



Sea Loads on Vertical Cylinder Groups induced by JONSWAP Spectra

Diploma Thesis

Part of the DFG-Project „Investigations on Wave Loadings of Cylindrical Marine Structures“

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Background

- Wide field of application of cylindrical structures in offshore constructions.
- Lack of calculation approaches for close-grouped cylinders.
- What is the influence of neighboring cylinders of the wave load on a single cylinder?



Foto: Matthias Ibeler, alpha-ventus.de



Foto: Arndt Hildebrandt, WeserWind



The Large Wave Channel (GWK) of the Coastal Research Centre (FZK)



Length 310 m

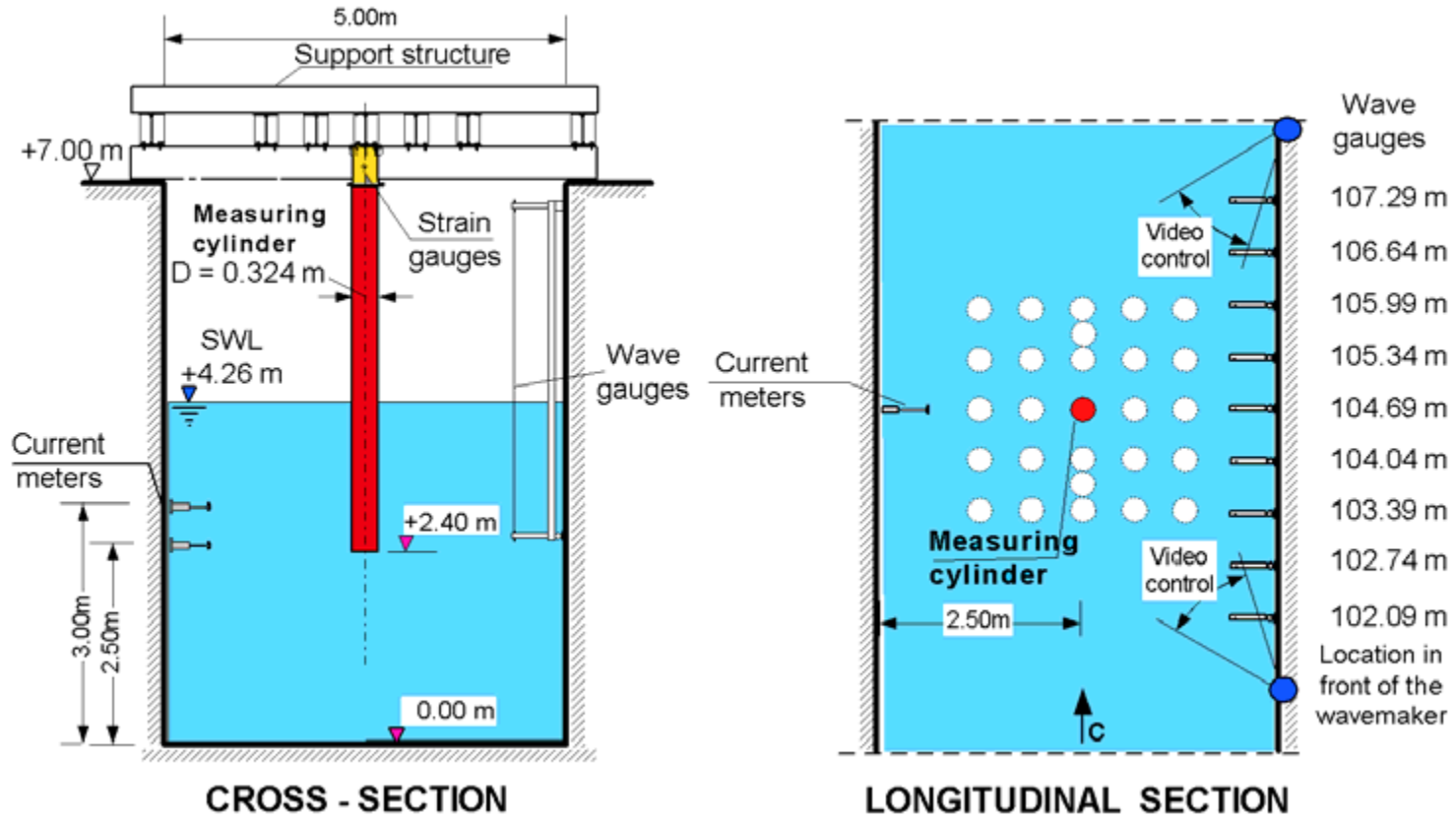
Width 5 m

Depth 7 m

Max. water depth 5 m

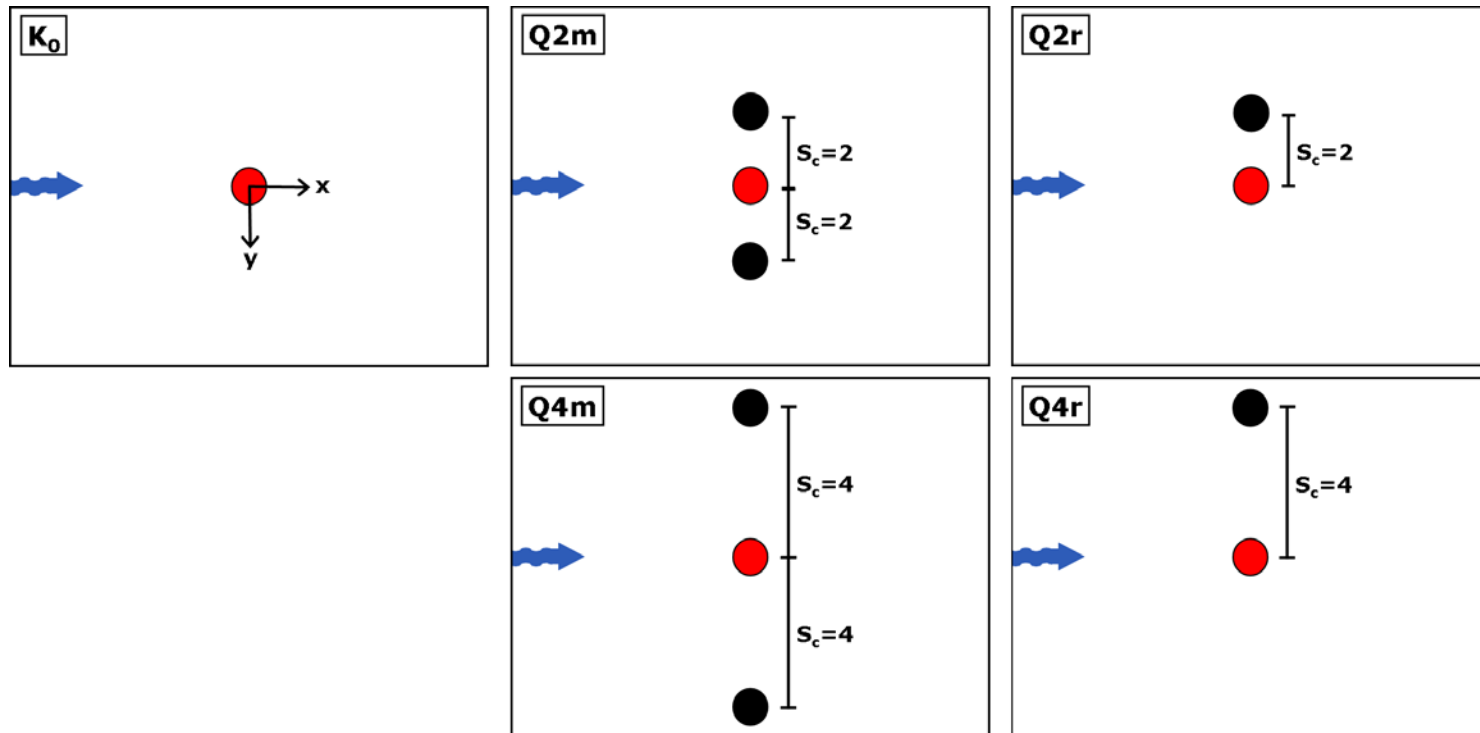
Max. wave height 2.5 m

Test Set-Up



Test Set-Up

Analysed cylinder group configurations



$$S_c = l/D$$

Test Set-Up

Jonswap Spectra

d = 4.26 m		Peak Period T_p [s]		
		4	6	8
Significant Wave Height H_s [m]	0.80	x	-	-
	1.00	-	x	-
	1.00	-	-	x

Regular Waves

d = 4.26 m		Wave Period T [s]				
		4	5	6	7	8
Wave Height H [m]	0.80	x	x	x	x	x
	1.10	x	x	x	x	x
	1.40	x	x	x	x	x



