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THE INFLUENCE OF A CROWN WALL ON WAVE OVERTOPPING OVER RUBBLE MOUND STRUCTURES

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Dredging, Environmental & Marine Engineering

FACULTY OF ENGINEERING AND ARCHITECTURE
Department of Civil Engineering

CONTENTS

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1. INTRODUCTION

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BREAKWATER DESIGN

- Low crested breakwaters
  - Open view to the sea
  - Lower building cost
  - Existing high crested: decrease due to SLR
- Low overtopping discharges

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HOW TO CALCULATE OVERTOPPING?

Non-breaking waves on rubble mound structures

EurOtop 2007

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.2 \cdot \left[-\left(2.6 \cdot \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta} \right) \right]$$

for $R_c/H_{m0} > 0.5$

EurOtop 2016

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.09 \cdot \exp \left[-\left(1.5 \cdot \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta} \right)^{1.3} \right]$$

for $R_c/H_{m0} \geq 0$

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.09 \cdot \exp \left[-\left(1.5 \cdot \frac{R_c}{H_{m0} \cdot \gamma^*} \right)^{1.3} \right]$$

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HOW TO CALCULATE OVERTOPPING?

- Crest Freeboard (R_c) vs Armour Freeboard (A_c)

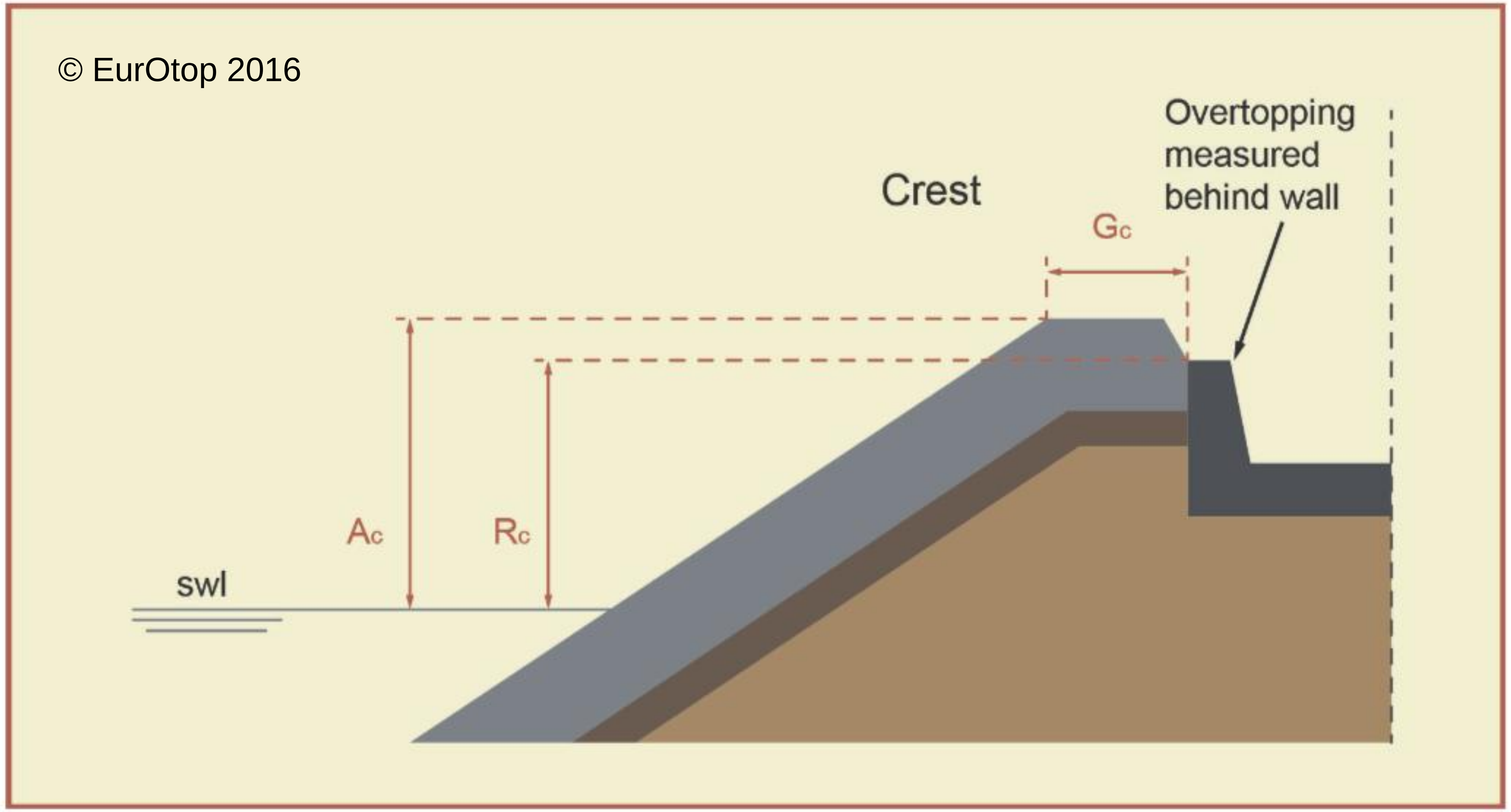

Figure 1.4: Crest freeboard different from armour freeboard. R_c can also be equal or larger than A_c.

- Formulae set up for $R_c = A_c$, $G_c = 3D_{n50}$

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HOW TO CALCULATE OVERTOPPING?

1 INTRODUCTION

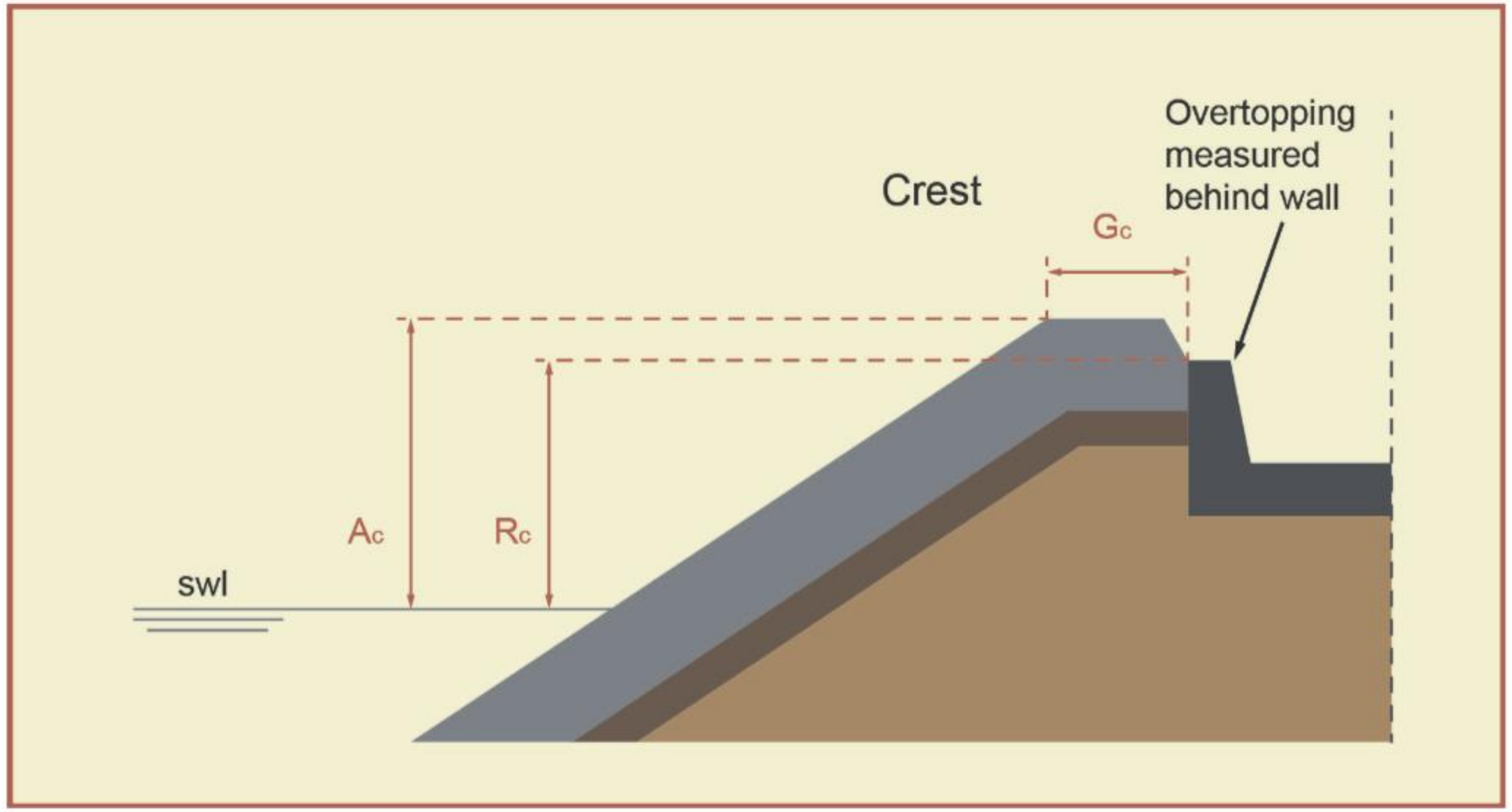
2 TEST SET-UP

3 RUBBLE MOUND

4 CONCRETE UNITS

5 CONCLUSIONS

- Unclear advice when $R_c \neq A_c$
- Use the highest value, except when $A_c > R_c$



no wall

using A_c → underestimation

EurOtop 2007: use R_c

EurOtop 2016: use $(A_c+R_c)/2$

small wall

using A_c → (slight) underestimation

EurOtop 2007: use R_c

EurOtop 2016: use A_c

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ADVICE EUROTOP

- Varying crown wall

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.09 \cdot \exp\left[-\left(1.5 \cdot \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta}\right)^{1.3}\right]$$

$R_C > A_c \rightarrow R_c$

$R_C < A_c \rightarrow A_c$ (wall)

$\rightarrow (A_c+R_c)/2$ (no wall)

$\rightarrow R_c$ (EurOtop 2007)

VERIFY AND IMPROVE ADVICE EUROTOP THROUGH EXPERIMENTAL MODELLING

- Varying crest wi

  ↳ No clear guidelines available!

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2.
TEST PROGRAMME & MODEL SET-UP

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TEST PROGRAMME

Data series	h_{wall}	G_c	T_p
Ref. case	0	$3D_{n50}$	10 s
Wall variation	≠0	$3D_{n50}$	10 s
Crest and Period variation	0	$1/3/5D_{n50}$	7/10/12 s
Combination	≠0	$1/3/5D_{n50}$	7/10/12 s

→ Varying wall, other parameters fixed

→ Varying crest width & wave period, other parameters fixed

→ Combining the above

2016/2017: 191 tests on rubble mound, 21 on HARO
2017/2018: 33 on rubble mound, 128 on HARO, 74 on Xbloc^{plus}

} 447 tests

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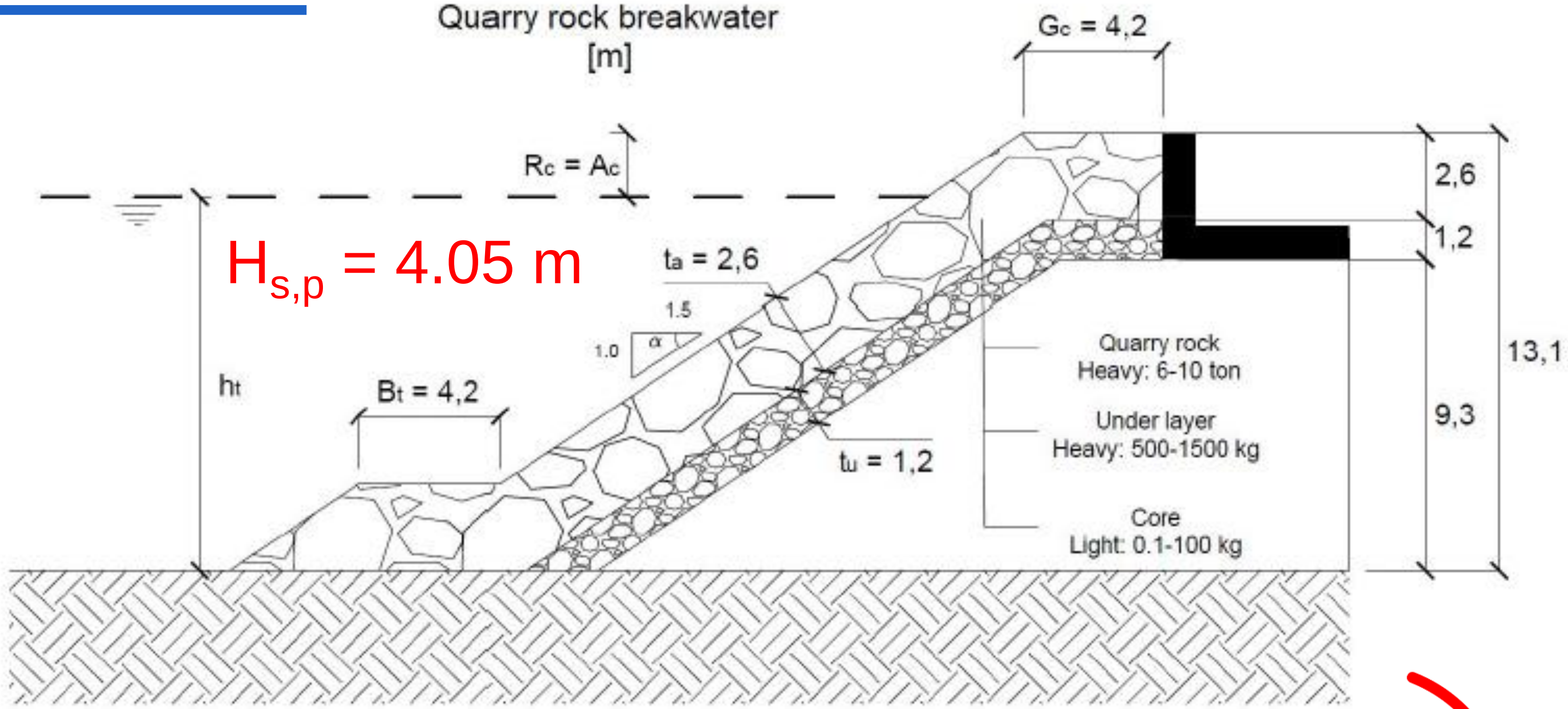
MODEL SET-UP

