A COMPARISON OF REGULAR AND WIND-GENERATED WAVE ACTION ON RUBBLE-MOUND BREAKWATERS

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ABSTRACT

The general purpose of this research is to study wave action on rubble-mound breakwaters with periodic waves on the one hand, and random wind generated waves on the other hand, and to compare the effects of these two types of waves by use of the storm duration.

With the first serie of periodic waves experiments, we obtained the destruction of breakwater cover-layer for different storm durations t, and waves height H and period T. The risk criterion is :

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$$\frac{t}{T} = - A \log \left(\frac{H^2}{\nu T}\right) + B$$

A and B being constantes, ν the kinematic-viscosity.

With the second serie of tests, with random wind generated waves, we found that the destruction during the same storm duration was obtained for a significant wave height $H_{1/3}$ equal to the constant periodic wave height H. This is an experimental demonstration of the use of $H_{1/3}$ to study breakwaters on scale models.

MODEL

The studies (Ref.1) were made in two wave-flumes with the scale 1/40 (Fig.1) filled with water to the level 0.35 m (14 m in nature,

The breakwater profiles had three layers of stones of specific gravity 2.6 g/cm^3, weighed one by one, and arranged always in the same way for all experiments. Their size distributions for each layer were (Fig.2) :

layer A : 50 - 80 g (3-5 tons in nature)
layer B : 20 - 50 g (1.5-3 tons in nature)
layer C : 5 - 25 g (0.32-1.6 tons in nature).

Four slopes of profiles were tested (30, 32, 34 and 36 degrees).

The storm duration t, corresponding to the destruction of breakwater, was the time of the test for which the complete destruction of profile was obtained. In fact when the cover-layer was destroyed, all the profile was radidly broken up.

EXPERIMENTS WITH PERIODIC WAVES

For each slope of profile, 16 tests were made with 4 wave periods : 0.948, 1.265, 1.581 and 1.897 s (6, 8, 10, 12 s in nature) and 4 wave heights : 0.05, 0.075, 0.10 and 0.125 m approximately (2,3,4 and 5 m in nature).

During the first minutes of every experiment the profile slope was transformed to a discontinious seaward profile (Fig.3), by moving of armor units from the upper part to the lower part of the slope, with the 3 angles : $\alpha_1 = 43°$ $\alpha_2 = 21°$, $\alpha_3 = 38°$ approximately. If the equilibrium profile did not reach the every layer, it was no risk of destruction ; the profile was stabilised and every test lasted 3 hours 45 minutes (24 hours in nature). If the second layer was reached the destruction was rapidly obtained, and then the storm duration was noticed.

The wave height H was obtained from a record of the clapotis along the channel.

The relationship among t, H and T is researched as a correlation between the number of waves $\frac{t}{T}$ required for destruction of the profile and the dimensionless parameter $\frac{H^2}{\nu T}$. We found (Fig.4) :

$$\frac{t}{T} = - A \log \left(\frac{H^2}{\nu T}\right) + B \qquad (1)$$

with the coefficient of correlation r = 0.796.

EXPERIMENTS WITH RANDOM WIND GENERATED WAVES

Random waves were induced by an air flow over the channel. By variation of fetches (up to 30 m) and cycles of starts-off and stops of wind (velocity 0 or 9.4 m/s), a sufficient variety of wave heights and periods were obtained. Surface elevations were measured during 4 minutes with a sonar every 0.1 s and punched on a paper tape. A resistance wave gauge gave a picture of waves.

The purpose of this experiments was to destroy the total cover-layer in approximately the same time as in test with periodic waves. A series of preliminary experiments showed that it was possible to obtain only 8 kinds of random waves producing the same effects among the 13 destructions by periodic waves.

The 8 tests were made again involving the following operations :

- construction of the model,
- choice of fetch and cycle of wind,
- regulation of wind deflector to prevent the direct effect of wind on the breakwater,
- starting of blower,
- records of waves by sonar and resistance wave gauge at the beginning and the end of the test,

During the random waves experiments the evolution of the equilibrium profile was little different as for periodic waves ; the three different slopes (Fig.3) were $\alpha_1 = 46°$, $\alpha_2 = 19°$, $\alpha_3 = 36°$.