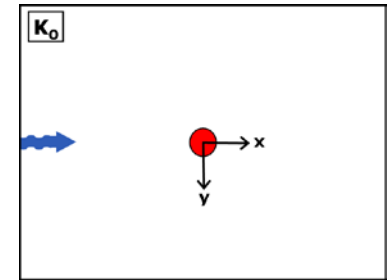
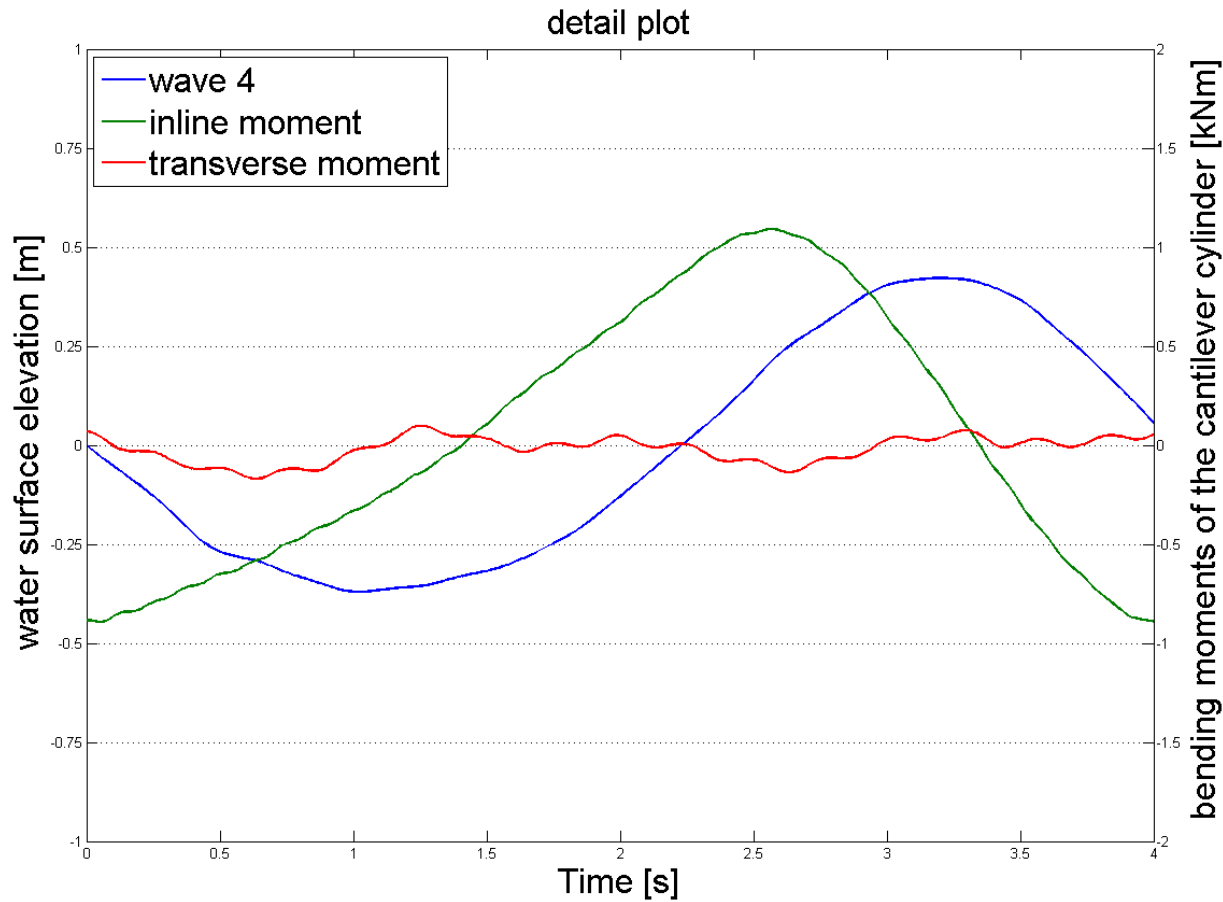


Experimental Procedure



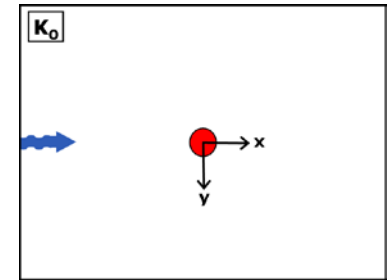
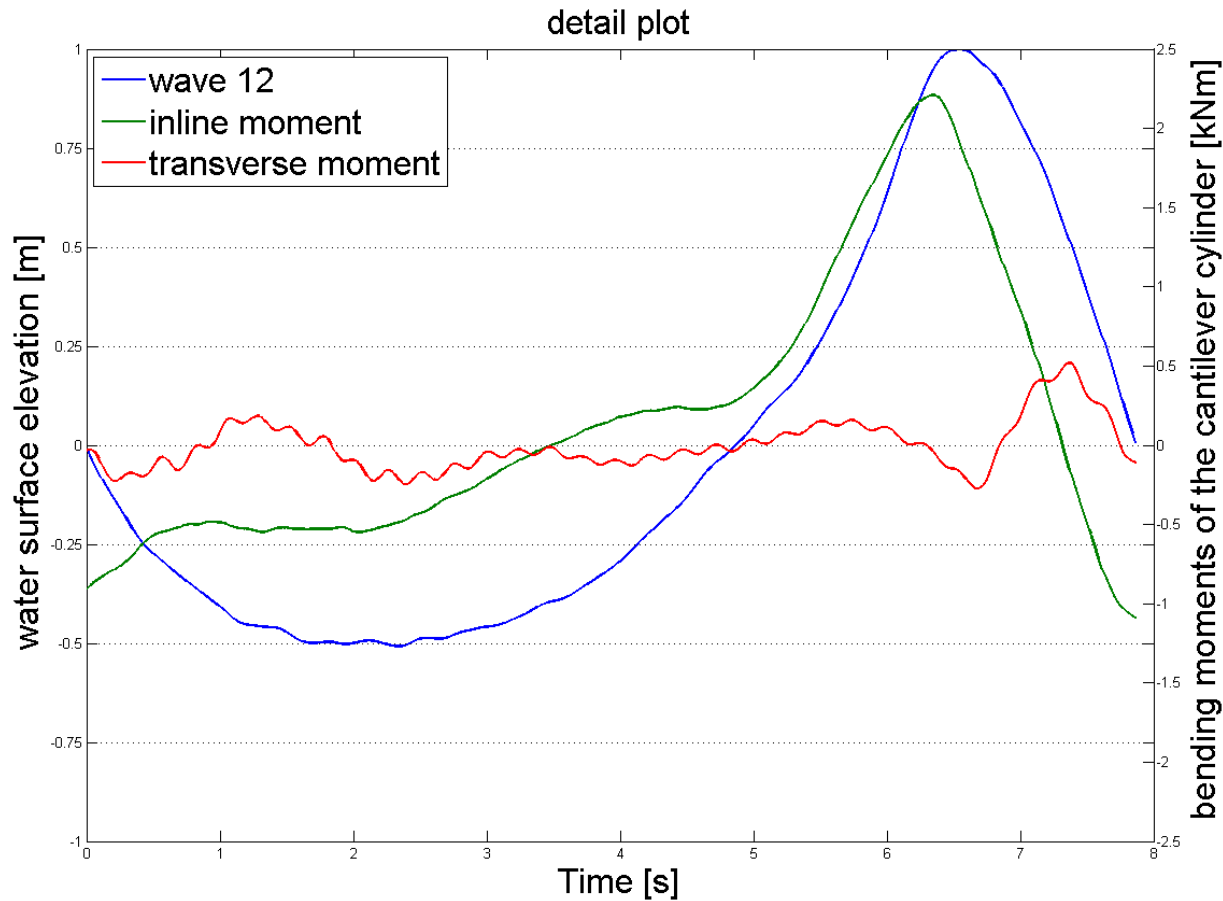
$T = 8 \text{ s}$ and $H = 1,4 \text{ m}$

