Tsunami Simulators in Physical Modelling

Concept to Practical Solutions

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- 2240 recorded tsunami events from 6100 BC to 2016*
- 5 major tsunami since 2004 (~ 297,300 deaths)
- Economic loss from Japan 2011 tsunami estimated at $210 Billion**
- 150M people and £20Trillion in assets forecast to be exposed to coastal flooding by 2070 (Nicholls et al 2007)

*Adapted from A.Nassirpour (2014) MSc thesis UCL  **Swiss Re (2012)
Solitary waves
Miles (1980)

N-waves
Tadepalli & Synolakis (1994)
Superimposition of solitary waves on measurements for a) the Tohoku tsunami and b) the Indian Ocean tsunami, from Schimmels et al (2016)
The Question from UCL:
- Can we generate realistic tsunami in a practical physical model facility?

What are the engineering questions?
- What are the tsunami forces on buildings and coastal defences?
- Are existing guidelines adequate?
- Is engineering design the solutions?

Credit: Professor Tiziana Rossetto, UCL
Tsunami modelling facilities

Large Hydro-Geo Flume, PARI, Japan

- 184 m long
- 3.5 m wide
- 12 m deep

Large Wave Flume, Oregon State University

- 104 m long
- 3.7 m wide
- 4.6 m deep

West Tank, W. M. Keck Hydraulics Laboratory of the California Institute of Technology US

- 32 m long
- 0.4 m wide
- 0.6 m deep

Hammack (1972), Goring (1978), Synolakis (1986)
How it works

- **Trough generation**
  - Control valve
  - Pump

- **Crest generation**
  - Control valve
  - Pump

- **Wave propagation**
  - Control valve
  - Pump
HRW Tsunami Simulator – 1st Generation

Facility
- 1.2 m wide by 45 m long

TS dimensions
- 1.8 m tall, 1.2 m wide and 4.8 m long
- Variable height outlet

TS equipment
- Pressure transducer
- Computer controlled 45° butterfly valve
- x1 ZepherUK vacuum pumps
Outlet improvements for 1st generation

Improving 1st generation TS

Calibration of ‘Mercator’ wave at 1:50 scale
Facility
- 1.8 m wide by 100 m long

TS dimensions
- 3.5 m tall, 1.8 m wide and 4.0 m long
- 0.4m outlet height

TS equipment
- x2 ultrasonic level sensors
- Pressure transducer
- Computer controlled 45° butterfly valve
- x2 ZepherUK vacuum pumps
# Elevated waves

The graph shows the free-surface elevation over time for different wave periods. The waves are categorized into four groups based on their period length:

- **T=160s** (blue line)
- **T=80s** (dark blue line)
- **T=45s** (teal line)
- **T=20s** (olive line)

### Table of Data

<table>
<thead>
<tr>
<th>Name</th>
<th>Period, T (s)</th>
<th>Crest amplitude, a⁺ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E160</td>
<td>160</td>
<td>0.056</td>
</tr>
<tr>
<td>E80</td>
<td>80</td>
<td>0.066</td>
</tr>
<tr>
<td>E45</td>
<td>45</td>
<td>0.085</td>
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<tr>
<td>E20</td>
<td>20</td>
<td>0.089</td>
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</tbody>
</table>
N-waves

The graph shows the free-surface elevation over time for different wave periods (T). The x-axis represents time in seconds (s), ranging from 0 to 250, and the y-axis represents free-surface elevation in meters (m), ranging from -0.08 to 0.08.

The legend indicates the wave periods: T=240s (light blue), T=200s (blue), T=166s (green), T=111s (red), T=80s (dark blue), and T=20s (gray).

The data points illustrate how the free-surface elevation changes with time for each wave period, demonstrating the wave's behavior and the effect of the period on the wave's characteristics.
Research with 2\textsuperscript{nd} generation – Phase 1

Run-up
Coastal defences
Single buildings
Initial building array tests
Facility
- 4.0 m wide by 70 m long

TS dimensions
- 4.0 m tall, 4.0 m wide and 4.4 m long
- 0.4m outlet height

TS equipment
- High resolution level sensors
- Pressure transducer
- Closed loop computer controlled 45° butterfly valve
- x2 ZepherUK vacuum pumps
Coastal defences
Building arrays
‘Failing’ coastal defences
Scour around buildings
Research with 3rd generation
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