TRANSPORT OF ALIEN PARTICLES IN SAND BEDS MOBILISED BY WAVES

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INTRODUCTION

Sand beds in the marine environment often contain discrete particles with properties that differ substantially from those of the native sand. These "alien" particles occur in a wide range of sizes, shapes and densities, with examples ranging from low-density plastic fragments to industrial particles with densities significantly higher than the native sand. Understanding and predicting the behaviour of these particles as the sand bed is mobilised by waves and currents is important for predicting their potential impact on the marine environment.

The motion of an alien particle in a mobilised sand bed depends on complex flow-particle and inter-particle interactions, which are governed by the flow conditions and the properties of the native sand, as well as the size, density and shape of the particle, and its position within the bed. Transport may occur in regimes that range from low-energy conditions just above the threshold of sand motion to high-energy "sheet-flow" conditions. In practice, the fate of alien particles in the marine environment can potentially be predicted using particle tracking models (e.g. MacDonald and Davies, 2006, Soulsby et al., 2011). In such models, the complex interactions are not modelled, but are instead represented through empirical functions which describe the availability, entrainment, and velocities of particles. However, these empirical functions are untested against data obtained under well-defined experimental conditions. This paper aims to address this knowledge gap through a systematic set of laboratory experiments where alien particle motions in oscillatory sheet-flow are investigated.

EXPERIMENTS

Experiments are conducted in the Aberdeen Oscillatory Flow Tunnel (AOFT), a 16 m long U-tube facility capable of producing oscillatory flows representative of near-bed conditions under full-scale storm waves. The central test section is 7 m long with a rectangular cross-section (0.3 m wide, 0.75 m tall), in which a 0.25 m deep sand bed is placed. Experiments involve placing a collection of alien particles on a flat sand bed, after which it is exposed to a short, controlled sequence of large-amplitude oscillatory flow where sheet-flow occurs. Flow velocities are measured in the "free-stream" using laser Doppler anemometry, and particle motions are recorded using high-speed imaging. By conducting repeated experiments involving a range of different alien particles, in which both the instantaneous and cumulative particle motions are observed, empirical descriptions of particle behaviour are obtained.

RESULTS

Preliminary experiments have been conducted, involving spherical particles on a coarse sand bed (d_{50}=0.46 mm). Particles of three different densities (plastic: specific gravity ≈ 1.5, glass: sg ≈ 2.5, and ceramics: sg ≈ 4.0) and three diameters (1 mm, 4 mm, and 10 mm) were used, under approximately sinusoidal flow with a period of 6 s and velocity amplitudes of up to 1.5 m/s.

Figure 1 is a close-up of ahigh-speed camera image, showing a side-view of the sand bed where a row of ceramic spheres (Ø4 mm) can be seen, during the accelerating phase of the flow period. At this instant, the sand bed is beginning to become mobilised while the ceramic particles are still stationary, and as a result, horizontal "scour lines" are observed on the sand bed. As velocity increases, the bed becomes fully mobilised and the particles undergo motion. Recordings show the alien particles undergoing different types of motion including rolling, sliding and saltation within the sheet-flow layer. Over successive flow cycles the particles undergo net motion in a direction determined by asymmetry in the oscillatory flow shape. A key aim of the investigation is to characterize the impact of the flow shape on net transport of particles, by varying the velocity skewness and acceleration skewness of the oscillatory flow.

The main body of experiments are still ongoing at the time of writing of this abstract. These experiments cover a broad parameter space, involving two different sand beds (coarse and fine sand) as well as a range of alien particle densities, sizes, and shapes (including spherical and non-spherical particles). Observations from these experiments will be presented and discussed, and key outcomes from early quantitative analysis will be presented.

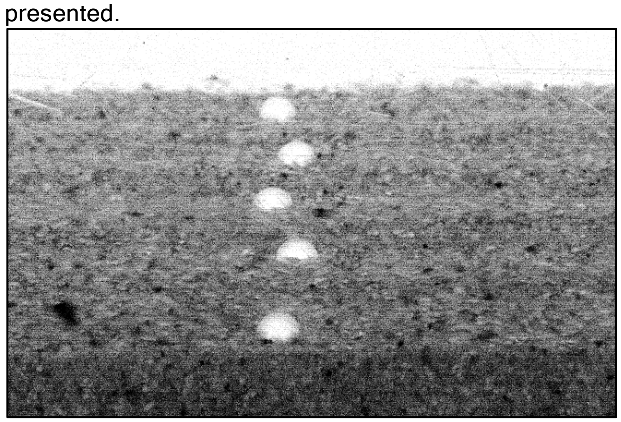

Figure 1 – Image from a high-speed recording of spherical alien particles on a sand bed during flow acceleration.

REFERENCES

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