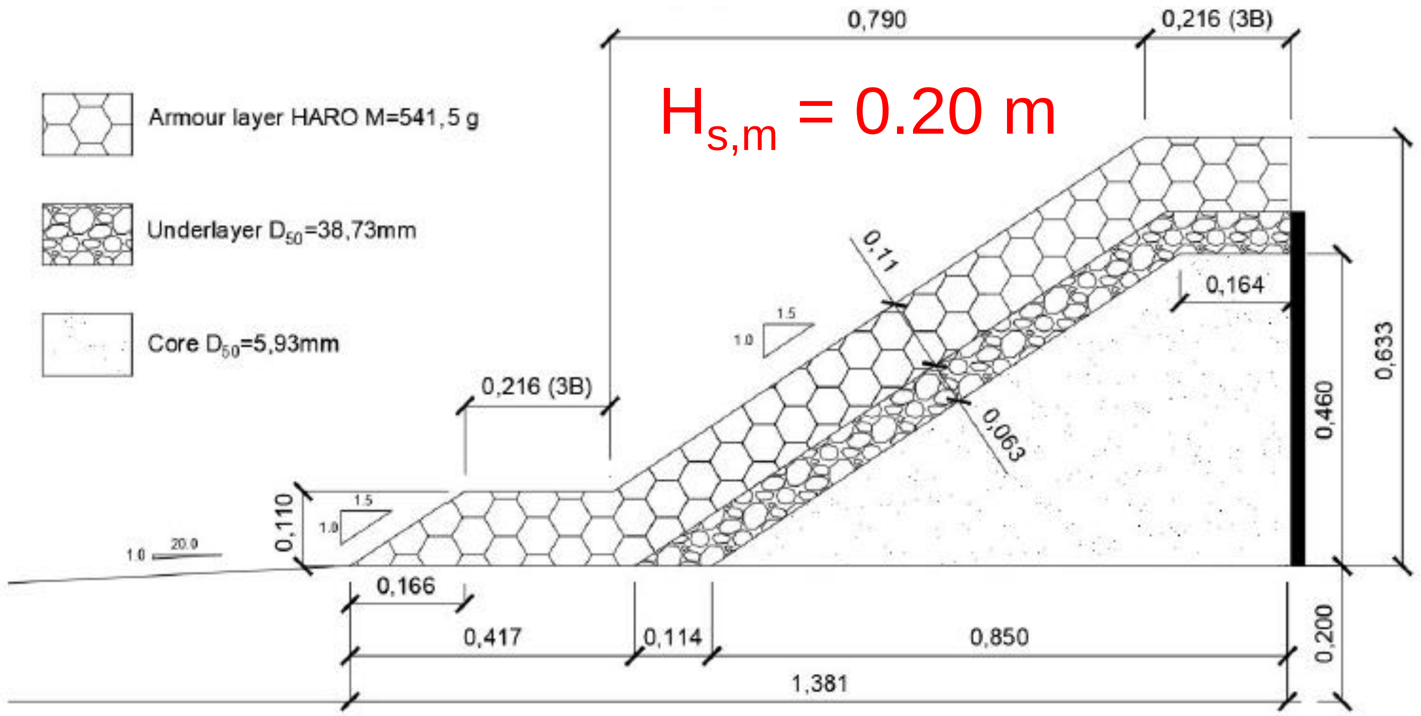


$H_{s,p}$ = 4.05 m

PROTOTYPE

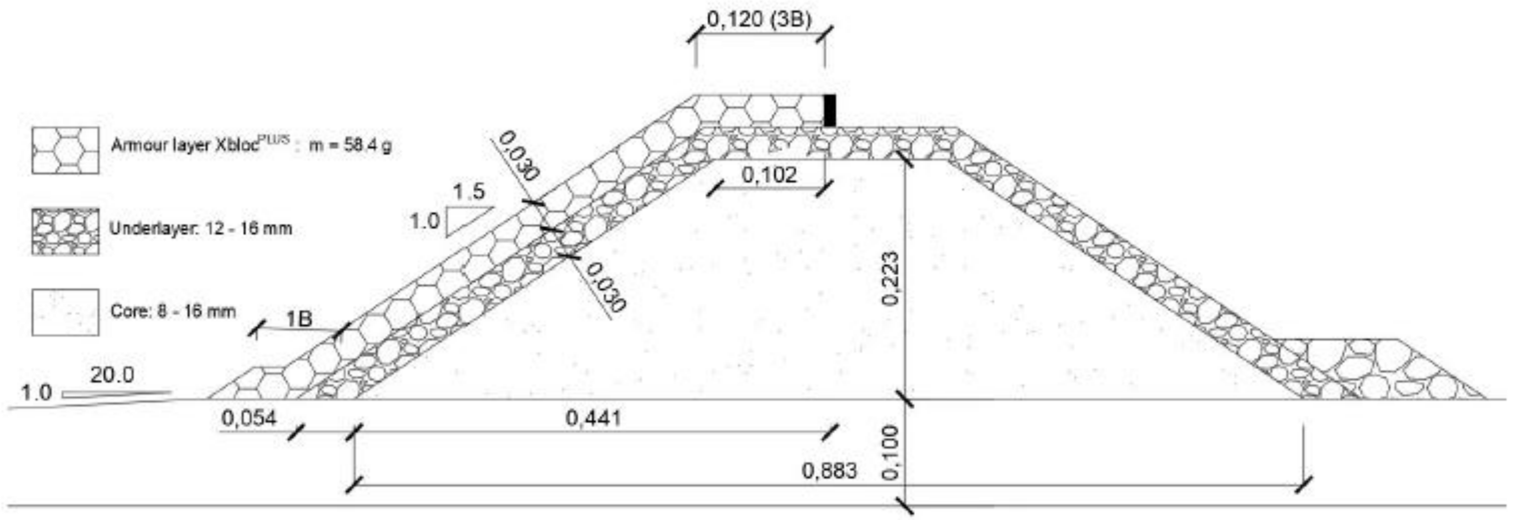
1/20

1/41



$H_{s,m}$ = 0.20 m

LWF MODEL



$H_{s,m}$ = 0.099 m

DMC MODEL

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TESTED CONFIGURATIONS

- Reference case

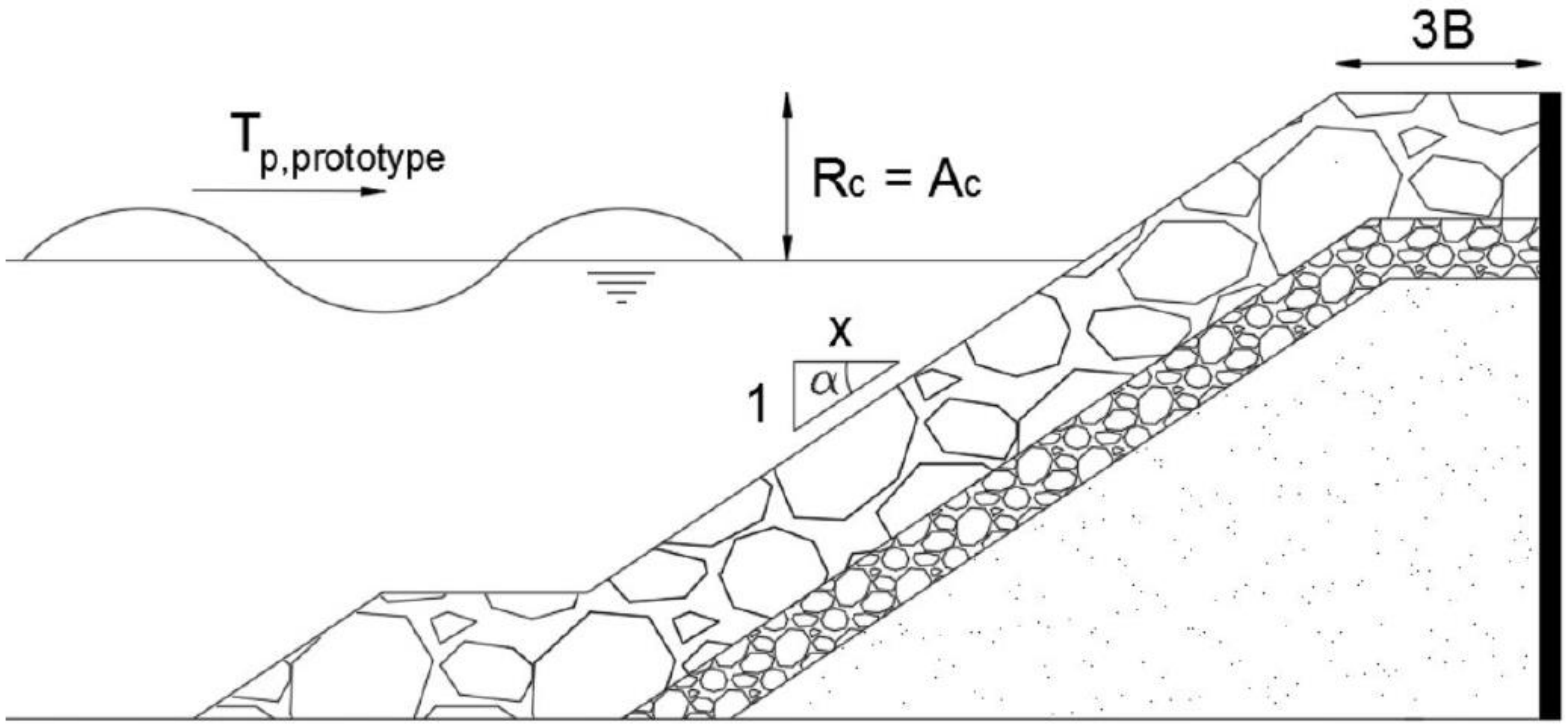

Table 3.7: Reference case conditions for a rubble mound breakwater

Reference case conditions	
Slope α	1 : 1.5
Crest width G_c	3B
R_c/A_c	1
$T_{p,prototype}$	$10s$

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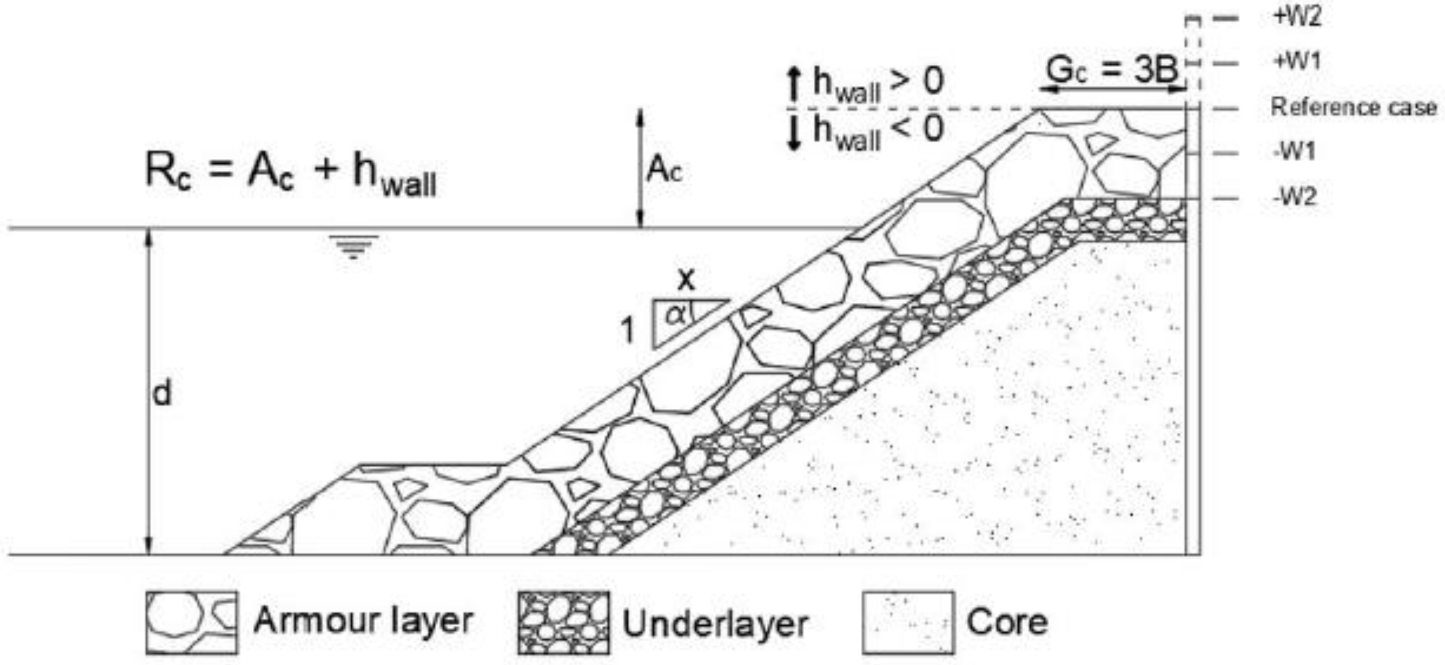
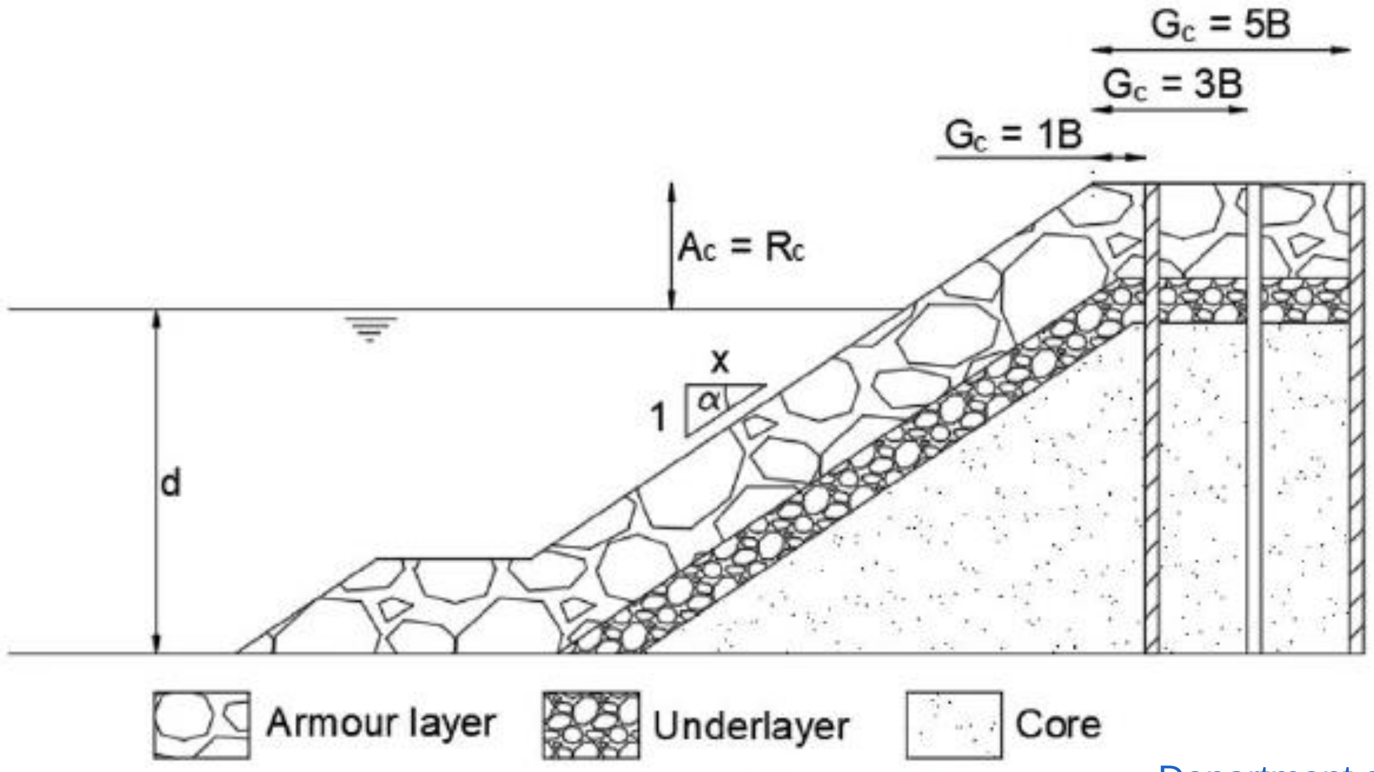
TESTED CONFIGURATIONS