Analysis



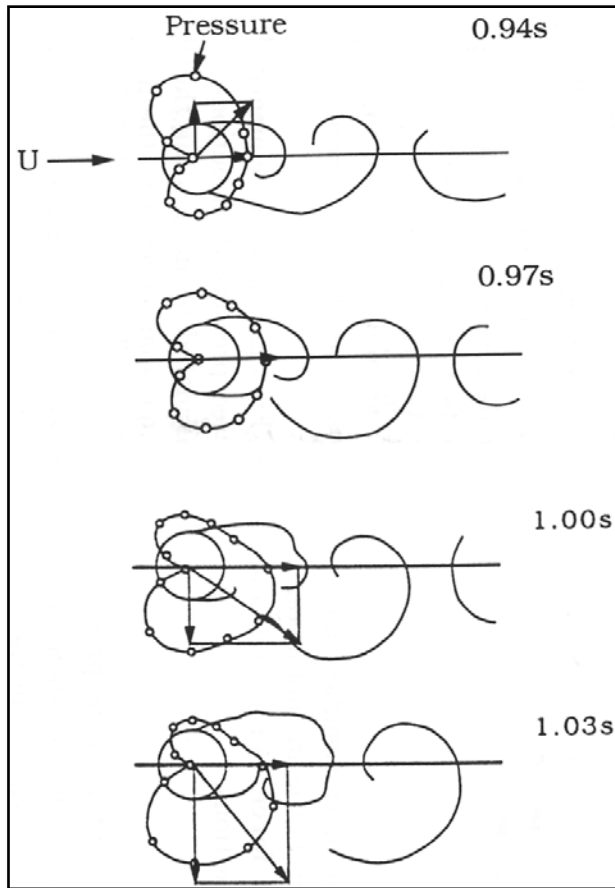
Single cylinder with $T=4$ s and $H=0.8$ m, $KC = 10.4$

Analysis



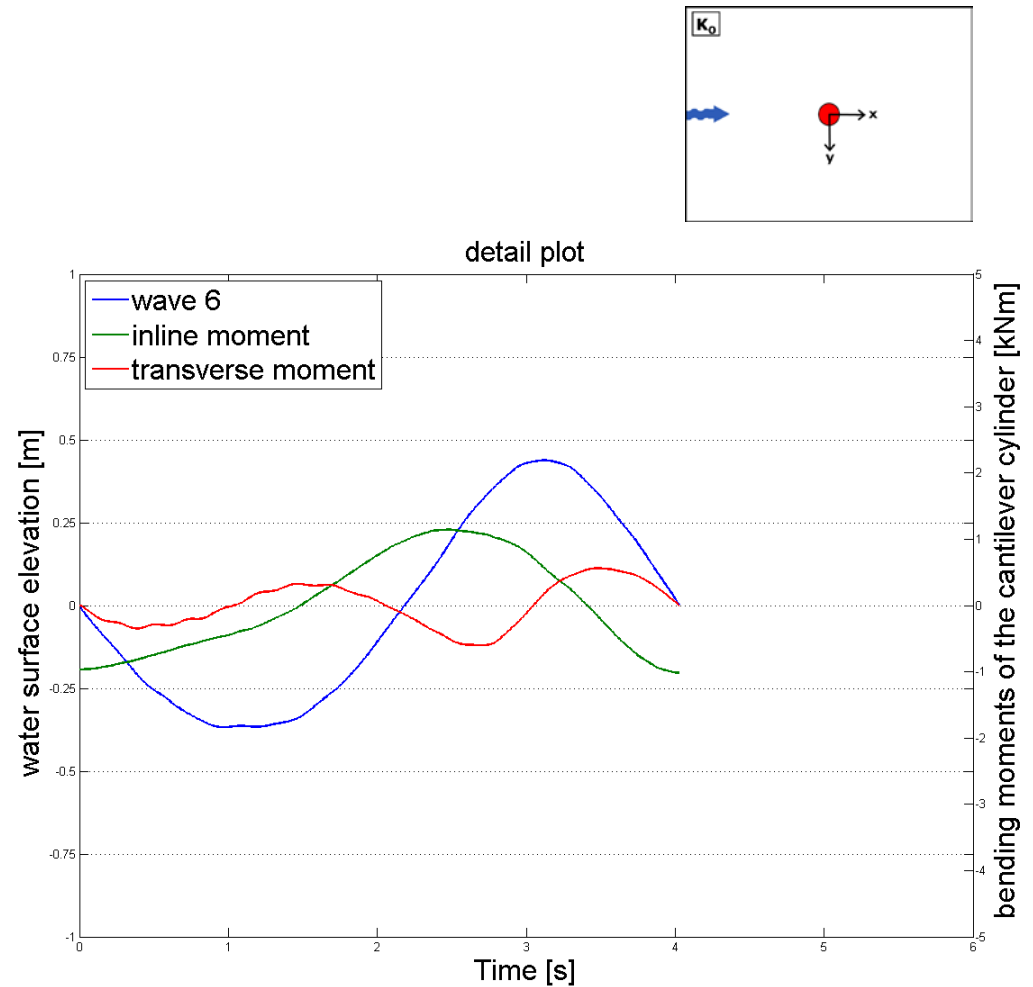
Single cylinder with $T=8$ s and $H=1.5$ m, $KC = 43$

Pressure Distribution and Vortex Shedding

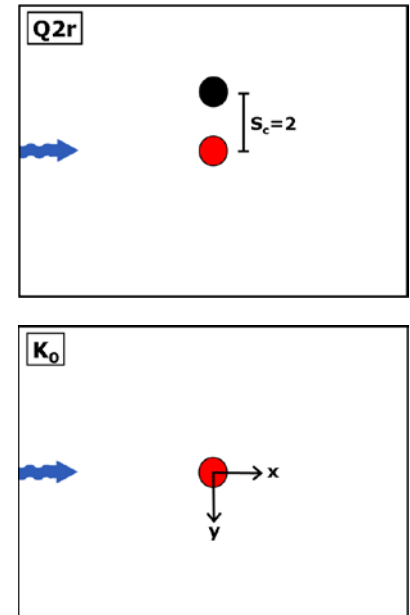
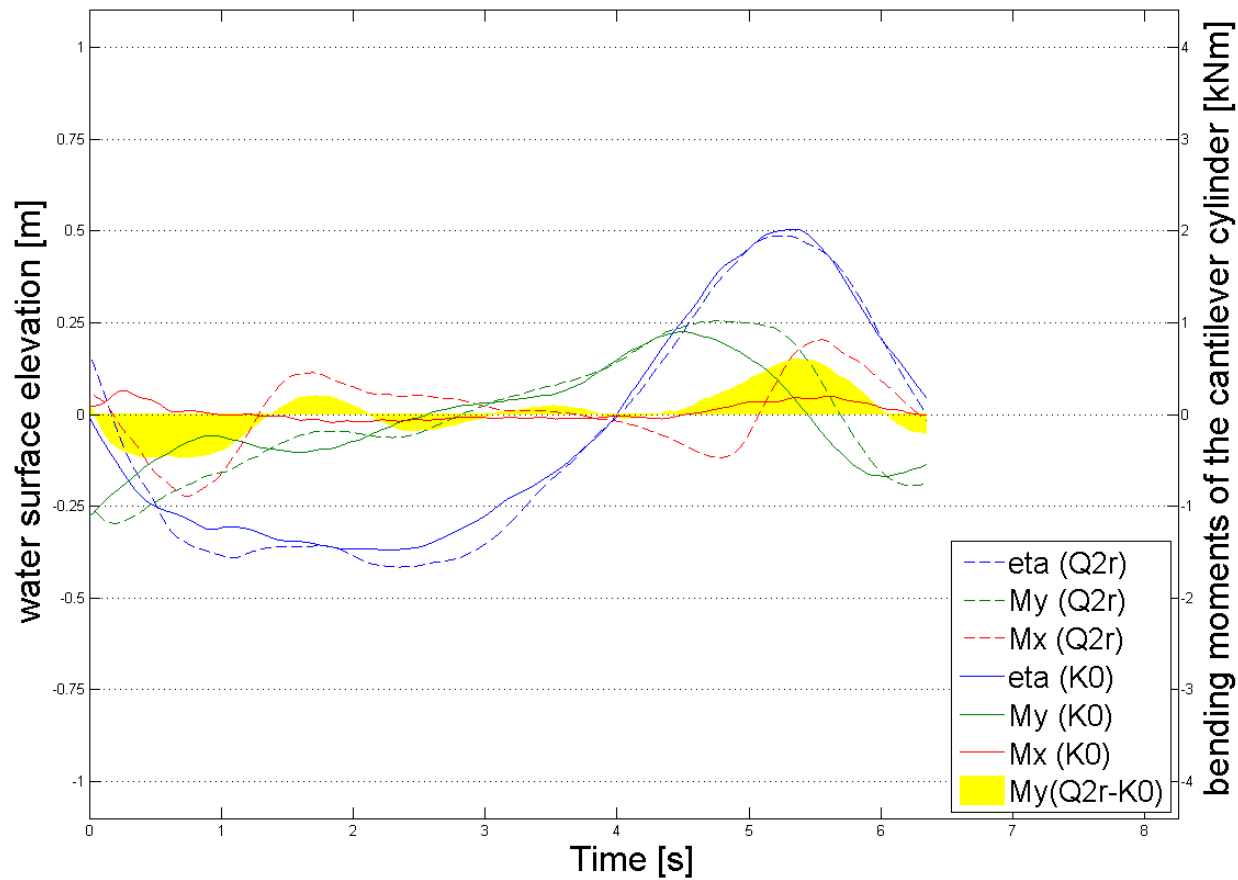


Source: Sumer

Notice: The pressure plotted is underpressure.

