FRANZIUS-INSTITUT für Wasserbau und Küsteningenieurwesen

Leibniz Universität Hannover

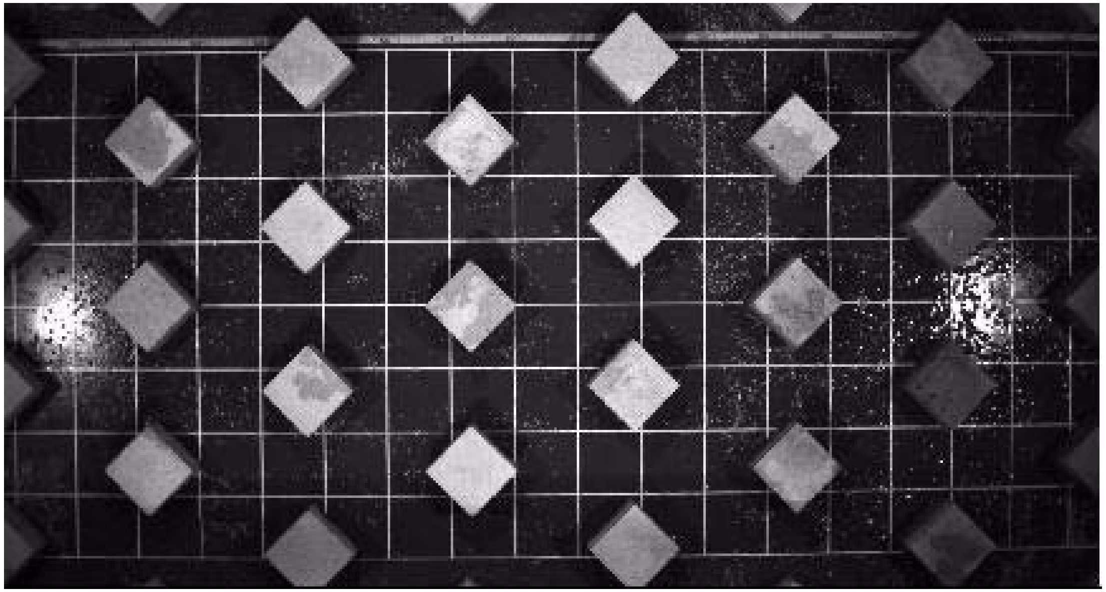
INTERAKTION KÜSTENNAHER STÄDTISCHER BEBAUUNG MIT TSUNAMI-WELLEN

FZK-Kolloquium, Hannover, 26.02.2013

Dr.-Ing. Nils Goseberg (goseberg@fi.uni-hannover.de) and Prof. Dr.-Ing. T. Schlurmann
Franzius-Institute for Hydraulic, Waterways and Coastal Engineering, Hanover, Germany

Outline

- Introduction and Objective
- Methodology
- Performance assessment of wave generation
- Run-up and Macro-roughness influence
- Conclusions and outlook



Introduction and Objective

Long waves and Coastal Impact

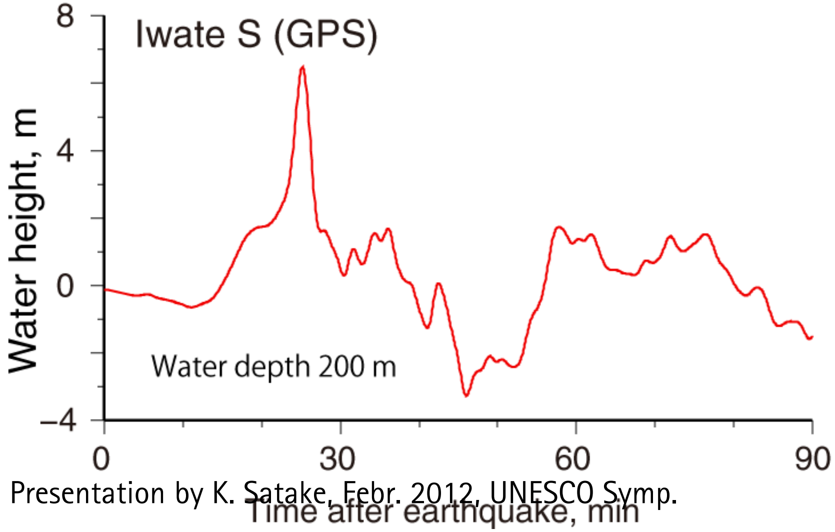
- High water levels and flow velocities
  - Extreme risk for coastal communities
  - Destruction of infrastructure and houses
  - Extensive inundation, esp. at coastal flats (e.g. salinisation)

Application beyond tsunami/long waves

- Dam and levee breach in urbanized areas
- Extreme flooding
- Flash flood events

Near-shore surface elevation examples of recent tsunami

- 2004 Tsunami, echosounding from Mercator Yacht, ca. 12 m depth
  - T = 13 – 14 min
- Tohoku March 2011 Tsunami, GPS-bouy (Univ. of Tokyo and MLIT)
  - T >30 min
- Are there accurate physical modeling technique available?
  - Most wave generation techniques not capable of generating those waves in scaled physical models (e.g. 1:100 length scale)



Presentation by K. Satake, Febr. 2012, UNESCO Symp.

