

MEASUREMENT OF LONG SHORE CURRENT AFTER PERMEABLE GROIN BY FLOATING OBJECT

H. Umar¹, N. Yuwono², R. Triatmadja² and Nizam²

ABSTRACT: Measurement of long shore current before and after permeable groin structure installation is difficult especially in hydraulic model of small water depth. The problems arise that no instrument is dedicated to measure such current at very small depth and long shore current varies quite significantly from the location of breaking wave to the maximum run up position. Measuring instruments that can be used to measure the long shore currents on a laboratory scale is very limited. Measurement of long shore current using floating objects is a method to overcome the limitations of measuring instruments of long shore current. Floating objects arranged width surf zone and then was dropped by observing the position of the wave. Then the movement of floating objects was recorded by using a video camera. The magnitude of long shore current velocity obtained from the observation of movement distance of floating objects per time unit. The results of measurements of long shore current by floating objects was verified by the results of calculations using the equations of long shore current (equation Longuet-Higgins, 1970). Verification of the measurement results with the results of calculations indicate relatively similar results, so the floating objects method can be recommended for the measurement of long shore current.

Keywords: Floating object, longshore current, measurements

INTRODUCTION

Longshore current occurs when the wave comes at an angle to the shoreline. The closer to the shoreline slope is getting steeper wave will come along with the reduced depth and the wave will eventually break. Breaking wave at an angle to the shoreline which then led to flow along the coast. Longshore current reaches a maximum at the breaker line position and will decrease until it reaches the maximum run-up position.

Small depth of water at the laboratory scale and variation of flow velocity significantly in areas surfzone currents along the coast of the measurement result to be difficult. Current measurement methods along the coast with floating object (buoy balls) was developed to overcome the problems of the current limitations of measuring tools along the coast on a laboratory scale. In this paper will discuss the current measurement method.

PERMEABLE GROIN

Permeable groins have a porous structure that still allows the current through the structure so the transport of sediment to the downdrift groin can still happen. The magnitude of longshore current and longshore sediment transport through permeable groins is controlled by the size of the gap in the structure of the groin. Permeable groins structure has also been extensively used especially permeable pile groin structures. One example of the use of permeable pile groins

discussed in Raudkivi (1996), namely permeable groins on the Baltic Sea coast. Permeable pile groin structure can reduce longshore current and longshore sediment transport while still providing the supply of sediment to the downdrift groin.

Permeable groins can be form of piles align with a certain distance in the direction perpendicular to the shoreline. Figure 1, shows one example of permeable pile groins on the Baltic coast, German (Raudkivi, 1996).



Fig. 1 Permeable groin Baltic Sea, Jerman (Raudkivi, 1996)

¹ Coastal Engineering Department, Hasanuddin University, Jl. Perintis Kemerdekaan km. 10, Makassar, 90245, INDONESIA

² Civil Engineering Department, Gadjah Mada University, Jl. Grafika No.2, Yogyakarta, INDONESIA

THEORY OF LONGSHORE CURRENT

Longshore Current Without Permeable Groin

Longuet-Higgins (1970) developed the long shore current theory by using radiation stress concept. Current is assumed as two dimensions (with no vertical variation), steady and uniform along the y , with the momentum equation of x direction drawn as follows:

$$\tau_y + \frac{\partial}{\partial x}(v_i h \frac{\partial \langle v \rangle}{\partial x}) - \langle \tau_{by} \rangle = 0 \quad (1)$$

where v_i is mixed coefficient (*eddy coefficient*), $\langle v \rangle$ is average velocity of the long shore current, τ_y is shear stress due to wave, $\langle \tau_{by} \rangle$ is average bottom shear stress. When shear strength due to turbulence is ignored, the shear stress due to wave $\langle \tau_y \rangle$ can only be balanced with base friction of $\langle \tau_{by} \rangle$. Thus, it will result in:

$$\tau_y = \langle \tau_{by} \rangle \quad (2)$$

Where shear stress due to wave can be written as follow,

$$\tau_y = \frac{5}{4} \rho u_m^2 \tan \beta \sin \alpha \quad (3)$$

and bottom shear stress can be written as follow,

$$\langle \tau_{by} \rangle = \frac{2}{\pi} C_f \rho u_m \langle v \rangle \quad (4)$$

where C_f is bottom friction coefficient, u_m is maximum orbital velocity of wave ($u_m = \frac{\gamma}{2} \sqrt{gh}$). Substituting Equation (3) and (4) into Equation (2),

$$\frac{2}{\pi} C_f \rho u_m \langle v \rangle = \frac{5}{4} \rho u_m^2 \tan \beta \sin \alpha_b \quad (5)$$

then the equation of long shore current without the influence of lateral mixing as follows (Longuet-Higgins, 1970),

$$\langle v \rangle = \frac{5}{16 C_f} H_b \sqrt{\frac{g}{h_b}} \tan \beta \sin \alpha \quad (6)$$

where u_m is maximum orbital velocity of wave (m/s), $\tan \beta$ is beach slope, α_b is angle of breaking wave, H_b is breaking wave height, h_b is breaking wave depth (m).

