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The State of the Art and Science of Coastal Engineering

VIOLENT IN-CHAMBER LOADS IN AN OSCILLATING WATER COLUMN

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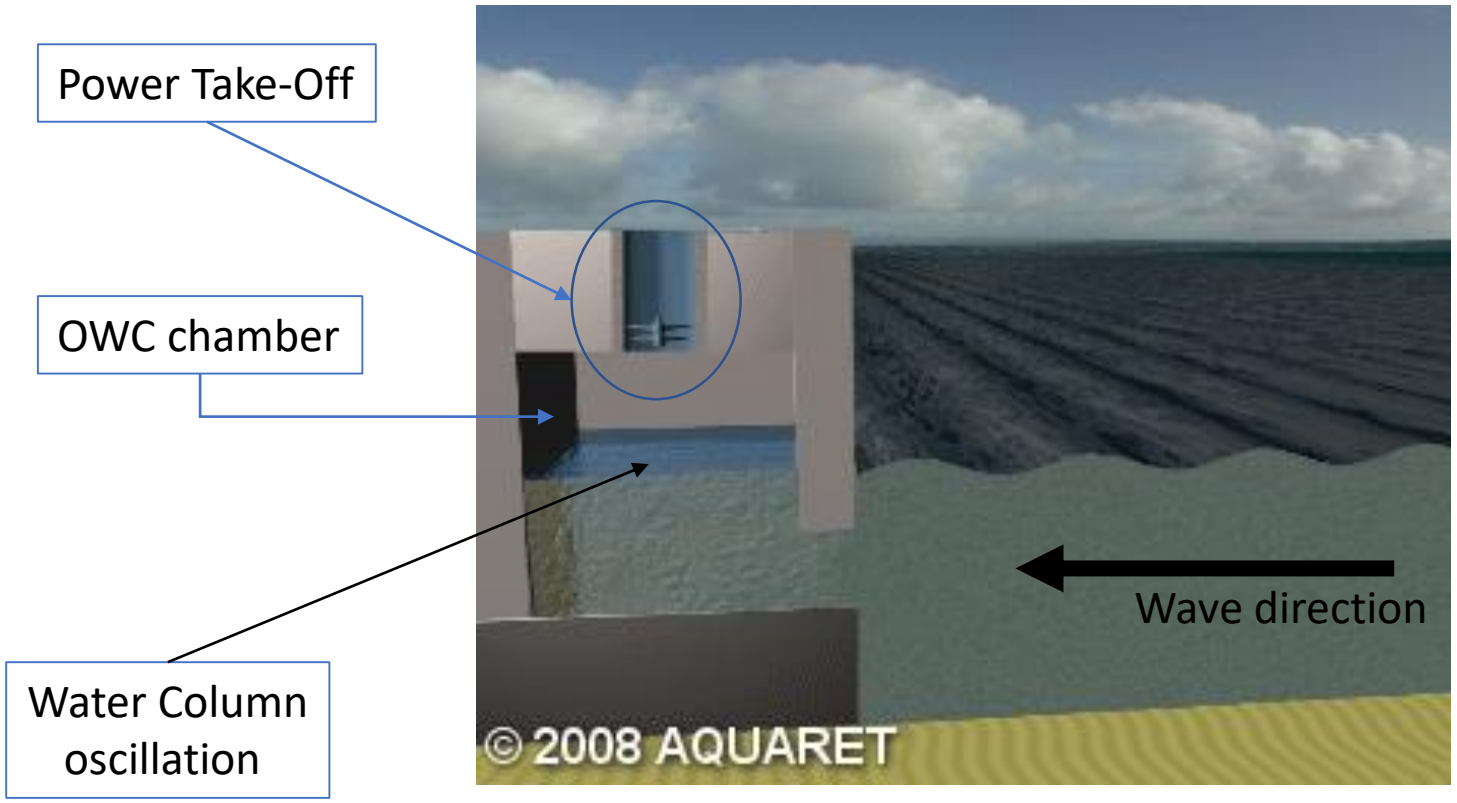
Oscillating Water Column mechanism

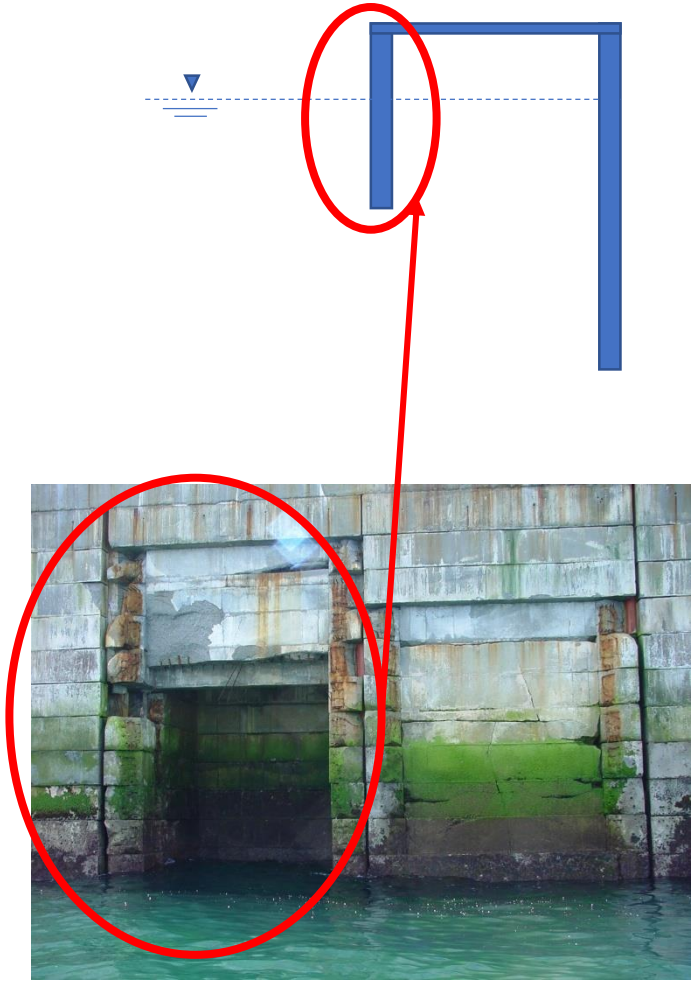


Source: Aqua-RET (aquaret.com)

