CHAPTER 36

THE EFFECT OF ARTIFICIAL SEAWEED IN PROMOTING THE BUILD-UP OF BEACHES

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ABSTRACT

The paper describes tests carried out in the laboratory and in the field in an attempt to discover whether a field of artificial seaweed placed offshore can promote an onshore transport of bed material and hence a build-up of beach levels. Tests in a wave tank showed that beach levels could be built up in this way - the effect of the seaweed being to increase the net drift of bed water in the direction of wave propagation i.e. towards the shore. The field trials were not as conclusive as was hoped, but nevertheless some build-up of beach levels did take place at a time when erosion of the beach due to many storms might have been anticipated.

A simple hydrodynamic model is proposed to represent the effect of artificial seaweed on gravity waves. The model predicts increased wave attenuation and increased shoreward mass-transport consistent with the experimental results.

Introduction

Considerable interest has been shown in recent years in the use of artificial sea-weed as a means of building up beaches by promoting an on-shore transport of sand. The Hydraulics Research Station at Wallingford, in co-operation with Imperial Chemical Industries (Fibres) Ltd., have been investigating the idea in the laboratory and in the field.

Tests in a Wave Tank

A model beach was subjected to regular waves until surveys showed that stability had been achieved. A field of polypropylene "pony tails" were then placed in an off-shore position and again the model beach was subjected to the same waves until it was established that no changes were taking place. (See Plate 1, Fig. 1)

Plate 1. Artificial Seaweed.

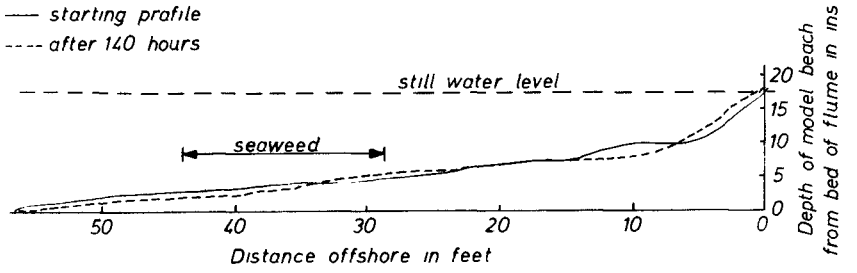

Fig. 1. Model beach with and without seaweed.

Many arrangements and spacing of "pony tails" were tried; the results shown in Figs. 1 and 2 were for the following test conditions. The "pony tails" consisted of 0.5 grammes of fibre having a specific gravity of 0.9 and a strand diameter of 0.055 mm. The strands, which were 3 in long, were spaced on a 3.6 in grid in the area shown in Fig. 1. The waves were 3 in high and had a period of 1.33 seconds.

The stable beach cross-sections, with and without the presence of sea-weed, are shown in Fig. 1. The result is typical of many experiments that were carried out; the effect of the sea-weed was to transfer material from the off-shore sea bed towards the shore causing an increase in beach levels.

The Effect on Wave Orbital Velocities

It was necessary to establish why an offshore field of artificial sea-weed promotes an onshore transport of sediment. To this end the change in the wave orbital motion at various cross-sections in the wave tank was established using a miniature propeller current meter having a high rate of response. The pulses from the meter were applied to a high speed pen recorder and the distances between pulses were measured by an electronic trace reader which automatically transferred the information on to punched cards suitable for processing on an IBM 1620 Digital Computer. This calculated the mean velocity between pulses and the time at which it was deemed to occur. One such record, for 10 consecutive wave periods, is shown in Fig. 2. (To speed up this time consuming process H.R.S. has recently developed a true instantaneous rate meter which produces a velocity plot directly on a high speed pen recorder.)

