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Wave Transmission on Submerged Breakwater with Interlocking D-Block Armor

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ABSTRACT:- Breakwater is a construction to reduce the effect of ocean wave that causes erosion/abrasion in coastal areas. The study is aimed at determining the stability of the interlocking D-block armor in breakwater. Laboratory experiment to confirm the findings uses variations of water depth, (d), wave period(t), topwidth(B) and thewave height(H). The breakwater type used in this researchis the submerged breakwater with the interlocking D-block armor that results in regular waves in the 2D glass channel (waveflame). To determine the parameters that influence the transmission wave, the breakwater here is designed to represent actual behaviors. Observations and measurements in the study was the effect of wave height(H), wave period(t) before and after passing the breakwater structure in the wave channel.

Results show that wave transmission through the breakwater structureis strongly influenced by the water level above the top(h), structural height(d-h) and water depth(d) as well as the ratio of wave steepness$\left(\frac{Hi}{gT^2}\right)$ with regression parameter obtaining the formula for transmission coefficient of Kt = 1,636 + 0,012 ($\frac{gT^2}{B}$)-1,376($\frac{d-h}{d}$)-1,970$\frac{Hi}{gT^2}$. Results also indicate that the higher the structure above water top(h), the bigger the transmission coefficient is, and the lower the value(h, the smaller the transmission coefficient. The parameters above top height(h) and top width(B) greatly affect the transmission coefficient(Kt) and breakwater performance in reducing wave height.

Keywords:- breakwater, transmission coefficient(Kt), interlocking D-block

I. INTRODUCTION

Indonesia is an archipelago with the second longest shoreline in the world. This shoreline also provides livelihood for many of its citizens. Therefore, the need for a defense against erosion/abrasion of the shoreline is of utmost importance. This significant defense against waves requires the proper techniques to minimize risks of erosion/abrasion.

Breakwater is an off-shore construction designed to break incoming waves into smaller waves. Based on its relative position to sea level, three types of breakwater are available: conventional breakwater, lower limit breakwater, and submerged breakwater. They are depicted in Fig. 1.1.

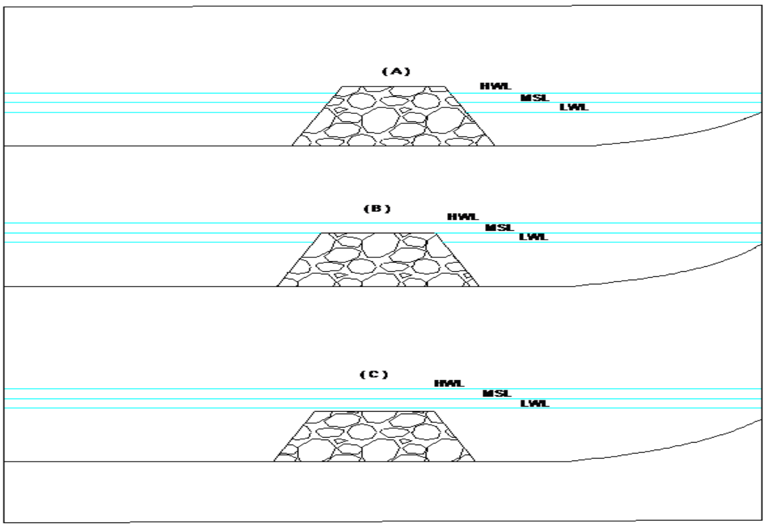

Figure 1.1 Conventional (A), lower limit, (B), and submerged breakwater (C).

This research is aimed at understanding the wave transmission on the breakwater structure that uses Interlocking D-block layer.

Interlocking D-Blok layer is a concrete protective layer that interlocks to improve the stability of the armor units of the breakwater. No earlier study has reported the use of interlocking D-block as the layer for breakwater. The advantages of interlocking D-block over available armors are:

- The stacking is in an orderly manner, in contrast to the current random placement of armor units.
- Stability at each armor unit does not depend on the weight of the unit.
- It has higher stability as it has better homogeneity.
- Unit weight is lower in its usage.
- It is environmentally friendly as it is well-stacked and is porous.
- The construction costs are more efficient.

