CHAPTER 137

RESEARCH OF WAVE FORCES OF BREAKWATER IN DEEP WATER AREA

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ABSTRACT

The design of breakwater in deep water requires a reliable assessment of the forces, it will be subjected to and full understanding of the behaviour of the structure. Wave forces on a vertical wall caisson of composite breakwater vary with the configuration of the rubble mound foundation as well as the condition of incident waves. If the conditions are very unfavorable, powerful impact-breaking-wave forces may act on the vertical wall caisson. It is an important subject to clarify the generation conditions of impact breaking wave forces, so that the breakwater under design would not be exposed to a very strong breaking wave force.

The present study points out on the basis of the experimental results for the typical example of slided caisson that careful attention should be paid to the possibility of the generation of impact breaking wave forces in the design of composite breakwater. The generation conditions are investigated by the two-dimensional experiments on the variation of wave forces due to the configuration of rubble mound and the three-dimensional experiments on the effect incident wave angle to the breakwater. The impact breaking wave forces are easily be produced on the vertical-wall caisson, where the mound is relatively high and has an appropriately broad crest width.

If the generation of impact breaking wave forces are unavoidable owing to the breakwater configuration, provision of an appropriate wave dissipating work in front of the caisson is recommended to alleviate the method of calculation of design wave forces on the caisson covered with wave dissipating concrete blocks and the wave dissipating caisson with a permeable front wall.

In the study, problems are highlighted with respect to wave climate range that will induce breaking wave pressure, model test is conducted to measure the wave pressure and the sliding effect. Then the current formula for calculated wave pressure is

discussed. The factor of experiment considered in the test flume is depth of composite breakwater, height, width and slope of rubble mound, etc.

1. Introduction

For dealing with the construction problems of the deep water breakwater, as for the caisson-composite type breakwater, the foundation work is the problem as the breakwater goes to deeper due to the limit of operation of diver in the deep water, the pavement of mattress, the leveling of the mound, etc. will cause much problem. Since the body of caisson is larger in the deep water, constructing, tawing and replacing caisson work will be more difficult than those of shallower water part. For flow chart of deep breakwater construction, planning and design of the structure need to he further considered.

For planning aspect, the huge deep breakwater that need to be made sure it is necessary. Since (1) invest benefit: due to expensive cost of engineering fee of deep breakwater, the after construction, its benefit is not larger than the invest cost, then it is unnecessary. (2) alternative plan:due to the elongation of existing breakwater to the deeper position, the construction fee is expected much higher, therefore, to find out the alternative plan such as, to construct one shallow breakwater could be also obtained the same harbor function; or if the breakwater was not prolonged, then to enlarge and repair some wharves could be also reached the same effect, etc. (3) calm wave sheltering area:due to high cost of breakwater, it is naturally to cut down the elongation of breakwater however, the harbor basin need to be calm. Therefore it is necessary to study the relationship between the elongation of hreakwater and the calm wave sheltering area of basin. The criteria of the calm basin is necessitated to determine.

2. Test Results and Analyses of Deep Breakwater of Caisson-Composite Type

Around the Taiwan coast, especially the international trade port, breakwater of the caisson-composite type is commonly used. Deep outer breakwaters of the 2nd entrance of Keelung Harbor are tested for impact pressure analyses. The typical design section of -35M deep is shown in Fig.1; while impact pressure (Fig.2c) is about triple of the normal wave pressure, its period is about 1/7 to 1/20 sec. In addition to the breakwater of 2nd entrance of Keelung Harbor, the varying mound shape, mound height of caisson-composite breakwater are tested and analyzed for further new information.

Fig.3 and Fig.4 are many cases of test results, the results show that, the higher mound of caisson-composite breakwater (d/h=1/3), wave pressure increases as the wave height becomes large; therefore the mound height has obvious effect on the wave pressure. The varying transverse width of the mound also shows that wave pressure has the different degree for increasing. Since the test results indicate that the wave pressure is larger as the transverse width of mound is wider, the wave pressure is bigger as the mound height is higher.

Fig.5 shows that the impact wave pressure occurring range of deepwater breakwater has the same tendency as that of shallower depth. That is as d/h smaller (or higher mound), the occurrence of the impact pressure is very often. The case of no wave overtopping is easier to occur than that of wave overtopping. The impact pressure occurring range is indicated by the dot line of Fig.5.

