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The State of the Art and Science of Coastal Engineering

Experimental Study of the Flow Induced by Waves in the Vicinity of a Detached Low-Crested (Zero freeboard) Breakwater

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OUTLINE

- ✓ Introduction
- ✓ Objective
- ✓ Experimental Setup
- ✓ Data Analysis
- ✓ Results
- ✓ Conclusions
- ✓ Future work

INTRODUCTION

- ✓ Environmental forcing
- ✓ Decreasing sediment supply
- ✓ Intense anthropogenic activities

→

- ✓ Severe erosion problems
- ✓ Decreasing beach width

- ➢ Coastal protection (e.g. groynes, detached breakwaters et.c.)
- ➢ Greek coasts
  - ✓ severe erosion problems
  - ✓ steep bottom slopes (1/3 – 1/20)
- ➢ Low-crested breakwaters (LCB)
  - ✓ reduced construction costs
  - ✓ effective harmonization with natural environment

INTRODUCTION

- Proper design
  - ✓ information on flow characteristics (currents, overtopping et.c.)

- Numerous existing studies of LCB
  - transmission coefficient (e.g. Seelig, 1980, Van der Meer and Daemen, 1994, D'Angremond et al., 1996, Seabrook and Hall, 1998 et.c.)
  - phenomena around LCB (e.g. Mory and Hamm, 1997, Garcia et al., 2004, Kramer et al., 2005, Zanuttigh and van der Meer, 2008, Vicinanza et al., 2009, Soldini et al., 2009 et.c.)

OBJECTIVE

- detailed PIV and ADV velocity and surface elevation measurements behind a detached LCB (Rc=0), parallel to shoreline, part of an array of LCB
- spatial distribution of wave generated currents
- wave transformation in the LCB leeside
- provide data for numerical model calibrations

EXPERIMENTAL SETUP

❖ Wave basin (Hydraulic Engineering Laboratory, Univ. Of Patras)

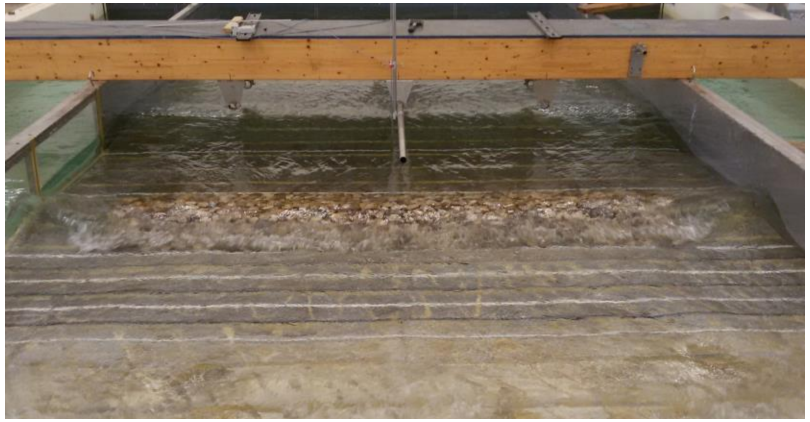
- ✓ surface of 12 x 7 m^2
- ✓ depth of 1.05 m

❖ Paddle wavemaker with A.W.A.C.S.

❖ Plane sloping beach of 1:15

❖ LCB physical model

- geometrical scale of 1:30
- zero freeboard
- two-layer rock armor with $D_{n,50}$=0.04 m (Van der Meer formula, 1990)
- steel-framed core



