Numerical Investigation of Plunging Breakers Over a Porous Artificial Surf Reef

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Agenda

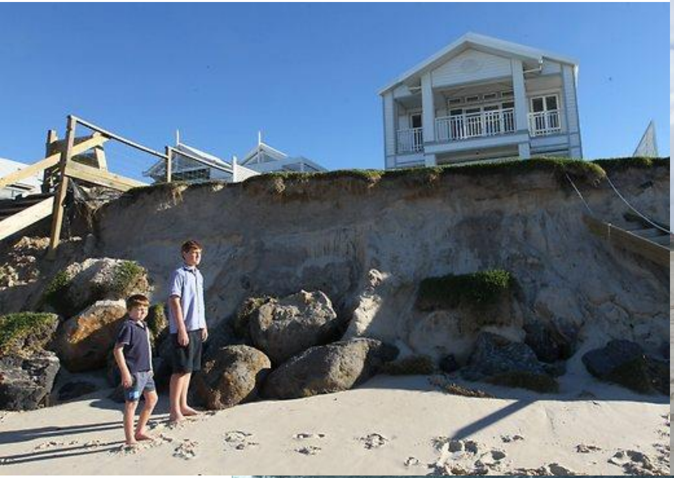
- Project background – Scope and Objectives
- Numerical model
- Model validation
- Palm Beach simulations
- Results
- Conclusions

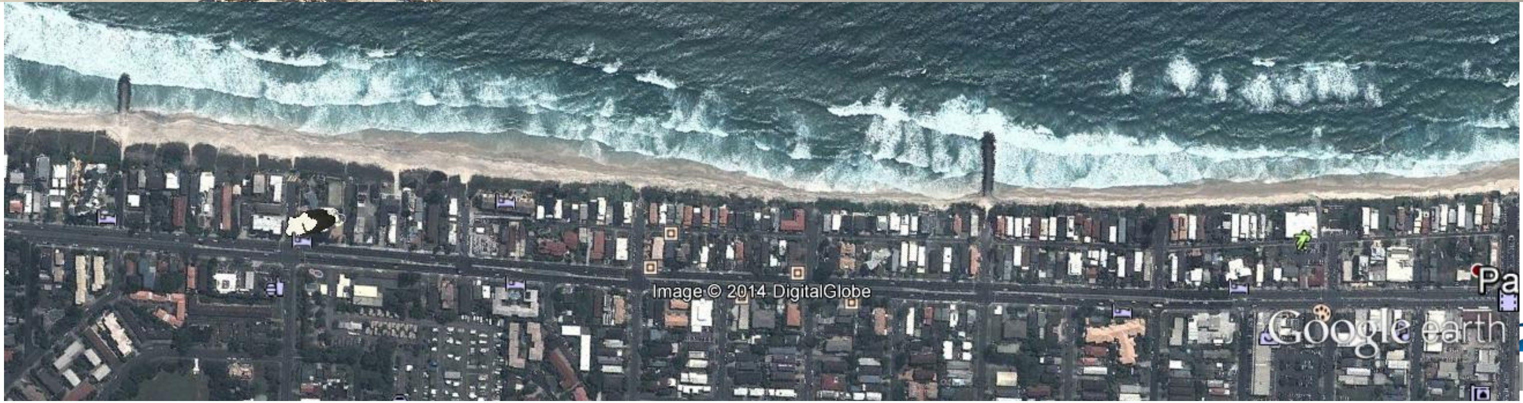
1.