Brief literature review on wave-structure interaction of long waves

- Solitary wave on vertical wall (Fenton and Rienecker [1982])
- Modelling broken long waves on vertical walls (Ramsden [1993])
- Submerged breakwater and long waves (e.g. Tomita et al. [2007])
- Impact forces on a square column (Pedro et al. [2007])
- Solitary wave on beach house (Xiao and Huang [2008])
- Submerged macro-roughness (Fujima [2001], Lynett [2007])
- Flood waves interacting with urban settlement (Soares-Frazão et al. [2008])
- Groups of buildings in steady flow (Goto and Shuto [1983])
- Seaside, Oregon model test (Cox et al. [2009])

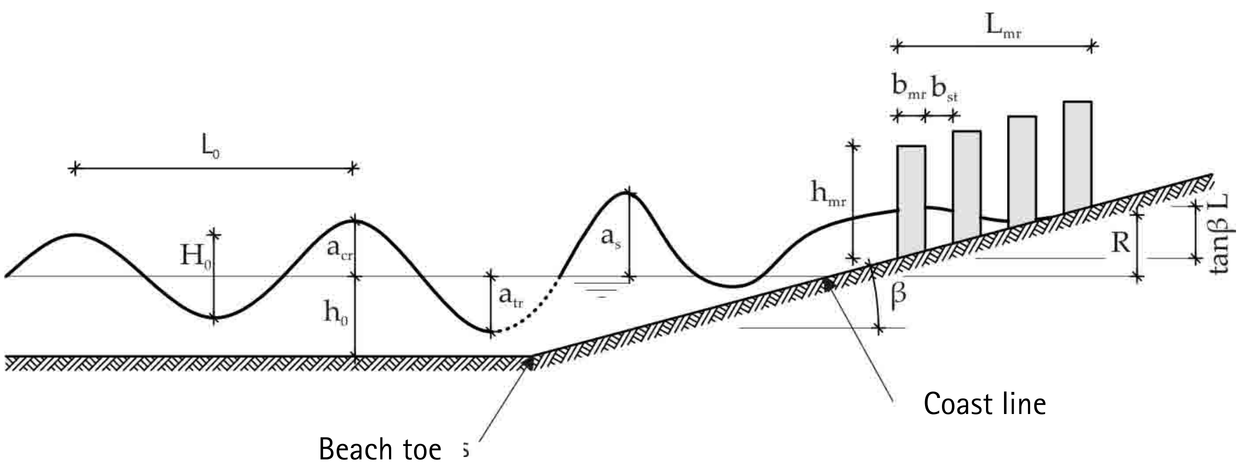
Questions:

→ Could urban settlements near-shore be idealized?

→ How is the run-up affected?

Objective

- Generation of arbitrary long waves - Near-shore tsunami waves
- Study of run-up reduction due to
  - Wave-structure interaction on-shore
  - Idealization of urban settlement
- More realistic representation of tsunami waves in the laboratory



Methodology

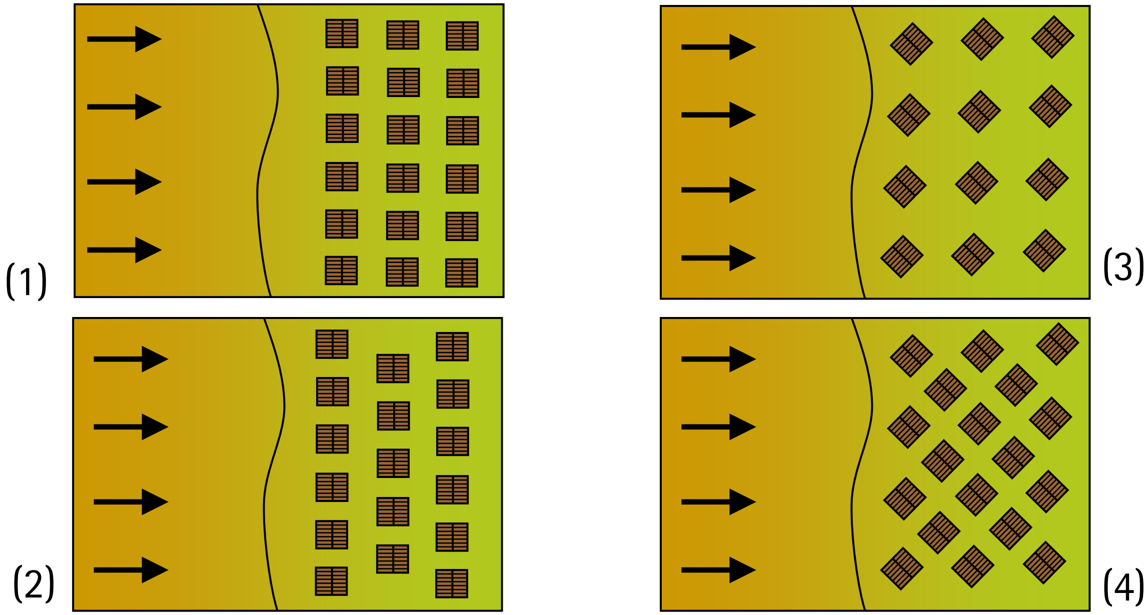
Hydraulic model test – Model setup

- Froude similitude, constant beach slope 1:40, length scale 1:100
- Macro-roughness elements made of concrete
- Beach surface, PVC-board, symmetric model with 2D-approach
- Variation of wave heights with constant wave length, sinusoidal waves

