Coastal erosion and slope instability at Downderry, south-east Cornwall: an outline of the problem and its implications for planning

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ABSTRACT: The Quaternary head deposits which overlay a wave-cut shore platform along a 2 km sector of coast between Seaton and Downderry in south-east Cornwall, have been subjected to significant coastal erosion over many years. As a result, a number of landslips have occurred with considerable damage and even loss of cliff top dwellings. An outline of recent investigations conducted on the cliff and landslip sections with regard to slope stability and the nature of the head deposits is presented. Attention is drawn to the need for adequate drainage of the cliff material, particularly in the siting of gutter soakaways from the cliff top settlements.

Despite the history of landslipping in this coastal sector, planning permissions have been granted and a number of new dwellings have been constructed on the cliffs. Ultimately, these properties will be affected by the receding cliff edge and associated slope failures.

The paper thus reviews the efficacy of both public and private coastal defence schemes, particularly in relation to the overall stability of the head materials, beach sediment budgets and the ‘natural’ protection provided by longshore sediment transport at the foot of the cliffs.

Introduction

Man’s predilection to use the coastal zone for residential purposes frequently highlights misunderstanding of the dynamic nature of such environments and ignorance of the processes responsible for coastal erosion. A number of well known cases exist of active coastal recession which threaten adjacent properties or even substantial settlement, as, for example, at Barton-on-Sea (Barton & Coles 1984). The 2 km coastal sector between Seaton and Downderry in south-east Cornwall (Fig. 1) has not previously received attention in the literature, although the threat to properties and the coastal road is probably equal to other better known examples. The village of Downderry is sited on a low cliff of Pleistocene soliflucted materials, and property development has continued throughout the present century despite the obvious continuation of cliff undercutting and erosion.

Background

In order to fully explain the nature of the cliff materials and their subsequent erosion, it is necessary to present some detail of the geomorphological history of these types of coastal deposit. Throughout south-west England, sea level changes resulting from glacio-eustasy have produced coastlines characterised by wave-cut rock platforms, some of which are frost-shattered or covered by variable thicknesses of locally derived solifluc tion deposits. These sediments (known generally as ‘head’) spread across the exposed coastal areas during a number of the Pleistocene ‘cold phases’ when sea level was lower. These glacio-eustatic changes culminated in a sea level rise during the post-glacial (Flandrian) period.

In the coastal sector between Seaton and Downderry, the local bedrock of lower Devonian slates, has provided the parent materials to establish an extensive solifluc tion terrace burying a low level rock platform at 0–2 m OD. This wave-cut feature, dating originally from the late Pleistocene (Devensian), emerges at low tide from beneath the modern beach sediments and is currently being actively trimmed. The soliflucted materials form a flat-topped feature nearly 2 km in length, varying in width from less than 5 m at Seaton to 130 m east of Downderry village. The thickness of the terrace ranges from 3–4 m in the east of the section to a substantial cliff some 25 m in height near Seaton. Inland, the low rock platform (here forming a fossil cliff) emerges from beneath the younger deposits landward of the many cliff-top houses that have been constructed, during the present century, along the B3247 coast road (Fig. 2).

The nature of the head deposits of the solifluc tion terrace, characterised by unconsolidated, poorly sorted and angular slate fragments in a silt and clay matrix with numerous down-slope bedding planes, renders the head of little resistance to erosion by waves or surface running water. Furthermore, landsliding is aided by saturation of the head materials above less permeable silt and clay horizons. The undercutting of the base of the cliff by winter storms has led many cliff-top property owners to protect the base of the cliffs with rubble, concrete,
The deposits have suffered continued erosion from two main causes. Firstly, as a result of the progressive rise in sea levels over the last 15,000 years, which according to Thomas (1985) is still occurring at a rate of 2 mm per annum in south-west England. Secondly, superimposed upon this are the influences of surges and modern storm wave activity. These processes have resulted in significant losses of land.

Evidence derived from Ordnance Survey maps at 1:1250 and 1:10560 scales in 1880, 1907, 1952 and 1964 indicates that the width of the beach (that is the measured distance between MHWOT and MLWOT) between Seaton and Downderry has been reduced by some 50 m — equivalent to a rate of 0.7 m per year. This removal of beach sediment could be linked to continued slow sea level rise (as indicated above) but is more likely a response to changes in the nearshore circulation of sediments and longshore drifting. Certainly, the construction of the small sea wall to the west of the Seaton river and the major coastal protection works further west at Looe have cut off some local sediment supply previously brought to Seaton/Downderry by an easterly longshore drift. This loss of material has resulted in a reduction in natural beach protection and virtually every storm now has the ability to attack the base of the solifluction terrace.

