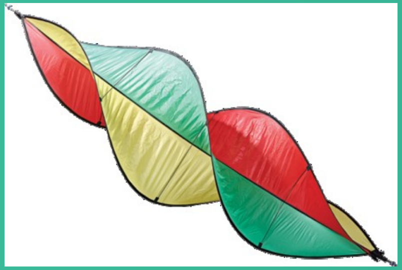
KU LEUVEN kulab

Earthquake stability of sand reclaimed areas



Experimental research through cyclic TXA-tests

Alexander Maes
Koen Surmont

Overview

- Problem and research
- Liquefaction
- Setup
- Parameterization
- Results and processing
- Conclusions

Problem

- Liquefaction occured by sand reclaimed areas
- Compaction till 90% of the maximal proctordensity is reached
- What is the critical relative density for liquefaction

Research

- What is the influence of:
  - Relative density (D_r)
  - Intensity of the acceleration during vibrations
  - Mean effective stress (p')

Liquefaction

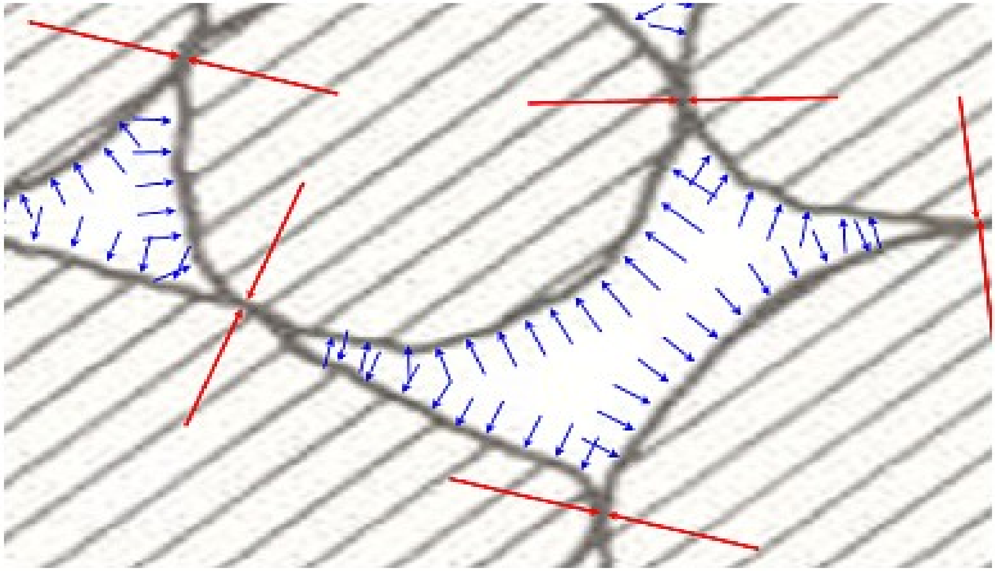
- Definition:

Describes a phenomenon whereby a saturated or partially saturated soil substantially loses strength and stiffness in response to an applied stress, usually earthquake shaking or other sudden change in stress condition, causing it to behave like a liquid.

