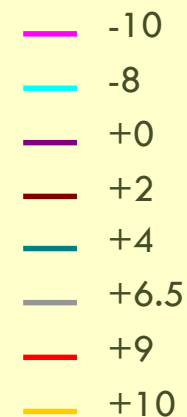
in concrete immersed sphere



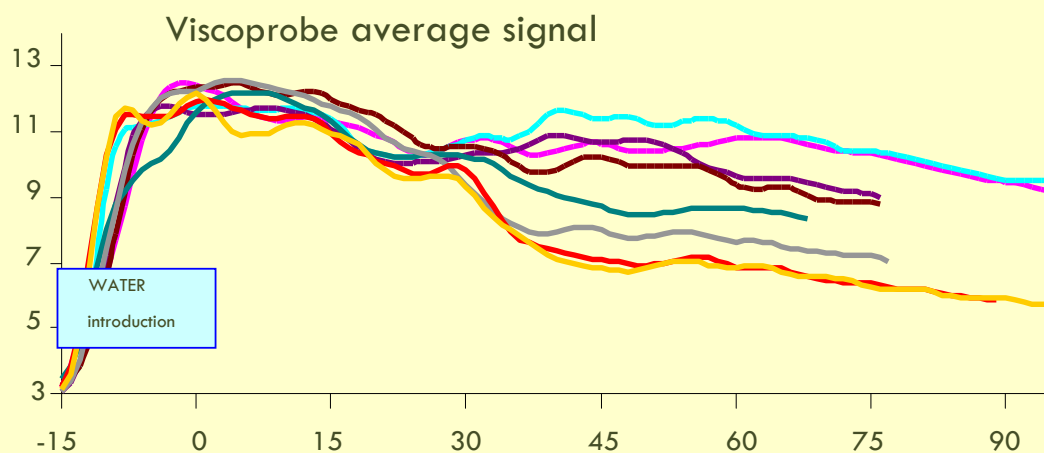
VISCOPE



The viscoprobe average force curves follow the wattmeter curves, with a better differentiation

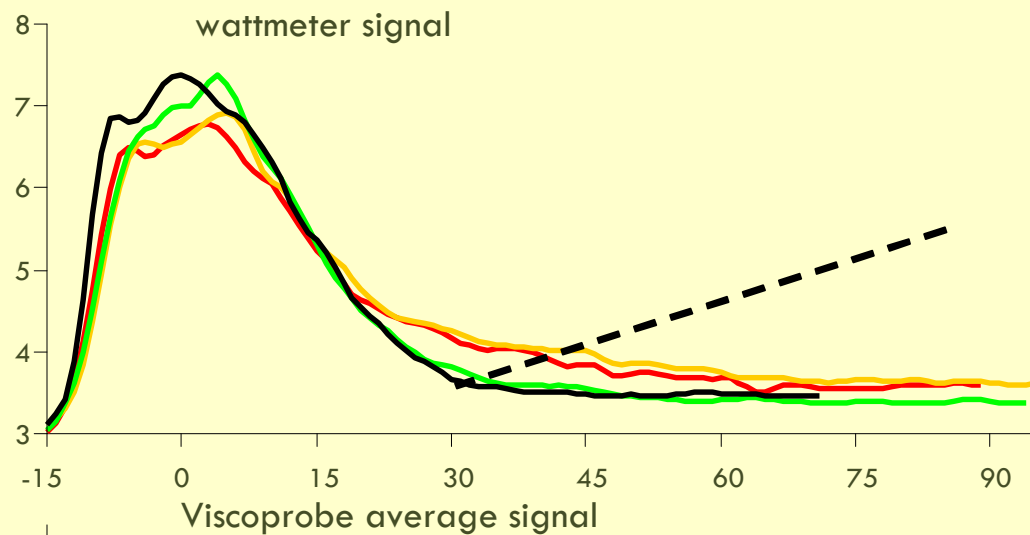


Around nominal



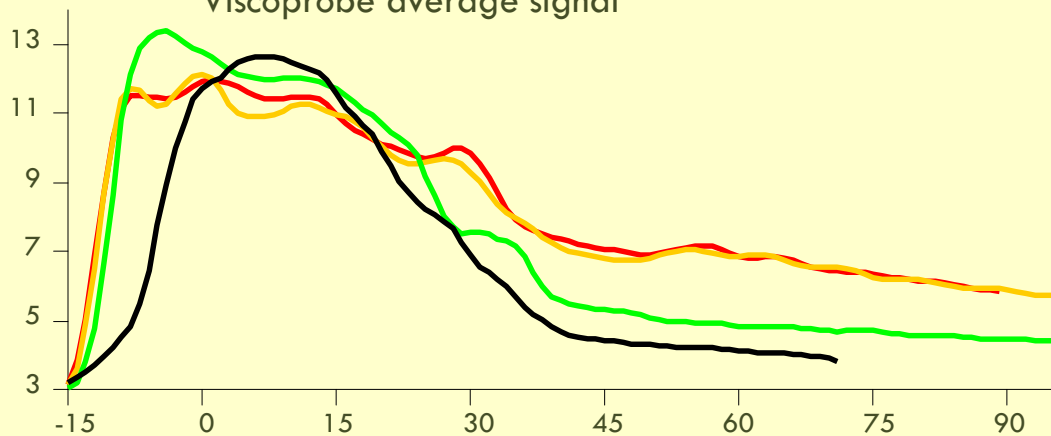
Cazacliu B., Brunquet E., *On-line mixing end-point detection by power measurement*, Rilem Proceedings pro054, 2007

