STUDY OF STATISTICAL CHARACTERISTICS OF IRREGULAR WAVE PRESSURE ON A COMPOSITE BREAKWATER

by

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ABSTRACT

Wave pressure is the most important external force for the design of breakwater. During recent years, there has been considerable development in the technology of vertical face breakwater; however, there is no reliable method to compute wave forces induced by irregular waves. The purpose of this study is to obtain statistical characteristics of irregular wave pressure distribution from the data of model tests.

The results of this study shown that vertical face breakwater under the action of irregular waves, some waves are reflected, so that the next wave breaks a critical distance resulting in a rapidly rising shock pressure on the breakwater. On the average, the wave pressure increase with incoming wave height, but the maximum wave force does not necessarily occur for the largest wave height. It can be occurred for serval larger wave group in an appropiate phase composition. The irregular wave pressure distribution on the breakwater is quite uniform; the ratio of tested and calculated wave pressures decreases with the reduction of relative crest height of breakwater.

Goda formula can predict the total horizontal force of the upper part of breakwater quite well except exetreme shock pressure occurred by non-breaking waves. Wave forces calculated by Miche-Rundgren and Nagai wave force formula are about 10% cummulated exceeding percentage of wave force obtained from model test.

Introduction

Sainflou (1928) drived a wave pressure formula for standing wave by using trochoidal wave theory. Sainflou formula has been widely used in calculating non-breaking wave forces for the past years. Rundgren (1958) by using Miche higher order wave theory and taking wave reflection into consideration, proposed Miche-Rundgren wave pressure formula for non-breaking waves. Nagai (1968) adopting small amplitude

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wave theory and test results suggested wave pressure formula according to three different relative depths. Goda (1974) suggested wave pressure computation method by taking the expected sliding proposed by Ito, into consideration and using the maximum wave height.

Lundgren (1974) studied the vertical face of composite type breakwater to reduce shock pressure by using irregular waves. When shock forces occur, they are functions of the ever varying combinations of wave shape. Hence they must be analyed statistically. The results show that the statistical distribution is often linear in a semilogarithmic diagram.

Katsutoshi (1984) studied random wave forces on upright section of breakwater, the test results show that for non-breaking wave trains, peak pressure can be predicted quite well by Goda formula to the joint distribution of wave height; the respective wave force defined as the same ways for the wave height can be predicted by Goda formula by using the corresponding respective wave. But, in case of breaking waves, the maximum pressure is far exceed the value predicted by Goda formula.

Experiment

A wind flume 100^m long, 1.5^m wide, 1.5^m deep, equipped with irregular wave generator, wind blower and circulation as shown in figure 1. Wave gauges, pressure gauges are interfaced on line with data acquisition system. The sampling rates for stage I and II are 45 samplings/sec. and 200 samplings/sec. respectively. The diameters of pressure transducer used for stage I and II are 8^{mm} and 1.8^{mm}.

Typical cross section is shown in figure 2. Two linear model scales 1/49 and 1/25 are used for stage I and II respectively. For the first stage, water depth range from 33.0^m to 37.5^m; wave heights are from 8.0^m to 16.5^m; the corresponding wave periods change from 12.0^{sec} to 14.6^{sec}. At the second stage, water depths vary from 10.5^m to 18.5^m; wave heights change from 3.0^m to 7.0^m; and wave periods are from 8.0^{sec} to 12.0^{sec}.

Test Results

Typical form of incident wave spectrum is shown in figure 3; cummulated exceeding percentage of wave height distribution is shown in figure 4. Time series of waves and corresponding pressure density are illustrated in figures 5 and 6 for the first and second stages respectively. Figure 5 shows that incident significant wave height 13.24^m, water depth 37.5^m, the relative water depth is 2.83. In general, it seems deep enough to prevent shock pressure induced by breaking waves; but, it occurs shock pressure at time 19.4^{sec}, when several larger waves attack the breakwater continually. It should be noted that the wave form is upside down in this figure. In the second stage, figure 6 shows that wave pressures are in phase with water level in front of the breakwater. Although, the relative water depth 2.85 (14.25/5.0) is almost equal to that of the first stage 2.83; but there is no shock pressure occurs in this test run.

The cummulated exceeding percentage of wave force for typical cases are shown in figure 7. Figure 8 shows comparision of wave forces acting on the same cross section for different test conditions. The force distribution on the vertical face breakwater shows quite uniform.

