Power inline control in ready mix concrete manufacturing

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with the participation of

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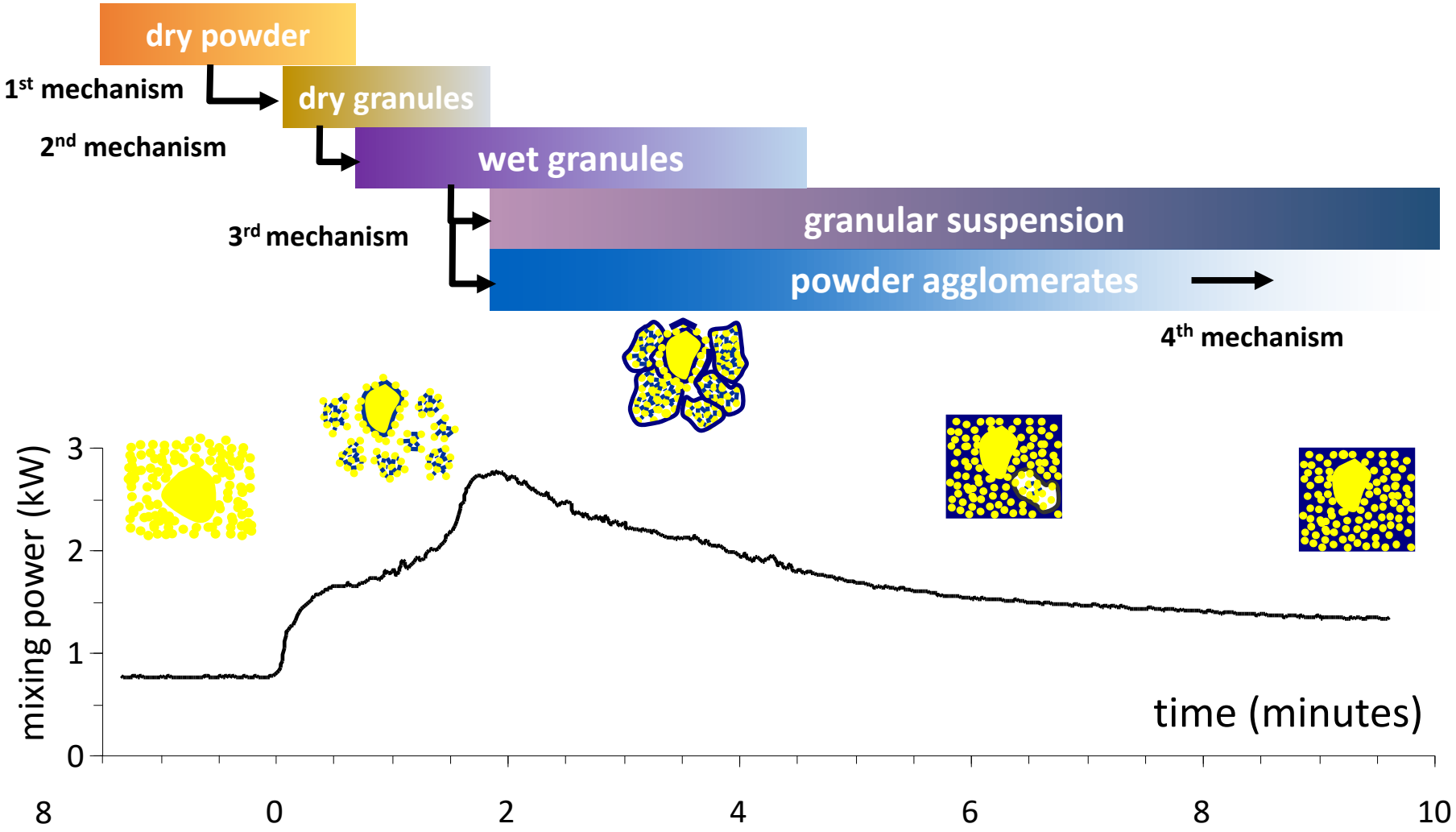
Fabbris Faber Eqiom - for the in-situ data

Chafika Dantec Univ. Artois – organizer of the Round Robin test

Mixing states and mechanisms



Mixing at low Water/Powder - SCC

* slow evolution of the mixture
* the different states well recognizable

Normal concrete

* time between states is short
* uniformity is sometimes longer

But we have the same behavior!

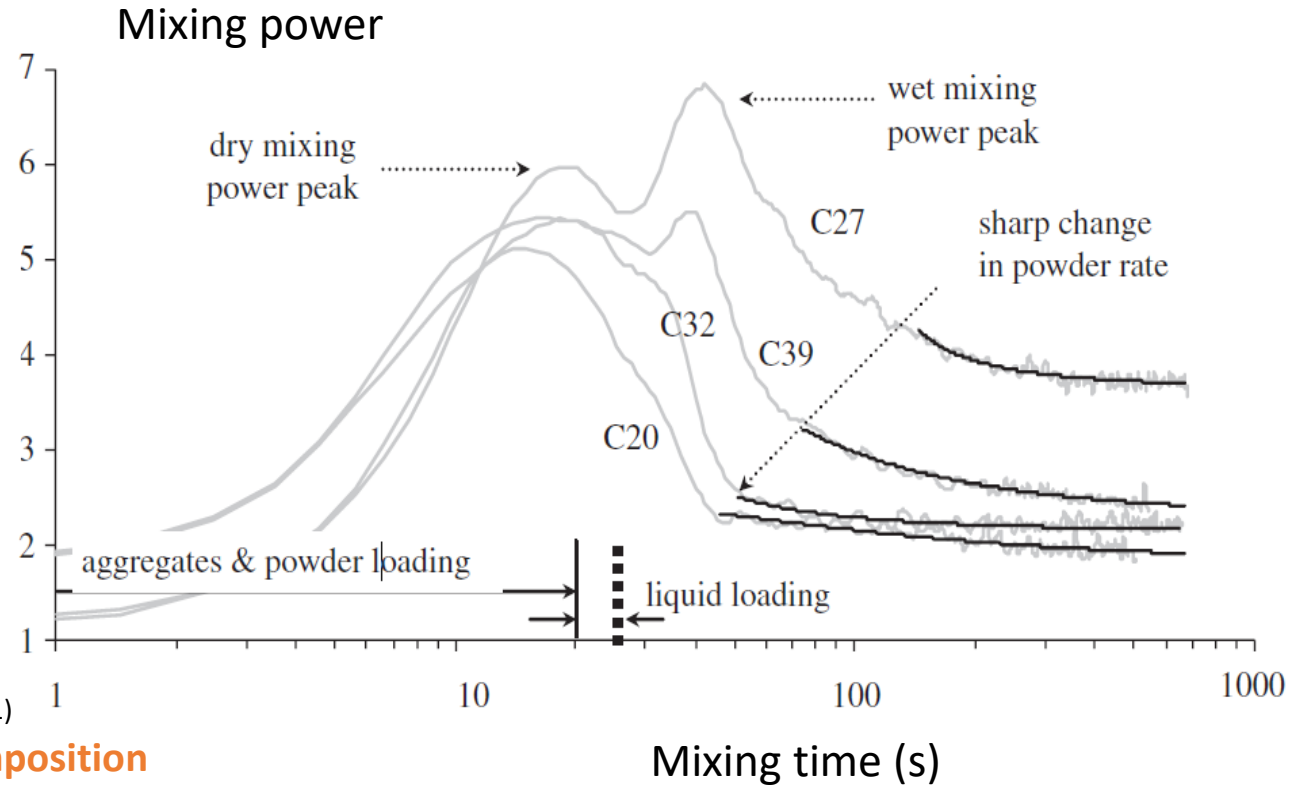
Cazacliu & Roquet, Cement & Concrete Research (2009)

Background

Mixing power evolution with the mixing time gives several characteristics points:

- Dry mixing power pic (maximum dry friction into the mixture)
- Wet mixing power pic (maximum liquid bridges)
- Fluidity point (mixture becomes essentially fluid)

These points (their position) are related to the **mixture composition, batch volume, loading sequence (and temperature!)**



Cazacliu & Legrand, Chemical Engineering Science (2008)

Common errors in analyzing power curves

We generally make use of bad correlations between:

* **Power measurement Vs. Concrete consistency** (Le, 2006)

excepting self compacting mixtures, after the fluidity time (Chopin 2001)

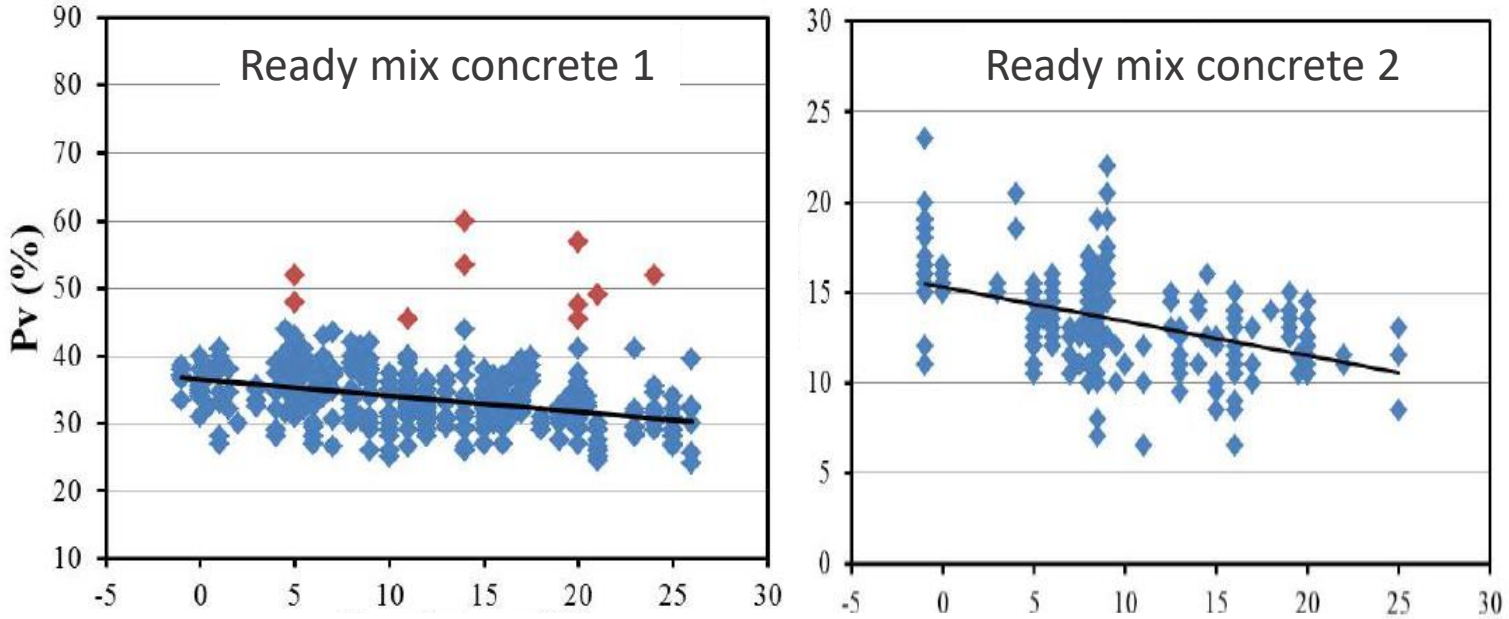
* **Mixing power at a fixed mixing time** (ex. 55 sec) **Vs. Mixture composition**

