Calculation of Wave Transmission through Single Perforated Sheets

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Abstract

The prediction of reflection and transmission coefficients through single perforated sheets plays an important role in the assessment of the hydraulic responses of screen breakwaters and upright perforated wave filters and absorbers and their efficient design.

This paper reviews the result of laboratory tests in wave flumes to determine the reflection and transmission coefficients (C_r and C_t, respectively) through single perforated sheets. It has been shown that these coefficients can be calculated by using two new formulas which relate C_r and C_t to the wave-screen parameter. This parameter is the ratio of the product of discharge coefficient and the porosity of the sheet to the root square of wave steepness in deep water.

Introduction

When waves impinge on a perforated sheet, a series of jet is created which dissipate the incident wave energy through the formation of turbulence and eddies.

Theoretical models for dissipation of waves through a single perforated sheet were presented by tuck (۱۹۷۱), Porter (۱۹۷۲), Guiney et al. (۱۹۷۲), Packham and Williams (۱۹۷۲), Hattori (۱۹۷۲), Chwang and Dong (۱۹۸۴), Macaskill (۱۹۷۹), Owen and Bhatt (۱۹۸۵), Chegini (۱۹۹۵ & ۱۹۹۷) and Isaacson et al.(۱۹۹۸ & ۲۰۰۰).

Hattori (۱۹۷۲) perfomed a series of laboratory tests to measure the reflection and transmission coefficients of waves through perforated walls. He found that the dissipation of wave energy due to the perforated wall depends on the porosity of the wall, the discharge coefficient of the perforated holes, the incident wave steepness and relative water depth.

Faure (۱۹۹۲) performed an empirical study on single sheets made of expanded metals as the porosity was increased by deforming sheet above each perforation. He carried out all the tests in the flume of the National Research Council of Canada (NRCC) with a depth of ۱ m. The periods of regular waves were ۱, ۱,۵۴, ۲,۱۶, ۲,۸۱ and ۳,۴۶ seconds. The porosity of the sheets was ۵, ۱۵, ۲۰, ۳۰, ۴۵ and ۵۵ percent. Faure measured the reflection and transmission coefficients and concluded that four factors determine the characteristics of reflected and transmitted waves through a perforated plate, which are: sheet porosity, shape of perforation, incident wave steepness and wave period.

McBride et al. (۱۹۹۳) carried out a series of laboratory tests on single perforated sheets to measure the reflection coefficients of irregular waves from these wave absorbers. The porosity of sheets was ۷,۲, ۱۴,۸ and ۲۶,۶ percent. The mean wave height was ۰,۹ and ۱,۴۸ meters.

Chegini (۱۹۹۵) carried out a set of experimental tests in the Water Research Laboratory of the University of New South Wales (WRL) to measure the reflection and transmission coefficients of waves through single perforated sheets. He used two kinds of porous sheers, i.e. expanded metals of ۲۶, ۴۲ and ۵۸ percent porosity and perforated plates of ۲۳, ۴۰ and ۶۲ percent porosity. Chegini (۱۹۹۵) performed his tests using regular waves in the ۰,۹ m wide, ۱,۷۵ m deep and ۵۰ m long wave flume of WRL. All the tests were undertaken in water at the depth of ۰,۸ m. The wave periods were ۱,۲۵, ۱,۳۵, ۱,۵, ۱,۷۵ and ۲,۵ seconds. The range of wave steepness was ۰,۰۰۳ to ۰,۰۱.

RostamiNia (۲۰۰۱) carried out a series of laboratory tests on perforated sheets in the ۳۲,۵ m length, ۵,۵ m wide and ۱ m deep wave flume of Soil Conservation and Watershed Management Research Center (SCWMRC), the Ministry of Jihad-e-Agriculture, IR of Iran. This flume is divided into three parts (figure ۱). The tests were performed in the middle part of the flume. The coefficients of wave reflection and transmissions were measured using five wave gauges installed in front and the rear of the perforated sheet (figure ۱). Goda's method was employed to calculate the reflection coefficients (Goda and Suzuki, ۱۹۷۶). To prevent the reflection of waves from the end wall of the flume, a gravel beach absorber was used. The porosity or the sheets were ۲۱, ۴۴ and ۴۸ percent. The tests were performed using regular waves of ۱,۲۵ to ۲,۵ seconds period. The wave heights were ranged from ۷,۶ to ۱۸.۴ centimeters.

