Paull Tidal defence optimisation using 2D and 3D physical modelling
Flood & Coast 2017
ERYC - Hull and Holderness Flood Alleviation Strategy: Phase 1 - Paull Tidal Defences

- Flood alleviation strategy - 200 year standard of protection against flooding
  - Embankments
  - Revetments
  - Walls
  - 1,461 residential properties (962 currently at high risk)

Capita - Project Appraisal Report (PAR) for the Hull and Holderness Flood Alleviation Strategy: Phase 1 - Paull Tidal Defences

- Identified the need for Physical Modelling

HR Wallingford - Desk Study, 2D & 3D Physical Modelling
Section 3

TYPICAL CROSS SECTION
Section D-D

TYPICAL CROSS SECTION
Section E-E
Section 4

Rock fronted

- No visibility over wall
- Existing path reinstated
  Raised up by 400mm
- +5.3m AOD
- New wave wall built on top of existing
- Driven Individual Piles
- Details of existing revetment structure not known
- New steel piles acting as cut off wall
- Extent of existing revetment foundation concrete not known
- Large sections of granite blocks
  to dissipate wave energy
  - Size to be confirmed
  - Within footprint of the existing revetment

Section C-C
Proposed Revetment Structure
Option 1 - Build Over Existing
Scale OS1:50
+6.8m AOD

Existing path reinstated
Raised up by 400mm
New wave wall built on top of existing
Driven Individual Piles
Details of existing revetment structure not known
New steel piles acting as cut off wall
Extent of existing revetment foundation concrete not known
Large sections of granite blocks to dissipate wave energy
- Size to be confirmed
- Within footprint of the existing revetment
BOX 3.5
WAVE RETURN WALLS ON IMPERMEABLE SEAWALLS
MEAN OVERTOPPING DISCHARGE

Figure 3.7 Wave return wall
Overtopping assessment

- 2 previous studies
  - 1st estimate – associated uncertainties

Overtopping potential

- Simplifications and assumptions
- Identified conditions with higher overtopping potential

Recommendations

- No calibrated empirical methods
- Physical Modelling
Recurve Wall

- Glass wall pressures
- Overtopping

Anson Villas

- Overtopping
- 2 different revetments

**TYPICAL CROSS SECTION**
Section E-E

- 1:3 slope
- Wave Return Level 5.8m
- Proposed Glass Wall Level 6.8m
- 1.0m
- 5.8m
- 11.293m
- 1.443m
HR Wallingford’s primary wave flumes
- 40m long
- 2m deep
- 1.2m wide

Piston-type wave paddle
- Wave absorption system
- Can generate non-repeating random sea-states to any required spectral form (JONSWAP, Pierson Moskowitz, or user-defined forms)
2D Physical Model - Recurve Wall

Overtopping

Glass wall pressures
2D Physical Model - Recurve Wall

Toe at 0mAOD

Toe at +2mAOD – accreted beach
2D Physical Model - Recurve Wall
Recurve overtopping prediction and results
Recurve overtopping prediction and results

- Graph showing the relationship between $q/\sqrt{gH_{m0}^3}$ and $Rc/H_{m0}$
  - The graph compares predictions with observed data from a recurve wall.
2D Physical Model - Anson Villas
Anson Villas overtopping prediction and results

![Graph showing prediction of overtopping](image)
Anson Villas overtopping prediction and results

![Graph showing the relationship between q/\sqrt{g}H and Rc/Hm0. The graph includes two lines: one for prediction and one for plain. The x-axis represents Rc/Hm0 ranging from 1.0 to 4.5, and the y-axis represents q/\sqrt{g}Hm0 ranging from 1.0E-07 to 1.0E-02. The data points are plotted on the graph, with a clear trend showing a decrease as Rc/Hm0 increases.]
Anson Villas overtopping prediction and results

- Anson Villas overtopping prediction and results

- Prediction
- Rock fronted
- Plain

- $q/\sqrt{gH_{m0}}$ vs $Rc/H_{m0}$

- $1.0 \times 10^{-7}$ to $1.0 \times 10^{-2}$
- $1.0 \times 10^{-1}$ to $1.0 \times 10^{1}$

- $1.0$ to $4.5$
Anson Villas overtopping prediction and results

$q/\sqrt{gH_m^3}$ vs. $R_c/H_{m0}$

- Prediction
- Rock fronted
- Plain
- Stepped
2D Physical Model - conclusions

Recurve Wall

- **Pressures**
  - Consistent with prediction from GODA’s method
  - Loads measured significantly lower than the glass design loads
  - Impulsive wave loading - natural variability – adopted design loadings likely appropriate

- **Overtopping**
  - Range of very small non-hazardous overtopping to zero overtopping
    - \(q=0.001\) to \(0.007\) l/s/m
    - \(q<0.001\) l/s/m (zero)
    - \(q<0.01\) l/s/m (very small)

Anson Villas

- **Stepped structure** \(q=0\) to \(0.177\) l/s/m
  - \(N_{ow}>10\%\) observed
  - Not likely to cause flooding

- Rock fronted marginally smaller – less overtopping – same hazard category as stepped structure

- **limit for aware pedestrians**: \(0.1\) l/s/m
  - \(N_{ow} < 2\%\)

Note: indicative limits from the EurOtop overtopping manual (EurOtop, 2007)
3D Physical Model – facilities

HR Wallingford’s Basin
- Approx. 30m by 23m
- Working depth 1m

Multiple (4m) mobile piston-type wave paddles
- active wave-absorbing system
- generate non-repeating random sea-states to any required spectral form
Test conditions same as 2D model from two nominal wave directions north west and south west

Scale 1:40

Measured overtopping discharges
- Constructed 3D model of the Paull Tidal Defences
- From Anson Villas to the Shipyard

Wave calibrations before model construction

Model construction:
- wood cross-sections
- moulded sand and cement mortar

28 March 2017
3D Physical Model - construction
3D Physical Model - construction
3D Physical Model - testing
3D recurve overtopping prediction and results

\[ \frac{q}{\sqrt{gH^3}} \] vs \( \frac{Rc}{H_{m0}} \)

- Prediction line

- Axes:
  - Y-axis: \( 10^{-7} \) to \( 10^{-2} \)
  - X-axis: \( 1.0 \) to \( 4.5 \)

- Gridlines

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3D recurve overtopping prediction and results

![Graph showing the relationship between \( \frac{q}{gH_m^3} \) and \( \frac{Rc}{H_{m0}} \).]

- **Prediction**
- **Recurve wall NW**
- **Recurve wall SW**
3D Physical Model - conclusions

Generally low overtopping discharges (q=0 to 0.3 l/s/m)

- Not considered to be hazardous
- Not cause any noticeable flooding

Exception q=0.8 l/s/m adjacent to lighthouse for 1:200yr climate change scenario storm direction NW

- Relatively high discharge
- In itself unlikely to cause significant flooding other than locally immediately behind the wall
- Possibly local effect caused by waves travelling along the wall
- Prudent to consider warning signs for most severe storm conditions
Glass wall

Before

After
Conclusions

- Absence of calibrated empirical methods to predict overtopping
- Physical model study was used to assess the overtopping performance
- Discharges obtained with the 2D study are unlikely to be hazardous or cause flooding
- Results from the 3D study generally showed low overtopping discharges that would not be considered hazardous or cause noticeable flooding. Except for one location during the 1:200 year climate change scenario
Thank you