If the turbulence is not ignored so that the completion of the long shore current velocity equation using a settlement with the lateral mixing the long shore current velocity profile will not form a triangle with the sudden change in the position of the breaker line (Figure 1). Completion of the lateral mixing will smooth and reduce the long shore current velocity at breaker position.

On the completion with influence of turbulence, Longuet-Higgins (1970) using a length mixed model of Prandtl for mixed coefficient (v_i) in Equation (6) is as follows.

$$v_i = N \rho x \sqrt{gh} \quad (7)$$

with dimensionless constants N ($0 < N < 0.016$).

Besides of mixed coefficient parameter (v_i) in the completion of with a lateral mixing is also used non-dimensional parameters as follows,

$$\begin{aligned} X &= \frac{x}{x_b} \\ V &= \frac{v}{v_b} \quad \text{and} \\ P &= \frac{\pi N m}{\gamma C_f} \end{aligned} \quad (8)$$

Then the differential equation is obtained as follows,

$$P \frac{\partial}{\partial X} \left(X^{\frac{5}{2}} \frac{\partial V}{\partial X} \right) - X^{\frac{1}{2}} V = \begin{cases} -X^{3/2}, & 0 \\ 1, & 1 \end{cases} \quad (9)$$

The boundary conditions used were V near zero at the breaker line position and infinite position, as well as the value of V and $\frac{\partial V}{\partial X}$ be continuous wave breaking position. Equation (9) is then integrated and obtained the following results (Longuet-Higgins, 1970).

$$V = \begin{cases} B_1 X^{p_1} + AX, & 0 < X < 1 \\ B_2 X^{p_2}, & 1 < X < \infty \end{cases} \quad (10)$$

With

$$B_1 = \frac{p_2 - 1}{p_1 - p_2} A, \text{ dan } B_2 = \frac{p_1 - 1}{p_1 - p_2} A \quad (11)$$

And

$$A = \frac{1}{(1 - \frac{5}{2}P)}; p_1 = \frac{3}{4} + \left(\frac{9}{16} + \frac{1}{P} \right) \quad (12)$$

If $P = \frac{5}{2}$ then equation (10) will be,

$$V = \begin{cases} \frac{10}{49} X - \frac{5}{7} X \ln X, & 0 < X < 1 \\ \frac{10}{49} X^{-5/2}, & 1 < X < \infty \end{cases} \quad (13)$$

With the completion of the equation (10), the long shore current velocity profile will become continue as shown in Figure 1.

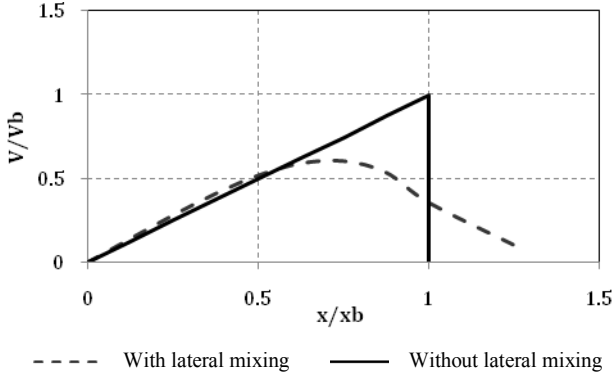


Fig. 2 Long shore current velocity profile without lateral mixing and with lateral mixing

Longshore Current With Permeable Groin

Development of longshore current equations with permeable groin based on the direction of longshore momentum equation without the influence of lateral mixing, Longuet-Higgins, 1970), with the basic assumption that the friction increased by the existence of permeable pile groins structure,

$$\tau_y = \langle \tau_{by} \rangle_{groin} \quad (14)$$

where $\langle \tau_{by} \rangle_{groin}$ is shear stress due to permeable groin barrier that is a function of the mean shear stress (shear stress between the water and the bottom) ($\langle \tau_{by} \rangle$) added the average shear stress between water and piles of groins ($\langle \tau_g \rangle$),

$$\langle \tau_{by} \rangle_{groin} = \langle \tau_{by} \rangle + \langle \tau_g \rangle \quad (15)$$

