CHAPTER 98

WAVE FORCES ON A PLATFORM WITH A RIBBED BOTTOM

Keith H. Denson
Professor of Civil Engineering
Mississippi State University
State College, Mississippi

Melville S. Priest
Director
Water Resources Research Institute
Mississippi

ABSTRACT

Observation of hurricane damage along the Mississippi Gulf Coast has stimulated studies of wave action on structures which permit the waves to pass beneath the floor or bottom surface. This paper reports a laboratory study which compares relative drag and lift forces on a structure with a plane, horizontal bottom surface to those on a structure with a ribbed bottom surface, for various conditions of relative wave height and relative clearance of the structure above the stillwater surface. Also, the effects of relative depth of ribs, relative spacing of ribs, and end webs or diaphragms are noted. The study was limited to the condition for which the bottom ribs were transverse to the general direction of wave motion. The results, which are presented in graphical form, clearly show the effects of the ribs.

INTRODUCTION

It is a rather common occurrence along portions of our coasts that structures supported on piles have encroached upon the sea to such an extent that, during the high stages of a storm surge, waves of considerable magnitude may actually pass beneath the structures. The authors[1] have reported on lift and drag forces exerted by waves on elevated platforms with plane, horizontal bottoms and plane, vertical sides, for the case of normal wave incidence. The waves were considered to be of the type which, in passing from deep water into shallow water, tend to behave more nearly as individuals than as parts of an oscillatory system. That is, wave period was not considered to be a significant quantity.

Observation of hurricane damage to elevated platforms with structural ribs, such as stringers, joists, girders, or T-beams, on the bottoms led to an extension of the earlier study by the authors[1] to determine the relative effects of the ribs on lift and drag forces, as compared to such forces on platforms with plane, horizontal bottoms. The results of this extension of the study are reported herein.

The lift and drag forces exerted by waves are time-dependent variables. However, the interests of this study were in the extreme values. Consequently, only maximum and minimum values of lift and drag are considered herein. The results are presented in graphical form, through dimensionless parameters which enable some degree of generalization.

DIMENSIONAL CONSIDERATIONS

For the previous, related study by the authors[1], in which the structure had a plane bottom surface, the physical quantities which were found to be useful in describing the lift force (F_l) or the drag force (F_d) were specific weight (γ) of the water, stillwater depth (D), wave height (H), clearance (Δ) between the horizontal bottom of the structure and the stillwater surface, width of structure (W), length of structure (L), and horizontal area (A) of the bottom surface.

For the study reported herein, some additional lengths are necessary for describing the geometry of the ribbed bottom. Specifically, the lengths are rib depth (δ), rib thickness (t), and rib spacing (S). Conditions with and without end diaphragms between ribs were studied, but no additional physical quantities are introduced to describe the diaphragms.

For purposes of generalization, the above mentioned physical quantities might be arranged into the dimensionless parameters shown in the implicit function

$$\Omega_1\left(\frac{F_l}{\gamma DA} \text{ or } \frac{F_d}{\gamma DA}, \frac{H}{D}, \frac{\Delta}{D}, \frac{W}{D}, \frac{L}{D}, \frac{\delta}{D}, \frac{t}{D}, \frac{S}{D}\right) = 0 \quad \ldots\ldots \quad (1)$$

in which it is evident that the quantity chosen as common to all parameters is the stillwater depth (D).

During the study reported herein, the width of structure (W), length of structure (L), and rib thickness (t) were held constant, as was the stillwater depth (D). Consequently, for purposes of analysis, Eq. 1 might be rewritten

$$\Omega_2\left(\frac{F_l}{\gamma DA} \text{ or } \frac{F_d}{\gamma DA}, \frac{H}{D}, \frac{\Delta}{D}, \frac{\delta}{D}, \frac{S}{D}\right) = 0 \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

EQUIPMENT AND EXPERIMENTAL PROCEDURE

The study made use of a wave basin in a laboratory of the Water Resources Research Institute, Mississippi State University. Interior dimensions of the basin are 30 ft width, 40 ft length, and 2½ ft depth. The wave generator is of the vertical plunger type. Stroke and speed are adjustable. Waves move from the deeper water near the generator over a ramp to the study area, which has a horizontal bottom, and on to a sloping gravel bank which serves as a wave attenuator.