- Geometrical modifications



(a) Representation of the crown wall variations



(b) Representation of the crest width variations

3. RESULTS FOR RUBBLE MOUND

TEST PROGRAMME

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.09 \cdot \exp\left[-\left(1.5 \cdot \frac{R_c}{H_{m0} \cdot \gamma^*}\right)^{1.3}\right]$$

Data series	h_{wall}	G_c	T_p	γ^*	Derived factor
Ref. case	0	$3D_{n50}$	10 s	$\gamma^* = \gamma_f$	γ_f
Wall variation	≠0	$3D_{n50}$	10 s	$\gamma^* = \gamma_f \cdot \gamma_v$	γ_v
Crest and Period variation	0	$1/3/5D_{n50}$	7/10/12 s	$\gamma^* = \gamma_f \cdot \gamma_{crest}$	γ_{crest}
Combination	≠0	$1/3/5D_{n50}$	7/10/12 s	$\gamma^* = \gamma_f \cdot \gamma_{crest\_v}$ $\gamma_{crest\_v} = fcn(\gamma_v, \gamma_{crest})$	γ_{crest_v}

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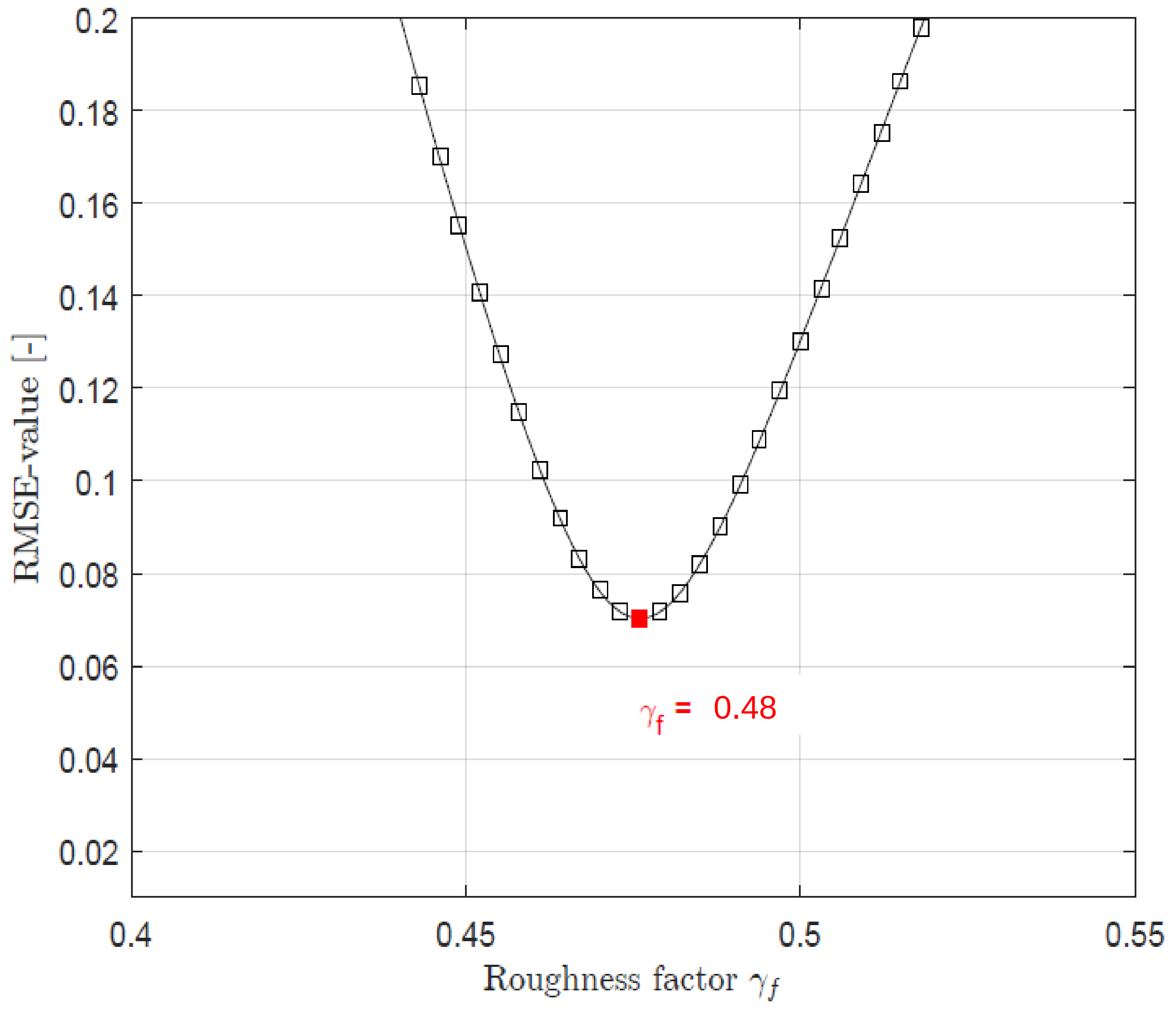
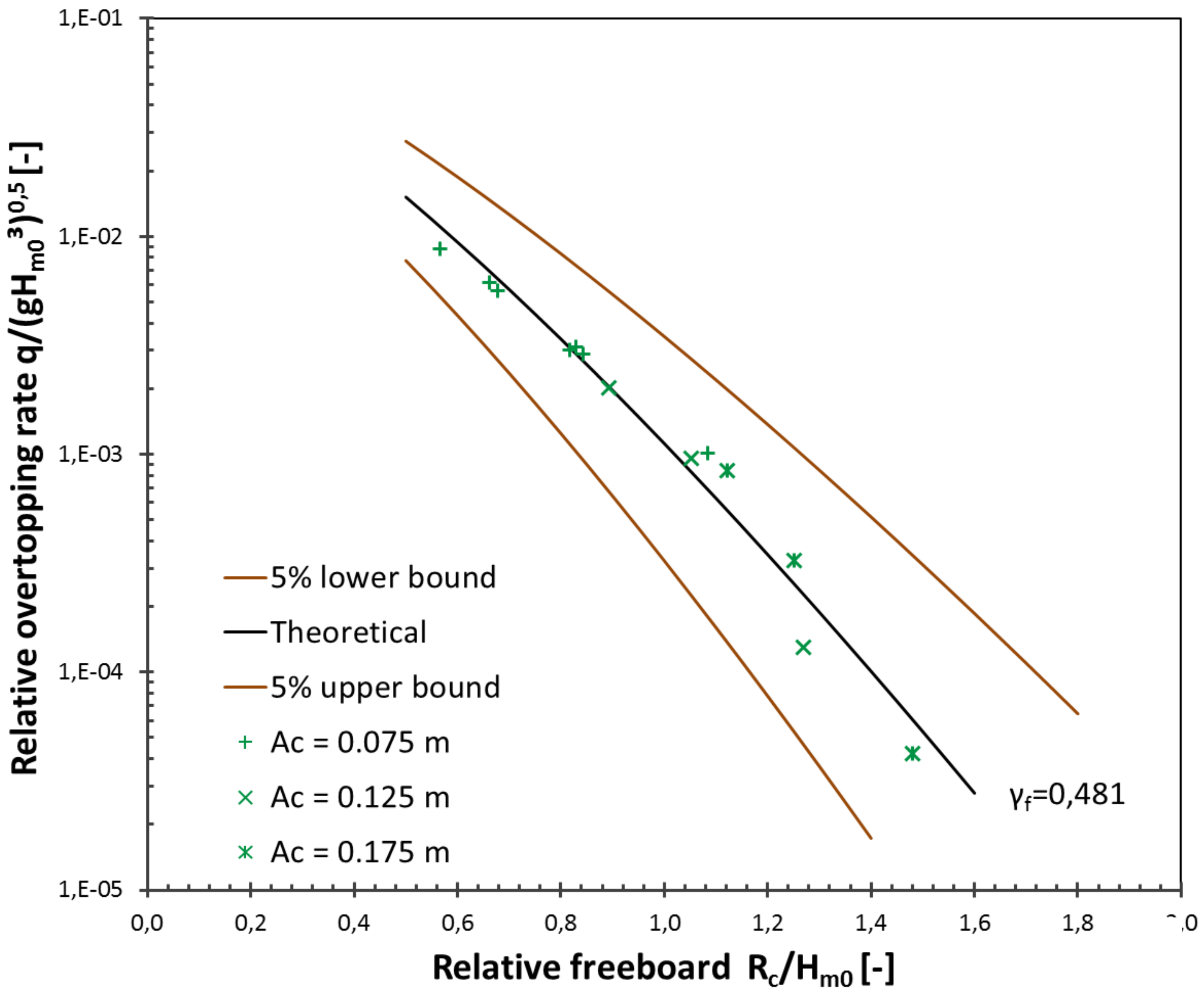
DETERMINATION ROUGHNESS FACTOR





γ_v = 0.48 within expected range (0.4-0.55)

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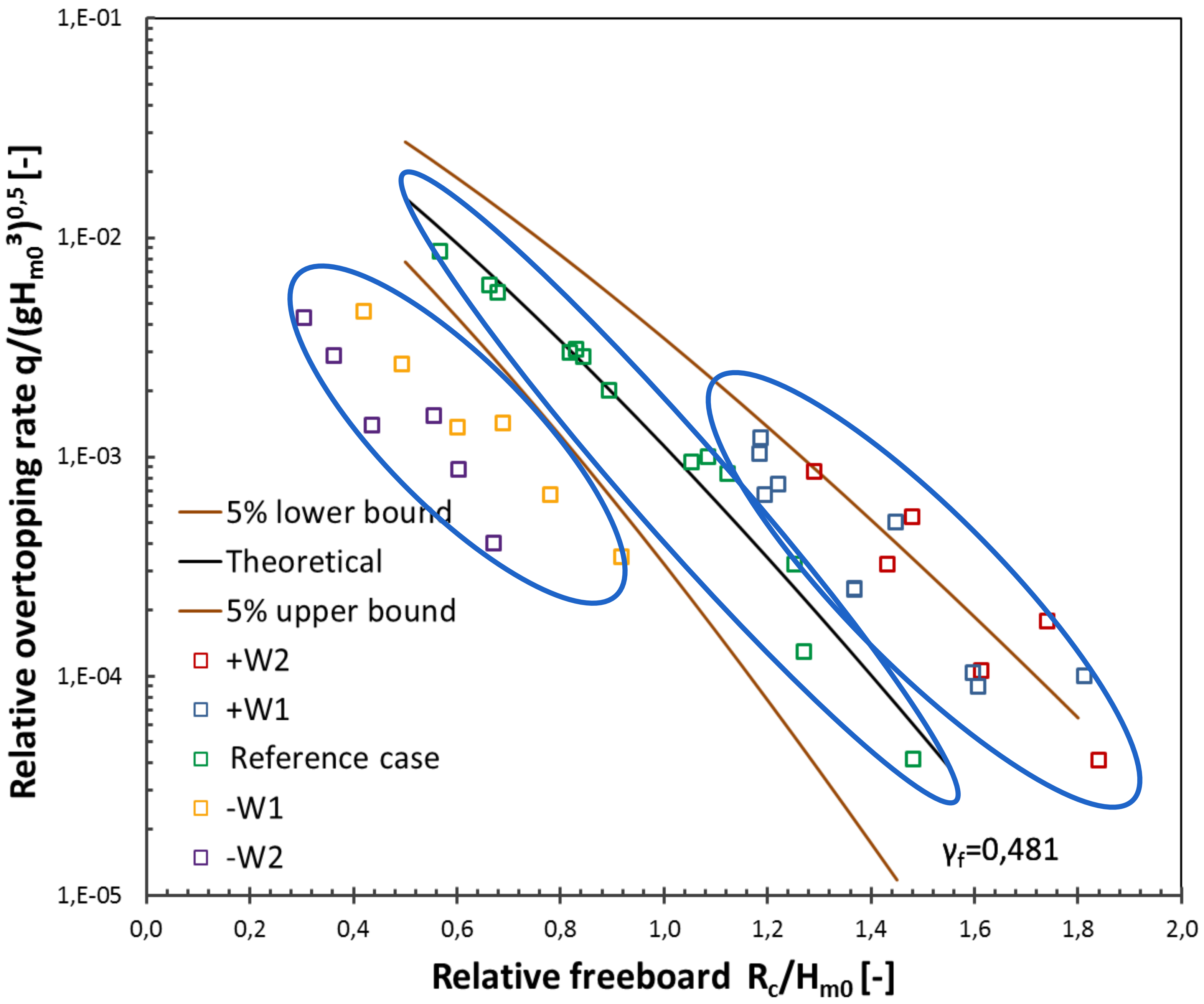
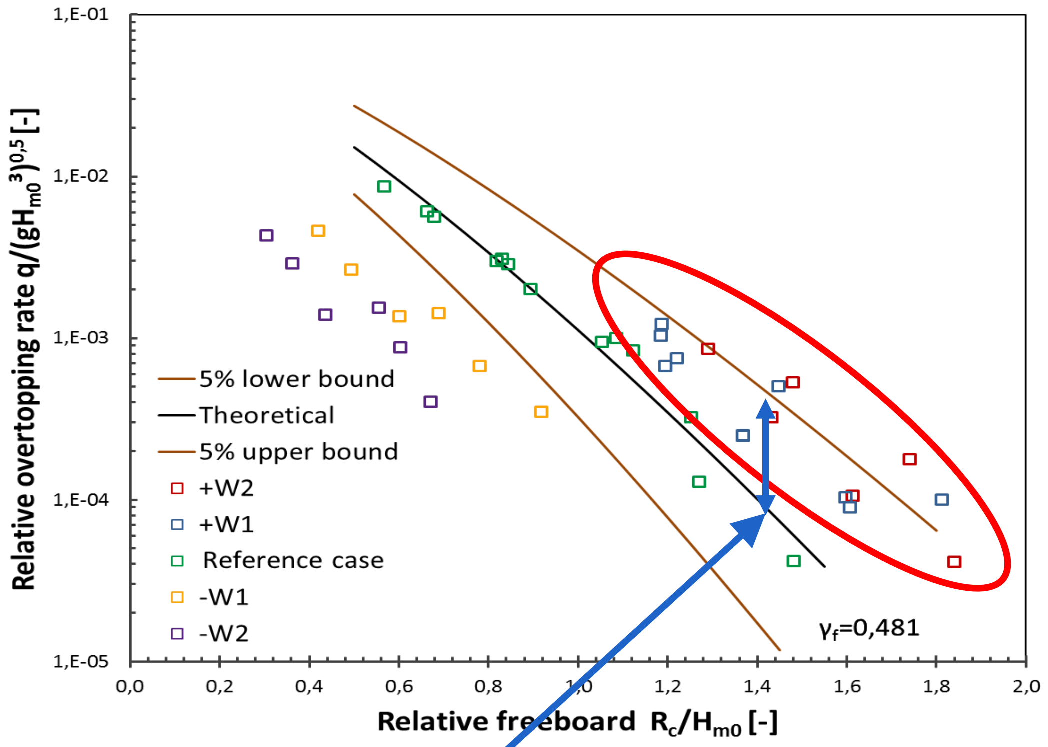
INFLUENCE OF THE WALL HEIGHT