Methodology

Idealized coastal settlement

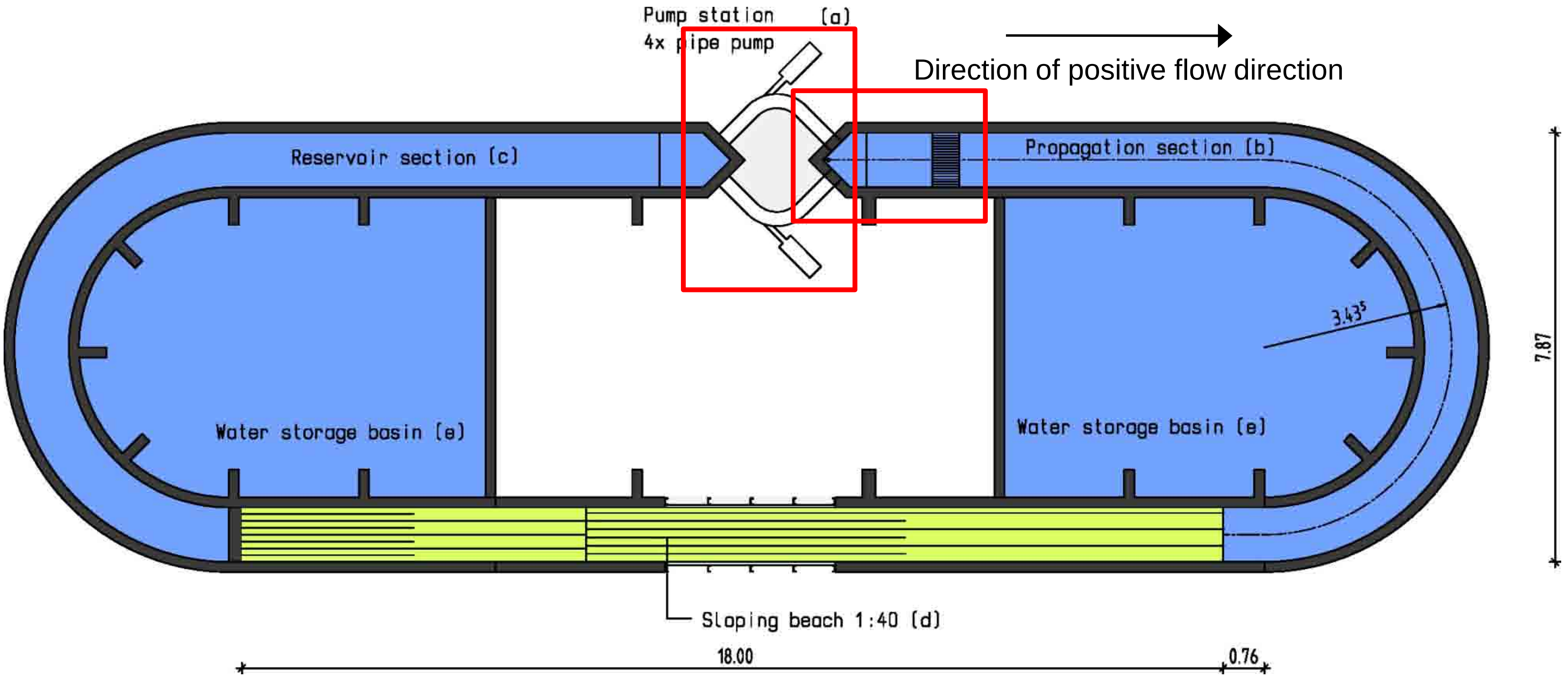
- Macro-roughness configuration and angle
  - (1) aligned, non-rotated (3) aligned, rotated
  - (2) staggered, non-rotated (4) staggered, rotated
- Definition of obstruction ratio cross- and long shore
- Wave run-up (78 exp.) and wave-structure interaction (212 exp.)



Methodology

Closed circuit flume / Race-track flume

- Separation of original flume into reservoir (c) / propagation section (b)
- Acceleration/deceleration at pump station with high-capacity pumps
- Froude similitude – length scale 1:100
- PID-controller - adjustment of rotational speed of pumps