And the disadvantages include:

- The installation can be quite a challenge as they must be stacked orderly.
- It is mostly suitable for beaches with relatively flat bathymetry and high erosion/abrasion levels.
- It therefore not suitable for steep, muddy, and rocky beaches as they hamper proper installation of the breakwater.

1. Theory

1.1 Wave Characteristic

Ocean wave has some categories depending on the force that causes it, and it can be enigmatic for coastal engineers.

Shore erosion/abrasion is becoming serious nowadays as it endangers people, properties, and natural resources, and also commercial activities down the shores.

The wave theories commonly used to explain the working of ocean wave are, among other things:

- *The Airy wave theory*
- *The Stokes theory*
- *The Conidial theory*
- *The Solitary theory*

The parameters commonly used to explain ocean wave are:

- Wave period (T); the time it takes for two wave peaks to travel certain points.
- Wavelength (L); the horizontal distance of two wave peaks.
- Wave velocity (C); the ratio of wavelength and wave period.
- Amplitude (a); the distance of a wave peak or a wave valley to the water level (H/2).

1.2 The Airy Wave Theory

It is also known as the small amplitude wave theory or linear wave theory. *Airy* (1845) developed an approach for the wave movement by describing it in a simple way or sinusoidal. This theory is based on the equations of continuity and momentum conservation put forward by *Laplace* and *Bernoulli.*

This theory applies for a wave where $H < d$ and $H < L$.

The equation for the wave front is:

$$\eta = \alpha \cos (kx - \sigma t)$$

Where : α = wave amplitude (around half the wave height)

k = wave number ($2\pi/L$)

$\sigma = 2\pi/T$ (wave frequency)

For shallow waters, $d/L < 1/120$

- Wave velocity : $C = \frac{L}{T} = \sqrt{gd}$
- wavelength : $L = CT = T\sqrt{gd}$
- Horizontal particle velocity :

$$\mu = \frac{H}{2}\sqrt{\frac{g}{d}}\cos[kx - \sigma t]$$

- Vertical particle velocity :

$$w = \frac{\pi H}{T}(1 + \frac{2}{d})\sin[kx - \sigma t]$$

For medium waters, 1/120 <d/L< ½

- Wave velocity: $C = \frac{L}{T} = \sqrt{gd}.\tanh kd$
- Wavelength: $L = \frac{gT2}{2\pi}\tanh.\ kd$
- Horizontal particle velocity :

$\mu = \frac{H}{2}.\frac{gT}{L}.\frac{\cos h\ [k(z+d)]}{\mathrm{Cosh\ Kd}}\cos[kx - \sigma t]$

- Vertical particle velocity :

$$w = \frac{H}{2}.\frac{gT}{L}.\frac{\sin h\ [k(z+d)]}{\mathrm{Cosh\ Kd}}\sin[kx - \sigma t]$$

For deep waters, d/L < ½

- Wave velocity: $C = \frac{L}{T} = \frac{gT2}{2\pi}$
- Wavelength: $L = \frac{gT2}{2\pi}$=1,56 T^2
- Horizontal particle velocity:

$\mu = \frac{\pi H}{T}e^{kz}\cos[kx - \sigma t]$

- Vertical particle velocity:

$w = \frac{\pi H}{T}e^{kz}\sin[kx - \sigma t]$

Measurements of wave height in the laboratory use the followings:

Hi = $\frac{\text{Hmaks} + \text{Hmin}}{2}$

Hr = $\frac{\text{Hmaks} + \text{Hmin}}{2}$

Ht = $\frac{(\text{Hmaks})t + (\text{Hmin})t}{2}$

1.3 . Wave Transmission

The ratio of incoming wave (Hi) reflected by the breakwater is stated as the transmission coefficient (Kt) as follow:

Kt = $\frac{Ht}{Hi}$

This research is founded on earlier research on breakwater, including:
Sila D-arma (1994) found the wave transmission coefficient for artificial reef:

Kt = exp [-0.509-0.206.Ln $(\frac{h-d}{Hi})$-1.32$(\frac{B}{gT2})$

Armono (2004) gained the formula for transmission coefficient (Kt) from submerged Breakwater made of hollow hemispherical shape of artificial reef (HSAR):

Kt = 1,616-31,322. $\frac{Hi}{gT2}$-1,099 $\frac{h}{d}$+ 0,265$\frac{h}{B}$

Seeling (1980) got the formula for transmission coefficient from the effect of breakwater on the wave transmission of Rabble Mound Breakwater:

Kt_0 = C (1 - $\frac{F}{Ru}$) not submerged

Kt_0 = C (1 - $\frac{F}{Ru}$) – C' (1 - $\frac{F}{Ru}$) submerged

where:

$\frac{F}{Ru}$< 0, C' = 0.24

where:

F = Freeboard
R = Run up
Kt_0 = Transmission coefficient

II. METHODOLOGY

This research was carried out at Balai Pantai, Gilimanuk – Singaraja street km. 122 Gekayak Bali using 2D wave tunnel of 40 m height, 60 cm width, and 110 cm length, and a wave maker to vary the period and height. And each set of the sensor is equipped with 4 wave probes to measure wave height, both in front of and behind the structure. The measurement result is saved using the *HR Dag Suite* software as depicted in the following figure:

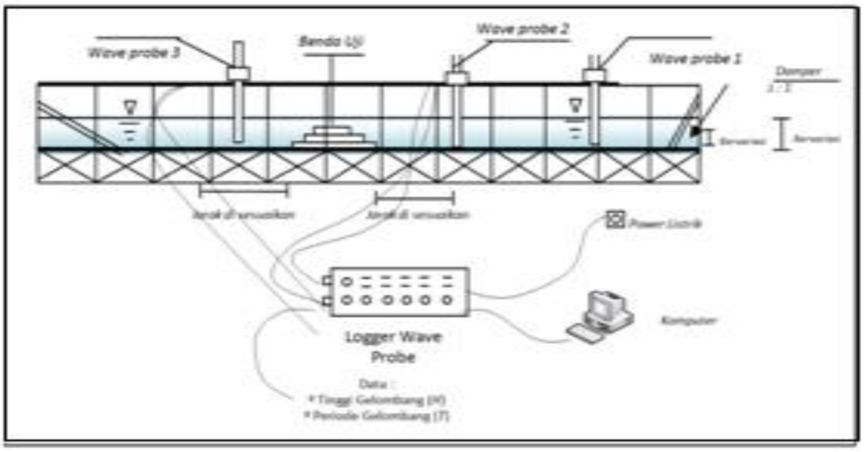

Figure 3.1. Wave probes connected to a computer.

Figure 3.2. Wave probe instrument calibration.

The breakwater model is made of concrete. And its dimension is as follow:
Concrete specific weight = 2000 t/m^3,
$V=B^2xE$

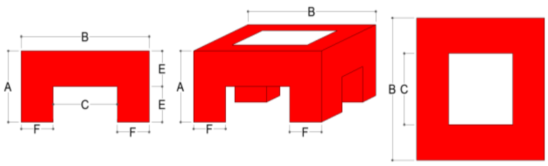

Figure 3.3. Interlocking D-block, Scale 1:10.