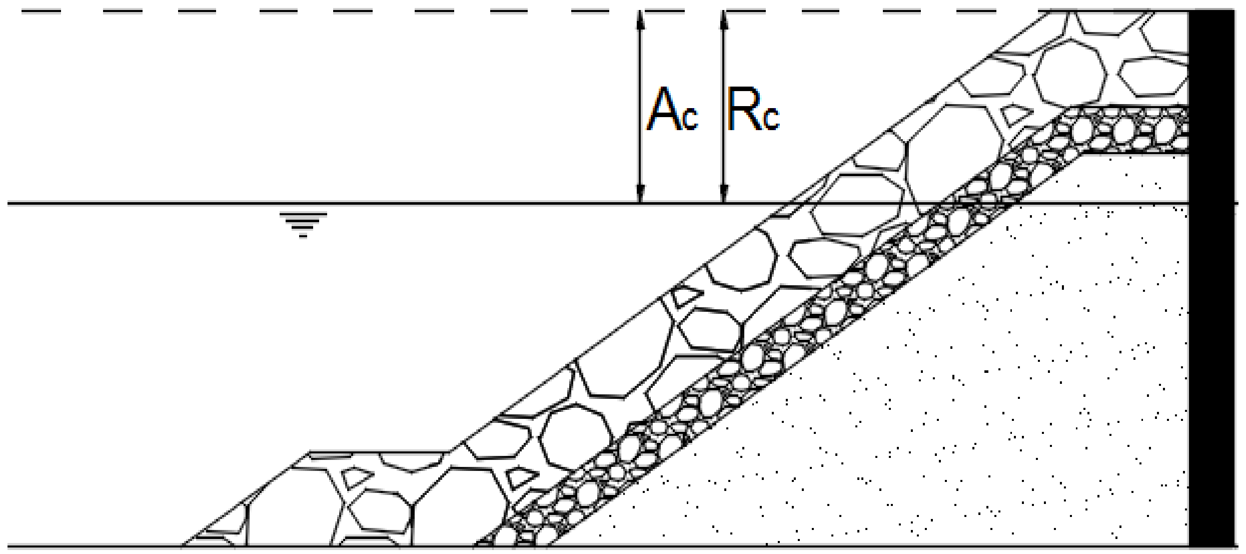


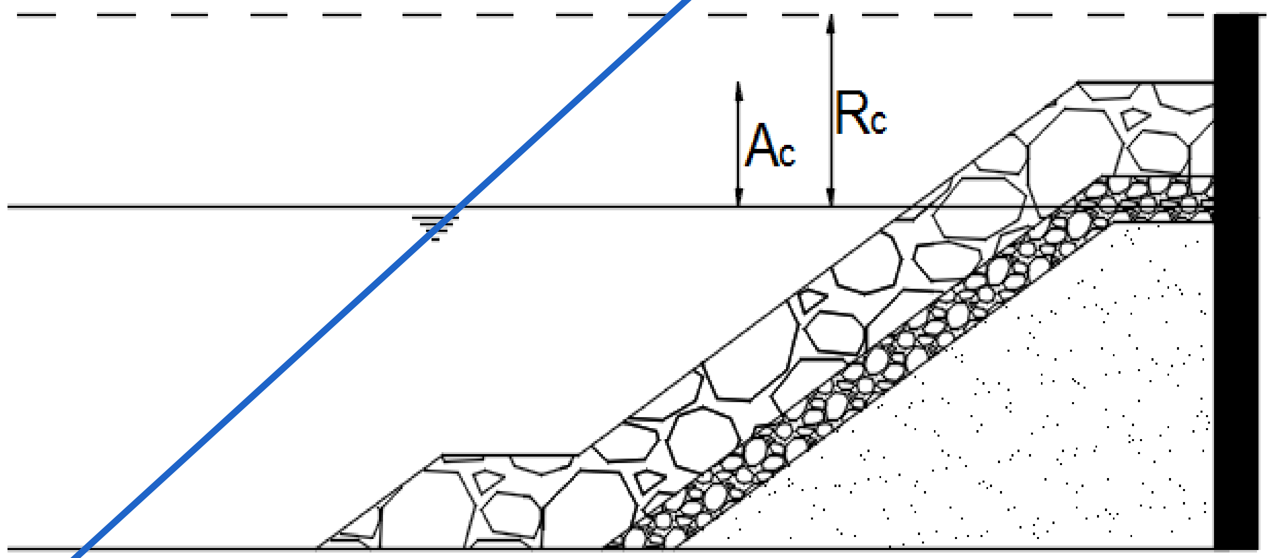
- Clear wall height variation
- Surprising results?

INFLUENCE OF THE WALL HEIGHT: +W

- Not that surprising…







- EuOtop's advice (use R_c) leads to underestimation

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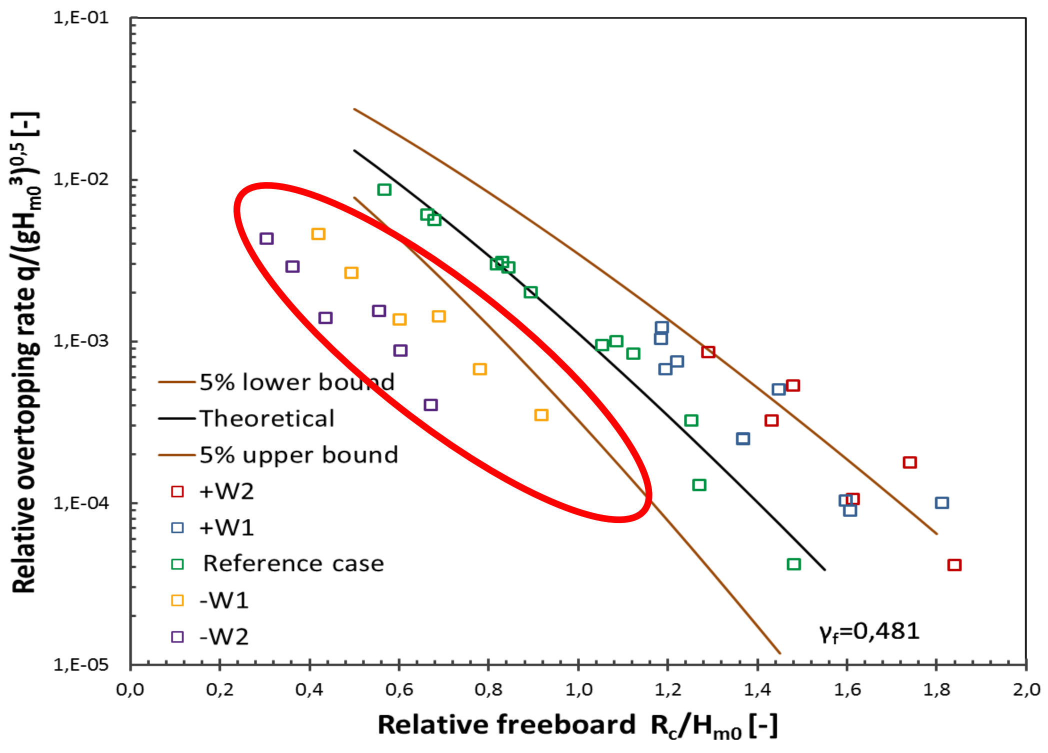
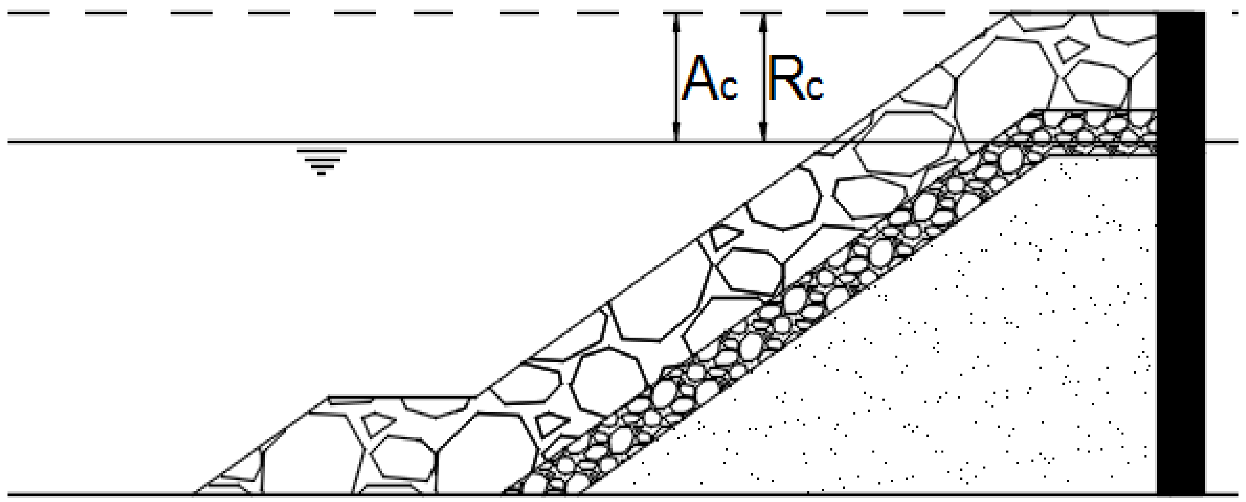
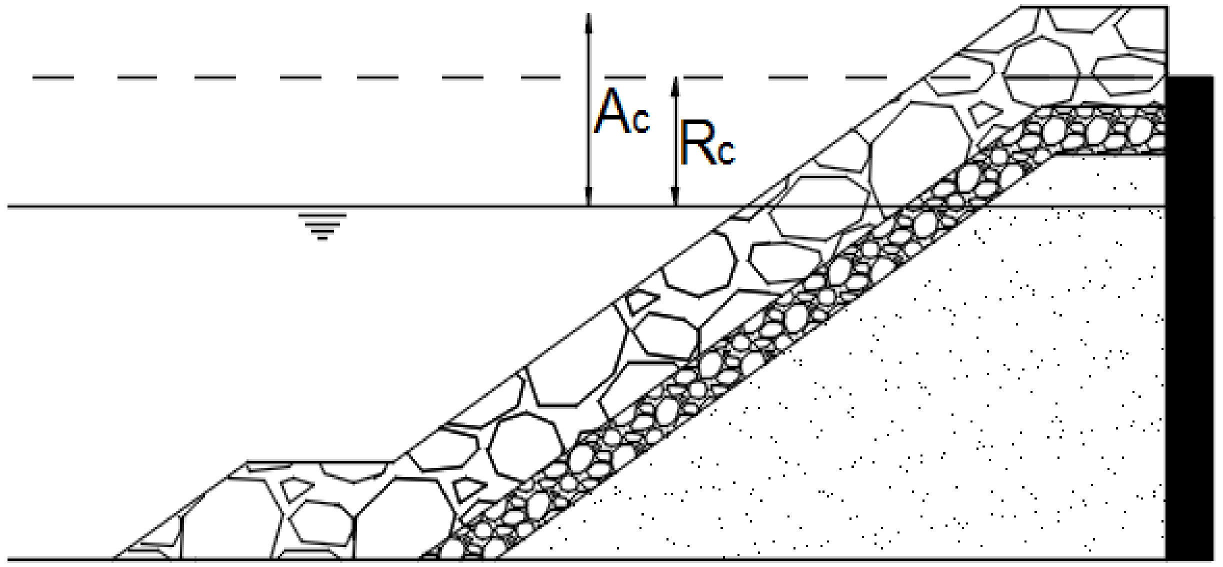
INFLUENCE OF THE WALL HEIGHT: -W

