A Comprehensive Numerical Analysis of Wave Transmission in Submerged Breakwaters

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ABSTRACT

The main objective of submerged breakwaters is energy dissipation of transmitted wave in leeward. In the present study, the capabilities of FLOW-3D and MIKE21-BW software for modelling of these structures have been investigated. In this regard, experimental results have been considered as a criterion to analyze the results of this two software. Comparison of numerical and experimental results revealed that applying FLOW-3D lead to more agreement against MIKE21. Therefore, FLOW-3D has been used to investigate the effect of submerged breakwater geometry on wave transmission. The effect of variables like shoreward slope, leeward slope and width of the submerged breakwater versus height of the structure, have been studied on transmission coefficient. The effect of shoreward and seaward slope on transmission coefficient is negligible; on the other hand, these parameters considerably affect the wave reflection. Finally, the correlation factor has been calculated to investigate the correlation of dimensionless parameters with wave transmission coefficient. Accordingly, the most correlated parameters to wave transmission coefficient are F/H and F/d, respectively, and the least correlation belongs to breakwater slopes.

Keywords: Submerged breakwater; Reef; Transmission coefficient; shoreward slope; seaward slope.

INTRODUCTION

Submerged breakwaters are detached structures constructed parallel to the shoreline with a crest below the still water level. The main objective of these breakwaters is energy reduction of transmitted wave in leeward, so wave transmission coefficient is the most important parameter to design submerged breakwaters.

Many researchers have been conducted numerical and experimental studies to investigate wave transmission coefficient of submerged breakwaters. However, all of the studies have two major weaknesses: limited validity range and inaccurate study of breakwater slope effect on wave transmission.

OBJECTIVES

- ***Assess FLOW-3D and MIKE21-BW software.***
- ***Conduct parametric studies.***
- ***Identify correlations.***

METHODOLOGY

MIKE21-BW

MIKE21 is an engineering tool to study waves in coastal areas. MIKE21-BW solves Boussinesq equations by a Galerkin finite element method with mixed interpolation and reduces computational cost by neglecting a dimension, which leads to simplification of equations.

FLOW 3D

FLOW-3D contains various models such as shallow water, cavitation, and porous media that make it useful in the fields of casting, hydraulic structures and ocean engineering.

FLOW-3D solves Navier-Stokes equations by finite volume method, which result in considerable computational cost; however, it presents a detailed representation of flow regime.

SOFTWARE ASSESMENT

The results of Womera (2011) experimental research have been used to calibrate and verify the software. Figure 1 illustrates the setup and experimental instruments of Worema's research.

In order to calibrate each software, after determination of effective parameters, by setting all the parameters constant except one of them, the effect of each parameter on the results has been investigated. Then, the best value has been selected.

•Calibration and verification of MIKE21-BW

- **Results:** the relative error of numerical model in MIKE21-BW for wave height and wave breaking relative height are **%8.58** and **%0.56**, respectively.

•Calibration and verification of FLOW 3D

- **Results:** the relative error of FLOW-3D numerical model for wave height and wave breaking relative height are **%1.7** and **%7.0**, respectively.

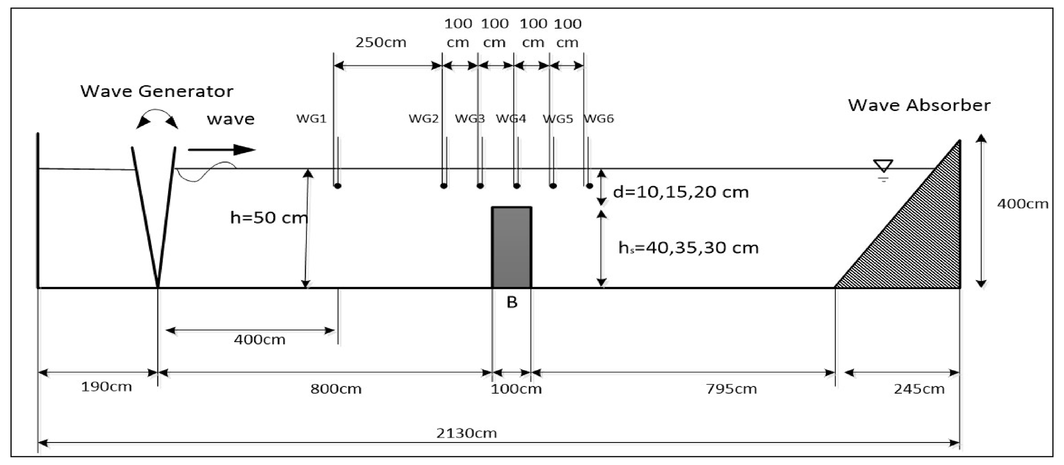

Figure 1. A scheme of wave flume, submerged breakwater properties, free surface recorders and wave generator

