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A PENETROMETER FOR USE ON WATER-COVERED BEACHES

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(Text-figs. 1 and 2)

The primary use of penetrometers has been in the road-building industry for testing materials such as tar and asphalt which are virtually homogenous in texture. They have also been used extensively and in wide variety in the food industry to determine optimum textures of products being canned, and an important application has been the determination of the toughness of cheese.

The idea underlying the use of devices to measure resistance to penetration has, of course, been to get away from dependence upon mere qualitative descriptions of firmness, and where interest attaches to investigating that of estuary bottoms and of other grounds covered by modest depths of water, quantitative description has become essential. Only so can conditions at places far apart be acceptably compared.

The importance attached in marine-biological literature to the nature of beaches in connexion with the burrowing powers of animals which inhabit them, has prompted the thought that it might be useful to make known the existence of an instrument which has been successfully used in shallow water to ascertain the firmness of bottoms *in situ*.

It will be convenient in what follows to speak of 'dry beaches' simply in contradistinction to water-covered beaches, by using the expression in the usual hydrographical sense to convey that the falling tide has uncovered them, and not with any connotation of aridity at all. As regards those striking sand properties dilatancy and thixotropy upon consideration of which Kendall thirty years and more ago based his stimulating theory of fossil earthquakes which alone could account for the large and economically important 'wash outs' which occur as amorphous sand infillings in certain coal seams of the West Riding, it does seem that students of sea and sand interrelationships might sometimes make useful small-scale application of Kendall's views on the events due to earthquake shock which can attend the quasi-liquefaction of vast stretches of sand traversed by a watercourse. There surely must be an important gradation of magnitudes between the mammoth physiographical events pictured by Kendall, and those on the micro scale seen by a man who contemplates the aureole of whitening and drying around his feet as he walks on a beach not far from the water's edge, and who finds that if he pats the ground repeatedly he produces a small quicksand.

In this connexion it is suggestive to think of the quicksands of the Solway shore which are in dangerous evidence at times when a rising tide effects a rapid extension of water cover landwards, and of such events as the extensive migration of buoys near the Goodwins which, after remaining firmly fixed for many years, suddenly lose their hold at a time of strong spring tides as very shallow water cover is quickly succeeded by deep. There is abundant reason why ever-increasing attention ought to be given to the study of the firmness and constitution of beach soils both when water-covered and dry.

The interest of the marine biologist in the dilatancy and thixotropy of the sand on beaches wherein animal communities live, has been discussed by Yonge (1950), by Chapman (1949) and by Chapman & Newell (1947).

In the two earliest of these papers there is an account of a device used for measuring the resistance to penetration of marine soils *in situ* on dry beaches.

Use of the small penetrometer in question produced results which were always expressed as the pressures in g/cm² necessary to thrust a disc 0·125 cm² in area 3 cm deep into a soil. Presumably where attention is limited to recording the resistance to a penetration of such modest amount as 3 cm the data collected can be accepted as measures of the resistance to burrowing which small animals would experience at the same place. It is to be assumed that the users of the small penetrometer just referred to (and apparently little longer than 40 cm overall), found no need to suppose that their results might have been somewhat falsified in point of intended applicability, by sand compaction changes occasioned by their own weight.

The concern of marine scientists with the texture, make-up, and morphology of beaches goes far beyond that of marine biologists of course, and very many factors have to be considered by those who study the potency of wave-sculpting, and the nature and magnitude of other causes of sea erosion, to say no more. Quite often it is necessary to be very chary of applying what is learnt regarding erosion trends, the effects of waves, the magnitudes of sand transports, etc., at one place, to the making of inferences in respect of other beaches even though exposures and wave conditions may be very similar. That very much indeed depends upon the actual make-up and natural compaction of the sands on a beach, is most impressively attested by the remarkable detail with which the Dutch have found it necessary to investigate the grain composition and the mineral constitution of their beach materials.

Where, as with them, the issues are so vitally important, it is risky indeed to assume that information gleaned at one place will necessarily apply adequately elsewhere.

There is in Britain nothing like the school of sedimentology of Wageningen led by Doeglas, nor has our country yet seen beach studies made in anything like the detail of those featuring so much in French marine-geological literature, but there are solid signs of an awakening interest.

It would be of interest (were this the place) to consider the findings of

Emery (1945) on the effects of the entrapment of air in different grades of beach sand, and those of Trask & Rolston (1950) regarding the relation of sediment strength to water content and grain size. Most of the considerations which were in mind when the large penetrometer to be described was designed, are set out in an excellent article by Kindle (1936). He describes beaches which exhibit all degrees of firmness and lack of it within the distance of a fraction of a mile, and dwells upon the abruptness of the transition from firm to soft sand which often exists. He cites such a contrast in the case of an English beach at Skegness, and gives a discussion of the effects upon beach sand firmness as the 'tide comes in'.