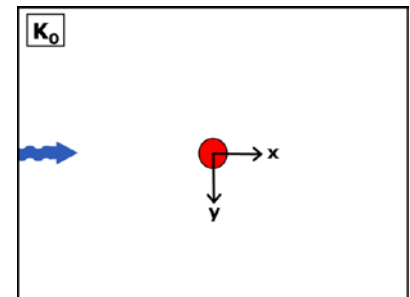
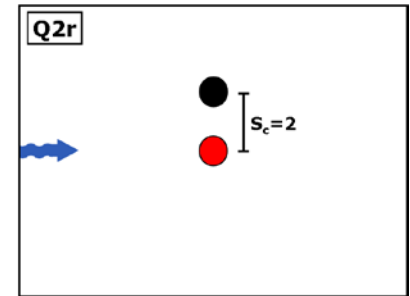
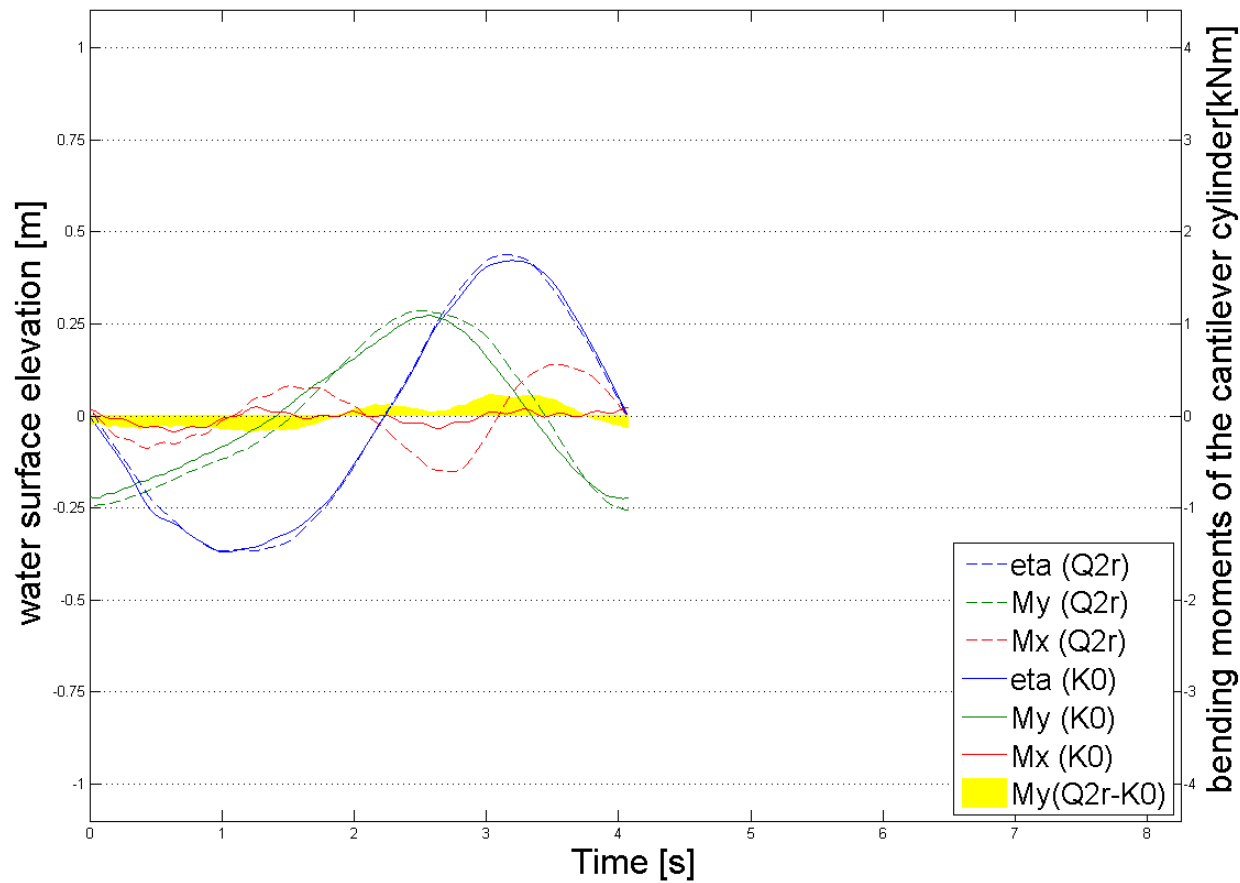


Analysis



Q2r in comparison to K0 for $T=6.4$ s and $H=0.8$ m

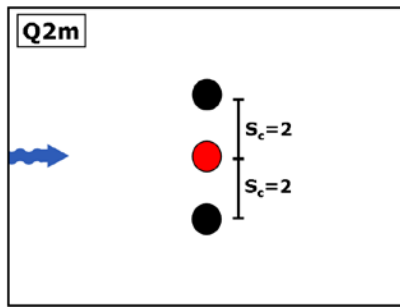
Analysis



Q2r in comparison to K0 for $T=4$ s and $H=0.8$ m

Results

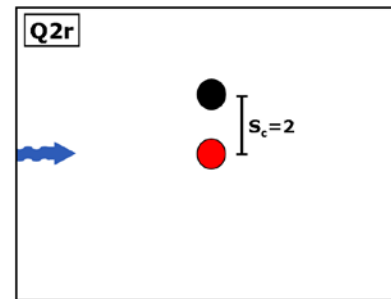
Increased loads on the measuring cylinder due to presence of the neighboring cylinders



+ 30% (mean value)

+ 59% (maximal)

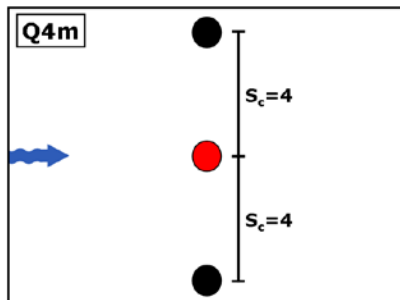
+ 6% (minimal)



+ 15% (mean value)

+ 38% (maximal)

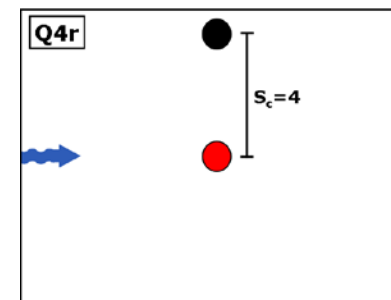
- 25% (minimal)



+ 14% (mean value)

+ 37% (maximal)

- 16% (minimal)