Shear stress between water and piles of groins ($\langle \tau_g \rangle$) is considered equal to the drag force of permeable groins (F_d) per unit area constraining groin area.

$$\langle \tau_g \rangle = \frac{1}{2} C_d \rho \left(\frac{N}{L_g d_t} \right) h_r d_t u_m \langle v \rangle \quad (16)$$

Total shear stress equation after the barrier of permeable pile groins can be written as follows,

$$\langle \tau_{by} \rangle_{groin} = \left(\frac{2}{\pi} + \frac{\gamma}{4} \right) C_f \rho u_m \langle v \rangle + \frac{1}{2} C_d \rho \left(\frac{N}{L_g d_t} \right) h_r d_t u_m \langle v \rangle \quad (17)$$

Longshore current velocity equation through the permeable pile groins developed from the momentum equation y direction (parallel to the shoreline) after the groins, there is a balance between the shear stress due to

waves (τ_y) and the average shear stress due the permeable pile groin ($\langle \tau_{by} \rangle_{groin}$),

$$\tau_y = \langle \tau_{by} \rangle_{groin} \quad (18)$$

where $\langle \tau_{by} \rangle_{groin}$ is the average shear stress due the permeable pile groin as a function of the average shear stress (shear stress between the water and the bottom) ($\langle \tau_{by} \rangle$) added the average shear stress between the water and the pile of groins ($\langle \tau_g \rangle$),

If Equation (3) and Equation (17) is substituted into (18), the longshore current velocity equation through permeable groins structure can be written as follows,

$$\langle v \rangle_{groin} = \frac{\frac{5}{8} H_b \sqrt{\frac{g}{h_b}} (\tan \beta \sin \alpha_b)}{\left(\left(\left(\frac{2}{\pi} + \frac{\gamma}{4} \right) C_f \right) + \frac{4 C_d p h_r}{2 \pi d_t} \right)} \quad (19)$$

where p is density of the groin (%), h_r is the average depth of the submerged groin piles (m), d_t is diameter of pile (m), C_d is drag coefficient.

EKSPERIMEN

Measurements of long shore currents on a laboratory scale facing constraints on gauge to be used. To obtain a better measurement then developed a method of measuring long shore currents using the floating object. The method of floating objects will measures average long shore current velocity by using a float balls. Floating object will throw using thrower as shown in Figure 3, taking into account the phase of the wave that happened, by putting measuring instrument of wave height near the thrower.

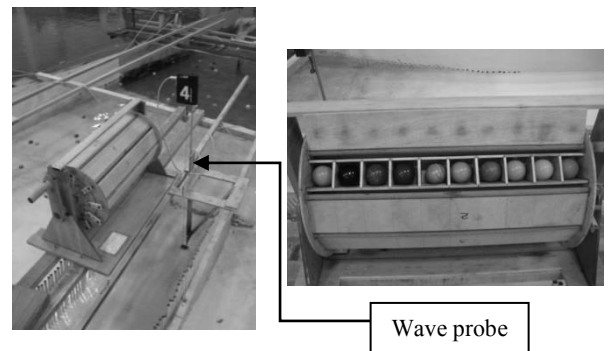


Fig. 3 Thrower of floating objects

Then the movement of the floating object was observed using a video camera, and the position of the floating object movements were analyzed using software

that is made of the programming language Visual Basic 6 to obtain the position x, y of a floating object that can later be determined magnitude of the average long shore current.

Balls are used as a floating object is small balls with a diameter of 3.4 cm (1.7 cm radius), so the volume was 20.6 cm³, a mass of 2.3 g. The ball that is used as a floating object must have a density close to the density of water so the ball movement can truly represent the movement currents. So the float balls used modified to have a density close to the density of water is 1 gram/cm³. To obtain a density close to the density of water (1 gram/cm³) the float balls must have the same amount of mass or volume of a ball is close to the amount of 20.6 grams, while the mass of the empty ball only by 2.3 gr. Therefore float balls filled with water until the weight reached or approached the 20.6 gr. Once the float balls weight the same or close to the density of water, and then the float balls given a different color for ease in digitization of ball position x and y (Figure4).