Every tape record contained 2,400 values which were punched on cards and investigated using a CDC 6600 digital computer. Figures 5 and 6 give a example of autocorrelation function R(J) and spectral density SP(J). This values were obtained from the N = 2 200 discreetized observations X(I) for each record, using the following equations (Ref.2) :

- for autocorrelation function (J = 0, 1, 2 ... 200)

$$R(J) = \frac{\sum_{I=1}^{N-J} X(I).X(I+J)}{\sum_{I=1}^{N-J} X(I)^2} \qquad (2)$$

- for special density

first a first approximation

$$LP(J) = \frac{1}{N}\sum_{1}^{N} X(I)^2 + 2\sum_{K=1}^{K=N-1} \frac{1}{N-K}\left[\sum_{I=1}^{N-K} X(I).X(I+K)\right]\cos\frac{KJ\pi}{N}$$

$$+ \frac{1}{N-200}\left[\sum_{I=1}^{N-200} X(I).X(I+200)\right]\cos J\pi \qquad (3)$$

and finally after smoothing by Hamming

$$SP(J) = 0.23\ LP(J) + 0.54\ LP(J+1) + 0.23\ LP(J+2) \qquad (4)$$

The wave heights H_r and periods T_r for every sample were obtained using the zero-up-crossings method. The seiches were eliminated using a moving-mean over 75 points. H_r and T_r values were classed in increasing order, to evaluate the mean values $H_{n/m}$, $T_{n/m}$ ($n = 1, 2, 3$; $m = 1, 2 ..., 10$) and the joint distributions (example on Fig.7).

** The main result is that the significant wave height $H_{1/3}$ of random waves producing the destruction of the breakwater in the same time that periodic waves, is equal to the height H of this periodic waves. This is an experimental demonstration of the empirical and theoretical assumption that $H_{1/3}$ is the representative wave height and this of the justifiable use of $H_{1/3}$ as a project wave height.

REFERENCES

1 - Rogan A.J. ; Comportement des jetées en enrochements vis-à-vis de la houle ; Bulletin de la Direction des Etudes et Recherches, Electricité de France, série A, 1968, volume 3.

2 - Blakman R.B. and Tukey F. ; The measurement of power spectra from the point of view of communications engineering ; Dover Publ.Inc.; New York , 1969.

LIST OF SYMBOLS

A,B	constantes
$\alpha_1, \alpha_2, \alpha_3$,	slopes of profiles
H	height of periodic waves
H_r	height of random waves
$\overline{H} = H_{1/1}$	mean value of H_r in a record
$H_{1/3}$	significant wave height
T	period of periodic waves
T_r	period of random waves
$\overline{T}$	mean value of T_r in a record
t	storm duration
ν	kinematic viscosity
R(J)	autocorrelation function (equation 2)
LP(J)	first approximation of spectral density (equation 3)
SP(J)	spectral density (equation 4)
X(I)	discreetized observation in a record.

