# CHAPTER 45

## DUNE EROSION AND PROTECTIVE WORKS AT PENDINE, CARMARTHENSHIRE, 1961-68

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ABSTRACT

The paper describes the application of a novel method of protecting parts of the sand dunes at Pendine, S.W. Wales. These dunes are subject to erosion under conditions when high tides are combined with south-westerly gales.

A series of random rock-fill mounds were sited 20 feet away from the toe of the dunes in certain areas where structures erected on the dune crest were liable to damage through erosion at the toe of the dunes. The object of the mounds is to trap wind-borne sand in the area enclosed between the mounds and the dunes, and also to check wind-driven waves before they can reach the dune face.

Over seven years the mounds and sand traps have operated in accordance with their design concept. Not only have the traps filled with sand but further sand accretion has occurred on the protected dunes, resulting in a flatter slope and a strong growth of self-sown pioneer vegetation on the protected face and on the sand trap surface.

## INTRODUCTION

This paper describes an empirical solution to the problem of combatting erosion on parts of the dunes at Pendine sands, and records the results achieved over a period of seven years. Pendine has a place in the history of mechanical engineering, since it was on Pendine sands that the world's land speed record was raised by Sir Malcolm Campbell from 146.16 m.p.h. in 1924 to 174.88 m.p.h. in 1927. It was at Pendine also that Parry Thomas, seeking to break Sir Malcolm's record, met his death.

## GENERAL DESCRIPTION OF THE SITE

### Topography and Geology

The site of the works lies at the head of Carmarthen Bay, S.W.Wales. It consists of a wide, flat, sandy beach - Pendine Sands and Laugharne Sands - backing on to a range of dunes, 6 miles long, which vary in width between 400 and 700 yards. Behind the dunes is an extensive area of reclaimed alluvial marshes, which extend northwards to the foot of steeply sloping hills of old red sandstone. At the west end, the site is bounded by limestone cliffs, and there is a limestone peninsula, worked as a quarry, jutting into the central marsh area. The eastern end is bounded by the river Taf.

The sand composing the dunes, both in the old-established and recent growth areas, is of a very uniform character, 100% passing B.S.52 and being retained on B.S. 200. Similar grading results