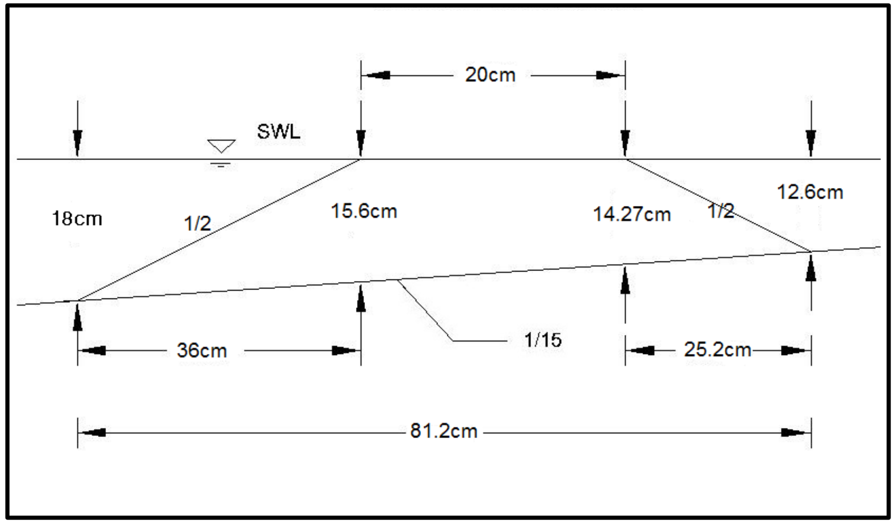


Fig. 1. Cross-section of the LCB physical model

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EXPERIMENTAL SETUP

- Free surface elevation measurements
  - ✓ 3 W.G. seaward of the LCB
  - ✓ 1 W.G. at seaward toe
  - ✓ Array of 8 W.G. at the LCB leeside

- Velocity measurements
  - ✓ 3D velocity, 16 MHz MicroADV probe at the LCB leeside and gap
  - ✓ 2D velocity, Underwater planar PIV at the LCB gap