Mutriku Wave Power Plant

Background problem

- Wave loading uncertainty inside the chamber



Damaged Mutriku wave power plant during construction due to storm

Image: courtesy of Ezter Horvarth

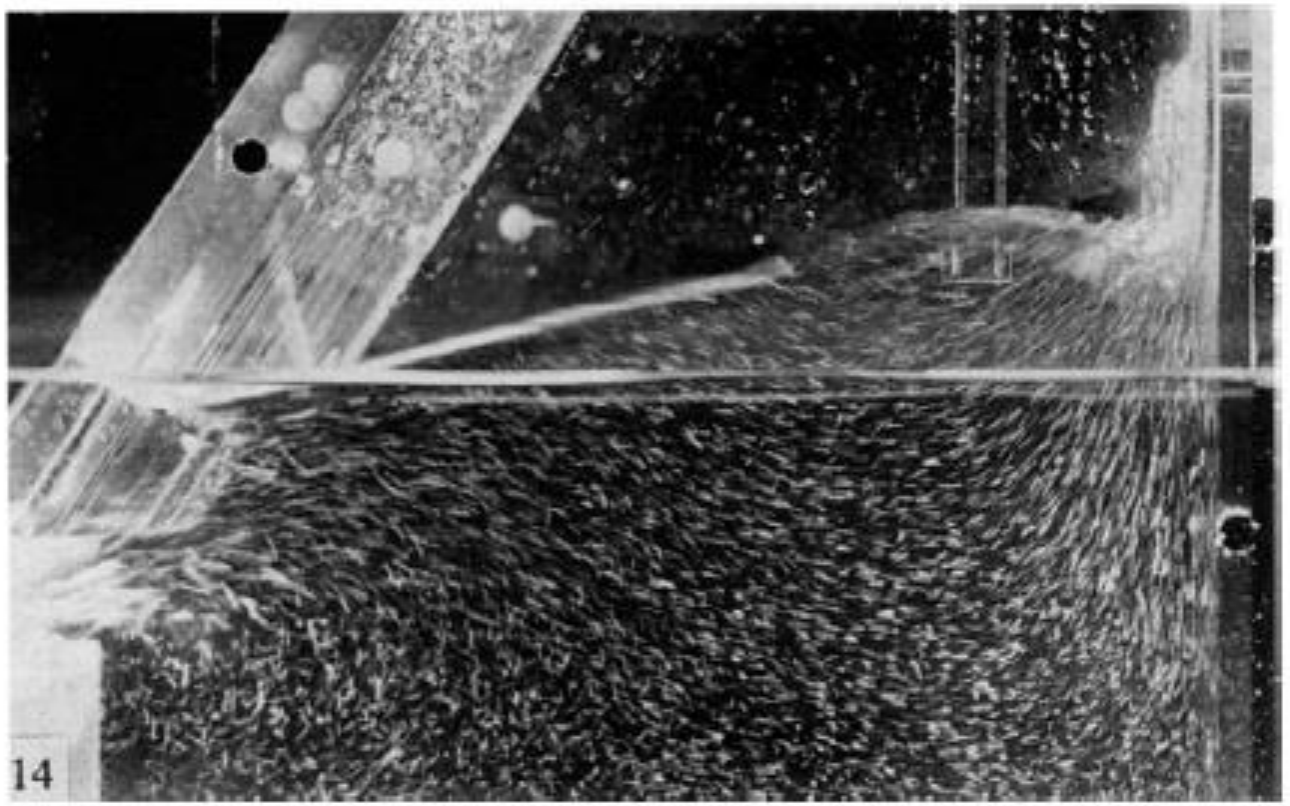


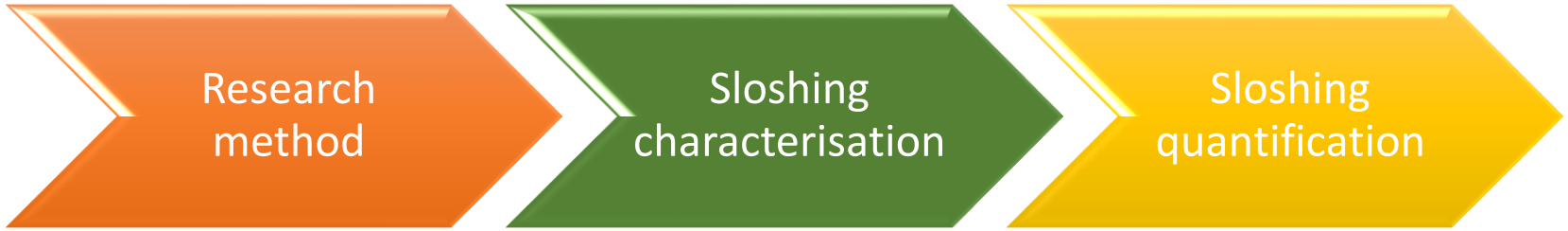
Fig. 14. Impact of breaker on back wall.

Taken from:
Müller, G. and Whittaker, T.J., 1995. Visualisation of flow conditions inside a shoreline wave power-station. *Ocean engineering*, *22*(6), pp.629-641.

Research aims:

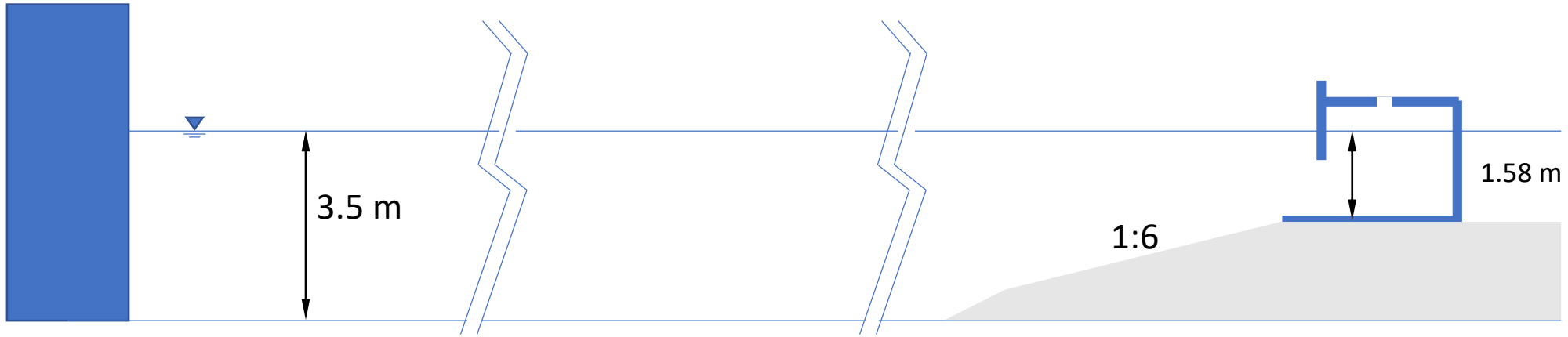
- Observation and quantification In-chamber water column behaviour and wave loading characterisation , including impact/slam

- Overview



How?