Concern by local residents about sea defence resulted in a public inquiry in 1959. Removal of sediment at Seaton beach (sand and gravel abstraction) was seen as a contributory cause but the investigation concluded that a £50,000 scheme for coastal protection works was 'unjustified'. Since 1959, there has been significant erosion despite the cessation of sediment removal.

In February 1974, two houses at the western end of the terrace lost their gardens due to landslipping. The foundations of one of these properties were undermined to such a degree that the building was no longer habitable. Rotational slumps exposed other house foundations and resulted in a 20 m downthrow of material towards the beach. Further cliff falls occurred subsequently, and the local District Council's engineers suggested that extensions to the cliff top dwellings had resulted in excessive loading, leading to instability.

The position of roof water soakaways is also of interest. The storms of February 1974, whose wave action undercut the base of the cliff were associated with simultaneous heavy rain. Over 200 mm (8 inches) of rain fell in the month, most of which came in five precipitation events of over 25 mm (1 inch). Rainfall intensity averaged 3 mm per hour for all of these events with ranges from 1.6 to 5.3 mm per hour. Thus, large quantities of water were directed from house roofs, via downpipes, to garden soakaways sited only a few metres from the property. The combination of rapid saturation of the downslope bedded soliflued materials, together with erosion at the foot of the low cliff led to major slipping along rotational shear planes (Fig. 2).

Since 1974, further erosion of the solifluction terrace has occurred at the seaward face. The cliff regularly spalls or slumps onto the beach and from time to time small mudflows can be observed, although evidence is rapidly removed by subsequent wave action at the next high tide. Such is the pace of retreat that in 1981 the coast road was threatened at the western end of the sector. Cracks of 10 mm width appeared in the road surface which caused the County Council (as highway authority) to draw up plans for protection of this part of the cliff and a new sea wall was completed in 1983. However, whilst protection is afforded to the road, the wall ends at the site of the 1974 slip (Figs 3 and 4) and thus properties here, and further east, still require protection. Consulting engineers retained by the local District Council consider that a number of properties in the immediate area are potentially at risk and estimated (1985) the cost of building a 155 m sea wall to adjoin the County Council's scheme to

**Fig. 1.** The coast of south-east Cornwall.

**Fig. 2.** Schematic diagram of the solifluction terrace at Downderry.
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Fig. 3. Site of the 1974 rotational slip showing the end of the County Council new sea wall (completed 1983).

Fig. 4. Comparison between the regraded slope behind the new sea wall and the 1974 landslip zone.

Fig. 5. Failed private sea wall with a vegetated (stabilized) slope behind and the site of the new bungalows with no sea wall protection.

despite the ultimate failure of the private sea defence schemes, a noticeable retardation in the rate of cliff erosion has resulted. The prevention of continuous removal and slumping has allowed the establishment of an extensive vegetation cover on the cliff face, which, in turn, imparts an increased stability to the cliff materials (Fig. 5). The longevity and degree of protection afforded by these privately funded ‘do-it-yourself’ structures varies considerably, but their effectiveness can be quite significant.

Nature of cliff materials

Over the last five years, work by the authors has been undertaken to establish the nature and properties of the cliff materials in conjunction with studies of current erosion, slumping and subsequent cliff recession. Although no major slumping, of a comparable scale to the 1974 events, has taken place over the last 12 years, minor cliff falls regularly occur and one resident reports up to 10 m loss of his land since that time.

The materials which make up the matrix of the head can be divided into coarser and finer components. Throughout, these materials are poorly sorted, and partial stratification gives rise to distinct lenses, or layers, in many parts of the cliff section.

<table>
<thead>
<tr>
<th>Table 1. Properties of materials.</th>
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<tr>
<td>% sand</td>
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<tr>
<td>Coarser layers</td>
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<tr>
<td>Finer layers</td>
</tr>
<tr>
<td><strong>Atterberg limits:</strong></td>
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<tr>
<td>Plastic limit = 14–19%</td>
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<tr>
<td>Liquid limit (cone penetrometer technique) = 25–35%</td>
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<tr>
<td><strong>Direct shear test (remoulded &lt; 2 mm material):</strong></td>
</tr>
<tr>
<td>Cohesion ($c'$) = 0.05 kg cm$^{-2}$</td>
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<tr>
<td>Angle of shearing resistance ($\phi'$) = 31–33°</td>
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be £576,000: a price well in excess of the market value of the properties protected. Thus, the extension of the sea wall is unlikely to attract any government grant aid or even local funding.