Scope and Objectives

Palm Beach, Queensland, Australia

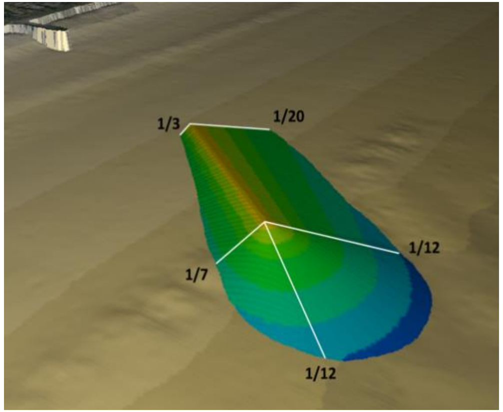
Erosion Problems on Palm Beach





Overview of Coastal Protection Schemes

Option 1: 750.000 m3 Beach Nourishment

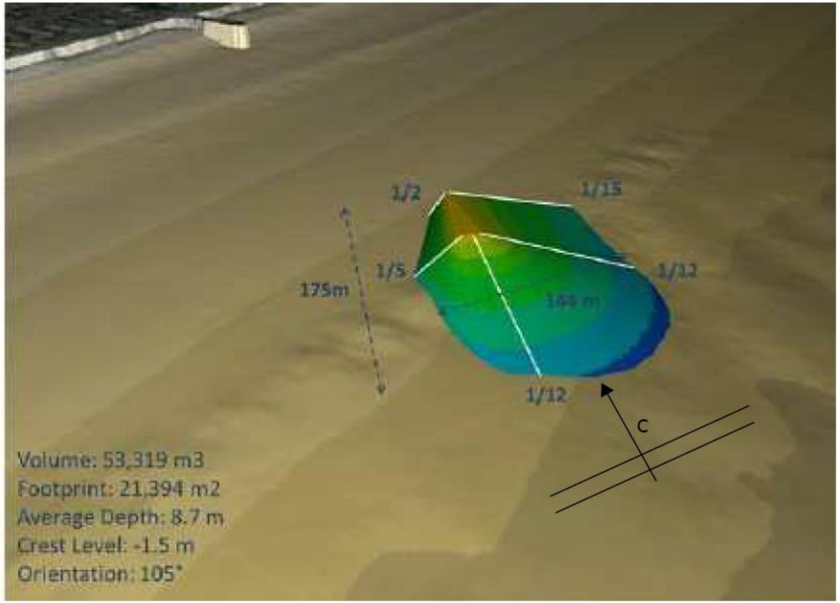


Option 2: Added Submerged Control Structure

Option 3: Added Artificial Headlands

Surf reef design

- Several possible reef designs were described in Mortensen et al (2015)
- The selected design for the present investigation contains approx. 53,000 m3 material
- Difference in slope angle on left and right side of the reef creates a “right-hander” breaking wave peeling from left to right seen from the surfers perspective
- Reef crest level is 1.5m below SWL



Scope and objectives

- Surf reefs are relatively new in terms of design methods
- Strong design basis exists for traditional coastal protection structures
- These methods do not have the additional aim of generating good surfing waves
- Existing methods and models used for designing surf reefs normally don’t include the effect of the actual porous reef structure (only seen as impermeable)
- In this study we investigate:
  1) Can a detailed CFD porosity model be used for designing surf reefs?
  2) What is the effect of the porous reef on breaking point, peeling velocity, breaking intensity, and length of surf ride?

2.

Numerical model

Numerical model description

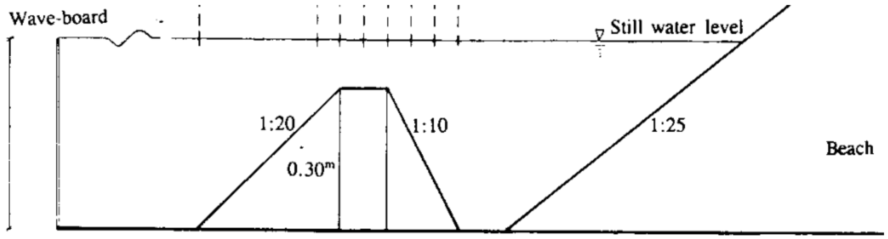
- The model is based on OpenFoam® with a three dimensional finite volume solution of Navier-Stokes equations on a collocated grid arrangement
- The free surface interface is treated by the Volume-of-Fluid (VOF) method
- Wave generation and absorption is based on relaxation zones as implemented in Jacobsen et al (2012)
- The porous reef structure is included by the porous media VARANS equation implemented in Jensen et al (2014a)