Some conclusions on how to analyze the power measurement:

- Better to analyze composition variabilities (and deduct after the consistency in the batch)
- Power curve should be interpreted at the fluidity point or (sometimes) at the wet mixing peak or dry mixing peak points
- For this points both power and time vary with the composition!

Temperature

Mixing power at emptying the mixer (% of nominal power)



Outdoor temperature (°C)

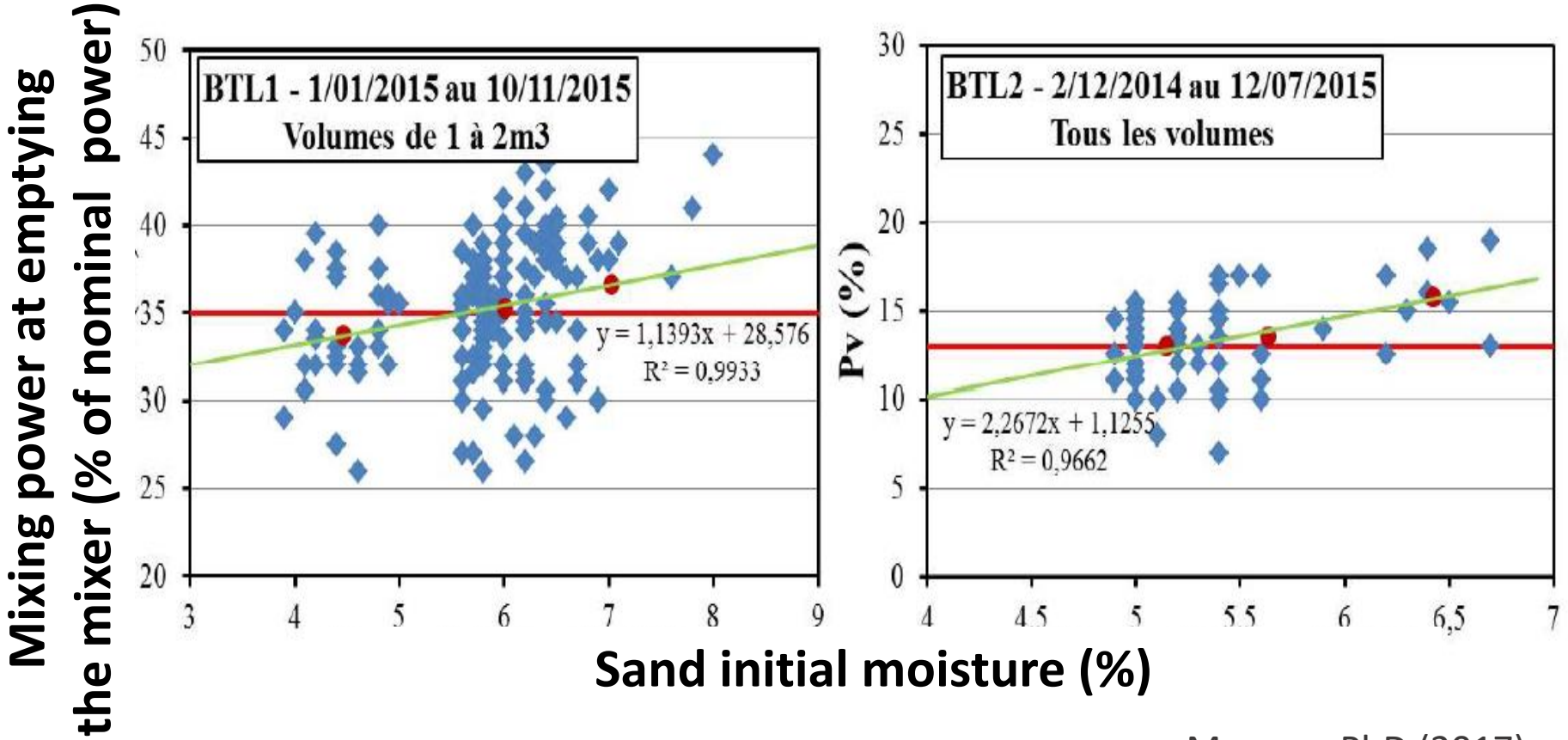
But nothing is simple!

Temperature also plays, mainly after fluidity.

So, cohesion point could sometimes be better indicator of composition

Moreno, PhD (2017)

Sand moisture



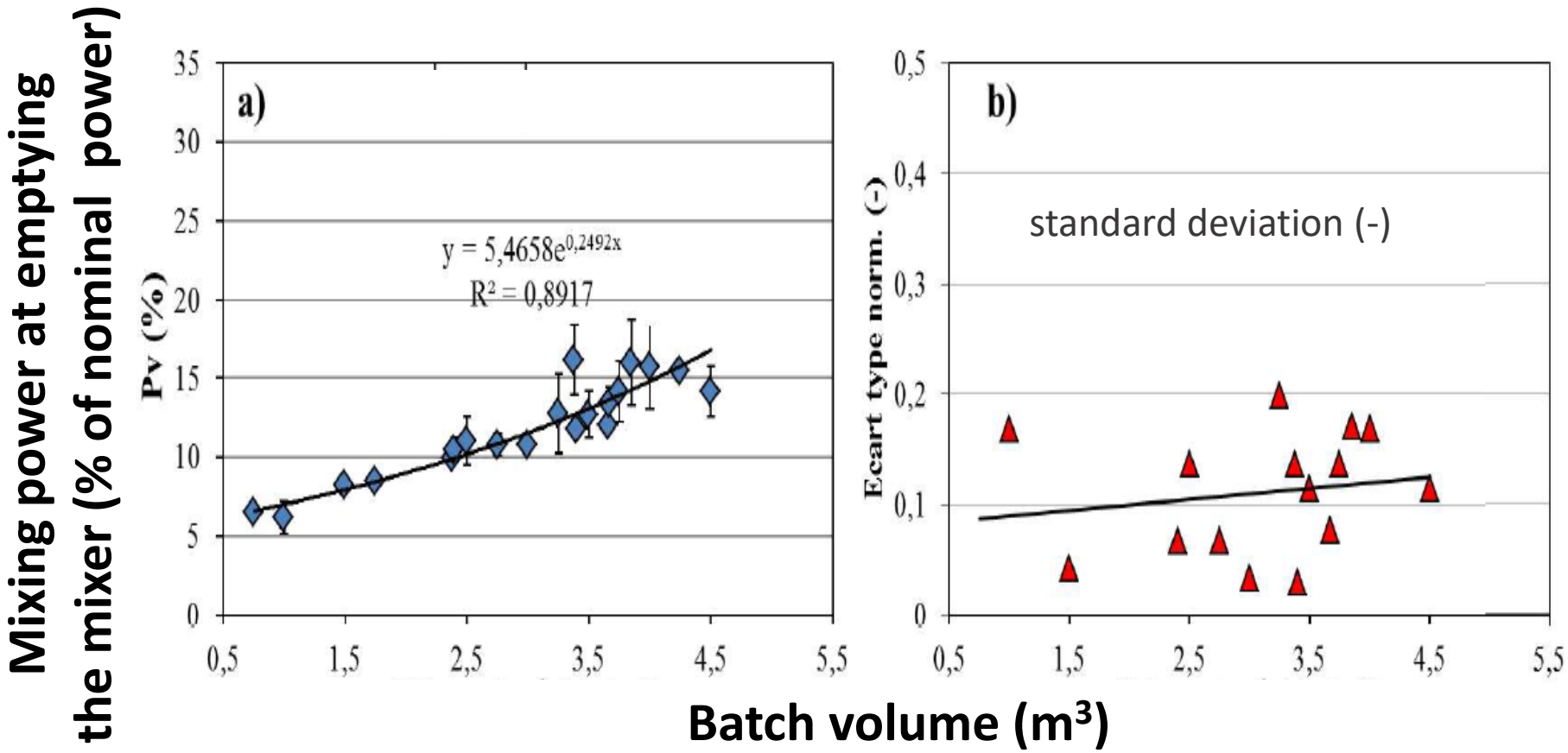
Moreno, PhD (2017)

And the aggregates initial moisture:

For sand, this could mainly be a problem of probe calibration (see PN BAP reports)

but the high variability is demonstrated to be introduced by the coarse aggregates initial moisture (Le 2006) !