It is interesting to note that a number of residents, whose properties are at risk, have, over a number of years, resorted to the construction of ‘do-it-yourself’ sea defences ranging from major concrete structures to relatively cheap stone-filled gabions. In certain cases,
The percentage of sand-sized materials is very high (Table 1) and it is notable that, even in the finer horizons, the clay content rarely exceeds 10 percent. The sand fraction consists of small fragments of slate and the further breakdown of the slate accounts for the silt-sized material. Of particular importance to slope stability is the occurrence of a finer horizon near the base of the head succession. This layer is characterised by an absence of coarse (>2 mm) fragments, is very compact and of low permeability. In the late winter and spring, a distinct seepage zone occurs near the boundary of this horizon and the overlying coarser units of the head. The build up of water above this horizon during the wetter weather increases pore water pressures in the head materials. This, together with more active marine undercutting, may account for the generally greater frequency of slope failure in the late winter and early spring.

Discussion

The work undertaken in reviewing both the history of erosion in this area and the nature and properties of the cliff materials suggests that active marine erosion, primarily generated by storm wave activity, is the main cause of coastal recession. Despite localized (private) attempts at sea wall construction, erosion continues due to the piecemeal nature of such undertakings. Owing to the discontinuous nature of these defences, wave attack works around the side and, eventually, behind these structures, which ultimately collapse (Fig. 5). In some cases, the lack of adequate drainage through concrete or masonry walling has led to a build up of pore water pressures on the landward side, leading to major fractures and failure of the structure. Quite often, inadequate toe protection provided by deeper foundations or vertical piling leads to these simple sea walls just ‘toppling over’ when even moderate wave action has shifted or removed the narrow zone of beach sediments which offer only short term natural protection to such low cost schemes.

To stop erosion completely would require the continuation of the County Council’s sea wall along the whole length of the coast at Downderry. Such remedial measures are out of the question, in relation to the total value of the properties under immediate threat, due to the high costs of such undertakings. Thus, erosion is likely to continue and it is difficult to predict at what point recession will cease, especially as the existing exposed wave cut platform, together with the buried platform, are at modern sea level and thus cannot provide any significant rock rampart for the dissipation of incoming wave energy. In fact, the gentle slope of the platform is more likely to create steeper wave fronts as approaching breakers encounter frictional retardation in the shallow water.

Deposite knowledge of the major slump of 1974, the subsequent inquiry, the construction of a sea wall by the County Council (Figs 3 and 4) and concern by the Environmental Services Department of the local District Council, it seems astonishing that planning permissions have been granted for the building of new properties in close proximity to the receding cliff edge. Fig. 5 illustrates the nature of the current situation. To the right of the terrace of older houses and on top of the soliftuction materials (low cliff) can be seen the roofs of two new bungalows which have been built in the last three years. Below this site, at the base of the cliff, there is no form of protection from regular wave attack, let alone storm wave activity. It is likely that the market value of these new properties will decline as cliff erosion proceeds, culminating in major structural damage within the normal life expectancy of these buildings. What is particularly important, in view of the 1974 failure, is that adequate drainage is provided for all dwellings along the cliff top. Such drainage should ensure that the concentrated discharge of intercepted surface water is not directed into soakaways which cause local rapid saturation of the head materials and thus increase the likelihood of rotational slumping.

Conclusion

The nature of the coast in this area of south-east Cornwall has been outlined together with a review of the history of local erosion problems. Recent studies undertaken by the authors indicate the likelihood of continued marine erosion resulting in cliff failures along this coastal sector. Natural protection afforded by longshore supplies of sediment seems to have diminished, exacerbating the problem. To this basic framework is added the complication of cliff-top settlements and the exact role of county and local authorities in coastal protection. In the absence of a general coastal zone management plan for this area, apparently contradictory decisions have been made resulting in extensions to existing dwellings or even the construction of new properties. In the context of coastal erosion and protection there would appear, therefore, to be a need for closer liaison between departments within local authorities, and between such authorities and scientists and engineers undertaking coastal research. In this way, both public and private interests can be safeguarded.

References