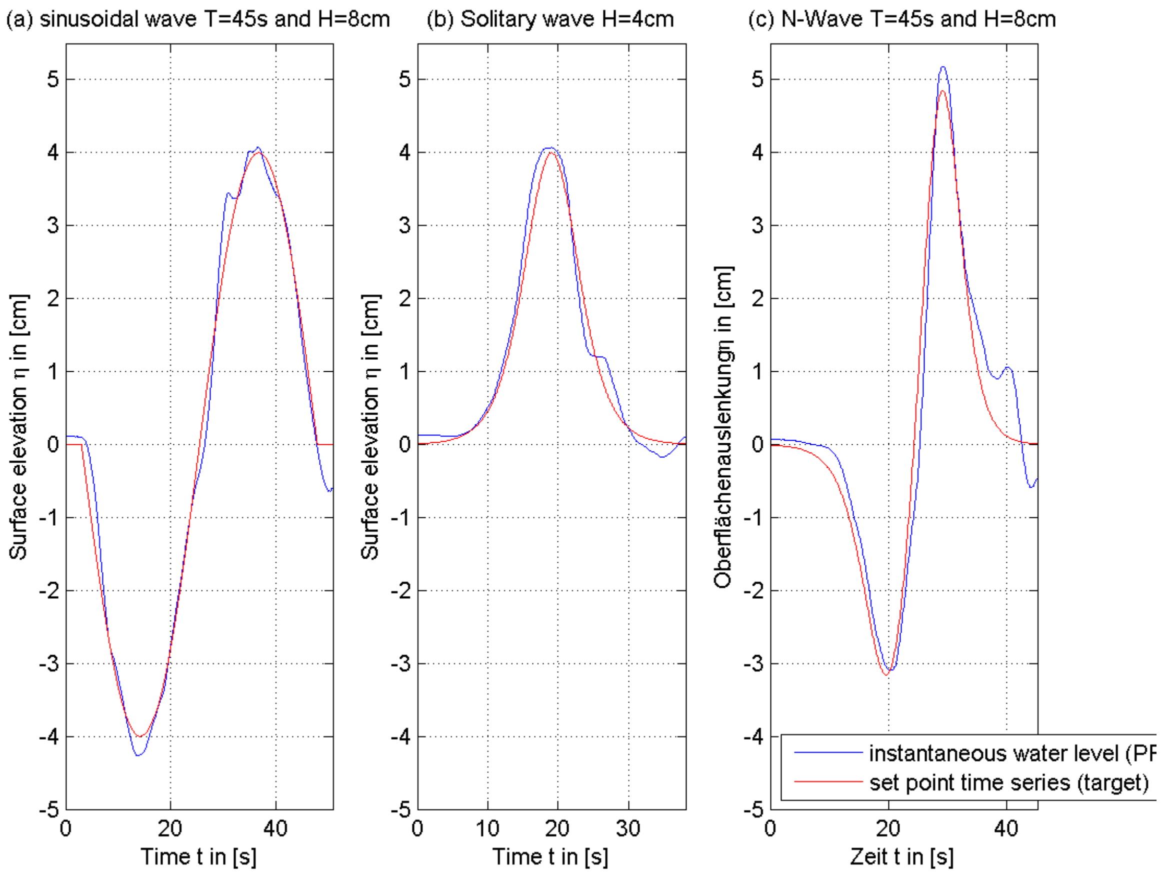


Performance assessment of wave generation

Performance assessment of wave generation

Long wave generation – Solitary and N-waves

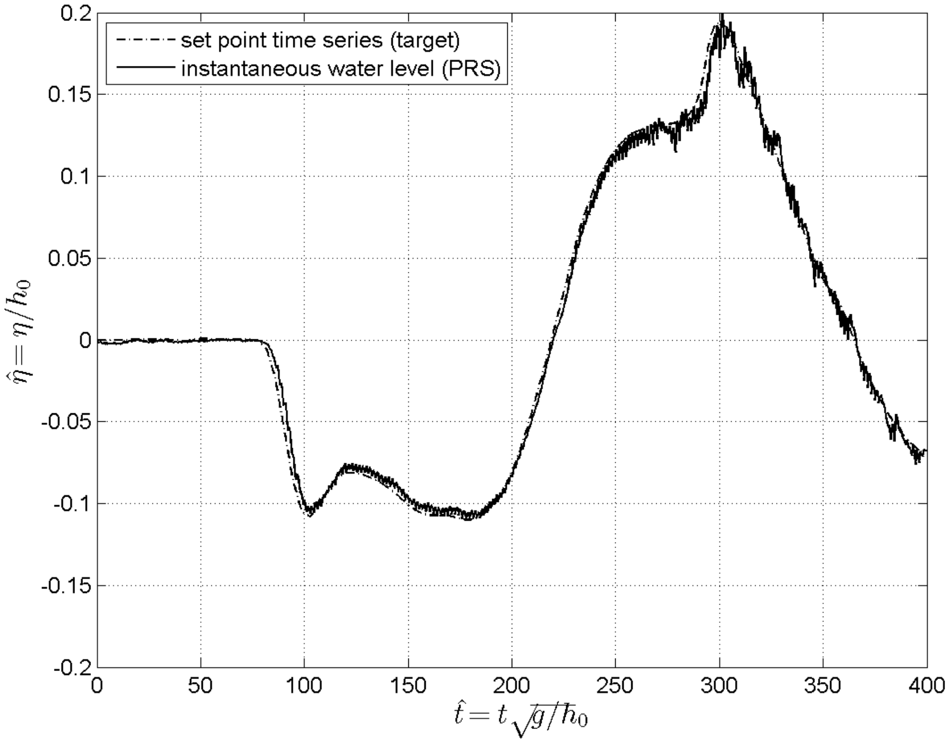
- Generation of various wave forms

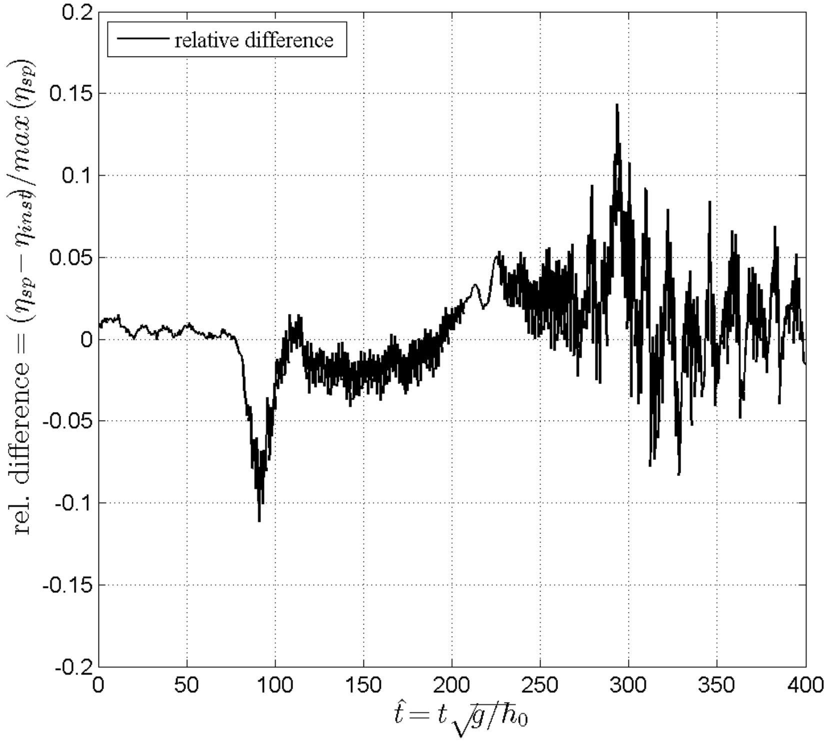


	H	T [s]	Standard deviation	
	[cm]	[s]	[cm]	[%]
Sinusoidal	8	15	0,5	5,7
Sinusoidal	8	30	0,4	5,1
Sinusoidal	8	45	0,5	6,7
Sinusoidal	8	75	0,4	4,7
Sinusoidal	8	120	0,4	4,8
N-Wave	8	~30	1,0	12,5
N-Wave	8	~45	0,9	11,9
Solitary	2		0,1	6,1
Solitary	4		0,2	4,7
Solitary	6		0,3	5,9
Solitary	8		0,6	7,2
Solitary	10		0,6	6,3

Long wave generation – realistic tsunami wave

- Time series from numerical modeling for Padang, Indonesia at h = 30 m
- Currently: Manual fine-tuning of controller P, I, D-values



