EUROTOP OVERTOPPING GUIDANCE APPLIED IN A TOOL WITH LARGE VARIETY OF COASTAL PROTECTIONS AT ILE DE RÉ

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**STUDY AREA**

**ILE DE RÉ:**

- **85 km²**
- **38 km² BELOW STORM SURGE LEVEL**
- **14 000 RESIDENTS**
- **10 COUNCILS**
- **103 KM OF COASTLINE**
- **68 KM COASTAL PROTECTIONS (136 DIFFERENT STRUCTURES)**
STUDY AREA

Ile de Ré:
- 85 km²
- 38 km² below storm surge level
- 14,000 residents
- 10 councils
- 103 km of coastline
- 68 km coastal protections:
  - Concrete embankments
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  - Masonry embankments
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  - Armoured rubble slopes
Study Area

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  - Armoured rubble slopes
  - Vertical walls
Ile de Ré:

- 85 km²
- 38 km² below storm surge level
- 14,000 residents
- 10 councils
- 103 km of coastline
- 68 km coastal protections:
  - Concrete embankments
  - Masonry embankments
  - Armoured rubble slopes
  - Vertical walls
  - Sandy dunes

Study Area

Typologies:
- Embankments
- Armoured rubble slopes
- Vertical wall
- Cliff
- Natural dunes

Elevation (m NGF)
**Xynthia (28/02/2010)**

- 19 km² FLOODED
- 22 % OF THE ISLAND
- 6400 M OF PROTECTION FAILURES
- EMERGENCY WORKS
- 100 M€ OF COASTAL PROTECTION REHABILITATION
Xynthia (28/02/2010)

- 19 km² flooded
- 22% of the island
- 6400 m of protection failures
- Emergency works
- 100 M€ of coastal protection rehabilitation
STUDY AREA

CURRENT SITUATION :

Many structures are vulnerable regarding wave overtopping or water overflowing :

⇒ Necessity to monitor frequently old structures after storms

⇒ Necessity to prioritize maintenance on this long stretches of heterogeneous coastal protections

⇒ Development of a dedicated tool
NEEDED TO HAVE ON EACH STRUCTURE:

- Water level
- Wave characteristics

To make decisions easier, a short list of scenarios is defined to create charts for each structure regarding offshore conditions.
TOOL DESCRIPTION

TOOL BASED ON DEFINED CHARTS REGARDING OFFSHORE CONDITIONS

1. **Offshore waves characteristics**
2. **Water level elevation**
3. **Joint probability on wave and water level to define a finite number of scenarios with an equivalent return period**
4. **90 scenarios were simulated with an hydrodynamic model coupled to a spectral wave model (Telemac 2D / Tomawac)**
5. **Wave overtopping evaluation on each structure**
TOOL DESCRIPTION

TOOL BASED ON DEFINED CHARTS REGARDING OFFSHORE CONDITIONS

1. Offshore waves characteristics
2. Water level elevation
3. Joint probability on wave and water level to define a finite number of scenarios with an equivalent return period
4. 90 scenarios were simulated with an hydrodynamic model coupled to a spectral wave model (Telemac 2D / Tomawac)
5. Wave overtopping evaluation on each structure
TOOL DESCRIPTION

WAVE OVERTOPPING EVALUATION

- CREST FREEBOARD VERIFICATION (OVERFLOW)
- EUROTOP (2016) – MANUAL ON WAVE OVERTOPPING
- EVALUATION METHOD FOR EACH TYPE OF STRUCTURE:

1) Coastal dikes and embankment seawalls (chap. 5)
2) Armoured rubble slopes and mounds (chap. 6)
3) Vertical and steep walls (chap. 7)
TOOL DESCRIPTION

WAVE OVERTOPPING EVALUATION

DECISION TREE:

What kind of structure?