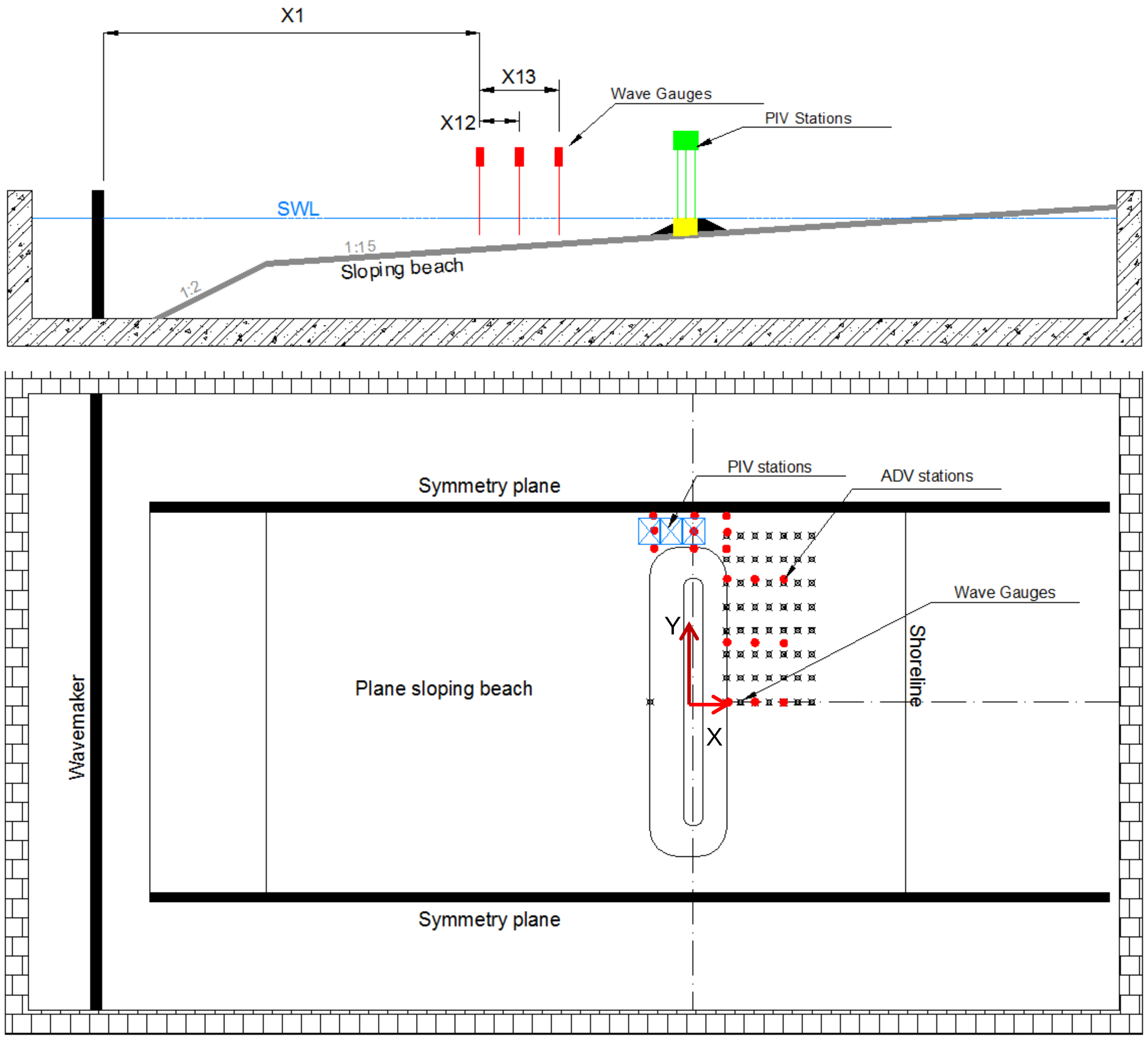

Fig. 2. Side and plan view of the LCB physical model

EXPERIMENTAL SETUP

❖ Wave scenarios

Wave Case		Wave Height H (m)	Wave Period T (s)	s_0
1	R	0.10	1	0.064
2	R	0.10	1.5	0.028
3	R	0.10	2	0.016
4	R	0.08	1.5	0.023
5	R	0.12	1.5	0.034
6	R	0.06	1	0.038
7	JON	0.085	1.312	0.032

❖ Measurements procedure

- ✓ Surface elevation measurements initiated with wave generation
- ✓ Velocity measurements initiated after quasi-steady wave conditions establishment (after ~150 waves)

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DATA ANALYSIS

- Surface elevation recordings
  - ✓ Reflection analysis (Mansard and Funke, 1980,1987) → K_R
  - ✓ Spectral analysis (FFT) → $H_{rms,m0}$
- ADV velocity recordings
  - ✓ Filtering → Average correlation >70%
    → Despiking (Goring and Nikora, 2002, Wahl, 2002)
  - ✓ Period-averaging → wave generated currents
- PIV velocity recordings
  - ✓ Particle displacement → two-frame, multi-pass cross-correlation
  - ✓ Period-averaging → wave generated currents

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RESULTS: wave transformation

