OBSERVATION AND PREDICTION OF ALONGSHORE TRANSPORT OF COBBLES ON NATURAL AND ENGINEERED COMPOSITE BEACHES

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INTRODUCTION

Coastal erosion is a common problem in the Pacific Northwest of the US (PNW), threatening both the built environment and the stability of public beaches. While traditional structural solutions may halt shoreline retreat, there is growing interest in natural and nature-based features (NNBFs) that can mitigate erosion while reducing the negative impacts of hard structures.

One of the most applicable NNBFs for the open coast of the PNW is a dynamic revetment. Dynamic revetments are inspired by examples of naturally occurring, dynamically stable composite beaches that remain resilient under the high-energy wave climate of the PNW, in which offshore winter wave heights can reach 10 m (Allan, Gabel, & O'Brien, 2018). In the PNW, composite beaches are typically composed of a gently sloping sandy foreshore and a steep cobble backshore. Composite beaches are expected to move in response to high-energy wave conditions. Dynamic revetments inspired by composite beaches have been constructed in several places on the PNW coast, including Westport, Washington, the South Jetty of the Columbia River, Oregon, and Cape Lookout, Oregon. However, engineering guidance for the design and construction of dynamic revetments is still extremely limited.

An important element of the dynamic revetment design process is designing a maintenance schedule. Like other NNBFs, dynamic revetments are expected to require monitoring and maintenance to maintain their performance throughout their design life as cobbles are transported off of the revetment. Net cobble movement on composite beaches is typically in the alongshore direction (Bayle et al. 2021). Therefore, a factor involved in the determination of a maintenance schedule is the rate of alongshore transport of the cobbles that make up a dynamic revetment. In addition, Predictions of alongshore transport are therefore an important factor in determining maintenance needs of a dynamic revetment over its design life.

In addition to predicting the time interval for cobble replenishment, predictions of alongshore transport are also important for determining the impact of the dynamic revetment on the beach. Prior to construction, stakeholders expect to know what parts of the beach may be impacted by cobble. Information on the alongshore transport of cobble will therefore help decision-makers predict the impacts of dynamic revetment on their sites and the surrounding environment.

To aid in the implementation, design, and maintenance of dynamic revetments, the goal of this study is therefore to improve the engineering estimations of alongshore transport of cobble on composite beaches on timescales from a single high tide to a year.

PREVIOUS MEASUREMENTS OF COBBLE TRANSPORT

Alongshore cobble transport has been observed to be related to cobble size, shape, and mass, and to hydrodynamic conditions, but results are not conclusive.
Some studies (i.e., Young et al., 2023) have found a relationship between cobble shape, cobble mass, and distance traveled. However, other studies (e.g., Allan, Hart, & Tranquili, 2006) have found only a correlation between cobble size and distance traveled, and others (e.g., Bayle et al., 2021) have found no correlation between cobble size or shape and transport.

Hydrodynamic conditions may also be a major factor in the direction and volume of alongshore transport. Allan, Hart, & Tranquili (2006) suggested that wave direction was the dominant factor in determining the direction of alongshore cobble transport in a study spanning 3 years. Bayle et al. (2021) observed that most cobble motion happened at high tide, regardless of the offshore wave conditions during a two-week intensive experiment.

It is also possible that runup height (parameterized as $R_{2\%}$, or the elevation of the highest 2% of swash events) is a predictor of the volume of alongshore sediment transport on engineering time scales. On composite beaches, $R_{2\%}$ is related to the still water depth at the toe of the cobble, and beach and cobble slopes (Blenkinsopp et al., 2022). As movement of cobble is driven by swash events, $R_{2\%}$ could predict the amount of cobble impacted by swash events and potentially mobilized.

SITES

In this research, we study alongshore cobble transport at three open-coast PNW beaches. Two are natural composite beaches (Arch Cape, Oregon, and Falcon Cove, Oregon), and one is an engineered dynamic revetment (Westport, Washington) (Figure 1). All three beaches have a wide, dissipative surf zone. The dynamic revetment at Westport is composed of a core of angular cobble with a cap of rounded river rock The cobble at Arch Cape is subangular, and the cobble at Falcon Cove is rounded. The study period is from October to February 2023, during which the wave climate is at its most energetic and the highest tides of the year are expected.