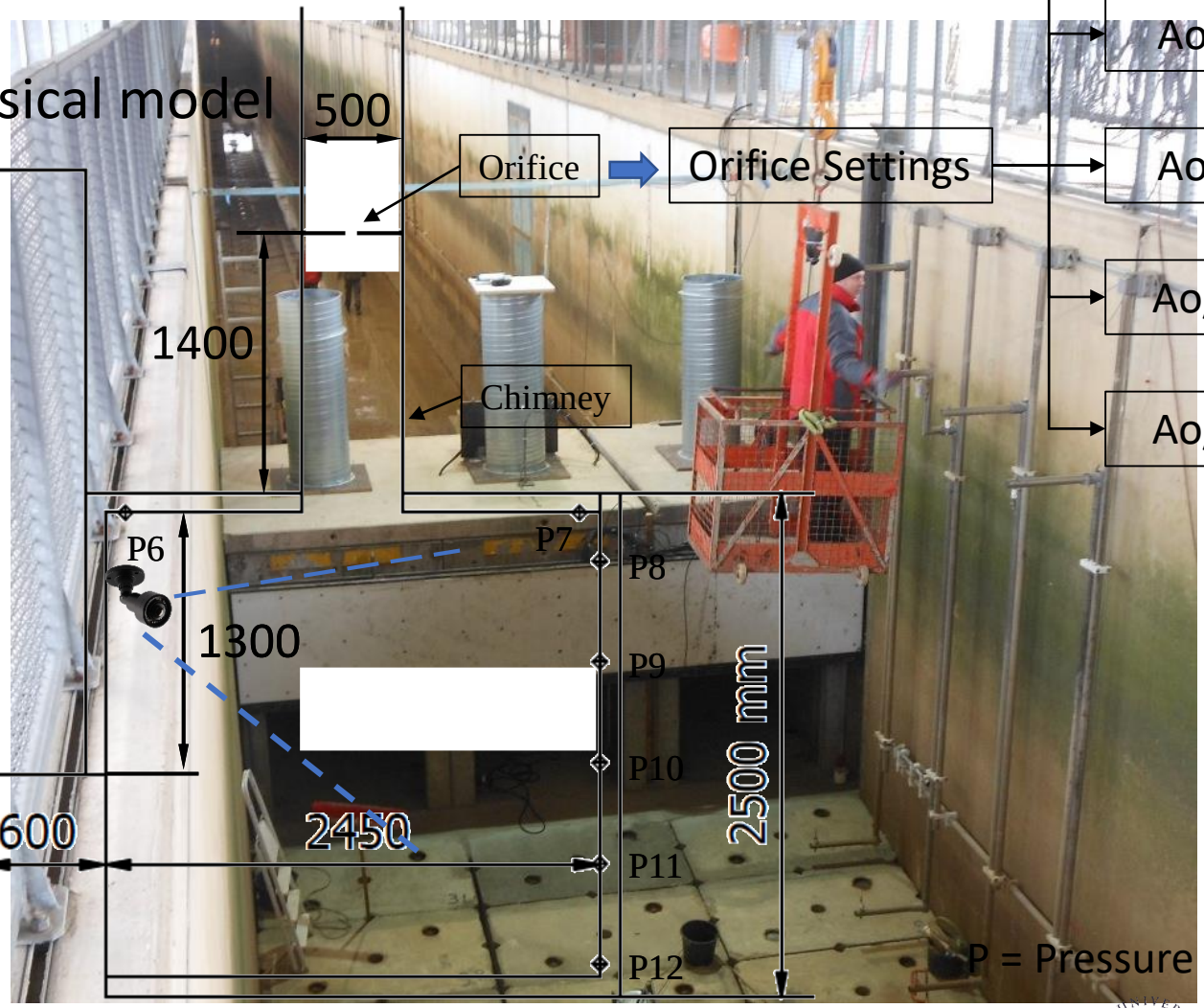
physical model testing in Large wave flume (GWK) Hannover, Germany.



	Regular wave condition	Irregular wave condition
Wave height [m]	$0.1 \leq H \leq 1.33$	$0.26 \leq H_{mo} \leq 1.00$
Wave period [s]	$3 \leq T \leq 6$	$3 \leq T_p \leq 6.5$
Relative orifice opening (A_o/A_c)	0% - 2%	0% - 2%

How?

Large-scale Physical model



Orifice → Orifice Settings

- Closed (0 m)
- Ao/Ac = 0.06%
- Ao/Ac = 0.22%
- Ao/Ac = 1.00 %
- Ao/Ac = 2.00 %

P = Pressure transducer position

Water column behaviour characterisation

- Sloshing: non-uniform water column movement

Well behaved OWC

Low sloshing

Medium sloshing

Impact Sloshing

Column behaviour regime for Regular wave

Properties:

- / = not tested
- ! = ceiling impact
- ^ = water column oscillation reached the ceiling

Bc/L	H (m)	Orifice Diameter in m (A_o/A_c)					
		Closed	0.06%	0.22%	1.00%	1.0% (lowered curtain wall)	2.00%
0.1394	0.1	/		/		/	
	0.15	/	/	/	/	/	
	0.2	/		/	/	/	
	0.26						
	0.39	/		/	/	/	/
	0.52						
	0.65	/		/		/	/
	0.78						!
0.1045	0.1	/		/	/	/	
	0.15	/	/	/	/	/	
	0.2	/		/		/	
	0.4						
	0.6	/		/		/	/
	0.8				!		!
	1	/	/	/	!	/	/
	1.2	/	/	/	/	/	!
0.0836	0.54				!		!
	0.81	/			!	/	/
	1.07	/	/	/	!	!	!
	1.61	/	/	/	/	/	!
0.0697	0.1	/		/	/	/	
	0.15	/	/	/	/	/	
	0.2	/		/	/	/	
	0.34						
	0.67						^
	1	/	/	/	!	/	/
	1.33	/	/	/	/	/	!