VISCOPROBE



Much better with upper water proportioning

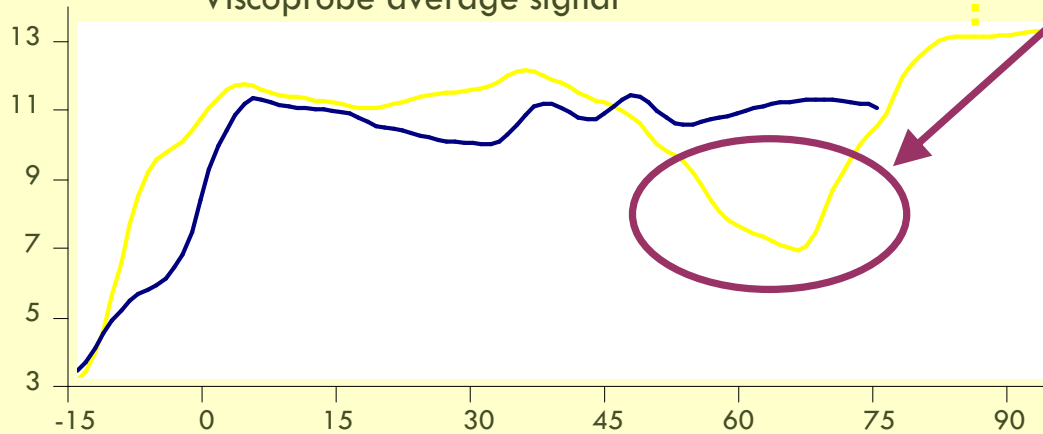
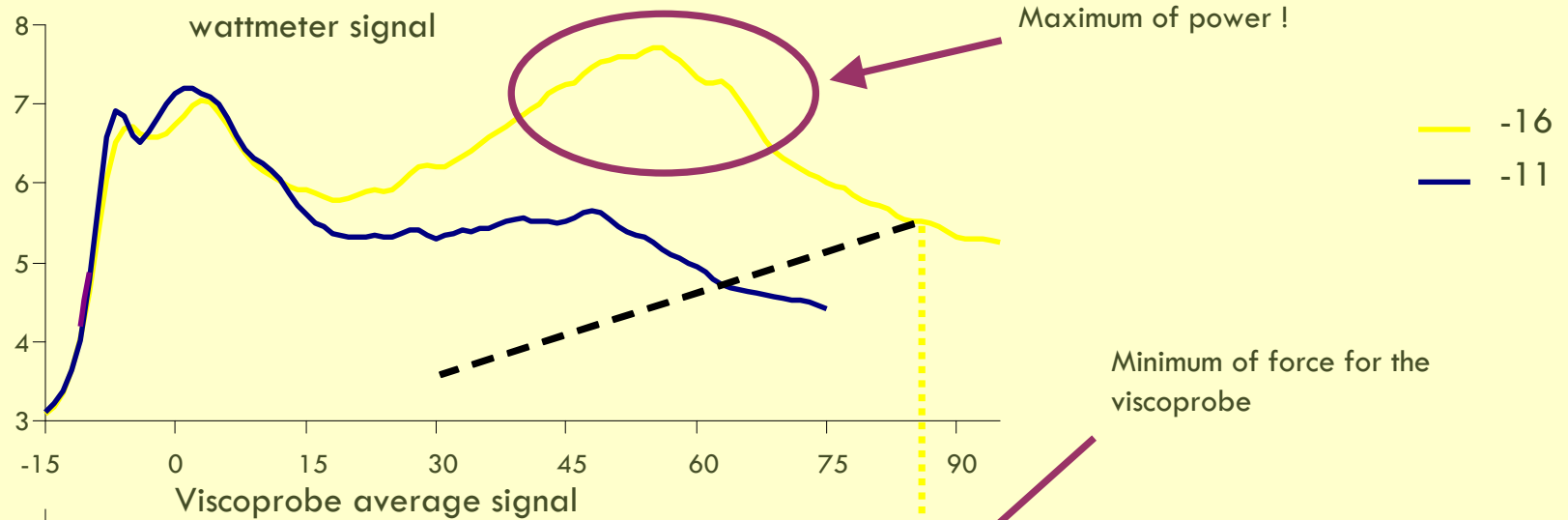
Good repeatability – see curves +9 and +10



- +9
- +10
- +20
- +24

Upper

VISCOPROBE

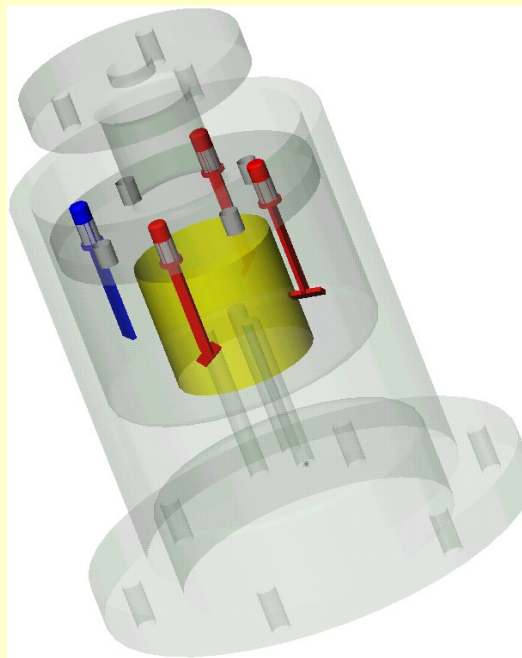
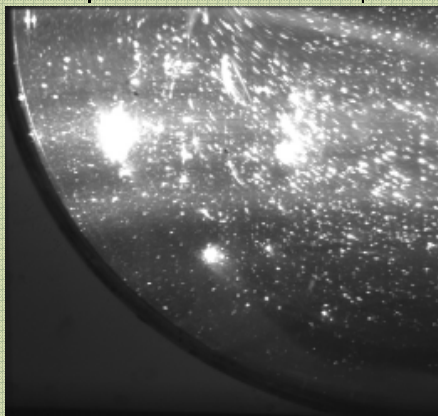
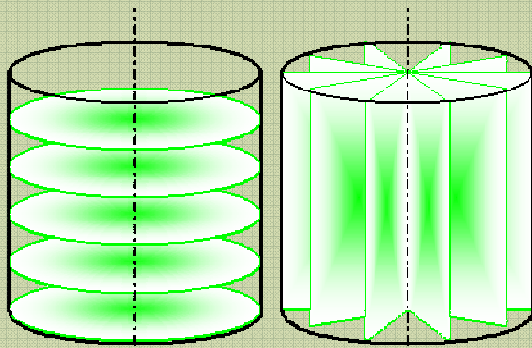


Minimum of force for the viscoprobe

For low water proportioning (-16l/m³ ie slump flow 49cm) the viscoprobe average force show a minimum when wattmeter shows a second peak!