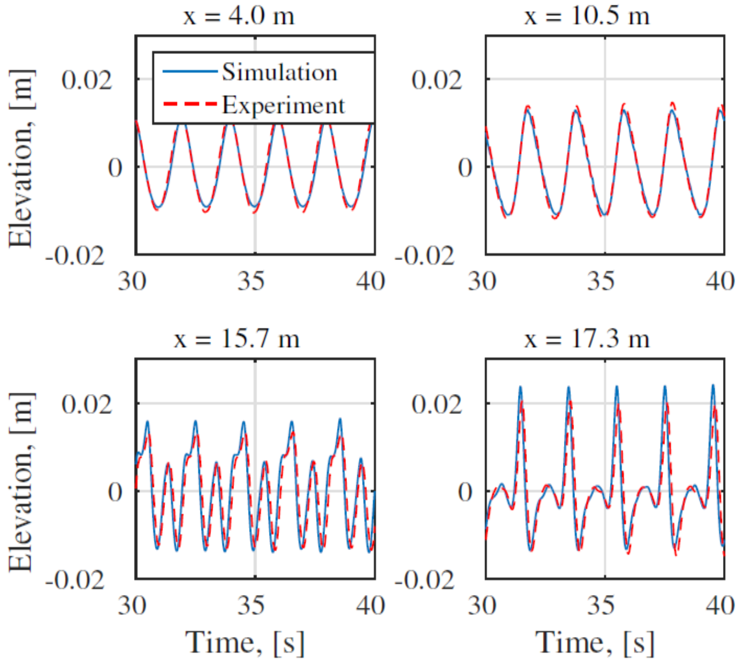
3.

Model validation

Wave transformation over submerged bar

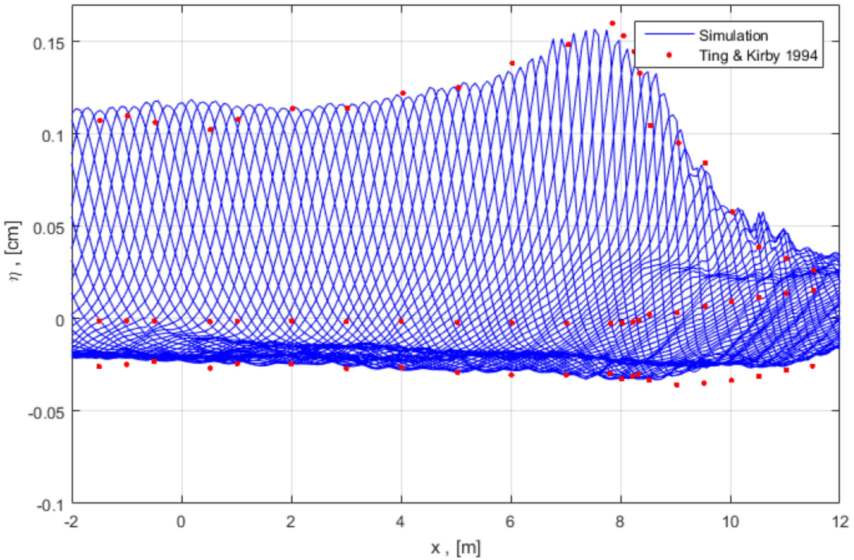
- Test case based on experiments in Beji and Battjes (1993)
- Validates the model for non-linear wave propagation and wave-wave interaction
- Results are sensitive to mesh resolution and Courant number
- Good results are obtained with Co=0.1 and a mesh resolution of approx. 10 cells/wave height