- Not that surprising…







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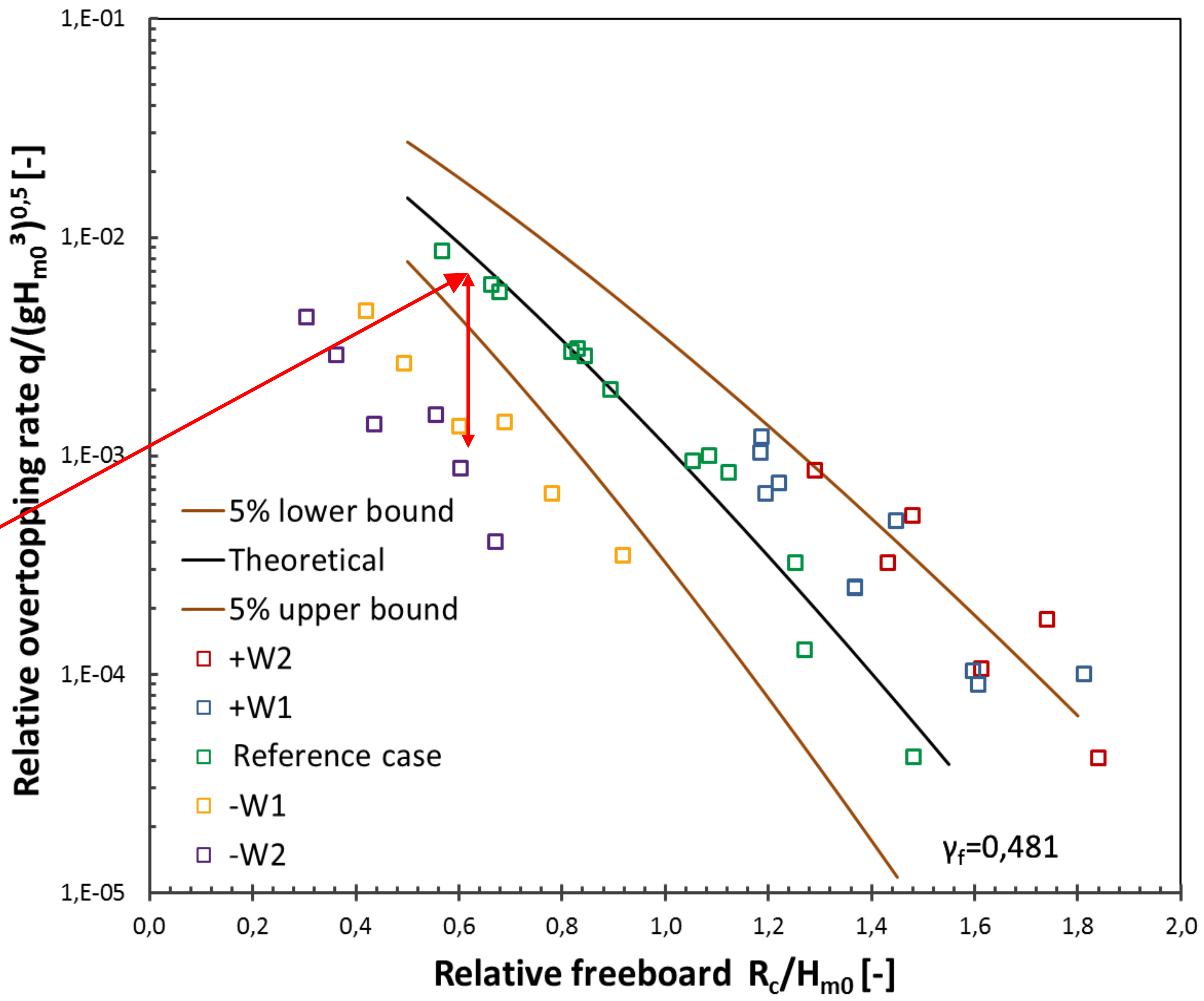
INFLUENCE OF THE WALL HEIGHT: -W

- Not that surprising…
- EurOtop's advice

  → A_c (wall)
  Underestimating

  → $(A_c + R_c)/2$ (no wall)
  Rather good advice coincidental

  → R_c (EurOtop 2007)
  Large overestimation



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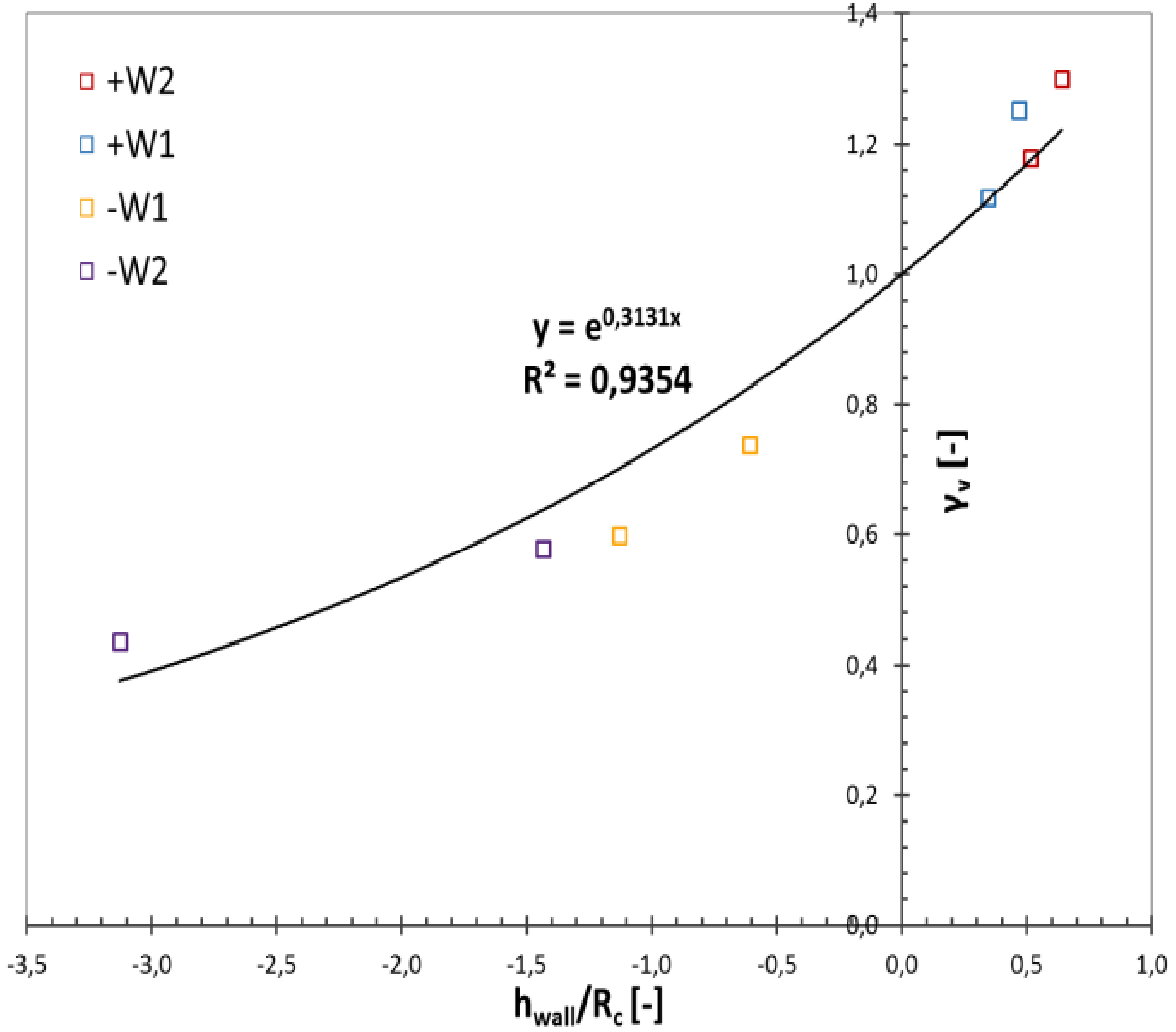
UPDATED ADVICE FOR WALL HEIGHT

Similar to smooth dike slopes: $\gamma_v = fcn(h_{wall}/R_c)$



$$\gamma_v = \exp\left(0.313\frac{h_{wall}}{R_c}\right)$$

$\gamma_v > 1$: less reductive <u>compared to reference case</u>

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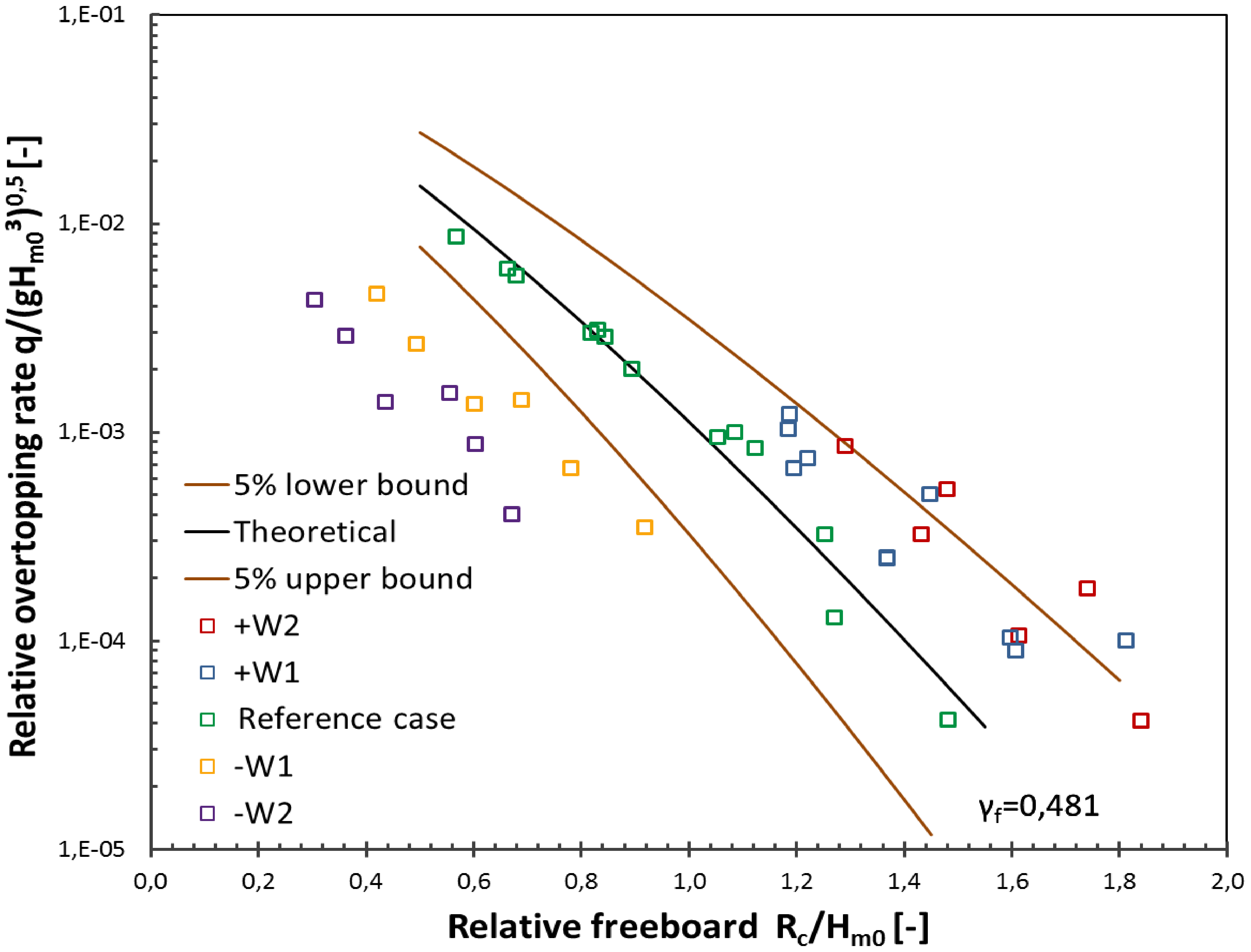
INFLUENCE OF THE WALL HEIGHT



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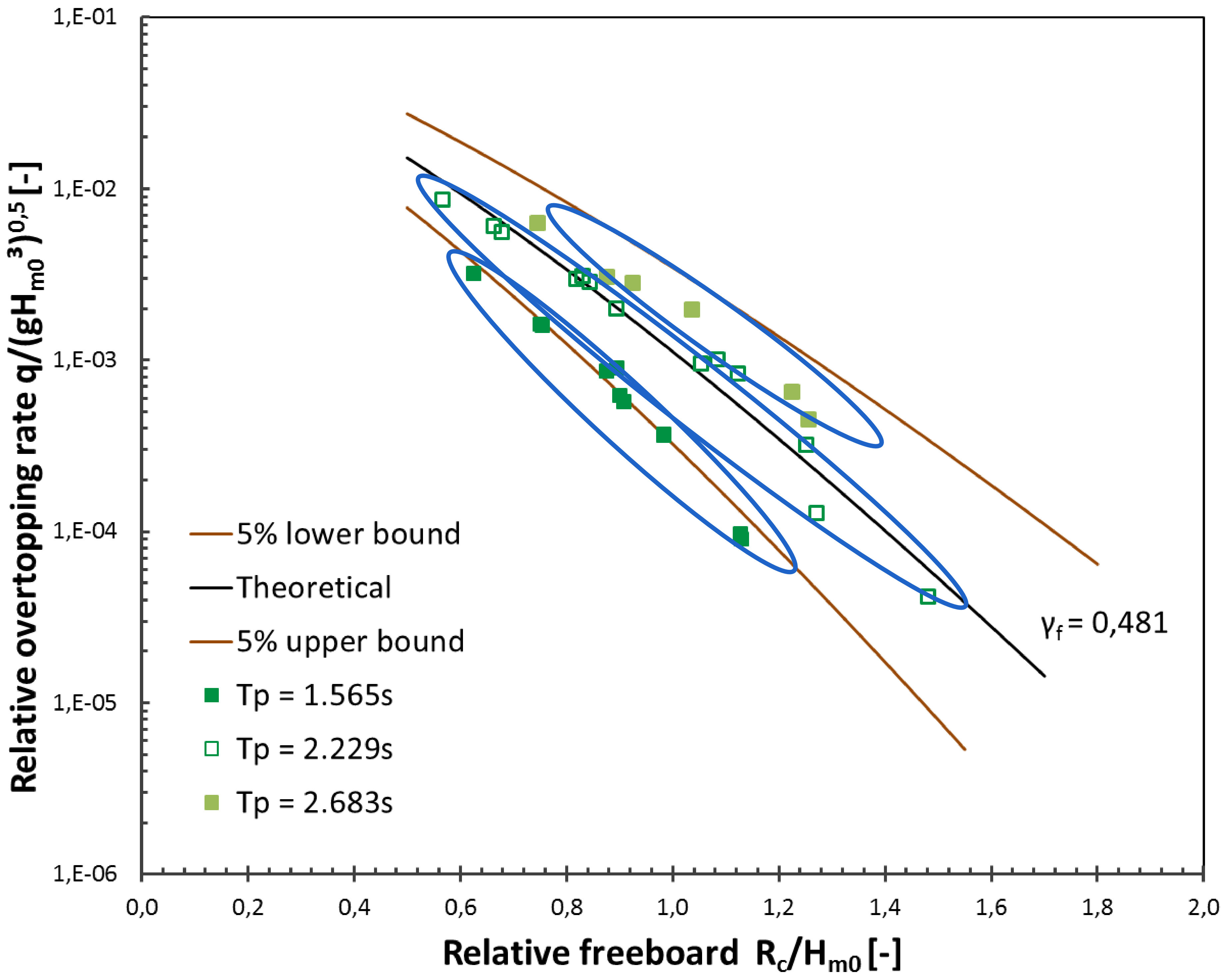
INFLUENCE OF THE WAVE PERIOD



