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Scour Analysis at Seawall in Salurang, Sangihe Islands Regency, North Sulawesi

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Abstract. Sangihe Islands Regency is one of the outermost regions of the unitary Republic of Indonesia. The area is dominated by coastal areas. Thus, many coastal structures protection built to guard the coastal areas from the threat of big waves. Local scour is the erosion of the basis on a particular part of a building coast. If it occurs continously, it could lead to instability of the structure or structural failure. The research takes a case study on scouring at Seawall in Salurang, Sangihe Islands Regency, North Sulawesi. This study aims to determine dominant factor of scouring and predict the maximum scour depth and scour length at seawall by using Van Rijn method (2013) which is one method of numerical calculation. The method is expected to provide the right solution for handling a scouring at coastal structures in this area. The right method to predict maximum scour depth in Salurang, Sangihe Islands regency is the scour method near the tip of wall-type or rubble-mound-type structure due to waves (plus weak currents <0.3 m/s). Scour due to combination of waves and currents. The maximum scour depth value is 0.36 m and the scour length is 3.6 m. The local government can protect the coastal structure by providing stone mound at the toe based on the calculation of the maximum scour depth.

Keywords*: Maximum scour depth, seawall, Van Rijn method, Sangihe Islands Regency*

I. INTRODUCTION

Sangihe Islands Regency is an integral part of the capital city of North Sulawesi Tahuna. Located approximately 142 Nautical Miles from the capital of North Sulawesi, Manado, located between 2 ° 4'13 "- 4 ° 44 '22" North Latitude and 125 ° 9' 28 "- 125 ° 56 '57" East, located between the Sulawesi islands and Mindanao (Republic of the Philippines), so the Sangihe Islands Regency can be categorized as "Frontier". The total area of Sangihe Islands Regency amounted to 736.98 km2 [1]. As a coastal region, this region, many built of coastal protection structures to prevent the influence of big waves. Seawall was built in Salurang village in 2003 with a length of 471.2 m, a width of 1 m and a height of 4 m. However, the scouring which caused by damage to some parts of the structure will occur in the local seawall few years later.

Sumer, et al. (2001) has conducted research on scouring the various types of coastal structures and scour depth development model with physical and numerical modeling [5]. El-bisy (2006) has studied on the seawalls and predict scour using neural network models (ANNs) [3]. This study will predict the maximum scour depth on the seawall in Kampung Salurang using Van Rijn method (2013) [9]. Thus, is expected to provide the right solution for protection against scouring. And, the proper handling of coastal protection.

Scour will occur anywhere the hydrodynamic shear stresses on the bottom are high enough to initiate sediment transport. Clear water scour occurs when bottom shear stresses are high only in a localized portion of the bed; outside the local region sediment is not moving. This occurs mostly in uniform, steady flow situations. In live bed scour, bottom shear stresses over the entire bed exceed the level for incipient motion with locally higher shear stresses where greater scour occurs. An equilibrium is reached when the volume of sediment being removed from the scour hole is exactly equal to sediment being deposited in its place. Understanding the physical processes involved in scour is difficult because the shear stresses responsible for scour are developed by waves, currents, or combined waves and currents, that usually are heavily influenced by the presence of a coastal structure. Because of the distinct influence coastal structures exert on the hydrodynamics, structural aspects such as geometry, location, and physical characteristics (roughness, permeability, etc.) impact the scour process. Therefore, modifying some physical characteristic of a structure may reduce scour potential. [2]

II. METHODS

A. Refraction Analysis

To get a value of wave height at structure, it is necessary to analyze the refraction, by some calculations below.

$L_0 = 1.56T^2$ (m)	[wave length at deep water]	(1)
$C_0 = L_0/T$ (m/s)	[celerity at deep water]	(2)
$L = d/(\frac{d}{L})$ (m)	[wave length]	(3)
$C = L/T$ (m)	[celerity]	(4)
$\sin a = (\frac{C}{C_0}) \sin a_0$	[a = incident wave angle]	(5)
$K_r = (\cos a_0 \,/\, \cos a)^{0.5}$	[refraction coefficient]	(6)
$K_s = (n_0 \times L_0/n \times L)^{0.5}$	[shoaling coefficient]	(7)
$H = K_s \times K_r \times H_0$ (m)	[wave height] [10]	(8)

B. Van Rijn Method

To predict maximum scour depth, used the formulas below.