Wave breaking on a sloping bed

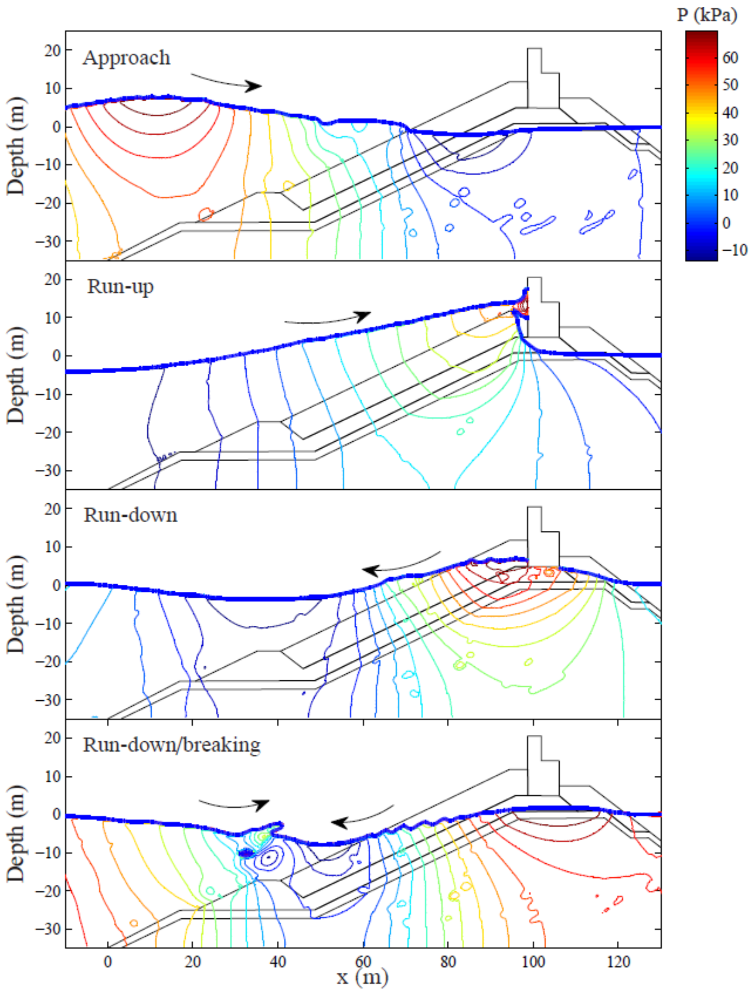
- Test case based on experiments in Ting and Kirby (1994)
- Both spilling and plunging breakers simulated
- Three-dimensional model gives acceptable results
- Captures breaking point and surface envelope
- Provides guidance to the required grid resolution in the surf reef simulations



Wave interaction with porous media

- The surf reef is treated as a porous media and is handled by the VARANS equations implemented in OpenFoam

- Validation tests from Jensen et al (2014a) and Jensen et al (2014b) confirms the capabilities to simulate wave interaction with porous media



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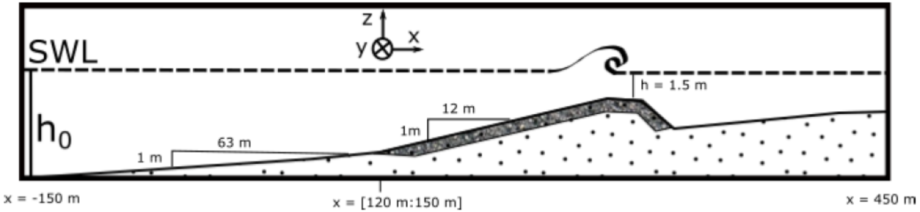
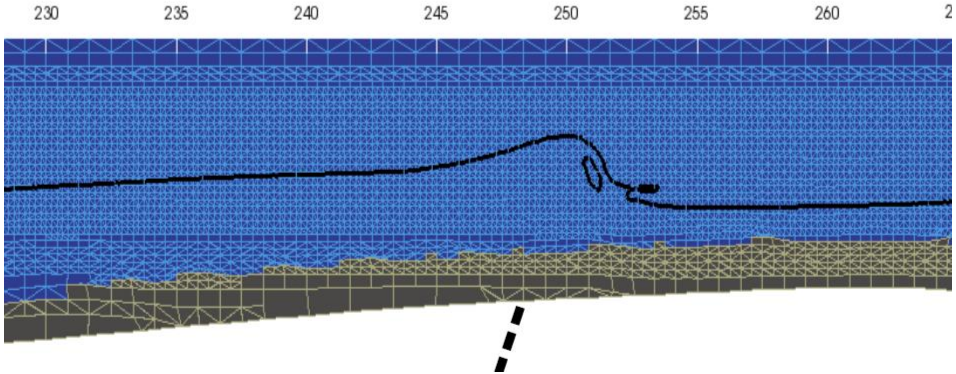
Palm Beach Simulations

Palm Beach model setup

- Model domain is 400m by 600m with an offshore bed level in -14m
- Hexahedral dominated mesh
- 10 cells/wave height or more in the breaking zone (based on validation cases)
- Porous reef armour layer with a thickness of 1.6m and d50=0.8m
- Total of approx. 12 million cells
- Inlet relaxation zones of 1-1.5 times the wave length