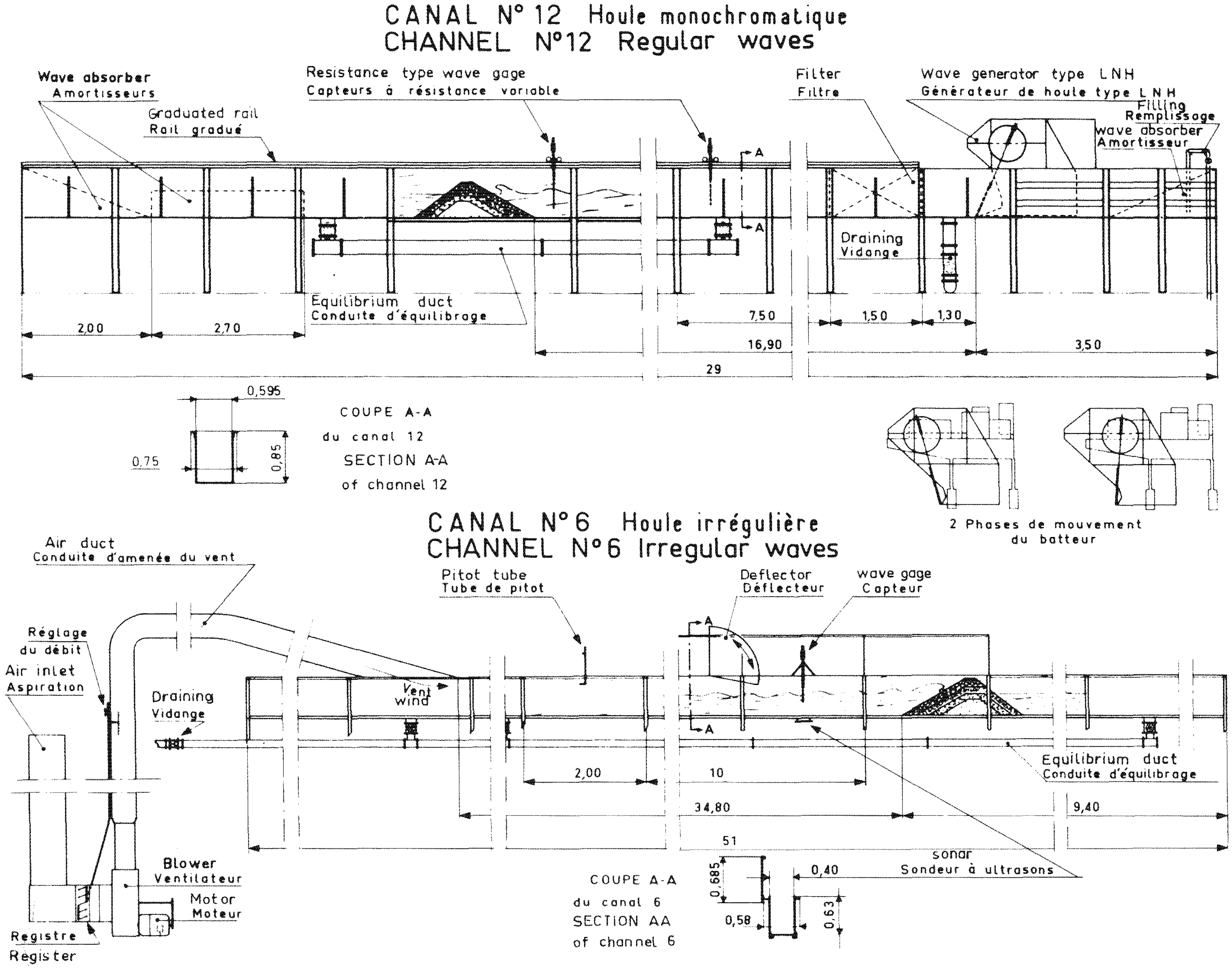

Fig. 1 Description of wave-flumes.

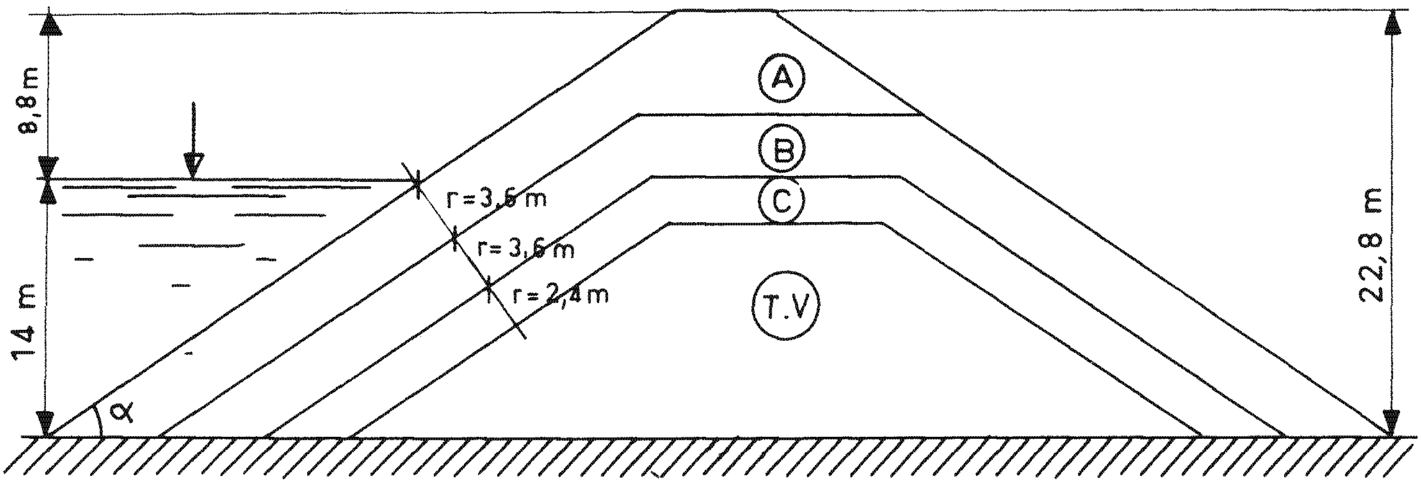

Fig. 2 Type of profile.

