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# FORCED SURFACE - WAVES ON SLOPING BEACHES

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## الأمواج القسرية السطحية على الشواطئ المائلة

الخلاصة : يقدم هذا البحث دراسة معملية لتعيين أداء وفاعلية مولد الأمواج من نوع (flap) على الشواطئ المائلة أخذا فى الاعتبار ، الترددات المختلفة ، أعماق المياه وذلك فى وجود زوايا مختلفة لميل الشاطئ. وقد تم تسجيل القياسات المختلفة لشكل الموجة عند أماكن مختلفة على طول القناة المعملية.

وأوضحت هذه الدراسة أن إرتفاعات الأمواج تزداد عند زيادة عمق المياه وأن الأمواج تتضاءل عند موضع معين على طول القناة وذلك نتيجة تأثير الضحالة وتكسر الأمواج. كذلك وجد أن مولد الأمواج من نوع (flap) له فاعلية فى توليد الأمواج تصاعدياً فى المنطقة الأولى من قناة الأمواج.

**Abstract :**

An experimental study is prepared to determine the efficiency and performance of flap type wave generator on a sloping bed. The experimental runs are made for different wave paddle frequency, different water depths and different beach slopes. The wave profile allover the flume length is measured at different locations. The wave height increase with the increasing of the relative water depth. A damping effect is exciting at a certain location of the flume due to the water shoaling and the wave breaking. It was concluded that, the flap type is an efficient device to generate progressive waves for the first regions of the wave flume.

**Introduction :**

The study of wave soil structure interaction may be analysed mathematically or experimentally or both. The experimental studies are carried out using tanks or wave flumes as long narrow enclosures with flap type wave generator. This generator is hinged support at the bed and connected by a flywheel at the top. In shallow water, *Galvin (1964)*[3] suggested a simply theory for the generation of waves by wave generators. He concluded that the water displaced the wave paddle should be equal to the crest volume of the propagating wave form. Galvin stated that, the wave height to stroke ratio (H/S) equals half the $kh_o$ value, where H is the wave height, S is the stroke length, k is the generating wave number and $h_o$ is the water depth at the wave paddle. This relation is given by the equation:

$$\frac{H}{S} = \frac{Kh_o}{2} \qquad (1)$$

This relationship is valid only in the shallow water region, $kh_o < \Pi/10$. There are other numerous investigators who have studied analytically the wave generating characteristics of vertical wave generators, among these are *Havelock (1929)*[4], *Biesel and Suquent (1951)*[1], *Ursel et al., (1960) and Madsen (1970)*[8]. *Gilbert et al., (1971) and Hammack (1973)* studied the behaviour of more usual generators, the former investigated the characteristics of a moving wedge and the latter studied the waves

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generated by the motion of a section of the bottom of a constant depth tank. Theoretical studies of long waves generation by the movement of continuously sloping beach have been concluded by *Tuck and Hwang (1972)*[(10)].

In this research behavior of the generating wave from the flap type wave generator on a continuously sloping beach under different bed slopes, water depths and wave paddle frequency has been conducted. Also, determination of the efficiency of flap type wave generator to generate progressive waves all over the tilting flume was studied.

**Experimental study :**

Experiments were carried out in the hydraulic laboratory, of Zagazig University to determine the performance of flap type wave generator in a tilting wave flume (Fig. 1). The flume dimensions are 12 m long. 0.45 m deep and 0.30 m wide. The flap type wave generator is hinged at the bed and connected with a flywheel and variable speed motor at the top. This wave generator predict surface waves having periods from 0.66 to 2.86 sec. The used stroke distance is 22 cm for all runs. The flume bed is tilting by different slopes, namely are 0.0%, 0.1%, 1.33% and 2%. A non-contact Ultrasonic water surface transmitter (OMEGA'S LV400) displays and transmits the fluctuation range of water surface with an accuracy of 1.0%. The wave height was measured at different stations 1.0 m apart along the wave flume for different water depths, wave periods and bed slopes.

**Results and analysis :**

The analysis of surface waves generated by wave paddle supporting on a sloping bed is performed under the different cases of bed slope, water depths and flap frequency. The dimensional analysis of this phenomena shows that the generated wave characteristics depend on the relative paddle frequency, the water depth to stroke length, bed slope and the relative distance from the wave paddle, i.e. :

$$\frac{H}{S} = \phi(\omega^2 h_o / g, h_o / S, S_b, x / h_o) \qquad (2)$$

Where, H is the generating wave height, S is the stroke length, $\omega$ is the angular wave frequency, $h_o$ is the water depth at the wave generator, $S_b$ the bed slope and x is the horizontal axis having its origin at the mean position of the paddle.