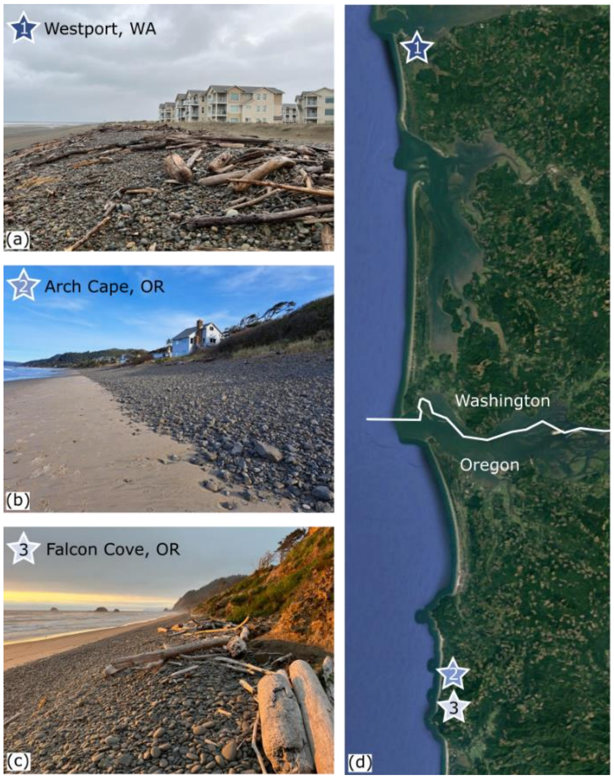

Figure 1 - Map and photos of project sites. (a) Westport, Washington is an engineered dynamic revetment constructed in January 2021. (b) Arch Cape, Oregon is a natural composite beach with subangular cobble. (c) Falcon Cove is a natural composite beach with rounded cobble. (d) A map of the project site locations.

METHODS

To monitor the movement of cobbles throughout the 2023 winter season, we are using a season-long monitoring program coupled with an intensive field experiment.

The monitoring program consists of Radio Frequency Identification (RFID) tracking of cobbles coupled with camera monitoring of the site. RFID tracking uses passive RFID tags embedded into the cobble. Then, an antenna can be used to find the cobbles and an RTK-GPS can be used to record their locations. There are 50 cobbles deployed at each site at the beginning of the winter season, and their locations will be monitored throughout the season. The cobbles used in the study originate from the study sites, and are representative of the range of cobble sizes found on the beach. Measurements of the size, shape, and mass of the cobble were recorded before deployment. In addition, there is video monitoring of the three sites from shore-based cameras recording near-continuously during daylight hours. The camera imagery is combined with RTK-GPS beach surveys to derive runup statistics during select storm events.

For the intensive field experiment, 50 additional cobbles will be placed on each beach as part of an intensive study during the spring tides of January 2024. An acoustic dopper current profiler (ADCP) and two acoustic Doppler velocimeters will also be deployed in the surf zone to quantify currents and waves at Arch Cape, Oregon. An alongshore array of pressure sensors at the toe of the cobble beach will monitor alongshore variations in runup.

RESULTS/DISCUSSION

Alongshore transport measurements will be compared to relevant statistics related to $R_{2\%}$, wave angle, and wave period to investigate possible predictive variables. We expect that the alongshore transport distance of cobbles on composite beaches will be predicted in part by $R_{2\%}$, which will likely be predicted by the still water depth. Wave direction and alongshore gradients in $R_{2\%}$ may also be factors in determining the direction and distance of cobble movement. Net northward transport is expected at all the sites, as that is the typical direction of sediment transport during the winter in these littoral cells. We also expect for cobble size and shape to have a relatively small impact on the distance traveled by the cobbles, as that appears to be the usual trend for high-energy composite beaches (Allan, Gabel, & Tranquili 2006, Bayle et al. 2021).

Based on the results from the monitoring program and intensive field experiment results, we will develop an empirical equation to aid in prediction of cobble transport during event and seasonal time scales. The equation will be based on typical engineering parameters such as wave direction, water depth, beach and cobble slope, and $R_{2\%}$. The findings of this study will aid engineers in predicting the direction and volume of cobble transported alongshore from the placement position of the dynamic revetment project.

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