Details of the modeling are depicted below:

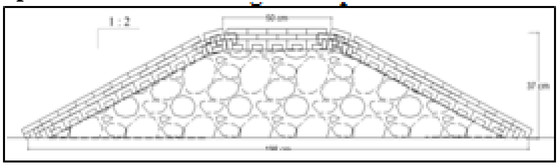

Figure 3.4a. Model of D-BI scenario

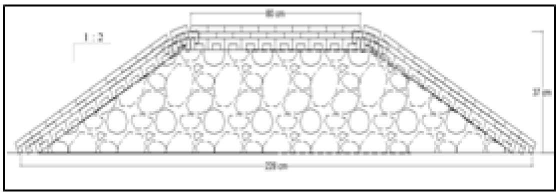

Figure 3.4b. Model of D-BI scenario

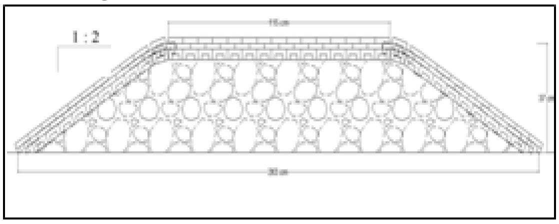

Figure 3.4c. Model of D-BI scenario

Figure 3.5. Model position before 'running'.

Structure parameter variation is based on the ratio of structure height (d-h) and water depth (d), for $\frac{d-h}{d}$= 0.65, 0.79, 0.88 and 1.0.

Wave parameter variation based on period (T) with *Stroke* (S) T=1.6. *Stroke* (C) T=2.0. *Stroke* (B) T=2.5. *Stroke* (A) for each $\frac{d-h}{d}$, a running of 15 times ensues.To figure out the effect of topwidth (B) on transmission, the top width (B) is made into three variations; B=0.50, 0.80 and 1.15 cm with the fixed structure height (d-h).

III. RESULT AND DISCUSSION

The effect of breakwater height (d-h) on water depth (d) in Kt vs $\frac{Hi}{gT2}$, can be seen in Fig.4.6. The greater the $\frac{d-h}{d}$, the less the transmission coefficient (Kt) is. And the smaller the $\frac{Hi}{gT2}$, the higher the transmission coefficient will be. They are depicted in the following(4.6,4.7,4.8) figures.

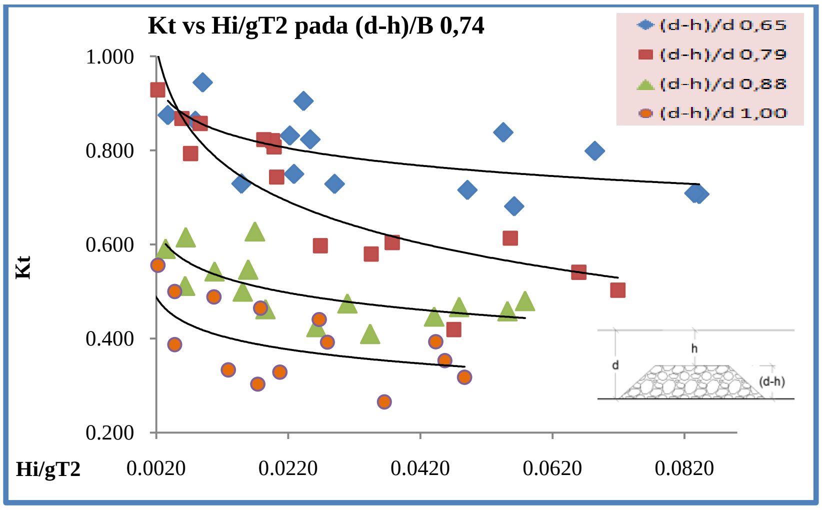

Figure 4.6. The relationship of Hi/gT^2 and transmission coefficient Kt in B 50 D-BI.