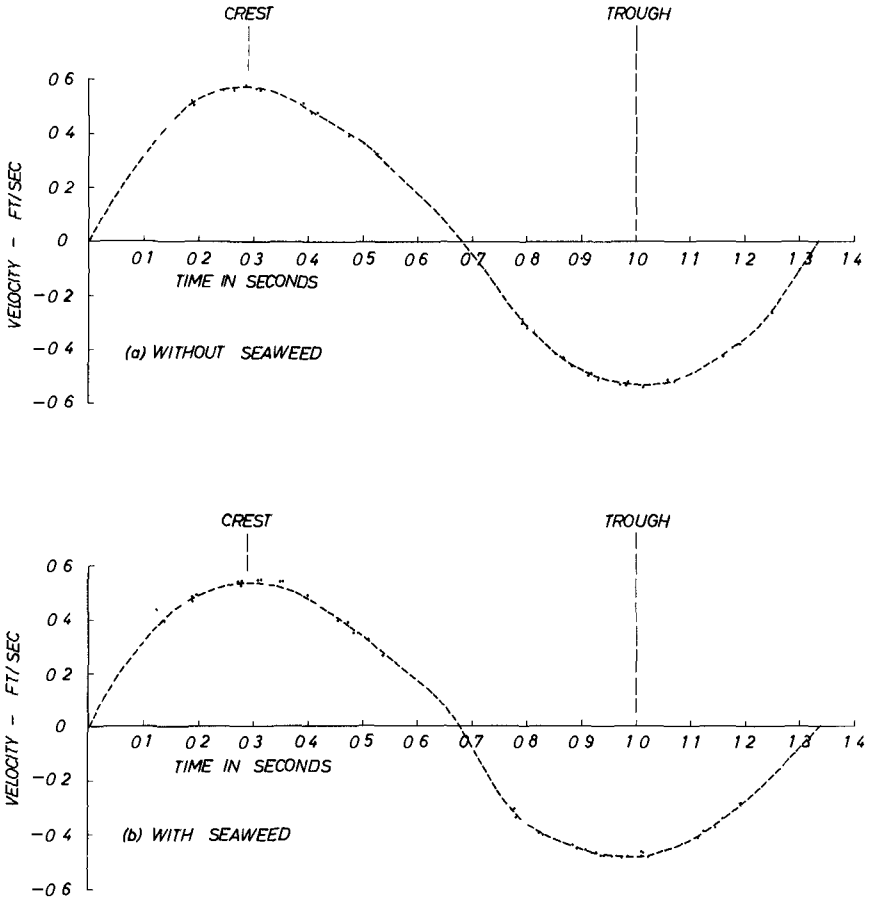

Fig. 2. Wave orbital velocities.

The area under the velocity/time curve is a measure of the length of water passing the observation point. The difference between the lengths of the forward and backward motion is a measure of the net drift. Carrying out such observations at many depths and sections it was established that the sea-weed increased the net drift near the bed in the direction of wave propagation, i.e. towards the shore. One result for a section situated in the centre of the sea-weed array is shown on Fig. 3.

The Effect on Wave Heights

The effect of the sea-weed was to reduce the wave height shoreward of the installation by approximately 4 per cent.

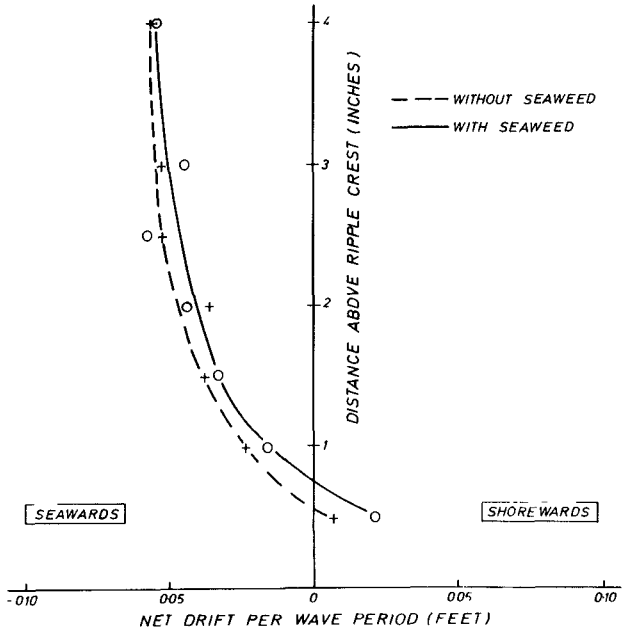

Fig. 3. Net wave induced drift.