For the horizontal bed condition, the generated wave height increases as the relative paddle frequency ($\omega^2 h_o/g$) increases up to a certain limit as shown in figure (2). The resulting empirical formulae may be used to calculated the generated wave height for horizontal beach :

$$\frac{H}{S} = 0.5kh_o \tanh(kh_o) + 0.1 \qquad \text{for} \quad \omega^2 h_o/g \le 0.75\, h_o/S \qquad (3\text{-a})$$

$$\frac{H}{S} = 0.30\frac{h_o}{S} - 0.06kh_o \tanh(kh_o) \qquad \text{for} \quad \omega^2 h_o/g \ge 0.75\, h_o/S \qquad (3\text{-b})$$

For sloping beach, many relationships are presented for bed slopes 1%, 1.33% and 2.0% for different relative flap frequency and relative water depths. Figure (3) shows the relative generating wave height along the beach starting from the flap position up to the wave absorber at the flume end. Three relations for the generating wave height for the bed slope of 1.0% and $h_o/S$ = 0.95, 1.14 and 1.36 respectively. For $h_o/S$ =0.95, the wave height increases with decreasing the relative wave frequency with maximum value of H/S = 0.35 and the wave height slightly affected by the relative distance from the wave generator. For $h_o/S$ = 1.14 and 1.36 the generating wave height increases with increasing the relative wave frequency up to $\omega^2 h_o/g$ = 1.0, 1.2 and after that, the wave height decreases by recognizable value due to the wave shoaling and wave breaking.

Figure (4) shows the relative generating wave height for bed slope of 1.33% and $h_o/S$ = 1.03, 1.21 and 1.44 respectively. For $h_o/S$ range from 1.03 to 1.44, the wave height increases with increase of the relative wave frequency up to $\omega^2 h_o/g$ range from 0.58 to 0.84. After that, the wave height decreases with the increase of the relative wave frequency. For the frequency range from 0.58 to 0.84, the wave height becomes smaller at certain location along the wave flume ($x/h_o$ 20) due to the partially wave breaking.

Figure (5) shows that relative generating wave height for bed slope of 2.0% and $h_o/S$ = 1.18, 1.36 and 1.59 respectively. For $h_o/S$ range from 1.18 to 1.59, the wave height increases with the increase of the relative wave frequency up to $\omega^2 h_o/g$ range from 0.67 to 0.89. After that, the wave height decreases with the increase of the relative wave frequency. For the frequency range from 0.67 to 0.89, the wave height becomes smaller at certain location along the wave flume ($x/h_o$ 10) due to the partially wave breaking.

**Conclusions :**

Different relationships are performed for the characteristics of waves generated by a vertical wave paddle supporting on a sloping bed. The different conclusions are :

(1) The flap type wave generator is performed for horizontal beach and an empirical equation is derived taking into consideration the relative wave frequency and the relative water depth.

(2) The flap type wave generator is performed also for sloping beaches for different relative wave frequency and relative water depth.

(3) In general, the flap type wave generator is described as being efficient to generate progressive waves on sloping bed for some distance apart from the wave generator.

(4) There are some precautions must be used for the end reaches of the flume in which the waves are breaking due to water shoating especially for steep slopes.

**Notation :**

The following symbols are used in this paper :

- **g** : Acceleration of gravity;
- **H** : Wave height;
- **h** : Water depth;
- $h_o$ : Water depth at the wave paddle;
- **k** : Generating wave number;
- **S** : Total paddle width;
- $S_b$ : Bed slope;
- **X** : Horizontal axis ; and
- $\omega$ : Angular wave frequency.

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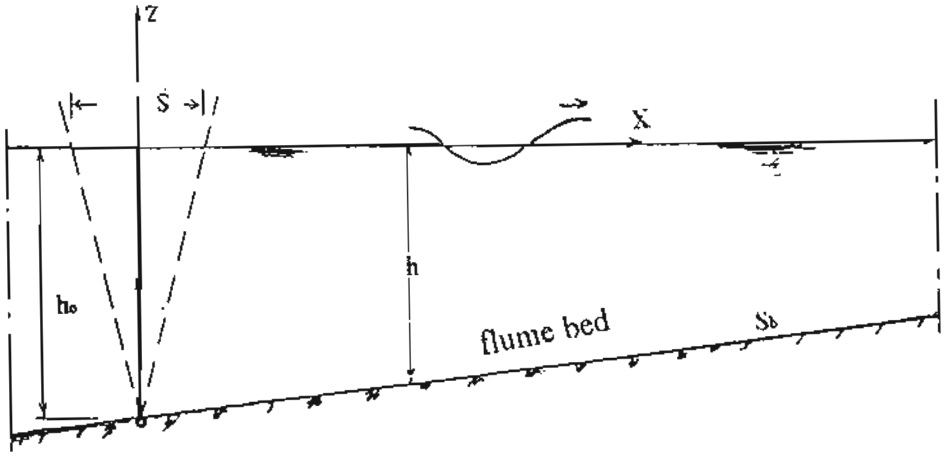


Fig. (1) : Schematic diagram of flap type wave generator.