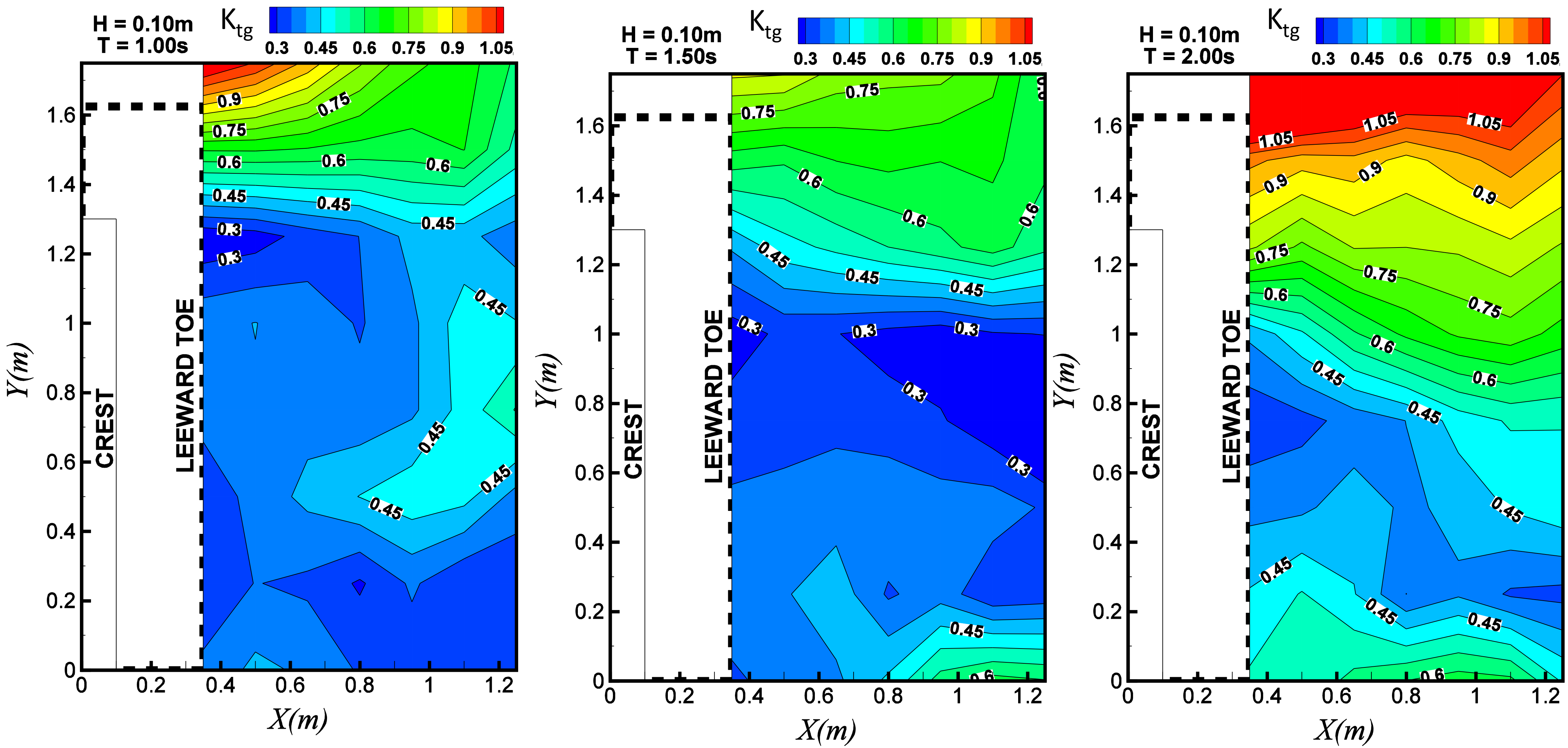


Fig. 3. Wave transformation at the leeside of the LCB for the regular wave cases with wave height *H* = 0.10 m and wave periods varying from *T* =1 s to *T* = 2 s

