



Aalto University  
School of Engineering

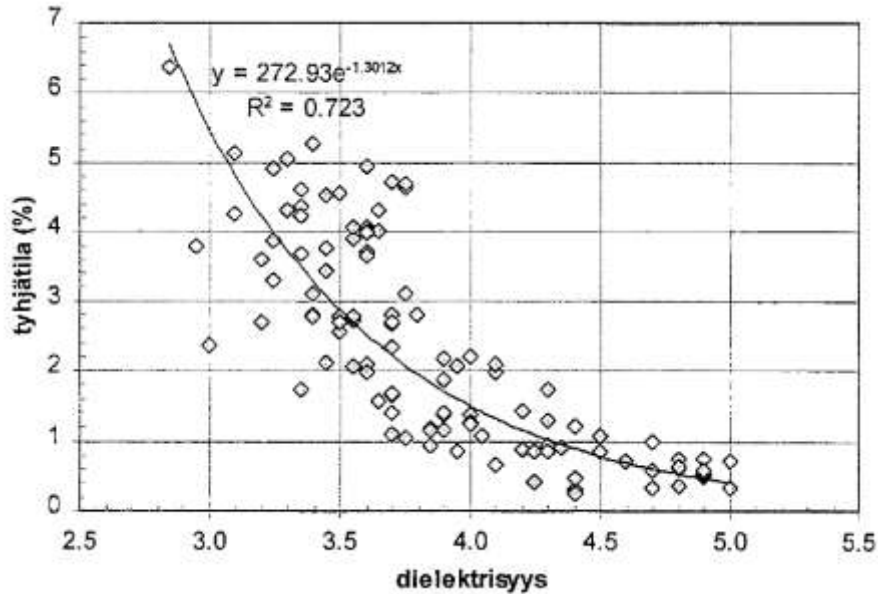
# Tiiveyden mittauksen ja arvioinnin kehittäminen

*”Tyhjätila”*

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Kuosmanen*

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# Mittausten kalibrointi



oikea ajoura

Poranäyte



Kappaleitiheys  $\rho_p$   
4 eri menetelmää

Massan  
maksimitiheys  $\rho_m$

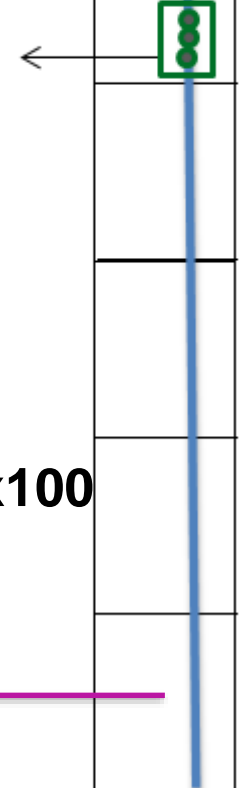
Tyhjätila  $TT = (1 - \rho_p / \rho_m) \times 100$

$$TT = 272,93e^{-1,3012 * k * \epsilon_r}$$

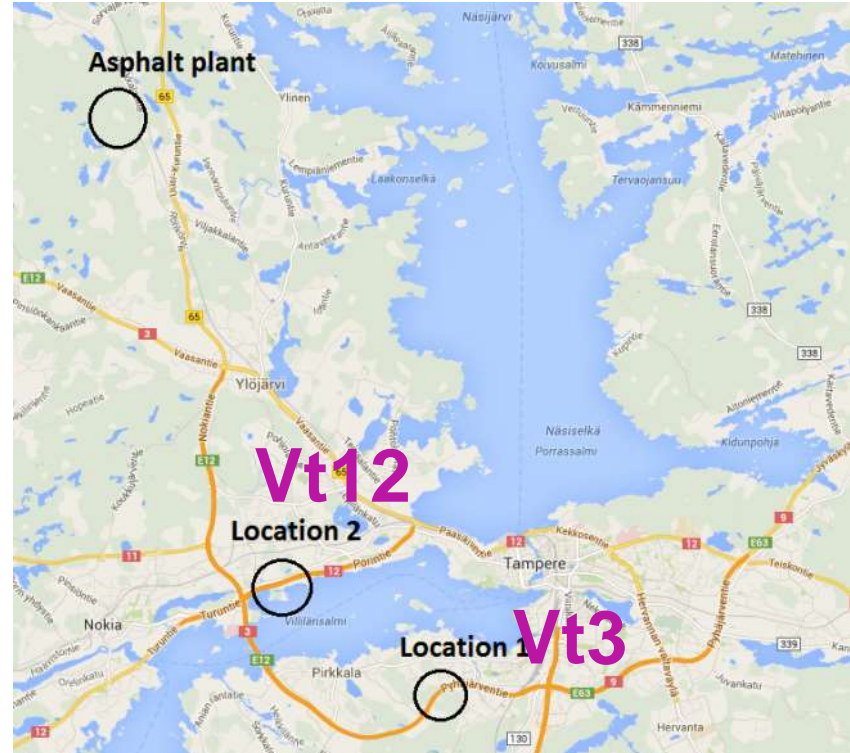
PANK-4122 menetelmä

lasketaan k

$ka \epsilon_r$



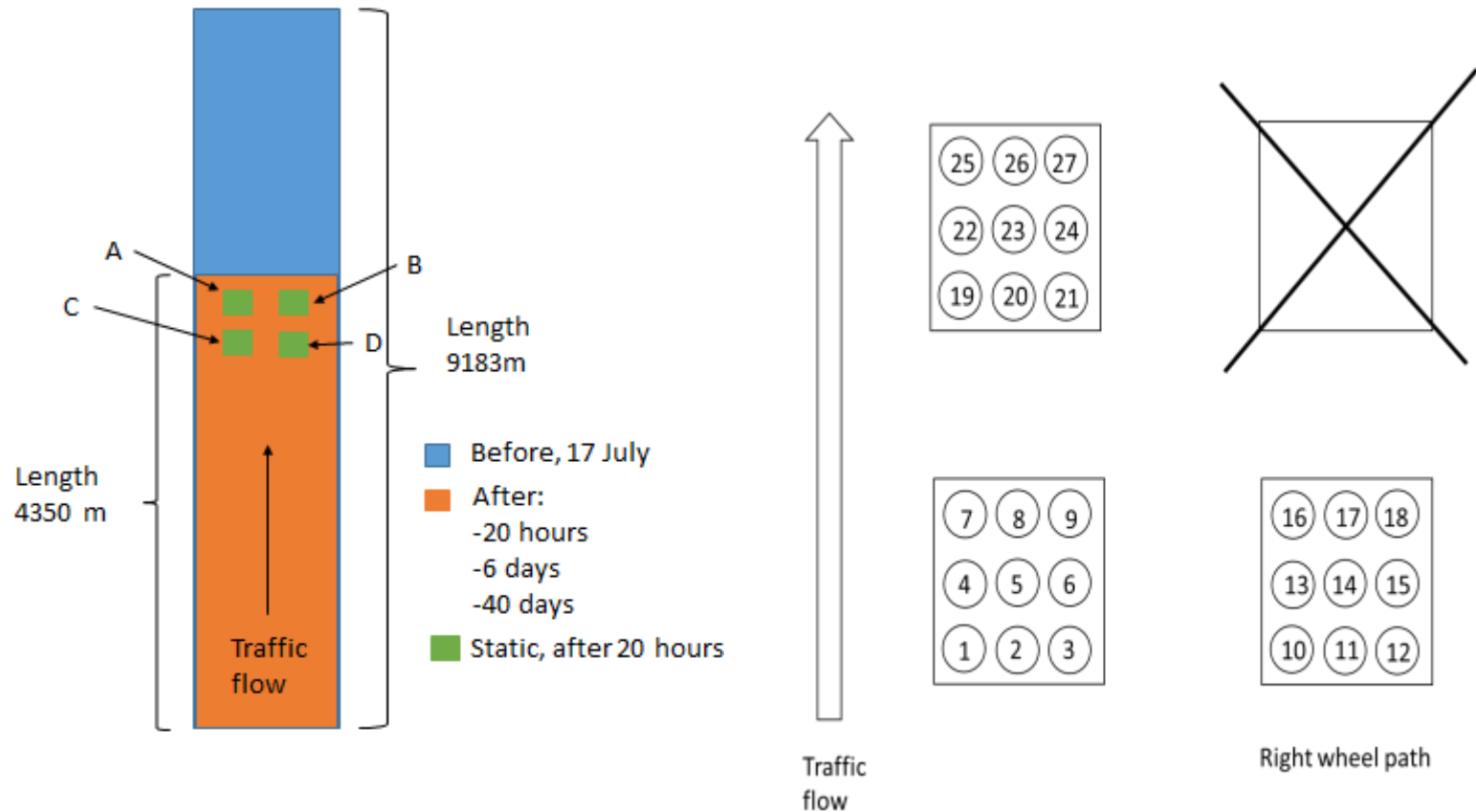
# Field sampling was done near city of Tampere



# GPR measurements in 2013

Road	Coordinates	Date 2013	Type of	measured distance, m	No. of data points
Vt3	6818486 N, 324209 E	17.07.	Continuous, right wheel path, centre <b>BEFORE CONSTR.</b>	2 x 9183	2x 9183
		20.08.	Continuous, right wheel path, centre	2 x 4350	2x 4350
		20.08.	<b>Stationary on coring locations</b>	4 x 0,3	4x100
		26.08.	Continuous, right wheel path, centre	2 x 4350	2x 4350
		30.09	Continuous, right wheel path, centre	2 x 4350	2x 4350
Vt12	6822254 N, 319144 E	11.11.	Continuous, right wheel path, centre	2x 3573	2x 3573
		11.11.	<b>Stationary on coring locations</b>	7x0,3	7x1350