Batch volume

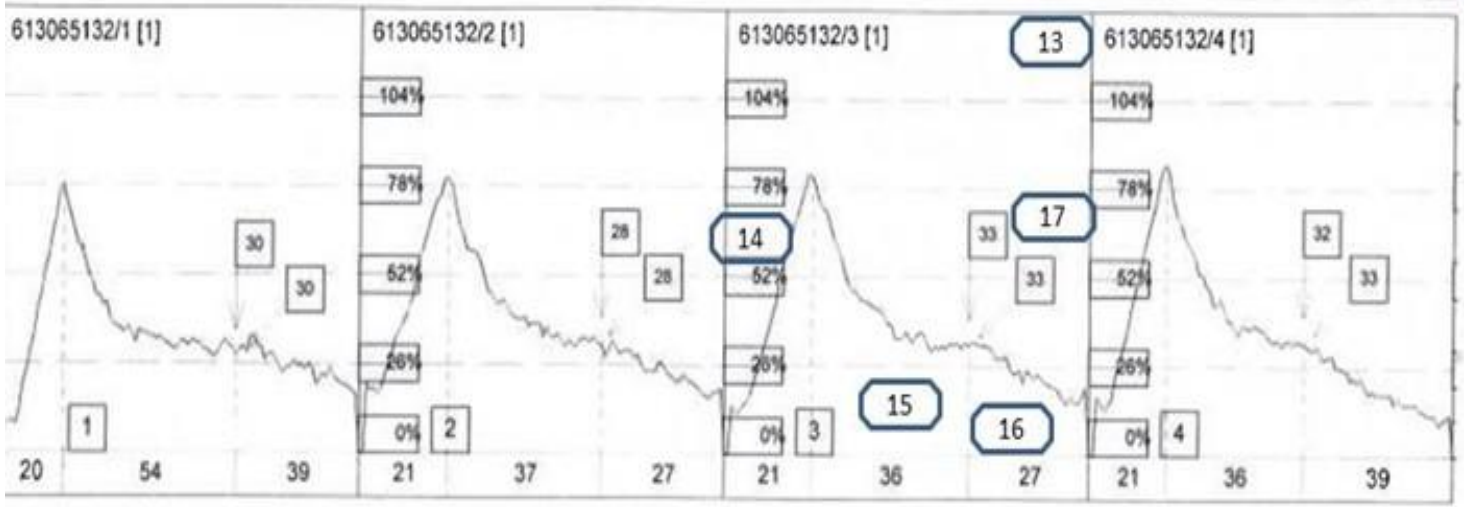


Moreno, PhD (2017)

And the batch volume: We can find good correlations with the end of mixing power (but not always!!!)
The normalized standard deviation is rather constant

Experimental Method

Consigne pour 1 m3					(1) 925	248	606	308	25	180,0	1,73	Masse volumique			
Tx. Abs./Eau Adj.					(2) 0,90%	0,90%	0,13%			(4) 11,3	(5)				
/Gachée : 1,30 m3					(3) 1 203	322	788	400	33	248,7	2,25	2 305,2 kg/m3			
GACHÉE			HYGROMÉTRIE			Granulats (kg)			Liants (kg)		Eaux (kg)	Adjuvants (l)			
N°	Heure	Malax.	6/12	0/4a	0/4b	6/12	0/4a	0/4b	Ciment	Liant			+/-	COMP.	
1	09:44	(6) 35s 1,30m3	1,5%	1,2%	5,7%	(8) 1 220	325	825	400	37	188,5	2,23	+6,5	-60,3	
		(7)				-0,1%	-0,3%	-1,0%		12,1%	0,1%	-0,9%	(9)	(10)	
2	09:46	35s 1,30m3	1,5%	1,2%	5,7%	1 225	325	835	400	36	189,0	2,22	+6,5	-60,3	
						0,3%	-0,3%	0,2%		9,1%	0,3%	-1,3%			
3	09:48	35s 1,30m3	1,5%	1,2%	5,7%	1 225	330	840	398	37	189,0	2,22	+6,5	-60,3	
						0,3%	1,2%	0,8%	-0,5%	12,1%	0,3%	-1,3%			
4	09:49	35s 1,30m3	1,5%	1,2%	5,8%	1 220	325	830	399	35	187,5	2,23	+6,5	-61,1	
						-0,1%	-0,3%	-0,4%	-0,3%	6,1%	-0,1%	-0,9%		-	
12 030kg/5,20m3						4 890	1 305	3 330	1 597	145	754,0	8,90	+26,0	-242,0	(11)
Quantité visée /m3						939	251	641	308	25	144,8	1,73			
Moyenne			1,5%	1,2%	5,7%	940	251	640	307	28	145,0	1,71	+5,0	-46,5	(12)

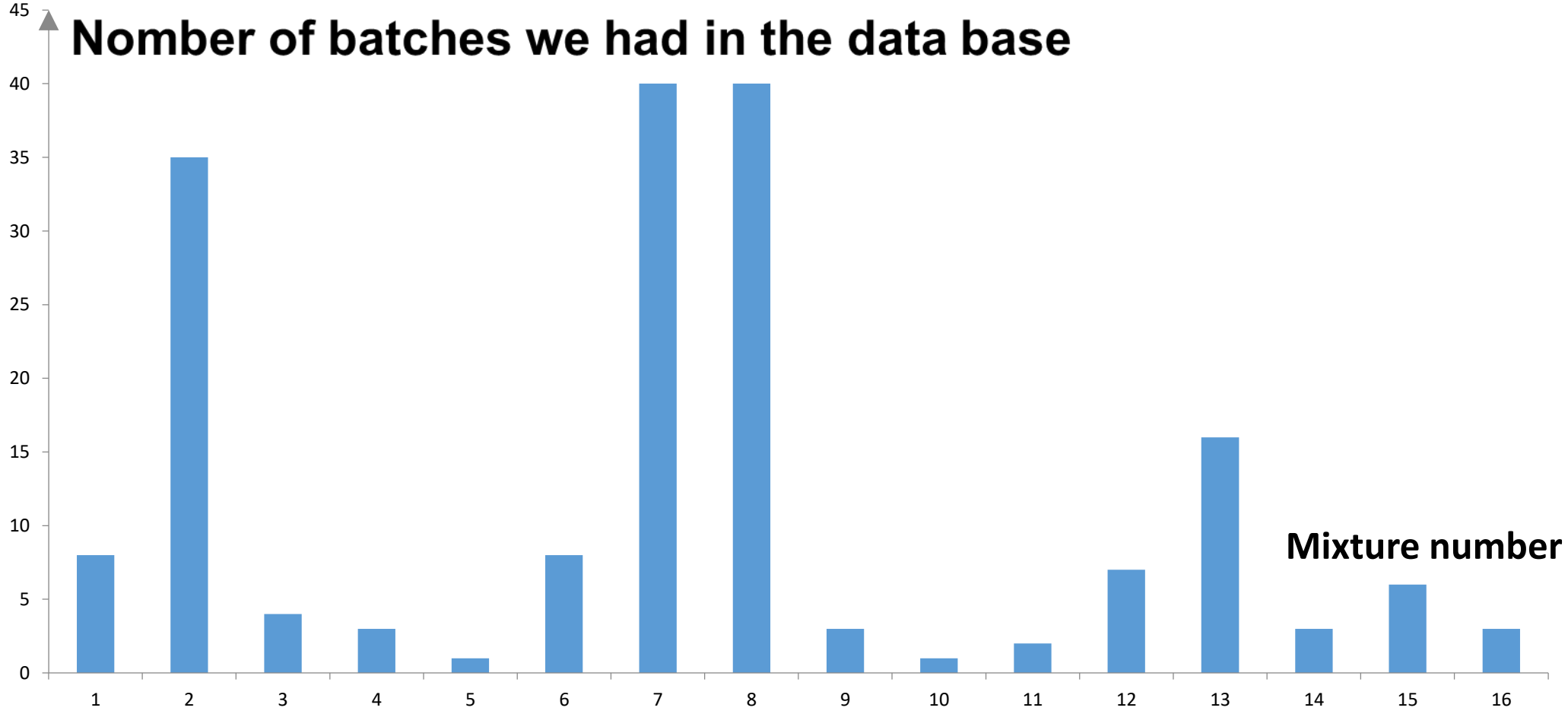


We collected lot of delivery reports during 2 days

+

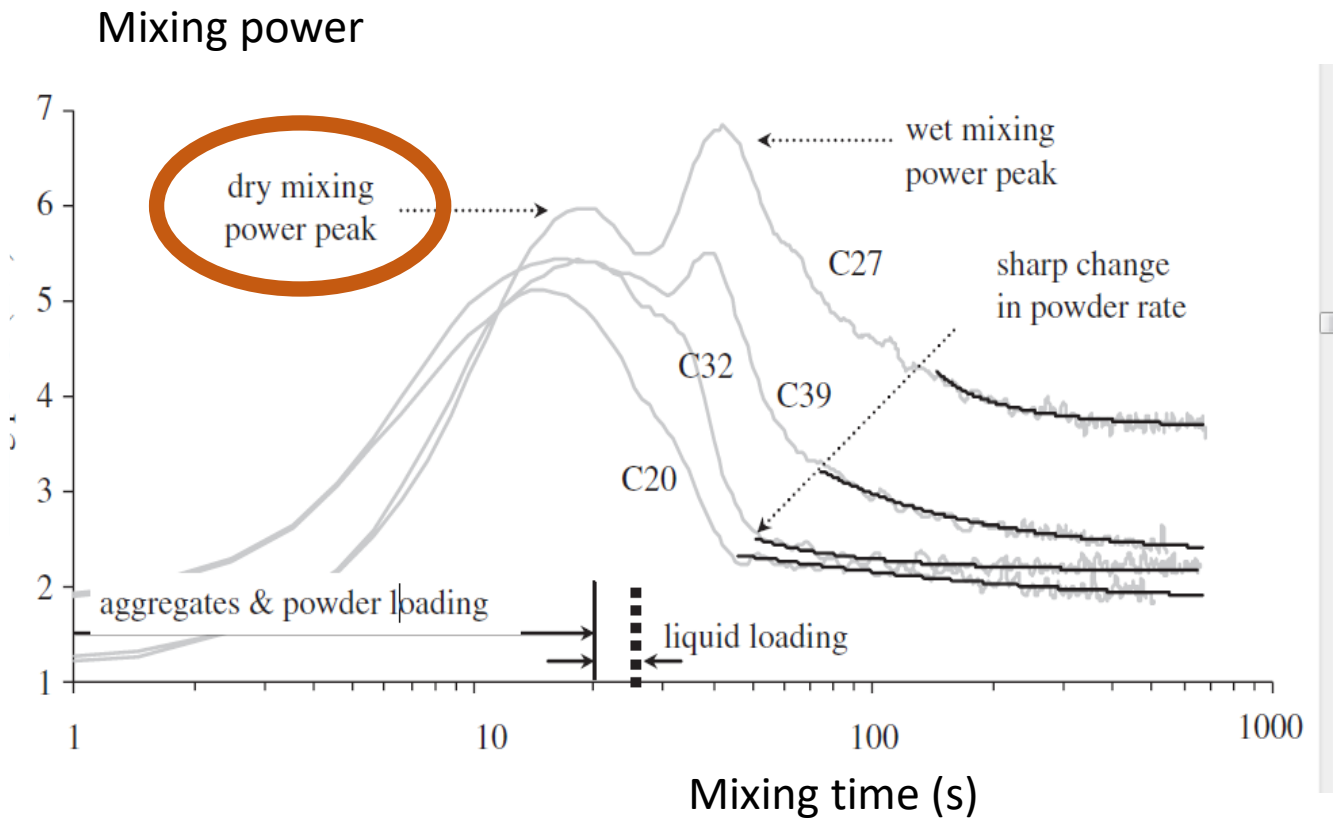
Independent mixing power measurement (independent from the plant control system)