KU LEUVEN kulab

Liquefaction

- http://www.youtube.com/watch?v=qmVYbjiNWds



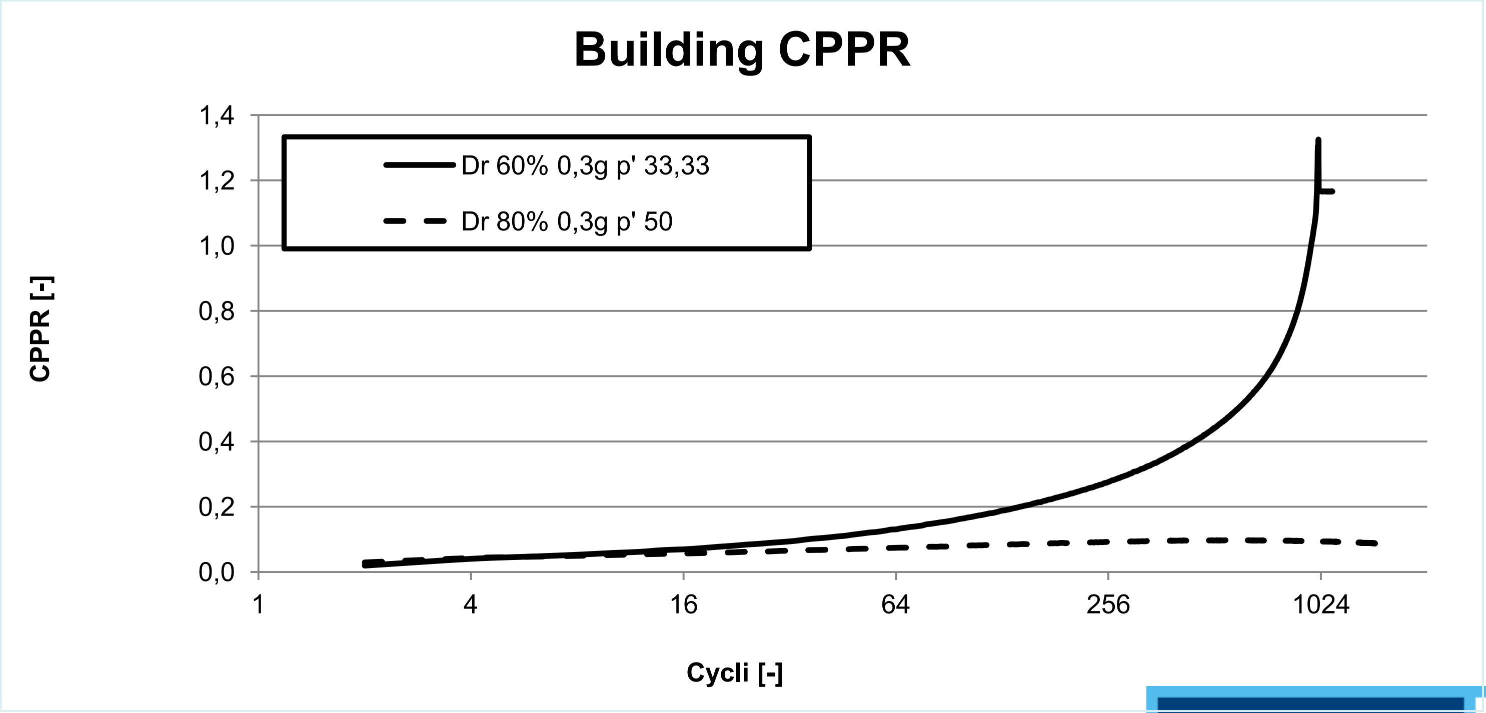
Liquefaction

- Three methodes to controle if liquefaction has occured:
  - Visually
  - CPPR
  - Pore water pressure

Liquefaction

- **CPPR: Cyclic Pore Pressure Ratio**

$$CPPR = \frac{\text{maximum excess pore pressure}}{\text{effective isotropic consolidationstress } \sigma'_{3,c}}$$



KU LEUVEN kulab

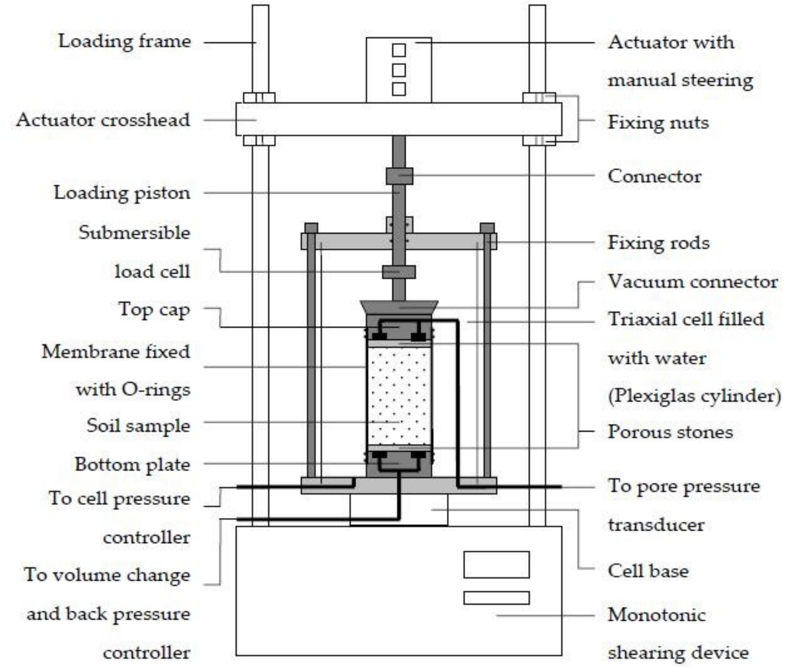
Liquefaction

- Pore water pressure
  - Measure the difference in pore water pressure during the test
  - Liquefaction degree
    - Different for every test (K_0 and p')
    - $= \frac{du}{cellpressure - backpressure}$

KU LEUVEN kulab

Setup

- Cyclic triaxialcell test device



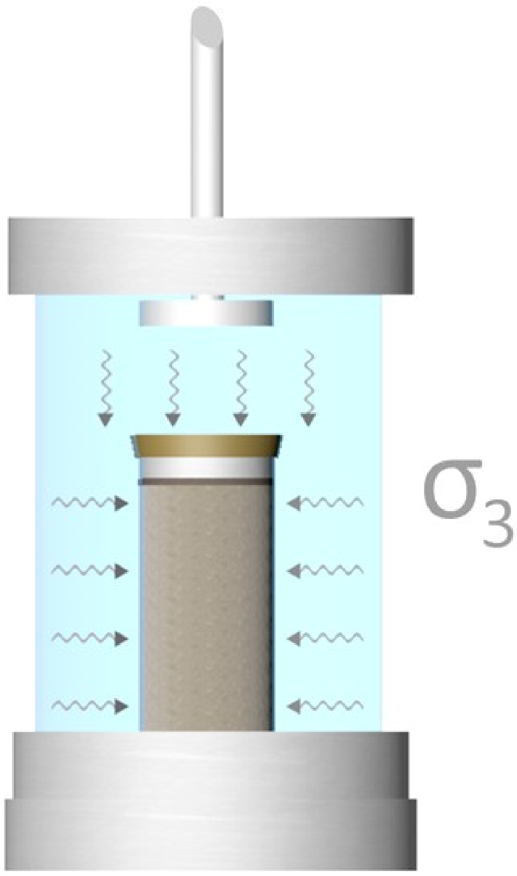
Setup

- Steps to be taken
  - Building the sample → D_r (%)
  - Fill the TXA with water
  - Replace O_2 with CO_2
  - Fill the sample with water
  - Apply 5 kPa pressure for stability
  - Build up cell and backpressure till 105 kPa, 100 kPa
  - Isotropic consolidation
  - Anisotropic consolidation
  - Test with certain cyclic load. → a (%g)