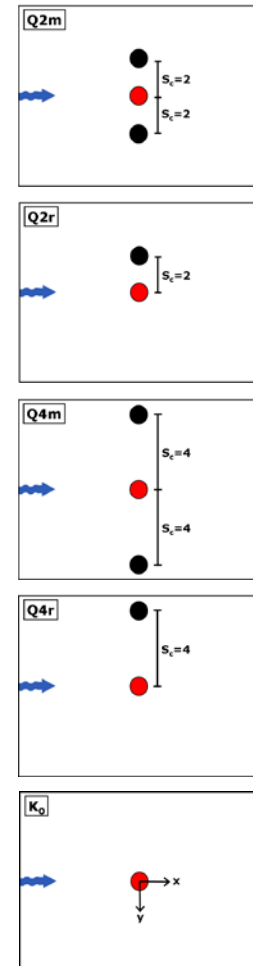
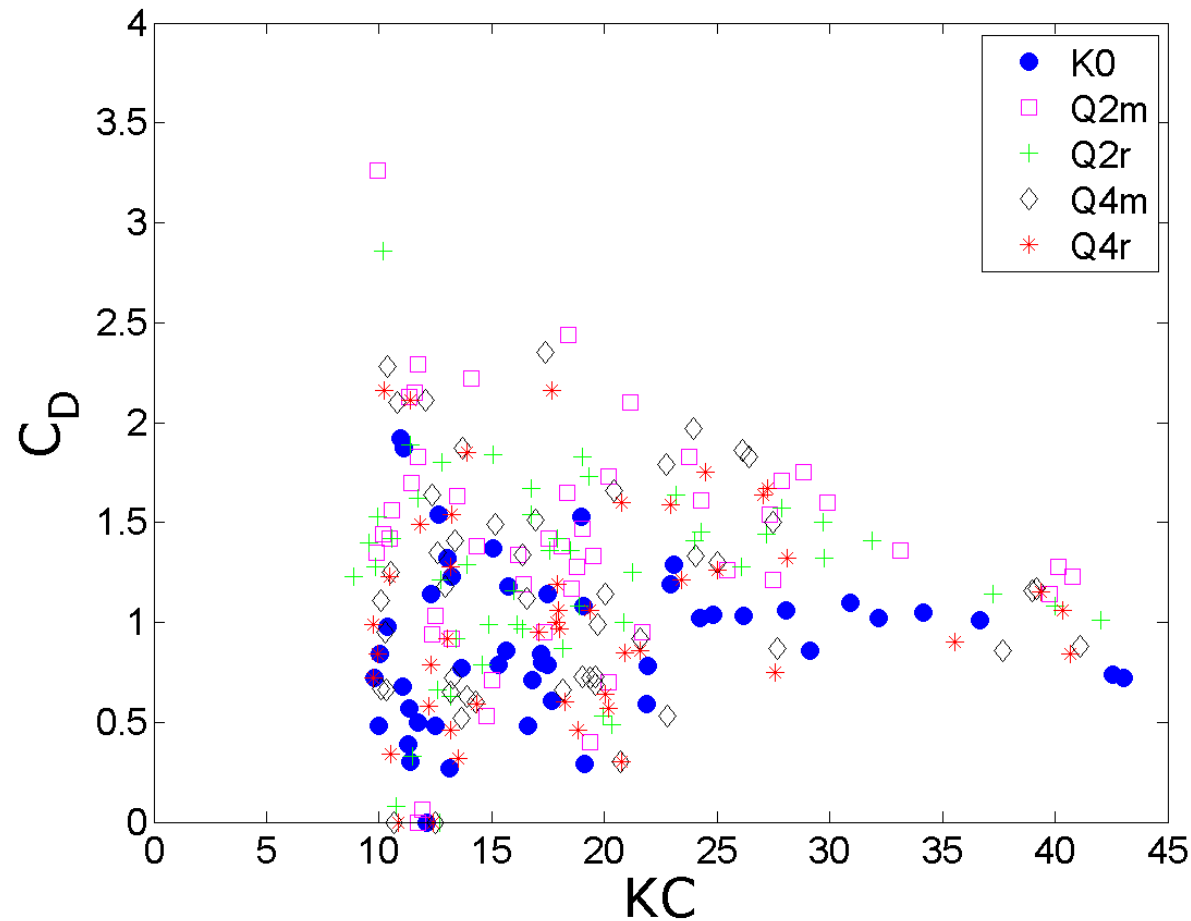
+ 11% (mean value)

+ 34% (maximal)

- 14% (minimal)

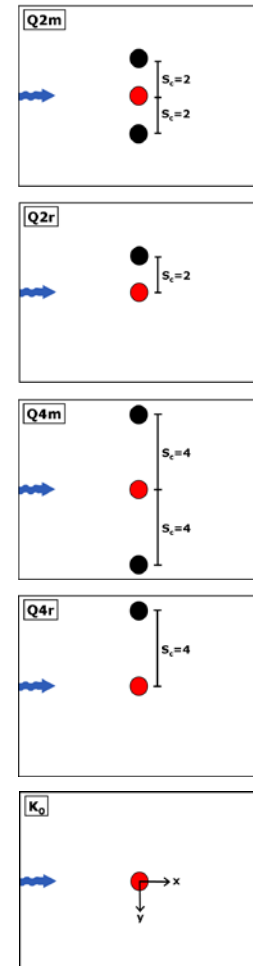
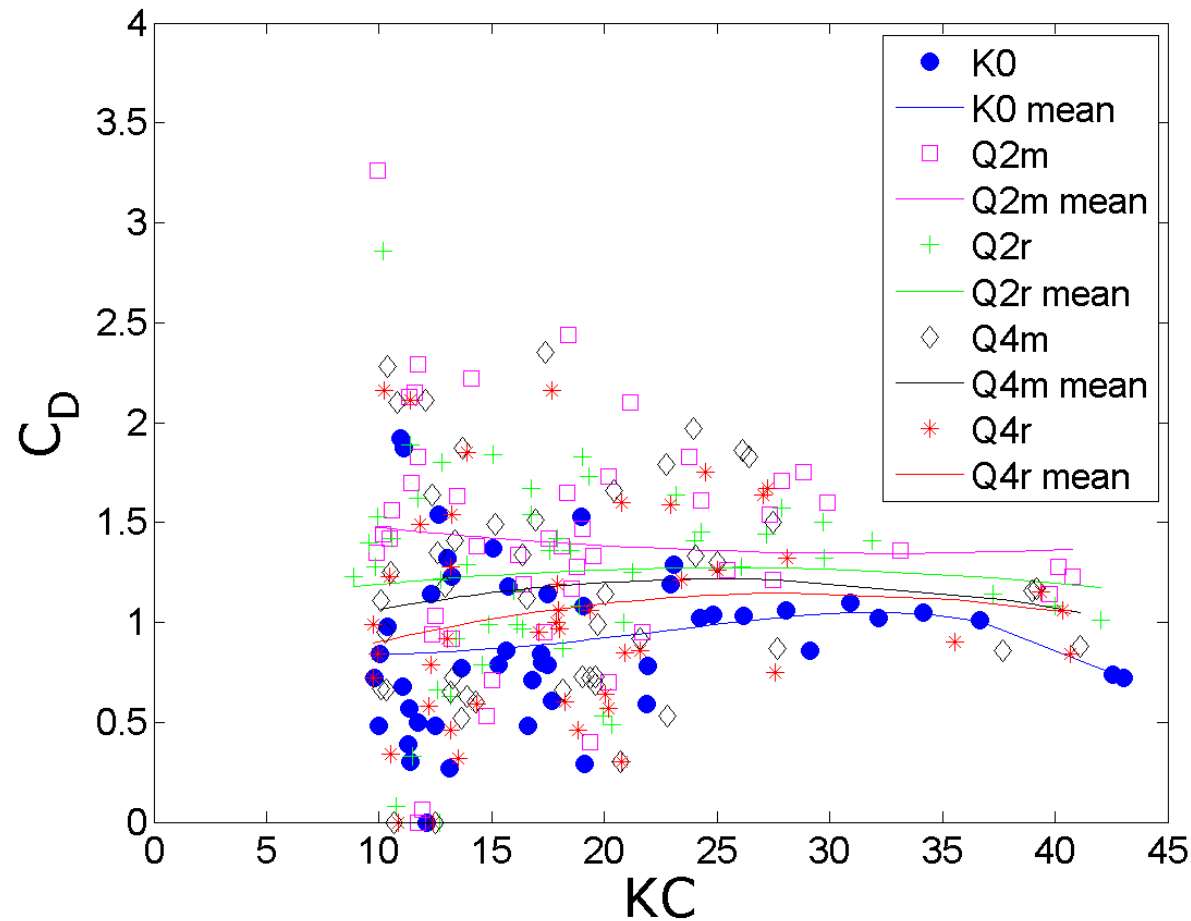
Results