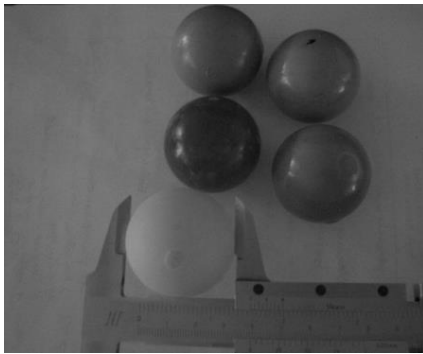


Fig. 4 Floating balls

The process of digitization movement float balls accomplished using the track object (Triatmadja, 2011) using the programming language Visual Basic 6. Speed of video camera used is 30 frames per second. Before the movement of the float balls frame pieces in the program if the first track object motion video recording float balls being broken into photo frames using the program Ulead VideoStudio 11. In processing the movement of the float balls position in the track program object is used as photo frames number 1 or wave period equal to T seconds the movement of the ball. From the processing of data obtained track objects program x and y position of the float balls over timescales of one wave period (T seconds).

Then the velocity of the movement of each float ball to the x direction (the direction of long shore) can be determined using the following equation,

$$\text{velocity} = \frac{\text{distance from the first frame to the last frame}}{\text{time}}$$

Data x and y position of float balls obtained from track object program is position in pixel units, so that the necessary unit conversions into centimeters. In analysis of current velocity data, determination unit conversion pixel to centimeter done in the following way.

1. Measure the distance between the actual position of the ball 1 and ball 10 in a row at the start of data collection, which is equal to 40 cm. Then measured the actual distance in pixels by using the program track objects, and obtained the actual distance in pixels is 80.8 pixels.
2. Having obtained the actual distance in centimeters and pixels, it can be determined the amount of the conversion unit distance from pixels to centimeters as follows (Table 1).

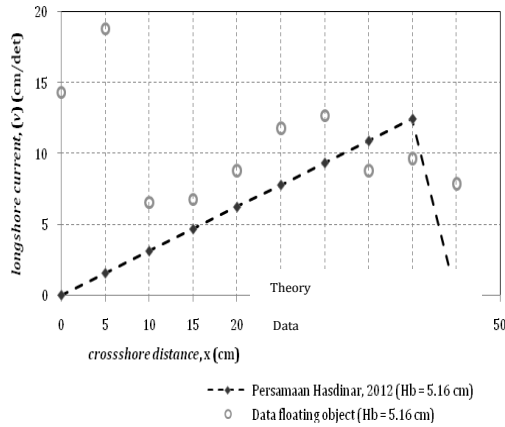
Table 1. Converting pixel units to centimeterst

Distance (cm)	Distance (pixel)
40	80.8
1	2.02

RESULT AND DISCUSSION

Longshore Current Velocity Profile

Long shore current velocity profile by ignoring the turbulence (without lateral mixing) using the equation $\langle v \rangle = \frac{5\pi}{16C} H_b \sqrt{\frac{g}{L}} \tan \beta \sin \alpha$ gives an overview of long shore current velocity profiles in the form of a triangle with a sudden change of velocity in a position breaker line (wave breaking point). Meanwhile, if the turbulence (with lateral mixing) put as in Equation (10) is $V = \begin{cases} B_1 X^{p1} + AX, & 0 < X < P \\ B_2 X^{p2}, & 1 < X < \infty \end{cases}$, then the long shore current velocity profile will be more smooth and the velocity along the shore at a point in the breaker line will be reduced. Data of measurement and velocity profiles shown in Figure 5. Figure 5 (b) shows the velocity profile of the current without lateral mixing triangles and current velocity profile with the influence of continuous curved lateral mixing. The figure also shows the position of the points along the flow velocity measurements using a float relatively close to shore curves flow velocity profile with the influence of lateral mixing. Current velocity data plotted in the graph is the mean flow velocity data from the measurement result using floats. At position $X = 0$ flow velocity measurements do not give the same rate to zero ($v \neq 0$), it is due to float in that position still experiencing movement due to thrust run up and run down the wave (influenced by wave up rush).



(a)

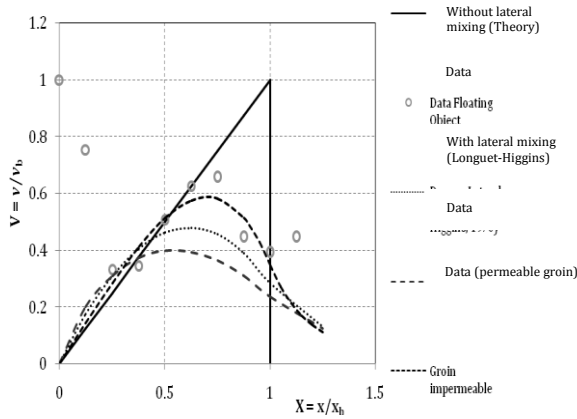


Fig. 5 (a) The results of measurement and calculation of long shore current velocity on each float in the surf zone on condition with permeable groin. (b) Long shore current velocity profile on the condition with permeable groins

