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The harmonious character in equilibrium aeolian transport on mixed sand bed

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Abstract

Wind tunnel experiments were carried out to measure the spatial distribution in equilibrium transport of four types of mixed sand. The flux profiles of each grain size group were calculated. It is found that the vertical distribution of mean grain size has a close relation with the grain size distribution in the sand bed. In a log-linear plot, the flux profiles of main grain size groups are all straight lines and their slopes are nearly equal. It is also found that the ratio of transport rate of each size group to the whole transport rate is directly proportional to the mass ratio of each size group in the sand bed and the proportion value is only dependent on the grain size. This harmonious law is applicable to all four types of mixed sand used in the experiment.

Keywords: Mixed sand; Grain size; Vertical distribution; Flux profile; Aeolian transport

1. Introduction

The airborne movement of sand grains causes some severe environmental problems, such as sand dune drifts and dust storms (Lynas, 2003; Lim and Chun, 2006). In aeolian sand transport, sand grains are dislodged into air, some small grains move in suspension and larger grains move in saltation and creep, hence the form of sediment surface is continuously changing as the sand grains on the surface are rearranged (Bagnold, 1941). These phenomena all bear a close relationship with the grain size composition of the sediment and, therefore, texture variation on the bed has significant effect on the aeolian transport process.

Considerable progress has been made in the study of aeolian sand transport. Many experiments in the field and wind tunnel were carried out to reveal the relationship between sand transport, wind velocity and bed surface characteristics (Bagnold, 1941; Chepil, 1945a,b; Zingg, 1953; Lettau and Lettau, 1977; White, 1979). The experimental equations are mostly empirical or semi-empirical and it is hard to get general agreement. Numerical simulation becomes important in exploring the intrinsic mechanism of sand transport. In most theoretical analyses or numerical simulation, sand grain size is assumed to be uniform and little attention has been paid to size composition of sand bed and the interaction between different sized sand grains (Sørensen, 1985; Ungar and Haff, 1987; Werner, 1990; Anderson and Haff, 1991; McEwen and Willetts, 1991; Spies and McEwan, 2000). However, the sand grains of a bed surface in the field or a wind tunnel are non-uniform and the grain sizes may vary considerably. The movement of grains in a mixed-grain-size sand bed is different to the grain movement in a uniform sand bed due to the relative difference of grain size or grain mass. Sand transport must, therefore, be dependent on the grain size structure

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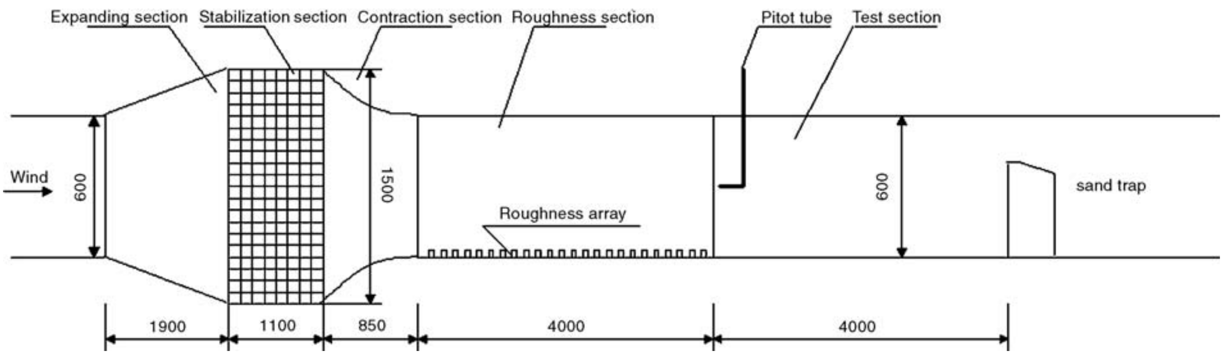

Fig. 1. Schematic diagram of the wind tunnel used for the experiments (units are given in mm).

of the bed surface. Consequently, much effort should be made to study the influence of bed surface grain size distribution on sand transport.

In past decades, some knowledge about spatial grain size distribution has been obtained from previous research. In Williams' (1964) wind tunnel experiment, he measured the spatial grain size distribution and analyzed the influence of grain shape and grain size distribution of the bed surface on the spatial distribution, but the sand was only sampled at five elevations in the airflow in this experiment. Other experiments are mostly field studies. Sharp (1964) reported that the weight percentage of each grain size group decreases with height but the trend of grains smaller than 62 μm is much different due to suspension. Nickling (1983) and Chen et al. (1995) indicated that the mean grain size decreases with height in a power function.

Nevertheless, the knowledge about the sand transport on a mixed sand bed is mostly concerned with the spatial distribution of grain size. Wind tunnel experimental research regarding the relationship between the spatial distribution of different grain size groups and the grain size composition of the sand bed is still limited. In order to understand the sand transport on non-uniform sand bed, we carried out an experiment in a wind tunnel to measure the spatial distribution of sand transport on four types of mixed sand bed. To measure the grain size precisely, an optical microscope system is employed. This experiment is expected to be valuable for understanding the mechanism of the complex sand transport process on a mixed sand bed and the interaction among different grain size groups.

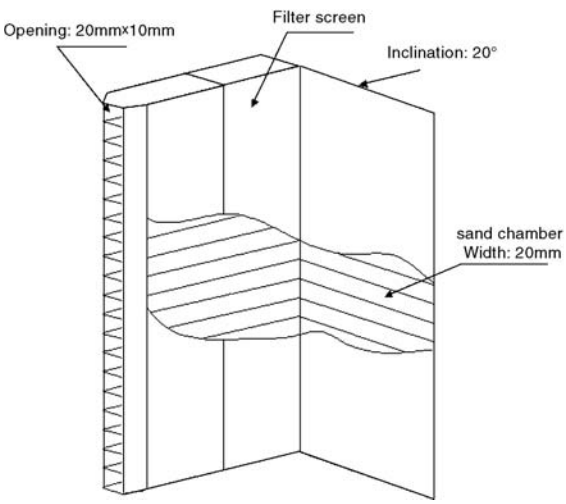

Fig. 2. Sketch of the vertical sand trap.

2. Experimental apparatus and procedure

2.1. Wind tunnel

The experiment was carried out in the wind tunnel at State Key Laboratory of Multiphase Flow in Power Engineering, Xi'an Jiaotong University. The blow-type non-circulating wind tunnel (Fig. 1) is composed of power section, expansion section, stabilization section (where drag screens and honeycombs are set to reduce large scale eddies; cross-section area is 1.5 m × 1.0 m), contraction section, roughness section (4 m long) and work section (6 m long). The cross-sectional area of work section is 0.6 m × 0.4 m. Wind speed can be changed continuously in the range of 2–30 m/s. The average turbulence is $\alpha < 1\%$, the stability coefficient of wind flow is $\beta < 2\%$, and the uniformity coefficient of wind velocity is $\delta < 2\%$. The depth of boundary layer in the work section is about 15 cm.

2.2. Measurement method

A Pitot tube was set at the centerline (30 cm height above tunnel floor) of the entrance of the work section to