#1 Scour near toe of wall-type or rubble-mound-type structures due to waves

- Scour's formula for Wall-type structure
  a. SPM, 1984 $d_{s,max} = SF.h_{toe}$ (9)
  b. Fowler, 1992
  $\frac{h_{toe}}{L_0} < 0{,}06 \rightarrow d_{s,max} = SF\left(11{,}4\left(\frac{h_0}{L_0}\right) + 0{,}54\right).h_{s,off}$ (10)
  $\frac{h_{toe}}{L_0} > 0{,}06 \rightarrow d_{s,max} = SF.h_{s,off}$ (11)
  c. SATO, 1968
  $h_0 < 9 \rightarrow d_{s,max} = SF(-0{,}2.h_0 + 1{,}9)$ (12)
  $h_0 > 9 \rightarrow d_{s,max} = 0{,}1.SF.h_0$ (13)
  d. Yokoyama, 2002
  $\frac{H_s}{h_{toe}} > 0 \rightarrow d_{s,max} = SF\left(2.\frac{H_s}{h_{toe}} - 0{,}5\right).h_{toe}$ (14)
  $\frac{H_s}{h_{toe}} < 0 \rightarrow d_{s,max} = 0{,}1.SF.h_{toe}$ (15)
  e. Xie, 1981
  $\frac{h_{toe}}{L_w} < 0{,}15 \rightarrow d_{s,max} = SF\left(-64.\frac{h_{toe}}{L_w} + 1{,}2\right)h_{toe}$ (16)
  $\frac{H_s}{h_{toe}} > 0{,}15 \rightarrow d_{s,max} = 0{,}25.SF.h_{toe}$ (17)
- Scour's formula for Rubble-mound-type structure

Scour length is assumed to be 0,7 × scour depth of wall – type structures.

#2 Scour near tip of wall-type and rubble-mound type structures due to waves (plus weak current < 0.3 m/s)

- Scour's formula for Wall-type structure

Sumer, 1997

Maximum value of: $KC\ Number < 10 \rightarrow d_{s,max} = 0{,}05.SF.\ KC\ Number.B$ (18)

$KC\ Number > 10 \rightarrow d_{s,max} = 0{,}5.SF.B;$ (19)

and $d_{s,max} = 0{,}2.h_{toe}$ (20)

- Scour's formula for Rubble-mound-type structure

a. Sumer, 1997
Maximum value between

$$T_p\left(\frac{9{,}81.h_{toe}}{h_0}\right)^{0,5} < 15 \rightarrow d_{s,max} = 0{,}03.SF.\left(T_p\left(\frac{9{,}81.h_{toe}}{h_0}\right)^{0,5}\right) \quad (21)$$

$$T_p\left(\frac{9{,}81.h_{toe}}{h_0}\right)^{0,5} > 15 \rightarrow d_{s,max} = 0{,}5.SF.h_{toe} \quad (22)$$

And, $d_{s,max} = 0{,}15.h_{toe}$ (23)

b. Field Data Japan, USA

$$h_0 < 15 \rightarrow d_{s,max} = SF.(-0{,}033.h_0 + 0{,}7).h_0 \quad (24)$$

$$h_0 > 15 \rightarrow d_{s,max} = 3.SF \quad (25)$$

$$d_{s,max} = 0{,}15.h_{toe} \quad (26)$$

#3 Scour near tip of wall-type and rubble-mound type structures due to relatively strong current (> 0.3 m/s) plus waves

$$h_0 < 14 \rightarrow d_{s,max} = SF \times (-0.25 \times h_0 + 4) \times h_0 \quad (27)$$

$$h_0 > 14 \rightarrow d_{s,max} = SF \times 7 \quad (28)$$

Generally, for scour length = 10 *x* Scour depth (29)