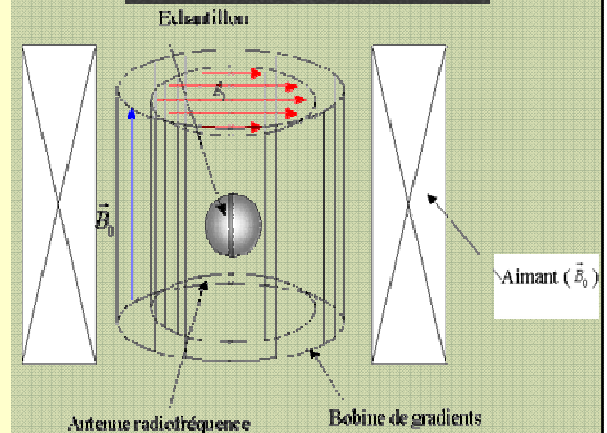
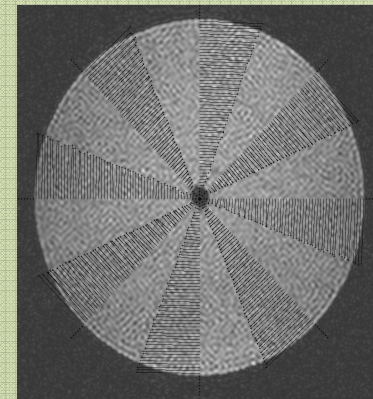
What is the structure of the flow

Particle Image Velocimetry



Philippe Poullain, *Étude comparative de l'écoulement d'un fluide viscoplastique dans une maquette de malaxeur pour bétons : PIV, IRM et simulation numérique*, PhD 2003

Nuclear Magnetic Resonance



What is the structure of the flow

Experimental

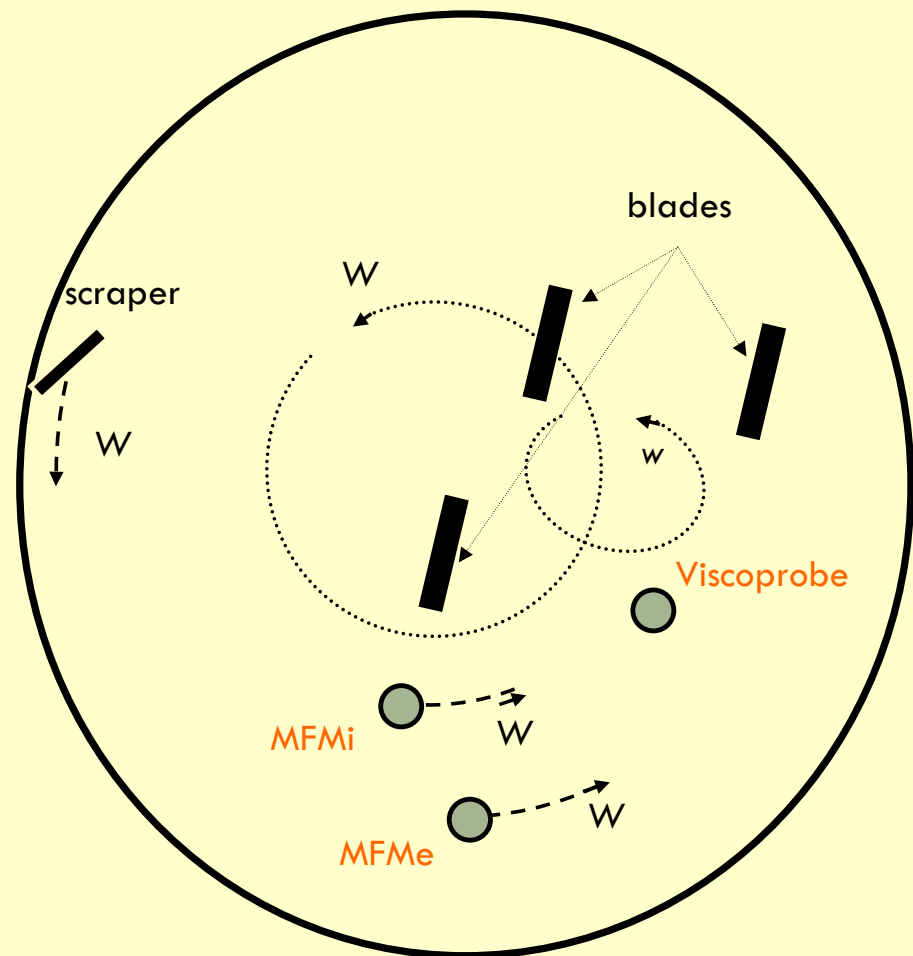
3 drag force probes



- **Viscoprobe** (planetary movement)
- **MFMi** (circular movement)
- **MFMme** (circular movement)

5 levels of mixing speed W :
(with constant w/W)