Experimental Method

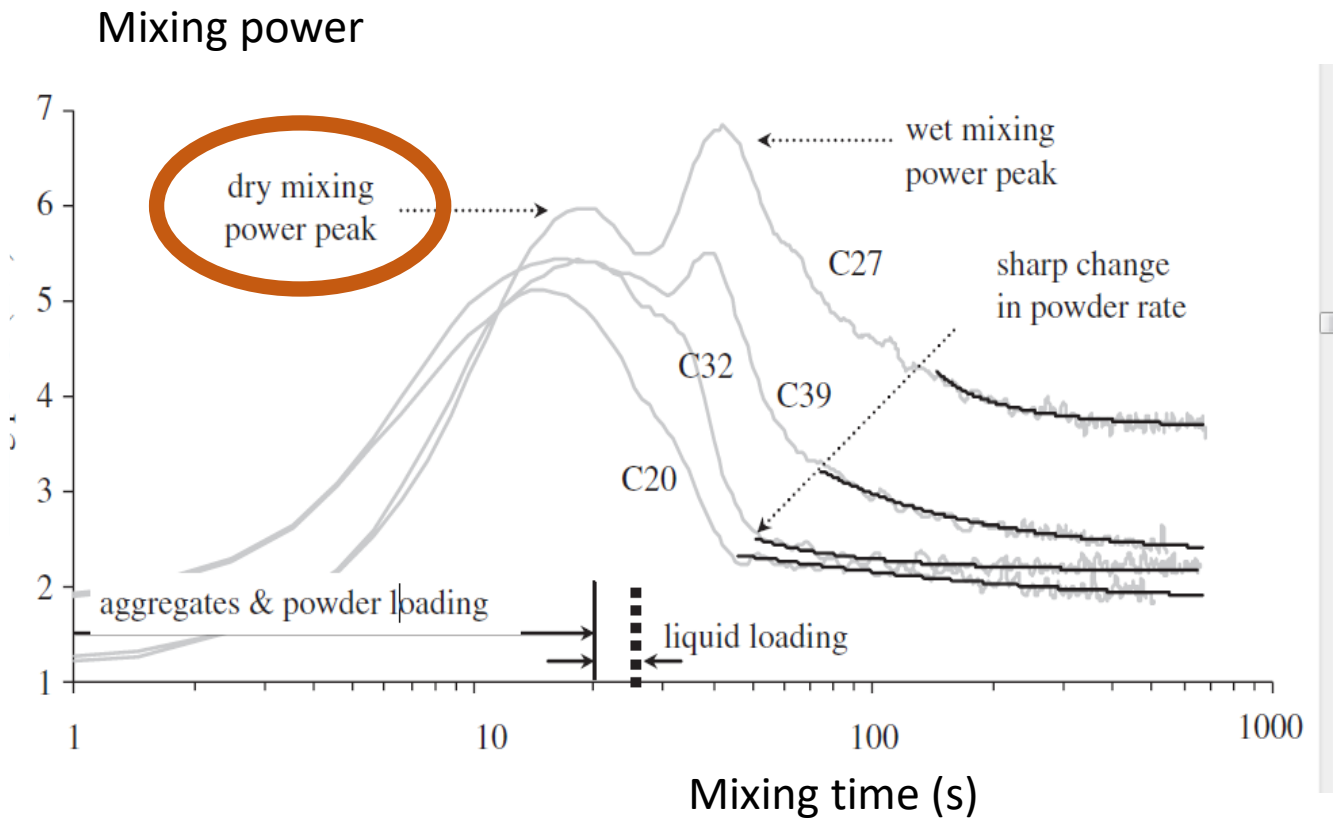


We chosen the most frequent mixtures (4)