Palm Beach simulation cases

- Four wave events selected for the investigation
- All event are classified as plunging based on the surf similarity parameter
- The maximum wave in each wave event is simulated as a regular stream function wave

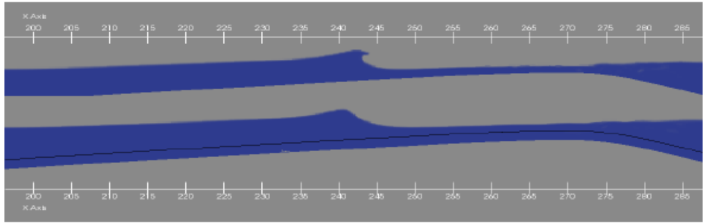
Wave event	date	$H_s(m)$	$H_{1/10}$	$T_p(s)$	$\xi_{1/10}$	$\beta_w(^\circ)$	β
1	19/03/2012	1.18	1.50	9.95	0.85	89.77	-14.61
2	5/10/2010	1.62	2.06	9.92	0.72	79.77	-24.61
3	12/01/2012	1.11	1.41	9.06	0.80	104.77	0.39
4	25/10/2008	1.58	2.01	13.10	0.97	94.77	-9.61

5.

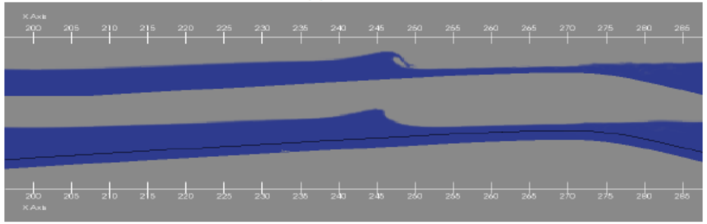
Results

Wave breaking point location

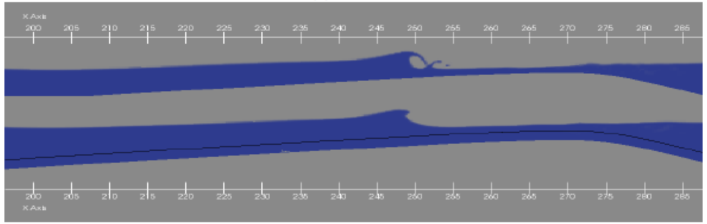
- The flow in and out of the porous reef during wave transformation along the reef gives a loss of energy
- Reduces the wave height and wave steepness
- Delays the wave breaking and moves the breaking point closer to the reef crest
- Breaking point is moved between 6m and 8m closer to the reef crest (toward the shore)