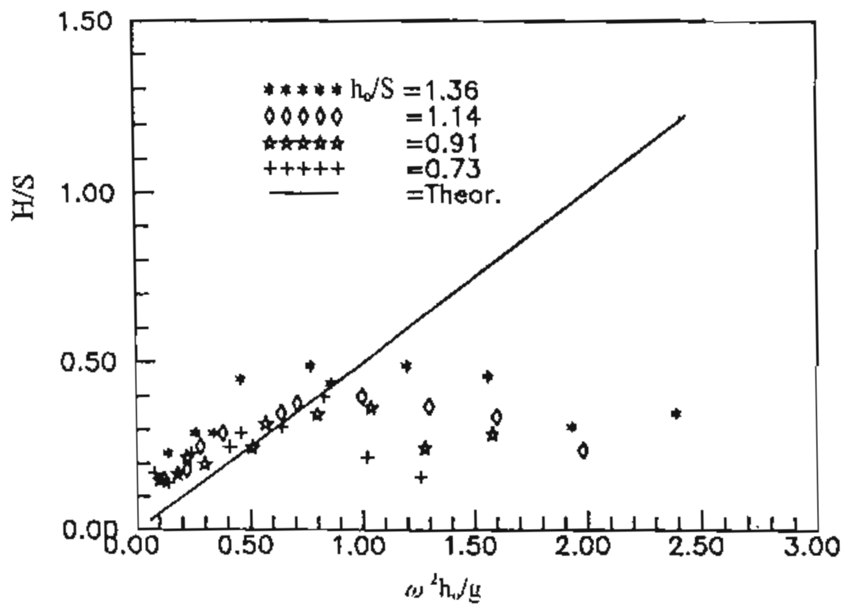


Fig. (2) : Influence of the relative paddle frequency on the relative wave height (H/S). ($S_b$=0)