100% (nominal), 75%, 50%, 25%, 10%

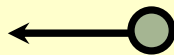


What is the structure of the flow

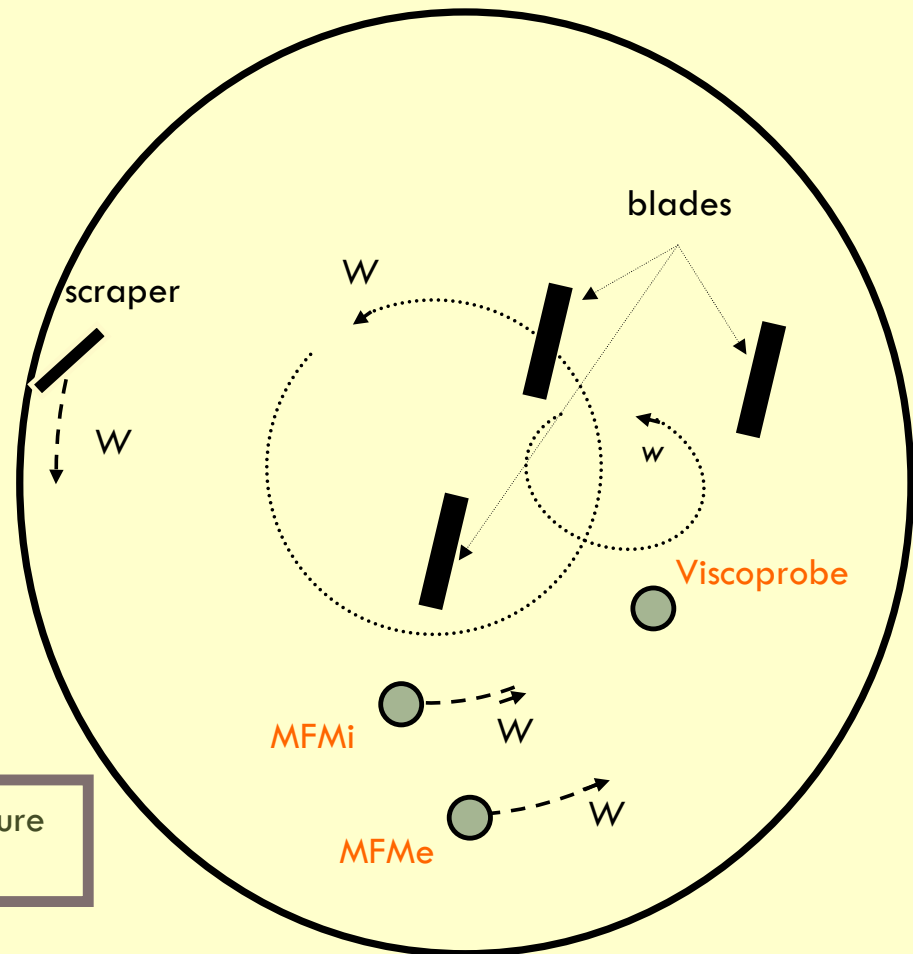
Experimental

Rheometry on samples
for each tested concrete
(9 SCC mixture tested)

Drag force = F (rheology, velocity)



for a known rheology the drag force is a measure
of the concrete velocity around the probe



What is the structure of the flow

Numerical simulations

code FloMix (IFSTTAR) :

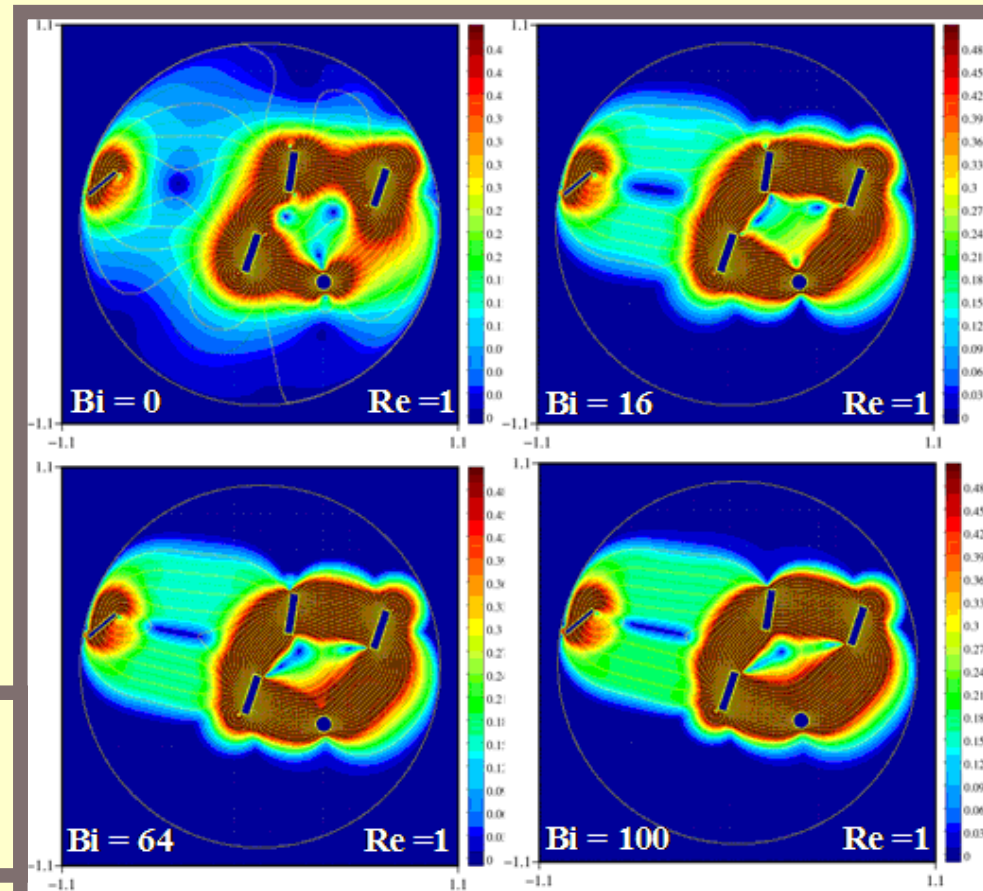
- velocity field determined by FME fictitious domain methods
- 2D, non-slip boundary conditions
- several **Bi** and **Re** numbers tested