Coastal dikes and embankment seawalls (chap. 5)
- Is there a shallow foreshore influence? 
  \( \left( \frac{h_t}{H_{m0}} \leq 1.5 \right) \)
  - Yes
    - \( R_{u2\%} \) : eq. 5.2
    - \( q \) : eq. 5.15
  - No
    - \( R_{u2\%} \) : eq. 5.1
    - \( q \) : eq. 5.10

Armoured rubble slopes and mounds (chap. 6)
- Is the \( \xi_{em-1,0} > 5 \)?
  - Yes
    - \( \gamma_f \) change in \( \gamma_f \) mod Eq. 6.7
  - No
    - Influence factors?
      \( \frac{R_c}{H_{m0}} > 0.3? \)

Vertical and steep walls (chap. 7)
- Is there a shallow foreshore influence? 
  \( \left( \frac{h_t}{H_{m0}} \leq 1.5 \right) \)
  - Yes
    - \( \gamma_f \) change in \( \gamma_f \) mod Eq. 6.7
  - No
    - Influence factors?
      \( \frac{R_c}{H_{m0}} > 0.3? \)

- How steep is the slope?
  - Slope \( < 1.5 \)
    - \( R_{u2\%} \) : eq. 6.1
    - \( q \) : eq. 5.10
  - Slope \( > 1:1.5 \)
    - \( R_{u2\%} \) : eq. 6.1
    - \( q \) : eq. 5.11 or 6.5

- Vertical or composite slope?
  - Vertical
    - Possible breaking? 
      \( h^2/(H_{m0}L_{m0} - 1.0) < 0.23? \)
  - Composite
    - Possible breaking? 
      \( h_d/(H_{m0}L_{m0} - 1.0) < 0.65? \)

- Low freeboard?
  - Yes
    - \( \frac{R_c}{H_{m0}} < 1.35 \)
  - No
    - Eq. 7.1 or 7.2

- Eq. 7.15

- Eq. 7.14

WAVE OVERTOPPING EVALUATION DEcISION TREE: TOOL DESCRIPTION

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**TOOL DESCRIPTION**

**WAVE OVERTOPPING EVALUATION**

- **EXAMPLE: DIGUE DU MARTRAY**

  - What kind of structure?
  - Coastal dikes and embankment seawalls (chap. 5)
  - Is there a shallow foreshore influence? ($ht/Hm0<1.5$)

  ![Graph showing wave overtopping evaluation](image)

  - Yes
    - $R_u$ : eq. 5.2
    - $q$ : eq. 5.15
  - No
    - $R_u$ : eq. 5.1
    - $q$ : eq. 5.13
**TOOL DESCRIPTION**

**WAVE OVERTOPPING EVALUATION**

- **EXAMPLE : DIGUE DU MARTRAY**

Xynthia conditions:
- $H_s = 1.3 \, m$
- Average slope: $1H/1V$
- $R_c : \text{(7-4)} \, 3 \, m$

Sensitivity on formula choice:
- Eq 5.13 (*general formulation Assessment approach*) $q = 30 \, l/s/m$
- Eq 5.16 (*embankment with shallow foreshore*) $q = 15 \, l/s/m$
TOOL DESCRIPTION

WAVE OVERTOPPING EVALUATION

- EXAMPLE: GRAND MARCHAIS

What kind of structure? Armoured rubble slopes and mounds (chap. 6)
Is the $\xi_{m-1,0} > 5$? Yes
$\gamma_i$ change in $\gamma_{fmod}$ Eq. 6.7
How steep is the slope?

- Slope < 1:1.5
  $R_{u2%}$: eq. 6.1
  $q$: eq. 5.10

- Slope > 1:1.5
  $R_{u2%}$: eq. 6.1
  $q$: eq. 5.13 or 6.6

EXAMPLE: RAND ARCHAISS TOOL DESCRIPTION

What kind of structure? Armoured rubble slopes and mounds (chap. 6)
Is the $\xi_{m-1,0} > 5$? Yes
$\gamma_i$ change in $\gamma_{fmod}$ Eq. 6.7
How steep is the slope?

