COMMENTARY ON LONG PERIOD SEA WAVES THAT MOVE INTO SHALLOW WATER

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ABSTRACT

For engineering purposes, the most important waves are probably those large, long period waves which move from deep water into relatively shallow water, as they progress shoreward. Despite the numerous related research efforts and publications on shoaling and shallow water waves, very questionable interpretations and applications persist. The commentary presented in this paper is directed at questions relating to the wave period and the "orbit" of water particles in transmitting the wave form. Photographic evidence of orbital behavior associated with such waves is presented. As large, long period waves move from deep water into shallow water they undergo a change in form and, ultimately, tend to behave more as individuals than as parts of an oscillatory system. That is, the wave period apparently ceases to be of any real significance in describing the wave behavior. Of the theories which have been considered for describing orbital behavior, and which have been compared with laboratory shallow water waves, it appears that the cnoidal theory may be the most generally acceptable. However, an orbital behavior that is characteristic of the large, long period waves, for which the period loses significance as the waves move shoreward, remains an open question.

TEXT

Although the search for oil, gas and other natural resources has extended man's activities into greater and greater depths of the sea, most marine structures are located in relatively shallow water. Questions as to the nature and severity of wave action on such structures arise immediately in connection with design considerations. The need for an understanding of wave behavior in relatively shallow water has long been recognized, and massive efforts have been directed toward acquisition of that understanding. Even so, there remains a marked degree of confusion concerning wave action in shallow water, particularly with regard to large, long period waves which move from deep water into shallow water.

Prior to the turn of the century it had been observed that as long period waves move from deep water into shallow water they tend to behave more nearly as individuals than as an oscillatory system. In fact, some investigators have suggested that they might be treated as solitary waves. This would not be strictly correct, because the passage of a solitary wave is accompanied by a shift of the water particles in the direction of wave motion without a return shift. That is, the particles do not move in an orbit. Be that as it may, an important conclusion from this observation is that wave period ceases to have any real meaning for such waves.

Statistical analysis of actual sea wave data, as reported by Harris[1], supports the idea that the period of such waves as are discussed herein may not be meaningful in describing wave characteristics. Harris[1] indicates that, for the conditions of his study, estimates of wave height are consistent, but estimates of wave period are not. In keeping with this, the question has been asked: "If you are going to use wave period, which period will you choose?"

A frequent application of wave theory is in the calculation of wave forces on marine structures. The more common of such applications seem to be of a nature requiring a knowledge of the orbital motion of water particles in transmitting the wave form. When one considers an actual sea wave of the type under discussion, a reliable knowledge of the "orbit" in which the water particle moves and the kinematics associated therewith seems questionable in the extreme. Theories which have been considered include variations of those by Airy and Stokes, the cnoidal theory and its limiting case, the solitary wave. Of course, a truly solitary wave is associated with a shift of the water particles in the direction of wave motion, without a return to the proximity of their initial positions. According to Le Mehaute, et al[2], laboratory tests of shallow water waves show the cnoidal theory to be the most generally acceptable of those considered. However, the orbital behavior that is characteristic of the large, long period waves, for which the period loses significance as the waves move shoreward, remains an open question.

Hydraulic model studies of wave forces on marine structures are frequently concerned with long period waves of the type under discussion herein. In order to insure as high a degree of similarity of model and prototype waves as practicable, it has been the practice of at least some investigators to generate waves for which the crests are relatively far apart and which appear to be more or less independent of one another. The profile of each wave is rather similar to that of a solitary wave. This practice seems to have been a reasonable approach to the problem.

In connection with various structural studies, the authors have used facilities available to them for generating such waves. Those facilities have again been used to enable illustration of points with which this paper is concerned. For a wave height to stillwater depth ratio of 0.43, the wave profile is that shown in Fig. 1, and an associated "orbit" is shown in Fig. 2. As previously indicated, the wave profile is rather similar to that of a solitary wave. As to whether the "orbits" of the water particles conform satisfactorily to any of the better known theories is a matter of opinion.

The trace shown in Fig. 2 was obtained by photographing reflected light from a small-diameter sphere of neutral buoyancy during the passage of a single wave through water within which the sphere was suspended. Study of "orbits" associated with the passage of numerous widely separated waves enables the following comments: (a) The "orbits" were relatively flat on the bottom side; (b) The vertical height or diameter of the "orbits" increased with distance removed from the bottom of the basin; (c) The extreme landward (right-hand in Fig. 2) portion of the "orbit" was usually more smoothly rounded than the extreme seaward portion; (d) The speed of the spheres usually appeared to be more or less the same throughout the "orbit," except for a pause at the extreme seaward (left-hand in Fig. 2) portion of the "orbit" until the next wave arrived; and (e) In the immediate vicinity of the bottom of the basin, the "orbits" were horizontal back and forth movements.

It is expected that the large, long period waves will break or collapse at some stage of their shoreward progress, with a relatively abrupt change in characteristics. Also, an actual sea wave is a spectrum of waves. That is, the actual wave is an intricate composite of many waves having different characteristics. Hence, even more problems in identifying and describing the "orbit" of a water particle are encountered.

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.