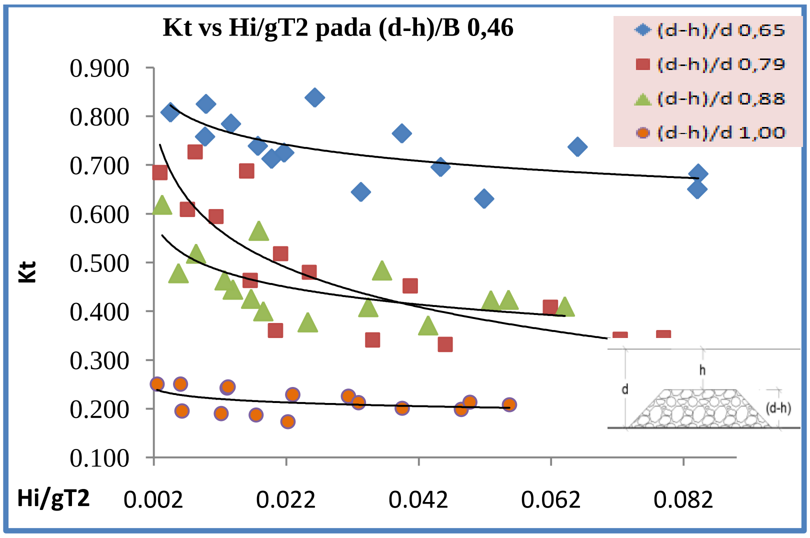

Figure 4.7. The relationship of Hi/gT^2 and transmission coefficient Kt in B 80 D-BI

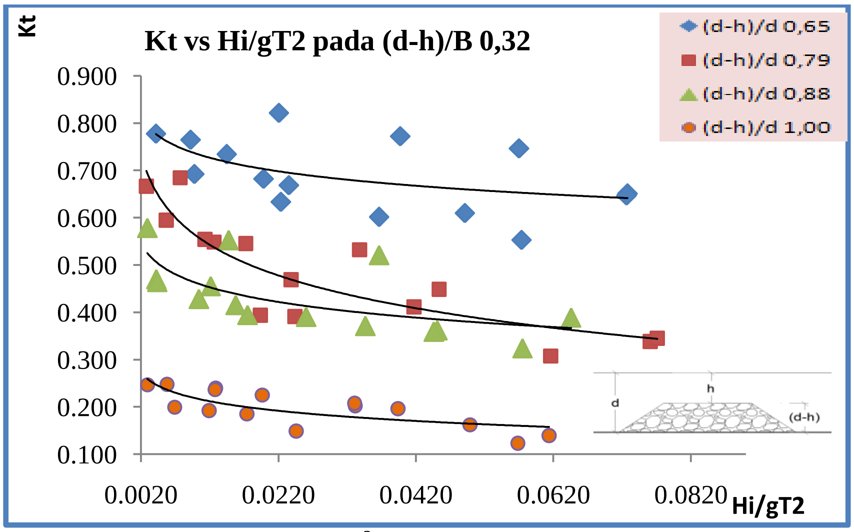

Figure 4.8.The relationship of Hi/gT² with transmission coefficient Kt in B 115 D-BI

Based on figures 4.6, 4.7, 4.8, it can be inferred that the effect of wave steepness $\frac{Hi}{gT2}$ as a horizontal variable and the transmission coefficient as the vertical variable is; the higher the value of $\frac{Hi}{gT2}$, the lower the transmission coefficient is. Therefore, wave transmission is influenced by the height of breakwater (d-h), water depth (d), and wave steepness ($\frac{Hi}{gT2}$), wavelength ($gT^{2)}$ and top width (B). This can be mathematically written as:

$Kt = \frac{Ht}{Hi} = f = (\frac{gT2}{B}, \frac{d-h}{d}, \frac{Hi}{gT2})$

And a multi parameter regression results in:

$Kt = 1.636 + 0.012\ (\frac{gT2}{B}) - 1.376\ (\frac{d-h}{d}) - 1.970\ (\frac{Hi}{gT2})$.