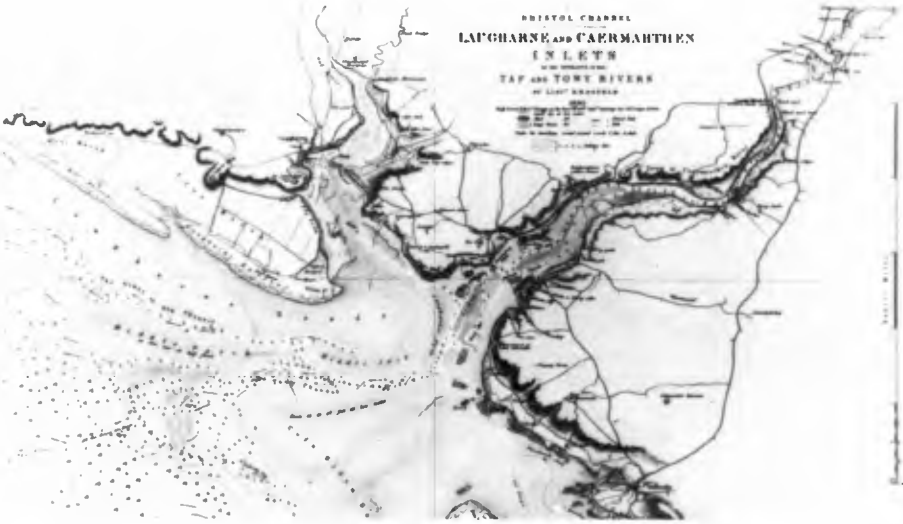

Fig.1. Pendine and the Taf estuary in 1830

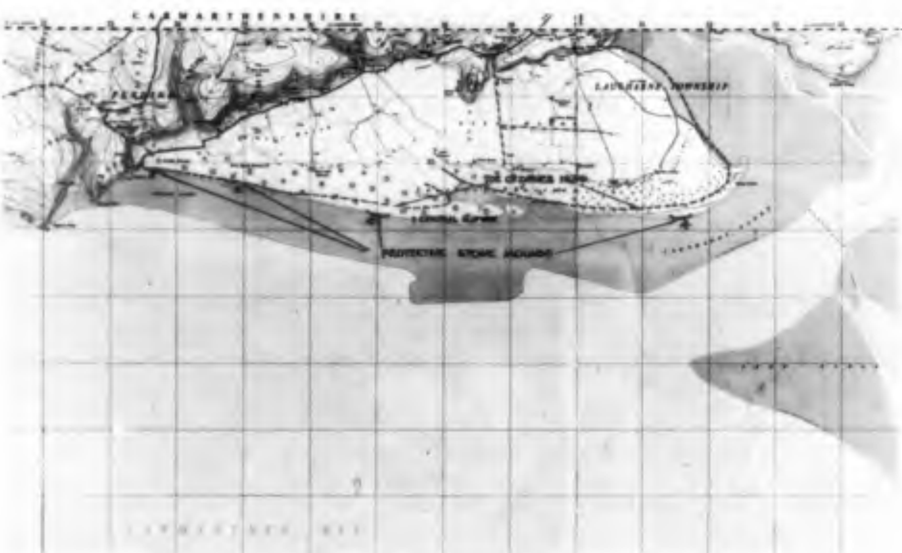

Fig. 2. Pendine and the Taf estuary in 1950

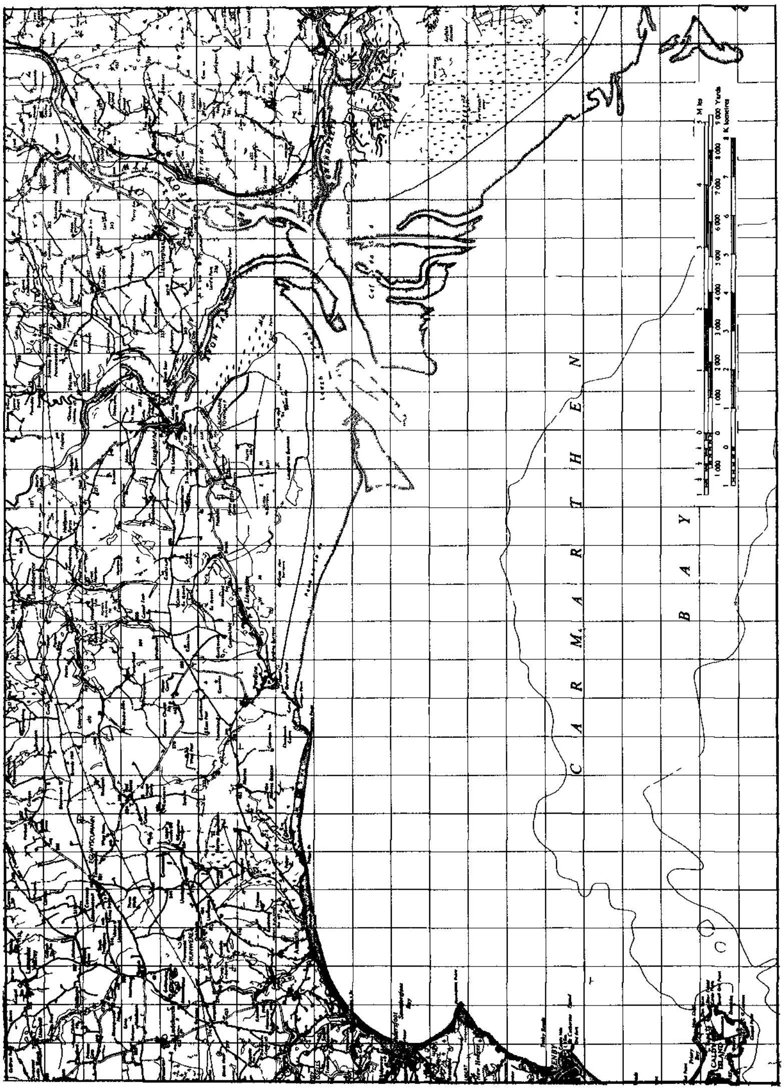


Fig. 3. Carmarthen Bay

were obtained from 10 out of 12 boreholes, situated at intervals over a 3,000 foot length behind the first ridge of the dunes and taken to depths of up to 60 feet. In two boreholes only, the typical grading was varied by the presence of shell fragments at depths of 25 to 30 feet.