# Vt3 GRP measurements & coring

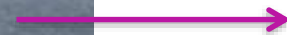


# Vt 3 Field sampling included 27 drilled core samples

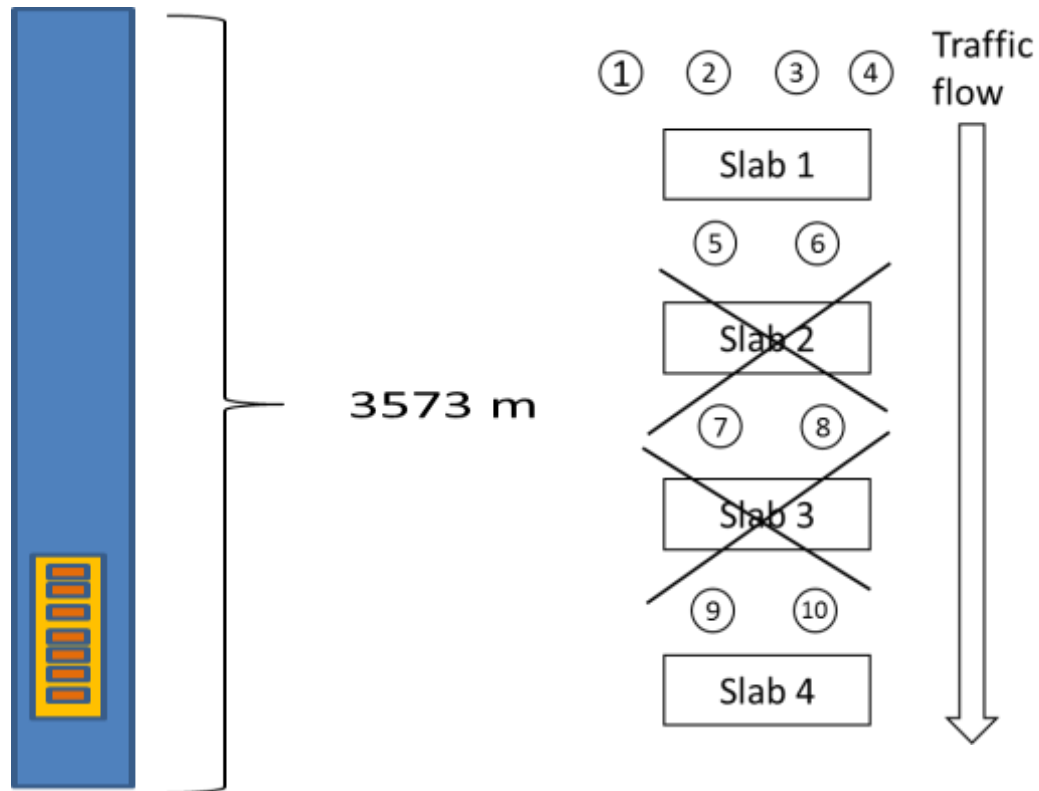
GPR measurements from same locations



Tampere



# Vt12 GRP measurements & coring





# Vt12 Field sampling included 10 drilled core samples and 2 slabs

Turku



Turku



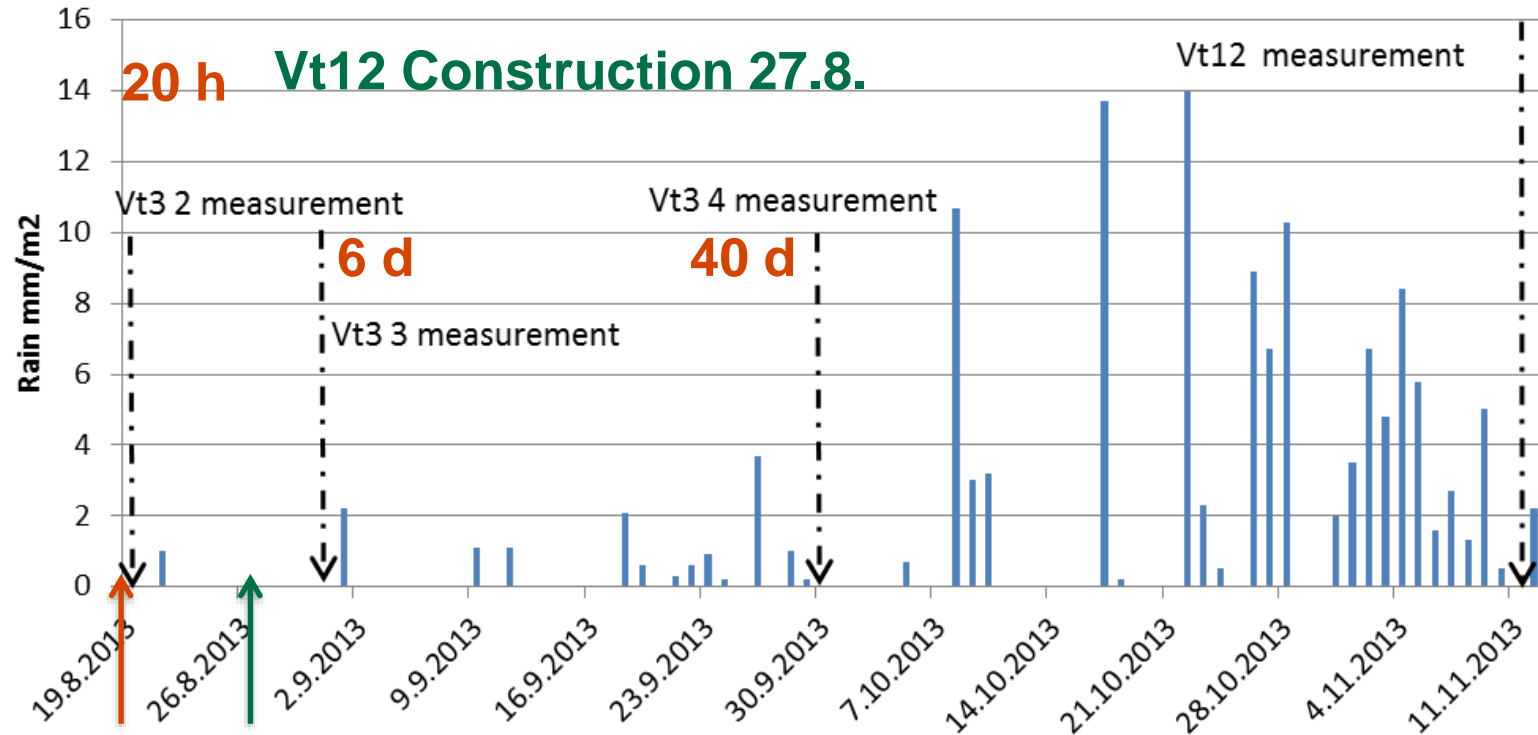


# Rain after paving work

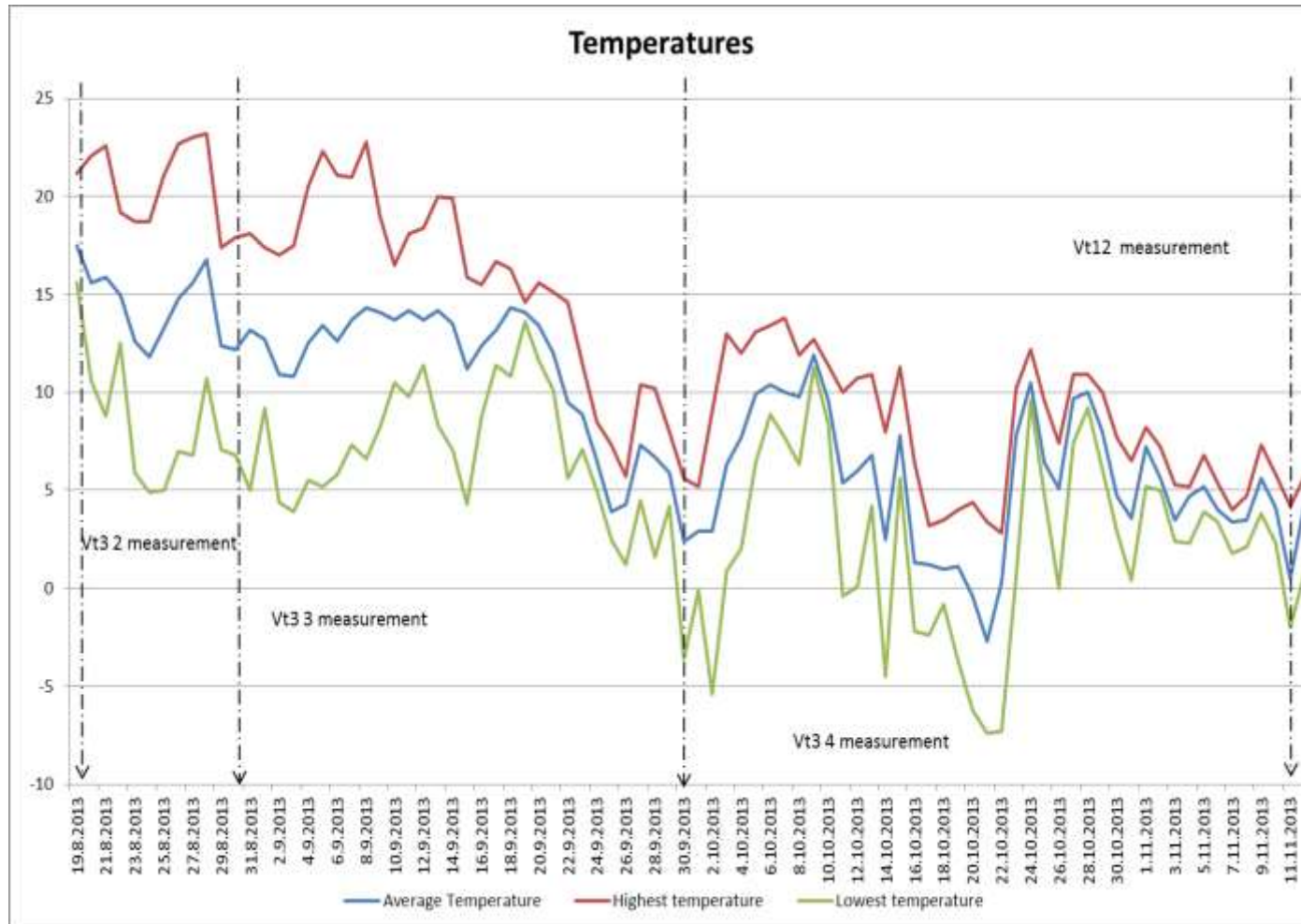
Vt3 Construction 19.8.