Comparison with Earlier Research

1. Armono HD (2004)

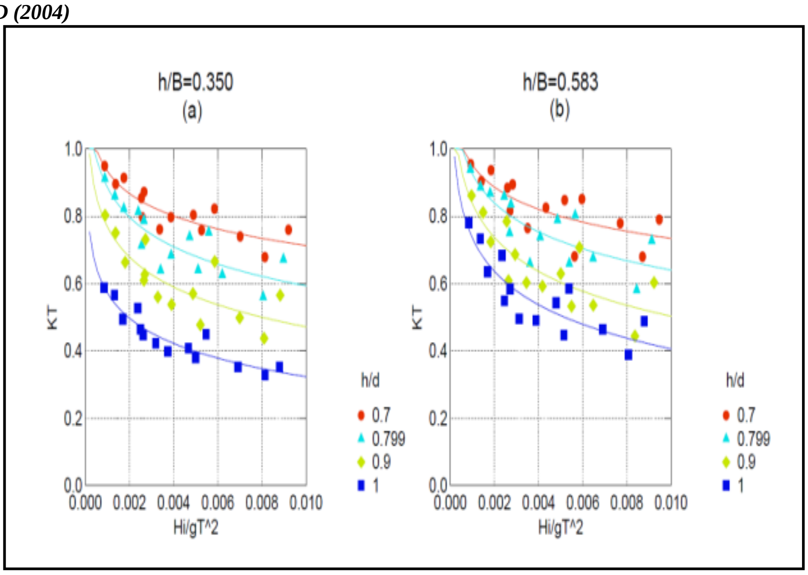

Figure 4.9. The relationship of K_T and $\frac{Hi}{gT^2}$ in $\frac{h}{d}$ (Armono, 2004)

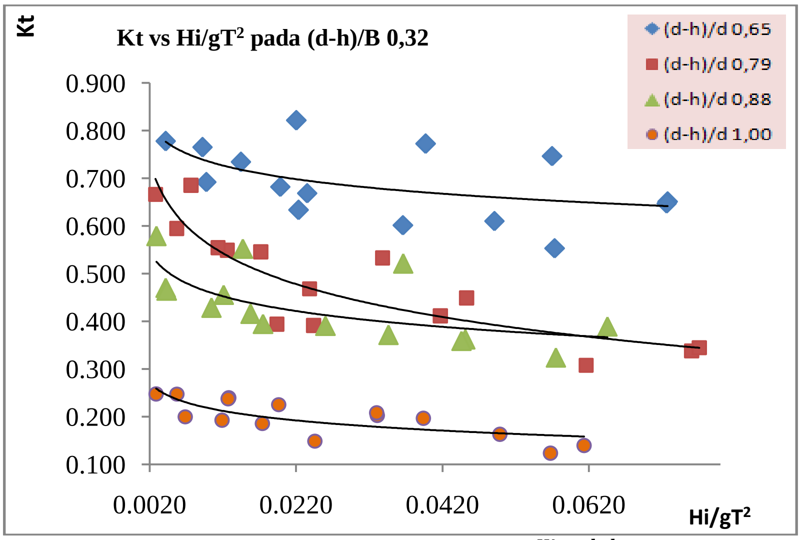

Figure 4.10. The relationship of K_T and $\frac{Hi}{gT^2}$ in $\frac{d-h}{B}$ B 0.32

