Characteristic of Wave Run-up on Schematic Precast System (SPS) Revetment

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Abstract. Revetment Sistem Panel Serbaguna (SPS) or Schematic System Precast (SPS) Revetment is latest innovation of SPS technology. It has been applied for various area of civil engineering such as bridge, dams and irrigation channel. For this upgrading, SPS has been tested in Hydraulic Laboratory of Experimental Station for Coastal Engineering Ministry of Public Works and Housing as revetment. SPS is tested with 14 scenarios of various wave steepness and water depth to determine the wave run-up characteristic. All hydraulic performance of SPS for each scenario is recorded with video camera. Using image processing technique, we calculate the wave run-up height for each scenario. From all scenarios, the wave run-up only happen in scenarios with water depth of 0.65 m while the rest only experience wave overtopping. Comparing to the classical Iribarren Number graph, relative wave run-up height on SPS revetment is higher than other type of revetment such as Riprap Ahrns, Riprap Gunbak, Batu Pecah, Qudripod, Dolos and Tetrapod but below Sisi Miring. For Sisi Miring Revetment, the maximum relative wave run-up height \( \frac{R_u}{H_{m0}} \) is 2.5 for Iribarren Number \( \text{Ir} \) = 2.5 as for SPS revetment, it is approximately 2.4 for \( \text{Ir} = 11 \).

1. Introduction

Schematic Precast System (SPS) or also known as SPS (Sistem Panel Serbaguna) in Bahasa Indonesia is Indonesia original-construction technology that is claimed as stronger, more cost-efficient, more eco-friendly, more durable and more quickly to install than other structure of the same type [1]. It has been applied to a wide range of civil engineering applications such as bridges, dams and irrigation channels. SPS Technology is emphasized in the construction process. Its design can be modified flexibly for different purposes.

The latest breakthrough is upgraded SPS technology as revetment. Coastal structure such as revetment is commonly designed in the parallel (or nearly parallel) position to the shoreline. This structure provides two main function shore stabilization and backshore protection [2]. It also has sloping front to reduce wave run-up and prevent overtopping.

The performance of SPS as revetment is evaluated in Hydraulic Laboratory of Experimental Station for Coastal Engineering Ministry of Public Works and Housing. The laboratory test is conducted to understand physical factor that influenced structure design such as wave run-up, transmission and overtopping. This paper only discusses about the interaction of wave run-up with SPS Revetment.
2. Methodology

SPS Revetment is built from several modules of SPS. There are 8 modules in two layers used in this laboratory test. Four modules are constructed for each layer. Each module has a length of 60 cm, a width of 15 cm, and a height of 10 cm. It is connected to a frame to maintain its slope at 1:1.12. The modules are then integrated as revetment and installed in the wave flume as shown in Figure 1. Another distinct feature is a perforated surface for absorbing wave energy.

![Figure 1. Revetment after installed in wave flume](image)

The physical model is built with a 1:10 scale. The size of the wave flume is 40 m x 3 m. SPS revetment is installed in 29.5 m from the wave generator. There are 14 scenarios of laboratory tests with variation of depth (d), wave height (H), and wave period (T) as shown in Table 1. Wave run-up is observed using a digital camera. Images are extracted from video with 25 fps (frame per second) and 10 minutes duration, and then, processed using a digital imaging technique developed by [3]. The wave run-up height (Ru) is calculated using time stack image processing by [4] and [5].

| NO  | Test Scenarios   | Water Depth (m) | Wave Parameter |
|-----|------------------|-----------------|----------------|
| 1   | Run01_1903_H6_T1.6 | 0.70            | 0.06 1.60      |
| 2   | Run03_2003_H5.5_T1.6 | 0.70            | 0.06 1.60      |
| 3   | Run04_2003_H5_T1.6  | 0.70            | 0.06 1.60      |
| 4   | Run05_2003_H2_T1.6  | 0.65            | 0.02 1.60      |
| 5   | Run06_2103_H1.6_T1.6 | 0.65            | 0.02 1.60      |
| 6   | Run10_2803_H4.5_T3.2 | 0.70            | 0.05 3.2       |
| 7   | Run11_2803_H4_T3.2  | 0.70            | 0.040 3.2      |
| 8   | Run12_2803_H1.6_T3.2 | 0.65            | 0.02 3.2       |
| 9   | Run13_2803_H1.5_T3.2 | 0.65            | 0.02 3.2       |
| 10  | Run14_2803_H1.2_T3.2 | 0.65            | 0.01 3.2       |
| 11  | Run18_2903_H4_T4.8  | 0.70            | 0.04 4.80      |
| 12  | Run19_3003_H3.5_T4.8 | 0.70            | 0.04 4.80      |
| 13  | Run20_0204_H1_T4.8  | 0.65            | 0.01 4.8       |
| 14  | Run21_0204_H0.8_T4.8 | 0.65            | 0.01 4.8       |
Commonly, there are two wave run-up parameters used for coastal structure design. First, average wave run-up, \( R_{u_{avg}} \). The second is \( R_{u_{2\%}} \) which means that the highest 2% of wave run-up is considered in the calculation. This method of run-up calculation is developed by [6]. The former is used in common engineering practice while the latter is for the worst case scenario of wave run-up. In simple, the equation is stated as below:

\[
\frac{R_u}{H_{sig}} = f.Ir
\]  

(1)

where:

- \( R_u \) = run-up wave height (m)
- \( H_{sig} \) = significant wave height (m)
- \( f \) = non-dimensional run-up coefficient relative to factor such as berm, roughness and angled wave attack.
- \( Ir \) = Iribarren Number

From this equation, relationship between non dimensional run-up and Iribarren Number can be drawn in graph. The relationship shows wave run-up coefficient.