Rain

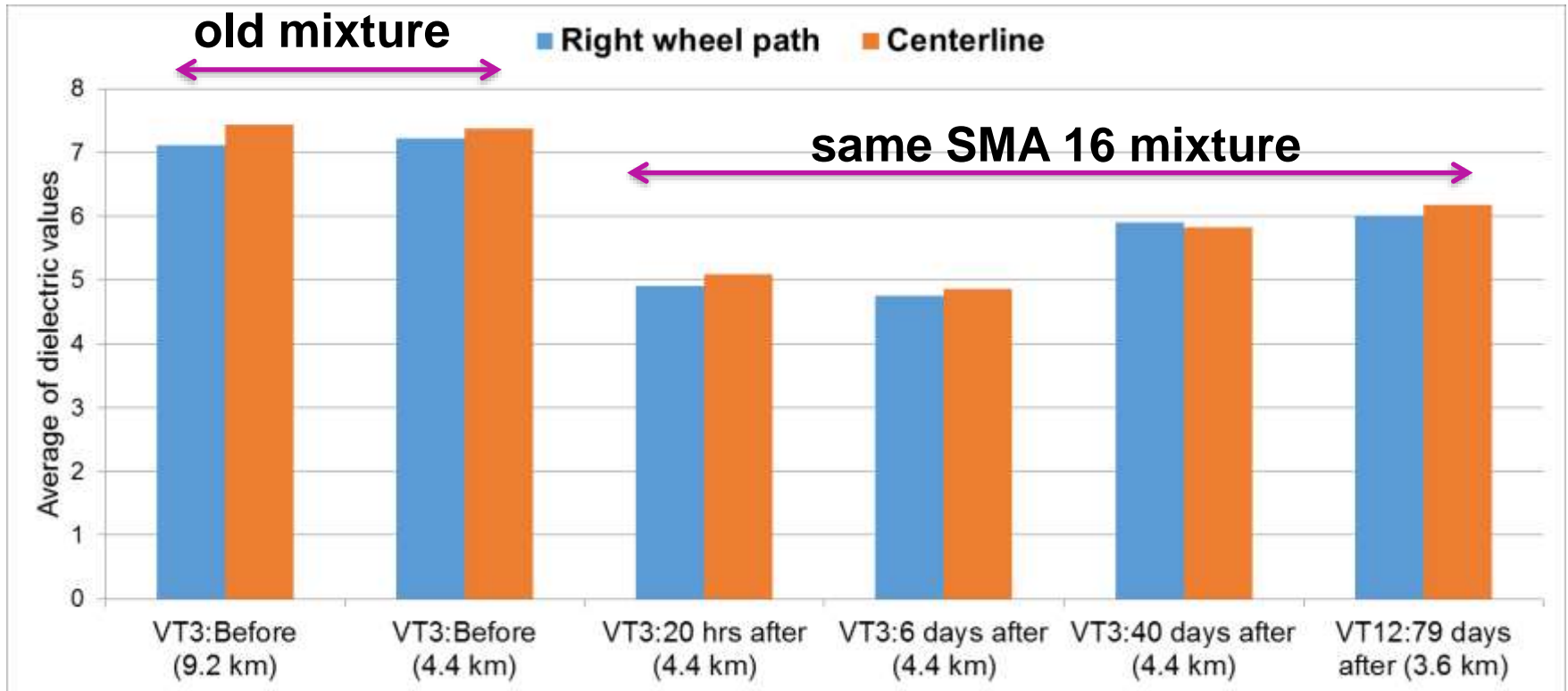
76 d



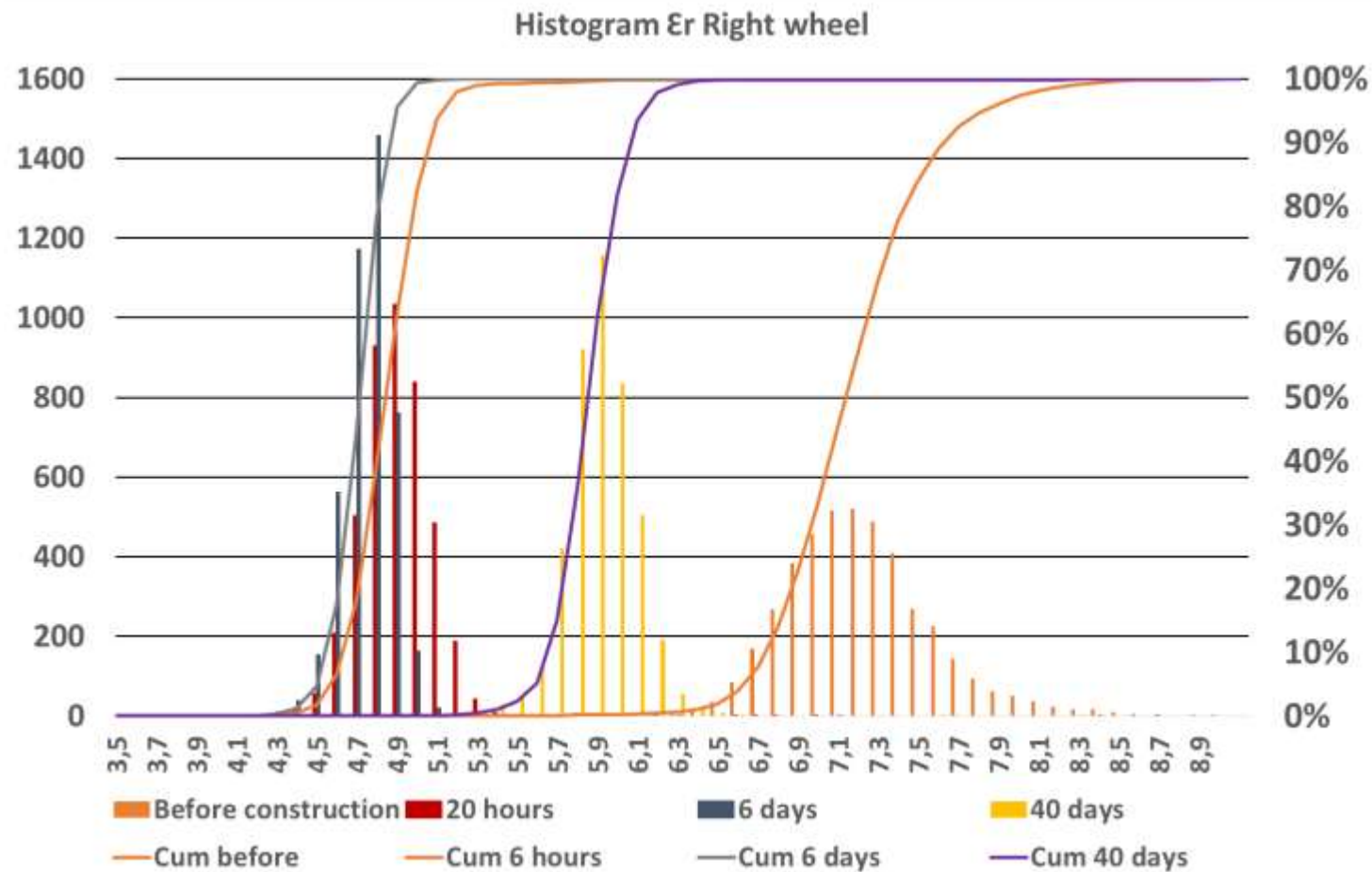
# Temperatures after paving work



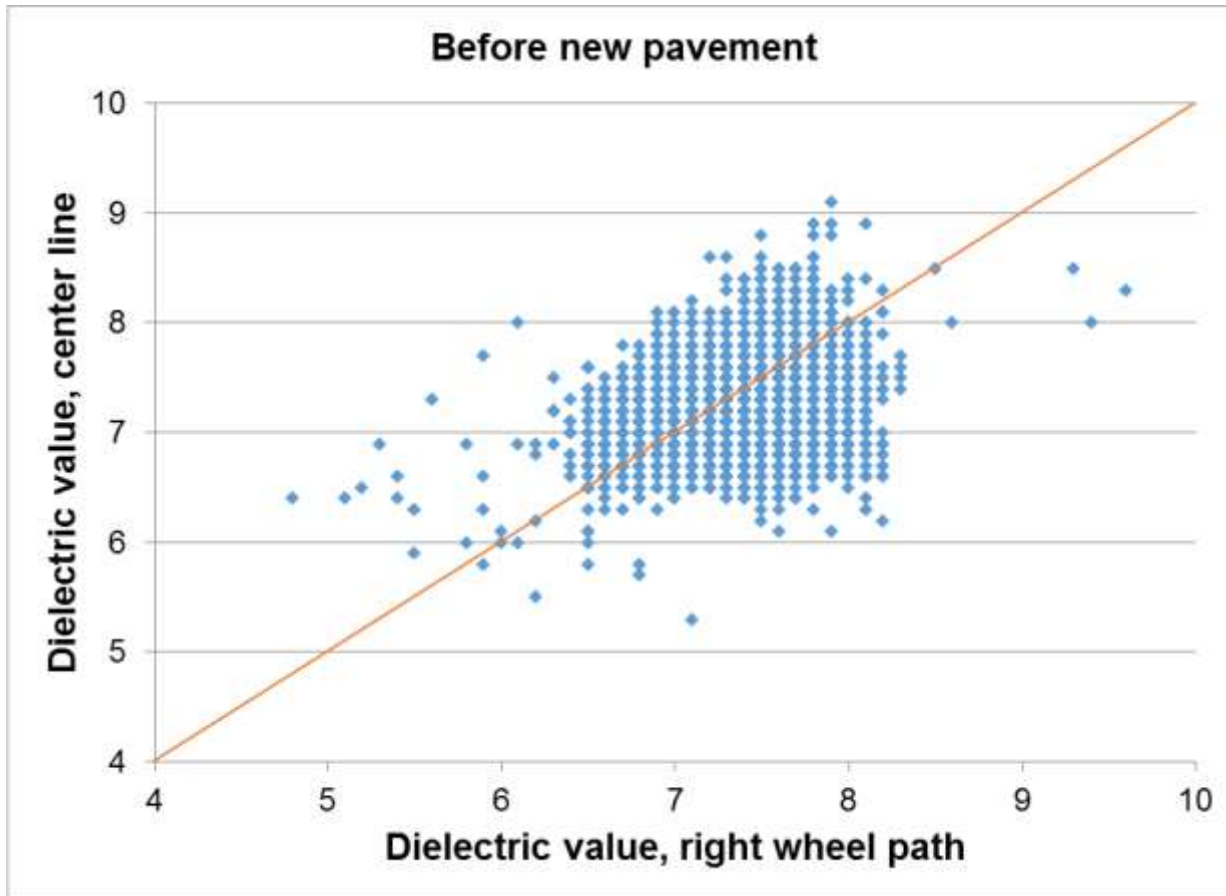
# Measured dielectric values $\epsilon_r$