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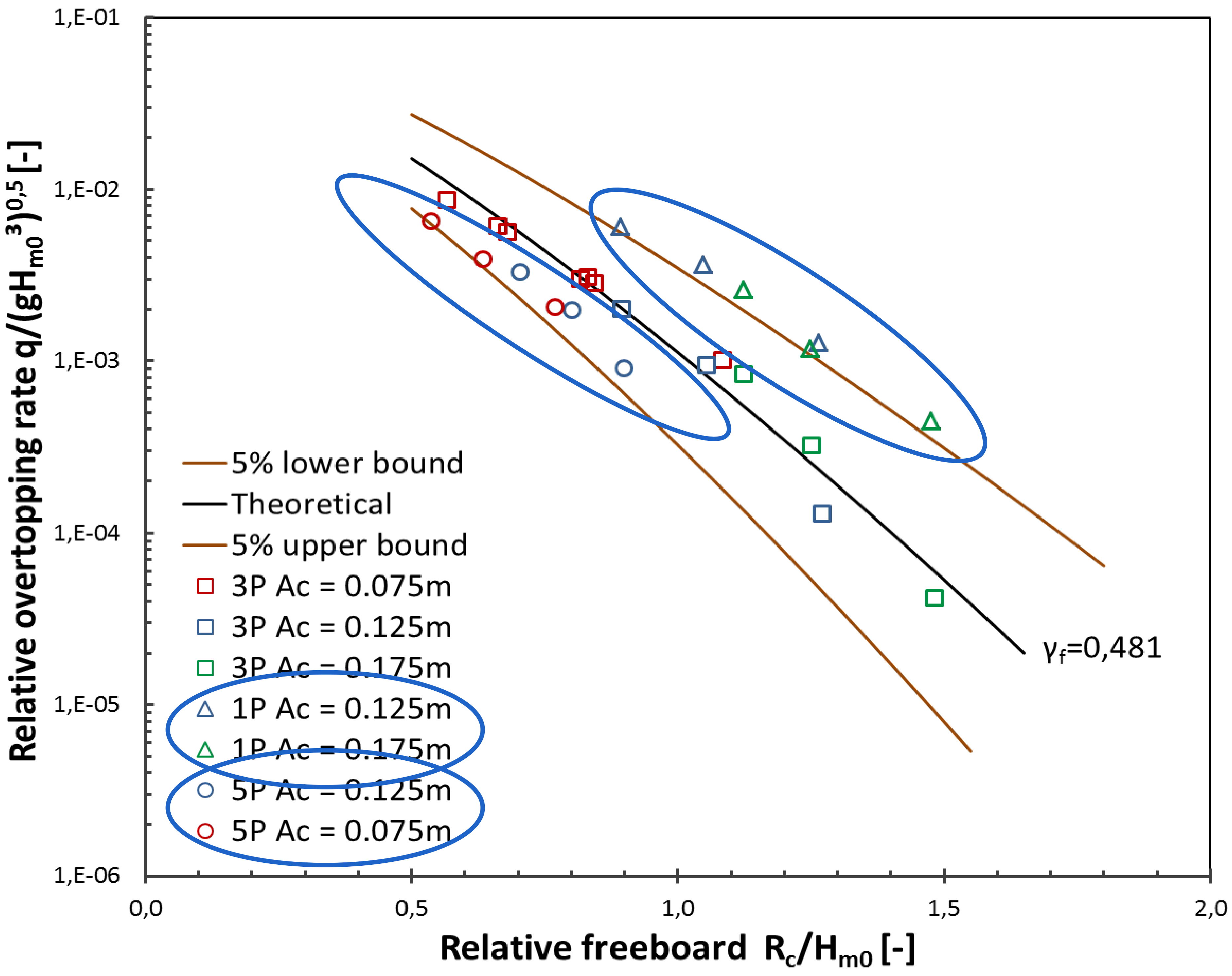
INFLUENCE OF THE CREST WIDTH



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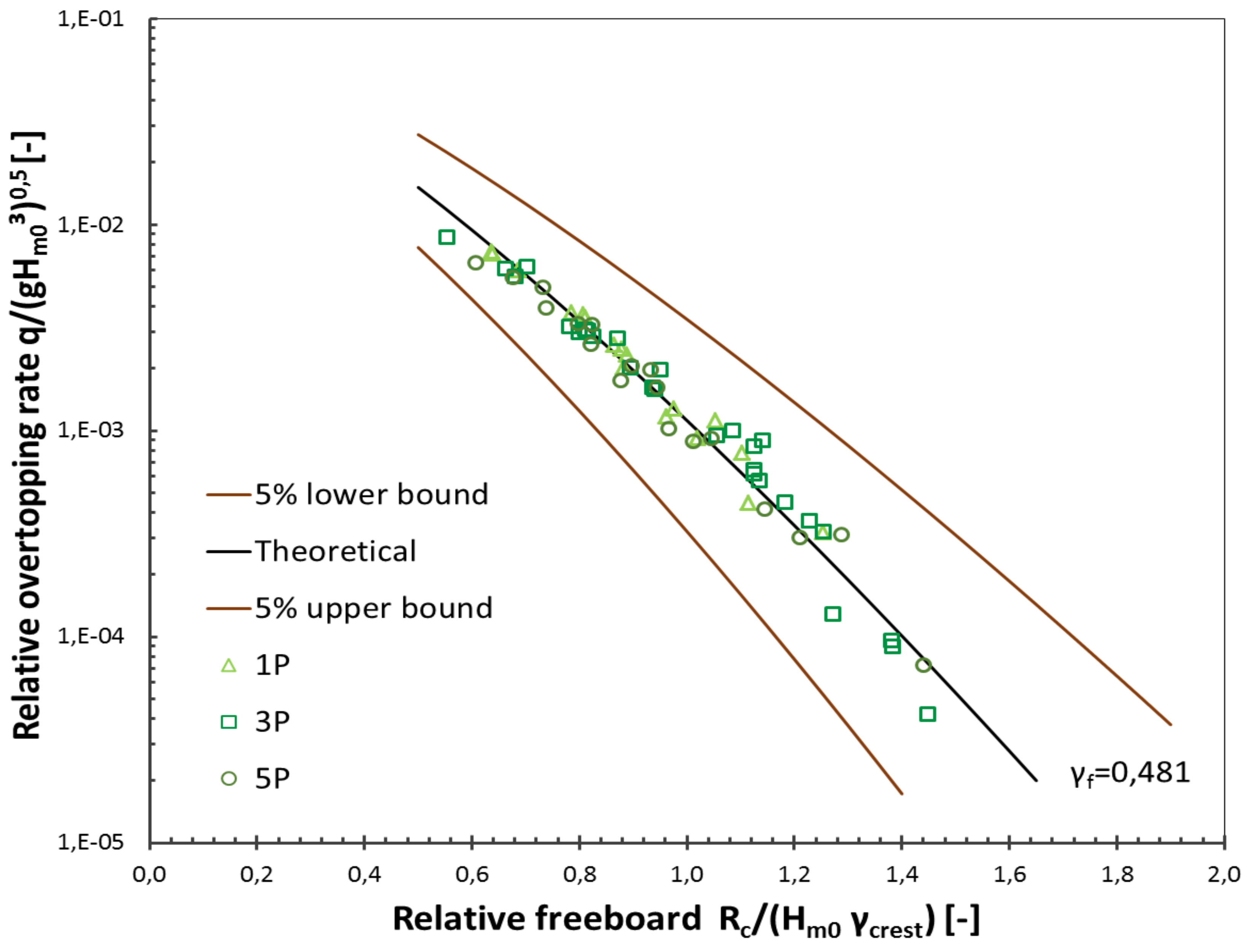
UPDATED ADVICE

Similar to smooth dike slopes: γ_{crest} = fcn ($G_c/L_{m-1,0}$)

→ Influence of wave period is also taken into account via $L_{m-1,0}$

$$\gamma_{crest} = 0.0695 - 0.274 \ln\left(\frac{G_c}{L_{m-1,0}}\right)$$



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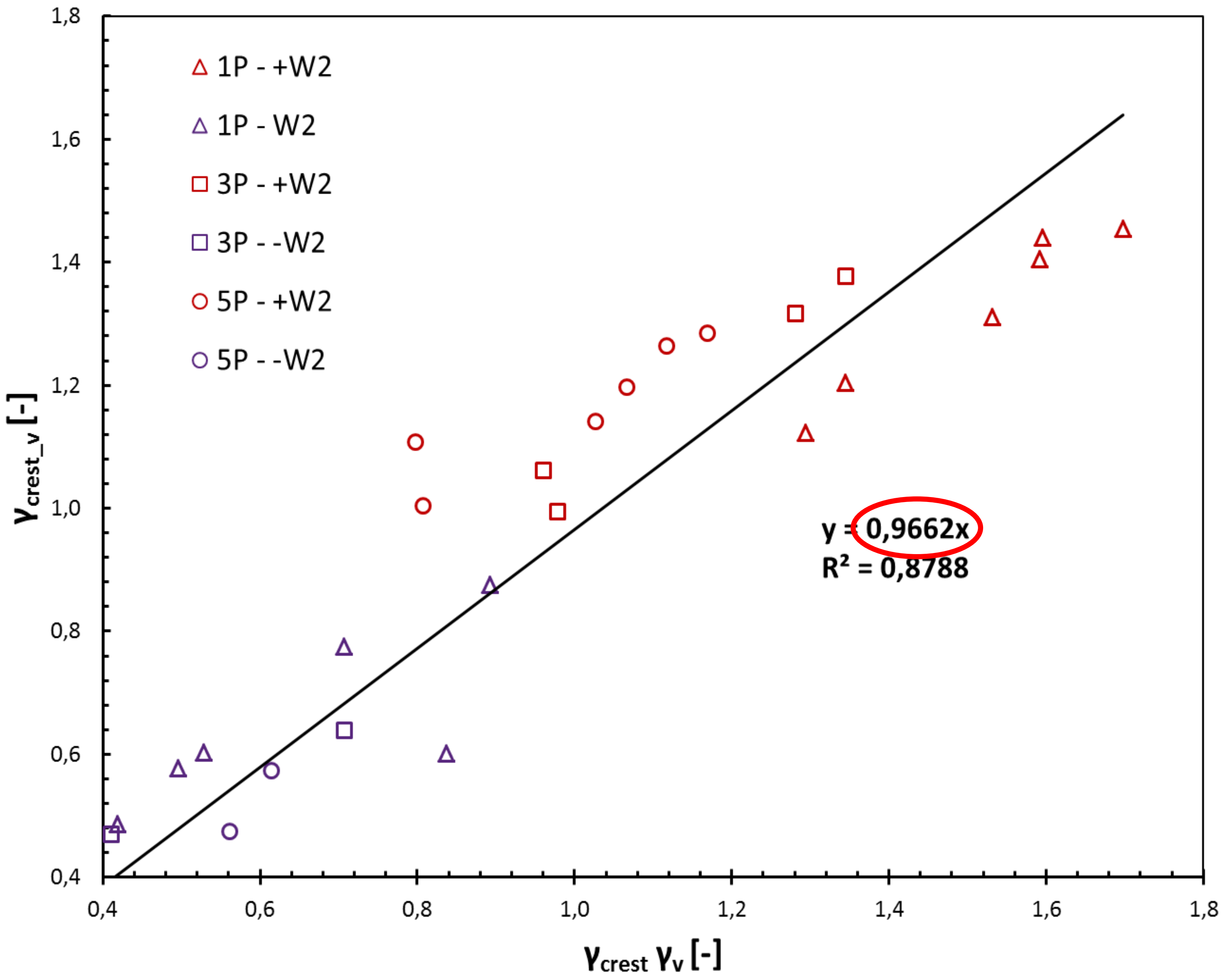
COMBINED INFLUENCE OF WALL HEIGHT AND CREST WIDTH



$$\gamma_{crest\_v} = \gamma_v \cdot \gamma_{crest}$$

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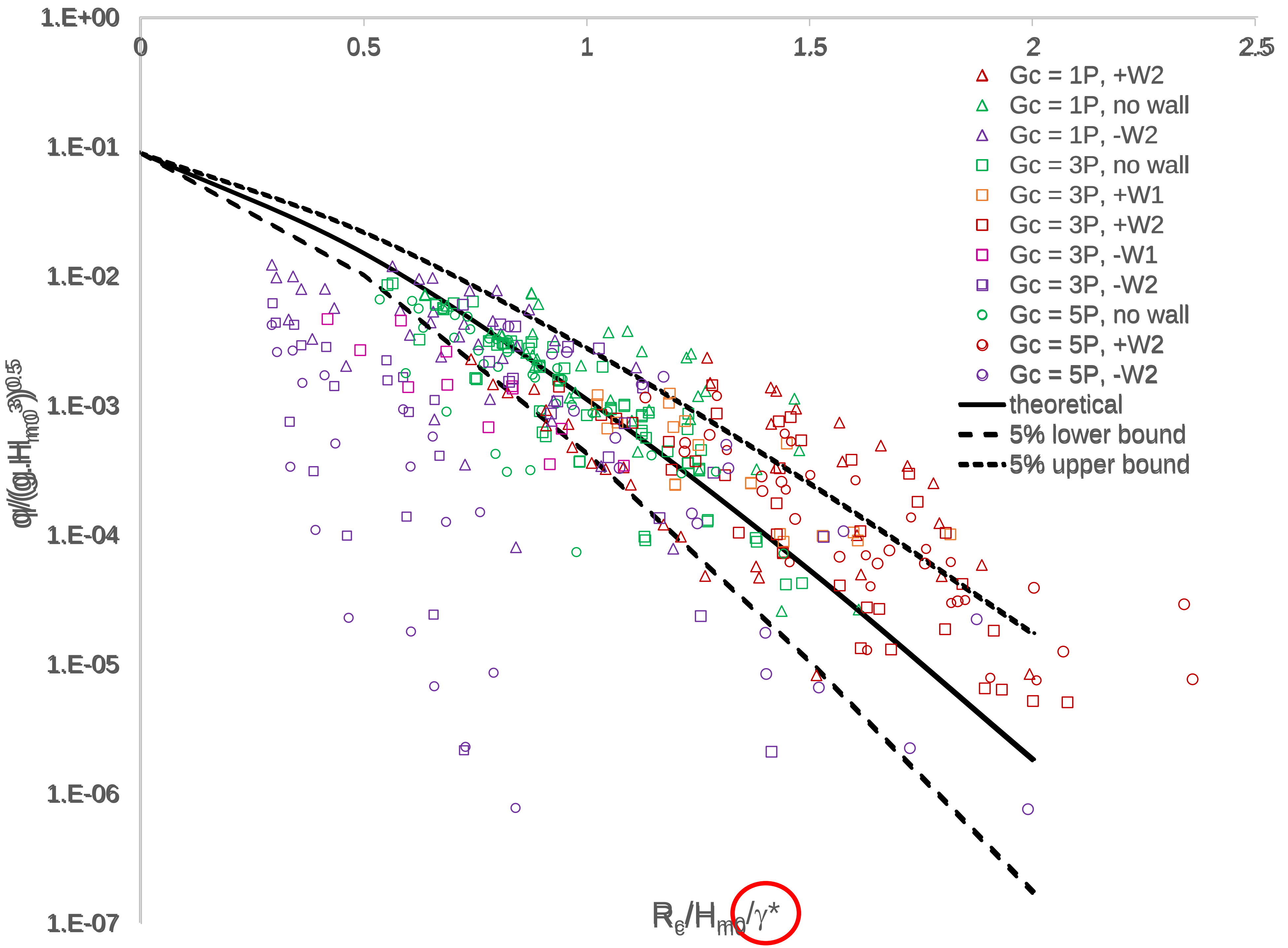
COMBINED INFLUENCE OF WALL HEIGHT AND CREST WIDTH