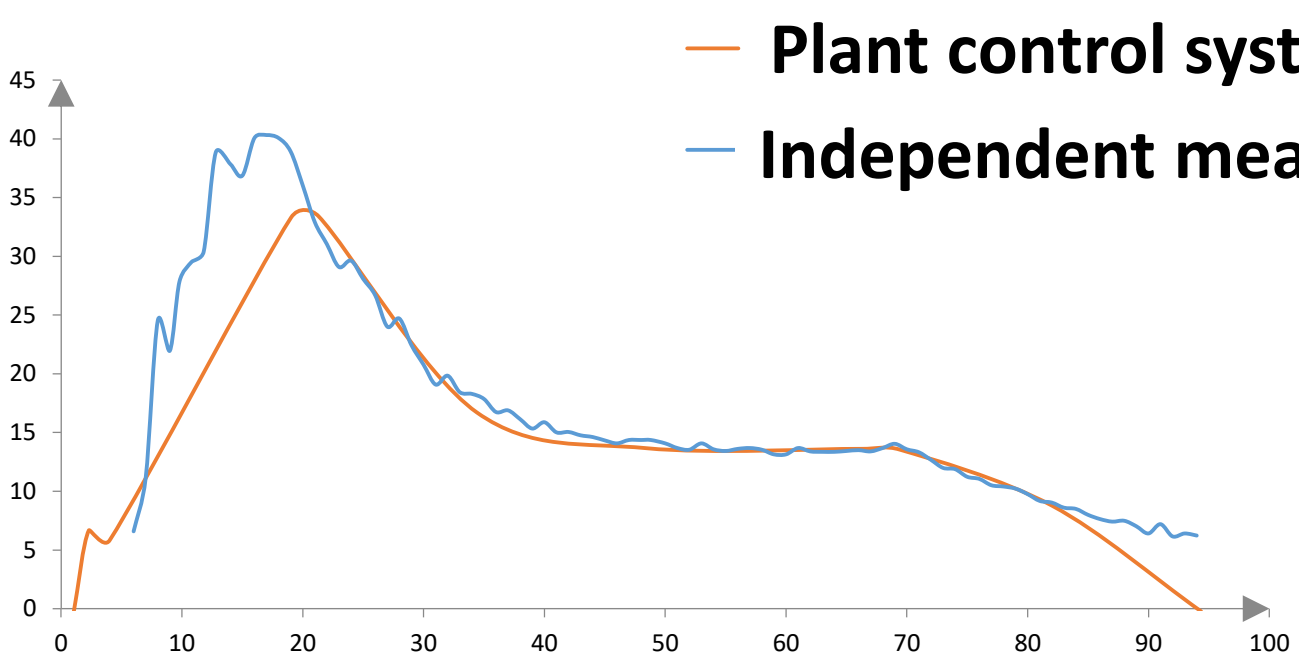
Dry mixing power peak

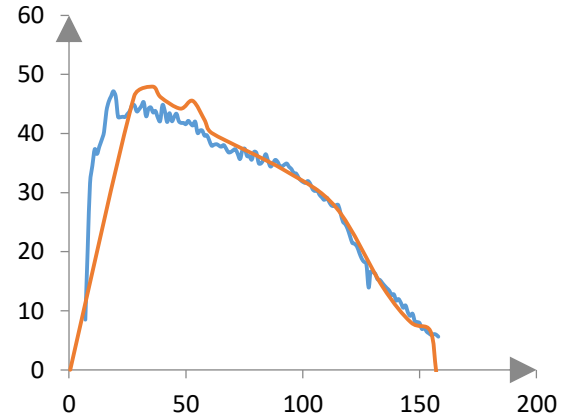


Dry mixing power peak



Error in mixing power measurement



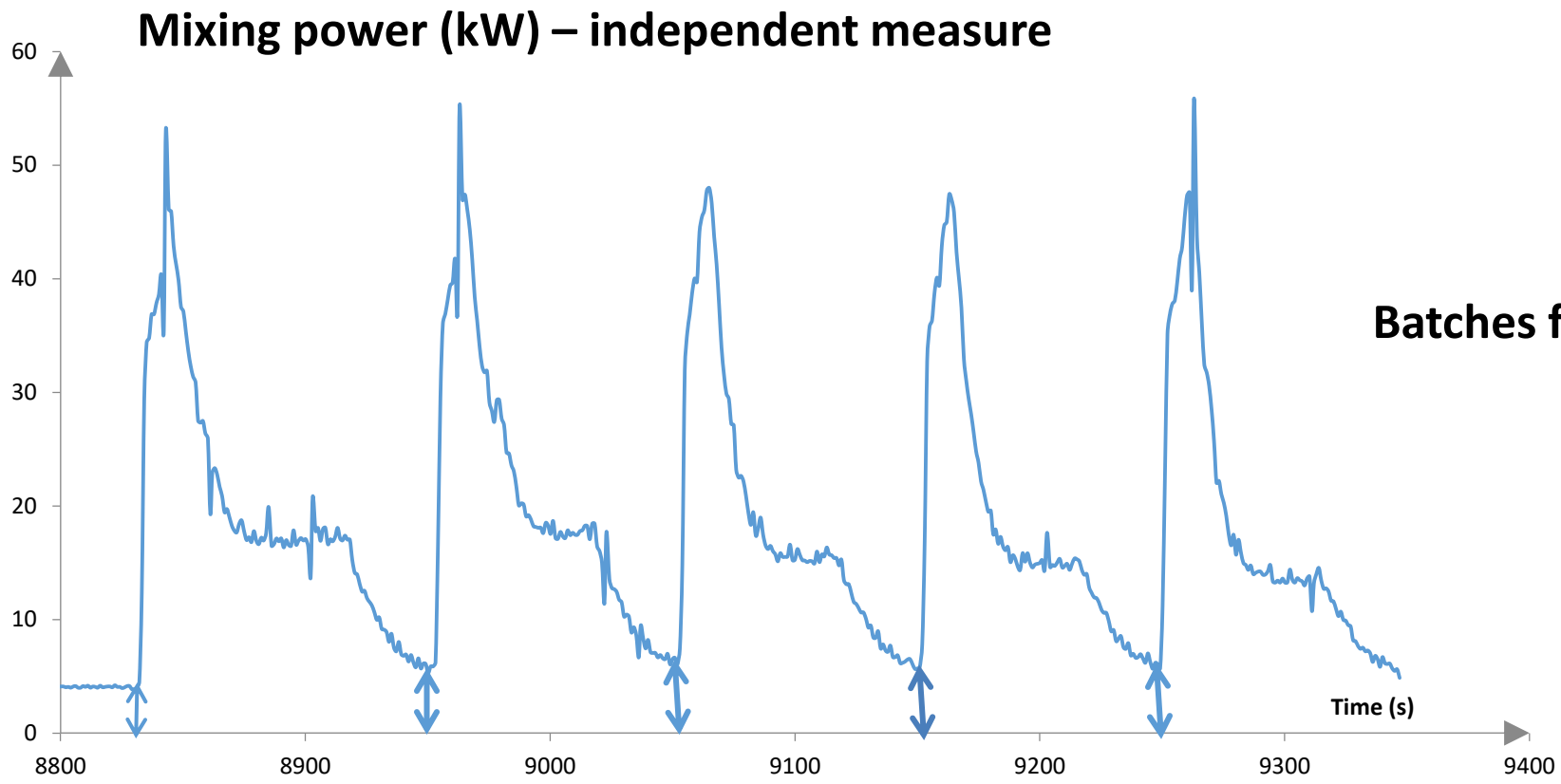


Another example …

The beginning of the batch power measure is biased in the control system

This is not a problem today, but a problem if we want to improve the automatic data mining and control!

Nominal volume and real volume of the batch



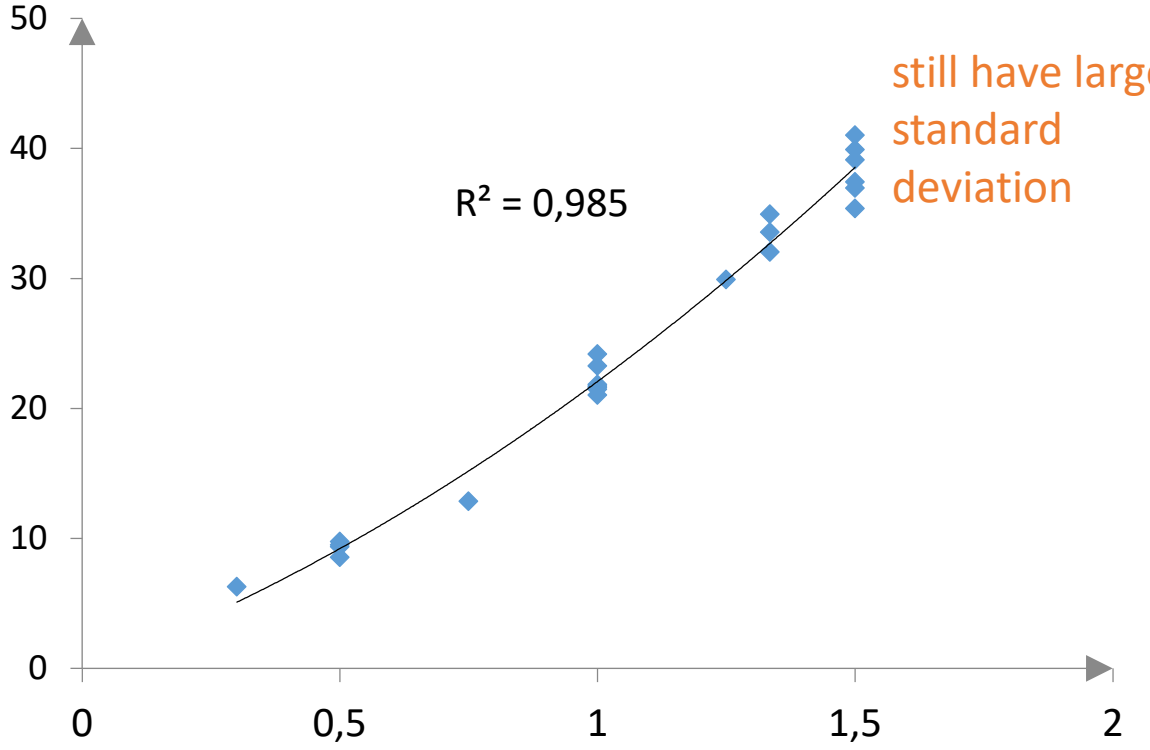
Batches for one same truck

Concrete from the previous batch is still in the new batch after emptying. Excepting the first batch of a truck !

The quantity of concrete still present in the mixer is a control system parameter (more exactly, a small mixing power is fixed)

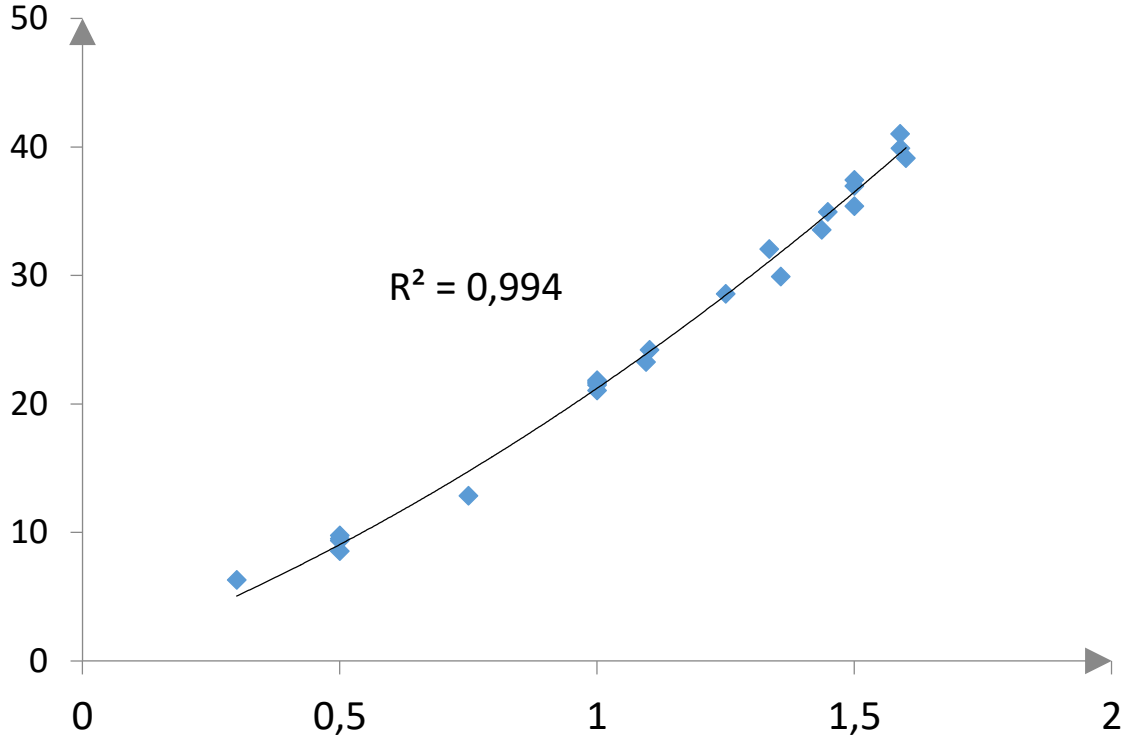
Real volume Vs. Mixing power dry peak

Dry Mixing power pic (kW) – mixture 1



still have large standard deviation

Batch nominal volume (m^3)



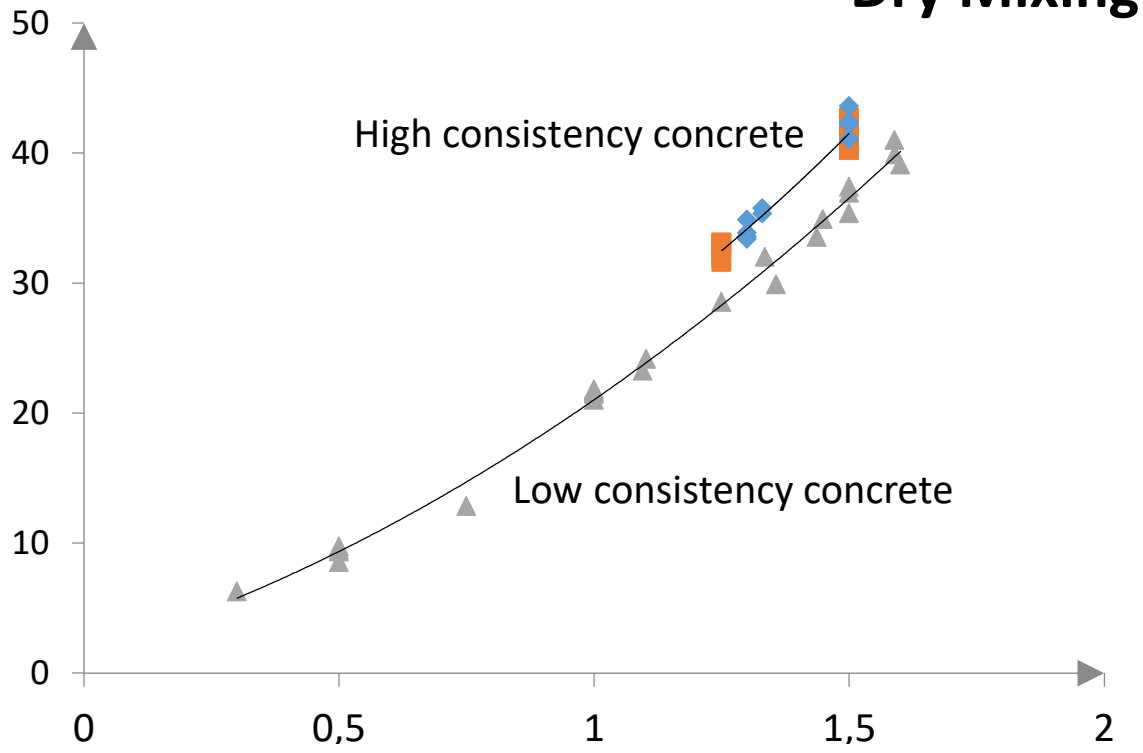
Batch real volume (m^3)