The basic test structure was a plastic box with a horizontal bottom of rectangular shape and vertical sides. Plastic ribs were attached to the bottom, with the exterior ribs flush with the front and rear walls of the basic box and the interior ribs located so as to obtain equal spacing throughout. This box was suspended from a metal frame by means of members upon which strain gages were mounted. The support system permitted adjustment of clearance between structure and stillwater surface. The electrical system of which the strain gages and an amplifier-recorder were parts was calibrated for measurement of lift and drag forces. Wave height and stillwater depth were measured by means of hook-point gages.

The common or reference values of physical quantities which appear in the independent parameters of the problem were H = 3.44 in, Δ = 0.25 in, W = 15.00 in, L = 12.00 in, δ = 0.38 in, t = 0.25 in, S = 3.92 in, and D = 8.00 in. All of the ribs and the end diaphragms were cut from one-quarter inch plastic sheets. When end diaphragms were used, they were the same depth as the ribs.

Data were collected to show the relation between maximum and minimum values of each of the dependent parameters $F_l/\gamma DA$ and $F_d/\gamma DA$ and the independent parameter H/D for various values of Δ/D, δ/D, and S/D, and to show the effects of end diaphragms. The results are presented in a graphical form which enables comparison with results from the earlier study by the authors[1], in which the bottom of the test structure was a plane surface.

RESULTS

Each of the Figures 1, 3, and 5 relates maximum and minimum values of $F_l/\gamma DA$ to H/D for a particular value of Δ/D, and each of the Figures 2, 4, and 6 relates maximum and minimum values of $F_d/\gamma DA$ to H/D for a particular value of Δ/D, for various bottom configurations of the structure.

Each of the figures provides a comparison of conditions with ribs versus those without ribs. In addition, Figures 1 and 2 are intended to show the effects of rib depth (δ/D), rib spacing (S/D), and the use of end diaphragms on maximum and minimum values of $F_l/\gamma DA$ and $F_d/\gamma DA$, respectively, for the common or reference value of Δ/D.[1] Figures 1-6 are intended to show the effects of clearance (Δ/D), with rib depth (δ/D) and rib spacing (S/D) at common or reference values, and no end diaphragms.

CONCLUSIONS

Within the limits of this study, it appears that the most significant effect of using ribs is some tendency to magnify the maximum and minimum values of $F_l/\gamma DA$ and $F_d/\gamma DA$, the degree of magnification increasing as H/D increases.[1] Both verification and limitations of the foregoing statement should become evident from inspection of the figures and the following comments.

As indicated in Figures 1 and 2, an increase in rib depth, which was an increase in δ/D, resulted in an apparent decrease in maximum values of $F_l/\gamma DA$ at moderate values of H/D and an increase at higher values of H/D. The effect of the increase in rib depth on the maximum values of $F_d/\gamma DA$ was to magnify them. The effect on minimum values of both $F_l/\gamma DA$ and $F_d/\gamma DA$ was, for the most part, to magnify them.

Again, as indicated in Figures 1 and 2, a decrease in rib spacing, which was a decrease in S/D, resulted in maximum values of both $F_l/\gamma DA$ and $F_d/\gamma DA$ that were lower at moderate values of H/D and higher at higher values of H/D. The effect of the decrease in rib spacing on minimum values of $F_l/\gamma DA$ was to magnify them. The effect, if any, on minimum values of $F_d/\gamma DA$ at moderate values of H/D was not clear, but there was a tendency to magnify at higher values of H/D.

As indicated in Figures 1 and 2, the use of end diaphragms resulted in some increase in maximum values of both $F_l/\gamma DA$ and $F_d/\gamma DA$ at moderate values of H/D. Otherwise, the effect on maximum values was slight. The effect of end diaphragms on the minimum values of $F_l/\gamma DA$ was a considerable magnification of them. The effect, if any, on minimum values of $F_d/\gamma DA$ was not clearly defined.

The maximum values of $F_l/\gamma DA$ were considerably different for conditions with and without ribs only for the intermediate clearance, for which $\Delta/D = 0.031$, and for initial submergence, for which $\Delta/D = -0.047$, at higher values of H/D. The minimum values of $F_l/\gamma DA$ were considerably different for conditions with and without ribs only for initial submergence, for which $\Delta/D = -0.047$, at higher values of H/D. The pattern of difference between maximum values of $F_d/\gamma DA$ for conditions with and without ribs appears to be more or less the same regardless of clearance, for values of Δ/D in this study. There was little difference between minimum values of $F_d/\gamma DA$ for conditions with and without ribs regardless of clearance.

