CHAPTER 105

SCALE EFFECTS OF WAVE TRANSMISSION THROUGH PERMEABLE STRUCTURES

by

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The energy in waves which impinge on a porous structure, such as a rubble mound breakwater, is divided into reflected energy, transmitted energy, and the energy dissipated by turbulence within the structure. Numerous studies on various aspects of this problem have been made in the past, the most recent of which are those by Kondo (1970) and Sollitt and Cross (1972). The reader is referred to these latter papers for a literature review and the presentation of the theory of wave transmission through a porous media (also see the previous chapters by these same authors). In the studies by Sollitt and Cross (Chap. 103), the porous media consisted of crushed stone; whereas, in the tests by Kondo (Chap. 104) the porous structure consisted of a lattice of circular cylinders. Experimental data which supplement the data obtained in the tests of Kondo, Sollitt and Cross where made at the University of California on a series of three structures constructed of closely packed uniform spheres. Each structure was installed in turn in a wave channel and subjected to wave action with the wave height being measured both seaward and leeward by resistance-type wave gages. The experimental procedure and results are summarized as follows.

EXPERIMENTAL PROCEDURE

The experimental work was performed over a horizontal bottom in a wave channel 3 ft deep, 1 ft wide and 106 ft long. Plastic-coated horsehair was placed in the ends of the wave tank to damp wave energy reflections (Fig. 1). The wave flap could be adjusted to the desired frequency by use of a vari-drive electric motor. Also the eccentricity could be adjusted to produce a wide range of wave heights.

Using the Froude law for scaling and considering the largest structure to be the control model with the smaller units as models, the following conditions were used in the tests of the three structures (see Table 1).

A structure was placed in the wave tank at the desired location. Side effects were minimized by extending the test section across the full width of the channel, thus simulating the condition of an infinitely wide structure.

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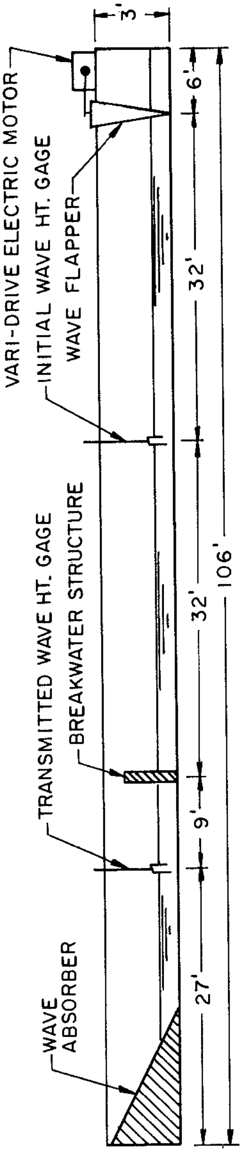
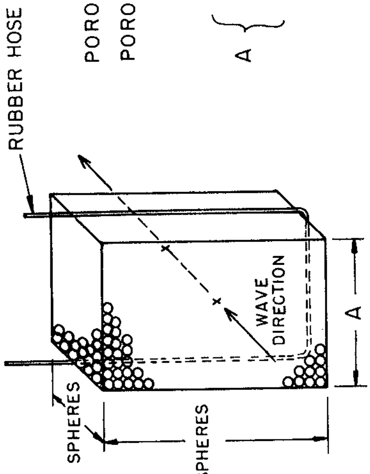


FIG. 1 SKETCH OF 3' x 1' x 106' WAVE CHANNEL



POROSITY = 1.0 - PACKING FACTOR

POROSITY = 1.0 - $\frac{\text{PARTICLE VOLUME}}{\text{BULK VOLUME}}$

A { CONTROL 5 SPHERES, DIA. = 2.125"
MODEL 1:2 10 SPHERES, DIA. = 1.063"
MODEL 1:4 20 SPHERES, DIA. = 0.532" }

FIG. 2 SKETCH OF BREAKWATER STRUCTURE

To prevent leakage between the structure and the walls of the wave channel, a rubber hose was extended around the bottom and sides of the structure (Fig. 2). The water depth and wave period was selected from Table 1 for a particular structure.

TABLE 1.--TEST CONDITIONS

Structure	Structure Length (ft)	Water Depth (ft)	Sphere Diameter (in)	Porosity of Structure (%)	Wave Period* (sec)	Reynolds No. $d^2/T\nu$
Control Model	1.0	1.6	2.125	40	1.9	1360
1:2 Model	0.5	0.8	1.063	40	1.34	481
1:4 Model	0.25	0.4	0.532	40	0.95	170

*Time scale = square root of length scale.

A parallel-wire resistance type wave gage and strip-chart recorder were used to record the incident and transmitted wave height. With the water level in the wave tank motionless, the experiment was begun by starting the strip-chart recorder and the wave generator. Recorded data were the incident wave height (H_i) and the transmitted wave height (H_t). Measurements taken from the wave records were based on fully developed waves, uninfluenced by reflection distortions, beats, or standing waves.

The wave characteristics were obtained as follows: d/L was held constant by maintaining a constant wave length (constant wave period) while adjusting the height of the incident wave (see Table 2).

RESULTS AND DISCUSSION

Using the experimental data the transmission coefficient (H_t/H_i) was calculated and plotted against the wave steepness (H_i/T^2) for each structure as shown in Fig. 3 (For the plotted relationships, H_i/T^2 replaced H_i/L, where L is wave length).