(Isotropic consolidation and Anisotropic consolidation → K_0, p')

Setup

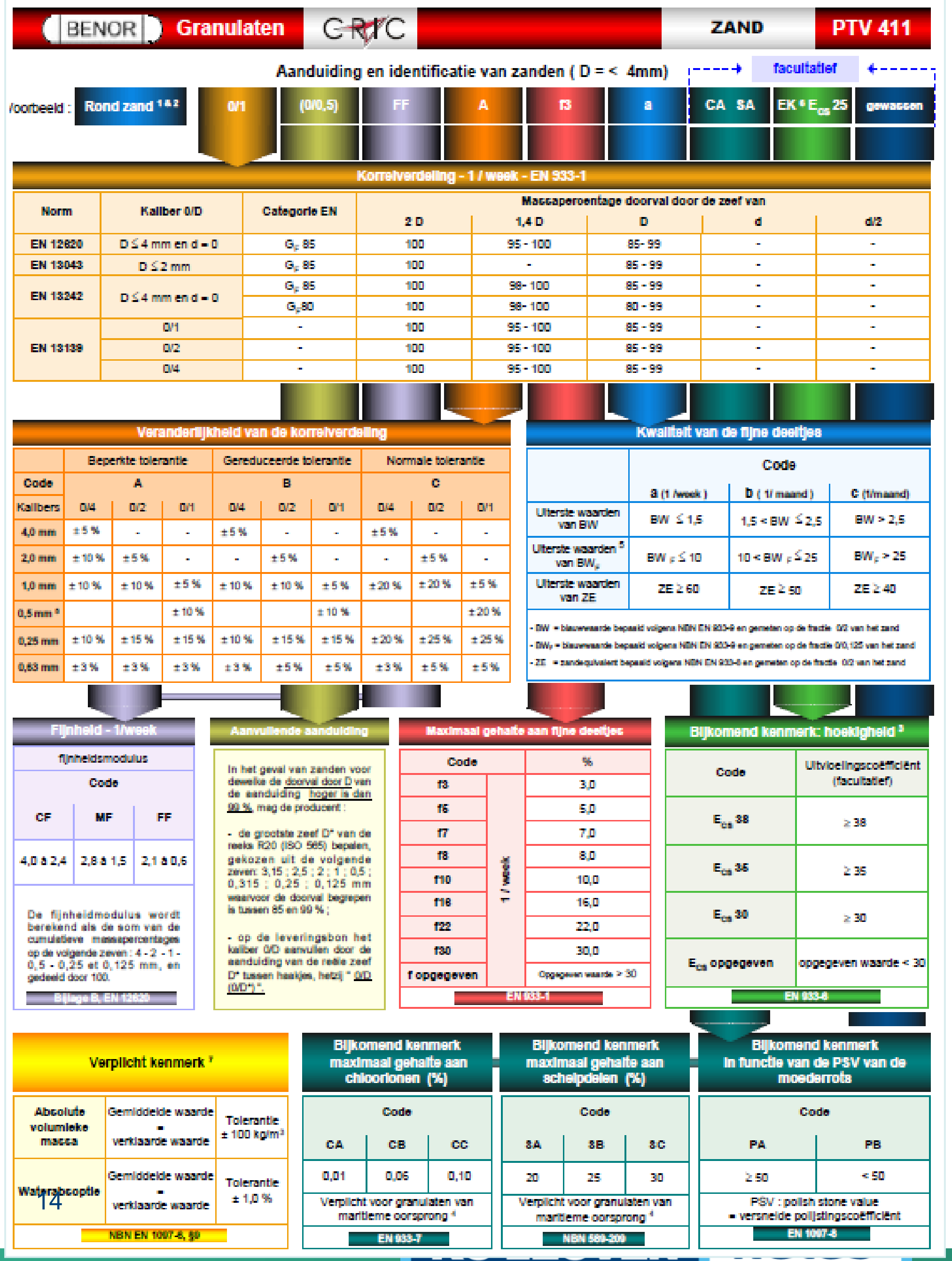
Setup



Parameterization

- PVT 411

Parameter	Result
Apparent density	1336,24 kg/m³
Absolute density	2618,35 kg/m³
Optimal water content	15,84%
minimal void ratio	0,3913
Percentage of fines	0,44%
Similarity degree	0,726
Mean grain diameter	0,140 mm
Active grain diameter	0,098 mm
Specific surface area	76,19
Lime content	7,19%
BW	0,04
BW_f	0,16
Roundness	0,25



Parametrization

- Result

0/2 FF A f3 a SA

With : **0/2** : The caliber of the sand in accordance with the grain size distribution