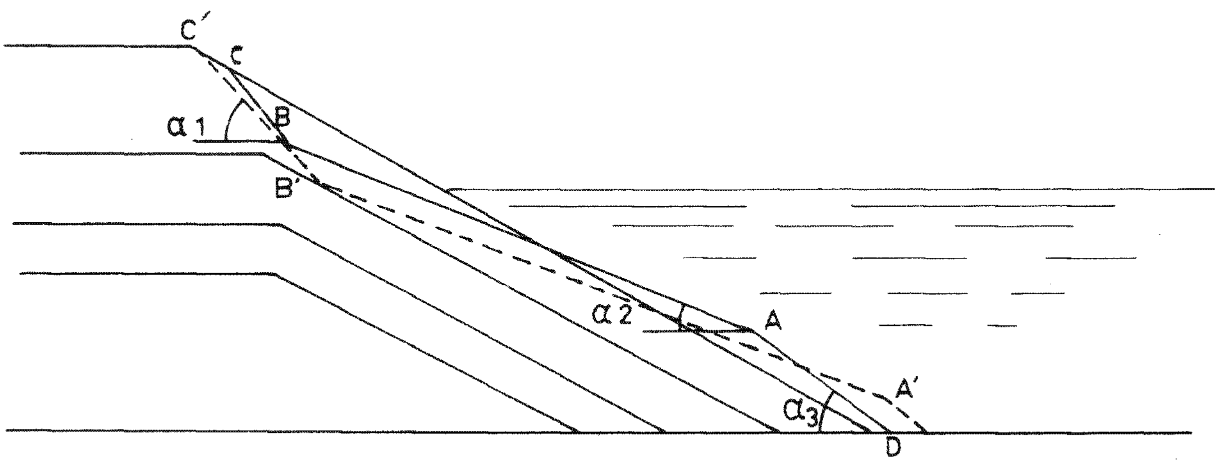

Fig. 3 Transformation of profile.