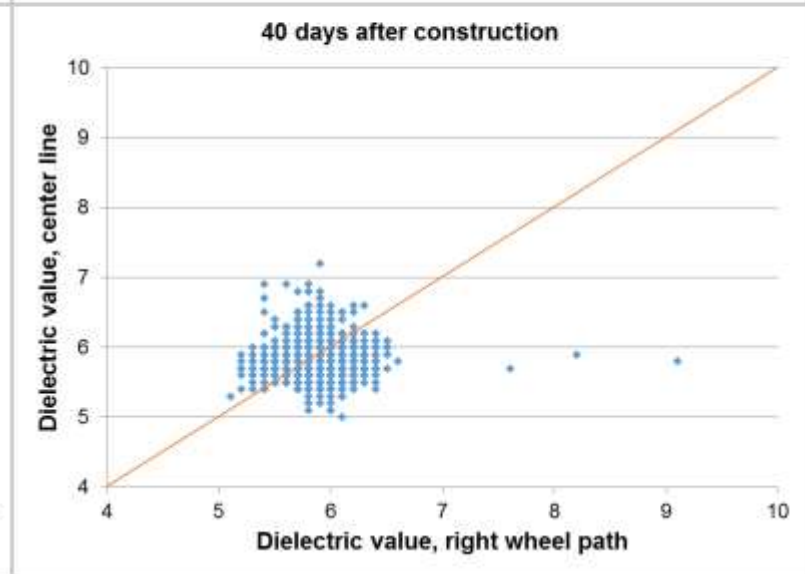
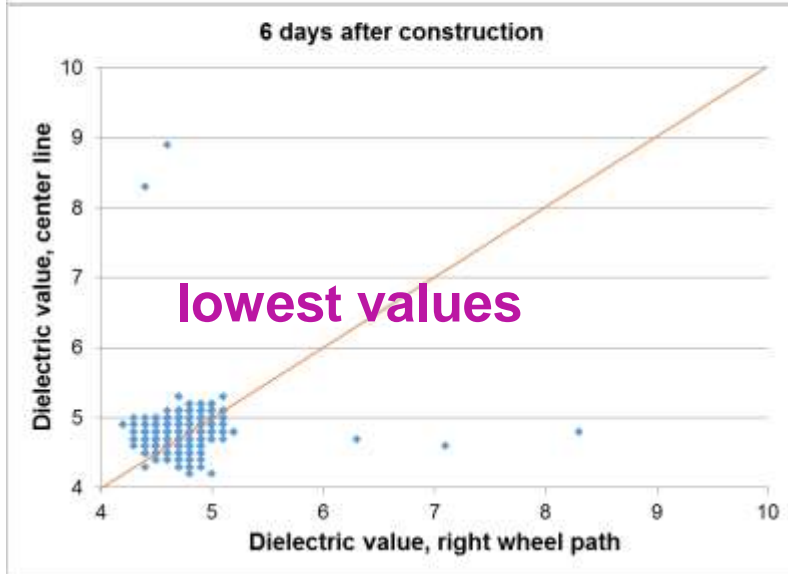
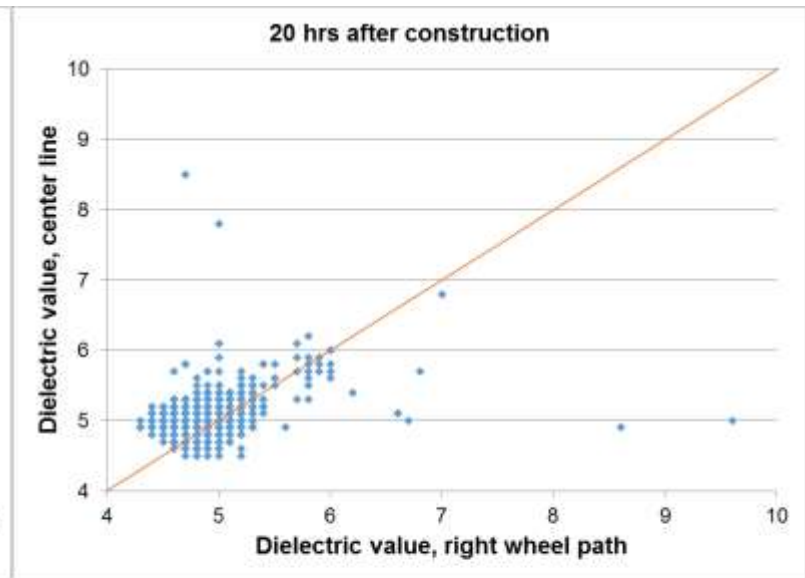
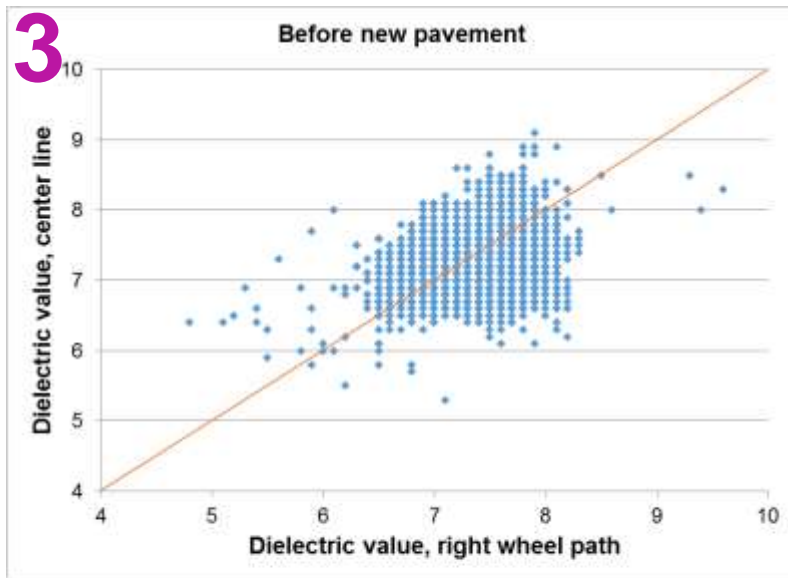
# Vt3: $\varepsilon_r$ histograms