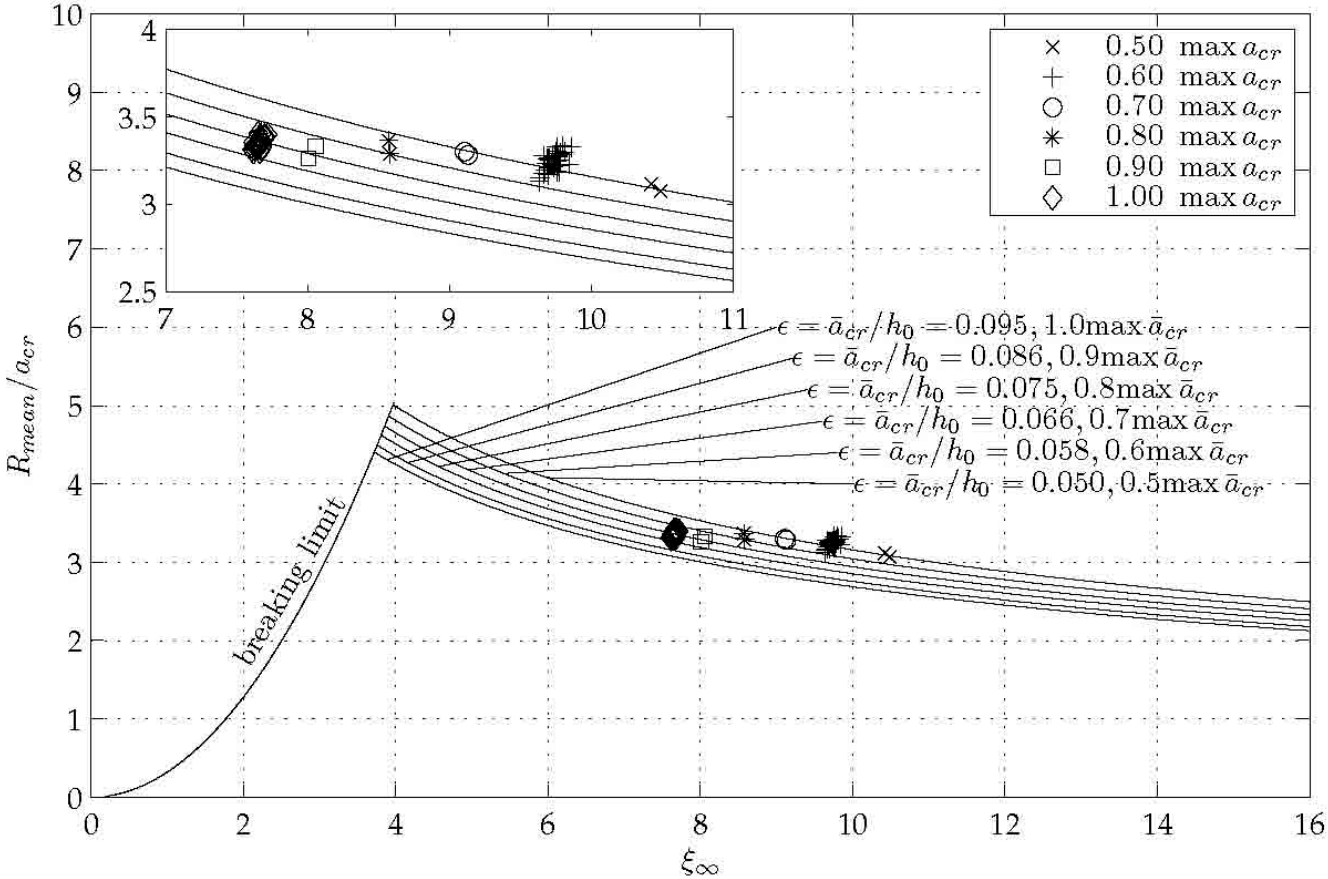


Run-up and Macro-roughness influence

Run-up and Macro-roughness influence

Wave run-up

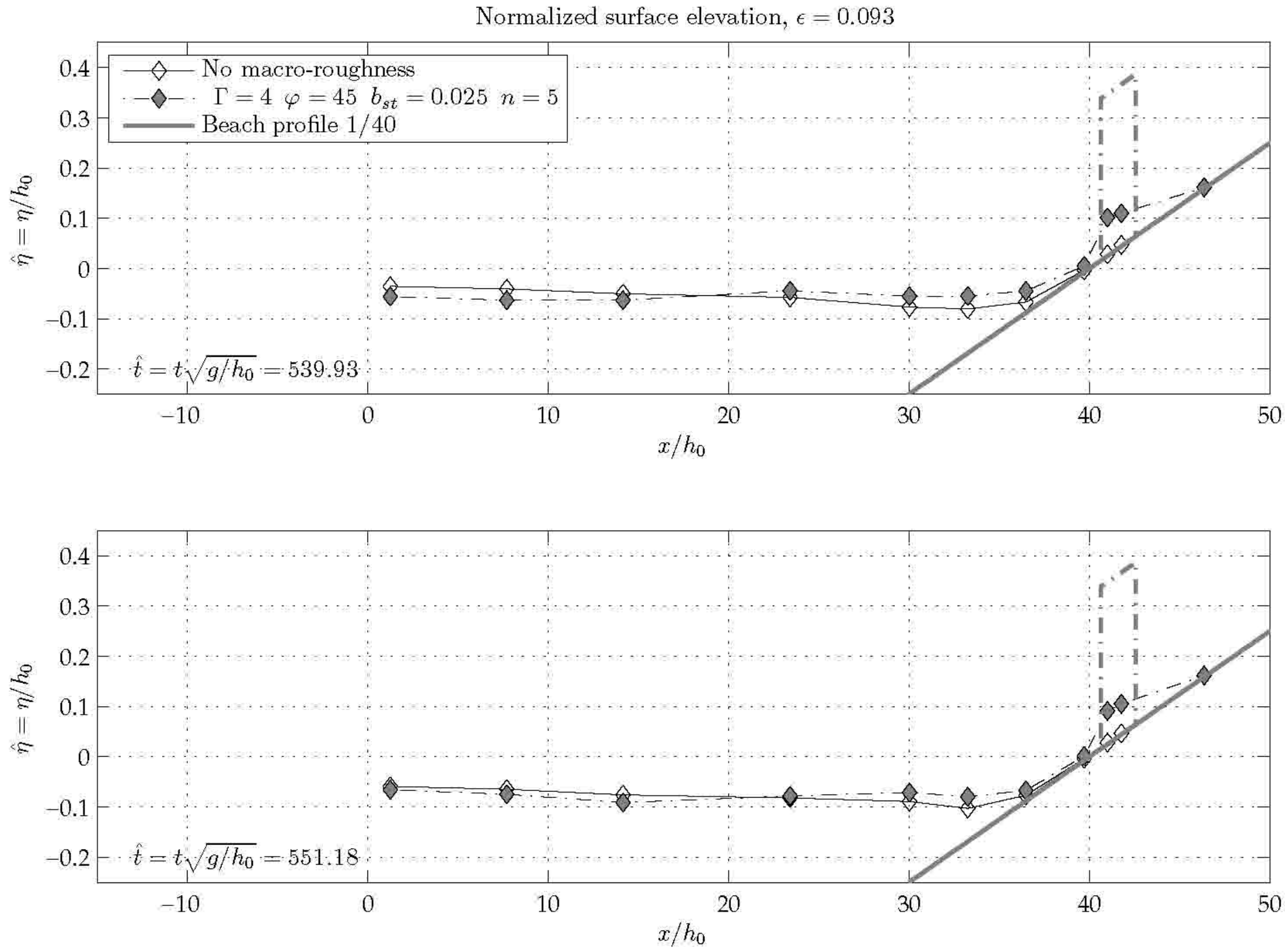
- Experimental results of wave run-up on plain beach, T = 60 s, ampl. var.
- Comparison with analytical solution of Madsen and Schäffer (2010), JFM