A purpose of the foregoing remarks has been to show the desirability of possessing a simple and rugged means of determining the firmness of beaches (whether dry or water-covered up to neck depth for instance), in such fashion that investigators far removed from each other can record their findings in common terms. It has been thought that such a possibility might make some appeal to marine biologists as well as seeming obligatory upon students of beach and sea-bottom topography.

The device to be described was constructed for use with both instrument and user completely submerged in a connexion which need not concern us here, but, since the instrument is tall it can easily be used by an observer within all wading depths. In these days when some marine biological laboratories possess their own frogmen, wading depths need not be the limit—though of course, the greater the degree of immersion of the user, the less becomes his power to force any instrument into the sea bed beneath his feet. The tallness of the instrument was a deliberate choice to aid the user to effect a vertical approach to the ground being investigated.

In the case of bottoms carrying more than wading depth of water, unless probing from some firm platform like a jetty be possible, no acceptable means is known of recording firmness *in situ* other than by invoking the services of divers of frogmen type, and they often find it far from easy to operate corers and penetrometers specially made for them except when water movements are very weak.

Description of the Penetrometer

For the accompanying drawing (Fig. 1) and the brief description which follows referring to it, I am indebted to Mr H. J. Garrood, A.M.I.M.E., who made the device to my instructions.

The penetrometer consists of a rod (1) pointed at the lower end (2). This rod is forced into the ground being investigated by pulling down by hand on the handles (6).

To the handles are attached two chains (7). These run over sprockets (8) and are fastened at their opposite end to a guide (9). The guide is connected through springs (10) to an anchor bracket (11). The guide (9) is able to slide on the rod (1).

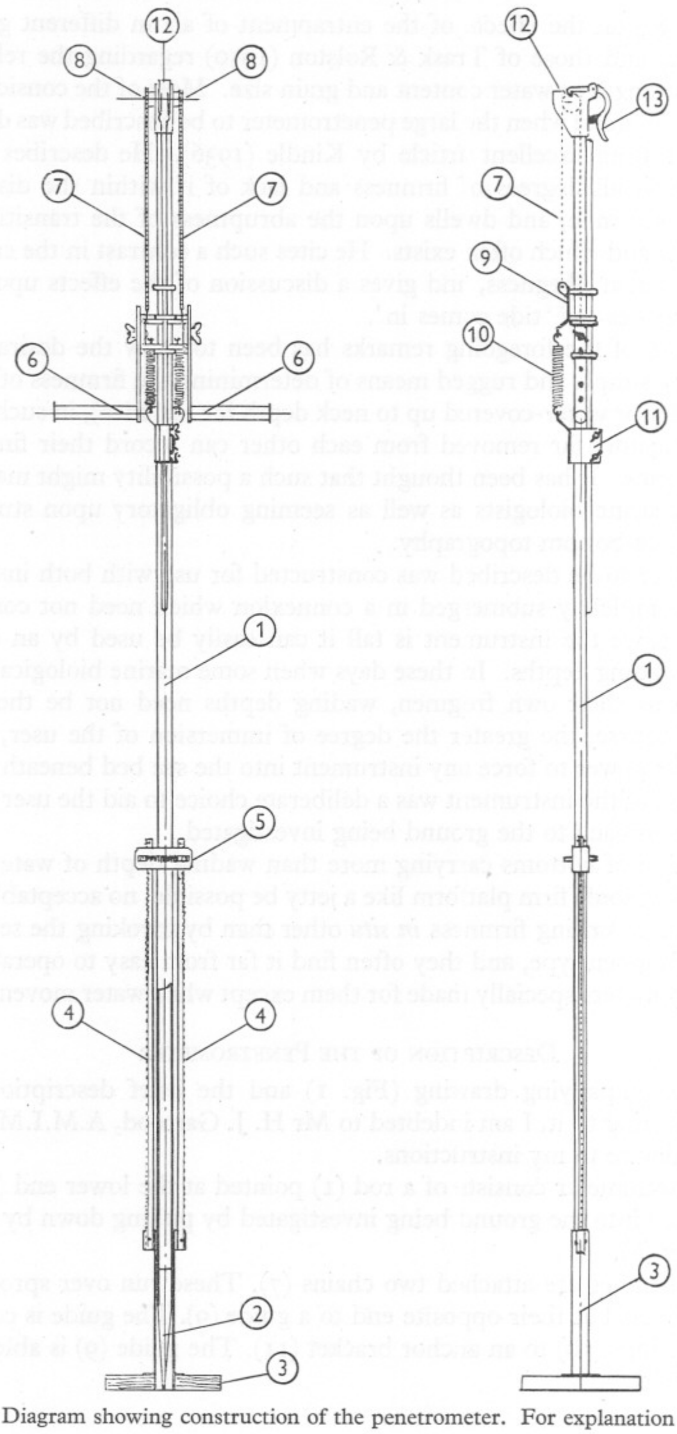

Fig. 1. Diagram showing construction of the penetrometer. For explanation see text.