Figure (۱): Plan of SCWMRC wave flume

Wave – Screen Parameter

Chegini (۱۹۹۵ & ۲۰۰۱) introduced the wave-screen parameter to describe the hydraulic responses of single perforate sheets. This parameter is:

$$\Gamma = \frac{C_d P}{\sqrt{H_i / L_.}} \quad (۱)$$

So that:
C_d = discharge coefficient of perforated sheet
P = porosity of perforated sheet
H_i = incident wave height
$L_{۰}$ = deepwater wave length

Discussion

The results of experimental tests performed by Hattori (۱۹۷۲), Faure (۱۹۹۲), McBride et al. (۱۹۹۳), Chegini (۱۹۹۵) and RostamiNia (۲۰۰۱) have shown that the reflection and transmission coefficients of waves through a perforated sheet are functions of the following parameter:

- porosity of perforated sheet
- shape of perforated sheet that can be expressed as the discharge coefficient of the sheet
- incident wave height
- incident wave period that can be described as the incident wave steepness

Therefore, it may be concluded that C_r and C_t can be determined from the wave-screen parameter (Γ) introduced by Chegini (۱۹۹۵ & ۲۰۰۱).

The results of all laboratory tests are analyzed and it is concluded that reflection and transmission coefficients through single perforated sheets can be calculated using the following formulas:

i.
$$C_r = -\tanh(۲.۴۵\Gamma) + ۱ \qquad \Gamma < ۰.۳۵ \qquad (۲)$$
$$C_r = -۰,۴\tanh(۰,۸۲\Gamma) + ۰,۴۲ \qquad \Gamma > ۰.۳۵ \qquad (۳)$$

ii.
$$C_t = \tanh(۲.۳۵\Gamma) \qquad \Gamma < ۰.۳۵ \qquad (۴)$$
$$C_t = ۰.۴۵\tanh(۰.۵۷\Gamma) + ۰.۵۵ \qquad \Gamma > ۰.۳۵ \qquad (۵)$$

The variations of C_r and C_t with Γ are depicted in figure (۲).

Conclusions

The results of laboratory tests have shown that:

۱. The hydraulic responses of single perforated sheets can be described as functions of the wave-screen parameter.
۲. Wave reflection coefficient from a perforated sheet decreases by increasing the wave-screen parameter.
۳. Wave transmission coefficient through a perforated sheet increases by increasing the wave screen-parameter.