FF : Sand with a fineness modulus between 2,1 and 0,6
0,6

A : designation for uniform grain distribution

F3 : Maximal 3% of fine particles

a : Methylene blue value BW < 1,5

SA : Maximum lime content of 20%

Parametrization

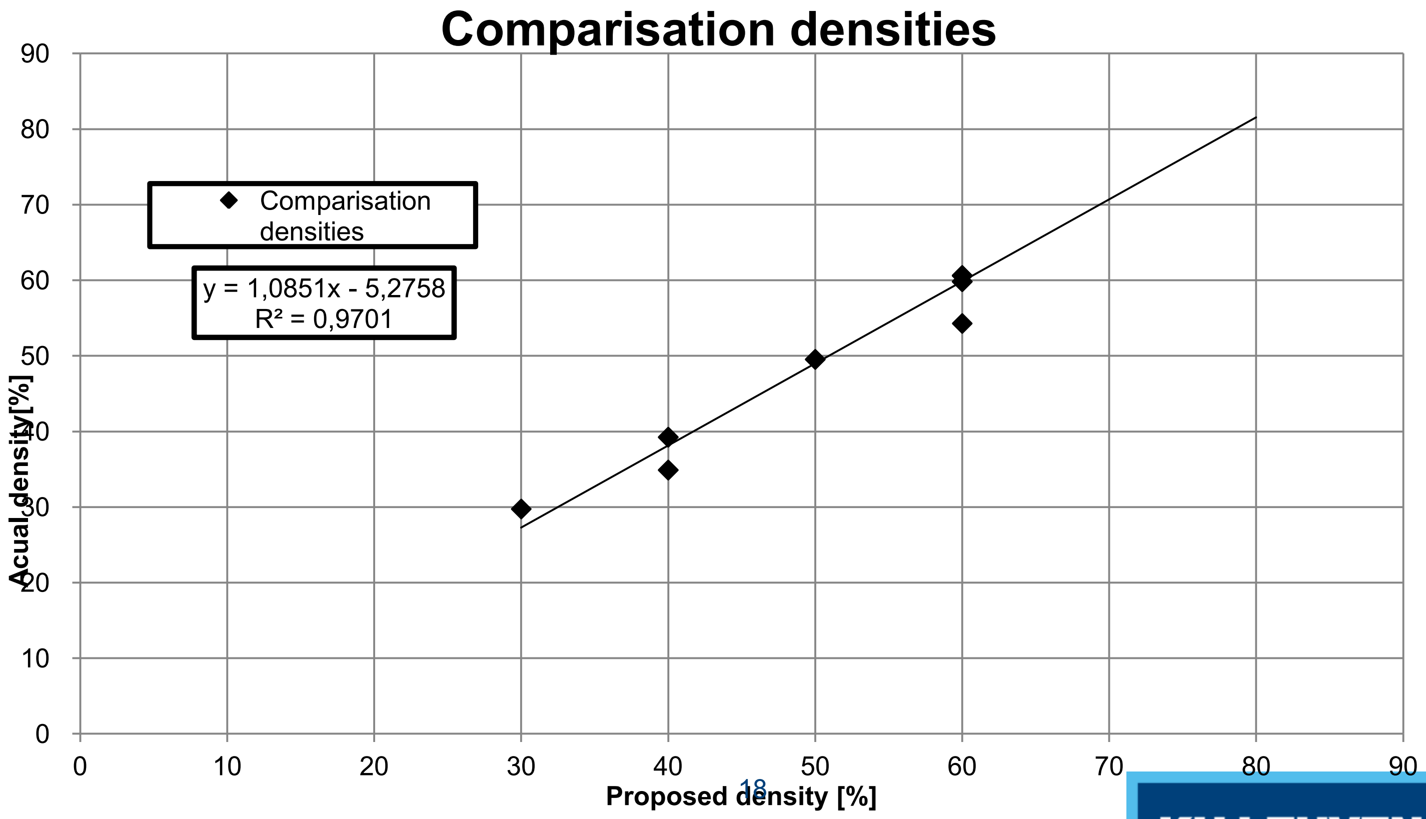
D_r [%]	γ_d [kN/m³]	W_s [%]	$W_{20\%}$ [%]	$W_{70\%}$ [%]	n [-]	e [-]
0	13,11	36,57	7,31	25,60	0,490	0,959
10	13,36	35,16	7,03	24,61	0,480	0,922
20	13,61	33,80	6,76	23,66	0,470	0,887
30	13,87	32,49	6,50	22,74	0,460	0,852
40	14,12	31,23	6,25	21,86	0,450	0,819
50	14,37	30,01	6,00	21,00	0,440	0,787
60	14,62	28,83	5,77	20,18	0,431	0,756
70	14,88	27,69	5,54	19,38	0,421	0,727
80	15,13	26,59	5,32	18,62	0,411	0,698
90	15,38	25,53	5,11	17,87	0,401	0,670
100	15,64	24,50	4,90	17,15	0,391	0,643

Results and processing

- 3 sets
  - Set 1: Getting familiar with the setup – validation
  - Set 2: Vary the relative density (D_r)
  - Set 3: Building the cyclic loads (%g)

Results and processing

- Density
  - Actual density ≈ proposed density



Results and processing

- When does liquefaction occur
  - Visually
  - CPPR-value > 1
  - Pore water pressure
- New method
  - Axial deformation

