# THE IMPACT OF AEOLIAN SEDIMENT TRANSPORT ON DYNAMIC COBBLE REVETMENT DESIGN

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## INTRODUCTION

Dynamic cobble revetments are used along high-energy coasts to mitigate coastal erosion. Specifically, dynamic revetments can reduce shoreline retreat and wave runup (Bayle, 2020). Dynamic revetments are a category of natural and nature-based features that provide an alternative adaptation option to traditional static rock revetments. These features are intended to replicate natural composite beaches, which reshape under varying wave conditions. Composite beaches and dynamic cobble revetments consist of a low-sloping sandy section backed by a steeper gravel slope and crest (Figure 1). The sandy section is typically exposed during low tide. When the exposure of the sandy beach coincides with strong winds, aeolian sediment transport can occur on composite beaches (Figure 1a).

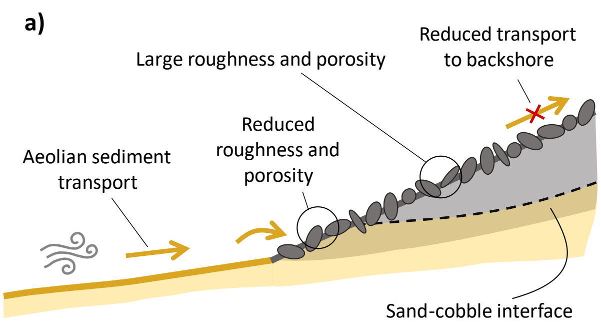



Figure 1 - Schematic profile of a dynamic cobble revetment showing how aeolian sediment transport might alter the roughness and porosity of the structure. b) Example of infilling after aeolian sediment transport on an engineered dynamic cobble revetment in Westport, Washington, USA (Photo: Hailey Bond).

When landward directed aeolian sediment transport occurs, the shape and roughness of dynamic cobble revetments are expected to cause sedimentation on their toe and face (Figure 1b). The break in slope at the dynamic revetment toe may reduce the wind velocity. More importantly, compared to the smoother sandy beach surface, the increased roughness of the cobbles at the dynamic revetment surface is also expected to reduce the wind velocity, resulting in deposition. Additionally, the sand transported by the wind may become trapped due to the porosity of the cobble surface. The deposited sediment may cause infilling of pores in between cobbles.

## INTERNAL SAND DYNAMICS

In the sub-surface, a dynamic revetment consists of stacked layers of pure cobble, mixed sand and cobble, and pure sand (Bayle, 2021). The interface between the pure cobble and mixed sediment layers can be referred to as the sand-cobble interface (Figure 1a). Above the sand-cobble interface, the permeability of the material is high, whereas below the interface the permeability is low. Therefore, when swash percolates through the dynamic revetment, the sand-cobble interface acts as a subsurface runoff interface (Bayle, 2021). The location of this interface is important for the development of dynamic revetments because it impacts swash processes that drive morphological change and can impact overtopping and overwash (Blenkinsopp, 2022).

The permeability and surface roughness of a dynamic cobble revetment may be reduced by aeolian sediment transport processes that cause sand to fill pores between cobbles. This infilling may affect the process of swash percolation, reducing the ability of a dynamic revetment to reduce runup. The persistence of this effect will depend on the retention of aeolian deposits within a dynamic revetment. Aeolian deposits may be removed by swash events that carry sediment through the structure towards the revetment toe. Thus, the long-term influence of aeolian deposition on the performance of a dynamic revetment is dependent on the marine processes that occur following an aeolian sediment transport event.

## REDUCTION OF LANDWARD AEOLIAN TRANSPORT

The presence of a dynamic revetment causes aeolian sedimentation, which can reduce the amount of aeolian sediment transport towards the backshore (Figure 1a). Thus, the construction of a dynamic cobble revetment may result in unintended consequences for coastal systems that rely on aeolian sediment transport. However, as of yet there is no design guidance available on the implementation of dynamic revetments in front of coastal dunes, or on their implementation as hybrid structures, e.g., in combination with dune creation.