3. Results and Discussion

For caisson-composite breakwater, it is designed that the armour concrete block such as dolos, hollowtripod, etc. to prevent wave acting directly toward the caisson from forming shock pressure (one form of impact pressure). By using porosity of armour concrete block to increase turbulence for dissipating wave energy therefore wave pressure should be minimized. Based on the previous test results, it is considered that in front of composite type, the covering layer of armour unit on the mound could reduce the wave pressure about 60% in the shallower water area. However, reducing of wave pressure depends on water depth, wave condition, mound height, mound slope and mound shape, etc. For the present test results (test section of -35M deep or more) show that the portion of caisson (vertical wall) is subjected to standing wave or part of breaking pattern, the cover layer of armour unit is easily happened that the wave acting on the slope forms the breaking wave and produces shock pressure (strong impact pressure) in a short time, the impact pressure is quite huge. Therefore, the placement of armour concrete unit is inefficient to the wave action and will be a negative effect;

therefore, it is suggested the design section be changed to the section as shown in Fig.6

4. Failure of Deep Water Breakwaters

Failures to deep water breakwaters have occurred over the past decade,are due to the following (main) reasons:

Rubble Mound Type: the increase of depth and related increase of design wave heights led to designs with very steep slopes and protected by concrete armour units of weights and sizes far in excess of previous experience. The strength of these concrete blocks appeared in many cases to be insufficient due to the high peak forces, which occur on the blocks during a storm. The blocks broke and were subsequently easily removed from the slope. The great steepness of the slopes may also have contributed to failure, since the geotechnical stability of the mound becomes critical under wave loading.

Vertical Wall Type: failures to this type of breakwater occurred mainly due to high impact forces of breaking waves at the vertical front, leaking to horizontal displacements of the caissons and in some cases to geotechnical instability of the foundation and tilting. The author has been invited in many cases of breakwater failure to investigate the failure and make a design for repairing, e.g. Su Ao Harbor Breakwater and Hualian Harbor Breakwaters in the east coast of Taiewan, R.O.C.

The solution to the problems mentioned above lies primarily in following the proper design procedures, as applied by Hou('78 '80) throughout its breakwater projects. The main features of this procedure are systematic failure analysis of each design and an integral approach, including hydraulic-, geotechnical- and concrete strength aspects in a balanced way.

5. Conclusion

1) For the deep water breakwater construction, the field measurement of deep water wave, geological, oceanographic data, foundation and earthquake problem, etc. need to be further studied.
2) For the caisson-composite deep breakwater, the higher mound is easily to subject to occur the impact pressure, the lower mound has little such phenomena.

3) The wider of the transverse width of the caisson-composite breakwater, of which the wave pressure is higher, some impact pressure may occur. However, for the vertical caisson breakwater (no mound outside the harbor) only, may not occur impact pressure.
4) For the deep water breakwater design, if the width of caisson is limited by the bearing capacity of foundation, then the body of caisson will be huge, the width may be 100 to 200M, therfore the design criteria of 50 t/m² bearing capacity, has to be further considered for increasing.
5) As the enlargement of caisson breakwater in the deep water, its problem of design and construction need to be solved. Some special cases of hydraulic experiment need to be conducted after design and before construction of the deep caisson-composite breakwater.
6) For the Deep Water Port at the Western Coast of Taiwan breakwaters will be founded in maximum waterdepths varying from 15-50 m, depending on the layout of the selected port and the characteristics of the foreshore. No general indication of the type of breakwater can be given. It is likely that for a breakwater in less deep water a composite type breakwater will be more feasible. For the wharves, the type of vertical walls are envisaged, provided that the tranquility level inside the port can be achieved.