Column behaviour regime for Irregular wave

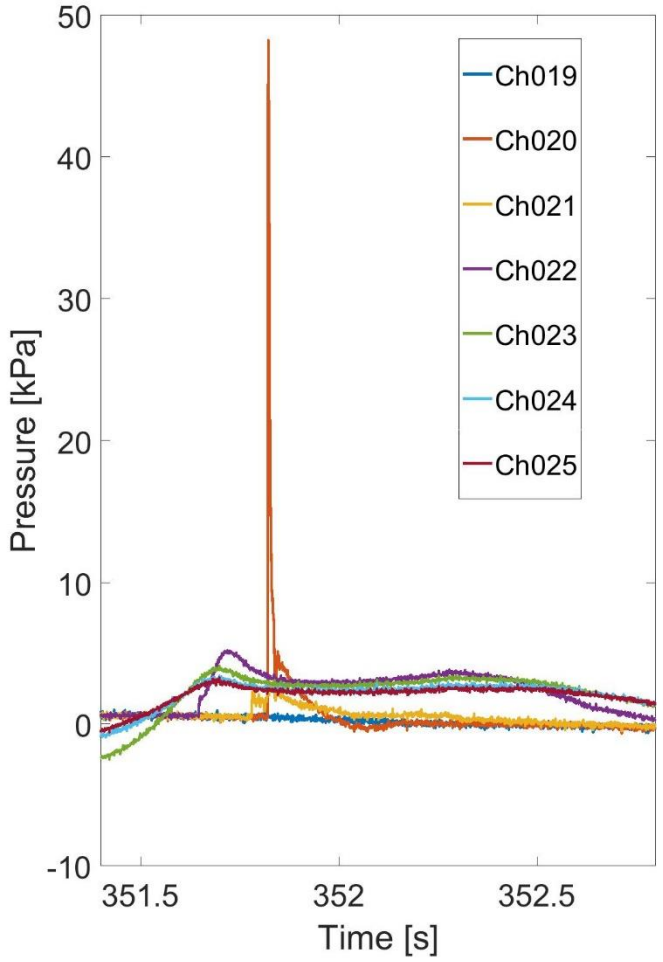
Properties:

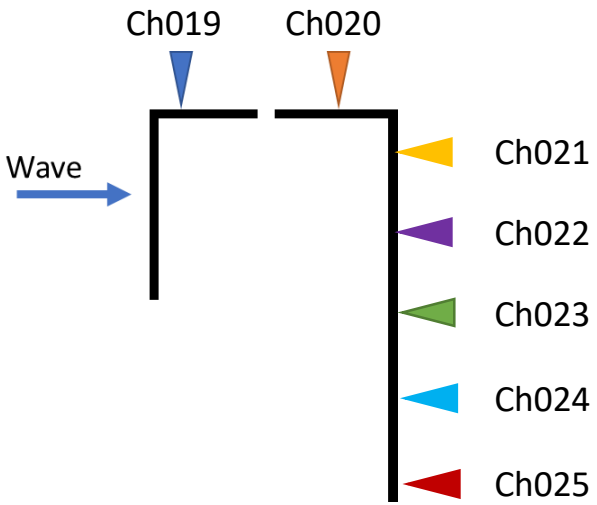
- / = not tested
- ! = ceiling impact
- ^ = water column oscillation reached the ceiling

Bc/L	Hm0 (m)	Orifice Diameter in m (A_o/A_c)					
		Closed	0.06%	0.22%	1.00%	1.00% (lowered curtain wall)	2.00%
0.1394	0.26						
	0.39	/	/	/		/	/
	0.52		/	/			/
0.1045	0.4	/				/	!
	0.6		/	/			/
	0.8	/	/	/	!	/	/
0.0929	0.26		/	/		/	/
0.0836	0.54				!		!
	0.81	/	/	/	!	/	/
0.0697	0.67		/	/	/		!
	1	/	/	/	!	/	/
0.0643	0.4	/	/	/		/	/