Saxton's map of Carmarthen and Pembroke (1578) shows the area, but with insufficient accuracy for scaled measurement. Morris's chart of "Carmarthen, Laugharn and Cydwely" (1800) locates certain fixed points with sufficient accuracy for comparisons to be made with the Admiralty charts of 1830, 1856, 1888 and 1952, and these, together with the Ordnance Survey maps, enable major changes in the Pendine dunes to be assessed with some accuracy. In 120 years the average depth of the dunes has increased by approximately 100 yards.

The outlet of the Watchett Pill onto the beach has moved approximately 1300 yards eastward, due to the eastward growth of the dunes. During the same period the channels of the rivers Taf and Towy have tended to move eastward, the Gwendraeth inlet has largely silted up, and there has been a general accretion on the west side of the Towyn Burrows sand dunes, between Kidwelly and Burry Port.

Between 1800 and 1830 the Pendine Marshes were reclaimed for agriculture by installing drainage and by the construction of earth banks on the Taf estuary. In 1940 the marsh area was acquired by the Government for an Experimental Establishment, and the site is now controlled by the Ministry of Defence.

## Morphology

Fig. 1 reproduces the Admiralty chart of 1830. Fig. 2 shows the 1830 dune line transferred to the 1950 Ordnance Survey 2½" to 1 mile map, together with the location of four protective stone mounds at intervals along the six mile dune front. Fig. 3 shows Pendine sands in relation to the whole of Carmarthen Bay.

The half-heart shape of Saundersfoot Bay is a text-book example of a stable sedimentary coastline shape, as described by Silvester[1] in a paper published in 1962. At present Saundersfoot Bay (sand) and Marros Bay (shingle) appear to be relatively stable, while parts of Pendine sands, Laugharne sands, the Gwendraeth estuary and Pembrey sands all show evidence of accretion. There is insufficient data at present to establish whether there are three (or four) half-heart shapes evolving or whether Carmarthen Bay will eventually stabilise on a single macro-half-heart system. The research carried out by Yasso[2], published in 1965, suggests that the mathematical form of such a coast when in equilibrium is a logarithmic spiral. He obtained reasonably accurate fitting, using an IBM 7000 computer programmed to generate a best-fitting log-spiral to each shoreline curve surveyed. With all log-spiral fits, however, there comes a point where the spiral deviates away from the coast and into the ocean. It seems possible that a cubic parabola may hold the key to this problem, but this hypothesis has yet to be tested.

## Present Conditions

The prevailing wind is from the S.W., and there is considerable movement of sand, both sea- and air-borne. High water spring tide mark is normally about 20 to 30 feet seaward from the toe of the dunes. Records of beach levels are few, and insufficient data are available to establish whether there is any seasonal pattern of beach movement. While most of the Establishment's buildings are sited inland from the dunes, certain installations are built on the dune edge. In the autumn of 1961, a combination of high tides and S.W. gales caused some erosion at the toe of the dunes, which was sufficient to endanger the stability of these installations. At one site a stepped mass concrete wall was built on the dune face as a protective measure. Completed in March 1962, this work in fact aggravated the problem. Some undercutting of the beach in the centre of the wall resulted, together with further dune erosion at the ends, thus endangering both the wall and the installation behind it. An alternative method of protection was urgently required. A novel system, using a pervious random rock-fill mound and sand trap, was designed in order to make the best use of local materials and physical conditions.

# THEORETICAL OPERATION OF THE MOUND AND SAND TRAP

## Hypothesis

Under normal conditions, high spring tides do not reach the toe of the dunes. If, therefore, a pervious rock-fill mound was set up 20 feet from the toe of the dunes, such tides would reach the edge of the seaward face of the mound. Wave action would be checked, and this would result in sand deposition in the voids of the mound and subsequently on the beach in front, thus raising the beach and steepening its gradient. At the same time wind-blown sand would be checked at the returned ends of the mound, and this sand would be trapped in the area enclosed between the mound and the toe of the dunes. A combination of S.W. gales and high tides might result in some overtopping of the mound, but the mound would have to be breached before any damage could be inflicted on dunes so protected.