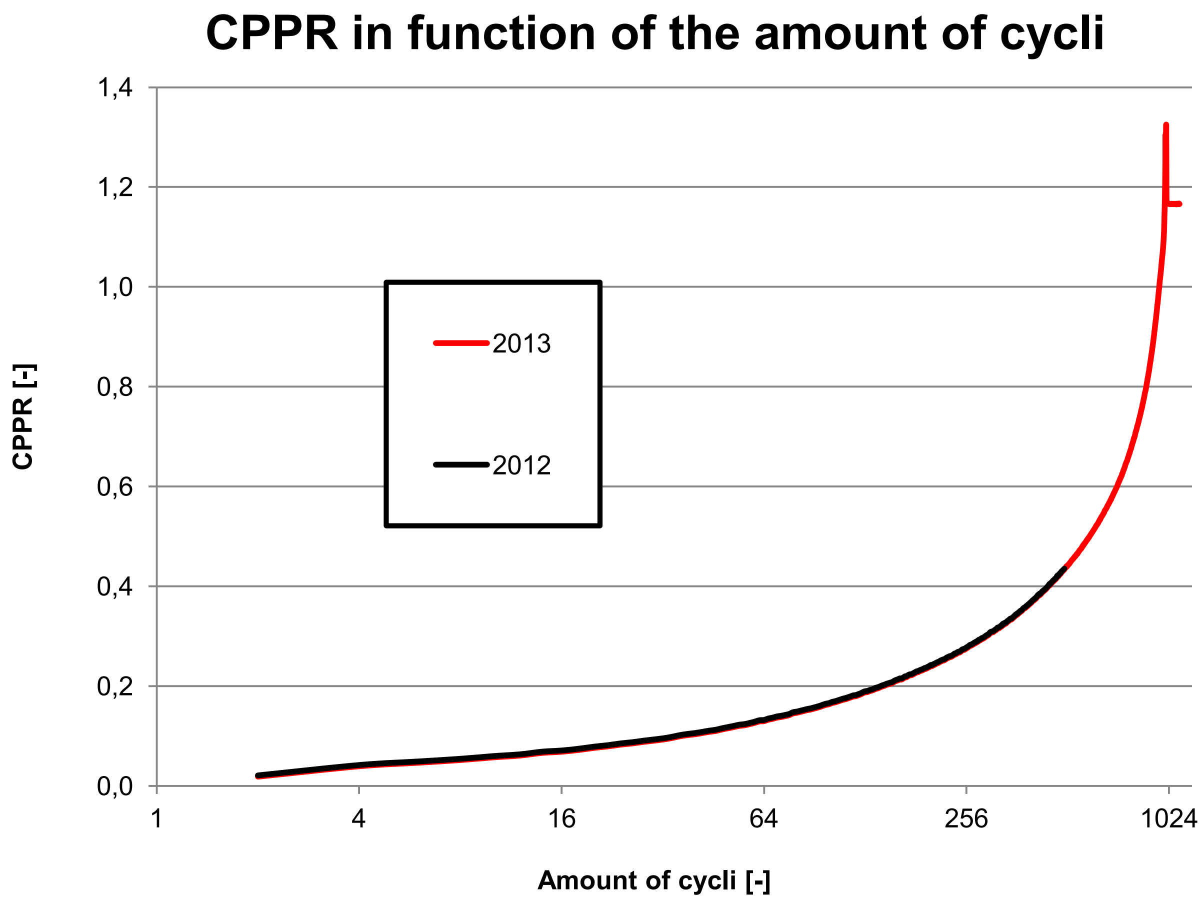
Results and processing

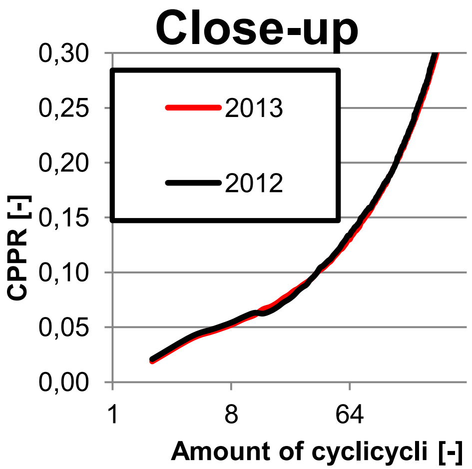
- Set 0: Boundery conditions
  - Relative density (D_r) = 60%
  - Frequence = 2 Hz
  - K-value = 0,74
  - Accelleration (a) = 0,3g
  - Mean effective stress (p’) = 33,33 kPa
  - Amount of cycli = 1500

Results and processing

- Set 0: Comparisation
  - Test Tournoy & Popeye: 500 cycli
    - No liquefaction
  - Test Maes & Surmont: 1500 cycli
    - Liquefaction after 998 cycli
  - The values correspond to eachother