Impact pressure measurement

- Single impact on the front or rear of the chamber's ceiling

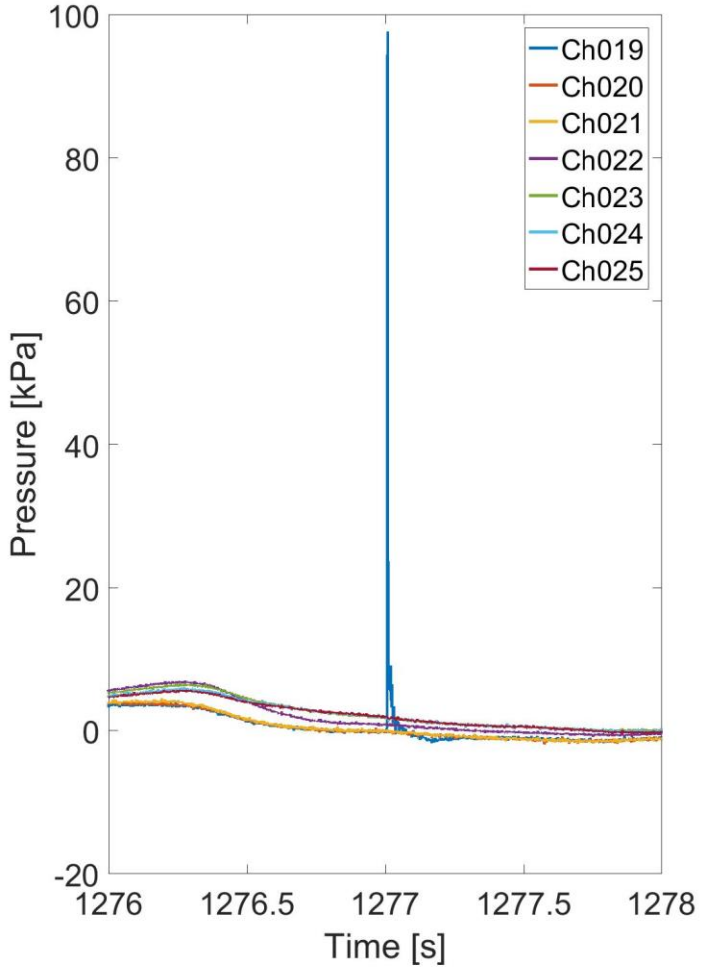


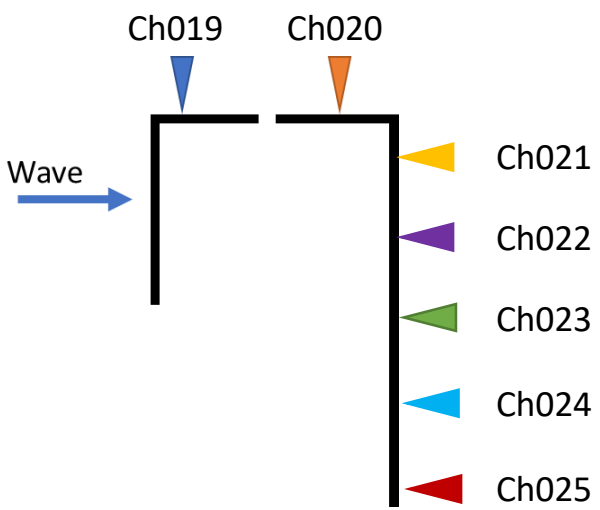


T_p = 4.0 s
H_{mo} = 0.4 m
P_{max} = 12.29 ρgH

Impact pressure measurement

- Single impact on the front or rear of the chamber's ceiling

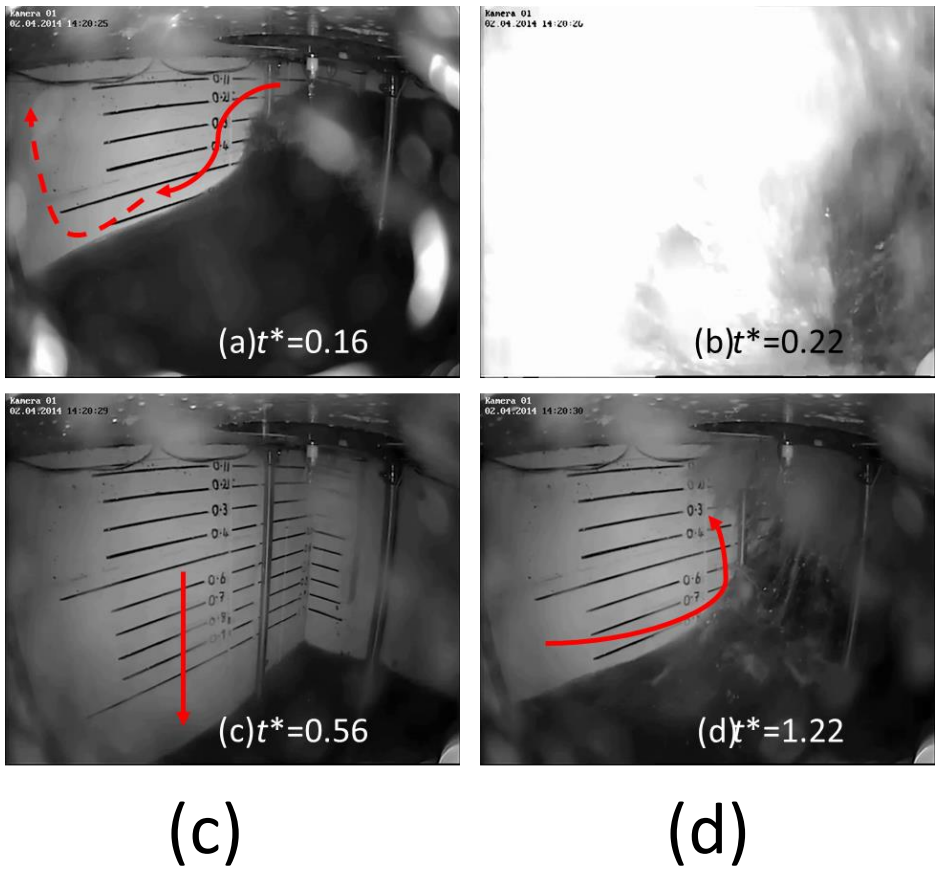