Good correlation between the dry mixing pic and the batch volume (of coarse for the independent measure)

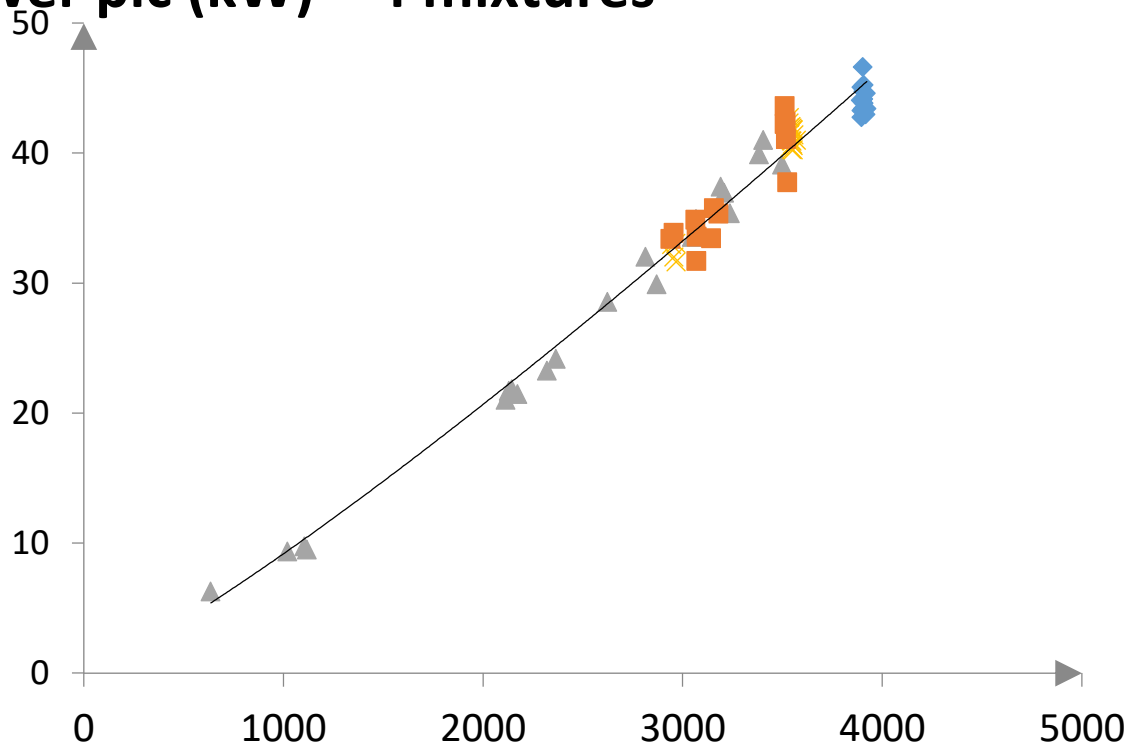
It works much better when we use the real volume of the batch (we made a mass correction in the batches)

Batch real mass

Dry Mixing power pic (kW) – 4 mixtures



Batch real volume (m^3)

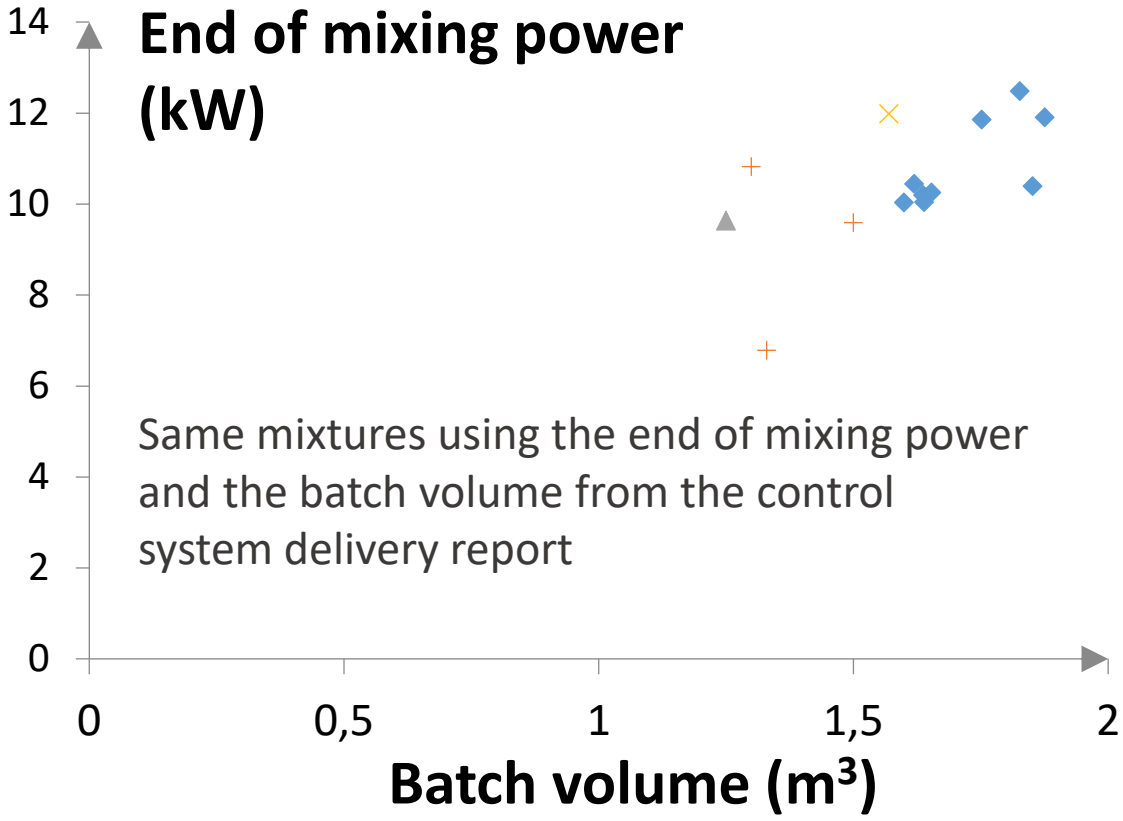


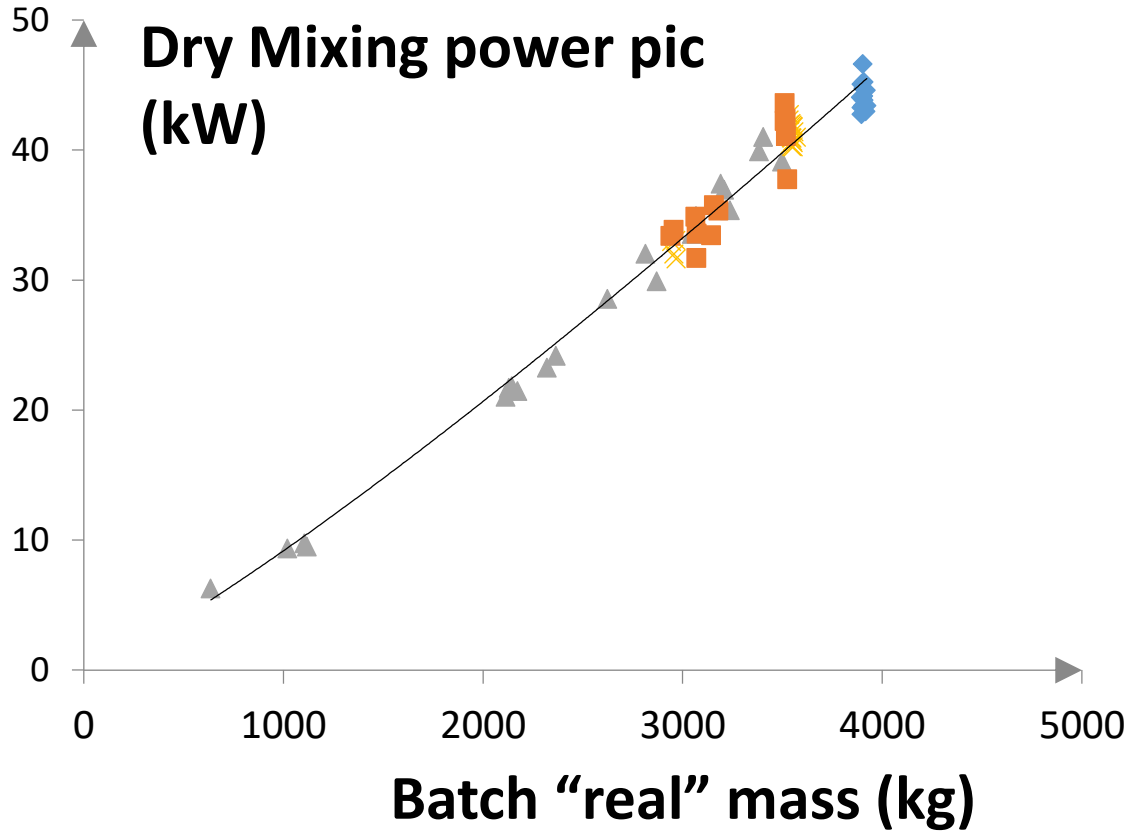
Batch "real" mass (kg) – with a correction for the initially fluid mixture

It seems that the final fluidity of the concrete plays!
Indeed, the mixture still in the mixer for the new batch is fluid not granular!