# Vt 3: Correlation between Centerline and Right wheel path: old pavement

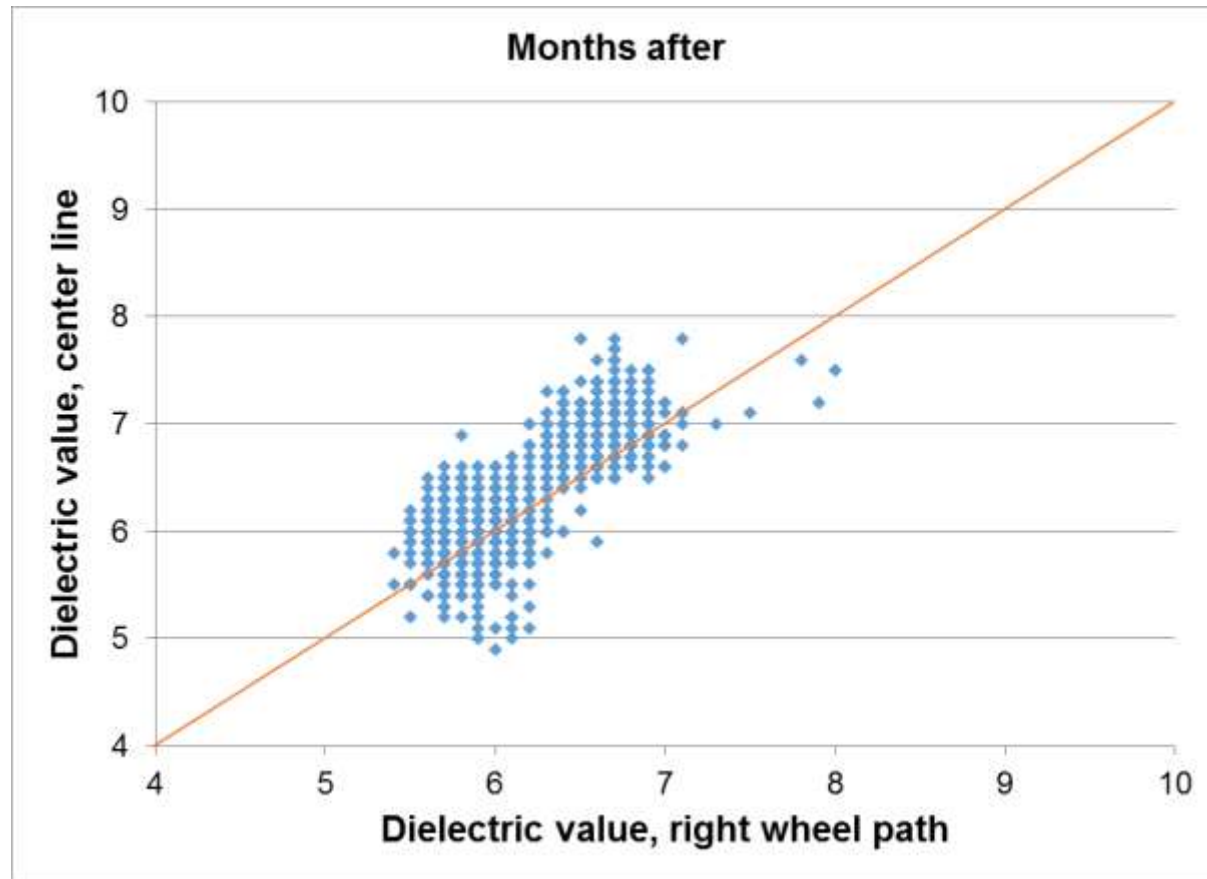


# Vt 3





# Vt 12: Correlation between Centerline and Right wheel path: 79 days after construction



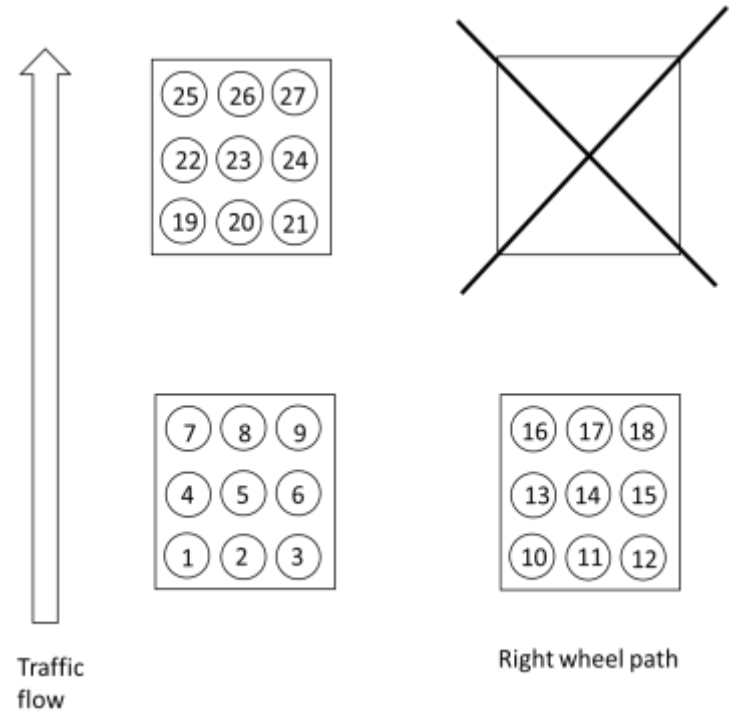
# Vt 3: Air voids for cores

Air voids			1,5 to 3,2		
SSD					
3,2	2,7	1,5			
2,1	2,1	1,6			
	1,7	1,9			
2,1	0,53				
1,9	1,9	2,1	2,3	2,6	2,8
1,9	1,7	2	1,7	3,4	2,7
2,4	1,6	1,6	2,8	2,9	3,2
1,9	0,23		2,7	0,46	

1,6 to 2,4                      1,7 to 3,4

$$\bar{x} = 2,2$$

$$s = 0,55$$



# Vt 3: Air voids vs $\epsilon_r$



Air voids					
SSD					
3,2	2,7	1,5			
2,1	2,1	1,6			
	1,7	1,9			
2,1	0,53				
1,9	1,9	2,1	2,3	2,6	2,8
1,9	1,7	2	1,7	3,4	2,7
2,4	1,6	1,6	2,8	2,9	3,2
1,9	0,23		2,7	0,46	