$$\mathbf{Bi} = \tau_o / \mu \Omega$$

$$\mathbf{Re} = \rho \Omega R^2 / \mu$$

Velocity intensity
scaled 0 to 0.5 of scraper velocity

Bi = 0, 32, 64 and 100; **Re** = 1



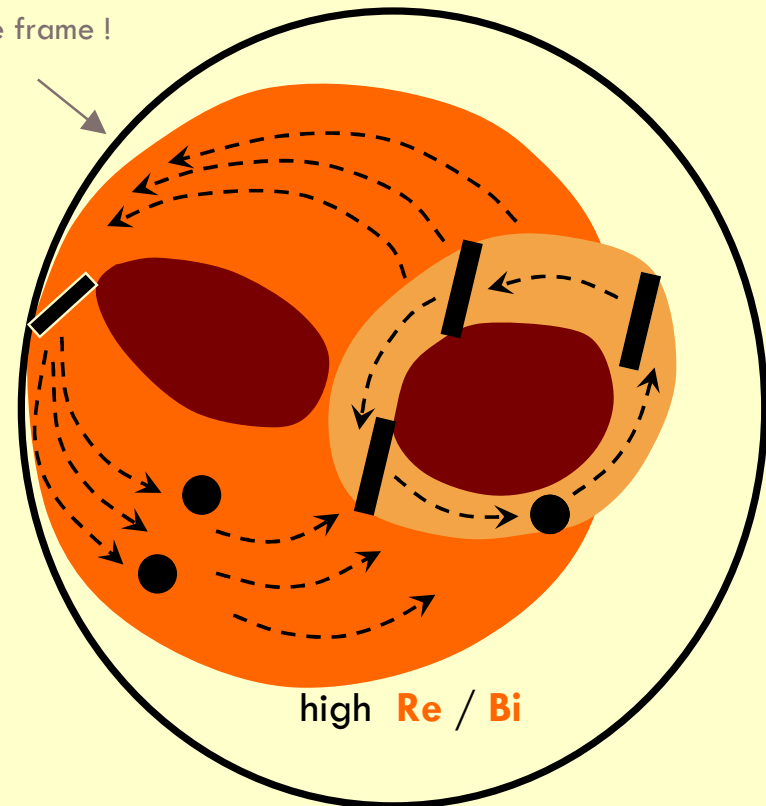
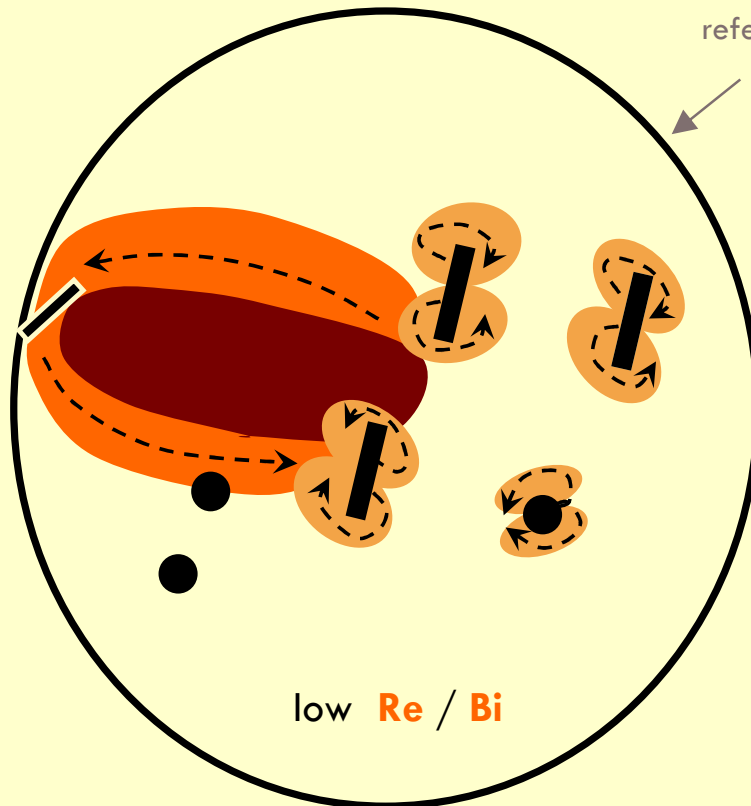
structure of the flow