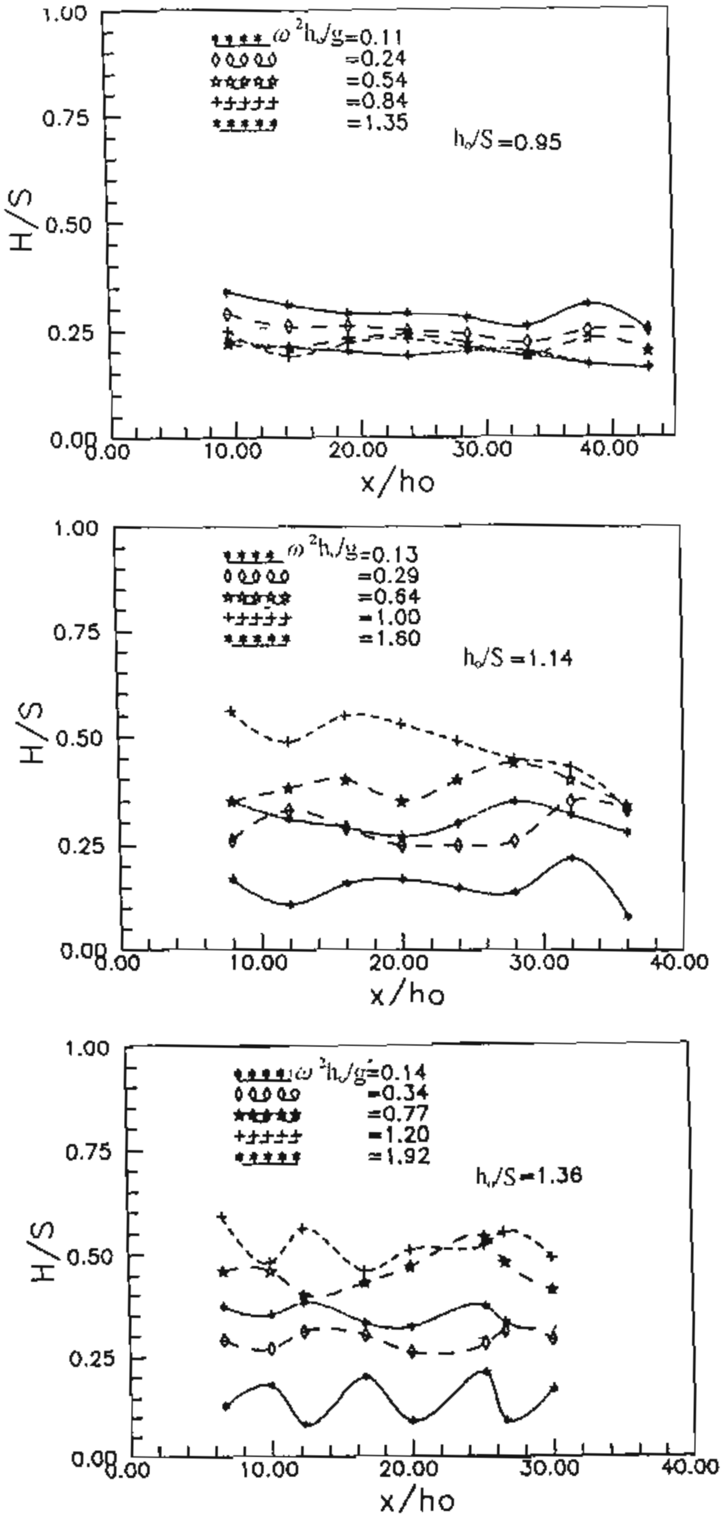


Fig. (3) : Influence of the relative distance ($x/h_o$) on the relative wave height (H/S) ($S_b$=1%).

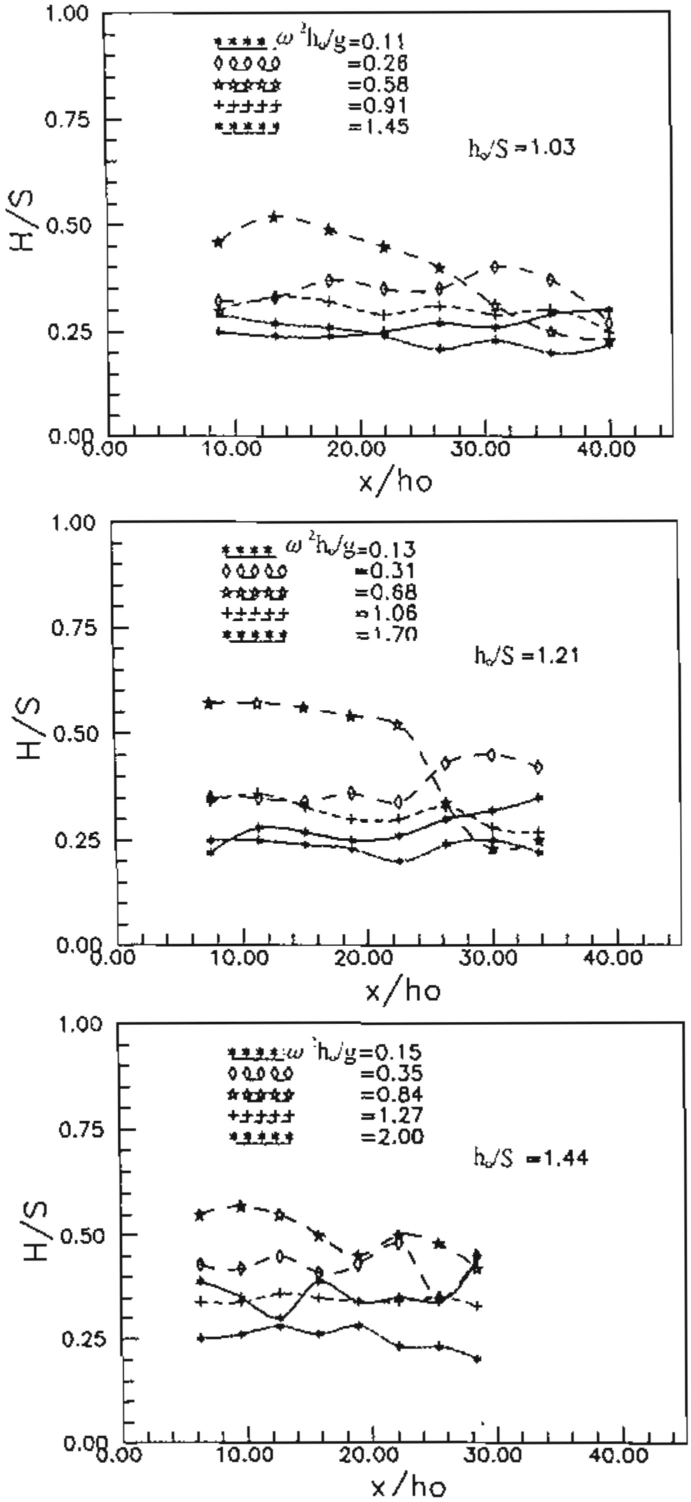


Fig. (4) : Influence of the relative distance ($x/h_o$) on the relative wave height (H/S) ($S_b$=1.33%).