Where h_0 = depth at toe exclude scour, $d_{s,max}$ = maximum scour depth, SF = safety factor, T_p = peak wave period, h_{toe} = local wave height at toe, $KC\ Number$ = Keulegan-Carpenter Number, B = width of structure, L_w = wave length, H_s = significant wave height, $h_{s,off}$ = offshore significant wave height. And the mathematical formula for computing correlation coefficient = r is:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2}\sqrt{n(\sum y^2) - (\sum y)^2}}, \quad (30)$$

where n is the number of pairs of data. The value of r is that $-1 \leq r \leq 1$. The $+$ and – signs are used for positive linear correlations and negative linear correlations, respectively. The coefficient of determination, r^2 or R^2, is useful because it gives the proportion of the variance (fluctuation) of one variable that is predictable from the other variable. The coefficient of determination is the ratio of the explained variation to the total variation. The coefficient of determination is such that $0 \leq r^2 \leq 1$, and denotes the strength of the linear association between x and y. The coefficient of determination represents the percent of the data that is closest to the line of best fit.

III. RESULTS AND DISCUSSION

The results of measurement and prediction for the maximum scour depth were shown in Tables 1-4. The comparison was given in Figure 1-3.

- Results of Measurement

TABEL 1. SCOUR DEPTH BY MEASUREMENT

h_0	Scour depth maximum = $d_{s,max}$ (m)	Scour Length (m)
1	0.6	6
1.79	0.64	6.4
1.95	0.37	3.7

- Results of Prediction

a. Scour near toe of wall-type or rubble mound-type structure due to waves

TABEL 2. MAXIMUM SCOUR DEPTH DUE TO WAVES

h_0	Scour depth maximum = $d_{s,max}$ (m)	Scour Length (m)
1	1.05	10.5
1.79	1.27	12.7
1.95	1.31	13.1

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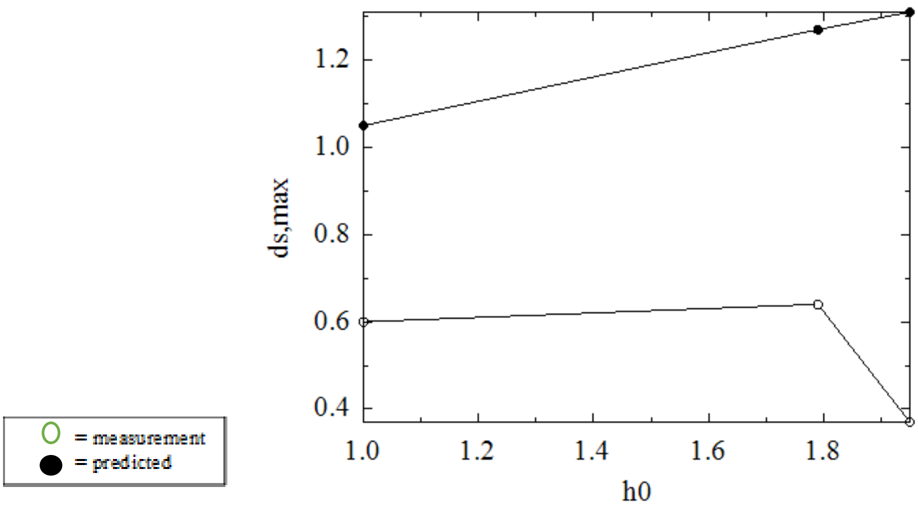

FIGURE 1. COMPARISON BETWEEN PREDICTION AND MEASUREMENT DUE TO WAVES

Based on the comparison between measurement and prediction have a coefficient correlation = r = 0.4. And $r^2 = 0.16$. It means that the prediction not accurately because the value of r^2 closest to 0.

b. Scour near tip of wall-type or rubble-mound-type structure due to waves (plus weak currents <0.3 m/s)

TABEL 3. MAXIMUM SCOUR DEPTH DUE TO WAVES PLUS WEAK CURRENT

h_0	Scour depth maximum = $d_{s,max}$ (m)	Scour Length (m)
1	0.3	3
1.79	0.36	3.6
1.95	0.35	3.5