addition of two flows

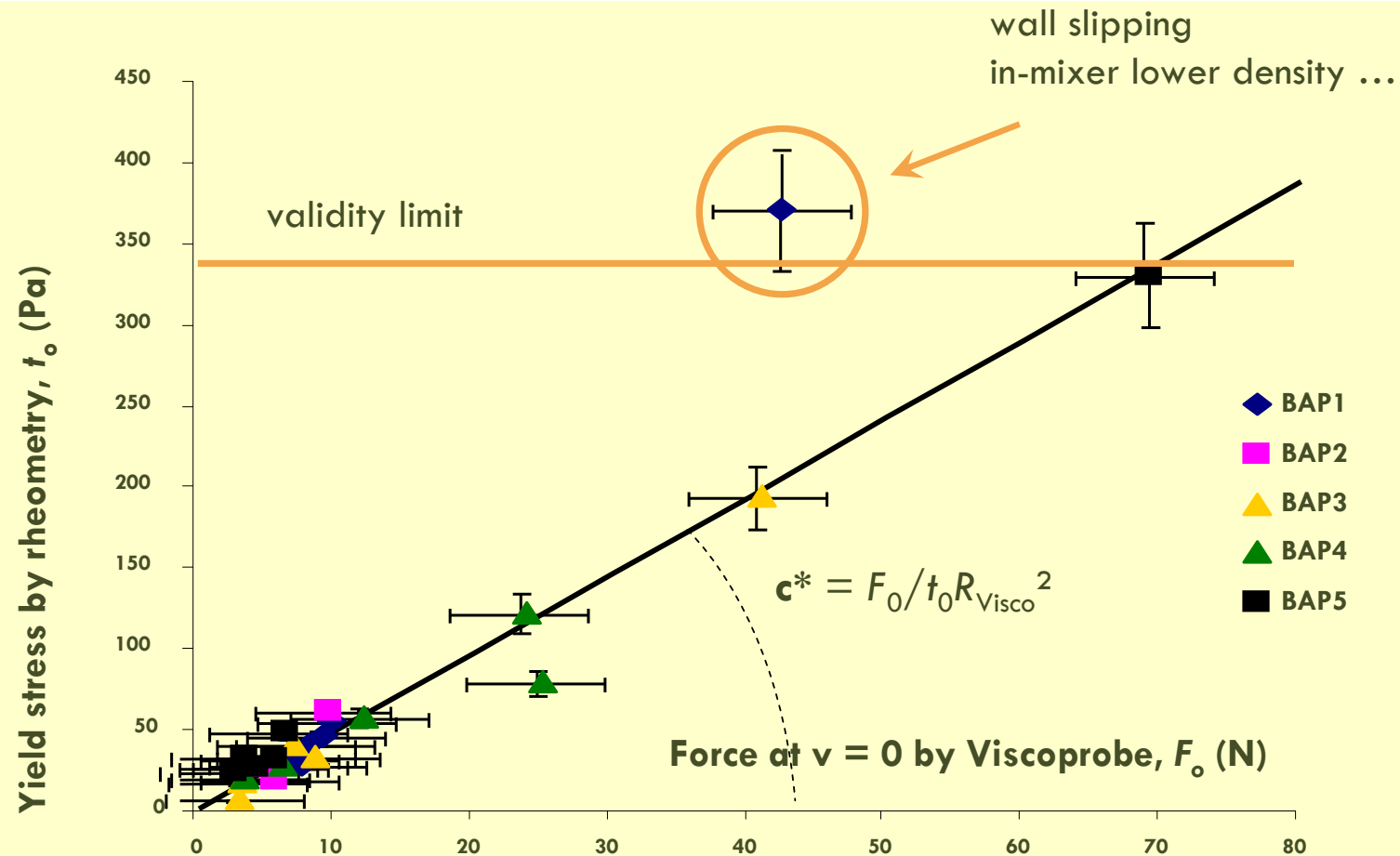
interaction flow

mixing star flow

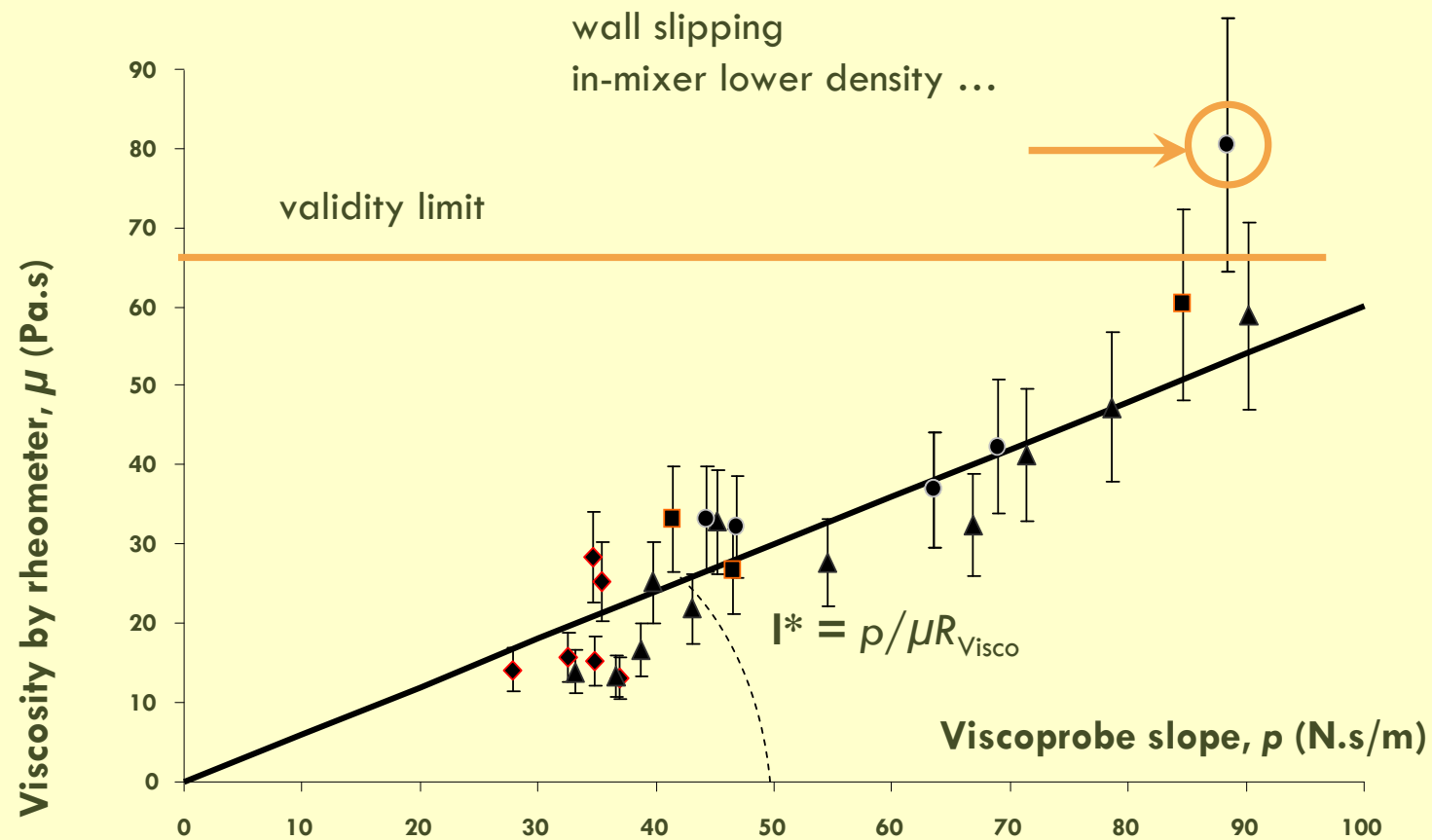
Non-inertial
reference frame !