RESULTS: wave transformation

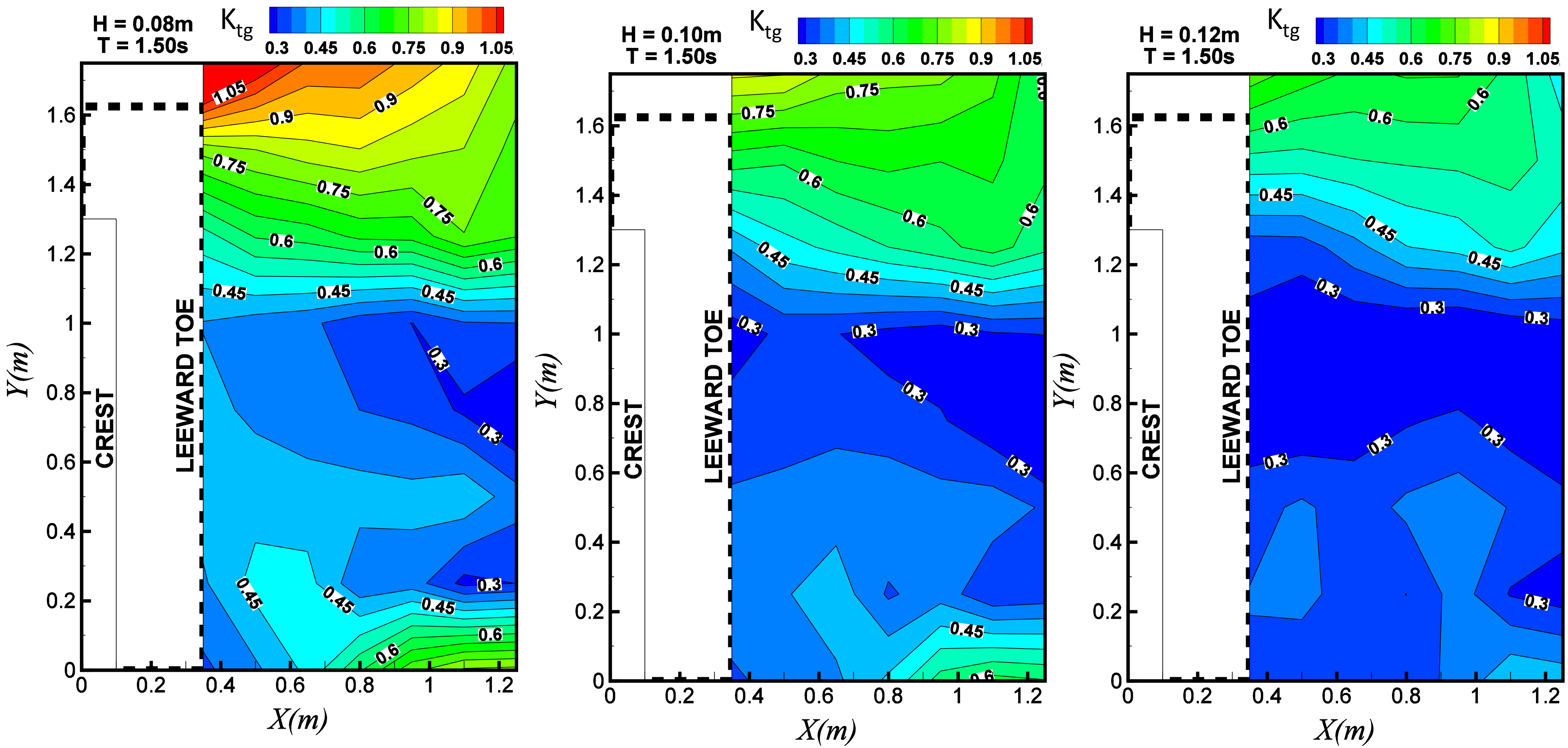


Fig. 4. Wave transformation at the leeside of the LCB for the regular wave cases with wave period T = 1.5 s and wave heights varying from *H* =0.08 m to *T* = 0.12 m