Wave forces calculated by different formula for wave height obtained from model test are plotted against the test results as shown in figure 9. Although, Goda formula can not predict wave pressure at a single point; but it can obtain the total horizontal force of the upper part of the breakwater quite well, except very exetreme shock pressure occurred by non-breaking waves. Wave forces calculated by Miche-Rundgren and Nagai formula is about the maximum one-tenth of the wave force (F10%) obtained from model tests.

From linear fitting curve, F1% and F10% are wave forces which occurred at cummulated exceeding percentage of 1% and 10% respectively. Figure 10 shows the ratio of wave forces between model test and formula computation (F_t/Fc). F_t is either F1% or F10% and Fc represents wave force calculated by Goda formula Fg. Miche-Rundgren formula Fm and Nagai formula Fn. The ratio Ft/Fc decreases with the decreasing of relative crest height d_c/y_c as shown in figure. Figure 10 shows when lower crest height of the breakwater, wave force formula predict larger wave force than those obtained in model tests. When d_c/y_c greater than 0.85, the ratio F_t/F_c varies from 0.9 to 1.0.

Conclusion

1. The maximum wave pressure does not necessarily occur for the largest wave height; the incident and reflected of a group of larger waves may induce the maximum pressure.

2. Under the action of irregular waves the pressure distribution acting on vertical force breakwater is quite uniform.

3. For non-breaking incident waves reflected by vertical wall, shock pressure can be occurred by an appropriate phase composition.

4. The ratio of wave forces obtained from model tests and calculated by different wave force formula decreases with the decreasing of relative crest height of breakwater.

5. Goda wave force formula can predict the maximum wave force in a wave train, except very exetreme shock pressure occurred by non-breaking waves. Wave forces calculated by Miche-Rundgren and Nagai formula are about 10% cummulated exceeding percentage of wave force obtained form model tests.

Reference

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4. Katsutoshi T., Shigeo T. and Kazuyuki M. (1984). Experimental study of random wave forces on upright section of breakwaters, Report of the Port and Harbor Research Institute, Vol. 23, No.3, Japan.