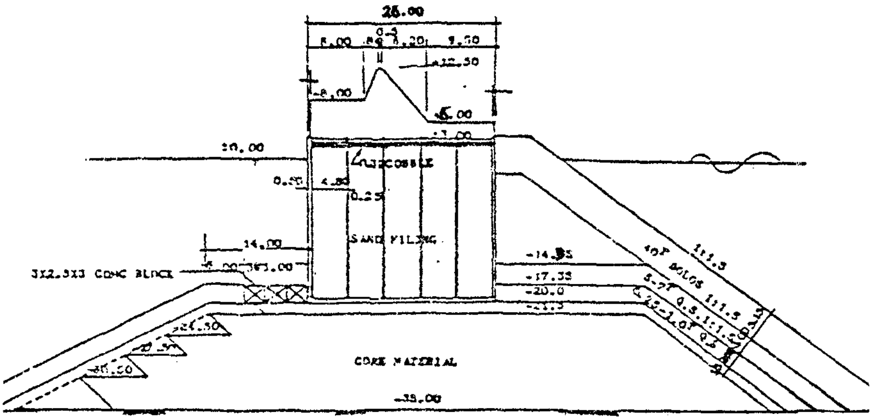
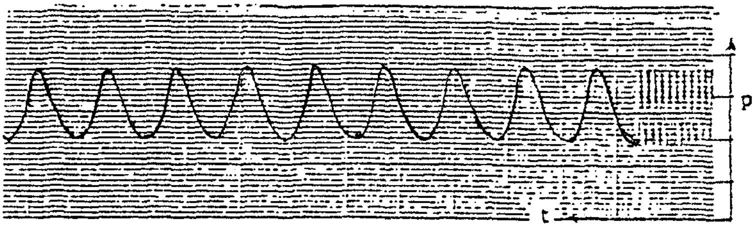
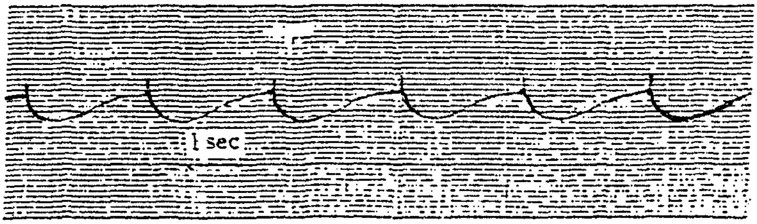


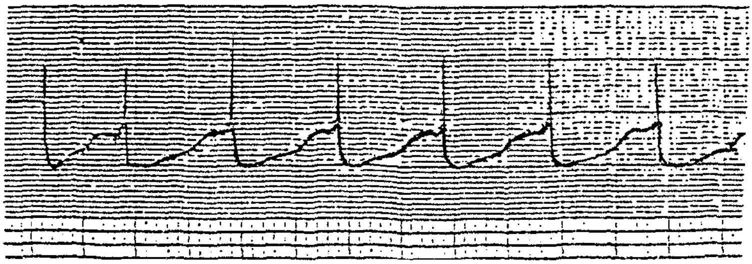
Fig.1 Deep Caisson Composite Type of Bah-Tsu Meng Breakwater at the 2nd Entrance of Keelung Harbor