Examination of Fig. 3 shows that the Froude law is not the only factor involved in this model study. This is evident particularly at small wave steepnesses, (H_i/T^2). Using the experimental data, when (H_i/T^2) = 0.02, H_t/H_i = 0.5, 0.4 and 0.3 for the control model, model 1:2, and model 1:4, respectively. The reflected energy is probably a function of the Froude number as well as the porosity of the structure; that is, the energy dissipated by turbulence within the structure is probably a function of a Reynolds number.

TABLE 2

TABULATION OF H_t/H_i vs. H_i/T^2

RUN NO.	H_t/H_i	H_i/T^2	
1	1.08	.0032	
2	.924	.0054	
3	.842	.00772	
4	.598	.0137	
5	.565	.0159	
6	.535	.0188	Control Model
7	.492	.0224	T = 1.9 sec.
8	.487	.0240	$1/T^2 = 2.77 \times 10^{-1}$ sec.$^{-2}$
9	.434	.0277	
10	.436	.0291	
11	.482	.0277	
12	.467	.0294	
13	.467	.0294	
14	.468	.0308	
1	.402	.0153	
2	.344	.0259	
3	.288	.0368	
4	.265	.0474	
5	.260	.0557	
6	.244	.0664	Model #1
7	.192	.0770	T = 1.34 sec.
8	.174	.0849	$1/T^2 = 5.57 \times 10^{-1}$ sec.$^{-2}$
9	.157	.102	
10	.149	.1085	
11	.144	.1210	
12	.141	.1235	
13	.136	.1290	
14	.129	.1360	
1	.219	.0304	
2	.194	.0487	
3	.174	.0703	
4	.164	.0914	
5	.160	.111	
6	.143	.132	Model #2
7	.126	.150	T = 0.95 sec
8	.114	.171	$1/T^2 = 1.11$ sec.$^{-2}$
9	.130	.153	
10	.135	.132	
11	.137	.137	
12	.114	.130	
13	.130	.123	
14	.108	.123	

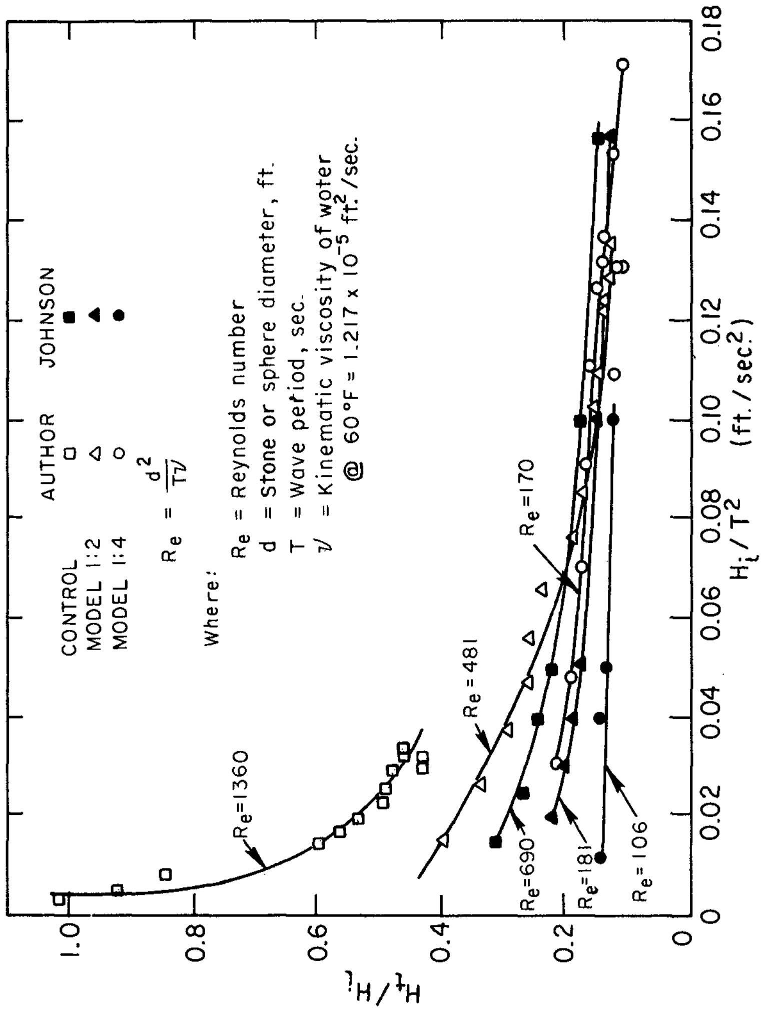


FIG. 3 PLOT OF TRANSMISSION COEFFICIENT (H_t/H_i) VERSES WAVE STEEPNESS (H_i/T^2)

Obviously, additional and more controlled experiments are required to completely define the limits in which scale models can be used to predict the transmission of wave energy through breakwater structures.

REFERENCES

Kondo, H. (1970). An analytical approach to wave transmission through permeable structures, Coastal Engineering in Japan, Vol. 13, 1970, pp. 31-42

Sollitt, C. K. and Ralph H. Cross, III (1972). Wave reflection and transmission at permeable breakwaters. Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Report No. 147, March 1972.