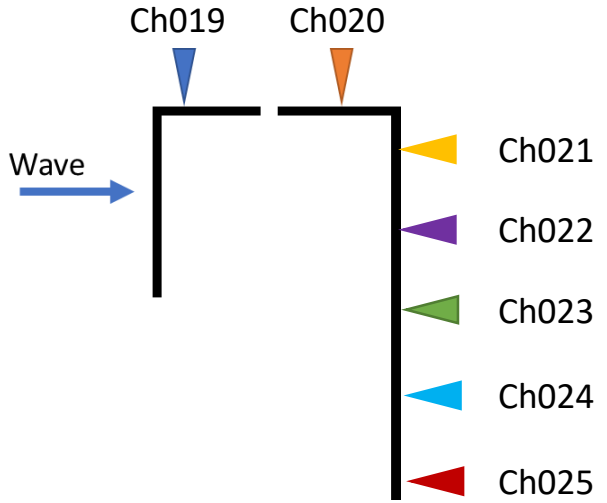


T_p = 6.0 s
H_{mo} = 1.0 m
P_{max} = 10 ρgH

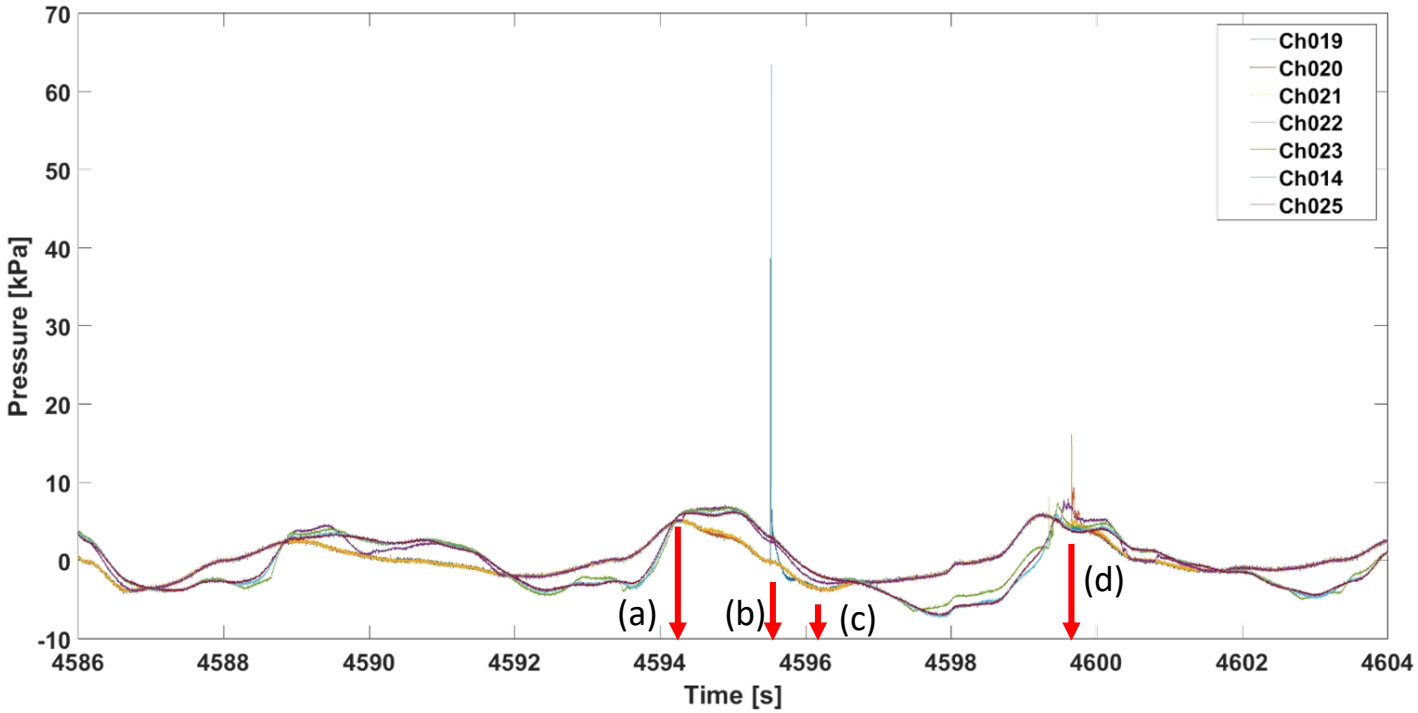
Impact pressure measurement

- Successional impact: rear -> front or front -> rear part of the ceiling



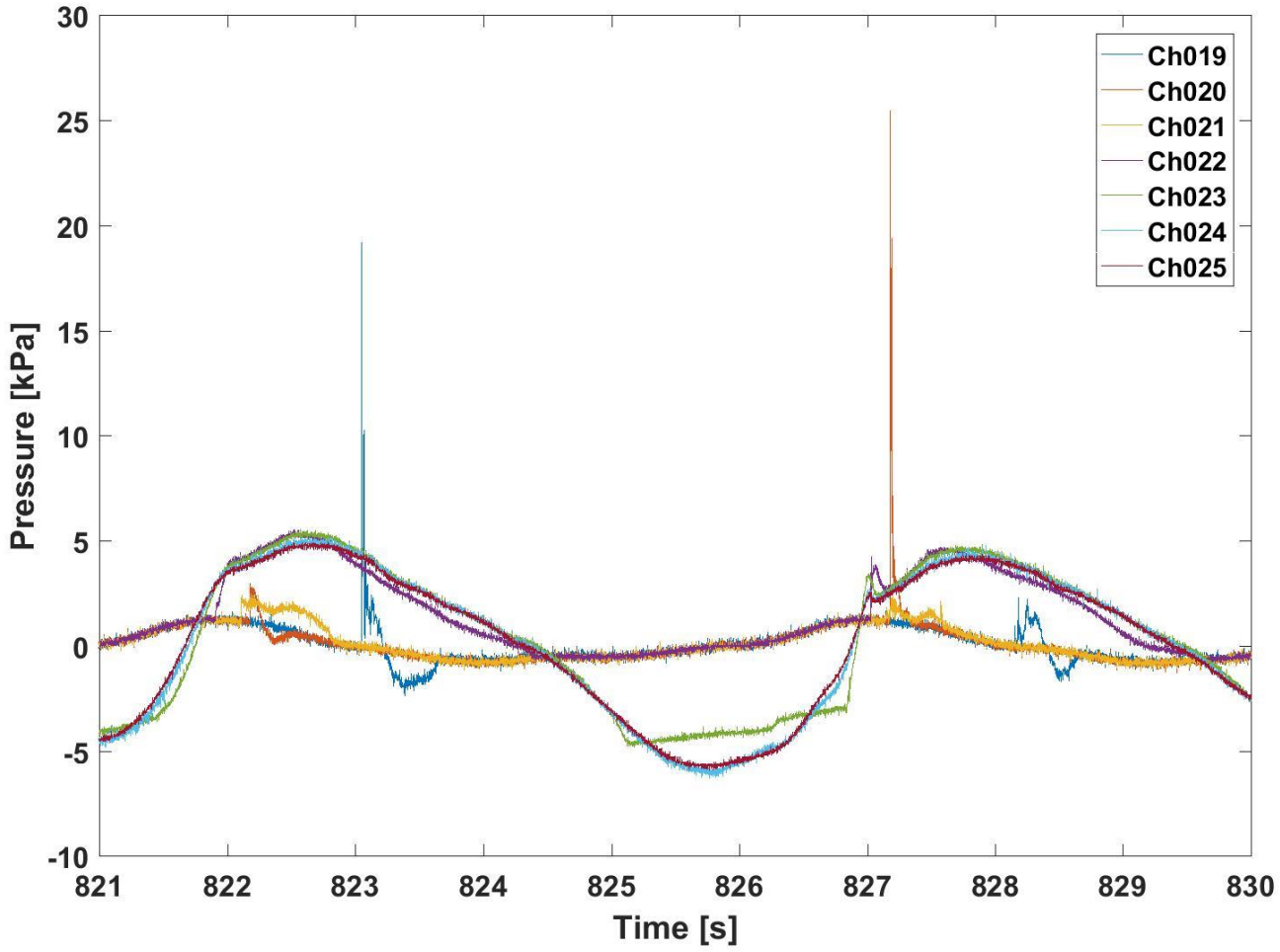


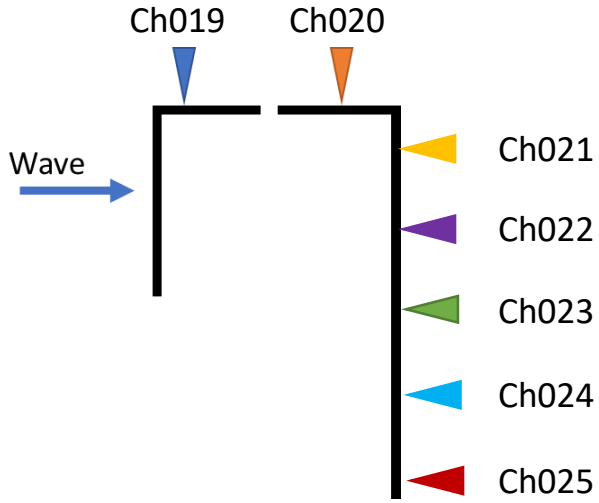
T_p = 5.0 s
H_{mo} = 0.8 m
P_{max} = 8 ρgH