2. *Seeling (1980)*

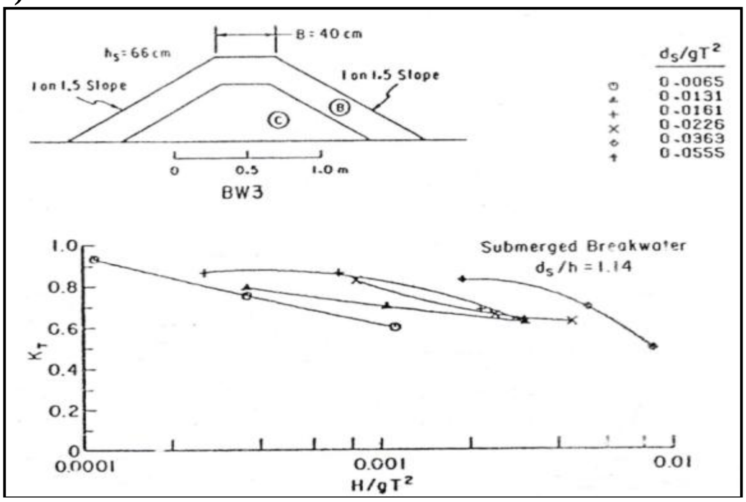

Figure 4.11.Transmission coefficient of submerged breakwater *(Seeling, 1980)*

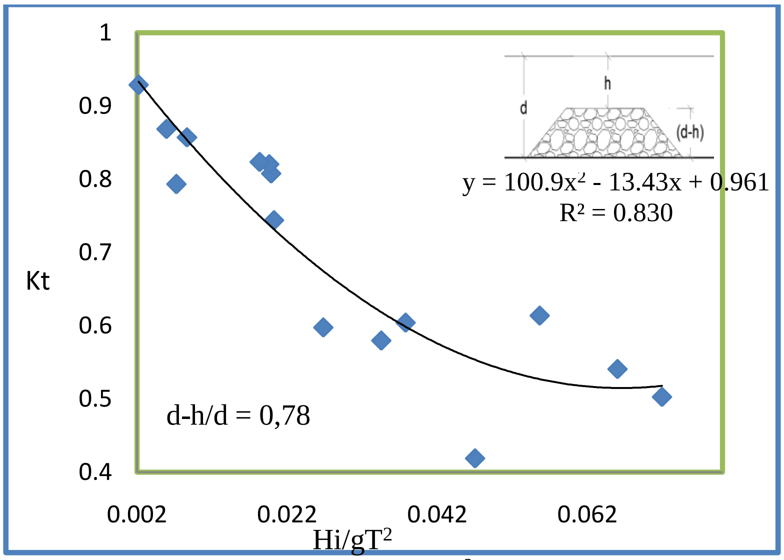

Figure 4.12. The relationship of Hi/gT^2 and Kt in B=50 (d=0,47)