A Theoretical Model

A simple hydrodynamic model is proposed to represent the effect of artificial sea-weed on gravity waves. The model predicts increased wave attenuation and increased shoreward mass-transport consistent with the experimental results. The introduction of regularly spaced tufts of polypropylene fibres at the sea bed creates a layer which possesses unusual rheological properties. This layer of water and fibres, adjacent to the sea bed, is to a small extent visco-elastic, but for the purpose of assessing its effect on gravity waves, it appears to be an adequate approximation to regard the layer as consisting of a fluid of somewhat higher viscosity than water. This simplification is suggested by the manner in which the slightly buoyant fibres remain near-vertical close to the bed, and thereby offer resistance to the shearing in horizontal planes caused by waves. This "stiffening" of the water is not isotropic, but since wave attenuation arises principally from viscous shearing stresses in a horizontal plane at the bed, suggests the use of an "effective viscosity" for the water-seaweed layer.

The modulus for wave attenuation with distance in a homogeneous fluid, due to dissipation of energy at the bed, is given to a first approximation by

$$K = \left(\frac{2\nu}{\sigma}\right)^{\frac{1}{2}} \frac{k^2}{2kH + \sinh 2kH} \qquad (1)$$

where k is the wave number $2\pi/\lambda$, σ the wave frequency and H the depth. The wave amplitude is then given by

$$y = A_o\, e^{-Kx} \cos(kx - \sigma t). \qquad (2)$$

Unpublished results on multi-layer systems by Dr. B. D. Dore, and Mr. M. J. Cross, show that in the case of two superimposed fluids, the upper of viscosity ν_1 and depth h_1, and the lower of viscosity ν_2 and depth $h_2 = H_1 - h_1$, the leading term in the decay modulus is given by

$$K = \left(\frac{2\nu_2}{\sigma}\right)^{\frac{1}{2}} \frac{k^2}{2kH + \sinh 2kH} \qquad (3)$$

Thus when we assume the densities of the two layers to be virtually the same, then the wave attenuation due to the bed depends only on the viscosity of the lower layer.

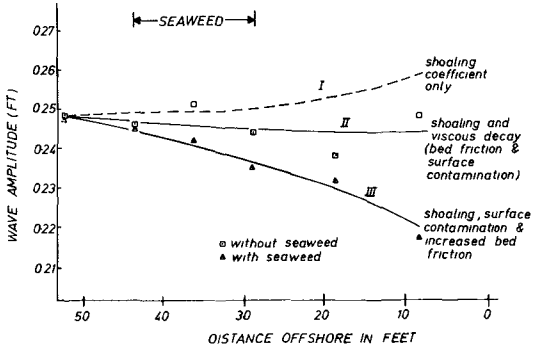

Fig. 4. Wave amplitudes.

In Fig. 4 the observed wave heights are plotted both with and without sea-weed in place. Curve I shows the variation in wave height to be expected without friction, that is, due to shoaling only. Curve II shows the theoretically expected variation of wave height with distance along the beach taking into account (i) the shoaling coefficient, as tabulated by Wiegel (1964) and (ii) bed dissipation based on equation (1) and surface contamination as calculated by Van Dorn (1966). The scatter of

the observations about the theoretical curve could be almost entirely due to rather less than 2 per cent wave energy reflected from the beach. Curve III represents the best theoretical curve through the observations made with sea-weed present, and includes shoaling, surface contamination and increased viscosity near the bed according to equation (3). Again, a component of reflected wave energy may be detected. The effective viscosity of the lower layer suggested by Curve III is $\nu_2 \approx 15\nu_1$, which corresponds to an increase in the laminar boundary layer thickness by a factor of 4.

Earlier theoretical work, Hunt (1961), showed the existence of an increased mass-transport near the bed in the presence of a layer of high viscosity. The observations of wave orbital velocity reported in the present paper, of which Fig. 3 is an example, showed the shoreward mass transport at the outer edge of the boundary layer to be increased by a factor of three in the presence of artificial sea-weed. With the viscosity ratio $\nu_2/\nu_1 = 15$ given by the wave attenuation data, the results of the 1961 paper suggests that the more viscous layer is of order $10(\nu_1/\sigma)^{\frac{1}{2}}$ thick. This is about twice the laminar boundary layer thickness $4(\nu_1/\sigma)^{\frac{1}{2}}$ but is still extremely thin.

In summary, the wave attenuation and mass transport observations are both consistent with a model in which the effect of the sea-weed is simulated by a very thin, but highly viscous, layer adjacent to the bed. If the model is applicable over a reasonably wide range of conditions, then it could be inferred that thicker, shorter fibres would produce similar effects in building up a beach, and that an increase in the number of fibres per unit area of the bed would further "stiffen" the boundary layer and enhance the build up process. Experiments to confirm or refute these suggestions would be very desirable, and would enable the model to be used to choose the optimum length and fibre spacing for any specified wave conditions.