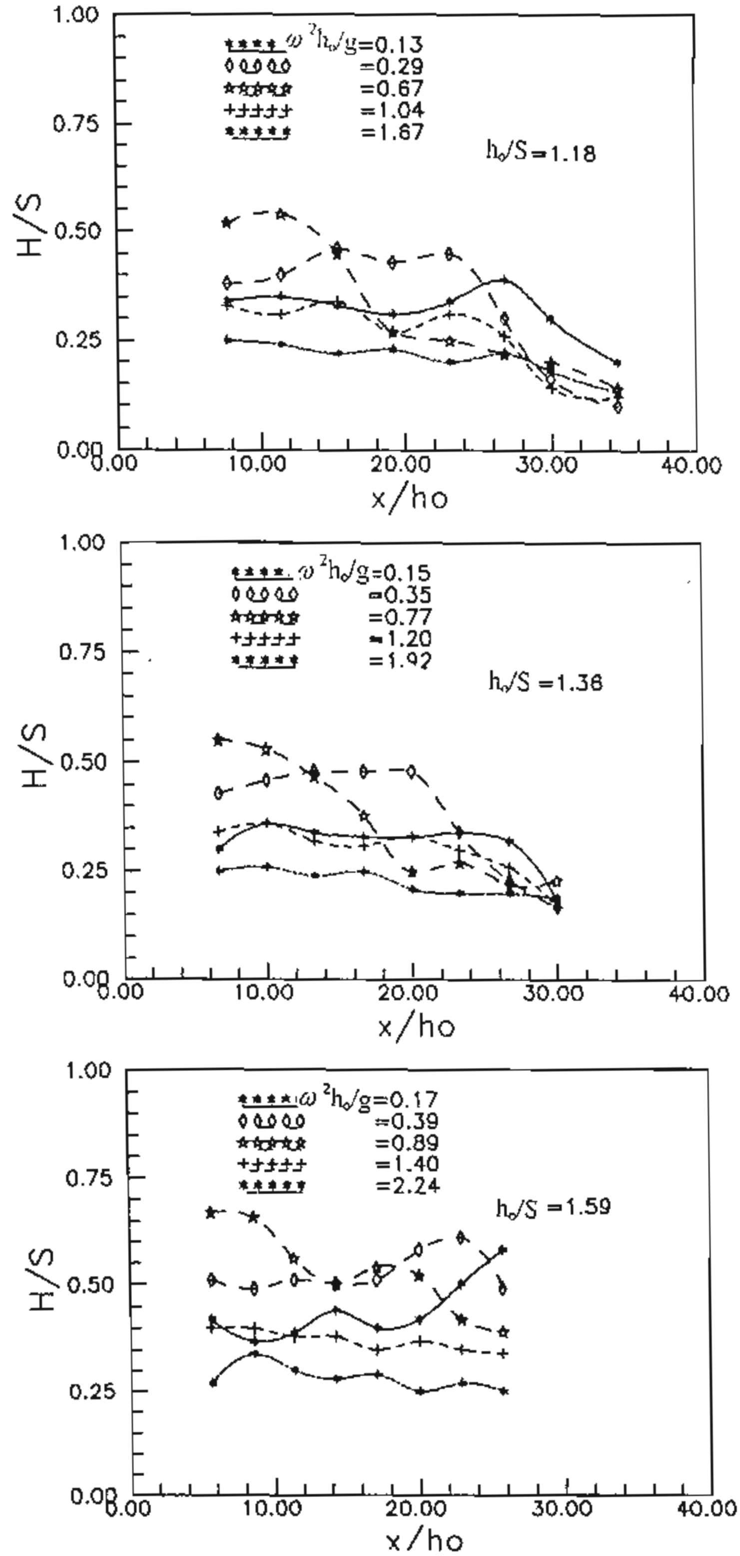


**Fig. (5) :** Influence of the relative distance ($x/h_0$) on the relative height (H/S) ($S_b$ = 2%)