C_D coefficients calculated with least-square method



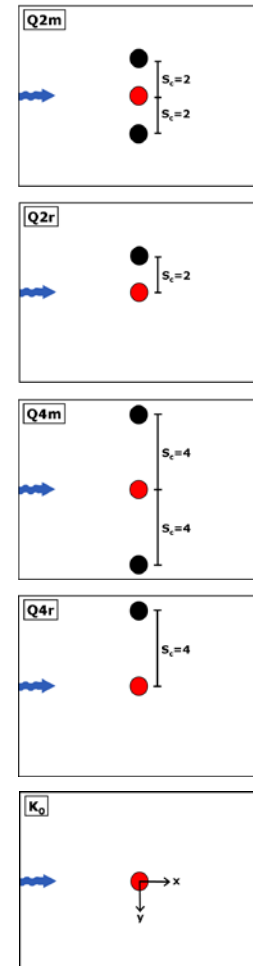
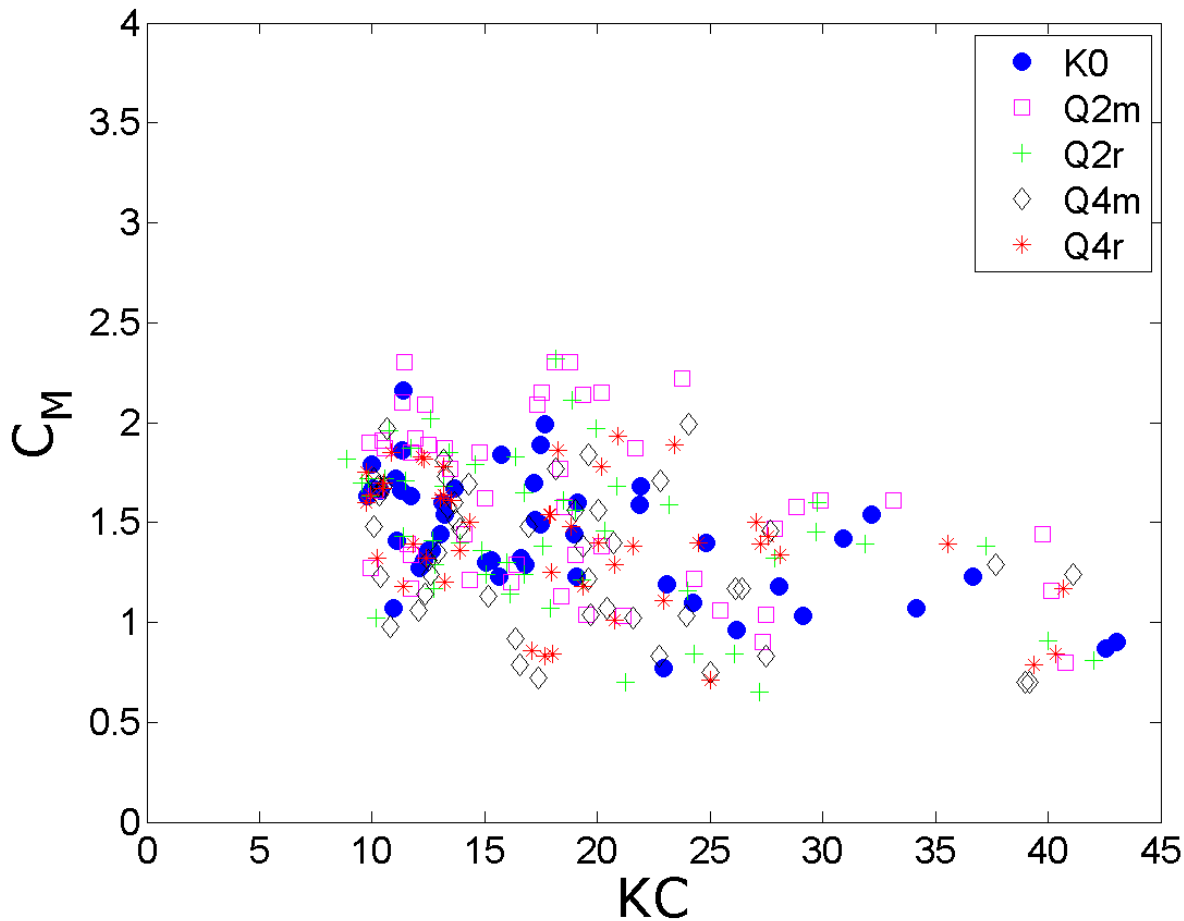
Results

C_D coefficients calculated with least-square method



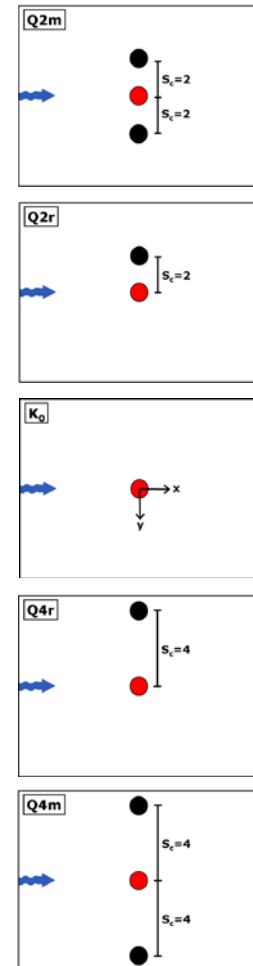
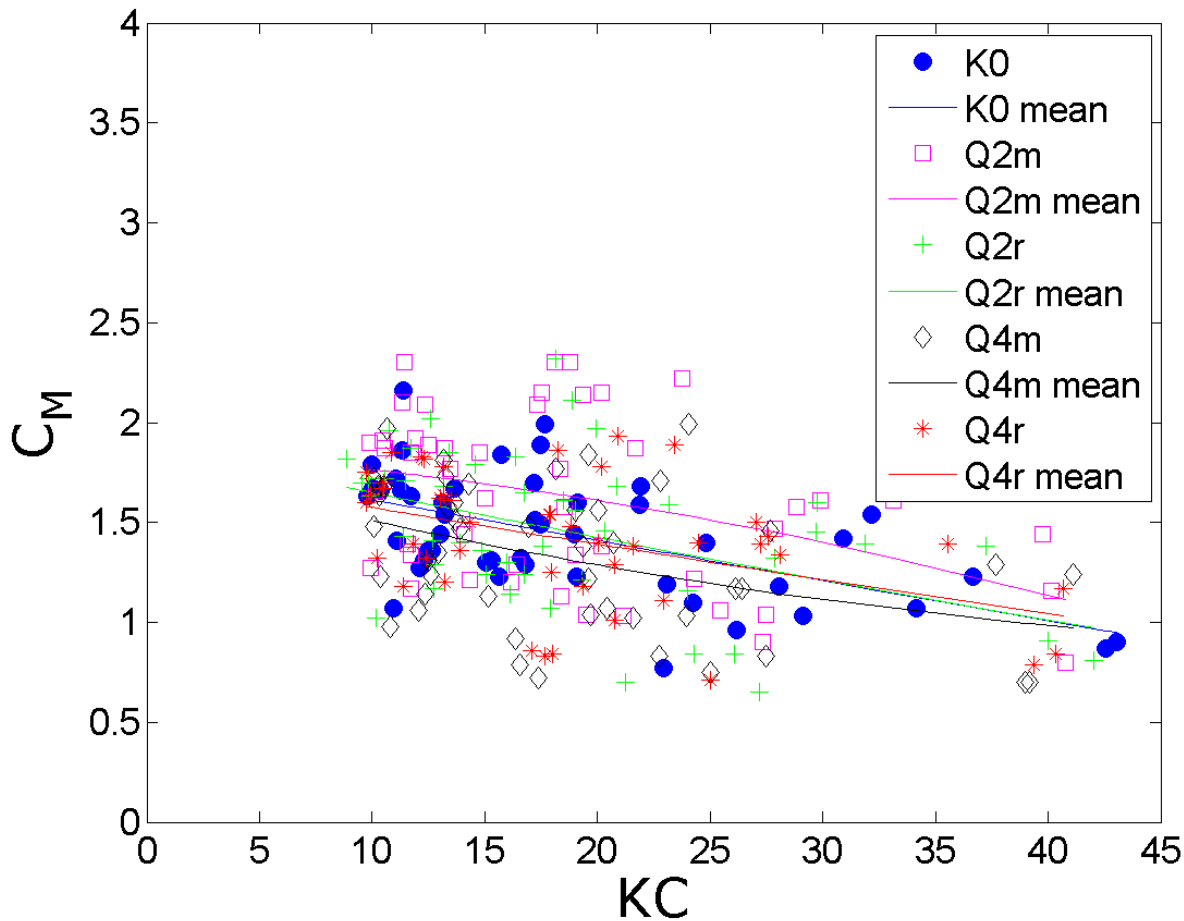
Results

C_M coefficients calculated with least-square method



Results

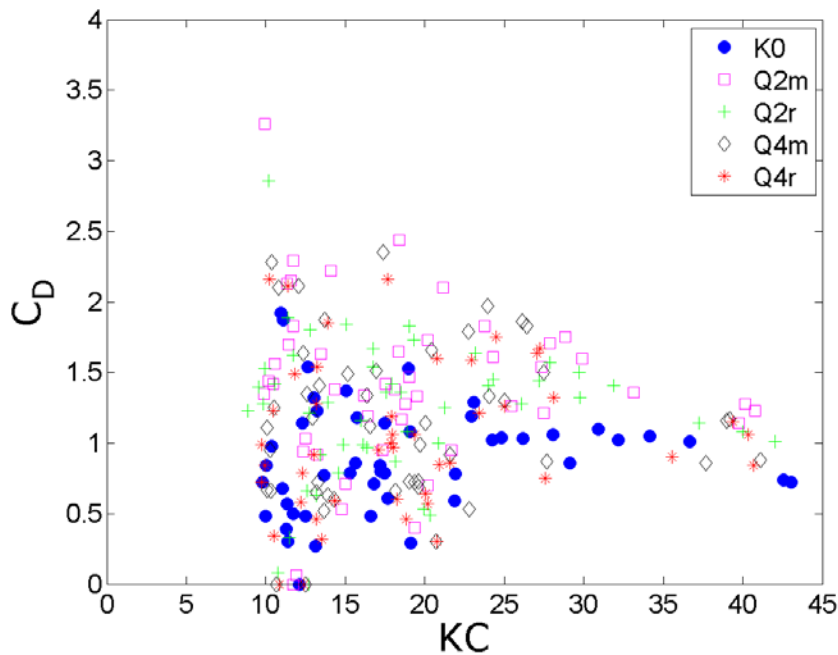
C_M coefficients calculated with least-square method