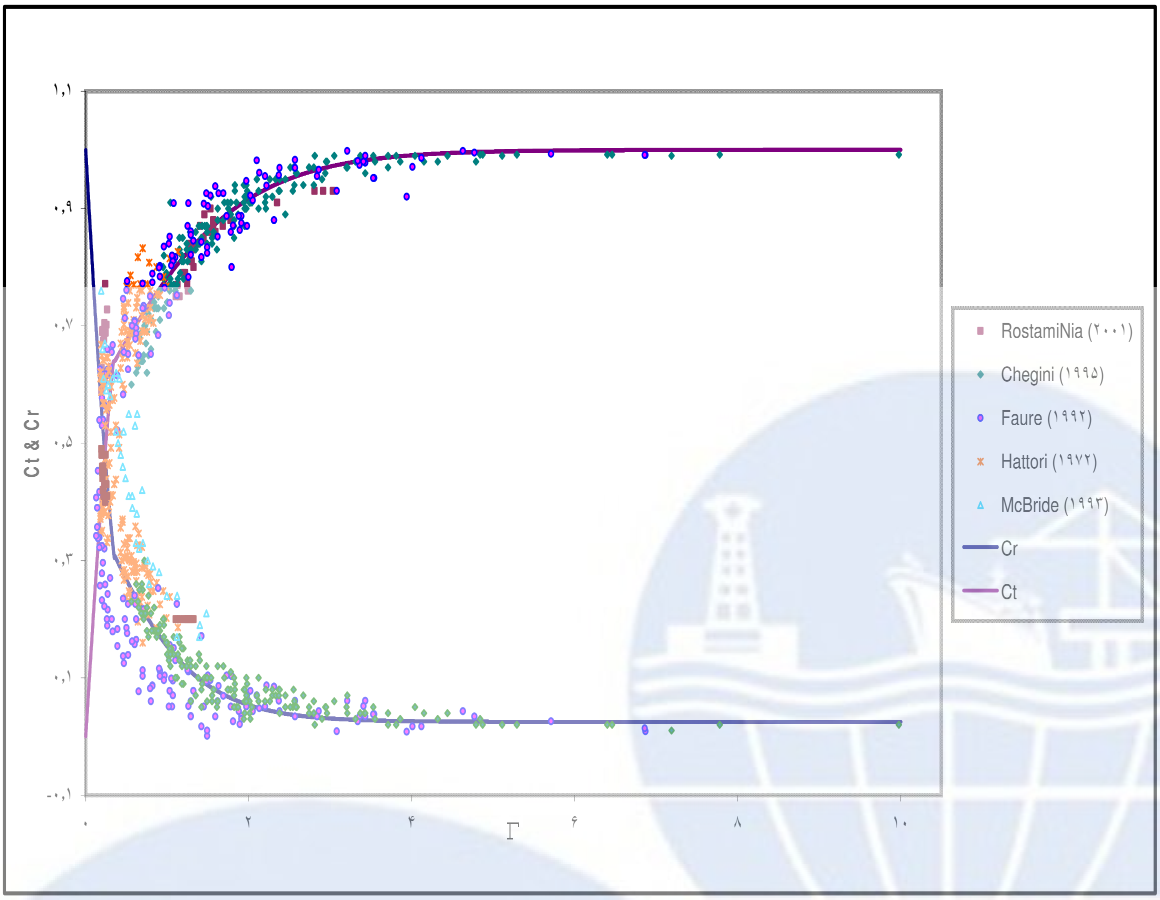

Figure (۲): Variations of C_r and C_t with Γ

References

Chegini,V. (۱۹۹۵): “Design of upright perforated energy dissipators for use in wave basins”, A thesis submitted in fulfillment of the requirements for Degree of Doctor of Philosophy, Dept. of water Eng., School of Civil Eng., Univ. of New South Wales, Australia, March ۱۹۹۵.

Chegini,V. (۱۹۹۷): “Reflection and transmission of water waves through single perforated sheets”, J. of Water Resources Eng. Vol. ۴, No. ۴, Winter, PP ۲۹-۴۶.

Chegini, V. (۲۰۰۱): “Introduction of wave-screen parameter”, Proc. of Theme E, XXIX IAHR Congress, Beijng, China, Sept. ۱۶-۲۱, PP ۱۴۹-۱۵۷.

Faure, T.D. (۱۹۹۲): “Numerical modeling of wave reflection from upright variable porosity wave absorbers”, National Research Council Canada, Inst. of Mech. Eng. Hydraulic Lab., Coastal Zone Eng. Program, Tech. Rep. No. ۱, IME-CZM-TR-۰۰۵, November, ۵۱ pages.

Guiney, D.C., Noye, B. J. and Tuck, E.O. (۱۹۷۲): “Transmission of water waves through small apertures”, J. of Fluid Mechanics, Vol. ۵۵, Part ۱, ۱۹۷۲, PP ۱۴۹-۱۶۱.

Hattori, M. (۱۹۷۲): "Transmission of water waves through perforated wall", Coastal Eng. In Japan, Vol. ۱۵, PP ۶۹-۷۹.

Isaacson, M., Premasiri, S. and Yang, G.: "Wave interactions with a vertical slotted barrier", J. of Waterways, Port, Coast and ocean Eng., ASCE, ۱۲۴(۳), PP ۱۱۸-۱۲۶.

Isaacson, M., Baldwin, J., Allyn, N. and Cowdell, S. (۲۰۰۰): "Perforated breakwaters", J. of Waterways, Port, Coast and ocean Eng., ASCE, ۱۲۶(۵), PP ۲۲۹-۲۳۵.

Macaskill, C.: "Reflexion of water waves by a Permeable barrier", J. of Fluid Mechanics, Vol. ۹۵, Part ۱, ۱۹۷, PP ۱۴۱-۱۵۷.

Owen, D. and Bhatt, B.S. (۱۹۸۵): "Transmission of water waves through small aperture in a vertical thick barrier", Q. J. Mech. Appl. Math., Vol. ۳۸, Part ۳, PP ۳۹۷-۴۰۹.

Packham, B.A. and Williams, W.E. (۱۹۷۲): "A note on the transmission of water waves through small apertures", J. Inst. Math. Applics, Vol. ۱۰, PP ۱۷۶-۱۸۴.

Porter, D. (۱۹۷۲): "The transmission of surface waves through a gap in a vertical barrier", Proc. Camb. Phil. Soc. Vol. ۷۱, PP ۴۱۱-۴۲۱.

RostamiNia, M.: "Determination of reflection and transmission coefficient of regular waves through single perforated sheets using physical modeling" (in Persian) (۲۰۰۱), M.Sc. Thesis, Islamic Azad University, Tehran, IR of Iran, ۱۲۱ pages.

Tuck, E.O. (۱۹۷۱): "Transmission of water waves through small apertures", J. of Fluid Mechanics, Vol. ۴۹, Part ۱, PP ۶۵-۷۴.