Iribarren Number is incident wave run-up on natural beaches or barriers. The original equation can be found in [7]. This number is also known as breaker parameter. It is written as

\[
Ir = \frac{\tan \theta}{\sqrt{H_{sig}/L}}
\]  

(2)

where:

- \( \theta \) = revetment slope
- \( L \) = wave length (m)

3. Results and Discussion

Image processing allows data to be extracted from the video. The sample of the extracted data is shown in Figure 2. This time series data shows wave run-up temporal variation in one single observation point. This data is then processed to be a non-dimensional run-up parameter.

![Figure 2. Extracted wave run-up data from video image](image-url)
Table 2 summarizes the wave run-up data for every scenario. From all scenarios, wave run-up only occurred for scenarios with water depth 0.65. The rest scenarios are associated with overtopping. There are two types of wave run-up that are calculated. The first one is wave run-up 2% calculation based on the van der Meer method [6] whereas the second one is the average one. The former is for the worst-case scenario. The latter is to be plotted in the classical Iribarren graph from [8].

Table 2. Wave run-up summary for every scenario

| Test Scenarios                  | Water Depth (m) | H (m) | T (s) | Ru 2% | Ru Avg | Irribaren Number |
|--------------------------------|-----------------|-------|-------|-------|--------|-----------------|
| Run07_2203_H2_T1.6_LED         | 0.65            | 0.025 | 1.6   | 0.1012| 0.0411 | 2.63            |
| Run08_2203_H1.6_T1.6_LED       | 0.65            | 0.022 | 1.6   | 0.0998| 0.0371 | 4.68            |
| Run15_2903_H1.6_T3.2_LED       | 0.65            | 0.017 | 3.2   | 0.0910| 0.0285 | 7.53            |
| Run16_2903_H1.5_T3.2_LED       | 0.65            | 0.017 | 3.2   | 0.1138| 0.0319 | 7.45            |
| Run17_2903_H1.2_T3.2_LED       | 0.65            | 0.014 | 3.2   | 0.0895| 0.0298 | 7.78            |
| Run25_1004_h1.4_t4.8_LED       | 0.65            | 0.012 | 4.8   | 0.0949| 0.0287 | 10.83           |
| Run22_0204_H1_T4.8_LED         | 0.65            | 0.011 | 4.8   | 0.0798| 0.0241 | 5.87            |
| Run23_0204_H0.8_T4.8_LED       | 0.65            | 0.008 | 4.8   | 0.0563| 0.0173 | 6.48            |

Figure 3a and 3b show the Iribarren graph of relative wave run-up average and 2% for SPS Revetment. The regression line has R² value of 0.926 and 0.8901 respectively. Value more than 0.5 means a good correlation. For Iribarren Number from range 0-10, the highest relative wave run-up 2% is about 8. This is quite high compared to the highest relative average run-up. However, this is important information to consider the damage of SPS Revetment due to run-up.

**Figure 3** Relative wave run-up (a) average and (b) 2% on SPS Revetment

The average wave run-up is plotted in the classical graph of Iribarren Number from [8]. Line with magenta color shows experimental data of SPS Revetment distribution within the Iribarren Number graph (Figure 4). Overall, relative wave run-up height on SPS revetment is higher than other types of revetment such as Riprap Arhens, Riprap Gunbak, Batu Pecah, Quadripod, Dolos and Tetrapod. SPS run-up is only below Sisi Miring. But, both Sisi Miring and SPS reach the same highest run-up for different
Iribarren Number. For Sisi Miring Revetment, the maximum relative wave run-up height (Ru/H_{m0}) is 2.5 for Iribarren Number (Ir) = 2.5 as for SPS revetment, it is approximately 2.4 for Ir = 11.

| Iribarren Number Graph for Ru average |
|---------------------------------------|
| Sisi Miring    | Riprap Arhens    | Riprap Gunbak    | Batu Pecah    | Quadripod    | Dolos   | Tetrapod   | SPS |
| 0    | 2    | 4    | 6    | 8    | 10    | 12    |

| Ru avg /Hsig |
|--------------|
| 0.1   | 0.5   | 1     | 1.5   | 2     |

**Figure 4.** Iribarren number graph Ru average

4. Conclusion

Physical model of SPS Revetment in Hydraulic Laboratory of Experimental Station for Coastal Engineering Ministry of Public Works and Housing is conducted to test wave run-up on the structure. The extracted data is obtained from video processed with a digital imaging technique. The results show run-up on SPS is significantly higher than most of the structures. Comparison to Sisi Miring is made for the same highest wave run up. Non-dimensional wave run-up height (Ru/Hsig) for Revetmen Sisi Miring is 2.5 for Iribarren Number, Ir= 2.8 whilst it is 2.4 with Ir = 11 for SPS Revetment.

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