Field Trials

These were carried out at Bournemouth by I.C.I. (Fibres) Ltd. in conjunction with H.R.S. Here the tidal range at springs is 8 ft, the beach sand has a mean diameter of 0.2 mm and there is an adequate supply of sand off-shore. Waves produced by local storms in the English Channel and those generated in the Atlantic produce a net littoral current from West to East. The beach had been eroding over the last few years.

The installation consisted of 1 lb hanks of fibre, (Specific Gravity 0.95) 8 ft long at 3 ft centres, layed over an area of sea bed 400 ft long and 150 ft wide. The landward edge of the installation was 480 ft from high water mark.

A series of beach and offshore cross-sections were surveyed prior to installing the sea-weed in October 1965. The intention was to re-survey these sections six times a year for a number of

years but unfortunately, due to an exceptional number of severe storms in the first winter, it was impossible to examine the site until March 1966. However, a comparison of the October 1965 and March 1966 surveys was very interesting, because whereas it might have been expected that general erosion of the beaches would have taken place during the long periods of destructive wave attack, a small increase in sand levels was found in the lee of the installation. Again, unfortunately, the story is not as simple as this because an inspection of the sea-weed array showed that it had been severely damaged and it was left to conjecture when this took place. A particularly severe storm occurred in February 1966 and it has been assumed that the installation was working satisfactorily up to this time.

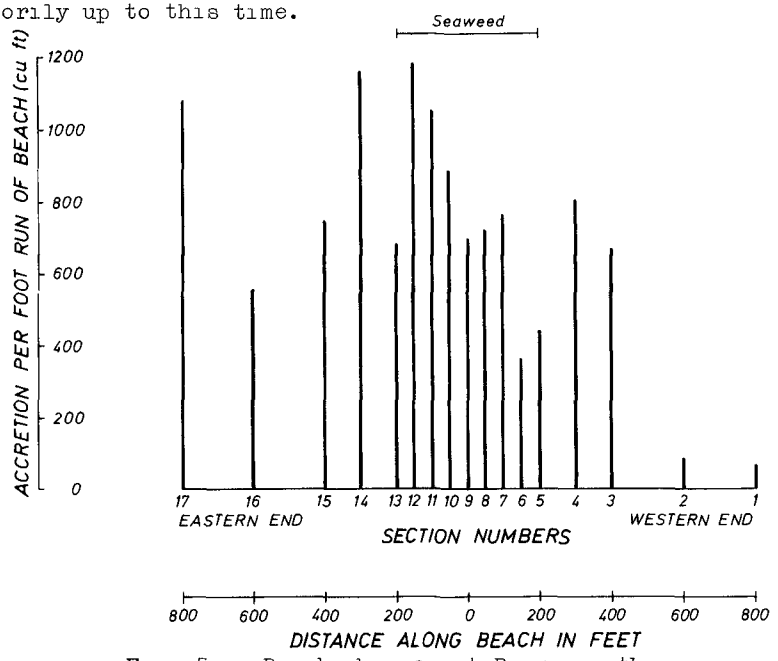

Fig. 5. Beach changes at Bournemouth.

Figure 5 shows the change in cross-sectional area of 17 cross-sections measured between the level of high water of mean spring tides and 5 ft below low water mark for the period October 1965 to March 1966. Accretion of the inshore zone was accompanied by erosion of the offshore sea bed; a result which might have been anticipated from the wave tank experiments.

Summary of results and future work

Enough has been done theoretically, in the laboratory, and in the field to suggest that artificial sea-weed can build up beaches by promoting an onshore transport of material. Plans are now being made to carry out a larger trial on the East coast

of England in the near future.

Acknowledgments

The authors would like to record their thanks to Mr. Bert Vallance whose careful experimental work, (carried out well before any theories were proposed) made the comparison with theory so satisfactory.

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References

Wiegel, R. L., (1964) "Oceanographical Engineering", Prentice-Hall.

Van Dorn, W. G., (1966) "Boundary dissipation of oscillatory waves", J. Fluid Mech. 24, 769-779 and Corrigendum.

Hunt, J. N., (1961) "Oscillations in a viscous liquid with an application to tidal motion", Tellus XIII, 79-84.