Temporal evolution of water surface

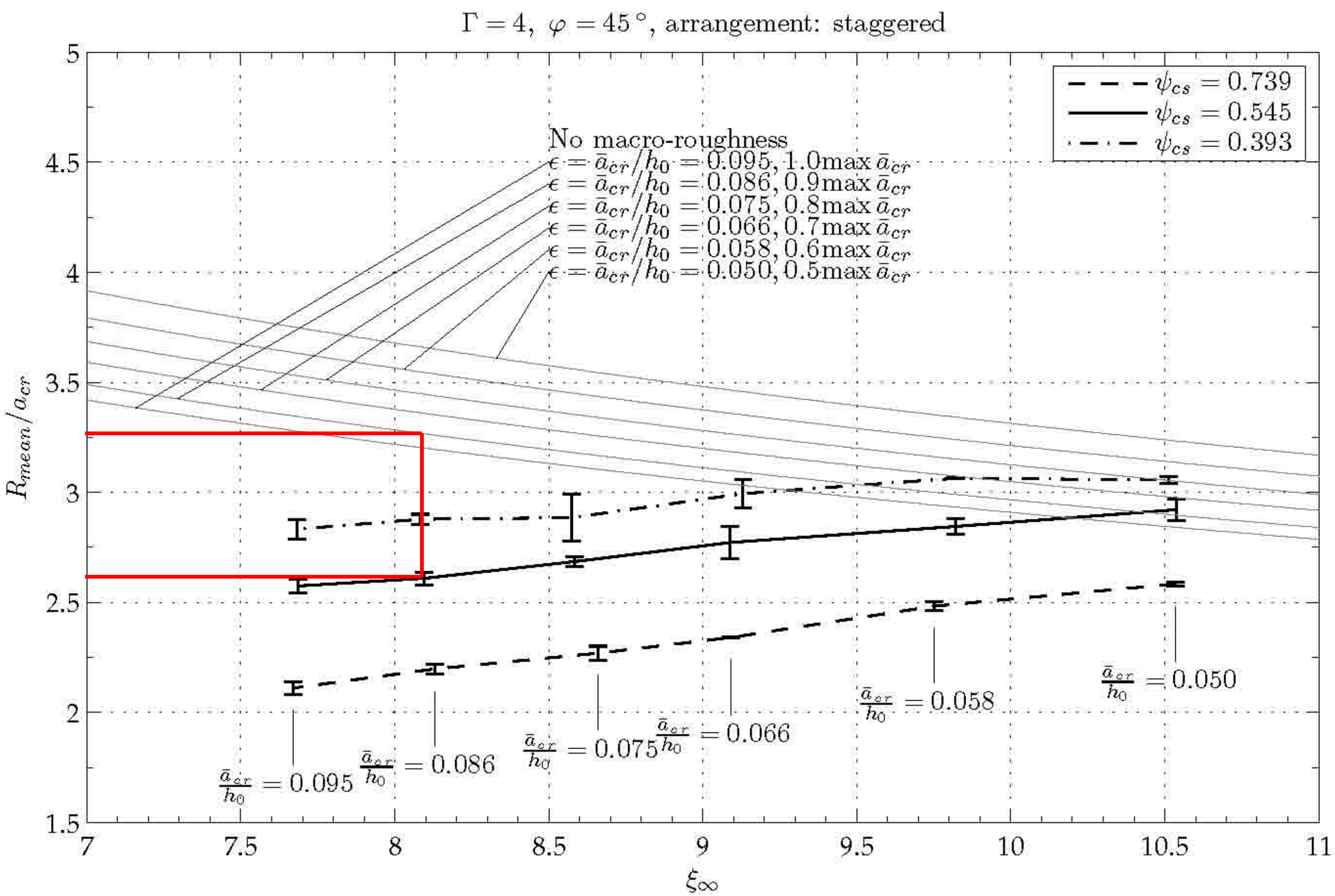
Water surface elevation in profile

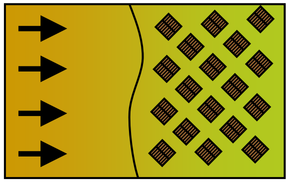
- Shock wave generation at the first macro-roughness row