5. CERC, Shore Protection Manual, 1977.

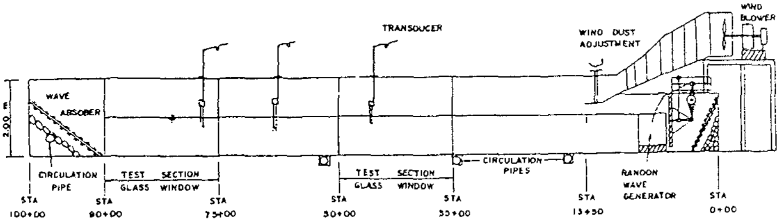


Figure 1 Wind Wave Flume

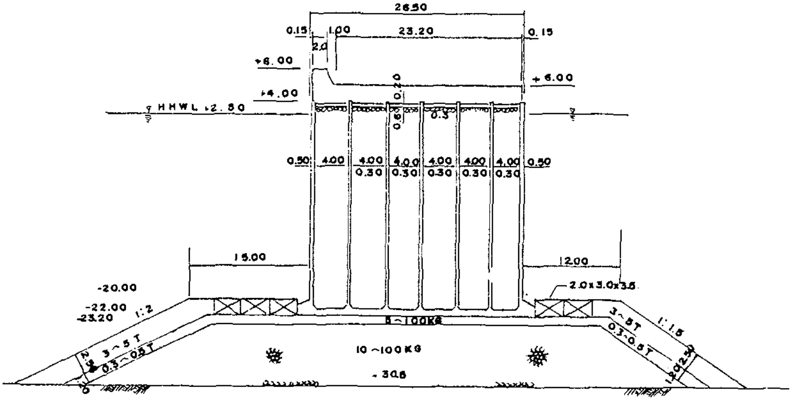


Figure 2 Typical Section of Composite Type Breakwater

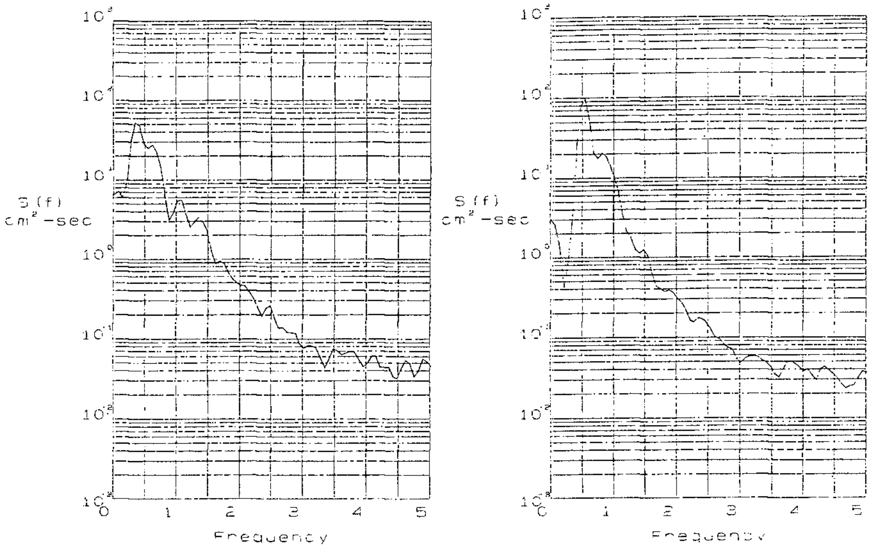


Figure 3 Incident Wave Spectrum

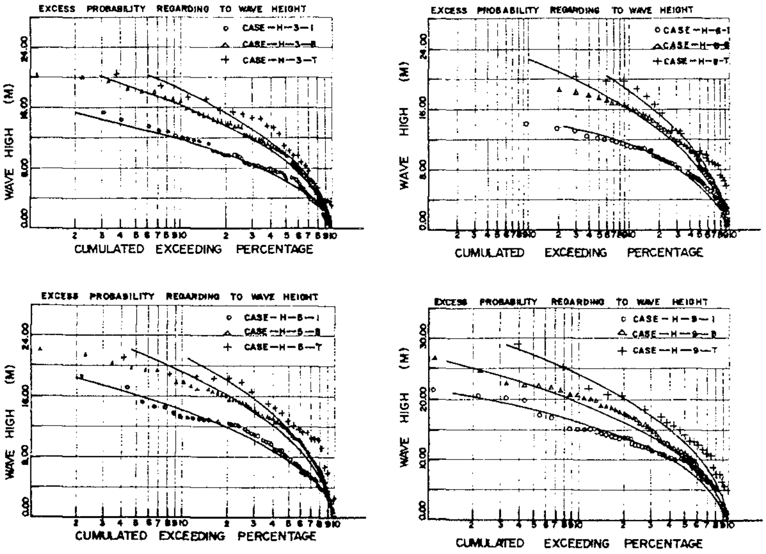


Figure 4 Cummulated Exceeding Percentage of Wave Height Distribution

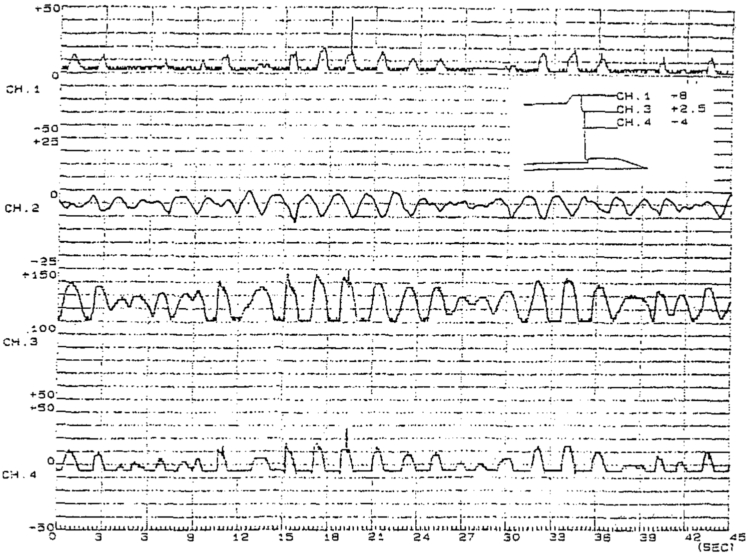


Figure 5 Time Series of Waves and Pressure (Stage I)