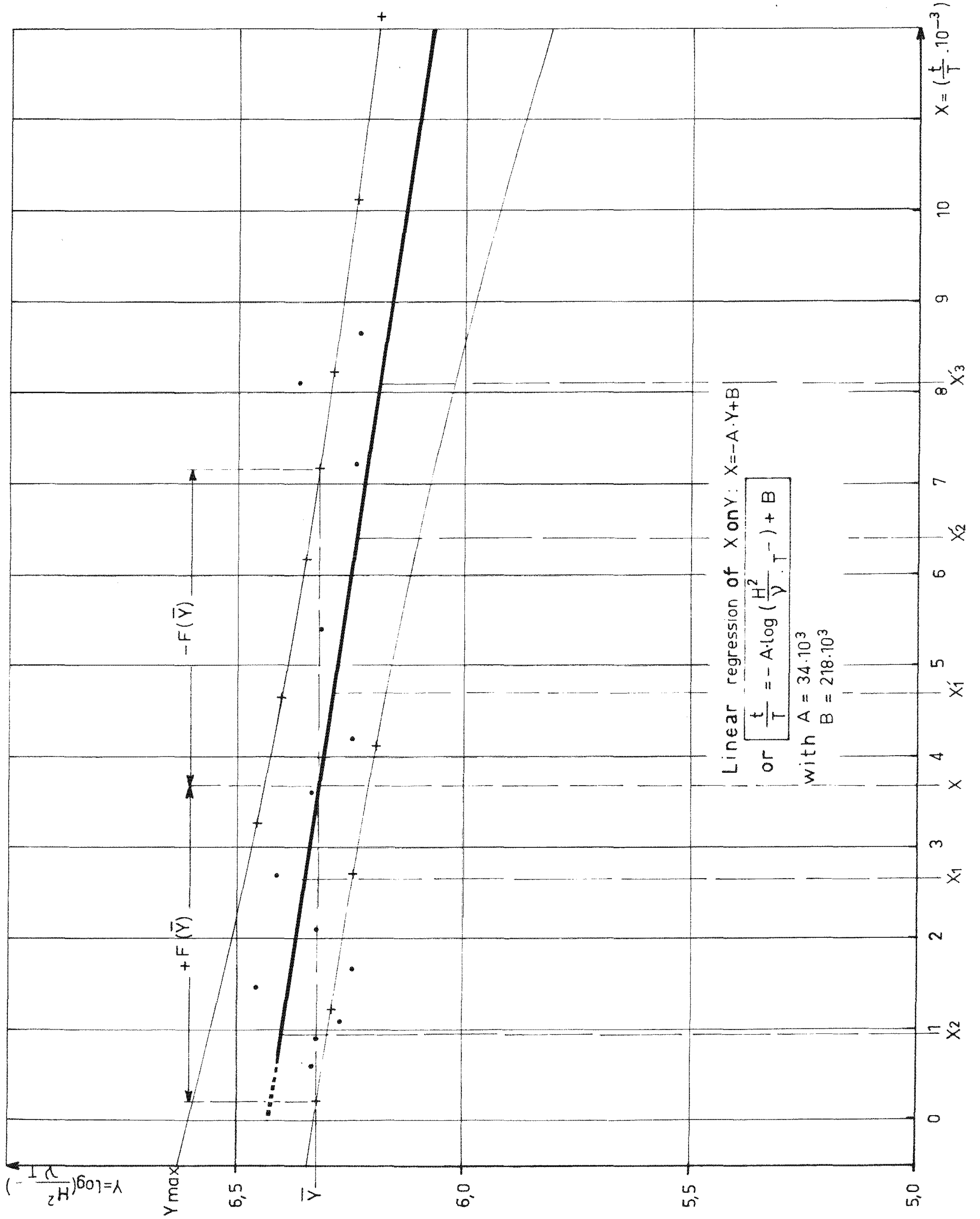

Fig.4 Correlation between $H^2/\nu T$ and t/T.

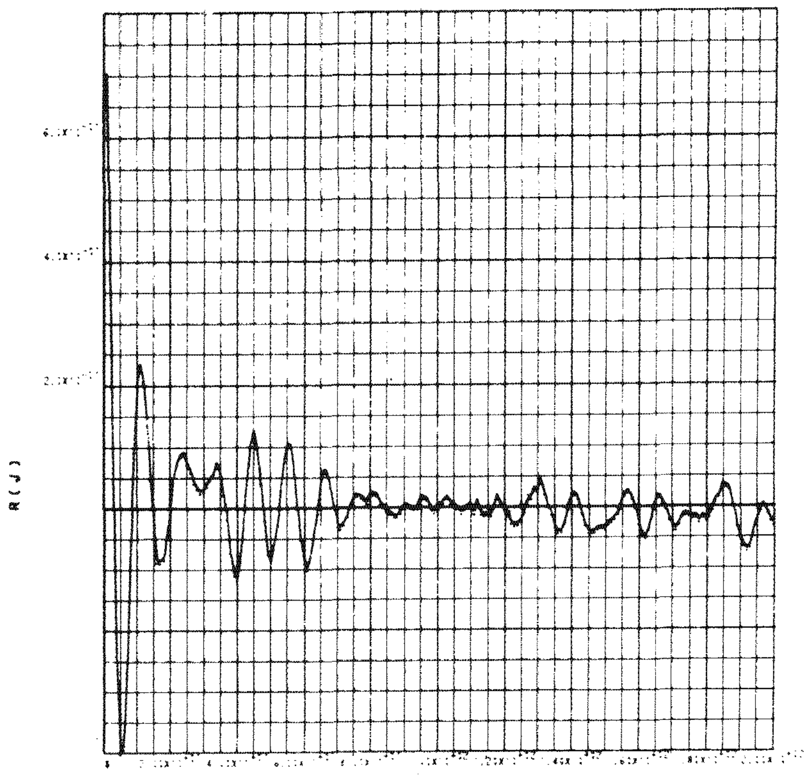

Fig. 5 Autocorre.ation function R(J).