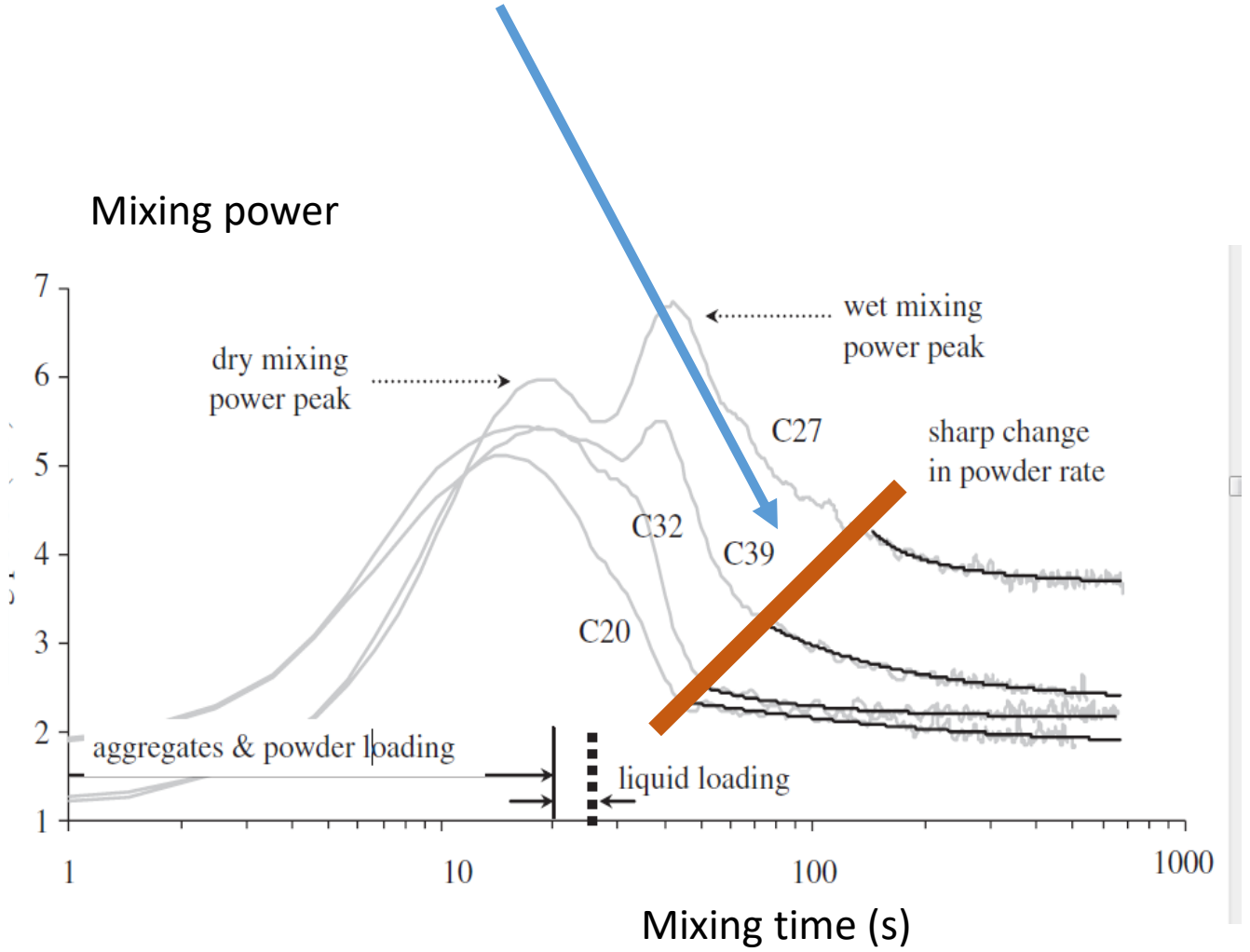
This curve could be use to retrofit the real volume. This will correct the data obtained with the fluidity point

with the delivery report …

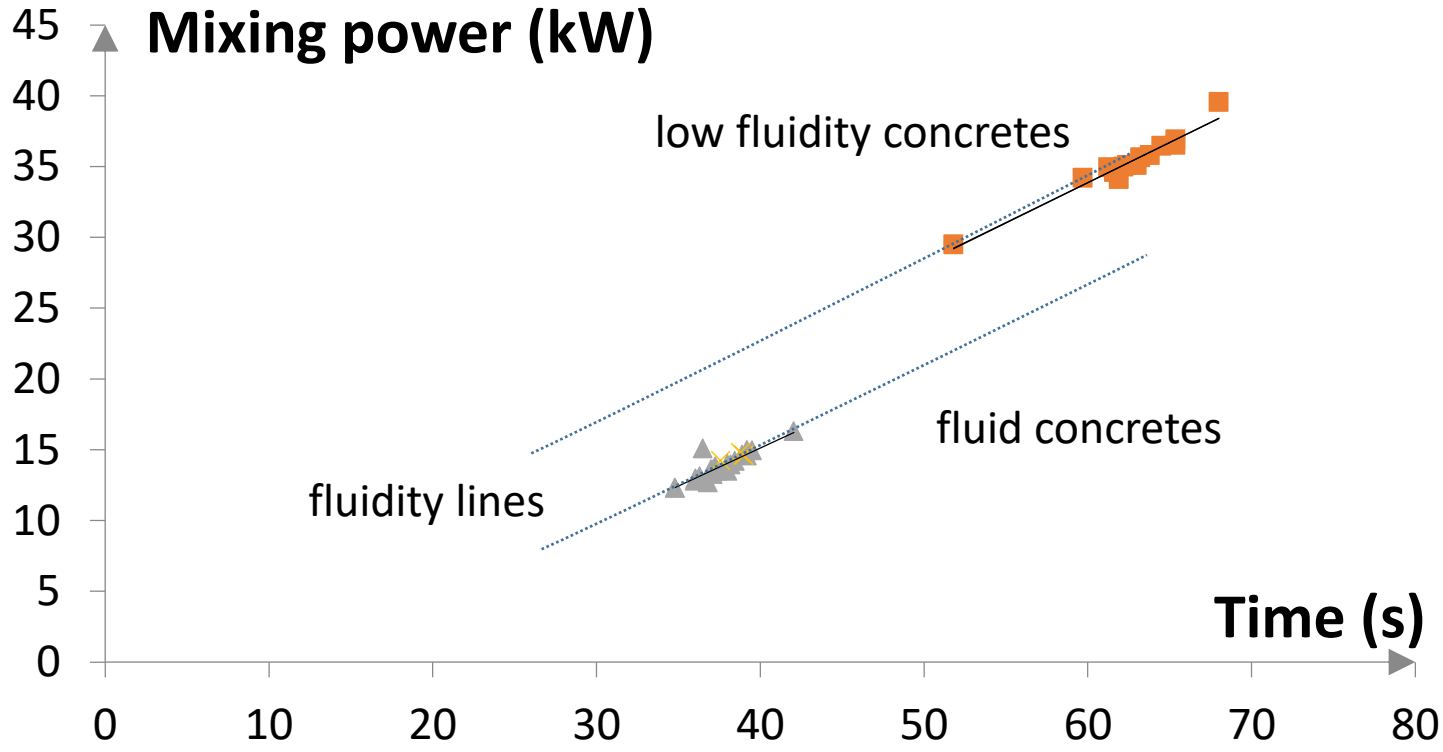




Fluidity line

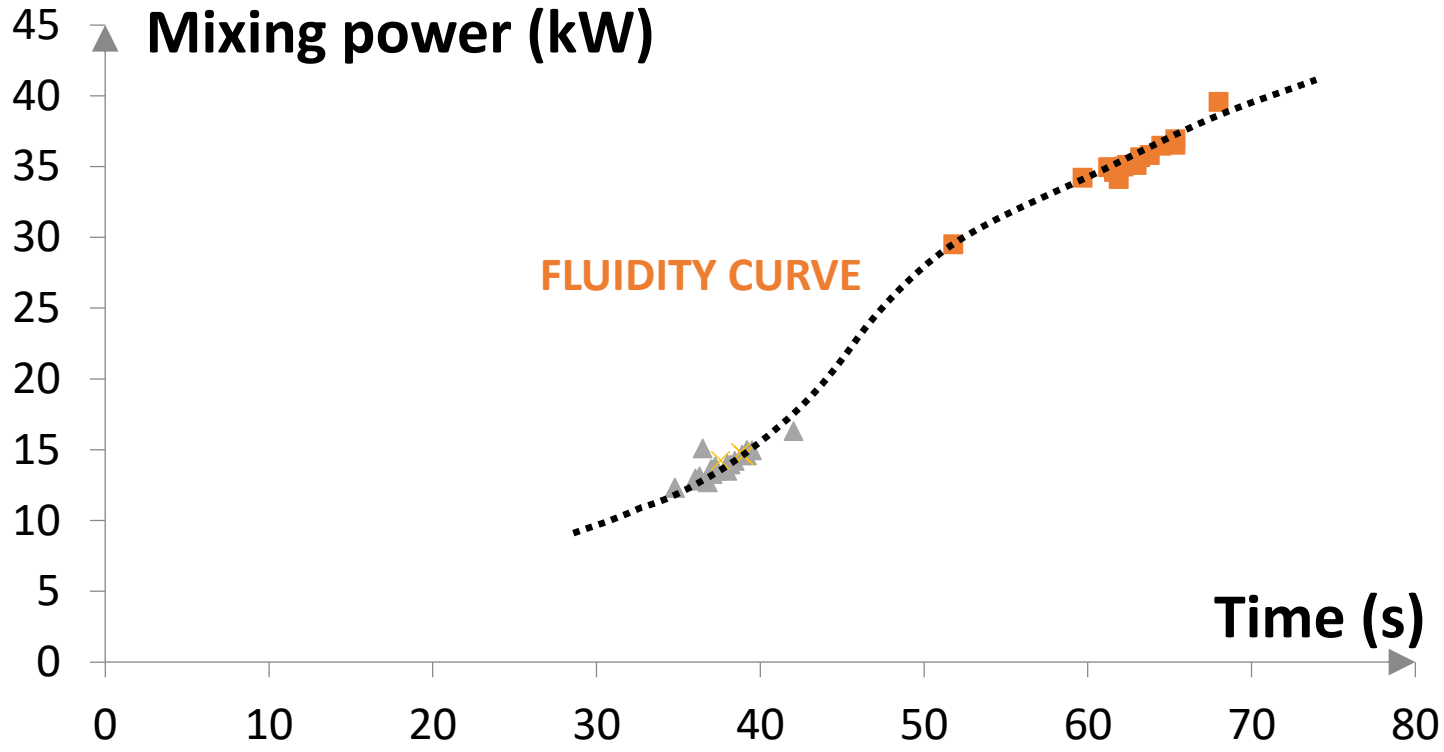


Fluidity lines Vs. Water Reducer



Influence of water reducer
This can be used to retrofit the composition!