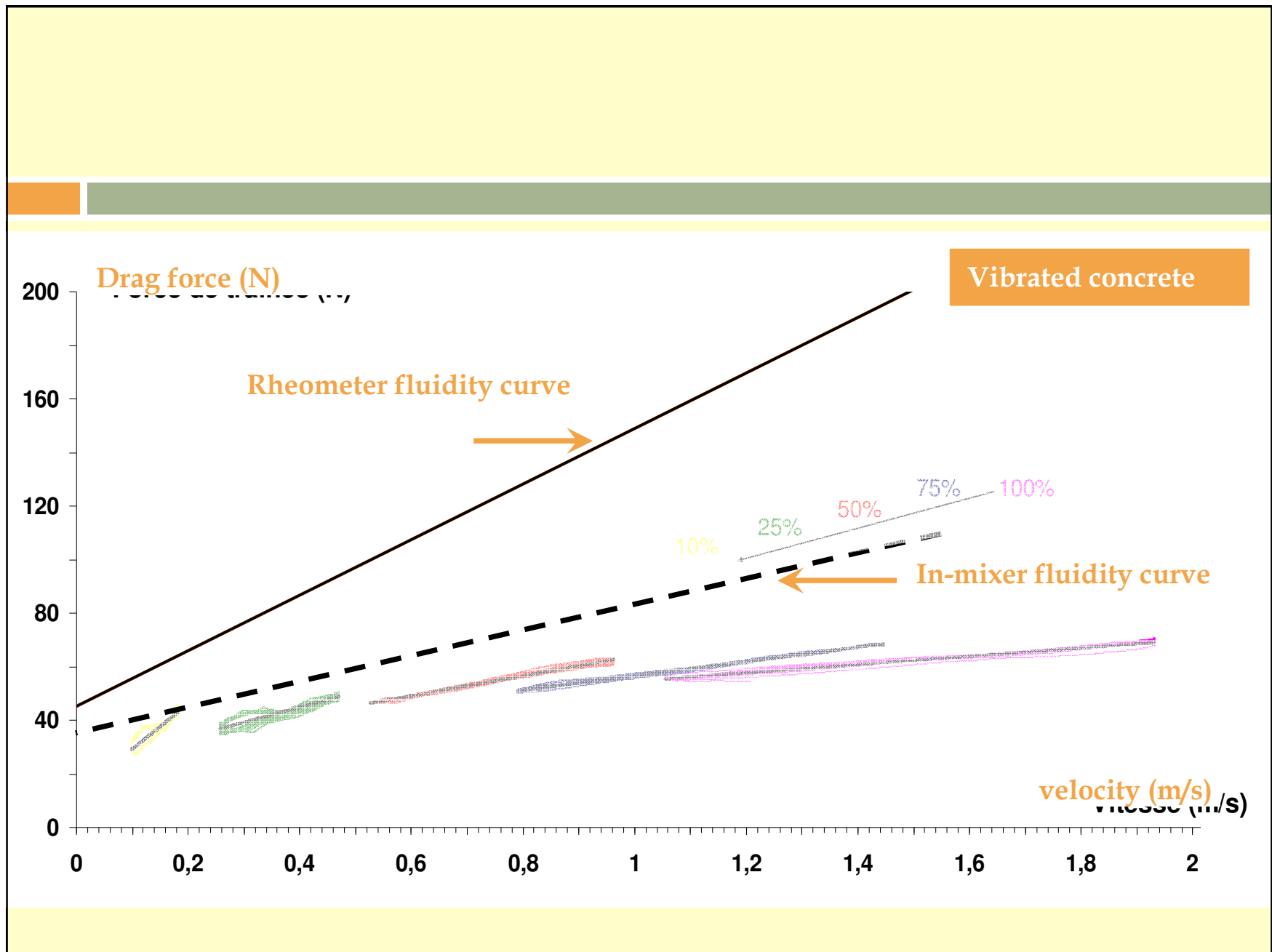


Concrete rheology - Drag force



Concrete rheology





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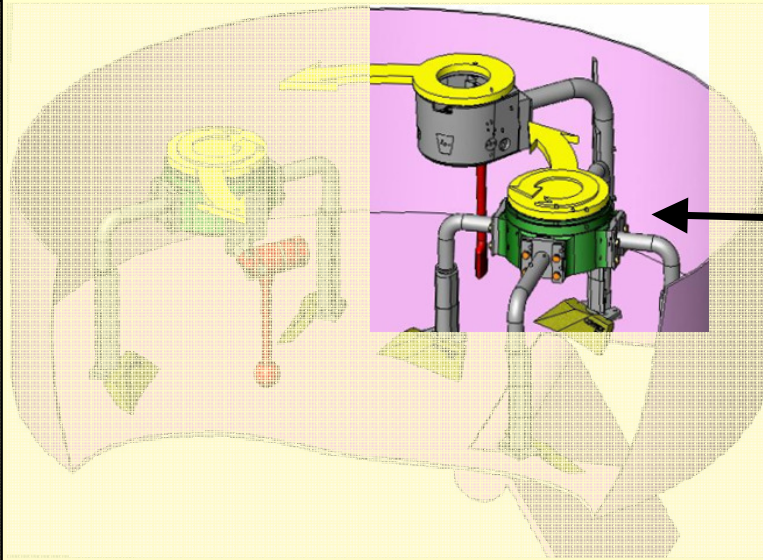
- For **DRY** concrete