Influence of Macro-roughness elements II

- Estimation of run-up reduction for a 1:40 beach

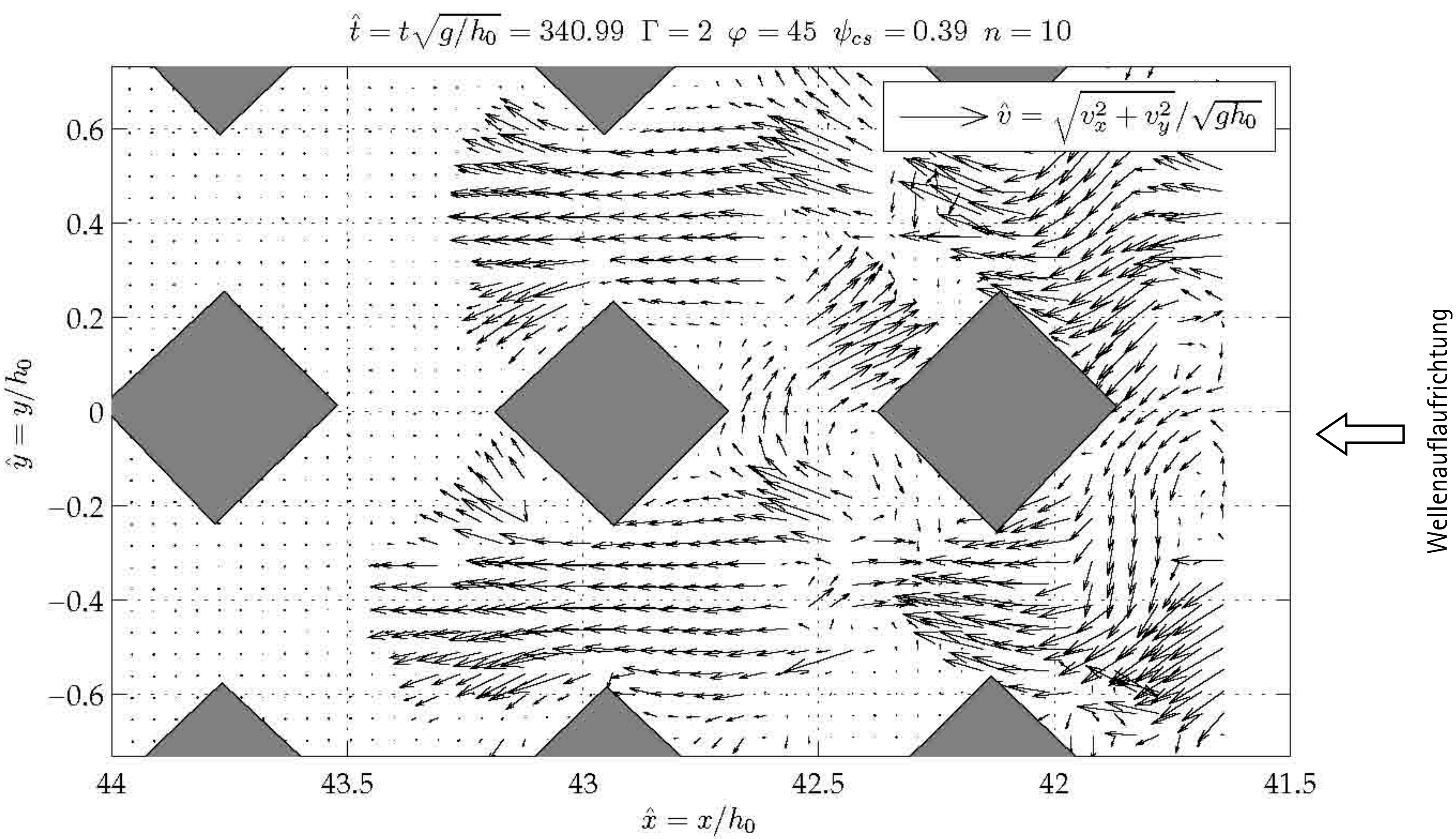




Flow velocities

Velocity measurements – Surface PIV

- Qualitative analysis – acceleration/deceleration

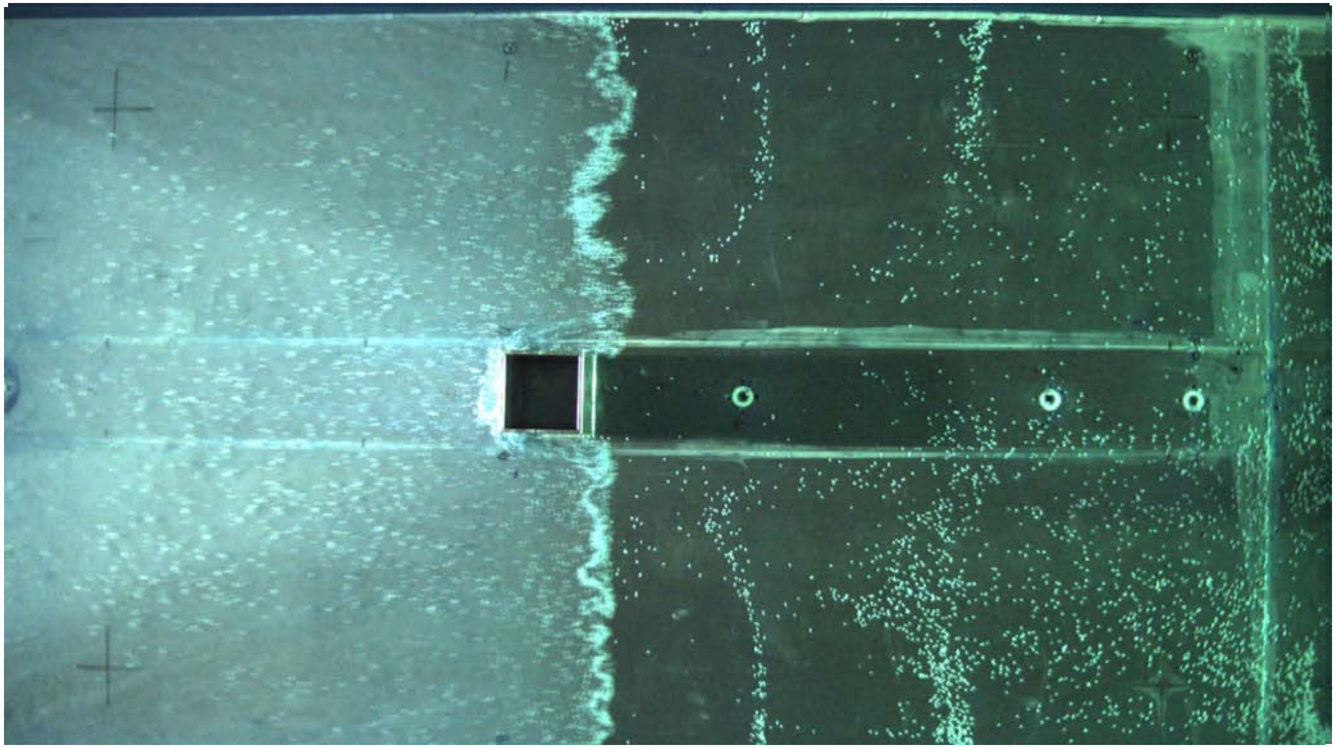


Flow velocities

Current studies

- Transition from sub- to supercritical flow

Wellenauflaufrichtung



Conclusions and outlook

Conclusions

- Generation of arbitrary long waves - Near-shore tsunami waves
  - Wave generation is feasible for arbitrary wave forms
  - Limitations:
    - a) Available pump capacity
    - b) Storage capacity of flume and reservoirs
- Study of run-up reduction due to
  - Wave-structure interaction on-shore
  - Idealization of urban settlement
    - Investigation of wave run-up reduction by macro-roughness elements - long-shore obstruction ratio dominant
- More realistic representation of tsunami waves in the laboratory
  - Not perfect, but simple enough to continue with
  - Other wave forms easily applicable