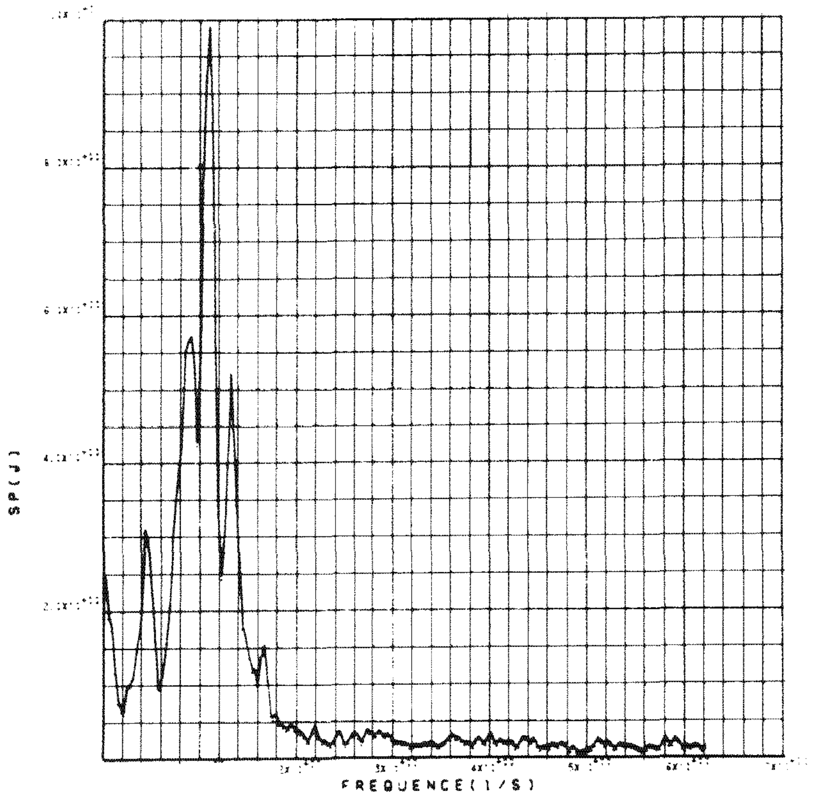

Fig. 6 Spectral density.