ACKNOWLEDGEMENT

Funds for support of this study were derived from the State of Mississippi and administered by the Water Resources Research Institute, Mississippi State University.

REFERENCE

1. Denson, Keith H., and Priest, Melville S., "Lift and Drag Forces Due to Wave Action on Elevated Platforms," Paper No. 1559, Offshore Technology Conference, Houston, 1972.

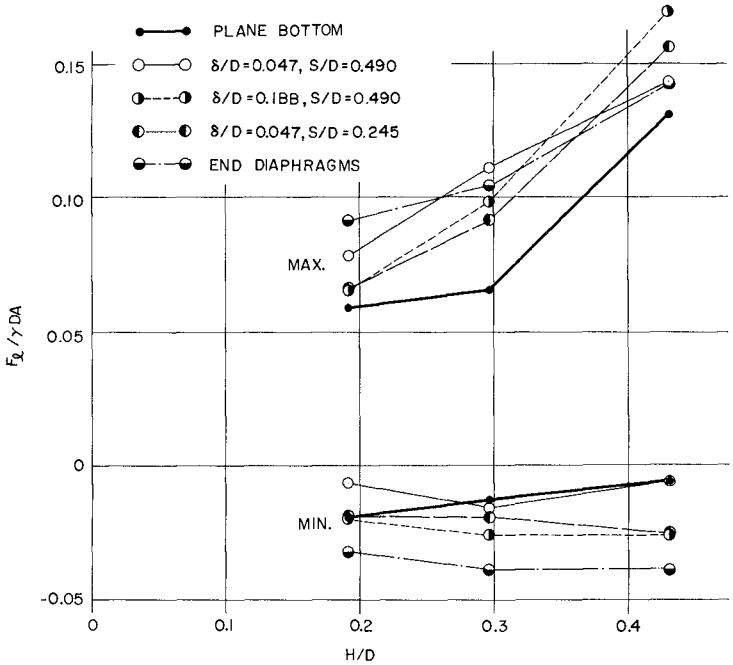

FIG. 1 - THE EFFECT OF BOTTOM RIBS ON LIFT FOR $\Delta/D=0.031$

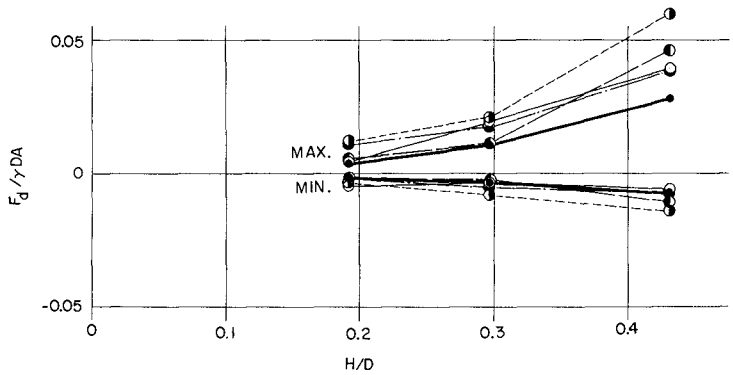