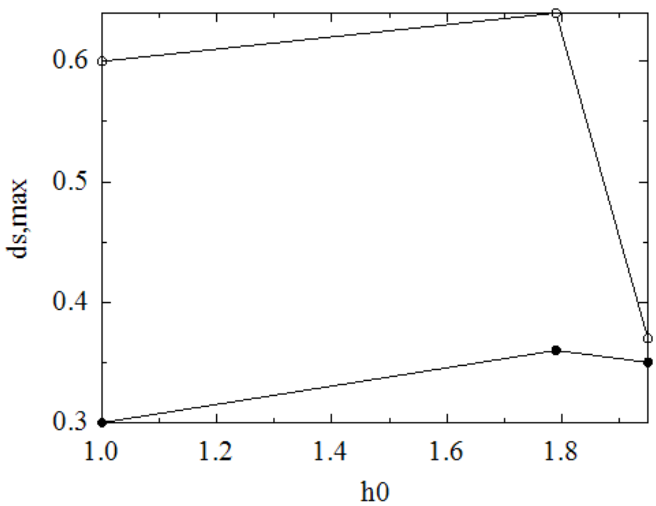

FIGURE 2. COMPARISON BETWEEN PREDICTION AND MEASUREMENT DUE TO WAVES PLUS WEAK CURRENT

Based on the comparison between prediction and measurement have a coefficient correlation r = 0.9. And $r^2 = 0.81$. It means that the prediction very accurately because the value of r^2 closest to 1.

c. Scour near tip of wall-type or rubble-mound-type structure due to relatively strong current (>0.3 m/s) plus waves.

TABEL 4. MAXIMUM SCOUR DEPTH DUE TO WAVES PLUS STRONG CURRENT

h_0	Scour depth maximum = $d_{s,max}$ (m)	Scour Length (m)
1	3.75	37.5
1.79	6.36	63.6
1.95	6.85	68.5

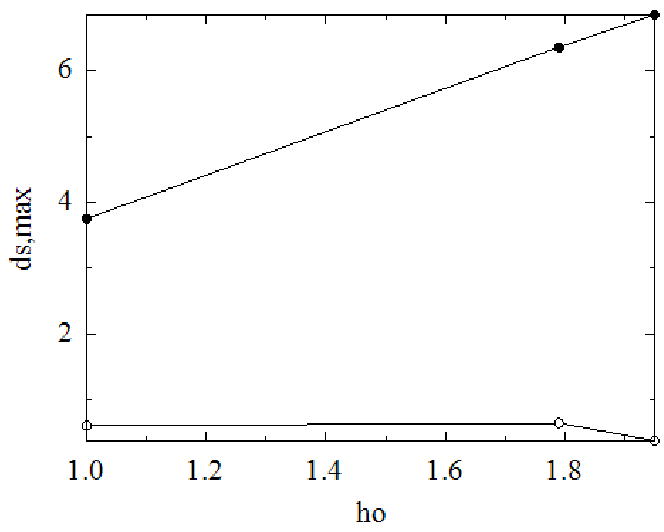

FIGURE 3. COMPARISON BETWEEN PREDICTED AND MEASUREMENT DUE TO WAVES PLUS STRONG CURRENT

Based on the comparison between prediction and measurement have a coefficient correlation r = 0.4. And $r^2 = 0.16$. It means that the prediction not accurately because the value of r^2 closest to 0.

From the results of comparison above, it can be seen that r^2 closest to 1 was on scour method calculation near the tip of wall-type or rubble-mound-type structure due to waves (plus weak currents <0.3 m/s). Scour due to combination of waves and currents. Thus, it can be said that the right method to be used in the calculation of scouring in the Salurang village, Sangihe Islands Regency is a scour method calculation near the tip of wall-type or rubble-mound-type structure due to waves (plus weak currents <0.3 m / s) with a maximum scour depth is 0.36 m and scour length is 3.6 m.

IV. CONCLUSION

The right method to predict maximum scour depth in Salurang, Sangihe Islands regency is the scour method near the tip of wall-type or rubble-mound-type structure due to waves (plus weak currents <0.3 m/s). Scour due to combination of waves and currents. The maximum scour depth value is 0.36 m and the scour length is 3.6 m. The local government can protect the coastal structure by providing stone mound at the toe based on the calculation of the maximum scour depth.

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