IMPLICATIONS OF CONSOLIDATION ON BARRIER BEACH STABILITY

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INTRODUCTION

Barrier beaches often overlie backbarrier deposits composed of poorly consolidated sediments. Hence, they can consolidate significantly if loaded. A retreating barrier beach provides such a load. In the static situation of beach nourishment, the increased load of the raised beach volume will also cause increased consolidation. These can lower beach elevation promoting wave overtopping, overwashing and retreat. However, there is limited research concerning the role of consolidation on the stability of barrier beaches worldwide.

This paper focuses on this issue using Hurst Spit on the UK south coast as a study site where consolidation is a known significant process (Nicholls, 1985; Burt et al., 2018). It is a storm beach composed of shingle (pebble and cobble) sediments and formerly retreated at 2 to 3 m/yr, Since the later 1990s it has been more stabilized by a major nourishment (Bradbury and Kidd, 1998), but continues to retreat slowly (Figure 1). A second nourishment phase is now being actively assessed following major damage in the large storm of 14 February 2014. In this context, the role of consolidation has been analyzed via new data collection, consolidation modelling and morphodynamic modelling. This paper presents these results and their implications.

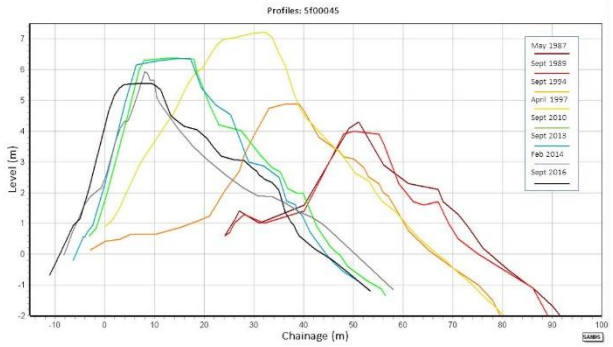

Figure 1 – A time series of cross-sections across Hurst Spit from 1987 to 2016.

METHODS

The poorly consolidated substrate in the lee of Hurst Spit was sampled by coring. These samples were used to determine the key geological and geotechnical properties and estimate the potential maximum consolidation under load due to the transgressing barrier. A generic model of consolidation beneath barrier beaches was also developed which allows consideration of a wider set of barrier configurations than existing at Hurst Spit. Lastly a set of simulations using the XBEACH-G morphodynamic cross-shore model (https://oss.deltares.nl/web/xbeach/xbeach-og) explored the effect of consolidation on overtopping of Hurst Spit.

RESULTS

The sampling shows that a thickness of up to 4-m of poorly consolidated backbarrier deposits above well consolidated Pleistocene and older sediments which would not be expected to consolidate. Calculations suggest that significant consolidation is possible due to the loading of tbe beach (Figure 2).

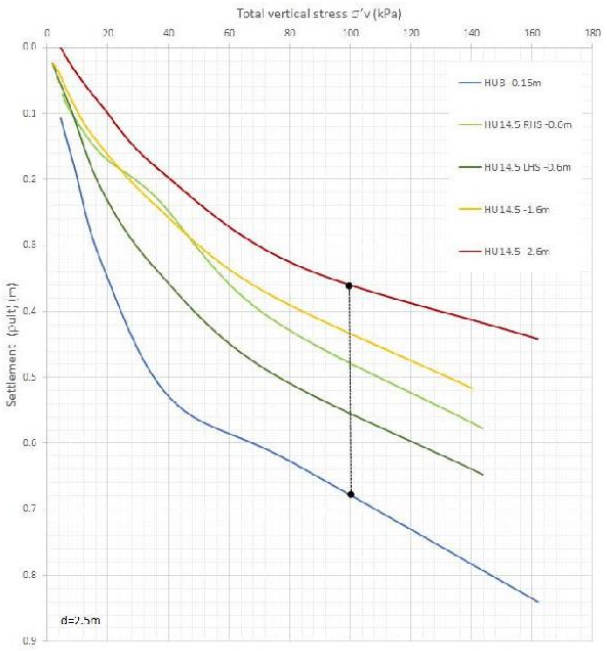

Figure 2 – Maximum settlement expected due to increases in total vertical stress, for each odometer sample from behind Hurst Spit – 100 kPa is equivalent to the maximum load of the beach below the crest. (assumed sediment thickness of 4m).

The magnitude of consolidation is dependent on the thickness of the poorly consolidated substrate, with rapid vertical consolidation of up to 1m in less than 10 years being possible beneath Hurst Spit. Empirical observations agree with this magnitude of change, providing an independent validation. Some sections of the barrier beach are more vulnerable to future consolidation and instability than others, representing a

variety of factors. This includes sections of the barrier subject to the highest wave impacts, which are more vulnerable to overwash of sediments and consequent landward migration of barrier sediments.

This leads to increased loading of the substrate landward to the beach crest. Peat was found to be a minor component in the materials at Hurst Spit: in other barriers with thick substrate peats this would contribute towards higher magnitudes of consolidation.

The numerical model demonstrates that Hurst Spit represents an ideal location for rapid consolidation. In addition to the highly compressible substrate properties already mentioned, the spit has steep slopes (about 10 degrees) due to the coarse grain size, and with rapid retreat the loads grow rapidly. In general, rapidly retreating shingle beaches with appropriate backbarrier substrate will be especially susceptible to consolidation processes. In contrast, Chesil Beach is a larger gravel barrier beach up to twice the height of Hurst Spit. However, the beach is much more stable and the rate of change in loads over time is much smaller. Hence, while absolute consolidation might be as large or larger, the rates of consolidation will be lower and consolidation is less important as a process.

The XBEACH-G simulations demonstrate that, consolidation can be rapid enough to influence the sediment budget and effect the rate of overwashing during storms on Hurst Spit. In effect, consolidation can be considered as a virtual term in the sediment budget.

IMPLICATIONS

These results demonstrate that consolidation has influenced the natural morphodynamics of Hurst Spit. In the past, rapid landward movement of the barrier was been reinforced by consolidation and loss of elevation.

Consolidation is also important to consider during beach nourishment. To achieve a given design cross-section, additional material is required to allow for consolidation. In addition, any recharge material should be added in stages. This minimizes the risk of substrate shear failure which has been observed to occur on several occasions during the first nourishment, and due to sudden natural barrier loading from sudden natural barrier loading due to overwash.

More generally, this research suggests that consolidation can be a significant process on barrier beaches. The methods used to support this study were simple and low cost. They have improved understanding of the geological and geotechnical properties of the back barrier sediments at Hurst Spit. It would seem prudent to consider similar investigations for other barrier beaches that provide important protection functions. This is especially true for rapidly retreating shingle beaches. If nourishment is planned the potential role of consolidation to influence the sediment budget should be considered.

In conclusion, there is a need to build our knowledge on the role of consolidation in barrier beach stability as with limited exceptions (e.g. Rosati et al., 2010), this issue is unstudied. This could lead to the development of guidance for coastal engineers on when and how to include this issue in management and design.

REFERENCES

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