To investigate the extent of the influence of aeolian sediment transport on the performance of dynamic revetments, and vice versa, this research aims to quantify aeolian sediment transport on natural composite beaches and beaches with engineered dynamic revetments. This investigation is based on field measurements on a time scale of days and aeolian sediment transport modeling on a time scale of seasons/years.

## FIELD MEASUREMENTS

Several intensive, short-deployment field campaigns are conducted to measure aeolian sediment transport on two beaches. The deployments are carried out during high-wind events that coincide with low tide. The deployments take place at a natural composite beach at Arch Cape, Oregon, and at an engineered dynamic cobble revetment at Cape Lookout State Park, Oregon, both in the United States. During each deployment, a cross-shore profile of wind sensors and sediment traps is used to measure cross-shore variations in the wind field and sediment transport. The amount of sand that percolates into the pore space of the cobbles is measured using subsurface sediment traps. To determine changes in surface elevation and sand coverage, lidar scans are collected before and after the aeolian sediment transport events. To determine temporal variations in the elevation of the sand-cobble interface, holes are dug every 5 meters along a transect parallel to the wind sensor array. The sand-cobble interface measurements are collected before and after each aeolian sediment transport event. At Arch Cape, they are also repeated during several low tides after the aeolian sediment transport event to monitor the retention of aeolian deposits.

Measured aeolian sediment transport rates on the seaward and landward side of the cobble surface are compared to determine the trapping efficiency of a dynamic revetment. Additionally, an estimate of the total amount of sedimentation on the revetment during each high-wind event is computed by synthesizing the field measurements.

## MODELING AEOLIAN TRANSPORT

Estimates of aeolian sediment transport on seasonal to yearly time scale are provided using the aeolian sediment transport model AeoLiS (Hoonhout and de Vries, 2016). Based on measured coastal profiles, the model is set up for the Arch Cape and Cape Lookout State Park study sites. The effect of the slope and roughness of the cobble surface on aeolian sediment transport is simulated by reducing the shear velocity, which is similar to the implementation of vegetation effects in AeoLiS (Dickey, 2023). This approach is validated at the event-scale using the field data consisting of wind and aeolian sediment transport measurements gathered during high-wind events. The model is then run for longer timescales using available long-term data of environmental conditions (like wind and waves).

Subsequently, changes in elevation of the sand-cobble interface caused by marine and aeolian processes are compared. The effect of aeolian processes on the sand-cobble interface is estimated by converting the modeled event-scale and yearly-scale aeolian transport into elevation changes of the sand-cobble interface. The model-based elevation changes are validated using the sand-cobble interface measurements obtained before and after each aeolian sediment transport event. The effect of marine processes on the sand-cobble interface is estimated based on the temporal variations measured after the aeolian sediment transport event in Arch Cape. Additionally, sand-cobble interface measurements collected by Bayle et al. (2021) are used as a reference. Comparing the changes in the sand-cobble interface elevation due to the marine and aeolian processes provides a quantitative indication of the contribution of aeolian sediment transport to the sediment transport within a dynamic revetment.

## EXPECTED RESULTS AND IMPACT

We expect to show that dynamic revetments reduce wind speeds near their cobble toe, which causes sedimentation on their seaward facing slope. Due to this sedimentation, considerable volumes of sand are introduced into the pore space of cobbles that make up dynamic revetments. This sand infilling may cause reduced permeability and roughness of the dynamic revetment after aeolian sediment transport events. Our measurements are expected to show that swash processes can redistribute these aeolian deposits within a few tidal cycles. We recommend further research into the redistribution of aeolian deposits by marine processes, and into the effect of infilled cobble pores on runup. Insights into these processes can provide more detailed quantification of the impact of aeolian processes on the performance of dynamic revetments.

In addition to the occurrence of sand infilling, we anticipate that our field measurements will show lower aeolian sediment transport rates towards the backshore than similar beaches without a dynamic revetment. This indicates that implementing a dynamic revetment where it is backed by coastal dunes may cause these dunes to receive less sediment, which could affect their resilience. This finding may directly impact the evaluation of the suitability of dynamic revetments for beach-dune environments.

## REFERENCES

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