Verification Result of Experiment and Theory

The data experimental results and theoretical calculations can be seen in Table 2 and Table 3 and Figure 8, which shows the relationship breaking wave height (H_b) with a velocity of longshore current (v). Table 2 The results of measurements of the average long shore current velocity

Kerapatan tiang	Kecepatan arus, (v) (cm/det)		
	$H_b = 5.16$ cm	$H_b = 3.52$ cm	$H_b = 3.08$ cm
54% (d = 1.5 cm)	12.95	9.55	7.84
51% (d = 1.25 cm)	13.88	10.90	8.94
47% (d = 1.5 cm)	11.27	9.13	8.53
43% (d = 1.25 cm)	12.30	10.44	9.52

Table 3. The result of calculation of long shore current velocity (Equation (19))

C_f	C_d	N	H_b (cm)	h_b (cm)	$\sin \alpha_b$	(v) (cm/det)
0.04	0.01	23	1.8	2.31	0.071	3.87
0.04	0.01	23	1.96	2.51	0.085	4.88
0.04	0.01	23	2.44	3.13	0.092	5.88
0.04	0.01	23	2.48	3.18	0.105	6.80
0.04	0.01	23	3.08	3.95	0.107	7.65
0.04	0.01	23	3.12	4	0.122	8.84
0.04	0.01	23	3.52	4.51	0.135	10.40
0.04	0.01	23	4.76	6.10	0.151	13.50
0.04	0.01	23	5.16	6.62	0.165	15.30

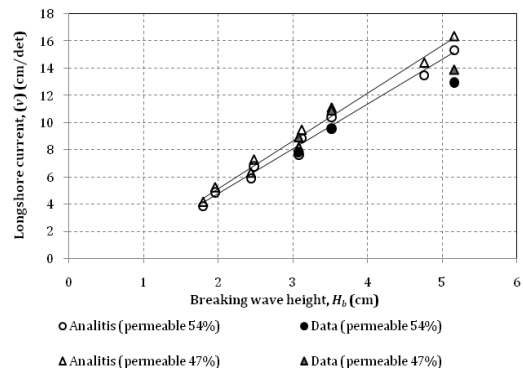


Figure 6. The relationship between breaking wave height (H_b) and average long shore current velocity (v), verification of the experimental results with a theoretical calculations (Equation 19).

Figure 6 shows the suitability of the data long shore current velocity of the measurement results with the results of calculations using the equations Longuet-Higgins (1970), where the data long shore current velocity (v) the of wave height (H_b) of the same theoretical line approach Longuet-Higgins equation (1970) with a coefficient of friction (C_f) of 0.04. Parameter of breaking wave height (H_b) is directly proportional to the flow velocity parameter (v), the larger the of wave height that occurs, the greater the current generated.

CONCLUSION

Verify the long shore current velocity equation (v) and experimental data showed a relatively suitable, using the coefficient of friction (C_f) = 0.04. So the method of current measurement using float balls can be recommended to measure the magnitude of the average long shore current through permeable groin.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Hydraulics Laboratory, Department of Civil Engineering and Environmental Engineering, Gadjah Mada University. Appreciation also extended to the entire academic staffs of Department of Coastal Engineering, Hasanuddin University.

REFERENCES

- Dean dan Dalrymple. (2002), "Coastal Processes with Engineering Applications", *Cambridge University Press*, USA.
- Dominic, et.all. (2004), "Coastal Engineering, Processess", *Theory and Design Practice*, Spon Press, London dan New York.
- Horikawa. (1978), "Coastal Engineering-An Introduction to Ocean Engineering", *University of Tokyo Press*.
- Horikawa. (1988), "Nearshore Dynamics and Coastal Processes", *University of Tokyo Press*.
- Velden. (1983), "Coastal Engineering, Faculty of Civil Engineering", TU Delft,
- Longuet-Higgins, (1970), *Longshore Currents Generated by Obliquely Incident Sea Waves,1*, *Journal of Geophysical Research*, Vol.75, No. 33, 20 November 1970.
- Longuet-Higgins, (1970), *Longshore Currents Generated by Obliquely Incident Sea Waves,2*, *Journal of Geophysical Research*, Vol.75, No. 33, 20 November 1970.
- Longuet-Higgins and Stewart, (1964), *Radiation stresses in water waves; a physical discussion, with applications*, *Deep Sea Research*, Vol. 11, pp 529 to 562: Pergamon Press Ltd. Printed in Great Britain.