## Application

The foregoing was applied in the protection of the mass concrete wall, and also of sections of unprotected dune. The rock-fill mounds were of triangular cross-section 4' 6" high, with the seaward face sloped at 1 : 5 and the inner face at 1 : 1 (Fig. 4). The mounds were built of random limestone "as blown", varying in size from 2 feet down to 6 inches. The rock was placed on a base of Somerfelt Track (a temporary airfield surfacing of galvanized wire and steel flats), the mounds being sited with the inner toe of the mound 20 feet from the toe of the dunes. The ends of the mounds were returned back at 45$^{o}$ to join the dunes. Three sites were protected in this way during the summer of 1962, and an additional

Fig.4. Stone mound, August 1962

Fig.5. Ice/Sand barrier, March 1963

site in 1966. (Sites 1, 2, 3 and 4 in Fig. 2).

Confirmation of the Mound Theory

From January to March 1963 there was continuous snow and frost at Pendine. This produced a build-up of an ice and sand barrier, 12 inches to 15 inches thick and of varying width, sited at mean high water mark (Fig. 5). The effect of this barrier was to cause sand to accrete between it and the toe of the dunes along the whole length of the beach, thus providing a reasonable confirmation of the theory of mound design. With the melting of the ice, this sand accretion was dispersed.

Operational Experience

Over the past seven years the mounds and sand traps have operated in accordance with their design concept. The voids have filled with sand, as also have the sand traps between the mounds and the dunes. The mounds have proved exceptionally stable. The slopes of the dunes so protected have flattened to between 20° and 30°, compared with the 35° to 37° slopes of the unprotected dunes. Natural growth of vegetation is much stronger on the surface of the protected dunes than on the unprotected, and this, in its turn facilitates further sand accretion. (Fig. 6). No planting has been carried out. The pioneer self-sown vegetation consists mainly of Sand Couch (Agropyron Junceiforme), Marram Grass (Ammophila Arenaria) and Sea Spurge (Euphorbia Poralias).

Some local erosion occurs at the junctions of the returned ends of the mounds with the dunes (Fig. 7) and similar erosion occurs at places where vehicle slipways cut through the dunes and join the beach. In May 1968 work was carried out to try the effect of lower mounds, of similar construction and shape, but 18 inches high only. These were sited so as to extend the ends of existing mounds by 50 feet, parallel to the dunes. The ends of these extensions were not returned back at 45° into the dunes, but were gradually reduced in height.

It is too early to predict how these low mounds will behave under a combination of gales and high tides. However, four months after their construction, there was already an appreciable build-up of sand between the mound and the toe of the dunes. Terminal erosion appears to have been halted, and, in fact, reversed.

Fig. 8 shows the application of a short low mound at Site No. 3.

Immediately behind the crest of the dunes between the east end of Site 3 and the Central Slipway there is a roadway, the stability of which was becoming endangered by dune erosion. Placing additional stone on the dune face and at the junction of the slipway with the dunes did not remedy the condition. Erosion has now been checked and the accretion of sand facilitated by the construction of a low stone mound, 20 feet from the toe of the dunes and running from the Site 3 mound to the Central Slipway (Figs. 9 and 10).

Fig.6. Sand accretion in sand trap, October 1967

Fig.7. Erosion of dune at returned end of mound

Fig.8. Short low mound extension, Site 3, September 1968

Fig.9. Low mound between Site 3 and Central Slipway, September 1968

Fig.10. Low mound looking eastward to Central Slipway, September 1968

Fig.11. Low mound extended beyond slipway, September 1968

The effect of continuing the low mound for 50 feet on the east side of the Central Slipway is shown in Fig. 11, when the beach has started to build up on the seaward face of the mound and also between the mound and the dune face.

Over the 7-year period since the original mounds were constructed, they have shown no tendency to settle into the sand or to disperse when over-topping has taken place. Where over-topping has occurred, some sand has been washed out of the sand traps, leaving behind a swallow-hole formation. However this has subsequently filled up with additional trapped sand.

So far, the works described have required no maintenance whatsoever, and, as regards the effects of overtopping, can be said to be self-maintaining. While the efficacy of the low mounds has yet to be proved over an extended period, the high mounds and sand traps have adequately fulfilled their local purpose of "controlling one of the great sources of power in Nature for the use and convenience of Man".

References:-

1. Silvester R.; "Sediment Movement Around the Coastlines of the World", Inst.C.E. Civil Engineering Problems Overseas Proceedings, Paper No. 14, 1962.

2. Yasso W.E.; "Plan Geometry of Headland - Bay Beaches", Jl. of Geology 73, 1965, 702-714.