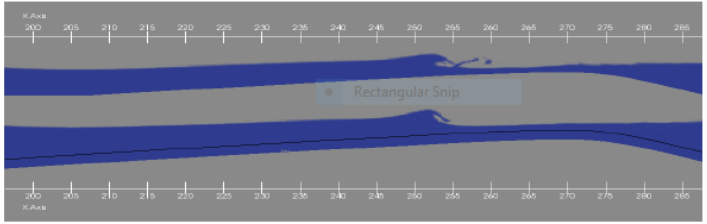
(a) Time 65.4 s



(b) Time 66.0



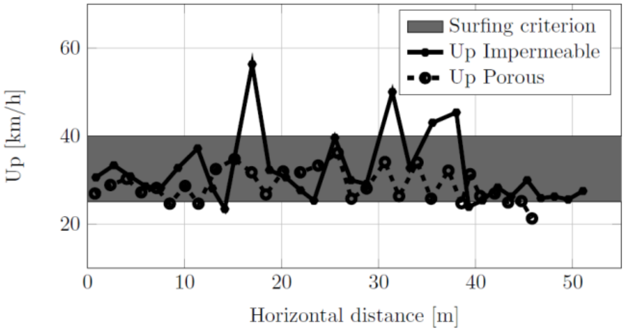
(c) Time 66.4 s



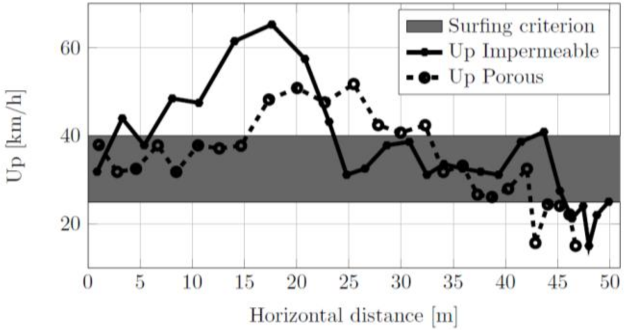
(d) Time 67.0 s

Peeling speed and length of surf ride

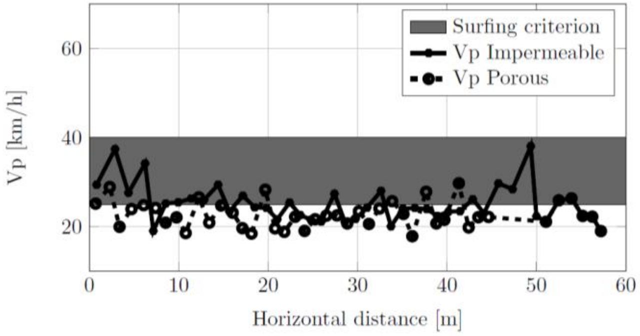
- Magnitude of the horizontal velocity of the breaking point
- Peeling speed is in general reduced
- Gives a more uniform speed along the surf ride
- Reduces the peeling speed to be within a more surfable range



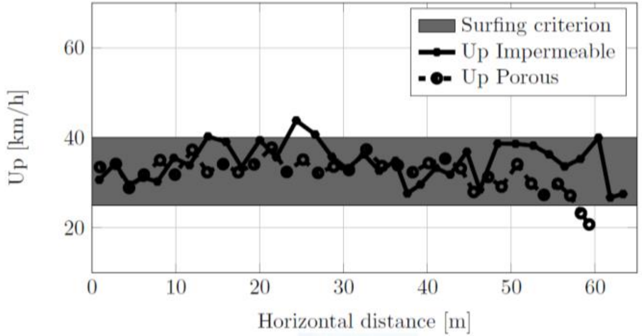
(a) Peeling speed plot for representative wave event 1



(b) Peeling speed plot for representative wave event 2



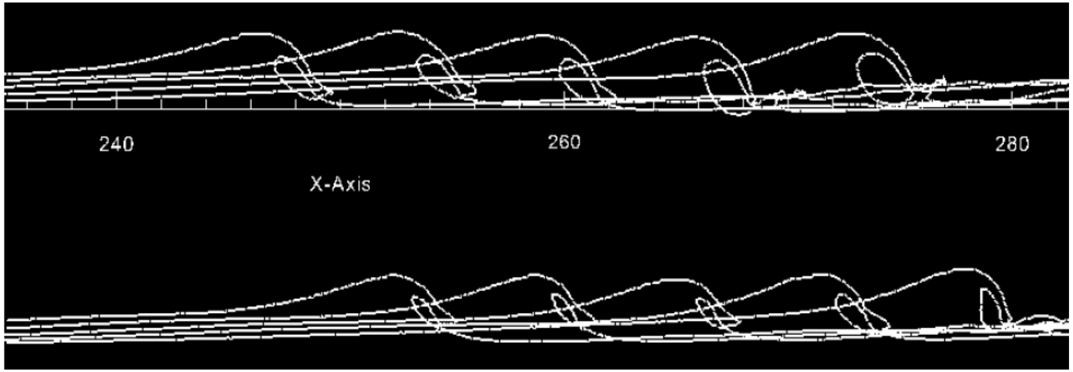
(c) Peeling speed plot for representative wave event 3



(d) Peeling speed plot for representative wave event 4

Breaking intensity

- Ratio between width and length of the breaker tube
- Determined by vertical planes through the breaking point
- The porous reef reduces the breaking intensity compared to an impermeable bed



(b) Development of breaking intensity presented for case 2

6.

Conclusions

Conclusions

- The breaking point is displaced from 6m to 8m closer to the crest (on-shore) of the reef
- The peeling speed is more than 12% higher on an impermeable reef compared to a porous reef
- The breaking intensity is up to 18% higher on an impermeable reef compared to a porous reef structure
- Including the porous reef in the numerical model as a design tool has proven to be necessary to correctly model breaking point, peeling speed and breaking intensity
- These parameters form the basis for defining a guideline for safety

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Thank you

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