RESULTS: ADV velocities

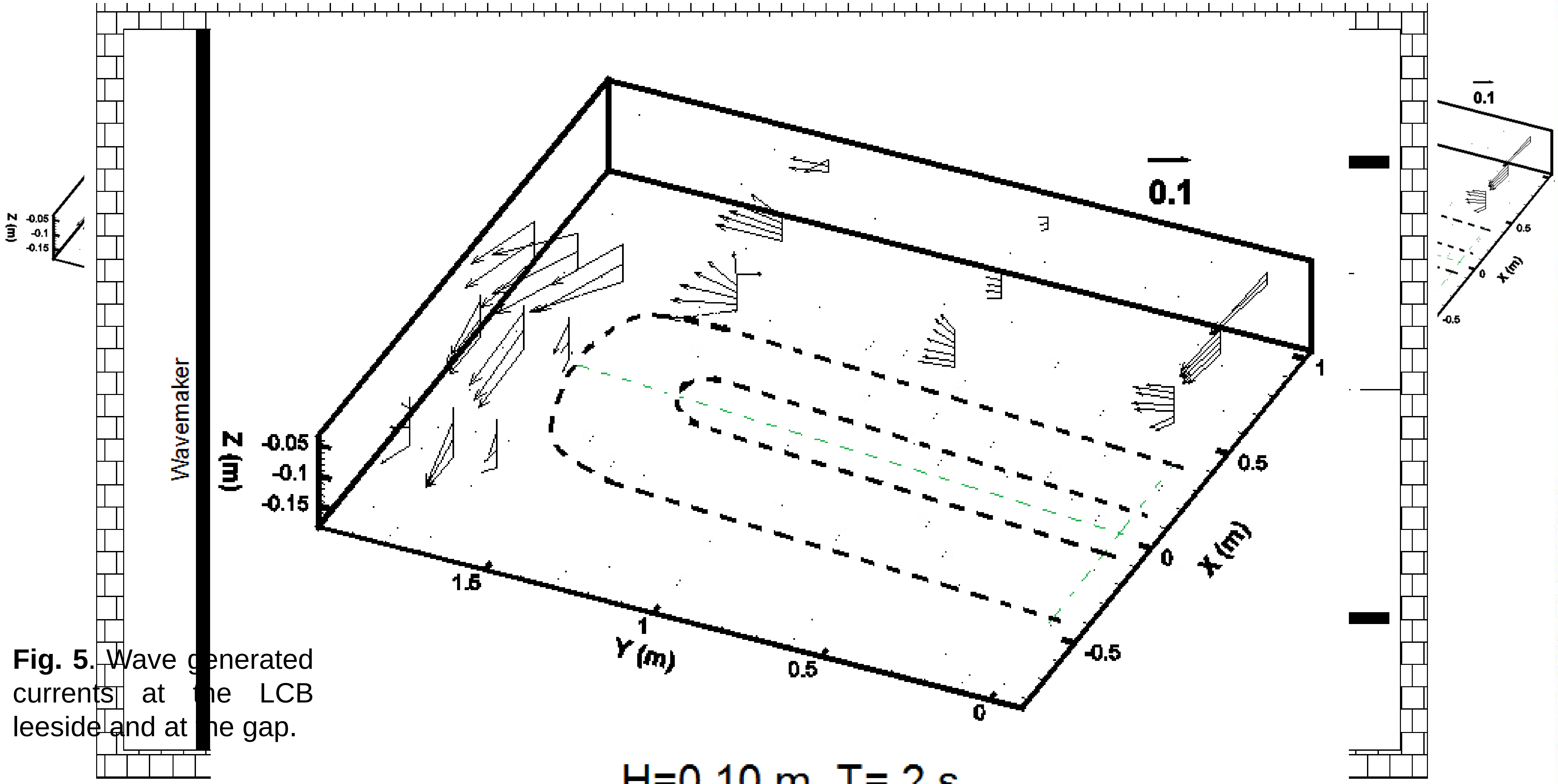
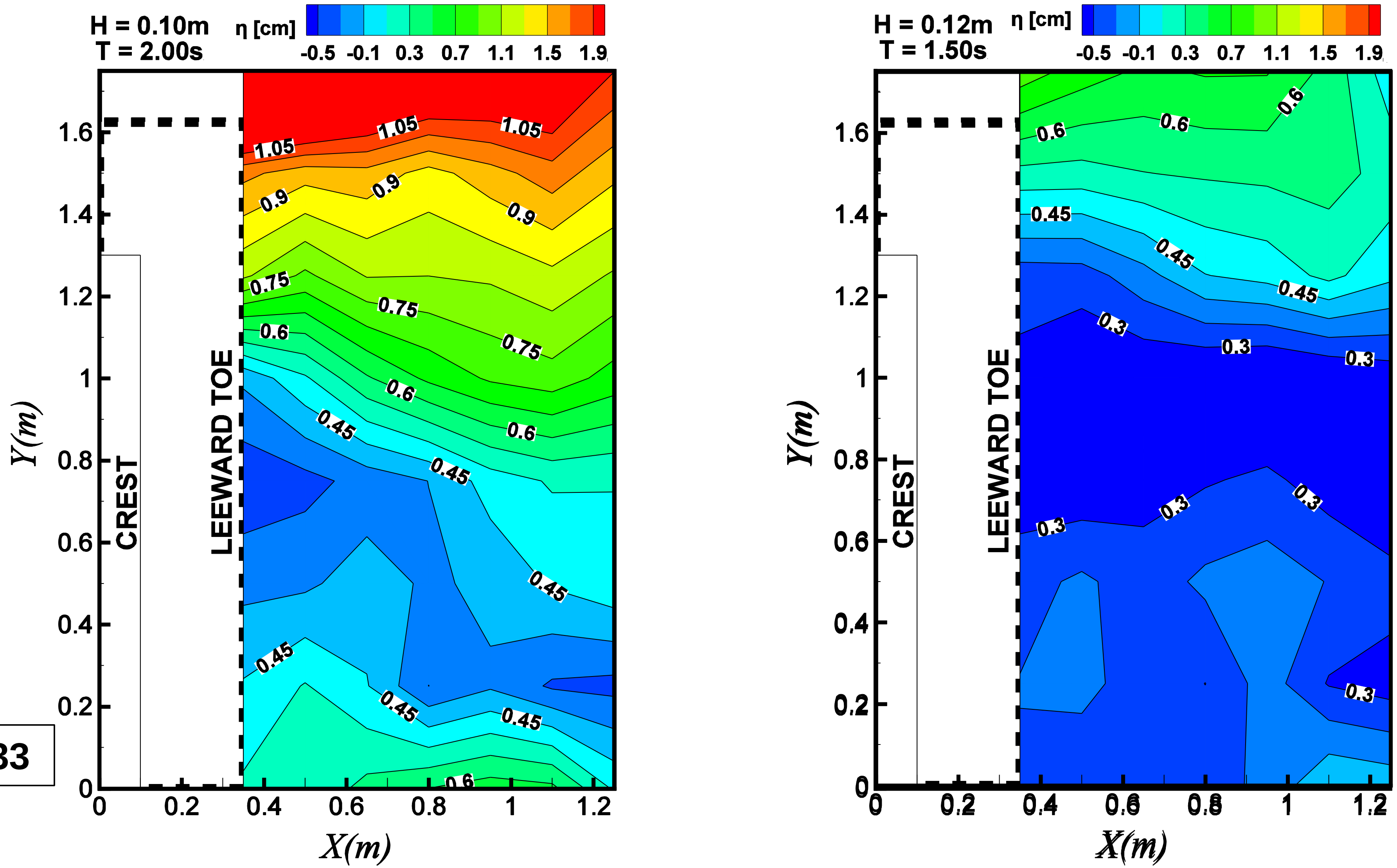


Fig. 5. Wave generated currents at the LCB leeside and at the gap.