RESULTS

- Seaward and shoreward slope
- Relative depth of breakwater (F/d)
- Relative wave height (H/F)
- Correlation factors

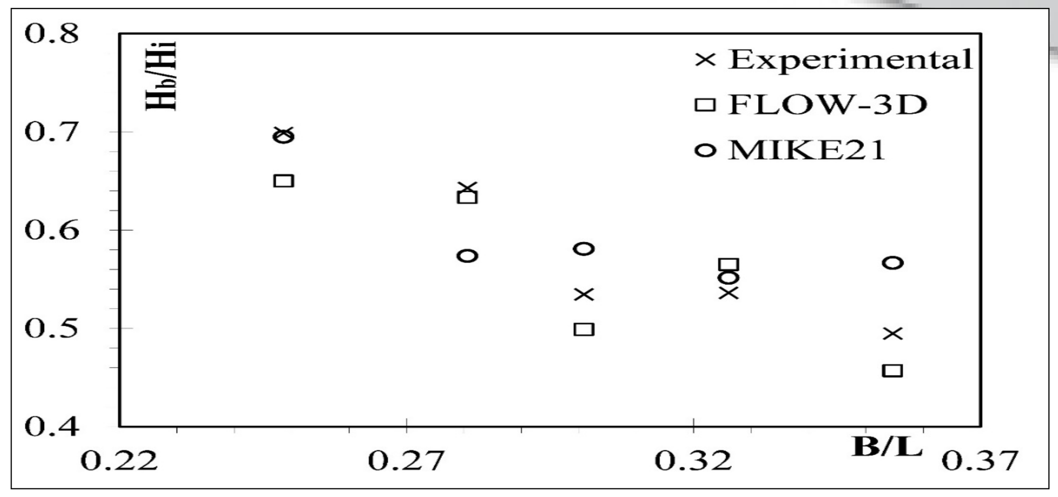

Figure 2. Comparison of Al Womera's (2011) experimental results with numerical models

The effects of seaward slope on wave transmission coefficient has been investigated, and it was observed that slope angle effect is not significant on wave transmission. This conclusion is consistent with Van der Meer's (2004) results. The result of this analysis is reported in the Figure 3.

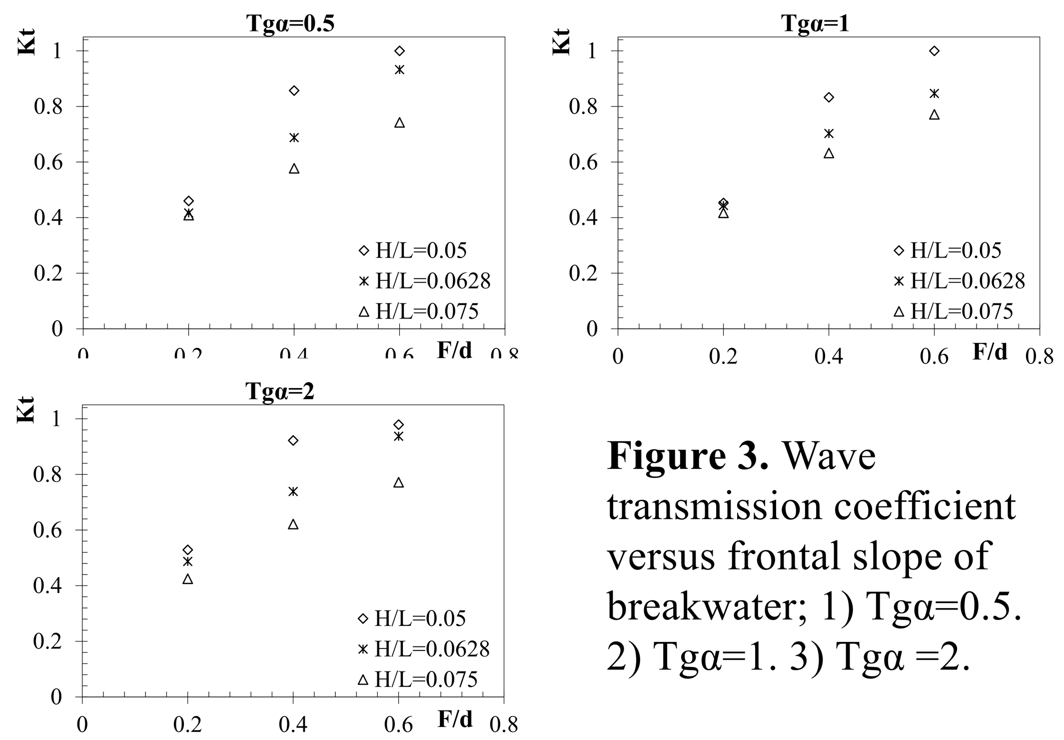

Figure 3. Wave transmission coefficient versus frontal slope of breakwater; 1) Tgα=0.5. 2) Tgα=1. 3) Tgα =2.