Results

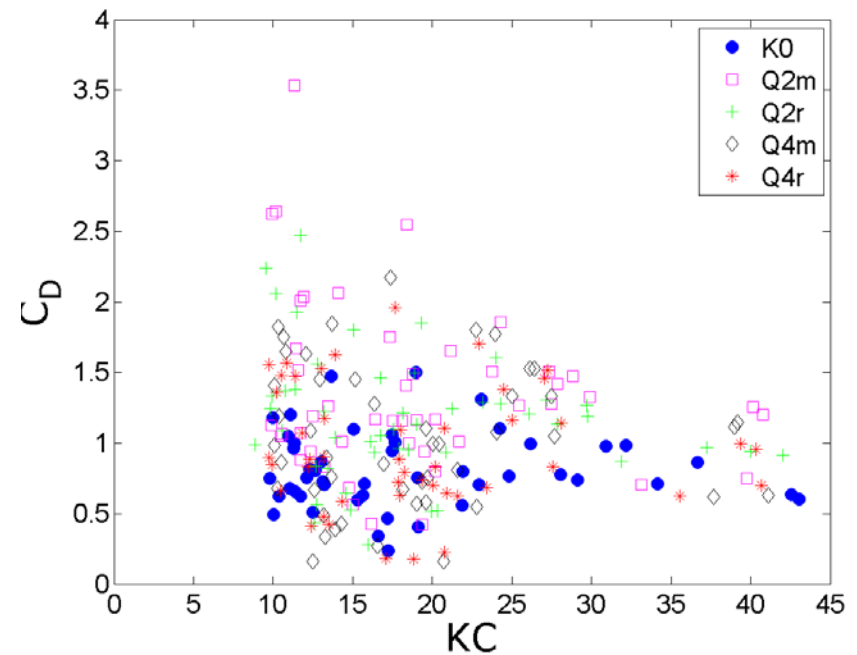
C_D coefficients dependent upon estimation method

Least-Square Method



	K0	Q2m	Q2r	Q4m	Q4r
C_D mean	0,90	1,41	1,23	1,15	1,04

Maximum Value Method

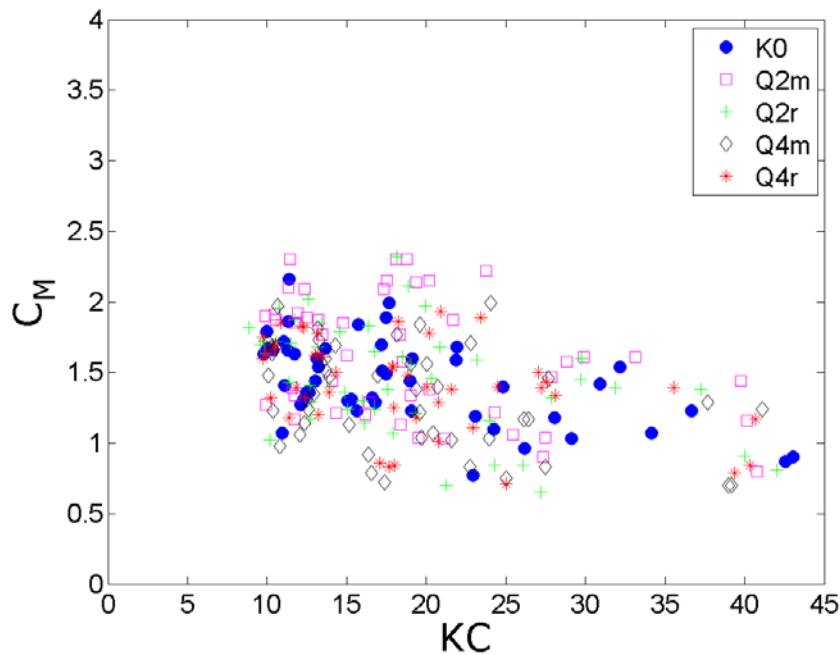


	K0	Q2m	Q2r	Q4m	Q4r
C_D mean	0,79	1,35	1,17	1,03	0,96

Results

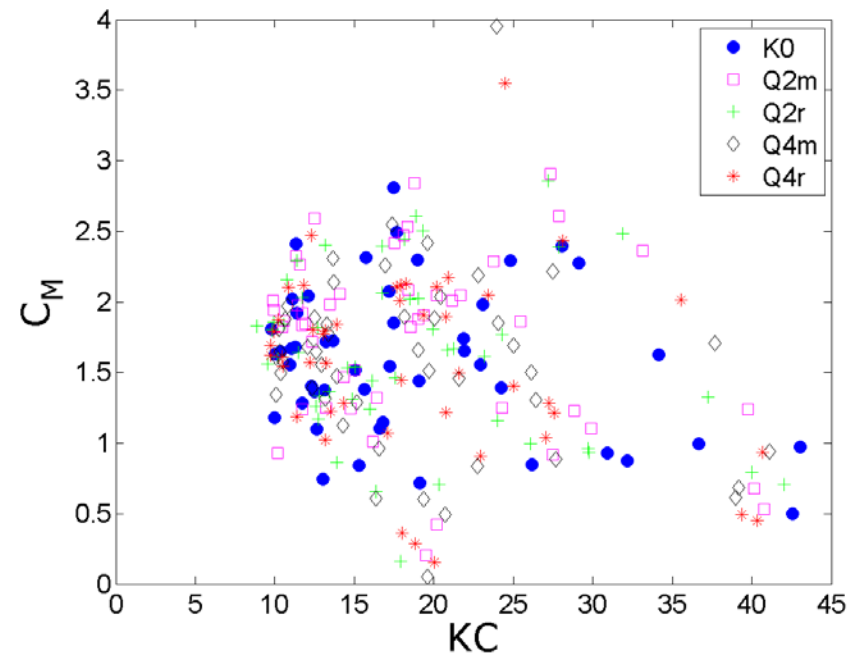
C_M coefficients dependent upon estimation method