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4.
OUTLOOK TO RESULTS FOR CONCRETE UNITS

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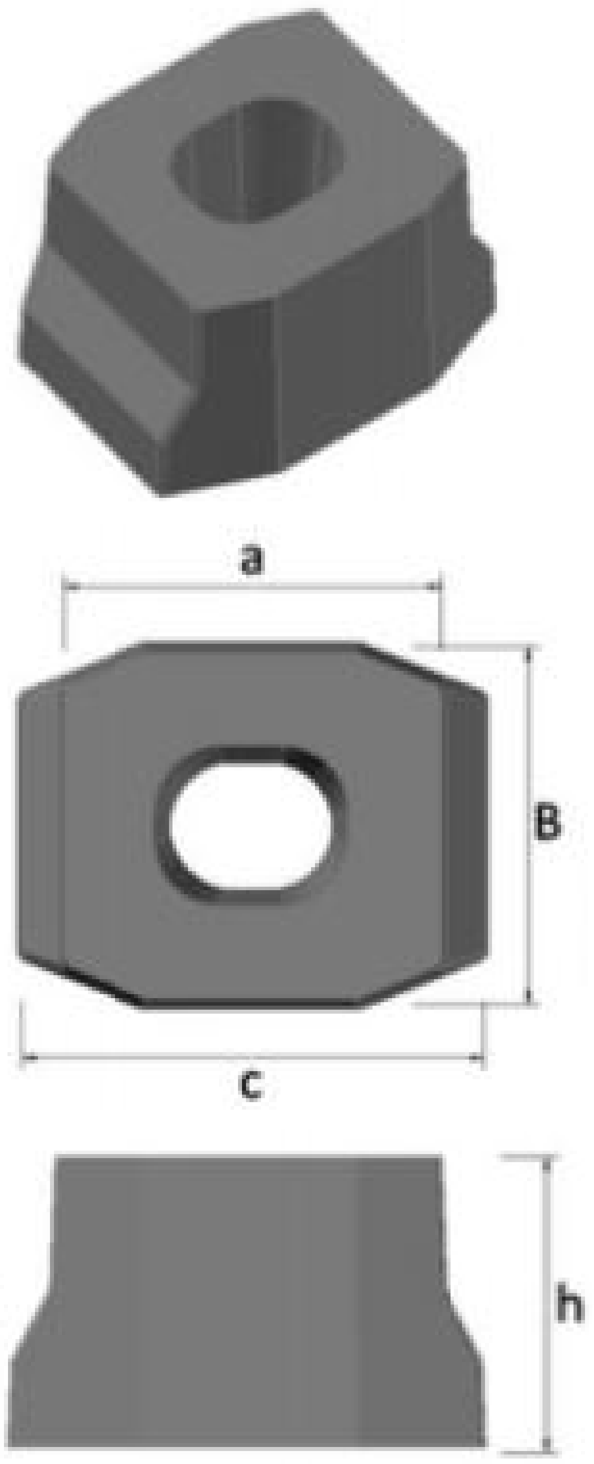
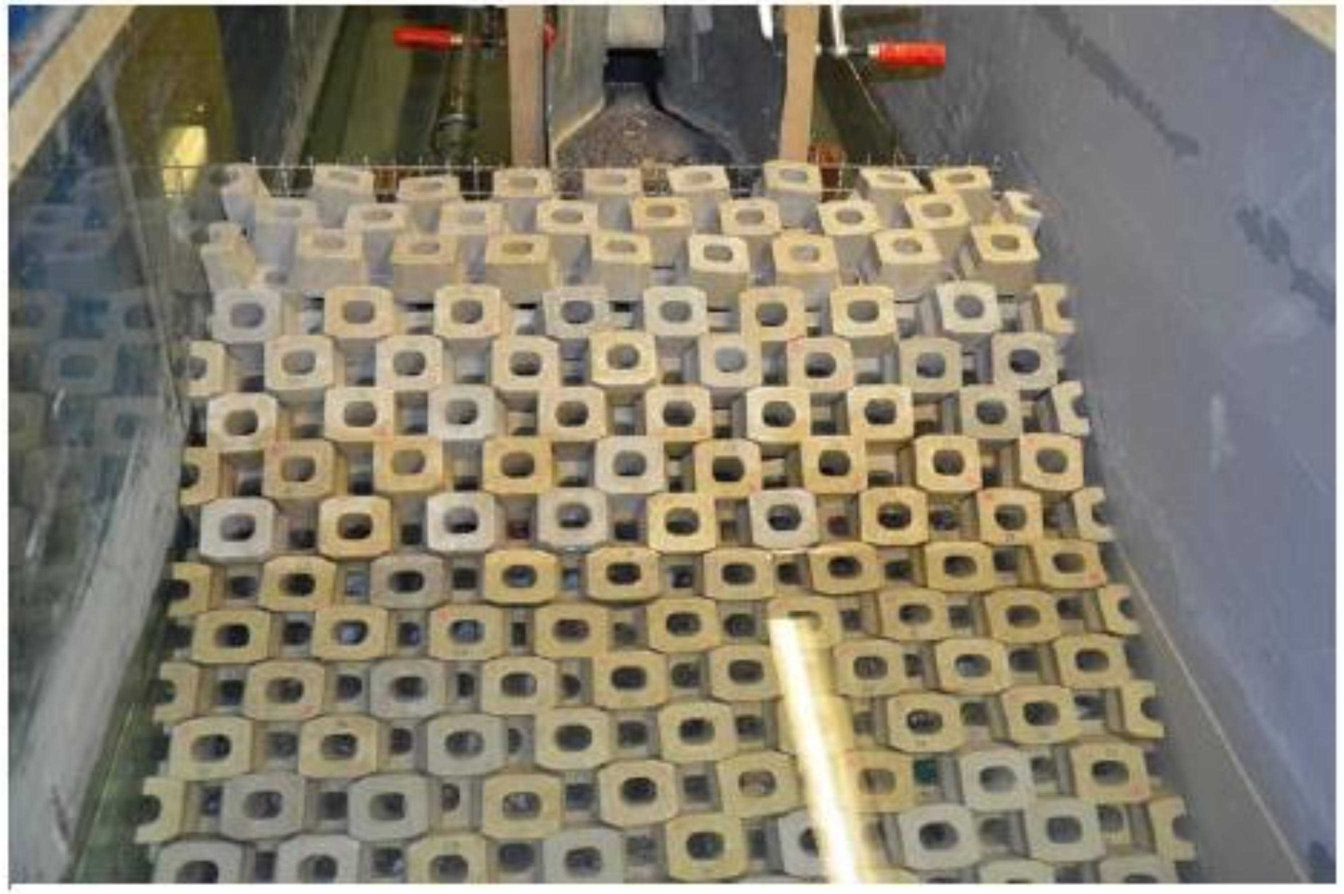
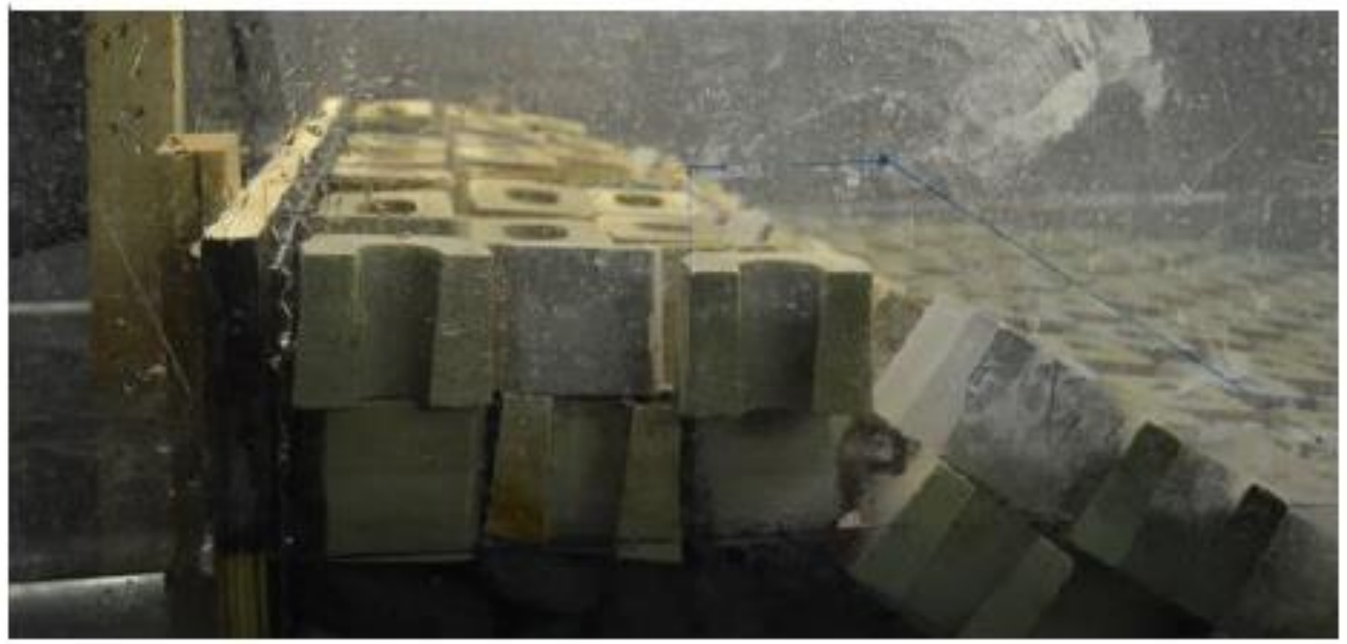
HARO ARMOUR UNIT





(a) Overview placement HARO model units



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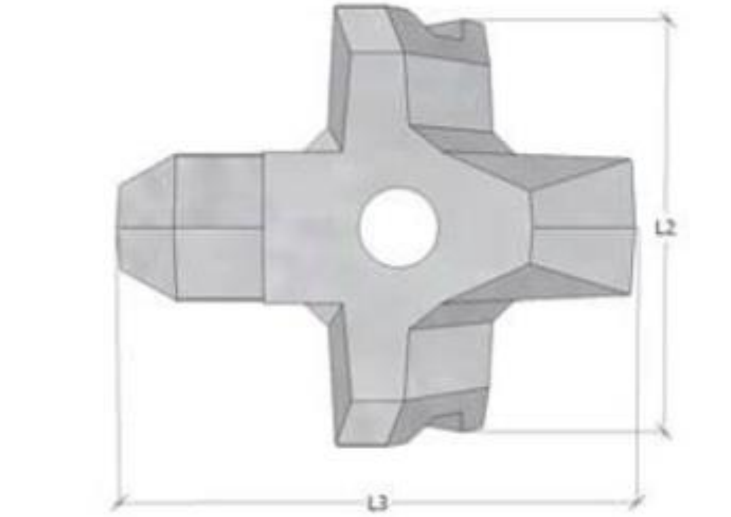
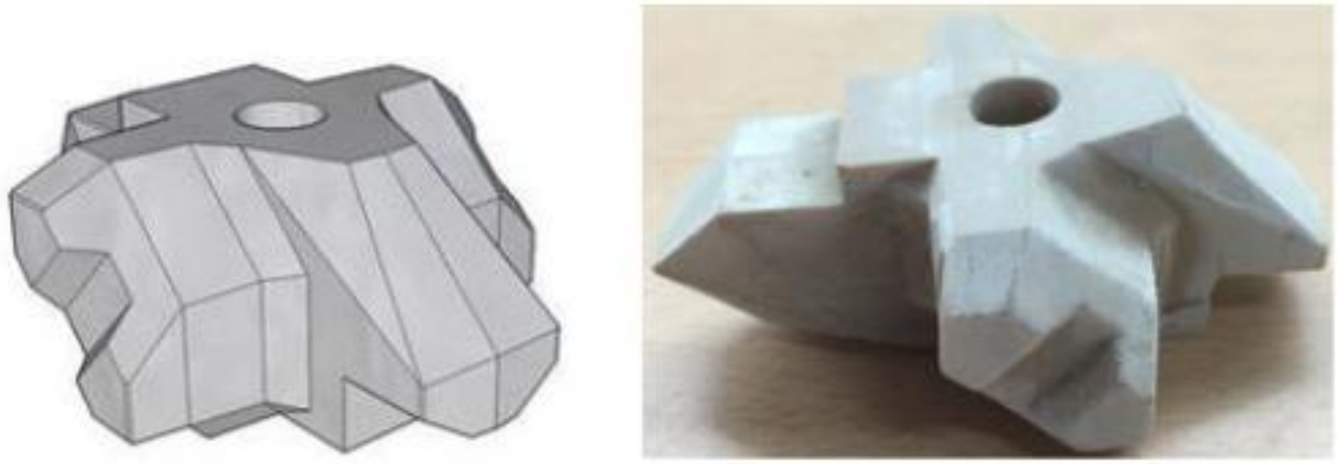
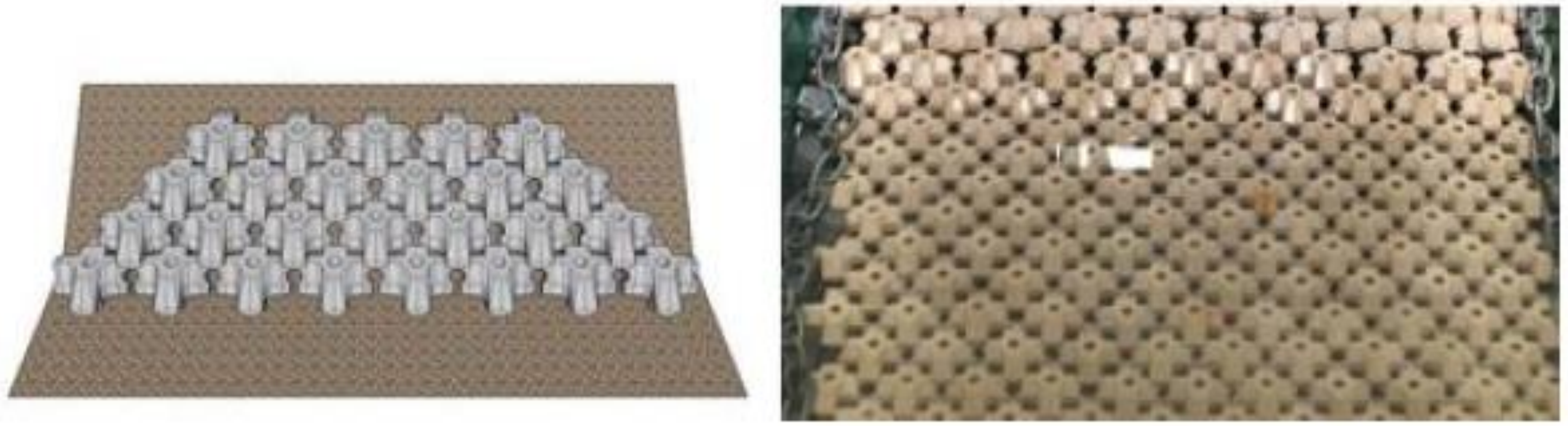
XBLOC^{PLUS} ARMOUR UNIT