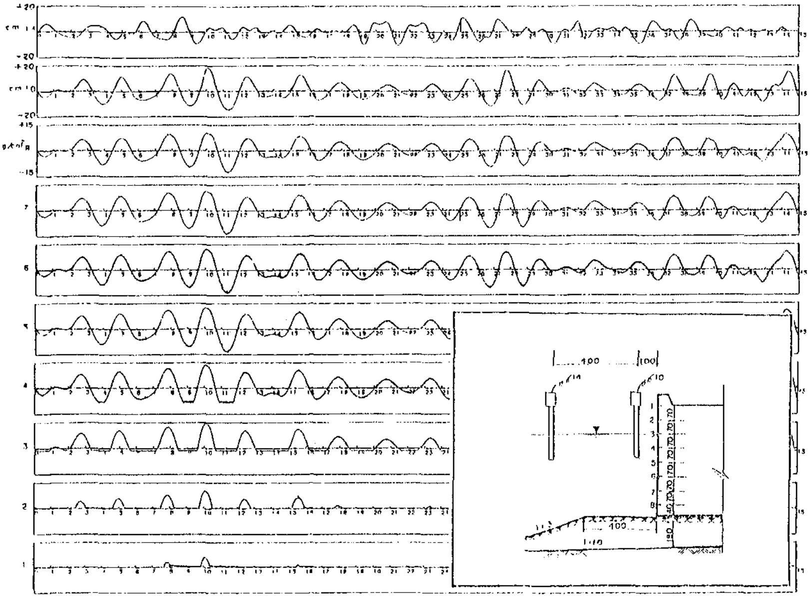


Figure 6 Time Series of Waves and Pressure (Stage II)

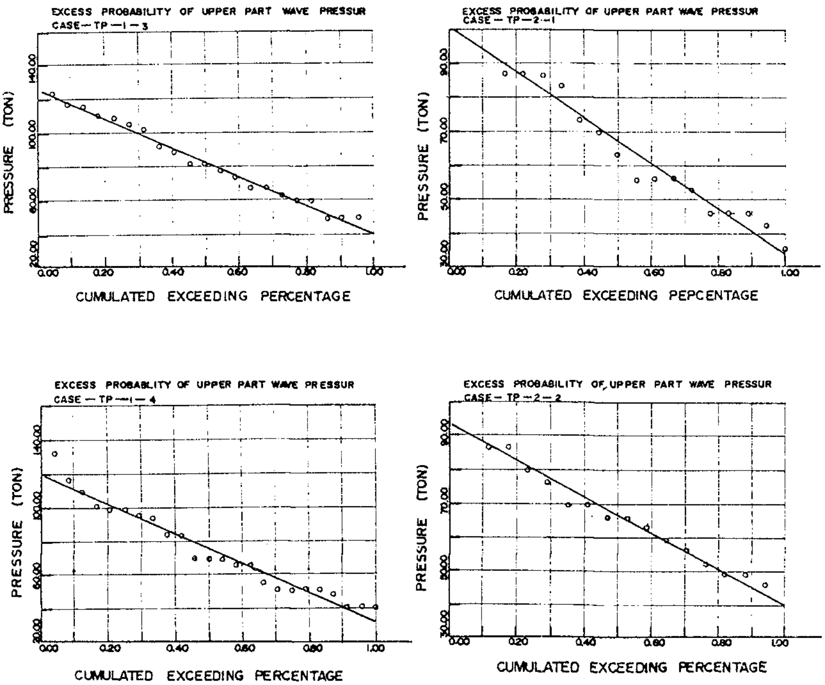
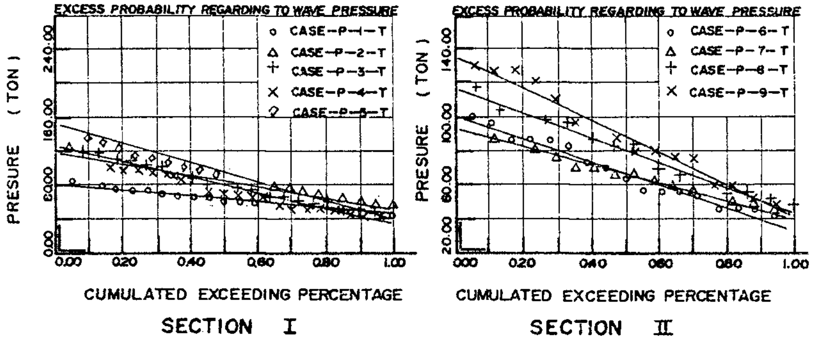