3. Sila D-arma, IGB, (1994)

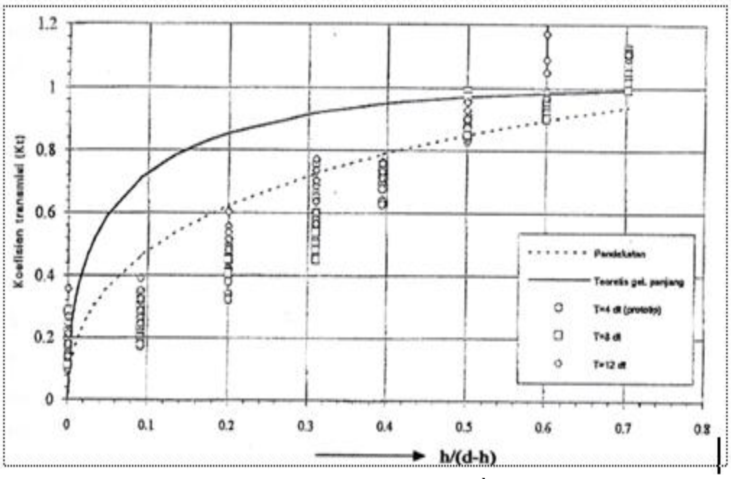

Figure 4.13. The relationship of K_T and $\frac{h}{d-h}$ by Sila D-arma

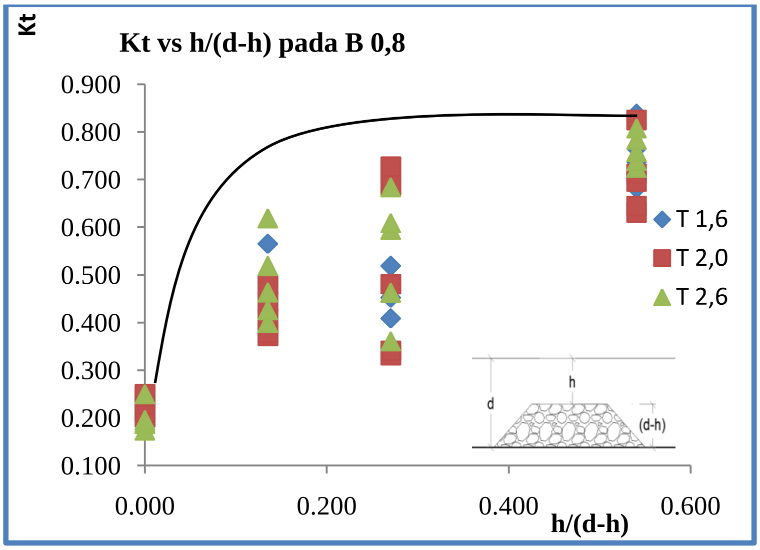

Figure 4.14. The relationship of K_T and $\frac{h}{d-h}$ B 0.8 m

Comparisons with earlier results also reveal the same behavior that bigger value of $\frac{Hi}{gT2}$ results in lower transmission coefficient.

IV. CONCLUSION

Results on the research on wave transmission coefficient (Kt) in the breakwater structure that uses interlocking D-block show that:

- The most influential parameters on the wave transmission for submerged breakwater that uses interlocking D-block are; structure height (d-h) compared to water depth (d), wave length (gT^2) compared to top width (B), and the wave steepness $\frac{Hi}{gT2}$. And the resulting formula for transmission coefficient (Kt) with the multi parameter regression analysis is:

$Kt = 1.636 + 0,012\ (\frac{gT2}{B}) - 1.376\ (\frac{d-h}{d}) - 1.970\ (\frac{Hi}{gT2})$

This result can further be used in considering the use of interlocking D-block as armors for breakwater.

BIBLIOGRAPHY

[1]. Armono, HD. And Hall, K.R., 2003, Wave Transmission on submerged Breakwater Made of Hollow Hemispherical Shape Artificial reef, 1st Coastal Estuary and Offshore Engineering Specialty Conference of the Canadian Society for Civil Engineering (4 – 7 Juni 2003), Moncton – Canada.
[2]. BambangTriatmodjo, 1999, Teknik Pantai, Beta Offset, Yogyakarta.
[3]. D' angremond, K., Van der Meer, J.W., and de Jong, R.J., 1995, Wave Meaurement and Analysis, San Fransisco, USA.
[4]. Dean, Robert G. And Dalrymple, Robert A., 1984, Water Wave Mechanics for Engineers and Schaintists (Advances Series on Ocean Engineering – Volume 2), Prentice Hall,Inc.
[5]. Dean, Robert G. And Dalrymple, Robert A., 2004, Coastal Processes with Coastal Engineering Applications, Cambridge University Press, Cambridge, United Kingdom.
[6]. NurYuwono, 1992, Dasar-dasarPerencanaanBangunan Pantai, Lab HidraulikdanHidrologi, Pau IT UGM, Yogyakarta.
[7]. NurYuwono, 1992, PedomanTeknikPerencanaanpantaiBuatan (Sand Nourishment), Lab HidraulikdanHidrologi, Pau IT UGM, Yogyakarta.
[8]. Paotonan, c., NurYuwono, Radiantatriatmadja, danBambangTriatmodjo, 2011, Two Dimensional Physical Moddeling of Sediment Loss Through a Submerged Coastal Structure, Proceedings : International Seminar on Water Related Risk Management, HATHI, Jakarta.
[9]. Sila D-arma, I GustiBagus, 1994, UnjukKerjaTerumbuKarangBuatan (Artificial Reef) sebagaiPeredamEnergiGelombang, Thesis S-2, UniversitasGadjahMada, Yogyakarta.
[10]. Van der Meer, J.W & I.F.R Daement. 1994, Stability and wave transmission at low Crested Rubble-Mpund Structures. J. Waterway, Port, Coastal, and Ocean Engineering, 120(1): 1-19
[11]. Van der Meer,J.W. 1988, Stability of Cubes, Tetrapods and Accropode. Breakwater '88. Ithomas Limited, London. 59-68 p24:99-122
[12]. Goda, Y., 1969. Re-Analysis of Laboratory Data on Wave Transmission Over Breakwater, Rep. Port harbor, res. Inst.