Impact pressure measurement

- Successional impact: rear -> front or front -> rear part of the ceiling





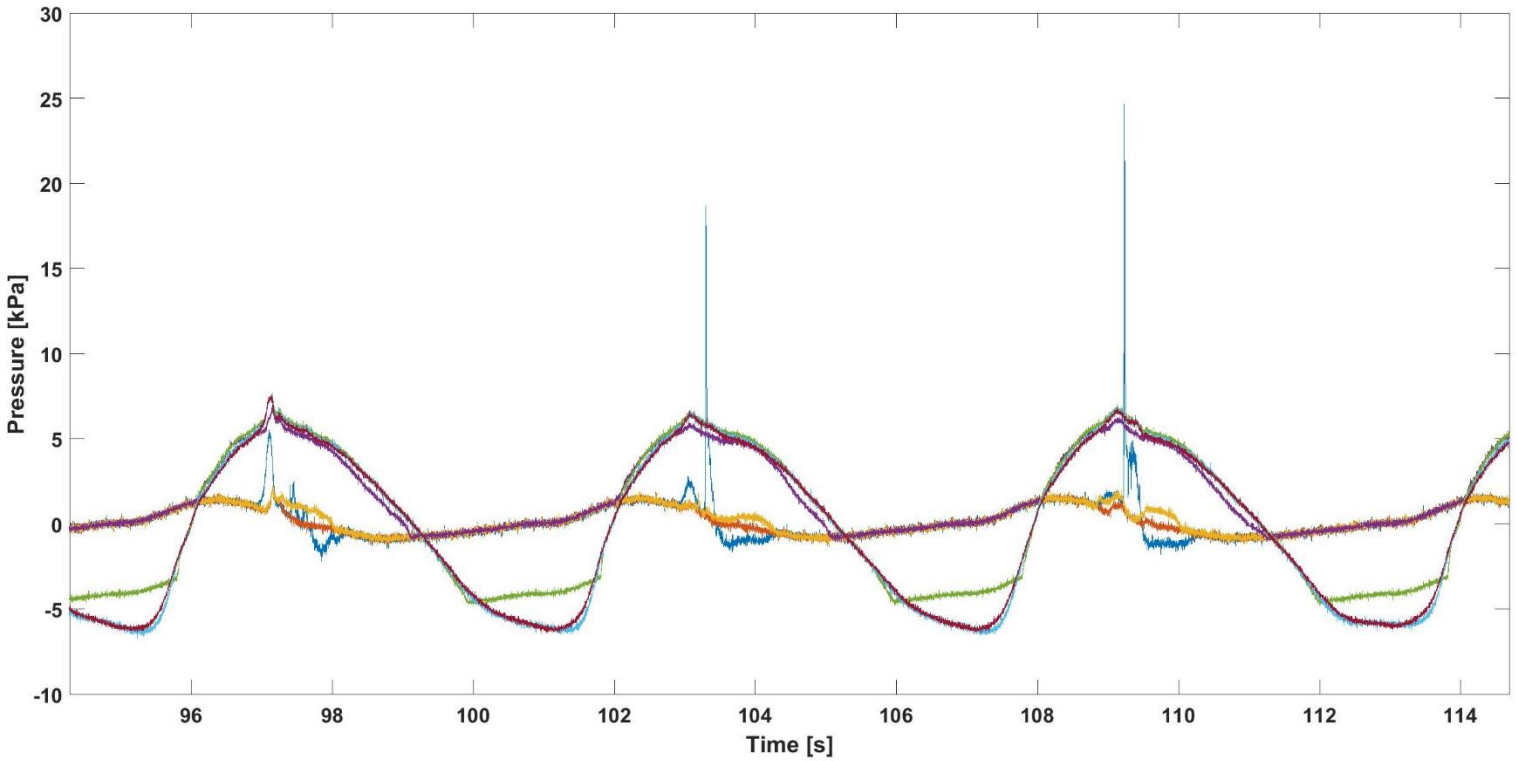
T_p = 5.0 s

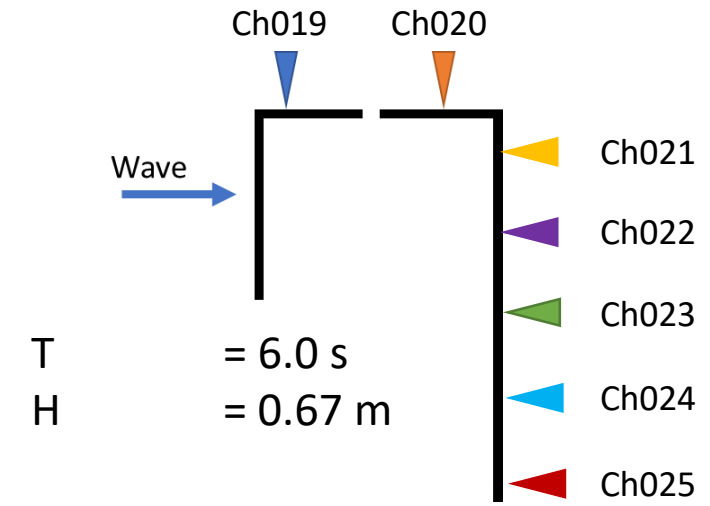
H_{mo} = 0.54 m

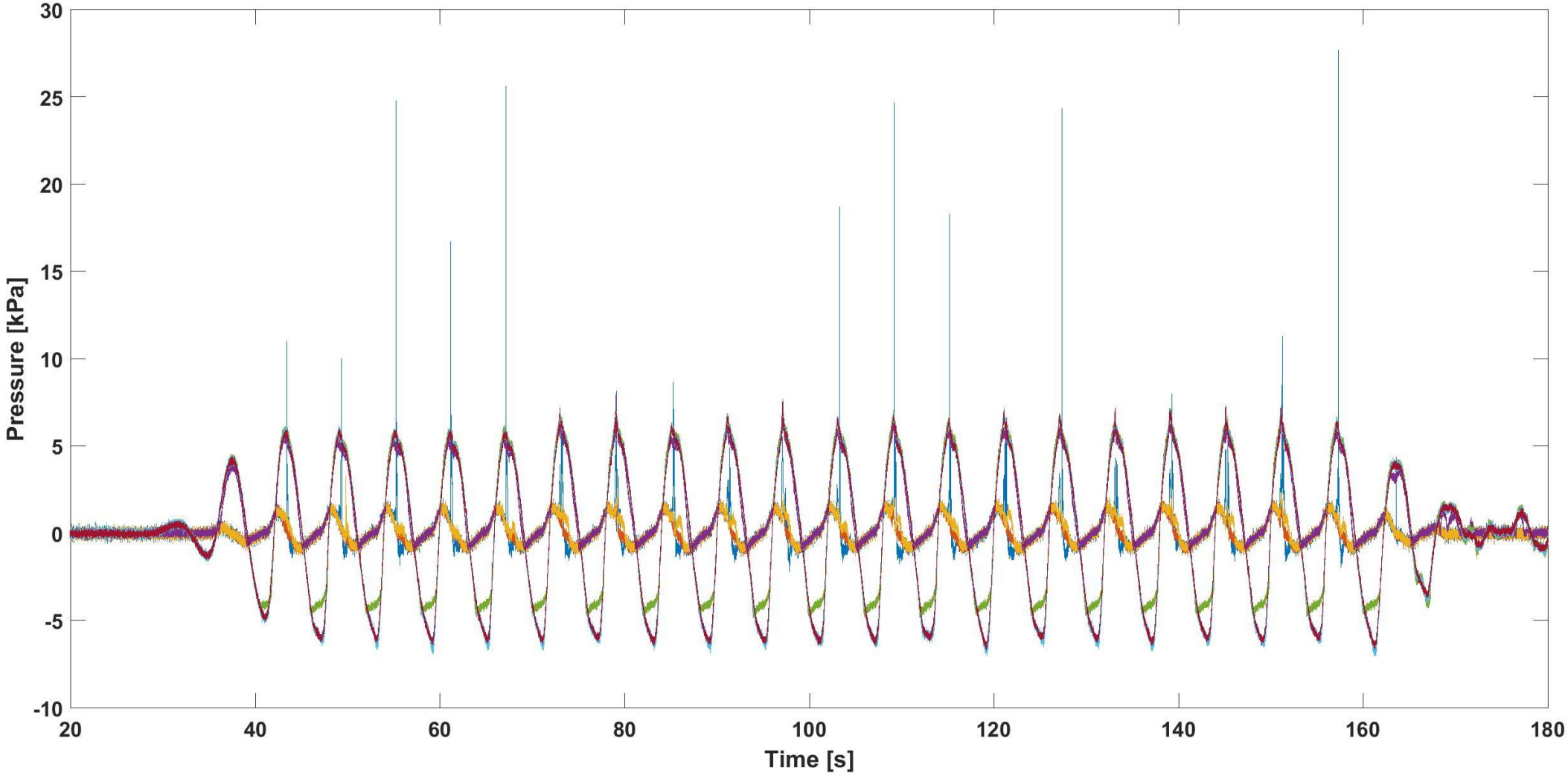
P_{max} = 4.7 ρgH

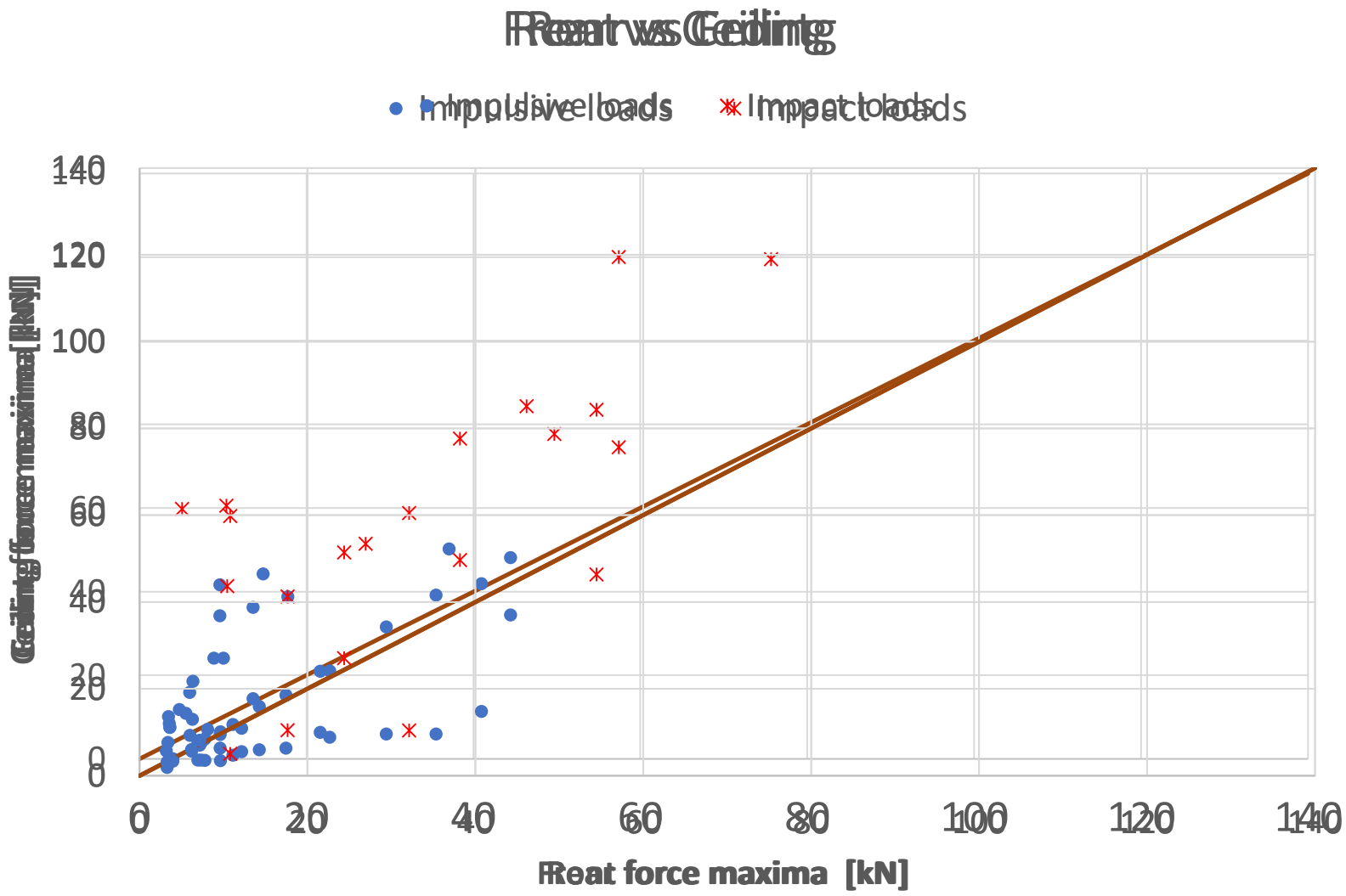
Impact pressure measurement

- Whole water column hits the chamber ceiling






Pressure [kPa]
30
25
20
15
10
5
0
-5
-10
20
40
60
80
100
120
140
160
180
Time [s]


Impulsive loads
Impact loads
0
20
40
60
80
100
120
140
Reat force maxima [kN]

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Conclusions

- Wave conditions under which sloshing is more likely to occur have been characterised for **no sloshing, low sloshing, medium sloshing, and impact sloshing.**
- Three types of in-chamber ceiling impact have been characterised and quantified: **single impact, successional impact, and whole water column impact**
- Impact pressures of up to **12 ρgH** have been measured within chamber
- Further comparison between the front wall and the in-chamber ceiling proves that the ceiling impact is **at least comparable** with the front wall
- Some degree of sloshing is not uncommon in an OWC chamber during operation, so it should be part of the design consideration