Least-Square Method



	K0	Q2m	Q2r	Q4m	Q4r
C_M mean	1,44	1,61	1,46	1,33	1,41

Maximum Value Method

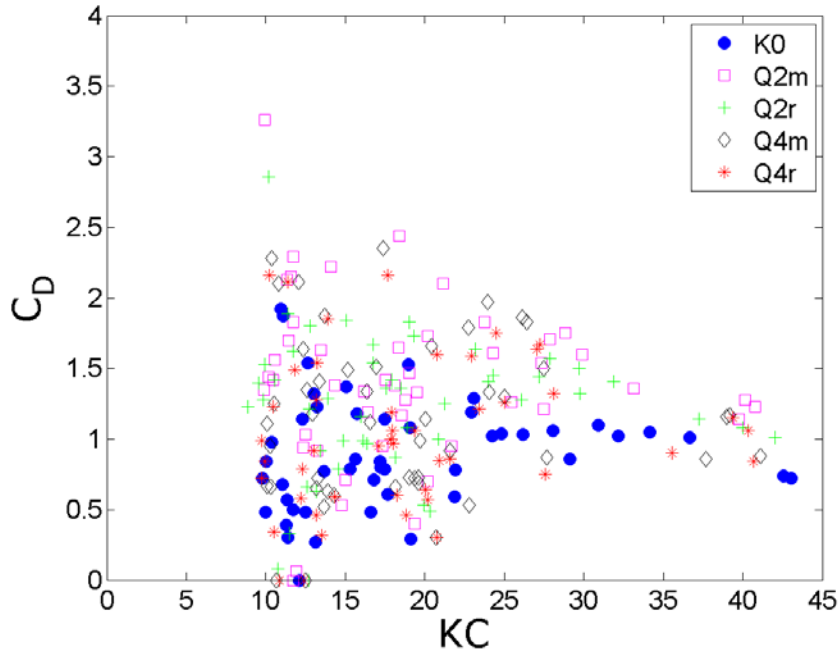


	K0	Q2m	Q2r	Q4m	Q4r
C_M mean	1,58	1,70	1,63	1,57	1,57

Results

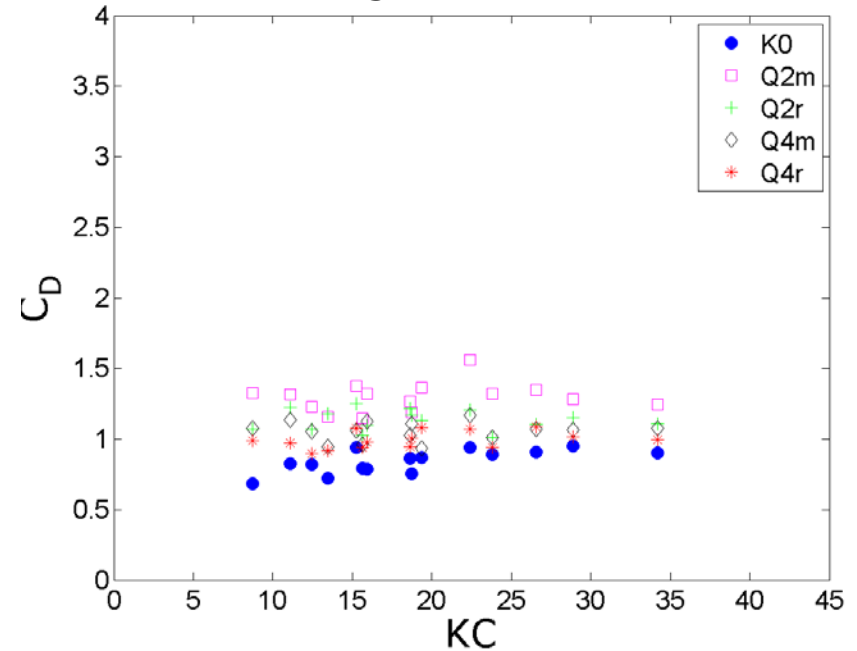
C_D coefficients calculated with least-square method

Jonswap Spectra



	K0	Q2m	Q2r	Q4m	Q4r
C_D mean	0,90	1,41	1,23	1,15	1,04

Regular Waves

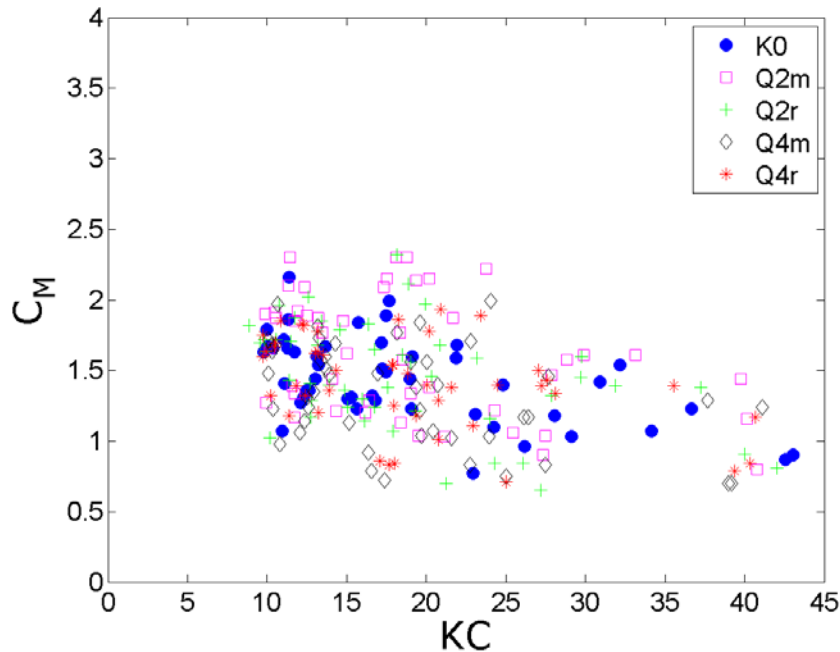


	K0	Q2m	Q2r	Q4m	Q4r
C_D mean	0,84	1,30	1,13	1,05	0,99

Results

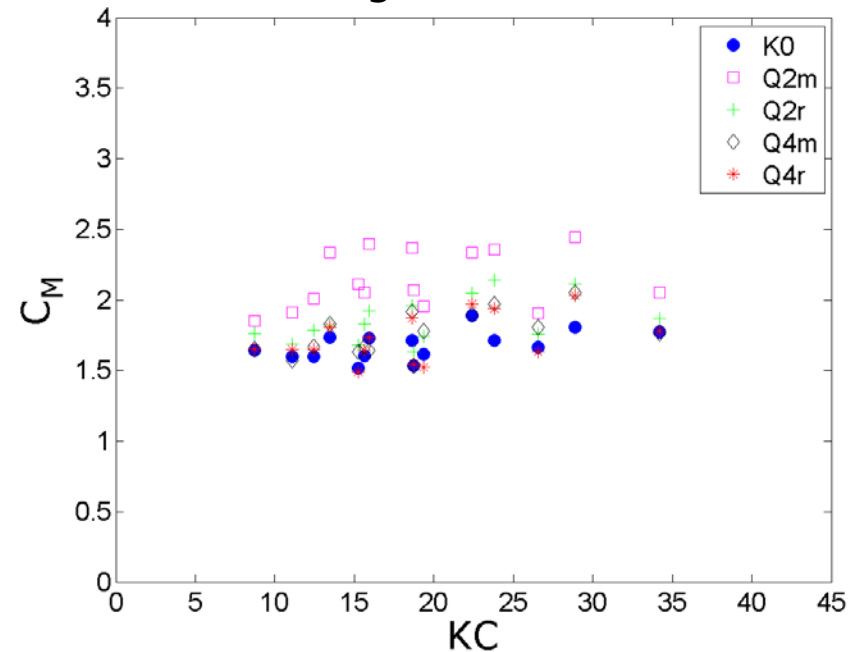
C_M coefficients calculated with least-square method

Jonswap Spectra



	K0	Q2m	Q2r	Q4m	Q4r
C_M mean	1,44	1,61	1,46	1,33	1,41

Regular Waves



	K0	Q2m	Q2r	Q4m	Q4r
C_M mean	1,58	1,70	1,63	1,57	1,57

Summary and Conclusion

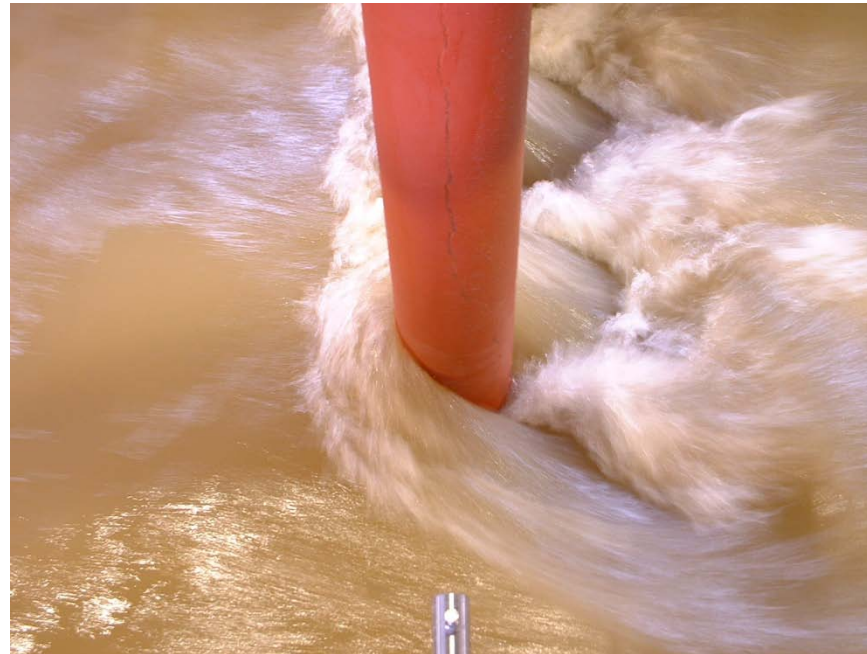
- Neighboring cylinders induce more intensive vortex shedding.
 - Thereby they induce an increase of load.
- The indicative point for the structural designation of the piers are the wave crests.
- The maximum increase of load depends on the wave regime.
- Middle cylinders encounter a larger increase of load in comparison with the cylinders having only one flanking cylinder.
- The influence of the neighboring cylinders on the single cylinder decreases with increasing cylinder distance.
- The C_D and C_M coefficients reflect the physical processes.

Outlook

- Video recording of the development of the vortices.
- Investigating more cylinder distances ($S_c < 2$ und $S_c > 5$).
- Investigating of more cylinder diameters.
- Investigating of more neighboring cylinders.
- Measuring the forces on more than one cylinder.
- Application of other estimation methods for the force coefficients C_D and C_M



Thank you for your attention



The provision of the measured data by Oumeraci et al. is gratefully acknowledged.