Results and processing





Results and processing

- Set 1: Overview tests

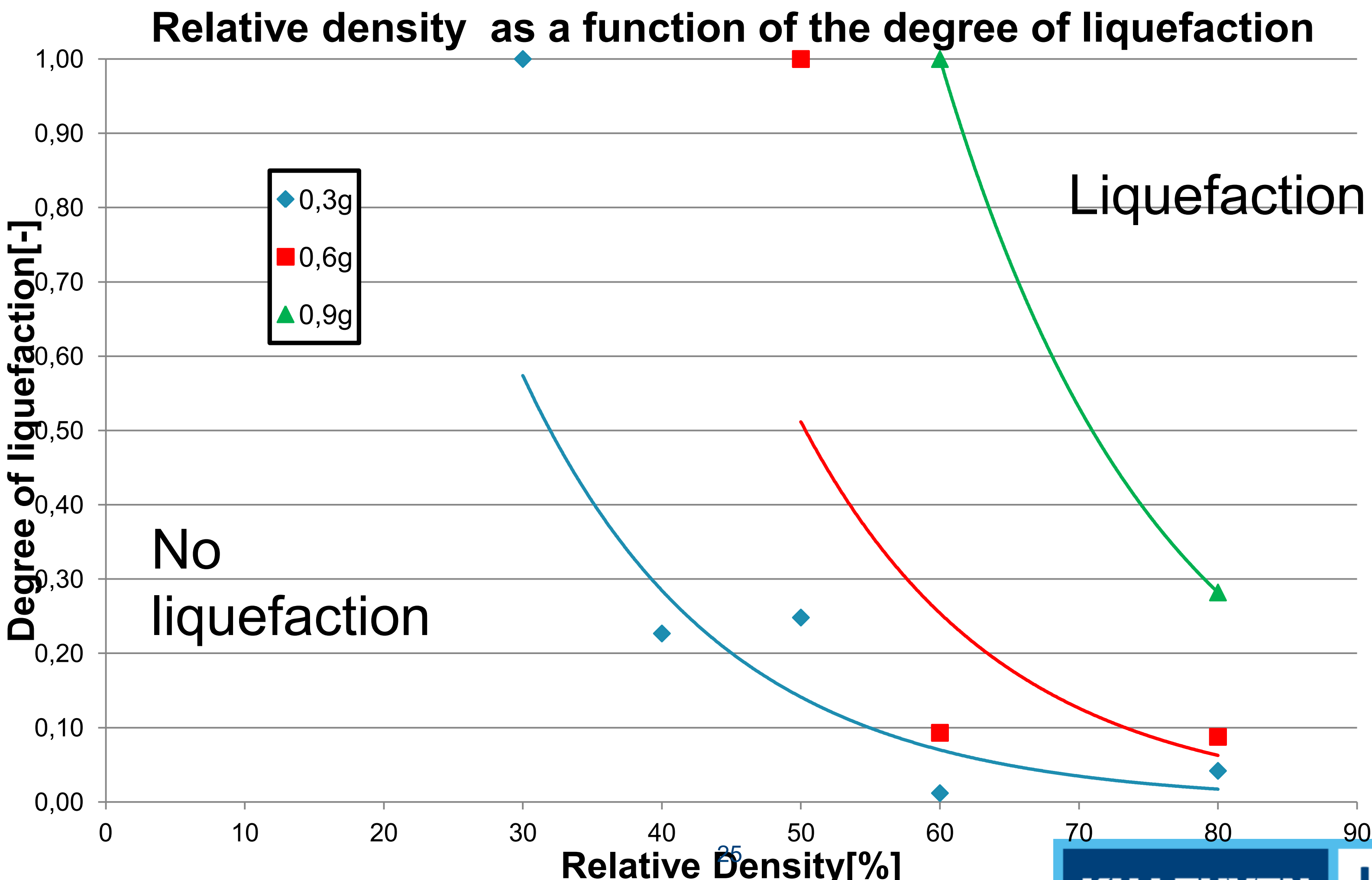
	D_r[%]	K_0[-]	a [m/s²]	Frequence [Hz]	p' [kPa]	Remarks
1	30	0,82	0,3	2	50	Liquefaction at 712 cycli
2	40	0,82	0,3	2	50	No liquefaction
3	40	0,82	0,6	2	50	Liquefaction at 32 cycli
4	50	0,82	0,3	2	50	No liquefaction
5	50	0,82	0,6	2	50	Liquefaction at 6 cycli
6	60	0,82	0,3	2	50	No liquefaction
7	60	0,82	0,6	2	50	No liquefaction
8	60	0,82	0,9	2	50	Liquefaction at 1350 cycli
9	80	0,82	0,3	2	50	No liquefaction
10	80	0,82	0,6	2	50	No liquefaction
11	80	0,82	0,9	2	50	No liquefaction

Results and processing

- Set 1: Overview results

	LIQUEFACTION - CYCLI			NO LIQUEFACTION
	CPPR [-]	DU [-]	PORE/CELL [-]	LIQUEFACTION DEGREE [%]
1	712	712	712	
2				22,22
3	32	30	32	
4				24,91
5	6	6	6	
6				1,2
7				9,45
8	1350	1350	1350	
9				4,18
10				8,77
11				28,24