MIXOMETER

COMPOSITION

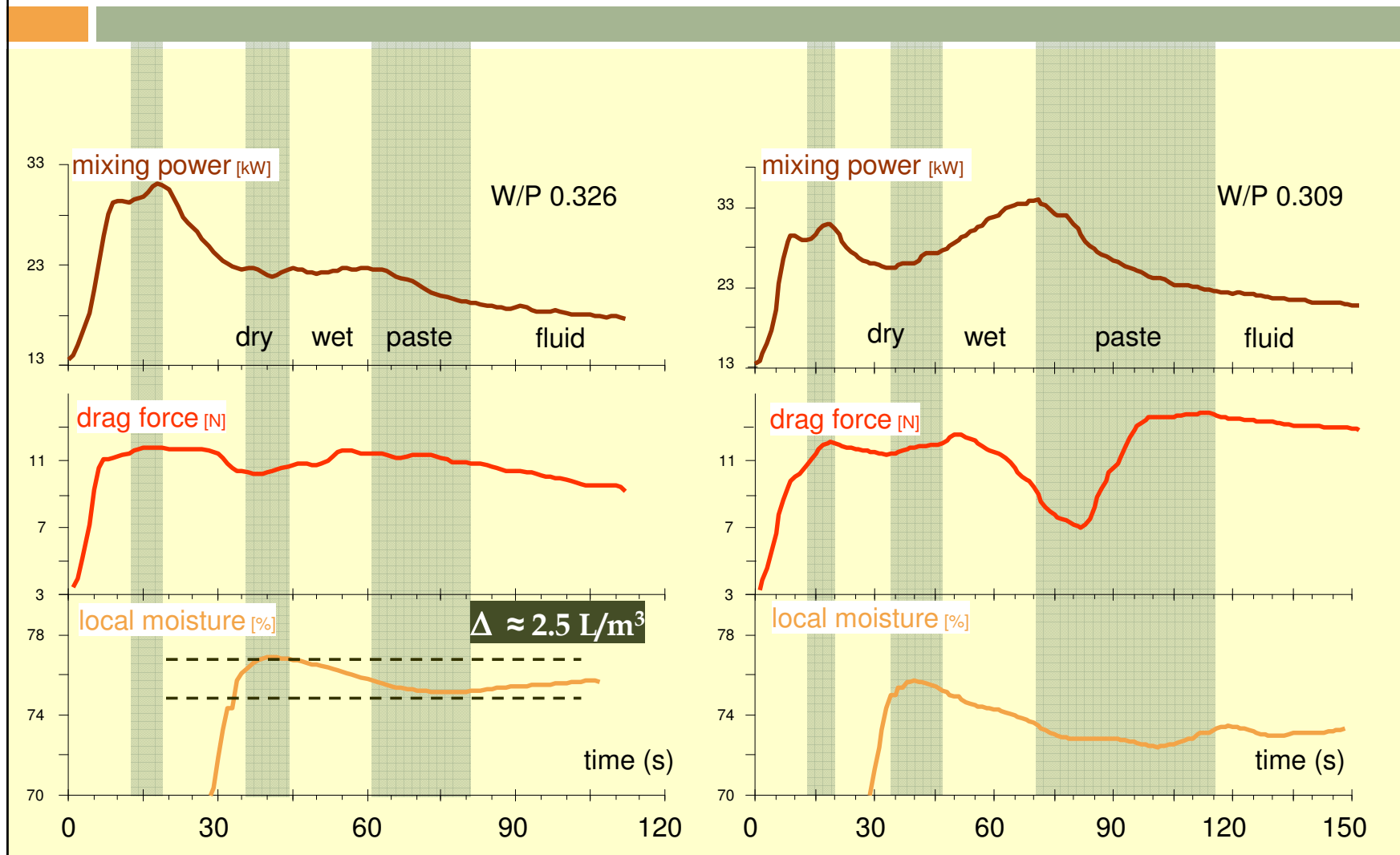
DRAG FORCE

Moisture content



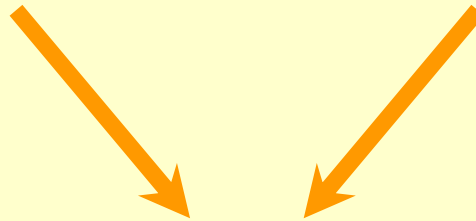
Cazacliu B., *In-mixer measurements to describe the mixture kinetics during concrete mixing*, Chemical Engineering Research and Development, Vol.86, 1423-1433, 2008

Moisture content



Moisture content

Microstructure + Temperature



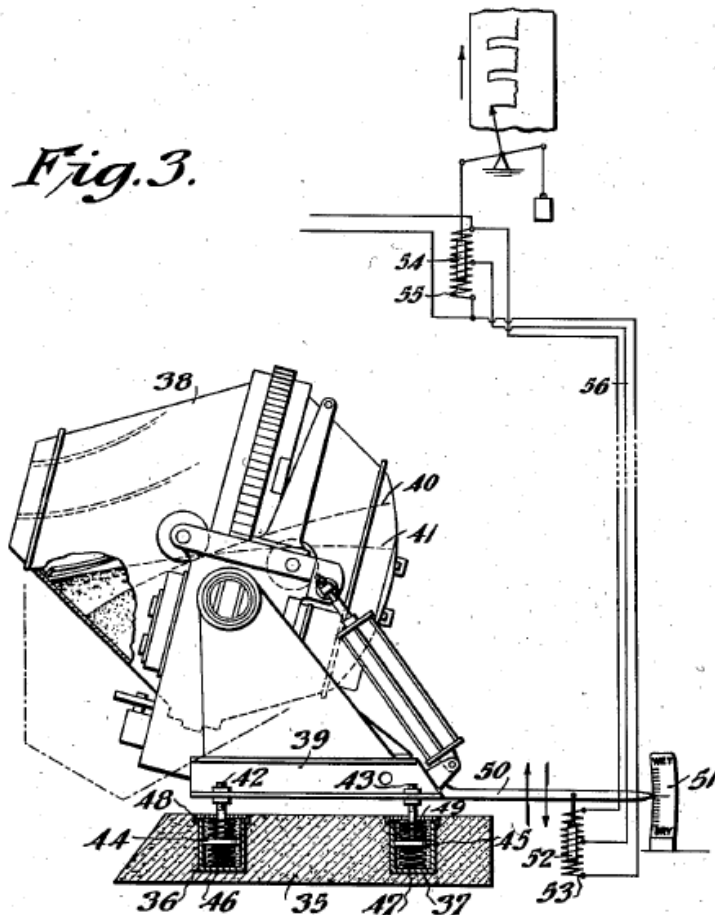
Composition ≠ Workability

Basic principles of in-mixer sensors

- | | | |
|-----------------|---|------------------------|
| • Power curve | stabilization level
before stabilization | WATTMETER
MIXOMETER |
| • Drag force | under mixing
mixer stopped | VISCOPROBE, MFM
... |
| • Composition | water content
air entrained ... | Moister meters |
| • Other methods | | |

Other methods

Fig. 3.



The primary object of this invention is to provide a method of determining the consistency of a concrete mixture which takes cognizance of the fact that the center of gravity of a batch of concrete in a mixer shifts in proportion to the relative consistency or water content, or workability or flowability, of the concrete as altered and influenced by variations in the water content in the ingredients or by changes in the mixing water, or to other variations of the factors affecting consistency changes in the mix.

Clagett 1938 - Method of determining the consistency of concrete mixtures

CONCLUSION

COSTS



RHEO



CONCLUSION

Slump (cm):

0

...

10

...

20

...

WATTMETER

NON

OUI

NON

MIXOMETER

NON

OUI

VISCOPROBE

NON

OUI

MOISTURE METER

OUI

NON



THANK YOU !

Acknowledgement to SKAKO Concrete