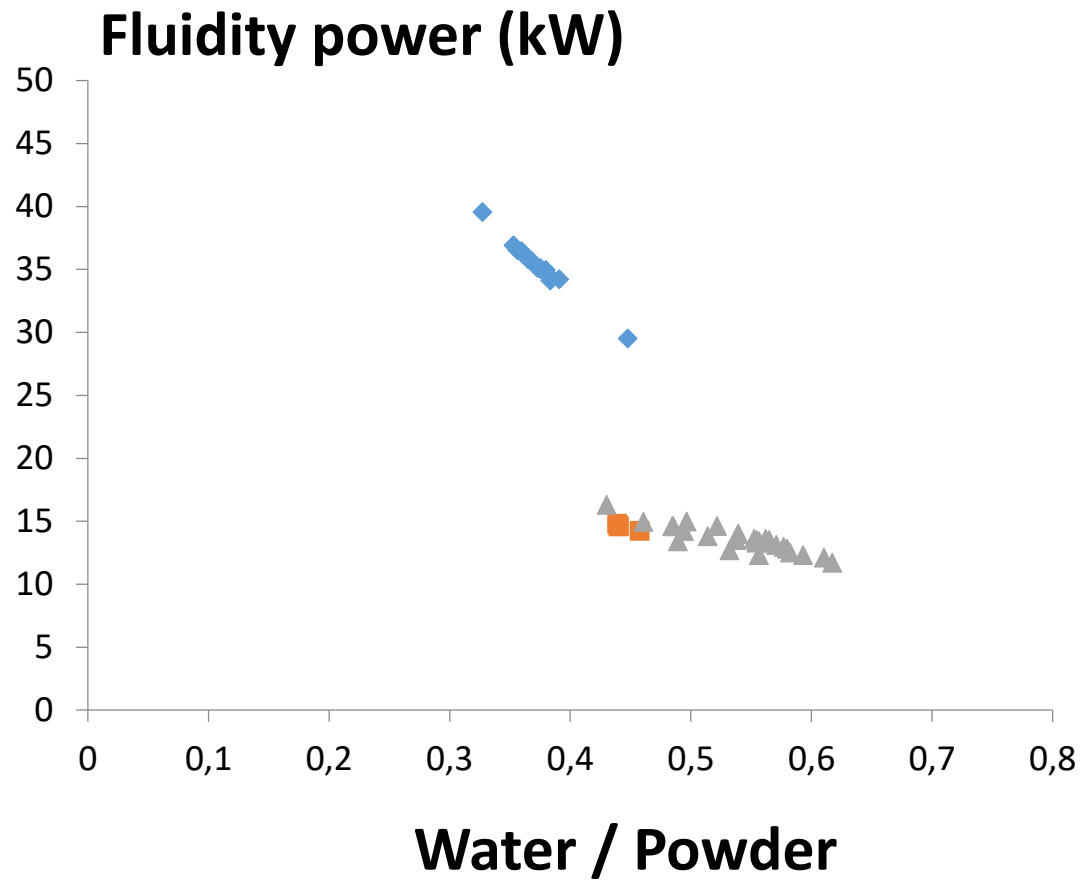
Fluidity lines Vs. Water Reducer



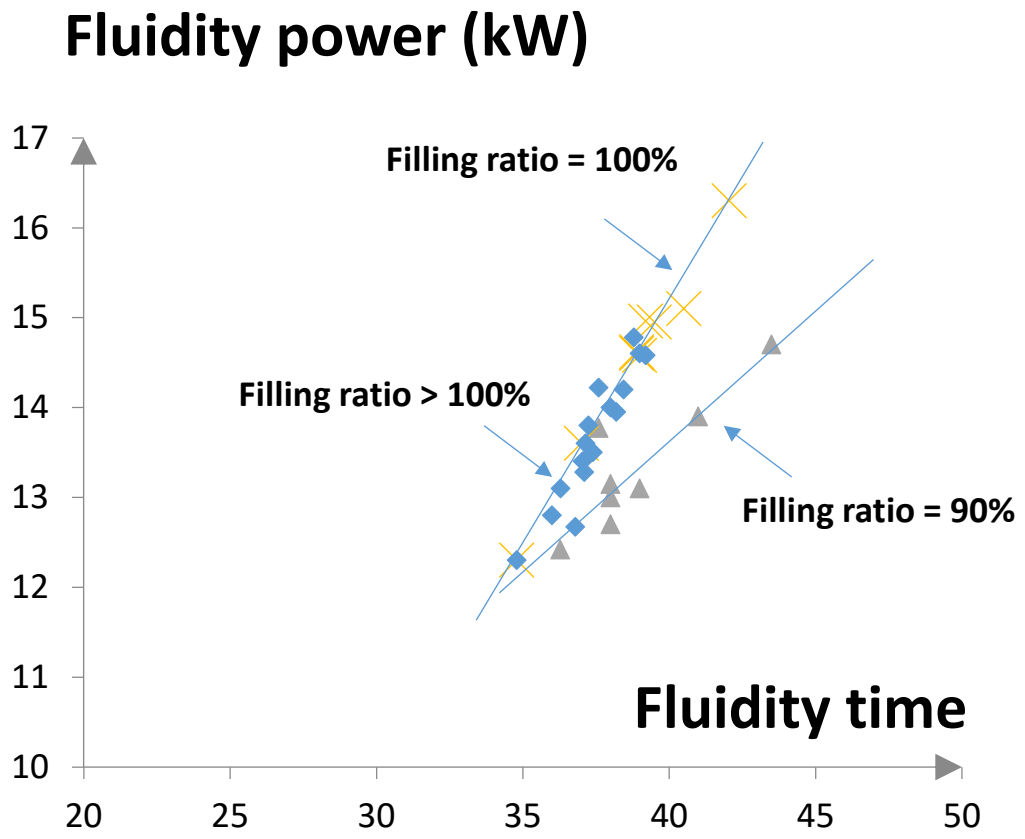
Influence of water reducer
This can be used to retrofit the composition!

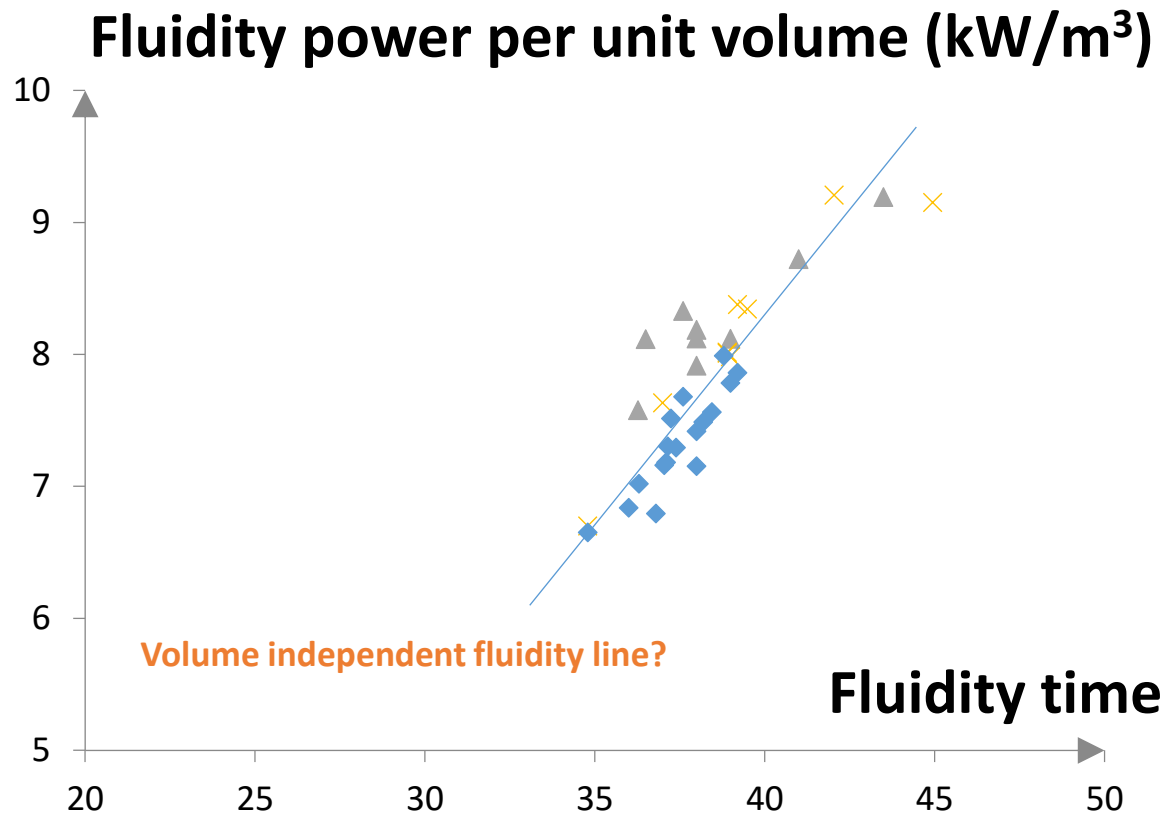
Fluidity power Vs. Water / Powder

How to measure the real water proportion in a batch?



Fluidity line Vs. Filling ratio





The batch volume is influent, but can be corrected

Conclusion

FLUIDITY CURVE separate two zones in the (**Mixing Power – Mixing Time**) space

- at short mixing time the mixture is not uniform
- at longer mixing time the concrete become uniform (but continue to structure under mixing!)

This is a powerful concept to **determine the real W/P** value into a batch mixer

However, the **filling ratio** change drastically the behavior: this can be corrected

The **DRY MIXING POWER PEAK** gives accurately the filling ratio

Other mix-design parameters could be determined
by using the **WET MIXING POWER CURVE**