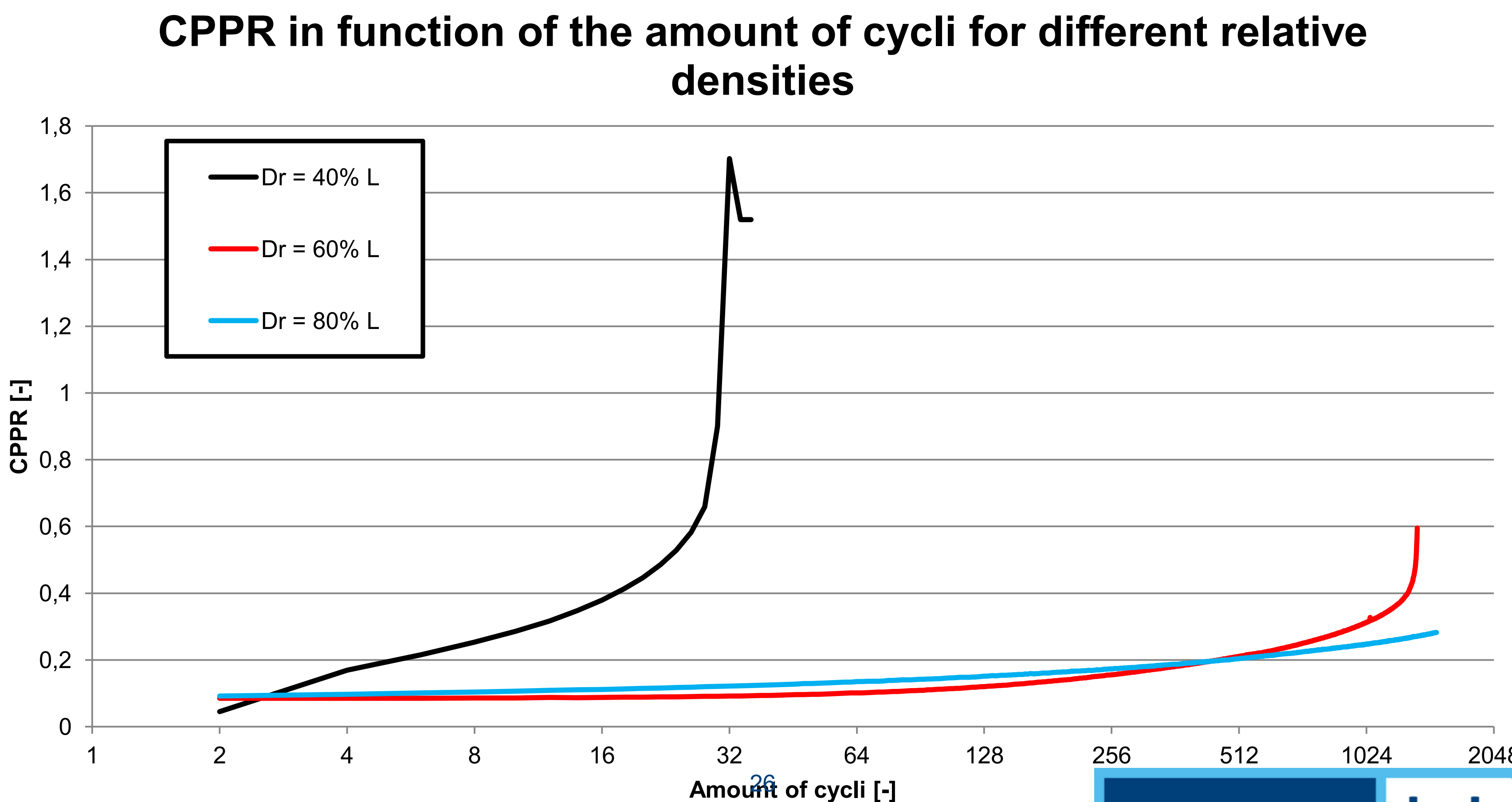
Results and processing



KU LEUVEN kulab

Results and processing

- Set 1: Results



KU LEUVEN kulab

Results and processing

- Set 2: overview tests

	D_r[%]	K_0[-]	a [m/s²]	Frequence [Hz]	p' [kPa]	Remarks
1	60	0,82	0,1	2	50	No liquefaction
2	60	0,82	0,2	2	50	No liquefaction
3	60	0,82	0,3	2	50	No liquefaction
4	60	0,82	0,4	2	50	No liquefaction
5	60	0,82	0,5	2	50	No liquefaction
6	60	0,82	0,6	2	50	No liquefaction
7	60	0,82	0,7	2	50	No liquefaction
8	60	0,82	0,8	2	50	Liquefaction at 898 cycli
9	60	0,82	0,9	2	50	Liquefaction at 12 cycli