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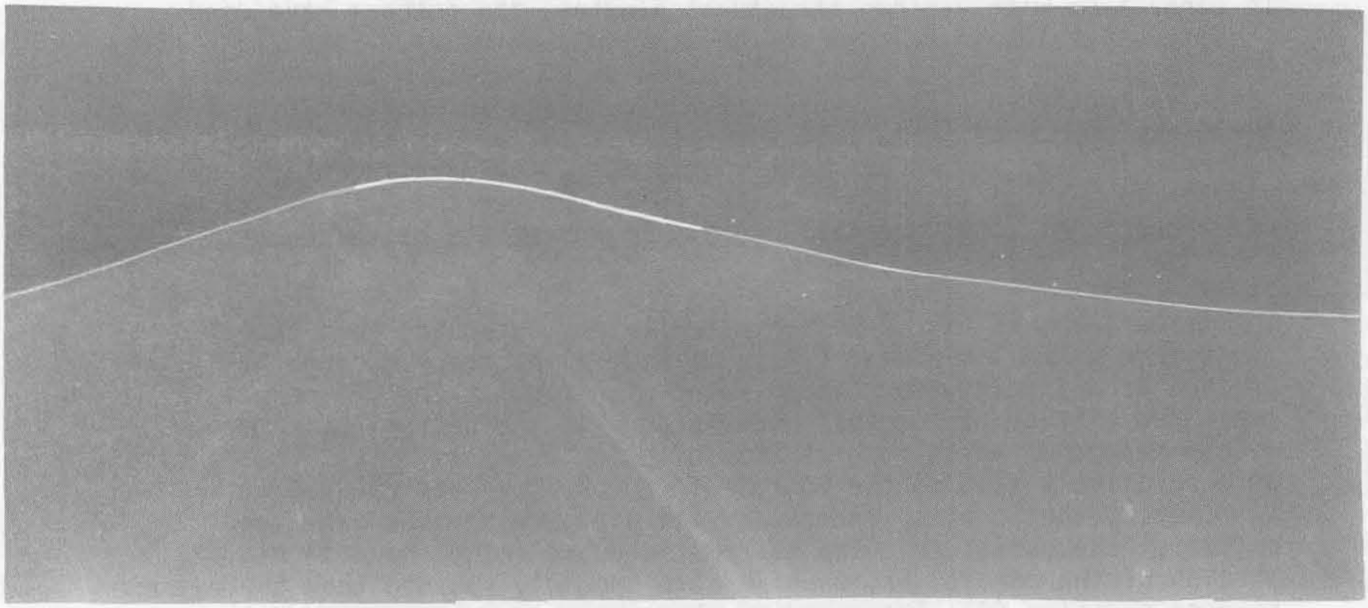

Fig. 1 - Wave profile

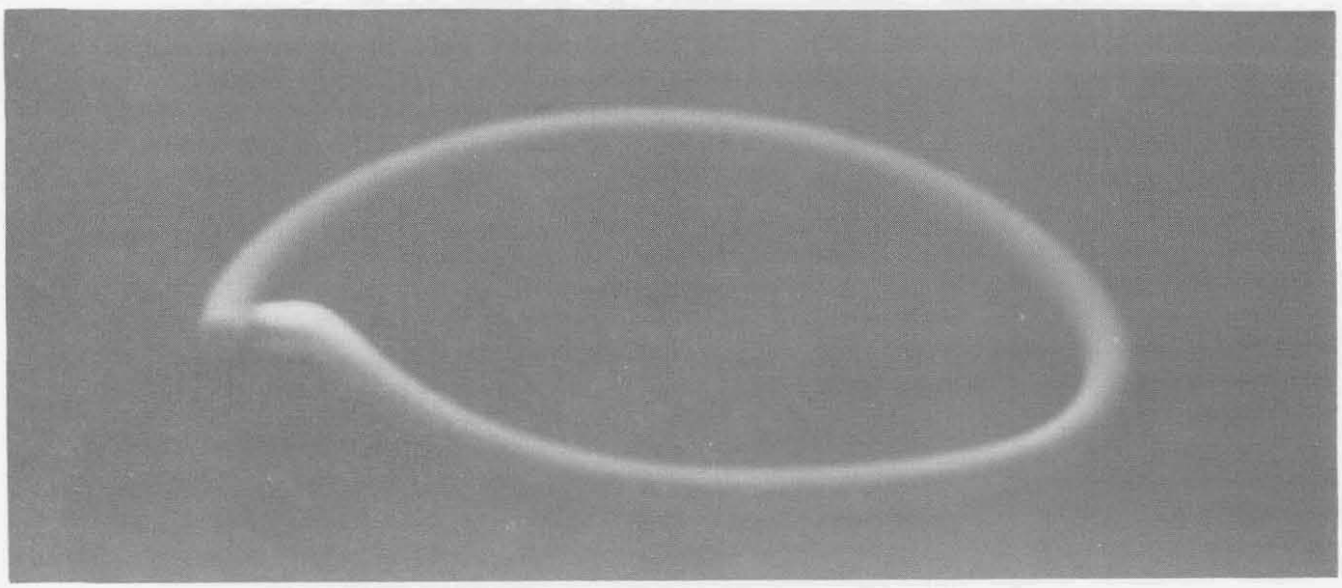

Fig. 2 - Orbit