H=0.10 m, T= 2 s

RESULTS: wave setup



K_R=0.233

K_R=0.295

Fig. 6. Wave setup at the leeside of the LCB for the regular wave cases with *H* =0.10 m, *T* = 2 s (left) and *H* =0.12 m, *T* = 1.5 s (right), respectively.

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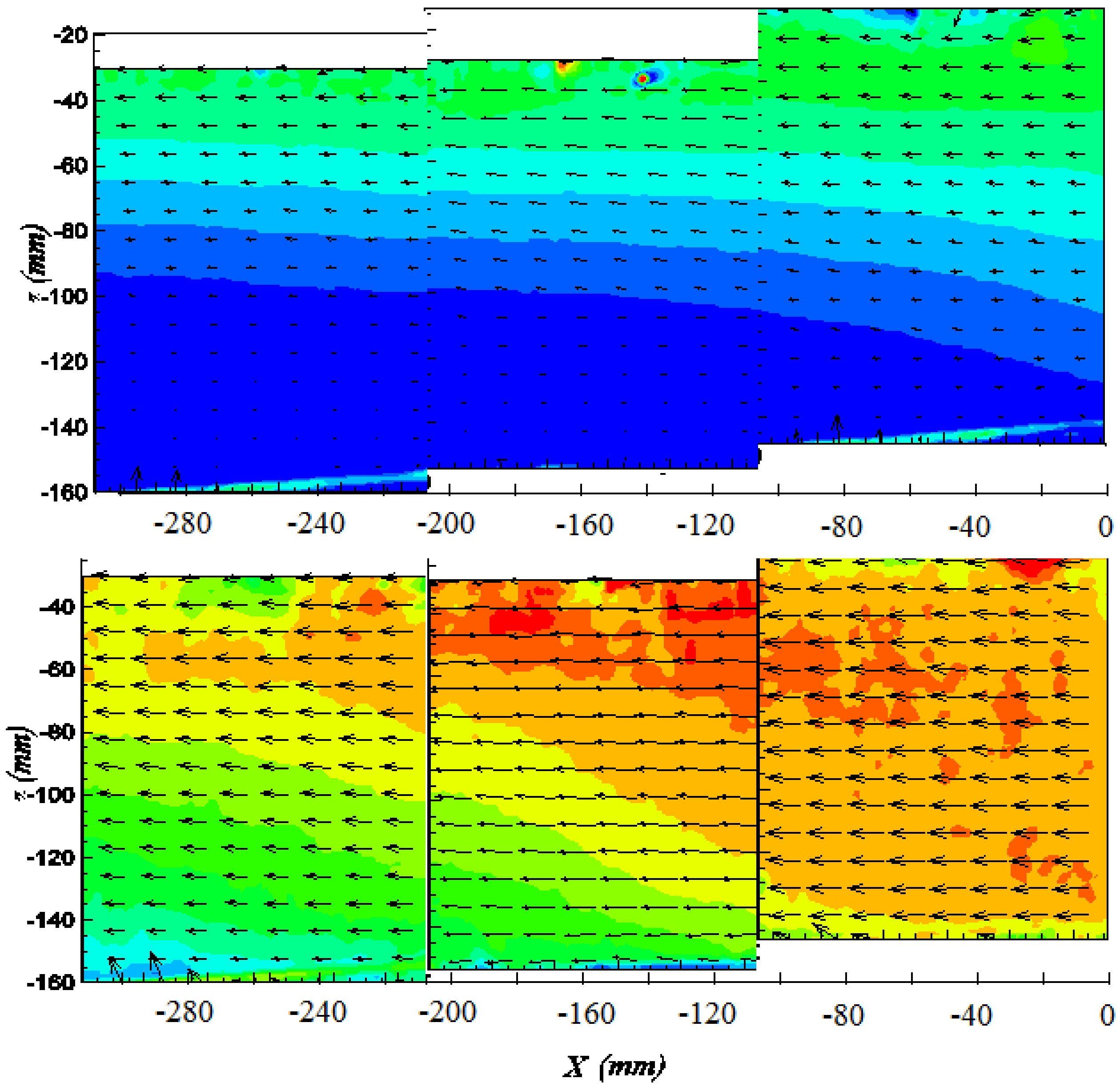
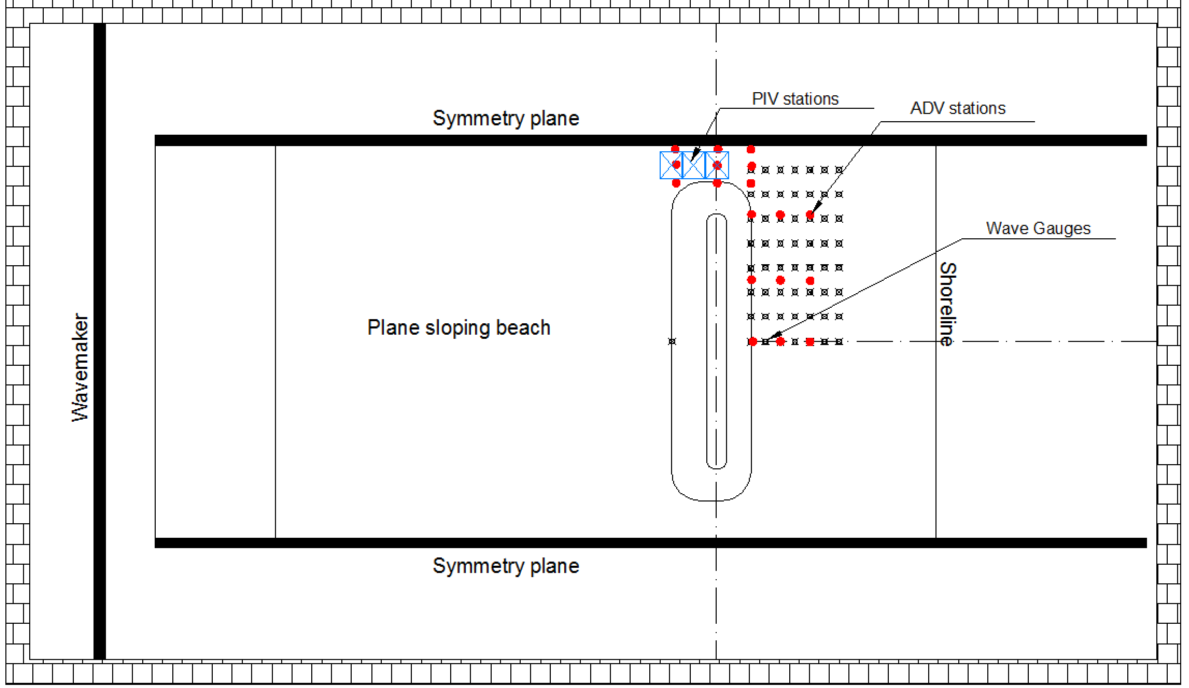
RESULTS: PIV velocities