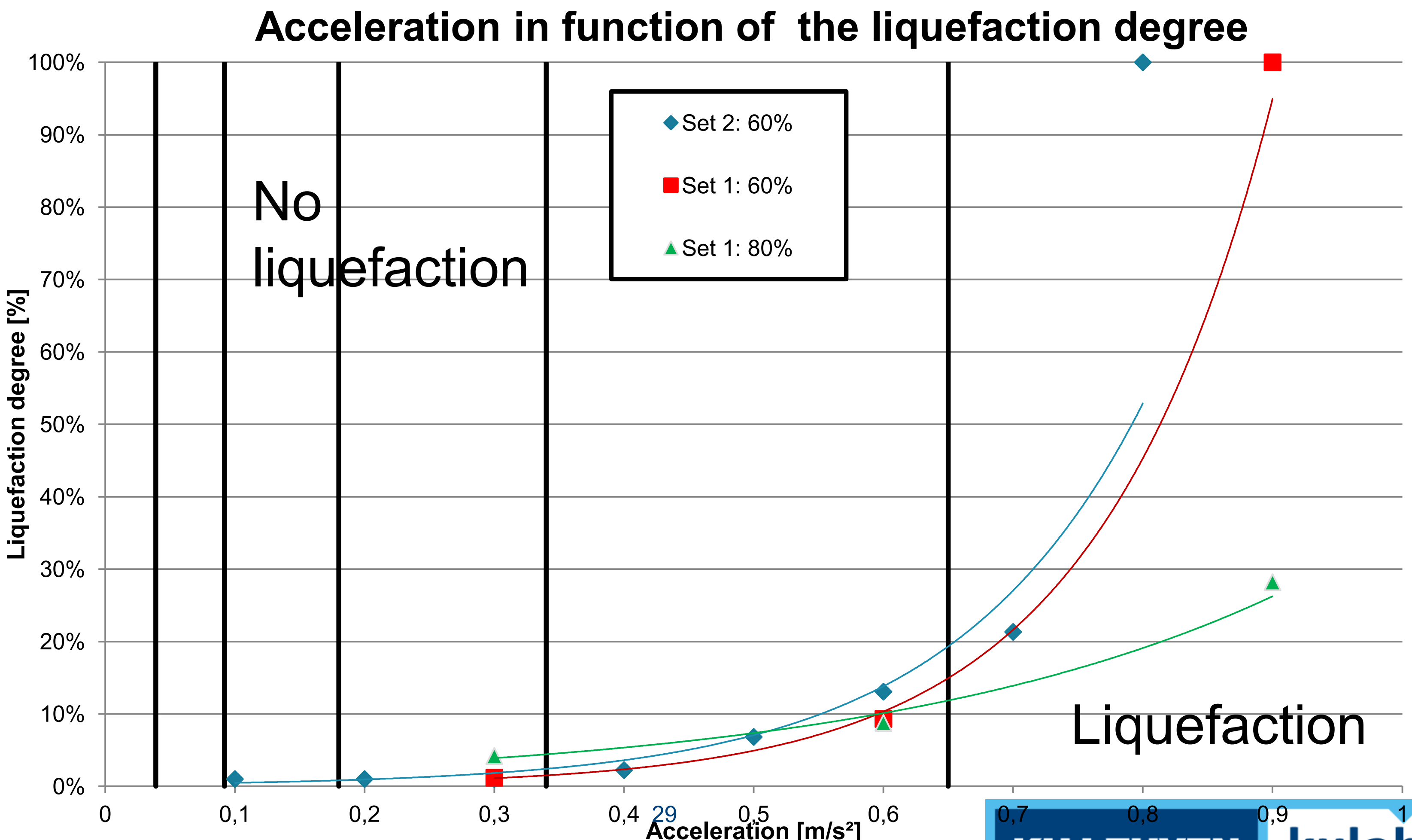
Results and processing

- Set 2: overview results

	LIQUEFACTION - CYCLI			NO LIQUEFACTION
	CPPR [-]	DU [-]	PORE/CELL [-]	LIQUEFACTION DEGREE [%]
1				≈ 0
2				≈ 0
3				≈ 0
4				2,18
5				6,65
6				12,76
7				20,18
8	898	898	898	
9	12	12	12	

Results and processing

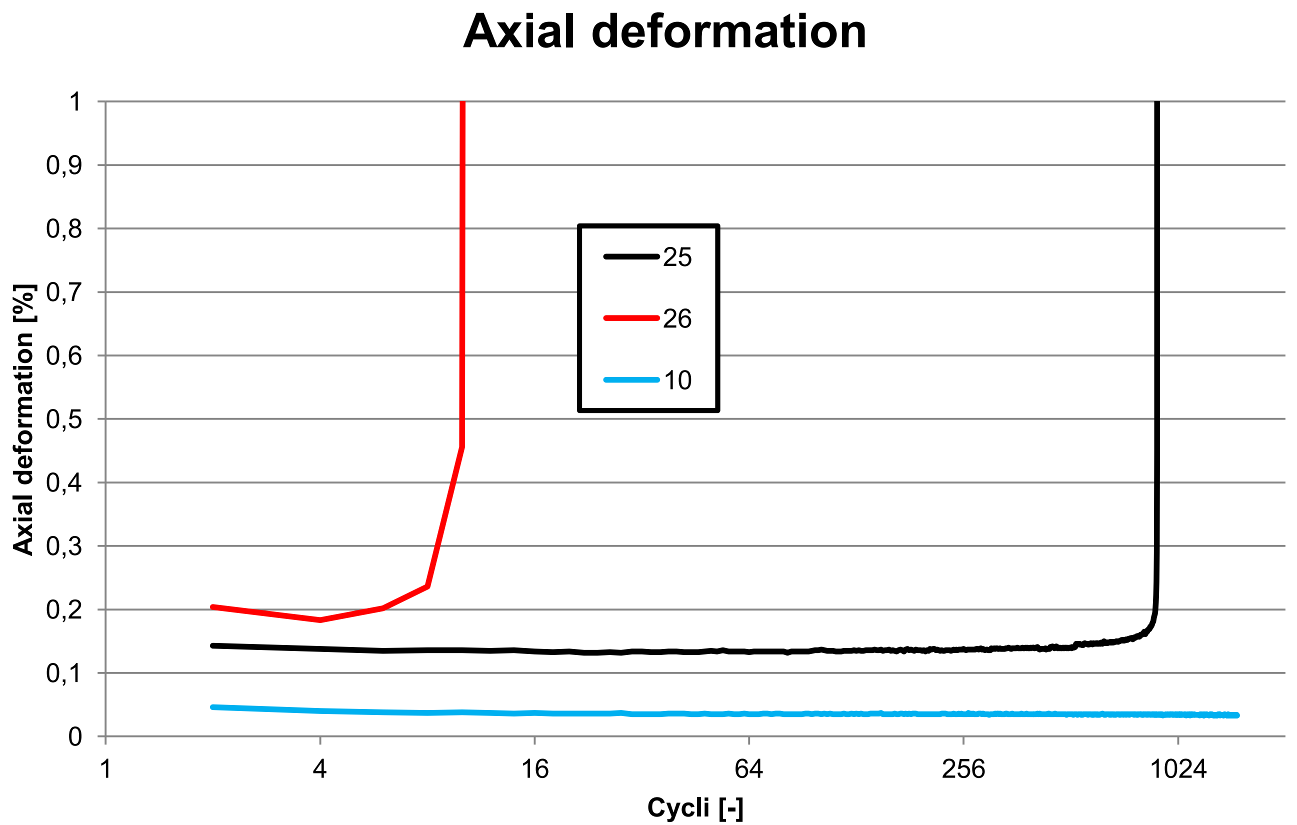
- Set 2: results



KU LEUVEN kulab

Results and processing

- Axial deformation



KU LEUVEN kulab

Results and processing

- Axial deformation
  - No liquefaction = maximal deformation = 0,1427%
  - Liquefaction = minimal deformation = 3,4403%

Conclusion

- Axial deformation has a threshold value
- How higher the K0-value, how faster liquefaction will occur
- How higher the relative density, how slower liquefaction will occur
- How higher the acceleration, how faster liquefaction occurs

Questions?