FIG. 2 - THE EFFECT OF BOTTOM RIBS ON DRAG FOR $\Delta/D = 0.031$

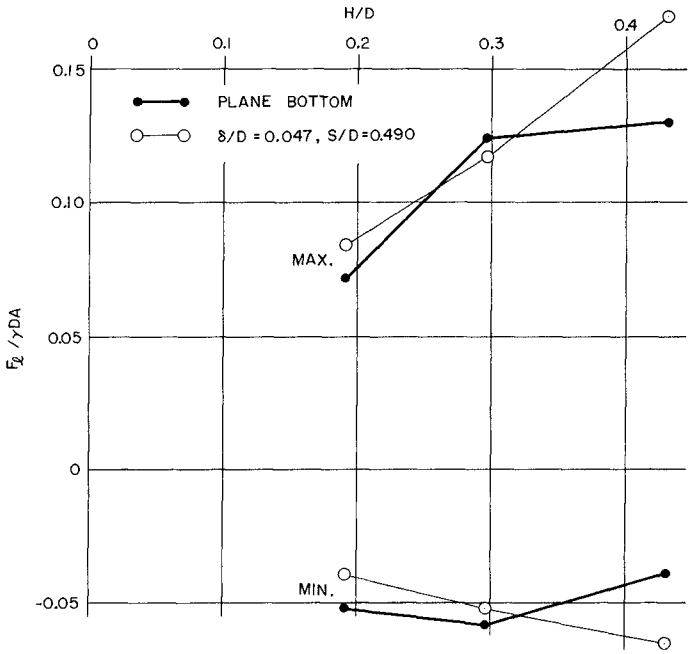

FIG. 3 - THE EFFECT OF BOTTOM RIBS ON LIFT FOR Δ/D = -0.047

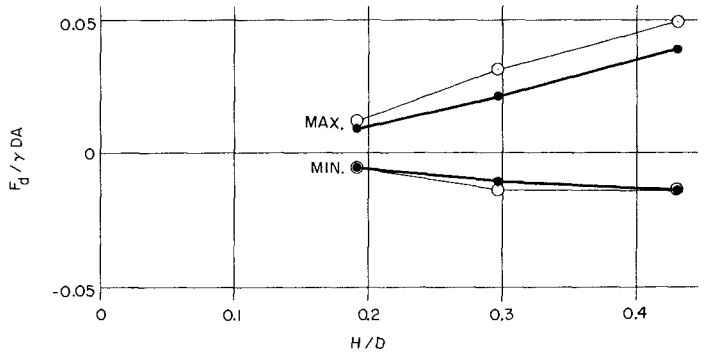

FIG. 4 - THE EFFECT OF BOTTOM RIBS ON DRAG FOR Δ/D = -0.047

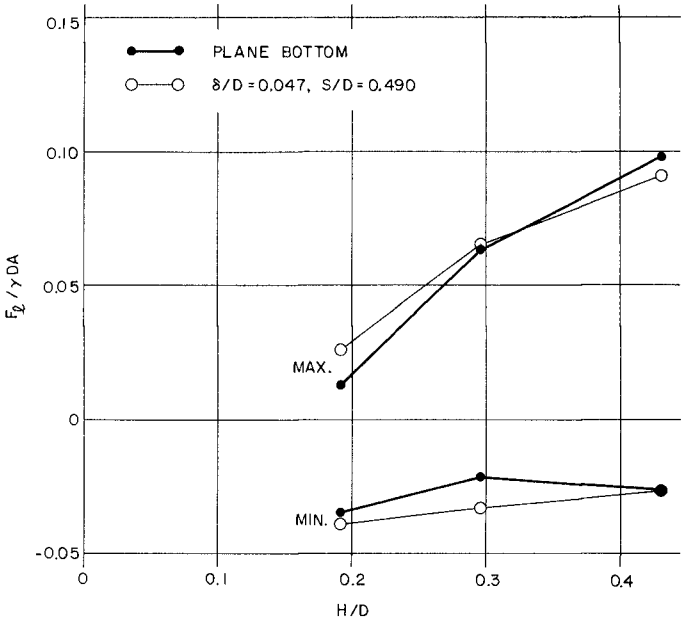

FIG. 5 - THE EFFECT OF BOTTOM RIBS ON LIFT FOR $\Delta/D = 0.109$

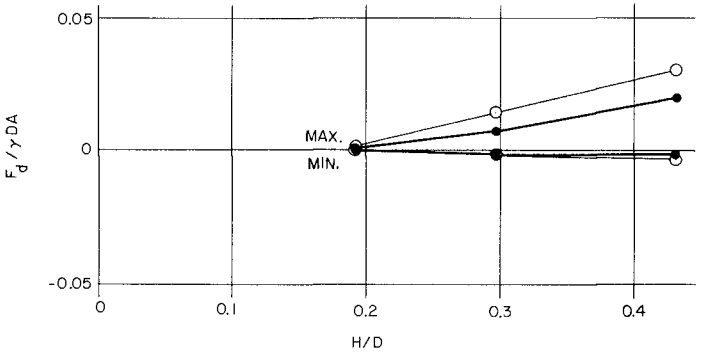

FIG. 6 - THE EFFECT OF BOTTOM RIBS ON DRAG FOR $\Delta/D = 0.109$