- Slope < 1:1.5
  $R_{u2%}$: eq. 6.1
  $q$: eq. 5.10

- Slope > 1:1.5
  $R_{u2%}$: eq. 6.1
  $q$: eq. 5.13 or 6.6
WAVE OVERTOPPING EVALUATION

- **EXAMPLE : GRAND MARCHAIS**

**Xynthia conditions:**
- $H_S = 1.1\ m$
- Average slope: $2H/1V$
- $R_c : (5.5-4.2) 1.3\ m$
- Friction: $\gamma_f = 0.7-1$

**Sensitivity on formula choice:**
- Eq 6.6 (*Armoured slope no shallow foreshore*) $q = 50\ l/s/m$
- Eq 5.16 (*embankment with shallow foreshore*) $q = 40\ l/s/m$
TOOL DESCRIPTION

TOLERABLE OVERTOPPING DISCHARGE:

- BIBLIOGRAPHY
- XYNTHIA FEEDBACK:
  - OVERTOPPING ESTIMATION WITH XYNTHIA STORM PROTECTION FAILURE ANALYSIS REGARDING STRUCTURE
  - ASSUMPTIONS ON BREACH OR FAILURE INITIATION PARAMETERS
TOOL DESCRIPTION

TOLERABLE OVERTOPPING:

- BIBLIOGRAPHY
- XYNTHIA FEEDBACK
- OVERTOPPING SIMULATOR (HTTP://WWW.OVERTOPPING-MANUAL.COM)

10 l/s per m; 1 hour
H_s = 1 m; T_p = 4.0 s
12 overtopping waves in 3 minutes
TOOL DESCRIPTION

TOLERABLE OVERTOPPING:

- Bibliography
- Xynthia feedback
- OVERTOPPING SIMULATOR (HTTP://WWW.OVERTOPPING-MANUAL.COM)

No overtopping
- Rare overtopping: $Q < 0.1 \text{ l/s/m}$
- Overtopping: $Q < 10 \text{ l/s/m}$
- Important overtopping: $Q > 50 \text{ l/s/m}$

Local overflow
Overflow

10 l/s per m; 1 hour
$H_s = 1 \text{ m}; T_p = 4.0 \text{ s}$
12 overtopping waves in 3 minutes

3000 l/m

232 l/m
**TOOL DESCRIPTION**

→ **OPERATIONAL TOOL SCHEME**

- Surge forecast (SWL, $H_s$, $T_p$, $D_p$)
- Wave forecast ($H_s$, $T_p$, $D_p$)
- Atmospheric forecast (Wind, MSLP)

**Storage DB**

- 4 days forecast
- Scenario selection for the highest tide of the day

**Website (4 update daily)**

**SMS (short message service)**
**UNCERTAINTIES ESTIMATION**

Forecast model comparison with observations (winter storms in early 2018):

- Bias of 9 cm for water level (closest tide gauge)
- Bias of 39 cm for wave height (closest wave buoys)

→ Consideration of threshold to detect scenario with offshore conditions (10 cm for water level and 1 m for wave height Hs)
**METHOD CALIBRATION**

**WINTER STORM – EARLY 2018**

**TOOL EVALUATION ON THE LAST WINTER:**

- 3 IMPORTANT STORMS DURING 2018 WINTER
- WATER LEVEL > 3.4 M
- WAVE HEIGHT > 6 M
Tool evaluation

- 3 important storms
- 2 scenarios detected:
  - 3rd of January 2018 4am: SWL=3.37 m, NGF and $H_s=4.68$ m (scenario 2)
  - 4th of January 2018 5am: SWL = 3.31 m, NGF et $H_s=5.03$ m (scenario 5).
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<td>Weak overtopping (&lt;0,1 l/s/m)</td>
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CONCLUSIONS

CONCLUSIONS ON CURRENT TOOL:

▪ Tool easy to use, based on charts
▪ Allow a quick evaluation of overtopping risks on the whole island
▪ Possible to use with global forecast model
▪ Calibrated on recent observations

FUTURE WORKS:

▪ Improvements with other observations (with stronger storms)
▪ Possibility to increase number of scenarios
▪ Possibility to use it on a long term analysis
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