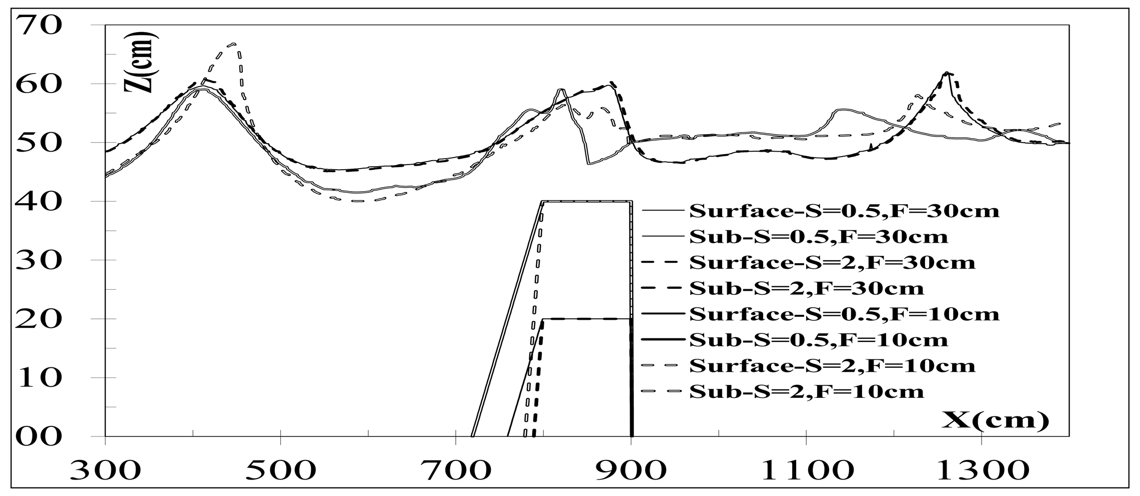

Figure 4. Wave Graphical representation of wave transmission in submerged breakwater. In all above cases t=28s, Hi=15cm and d=50cm. in this figure, case (1) correspond to seaward Slope.

It can be observed that seaward slope blocks the wave which results in wave reflection and wave height increase before reaching the breakwater.

DISCUSSION

- ***The seaward and shoreward slopes***
  - The highest reflection belongs to the breakwaters with vertical slope. In this case, wave breaks in front of breakwater which leads to toe scouring
  - wave blocking imposes significant forces on breakwater that result in structural damage and instability. Because sedimentation in leeward of breakwater is important for shore protection, breakwater requires vertical shoreward slope and inclined seaward profile for sedimentation in leeward of breakwater. This conclusion is consistent with Kabalec's (1963) study.
- ***Relative depth of breakwater (F/d)***
  - By increase in wave steepness and relative width, and decrease in relative depth , the wave transmission coefficient decreases.
  - If breakwater width is longer than incident wavelength (B/L > 1), the most significant fluctuations of wave transmission coefficient occurs for relative depth between 0.4 and 0.6
  - If B/L <1, the most significant changes happen in relative depths of 0.2 to 0.4,
- ***Relative wave height (H/F)***
  - If breakwater width is more than incident wavelength and wave height is more than 0.4 of water depth above the breakwater crest, the wave transmission coefficient remains constant.
  - If breakwater width is low and its depth is just more than 0.6 of water depth at breakwater toe, the wave reaches leeward of the breakwater and return to its previous state before breaking at breakwater crest due to shoaling.
  - It could be also concluded that low crested breakwaters play a significant role in transmitted wave energy reduction, while in breakwater with low relative depths, width effect is minor. In the other words, as relative depth of breakwater decreases, incident wave breaks
- ***Correlation factor***

Finally, the correlation between dimensionless parameters and wave transmission coefficient have been investigated, and it was observed that depth above breakwater crest to incident wave height ration (F/H) and breakwater slopes show the highest and lowest correlation, respectively.

Table 1. Correlation factors of dimensionless parameters with wave transmission coefficient

Dimensionless parameter	F/H	F/d	L/H	L/B	H/B	1/tgβ	tgα
Correlation factor	0.8772	0.8403	0.3643	0.3095	0.1959	0.1096	0.079

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