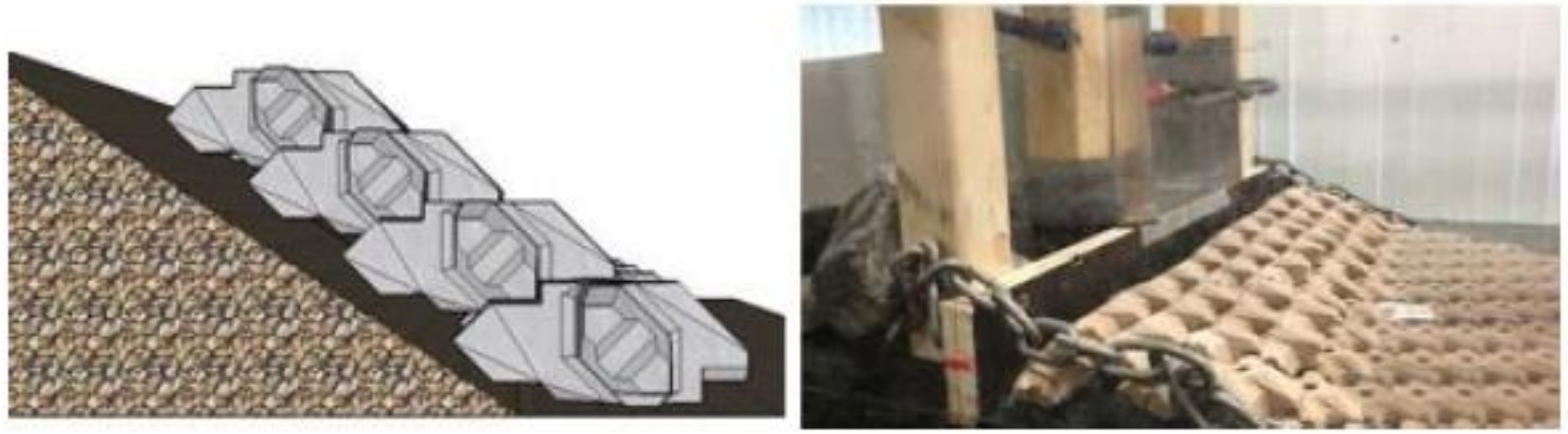




(b) Xbloc^{PLUS} 3D view



(c) Xbloc^{PLUS} front view placement pattern



(d) Xbloc^{PLUS} side view placement pattern

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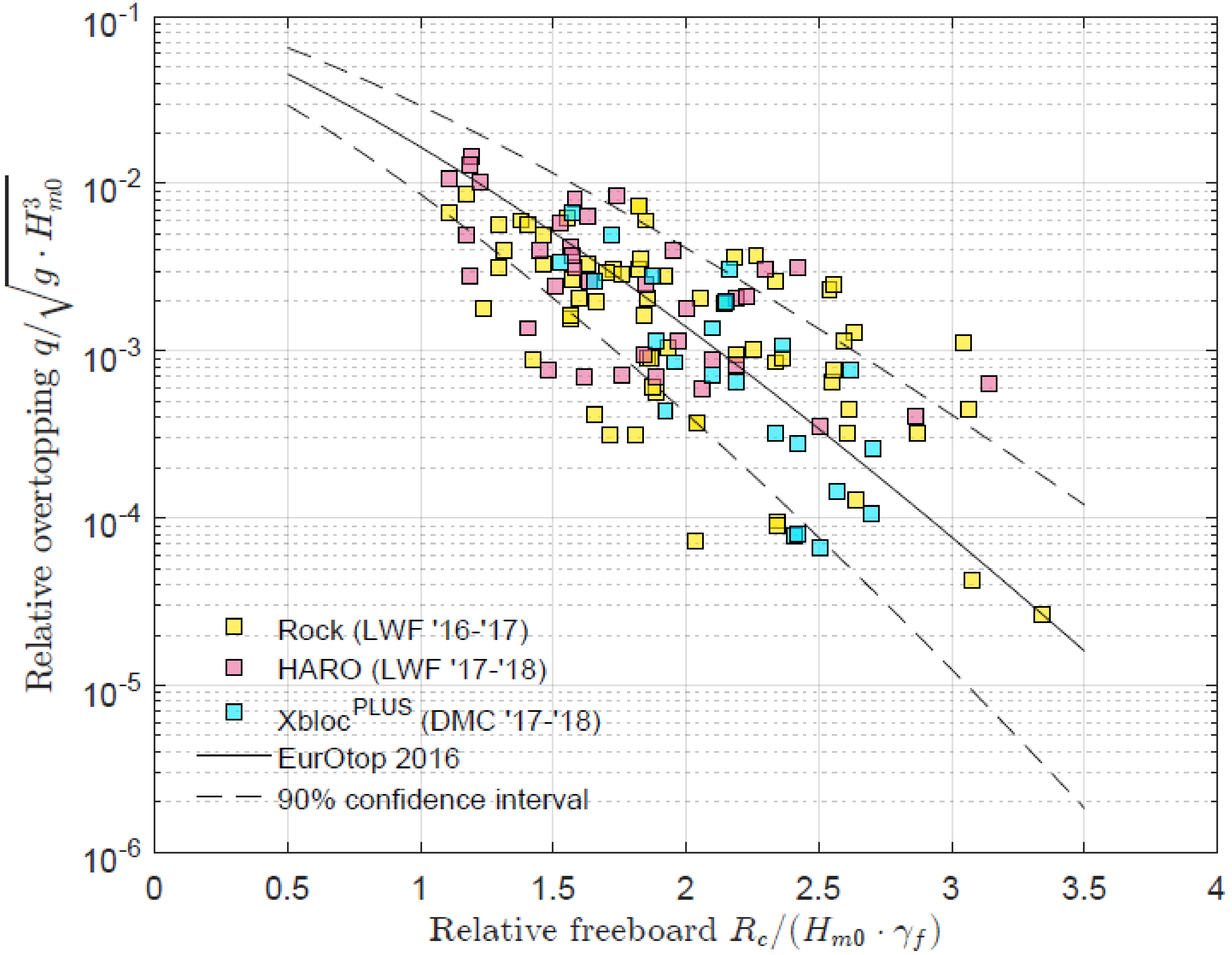
INFLUENCE OF THE CREST WIDTH: A GENERAL APPROACH



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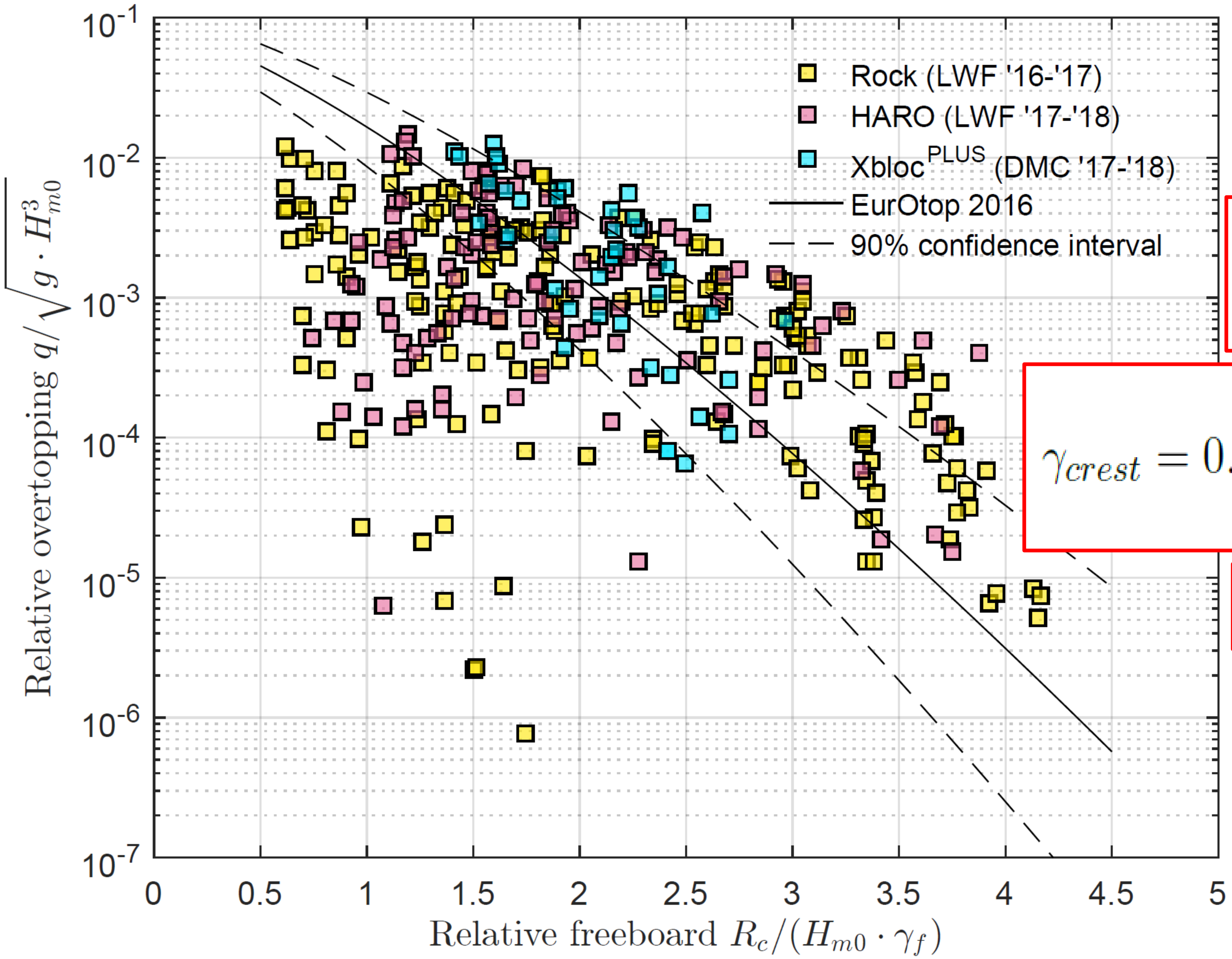
COMBINED INFLUENCE: A GENERAL APPROACH



$$\gamma_v = \exp\left(0.31 \frac{h_{wall}}{R_c}\right)$$

$$\gamma_{crest} = 0.2289 - 0.232 \cdot \ln\left(\frac{G_c}{L_{m-1,0}}\right)$$

$$\gamma_{crest\_v} = \gamma_{crest} \cdot \gamma_v$$

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5. CONCLUSIONS

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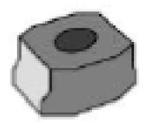
CONCLUSIONS

- Approach with influence factors in EurOtop (2016)
- Influence of a crown wall
  → independent of armour type
- Influence of crest width
  → slight dependency of armour type
  → nevertheless: general formula for preliminary breakwater design (approximate calculation)

DESIGN GUIDELINES FOR RUBBLE MOUND BREAKWATERS

INFLUENCE OF CROWN WALL AND CREST WIDTH ON WAVE OVERTOPPING

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.09 \cdot \exp\left[-\left(1.5 \cdot \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_{crest\_v}}\right)^{1.3}\right]$$

QUARRY ROCK	HARO	XBLOC^{PLUS}
		

ROUGHNESS

$\gamma_f = 0.481$	$\gamma_f = 0.476$	$\gamma_f = 0.421$

CROWN WALL

$$\gamma_v = \exp\left(0.31 \cdot \frac{h_{wall}}{R_c}\right)$$

CREST WIDTH

$$\gamma_{crest} = p - q \cdot \ln\left(\frac{G_c}{L_{m-1,0}}\right)$$

$p = 0.0695$	$p = 0.2066$	$p = 0.2785$
$q = 0.274$	$q = 0.229$	$q = 0.24$

$p = 0.2289$

$q = 0.232$

CROWN WALL AND CREST WIDTH

$$\gamma_{crest\_v} = \gamma_{crest} \cdot \gamma_v$$

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THANK YOU FOR YOUR ATTENTION!

Q&A

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