(a) Standing Wave Pressure Record



(b) Weak Impact Pressure Record



(c) Strong Impact Pressure Record

Fig.2 Wave Pressure Pattern

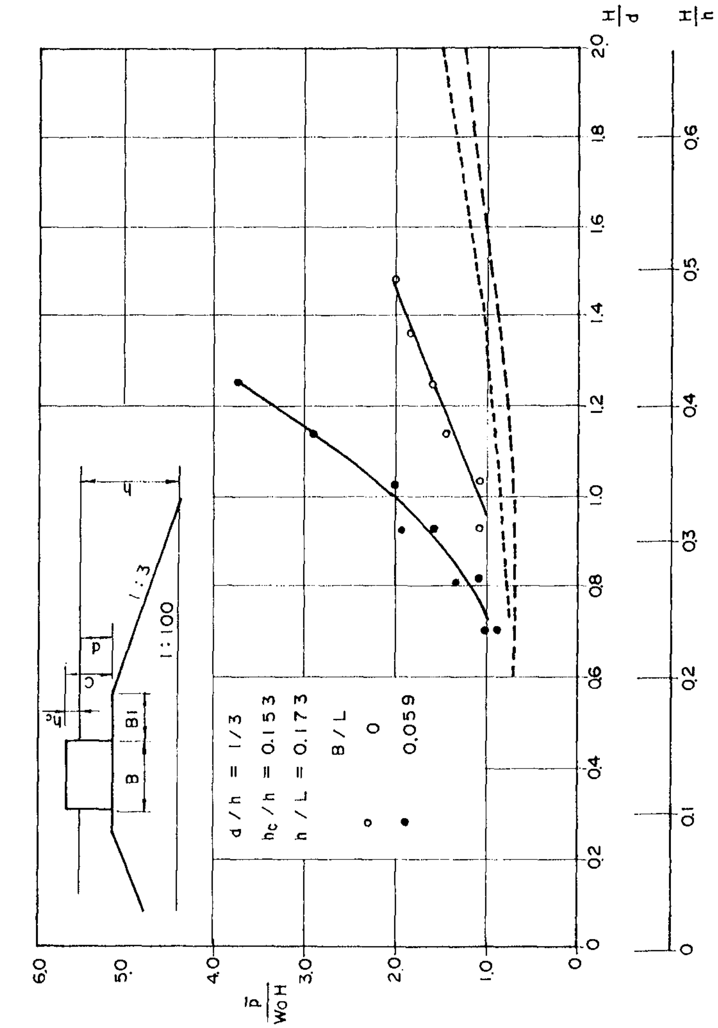


Fig.3 Mound Shape Affects the Wave Force Diagram

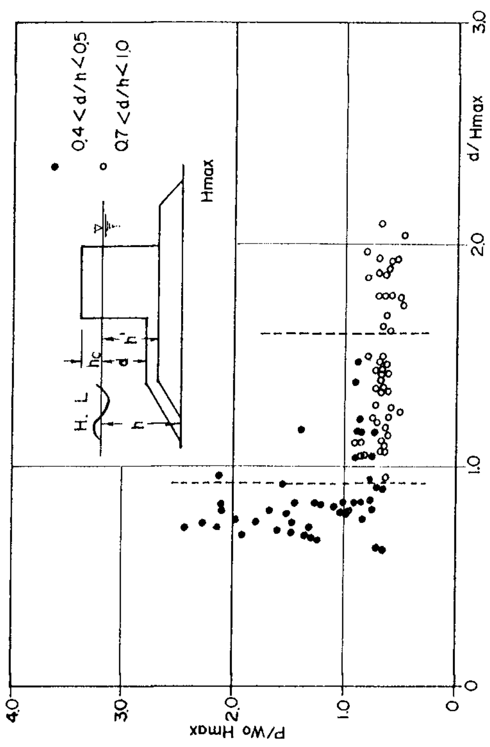


Fig.4 Mound Depth affects the Wave Force Analyses

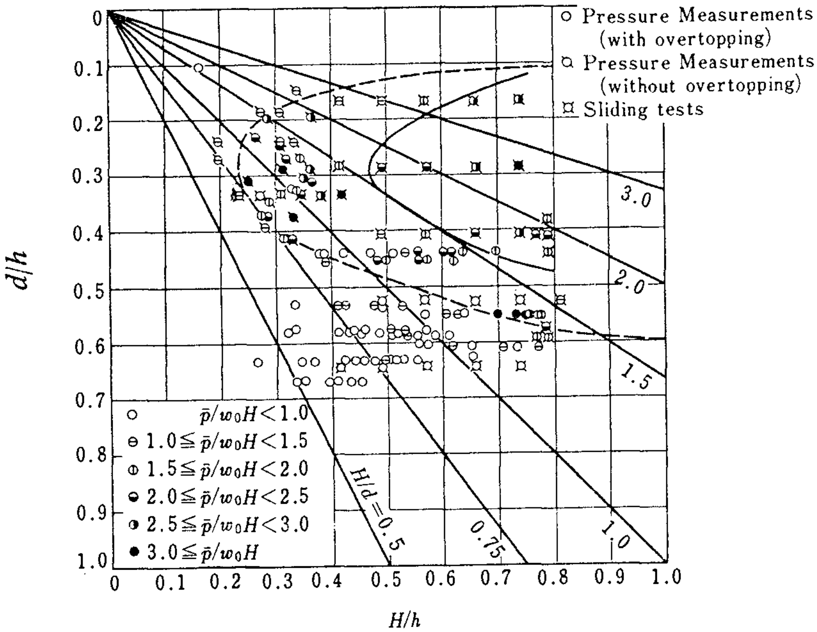


Fig.5 Possible range of the occurrence of impulsive breaking wave pressure

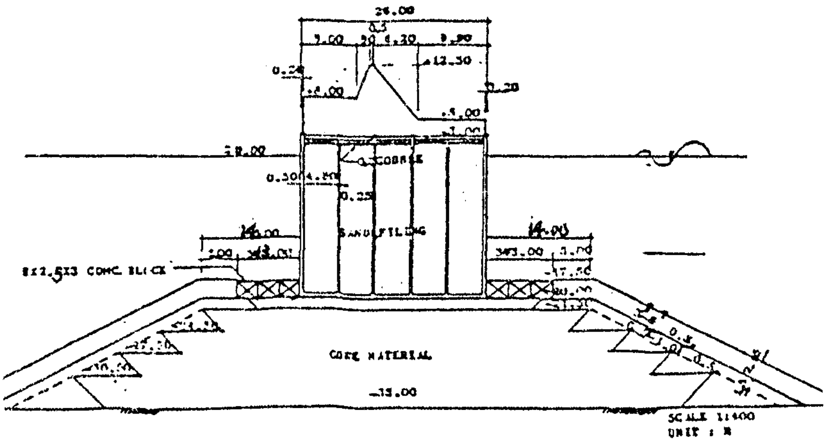


Fig.6 Modified Design Section of Deep Breakwater of 2nd Entrance of Keelung Harbor

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