$$\bar{x} = 2,2$$

$$s = 0,55$$

## Stationary GPR measurements

Center line  
A

$$\epsilon_r = 5,4 (0,04)$$

Wheel path  
B

$$\epsilon_r = 5,4 (0,06)$$

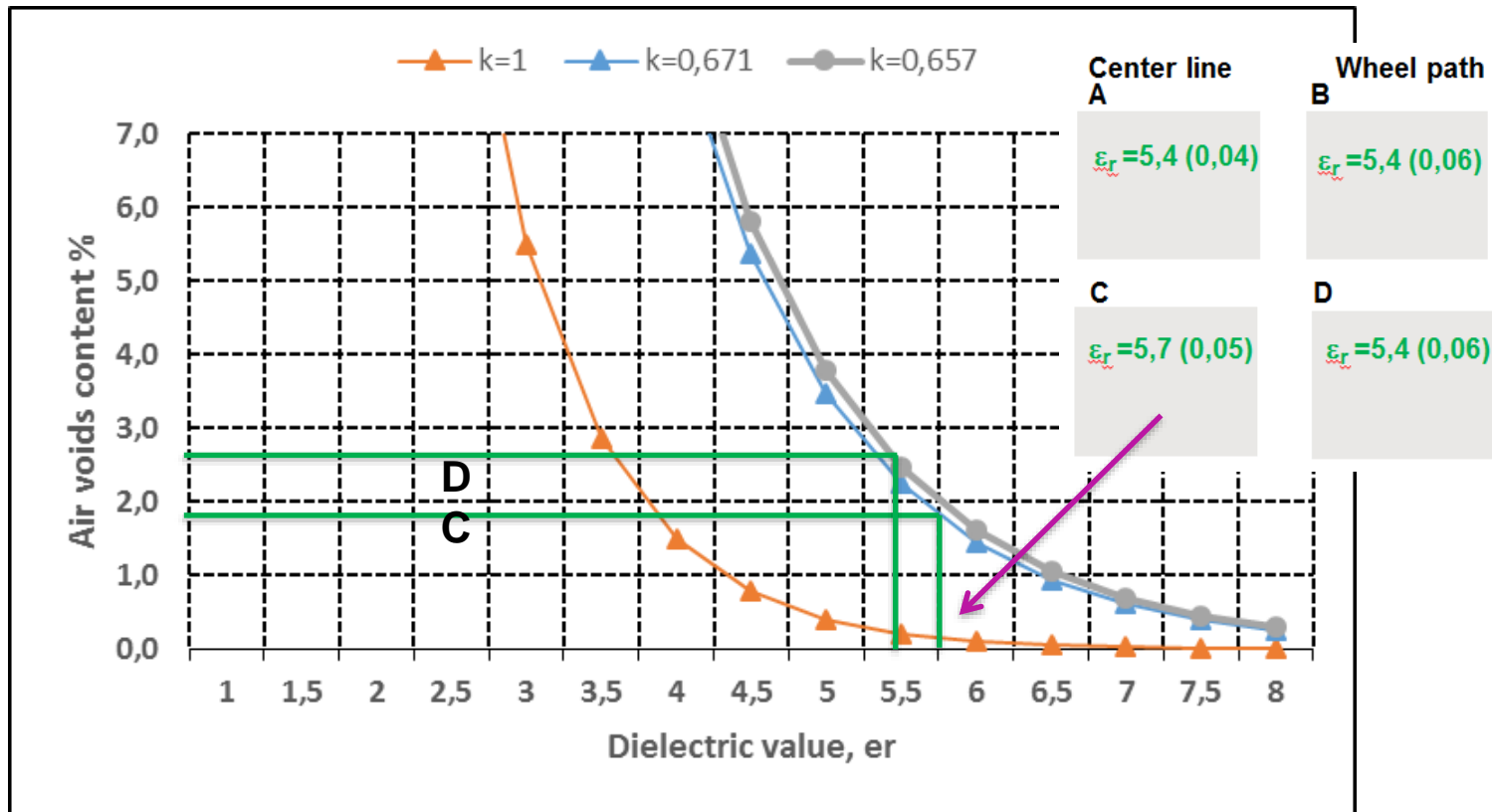
C

$$\epsilon_r = 5,7 (0,05)$$

D

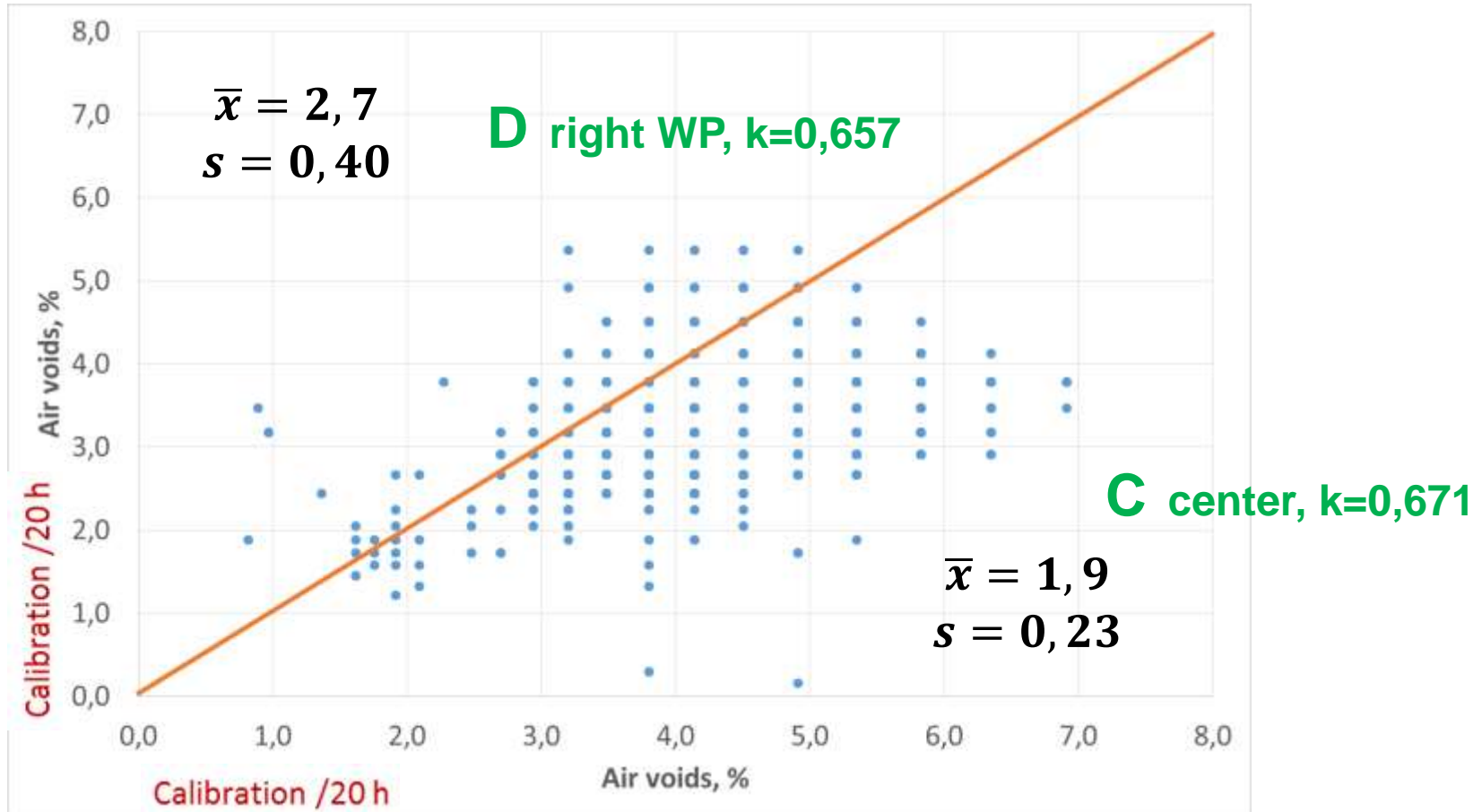
$$\epsilon_r = 5,4 (0,06)$$

# PANK-4122 Calibration



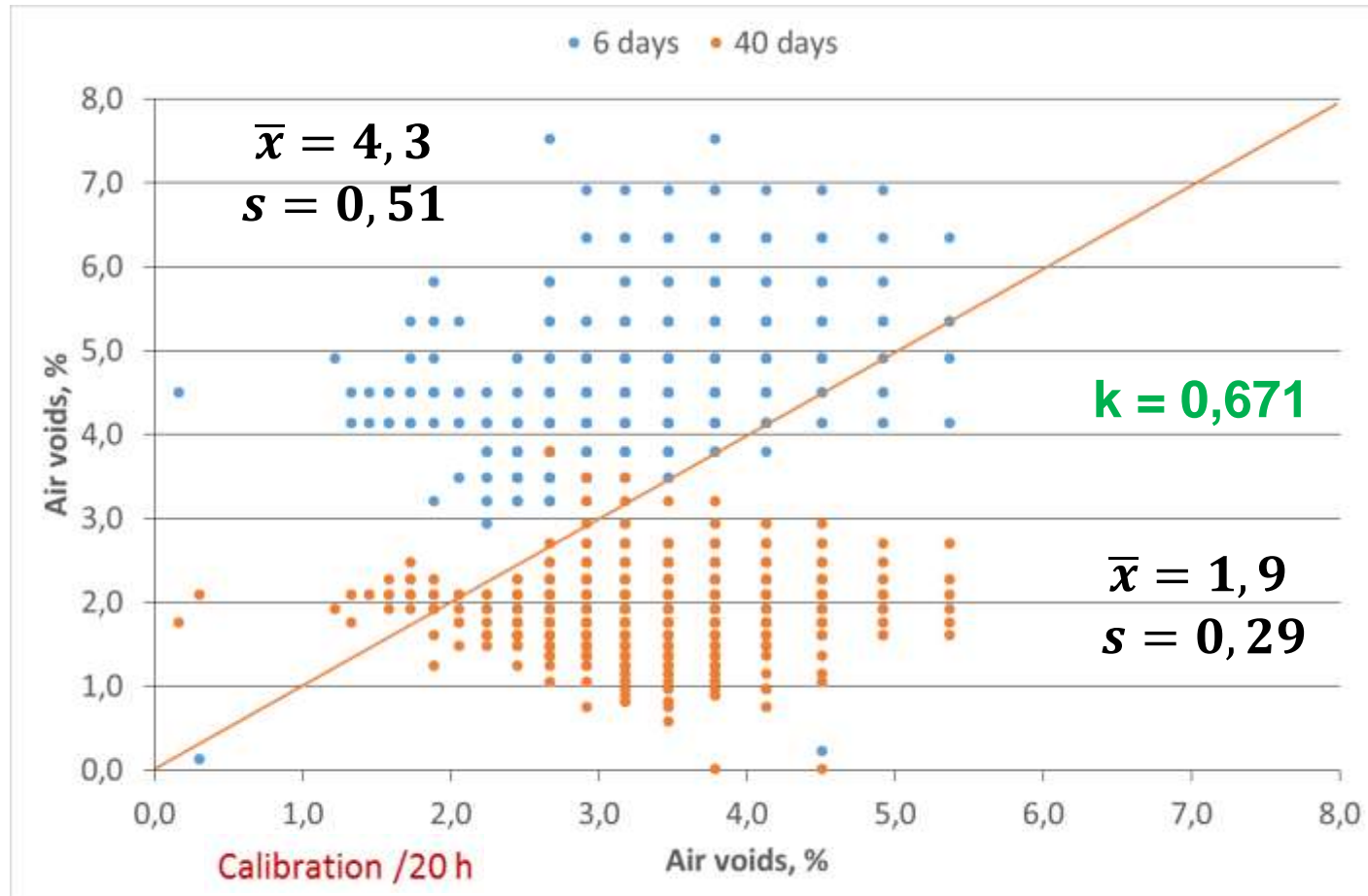
# Vt3: Calibration locations C and D

## Against independent stationary measurements



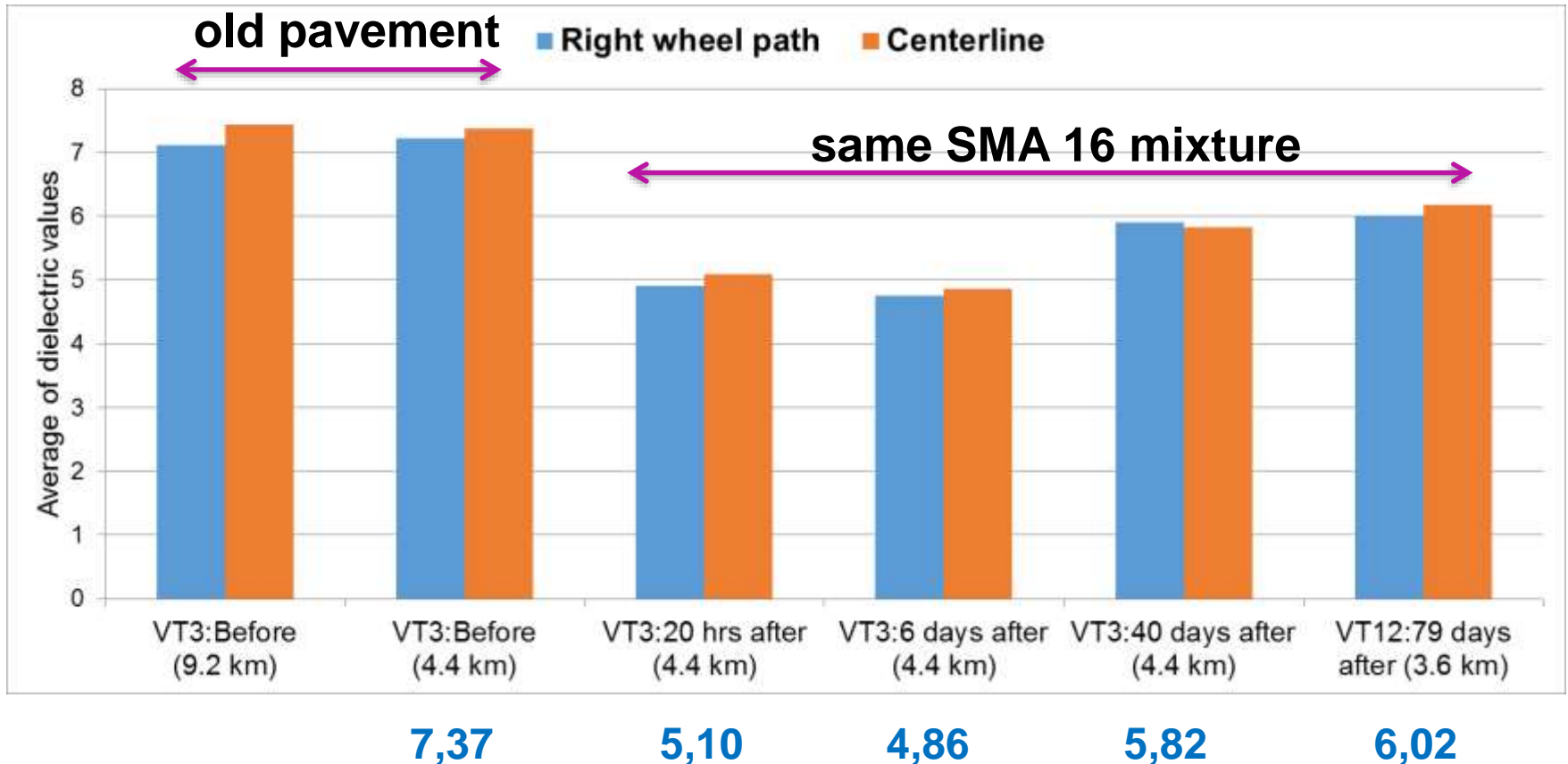
# Calibration location C center

## Against independent stationary measurements



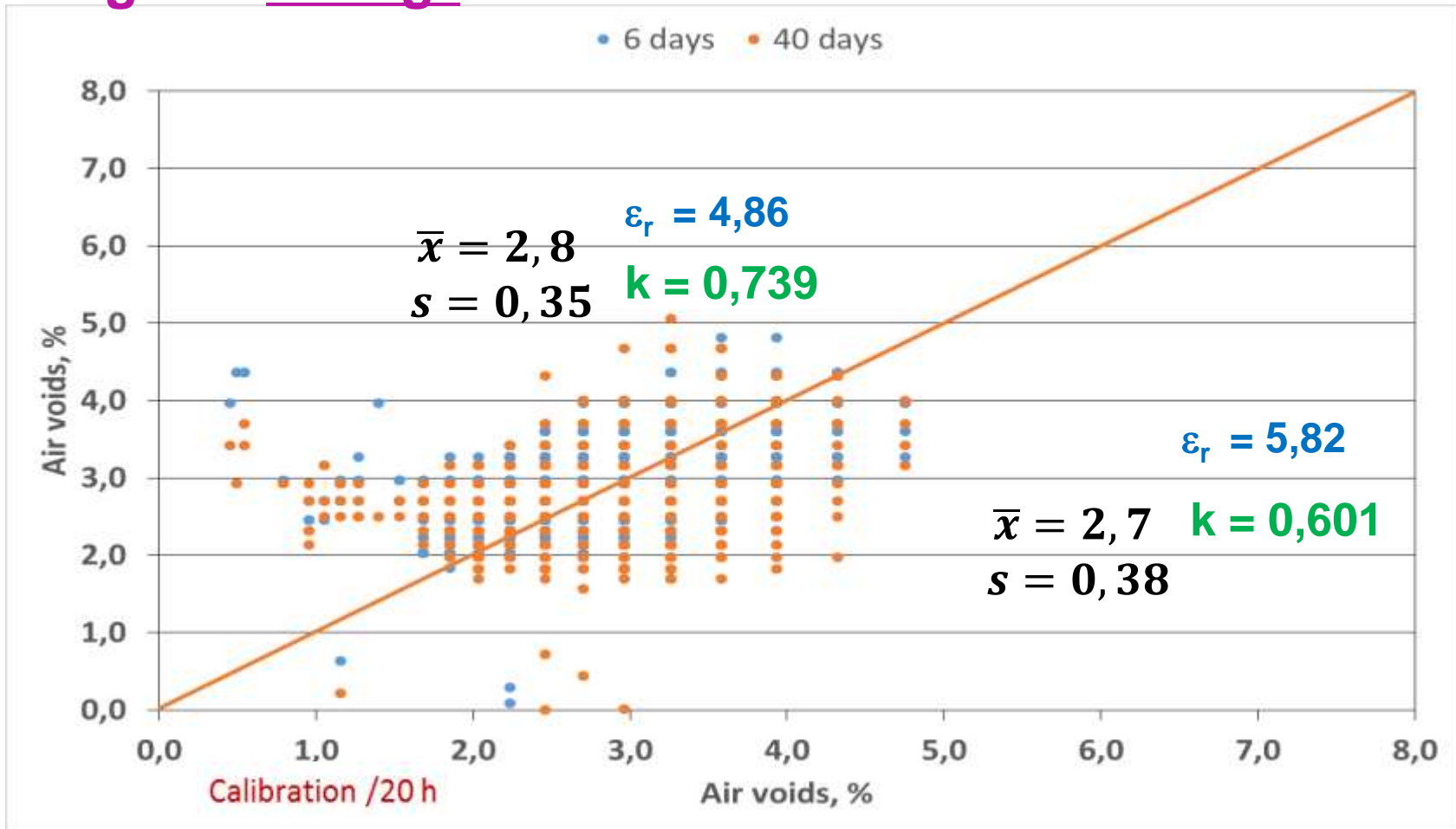


# Measured dielectric values $\epsilon_r$



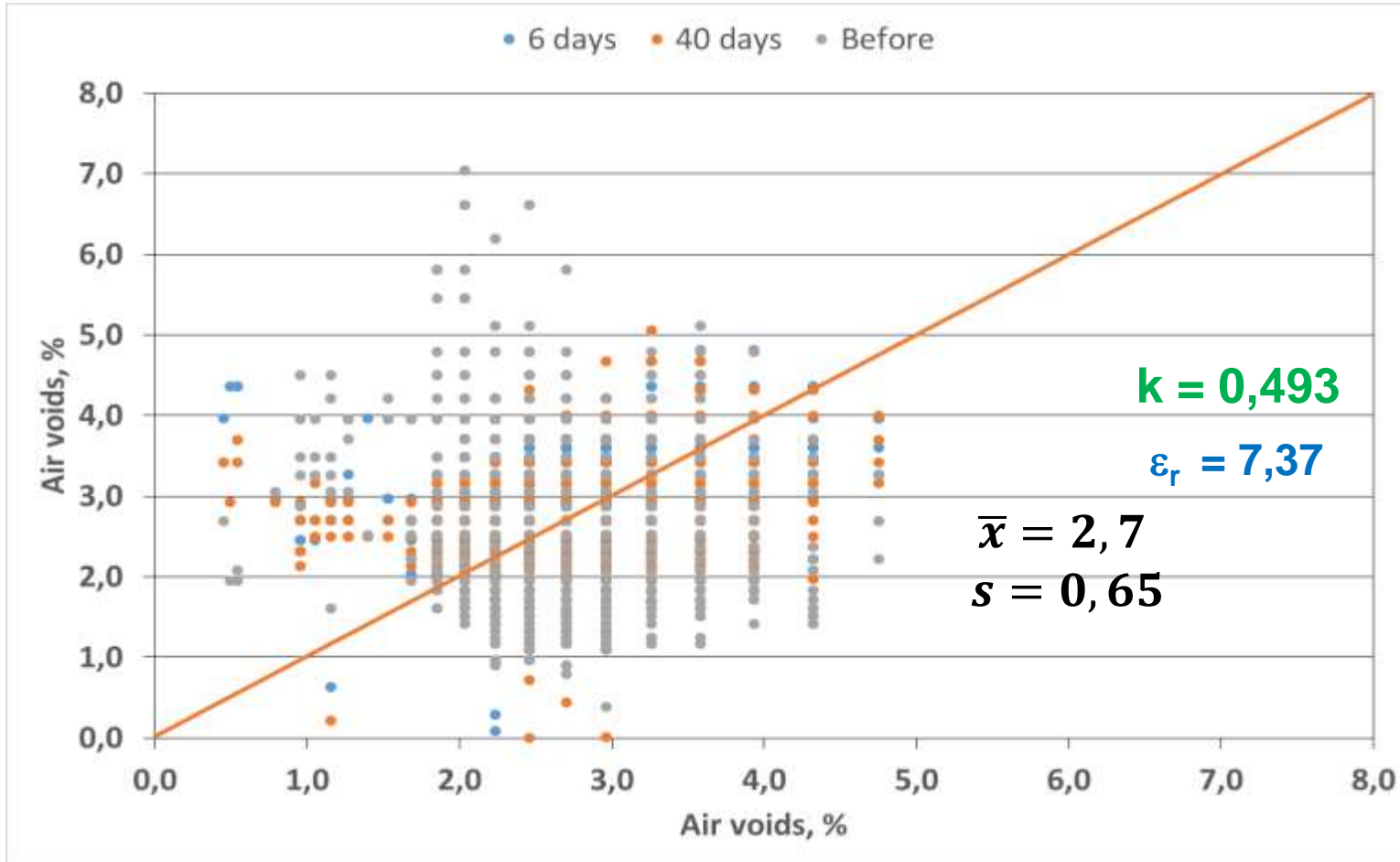