Figure 7 Cummulated Exceeding Percentage of Wave Force Distribution



SECTION I

SECTION II

Figure 8 Comparision of Wave Force Distribution for Different Test Conditions

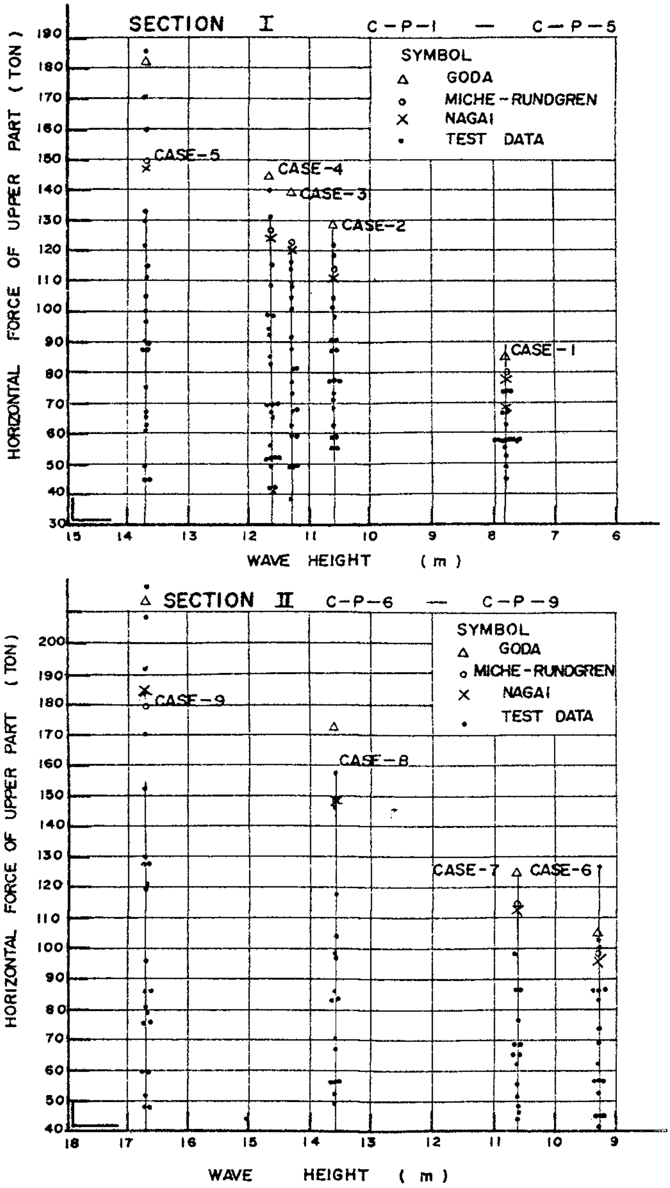


Figure 9 Wave Forces Calculated by Different Formula and Test Data

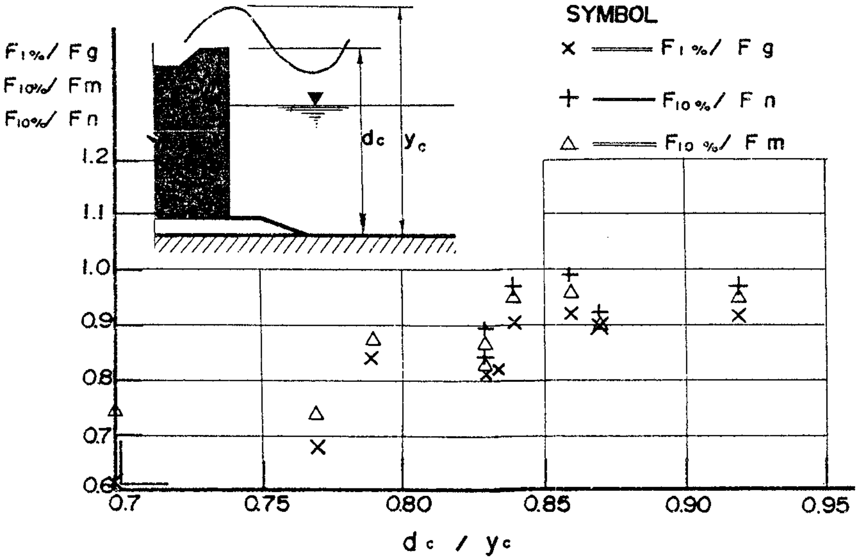


Figure 10 The Ratio of Wave Forces Between Model Test and Formula Computation