When the handles are pulled downwards, the rod penetrates the ground and the springs are stretched proportionately to the tension applied. A spring-loaded ratchet lever (13) engaging a toothed wheel (12) mounted between the

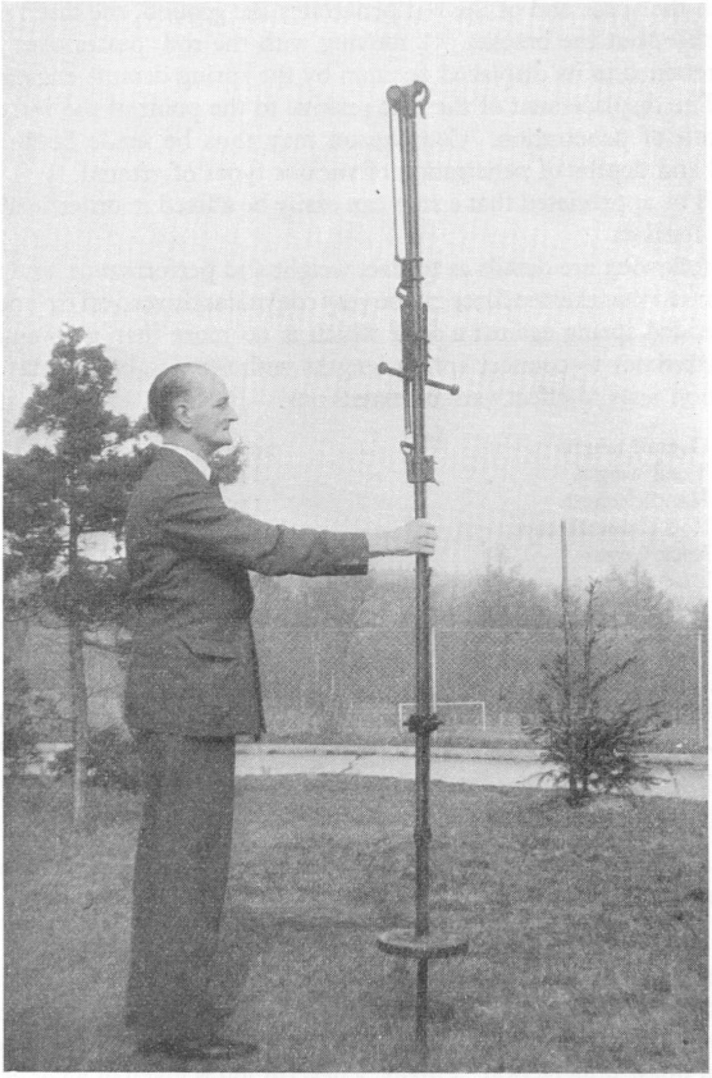

Fig. 2. Photograph of the submerged-beach penetrometer.

chain sprockets and fixed to them, prevents the springs from relaxing when the pull is released. By measuring the stretch of the spring, the force which has been exerted on the rod may be ascertained.

At the foot of the instrument a wooden disc attached to a tube (3) is arranged to slide on the rod. Moving with the disc and attached to it are two toothed racks (4) which pass through a bracket (5) fixed to the rod and having spring-loaded detents which engage in the ratchet teeth of the racks.

When the spear end of the rod penetrates the ground, the disc remains on the surface, but the bracket (5), moving with the rod, passes over the racks and is retained in its displaced position by the spring detents engaging in the teeth. The displacement of the disc relative to the point of the rod measures the depth of penetration. Comparison may thus be made between forces exerted and depths of penetration of various types of ground.

It will be appreciated that a stop can easily be affixed in order to always use a given tension.

The following are details as to size, weight and performance, and it should be remarked that exerted force can be very conveniently read off by 'measuring' the extended spring against a scale which is no more than a common white lath marked out to connect spring lengths with the weight loadings found in calibration tests to effect various extensions.

Overall height	265 cm
Total weight	11.3 kg
Handle length	15·2 cm
Rod circumference	9·1 cm
Rack length	71 cm
Disc diameter	22·9 cm
Spring length unstretched	30·5 cm
Spring length stretched:	
(*a*) by 14·7 kg weight	50·8 cm
(*b*) by 16·8 kg weight	58·4 cm
Penetration into loose recently dug soil	41·9 cm for 9·9 kg tension
Penetration into firm lawn	19·0 cm for 9·9 kg tension

N.B. The 'odd' dimensions and weights are due to conversion from British quantities into metric.

The accompanying photograph (Fig. 2) was kindly taken for me by my colleague Mr J. Darbyshire.

Summary

Comments on the uses of penetrometers in general are followed by remarks upon an earlier one for use on dry beaches. Some discussion is given of the behaviour of beds of sand disturbed by shocks and converted thereby into a state of quasi-liquefaction. Finally, a description is given of a tall pull-down penetrometer which can be used on beaches covered by modest depths of water.

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