# Calibration location D right WP

Against average of measurements



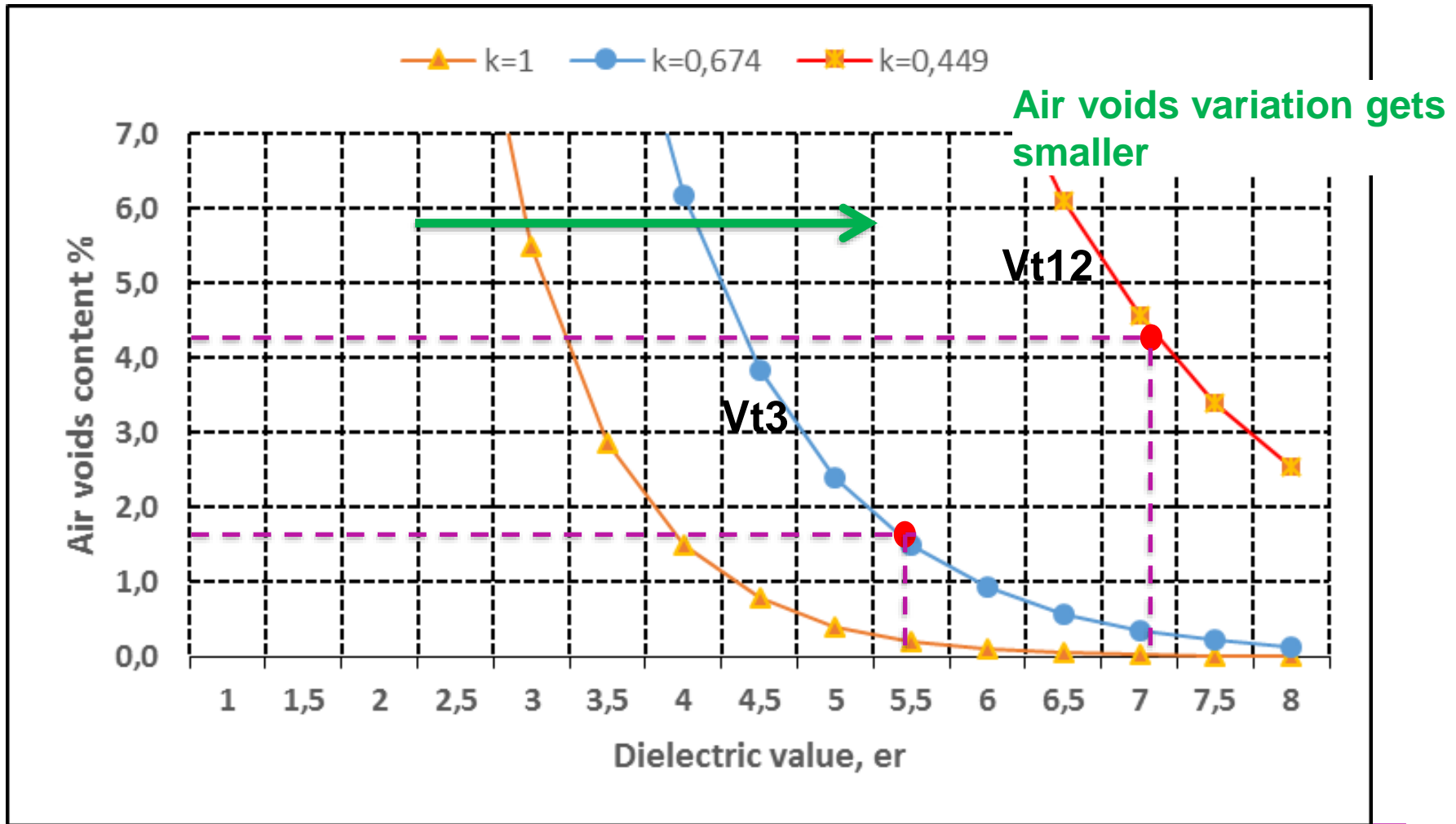
# Calibration location D right WP

Against average of measurements

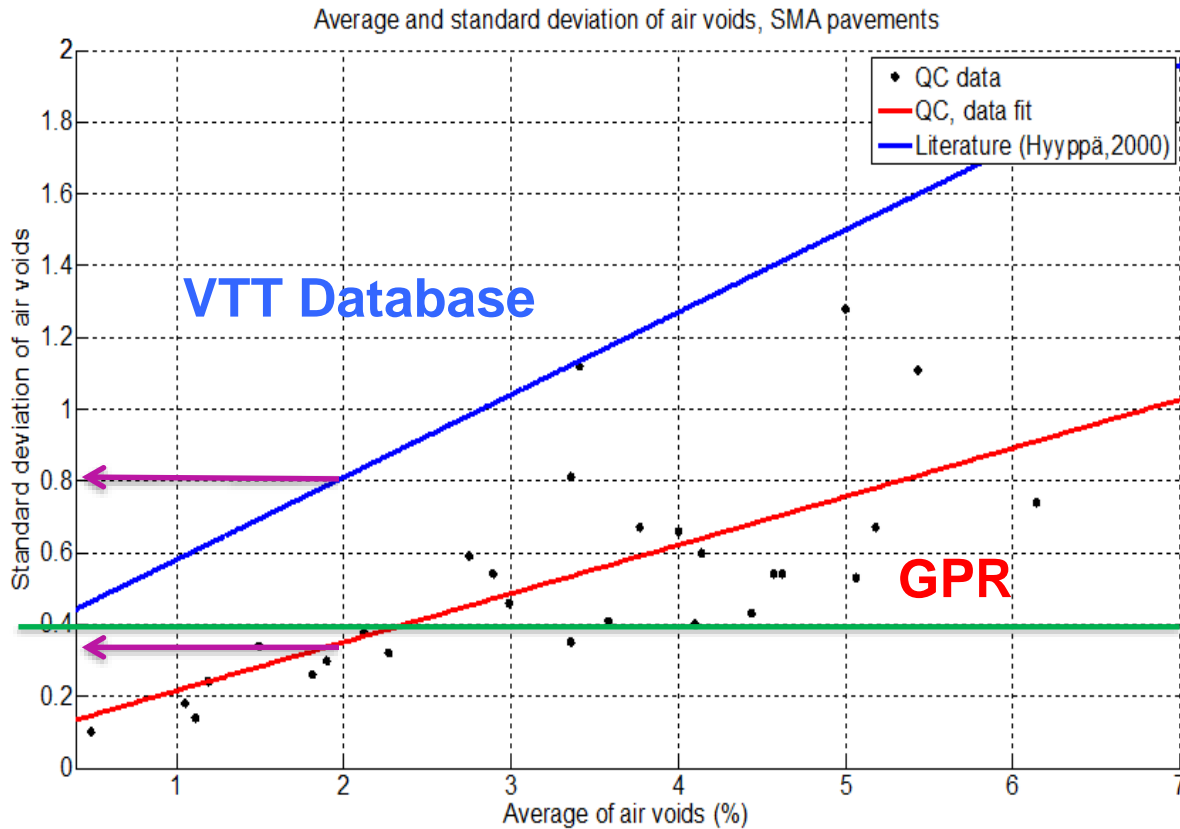


# Calibration coefficient k

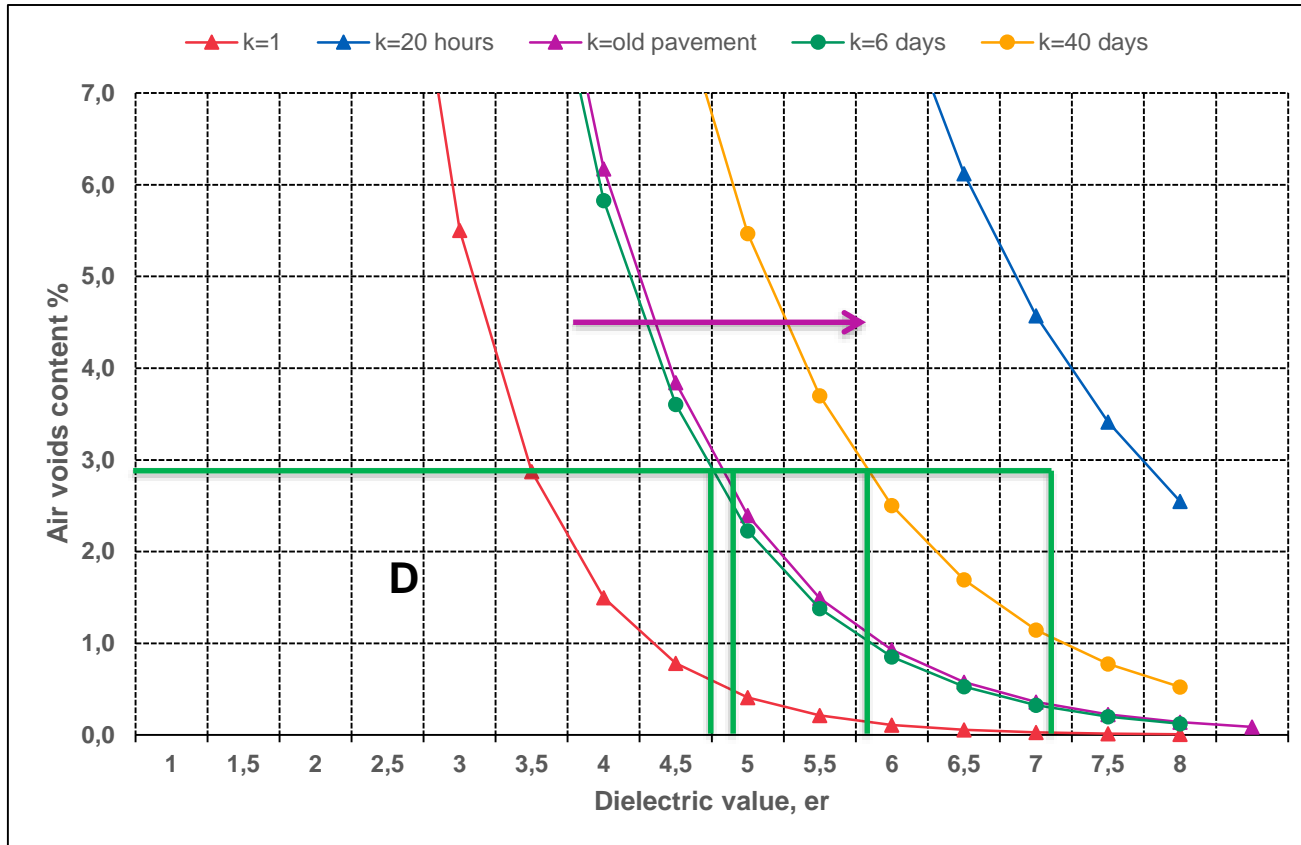
	Vt3	Vt12
$V_a$ (%)	2,2	4,2
$e_r$ (-)	5,5	7,2
k	0,674	0,449



# Cores vs. GPR measurements - variation



# PANK-4122 Calibration





# Conclusions

- **Moisture is increasing measured dielectric values**
- **Moisture increases as time elapses from construction**
- **Bulk dielectric value of  $\epsilon_r$  from 300x300mm area of measurement covers ca. 1-1.6% air voids variation**
- **Calibrating against average dielectric value  $\epsilon_r$  eliminates bias from the measurements**
  - this forces calculated average air voids to be equal of calibration core air voids → road air voids is then determined with one core
- **Shift of calibration equation towards higher dielectric values causes air void variation to decrease**

# Preliminary recommendations

- **Measurements should be done within a week before any rain to get “baseline true” dielectric value**
- **Perhaps calibration should be done with stationary measurements**
  - perhaps trial strip should be used before construction
  - mixture with no roller compaction and with maximum roller compaction (designed passes) should be measured to get the limits for the dielectric value for that site – this should be then used for calibration