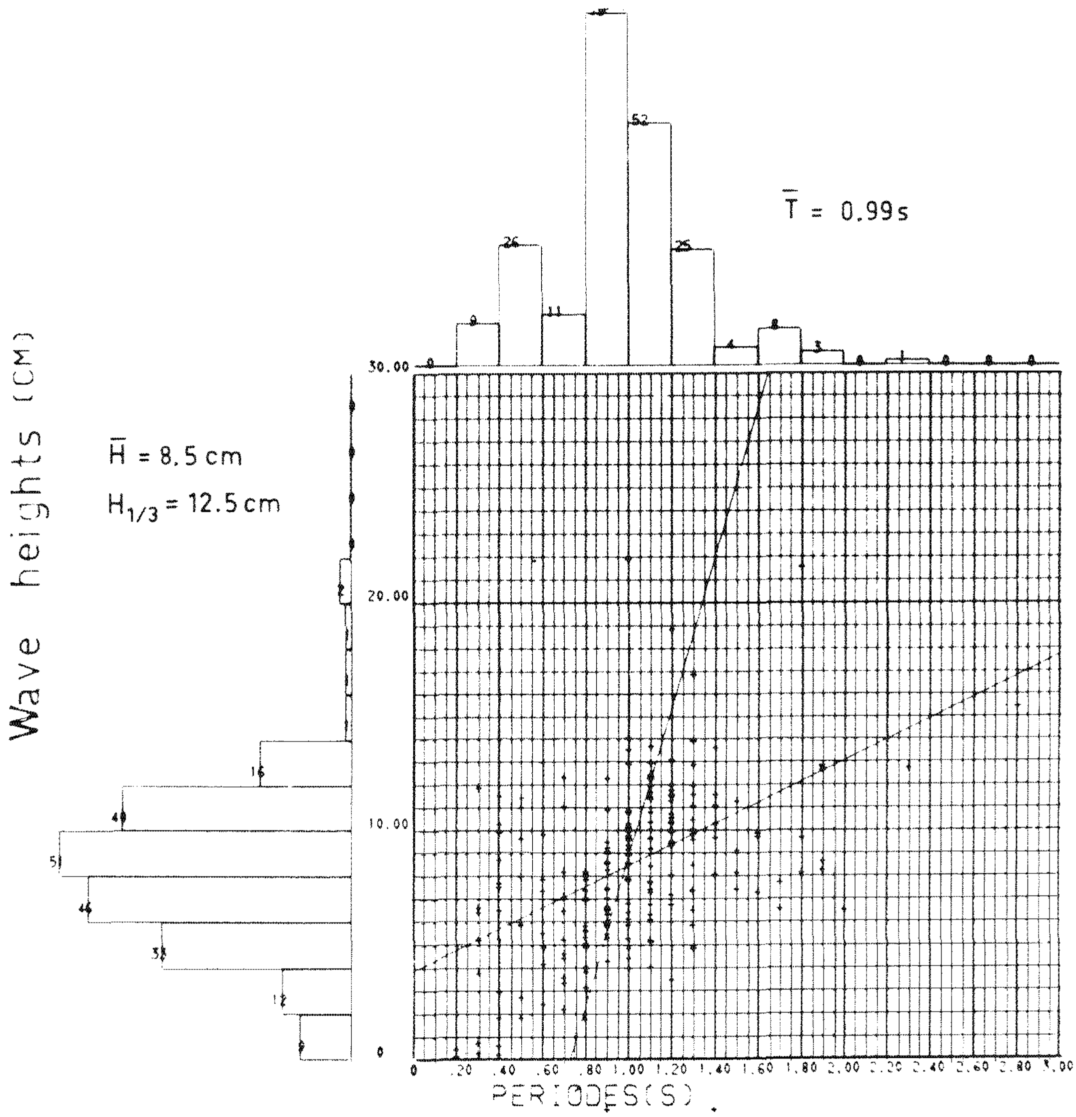

Fig. 7 Joint distribution of H_r and T_r.

DISCUSSION ON PAPER 3

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When the well-known Navier Stokes equation

$$\rho \frac{\delta v}{\delta t} + \rho v \ \text{grad} \ v = - \text{grad} \ p + \rho g + \eta \nabla^2 v \tag{1}$$

is plotted in a dimensionless way, dividing every term by a characteristic reference value, the following equation is obtained (Ref. 1):

$$Sr \frac{\delta \bar{v}}{\delta \bar{t}} + \bar{v} \ \text{gr}\bar{\text{a}}\text{d} \ \bar{v} = - \frac{1}{\bar{\rho}} \frac{1}{Eu} \ \text{gr}\bar{\text{a}}\text{d} \ p + \frac{1}{Fr} \bar{g} + \frac{1}{Re} \ \bar{\nu} \ \bar{\nabla}^2 \ \bar{v} \tag{2}$$

with

$$Sr = \frac{L_*}{v_* t_*}$$

$$Eu = \frac{\rho_* v_*^2}{p_*}$$

$$Fr = \frac{v_*^2}{g_* L_*}$$

$$Re = \frac{v_* L_*}{\nu_*}$$

L_*, v_*, t_* etc. being the characteristic reference values and $\bar{v}$, $\bar{t}$ etc. being the dimensionless parameters.

Substituting

$$L_* = H \text{ (wave height)}$$
$$t_* = T \text{ (wave period)}$$
$$v_* = \frac{H}{T}$$

in equation (2) gives

$$\frac{\delta \bar{v}}{\delta t} + \bar{v}\ \mathrm{grad}\ \bar{v} = -\frac{1}{\rho}\ \frac{p_* T^2}{\rho_* H^2}\ \mathrm{grad}\ \bar{p} + \frac{g\ T^2}{H}\ \bar{g} + \frac{T\ \nu}{H^2}\ \bar{\nu}\ \bar{\nabla}^2\ \bar{v} \qquad (3)$$

Accepting the average values for g and ν, it follows that the influence of gravity exceeds greatly that of viscosity provided velocity gradients are not too high.

Hydraulic phenomena, and hence damage as a result thereof, should be characterized by the parameter $\frac{g\ T^2}{H}$ rather than by the parameter $\frac{T\ \nu}{H^2}$ as was used by the authors.

If their relationship between $\frac{H^2}{\nu T}$ and $\frac{t}{T}$ is true, the equivalent time of demolition in prototype should be computed according to the Reynolds scale Law rather then according to the Froude's Law as was done by the authors.

** It is expected that results obtained when plotting $\frac{t}{T}$ against $\frac{g\ T^2}{H}$ will be different for regular waves and irregular wind-generated waves, since the value of $\frac{g\ T^2}{H}$, being a measure for the initial wave steepness, will be different in both cases.

Ref. 1: Vossers, Prof. dr. ir. G., "Inleiding tot de theorie van modellen en modelwetten", De Ingenieur, 1966, Dec. 2, pp. W 231 - W 238, (in Dutch with English summary).