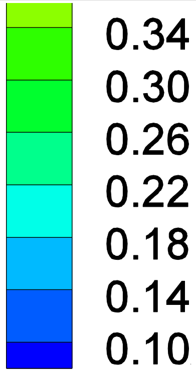


Fig. 7. Vertical distribution of the rip current velocity at the gap of the LCB physical model for the regular wave case with *H* =0.10 m, *T* = 2 s (top) and *H* =0.12 m, *T* = 1.5 s (bottom), respectively.

CONCLUSIONS

- Wave transformation
  - ✓ Increase of T results in larger K_{tg} values
  - ✓ Increase of H results in smaller K_{tg} values
  - ✓ Decrease of K_{tg} reduces wave setup
  - ✓ Increase of K_R enhances wave setup
- Currents in the LCB leeside
  - ✓ For a given H, increase of T results in a stronger cross-shore return current and a weaker parallel current
  - ✓ For a given T, increase of H results in a weaker cross-shore return current and a stronger parallel current
- Rip current in the LCB gap
  - ✓ Magnitudes between 0.12 – 0.50 m/s
  - ✓ Wave setup affects the magnitude of the rip current velocity
  - ✓ Non-uniform vertical distribution

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FUTURE WORK

- ❖ Further analysis of existing data
    - ✓ turbulence statistics
- ❖ More tests with irregular wave cases

Thank you…!