Oscillatory flows through porous media: influence of the specific surface on the wave behavior

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ABSTRACT

This communication is related to the energy dissipation by porous media. A particular attention is paid on the effects of specific surface on dissipated energy through a porous media constituted by a compact network of emerging vertical cylinders. Experiments have been performed with three porous structures with varying cylinder diameters. The porosity is chosen constant whereas the specific surface depends on diameters of cylinders. Two series of experiments have been carried out, the first with stationary flows and the second with regular waves. Finally, scale effects on the reflection and transmission coefficients are also studied.

KEY WORDS: Porous structure; Specific surface; Head loss; Wave; Reflection; Dissipation; Scale effects.

INTRODUCTION

The purpose of this paper is to study the effects of the specific surface on energy dissipation through porous media. Porous structures are known to significantly dissipate incident wave energy which is of great interest for many researchers and engineers in the context of the shoreline protection. The characterization of the effects of porous structures on flow dynamics is often based on the linear potential theory, as in Sollitt & Cross (1972), in association with experimental and numerical models. Whereas the porosity is clearly a major parameter, the specific surface, defined as the fluid-solid contact surface per volume unit (Guyon et al., 1991), remains poorly discussed. The present study demonstrates that it can be as significant as the porosity coefficient in the expression of permeability, at least for low Reynolds number flows.

For propagation studies of waves over porous bottom, the effects of attenuation are most frequently related to inertial and non-linear effects (Gu & Wang, 1991). Based on the work of Sollitt & Cross (1972), a complex expression of the dispersion relation is obtained taking into account these inertial and non-linear effects, which describes a propagation regime with dissipation. Yu & Chwang (1994) have studied the case of superimposed porous, for weakly to strongly dissipative conditions, including the influence of “evanescent” modes related to media index discontinuities in the propagation direction. Moreover, Lee & Lan (1996) extended the linear potential theory to the second order using the perturbations method, retaining the concept of complex dispersion relation. More recently, Molin (2011) proposed a quadratic approach for strongly Reynolds number flows and for thin porous media.

Many experimental works have been performed to validate theoretical models and study flow response to particular porous structure in terms of geometry and materials. Kondo & Toma (1972) studied the role of incident wave characteristics and breakwater thickness on reflection and transmission coefficients. Several other studies tested the influence of porous structure shape and steepness (Corvaro et al., 2010; Hall et al., 1995; Losada et al., 1995; Sulisz, 2008) or media anisotropy (Lee et al., 2003).

The present paper reports several series of experiments performed to describe the effect of the specific surface on head loss in the case of stationary flows and on reflection and transmission coefficients for wave propagation. The three models consist in arrays of emerging vertical cylinders. The porosity is kept constant while the specific surface varies using different cylinder diameters. Finally, this work relates the processes causing attenuation and the specific surface to study scaling factors.

EXPERIMENTAL SET-UP

Hydrodynamic wave tank and porous media

The experiments have been performed in a 10 m, 0.3 m wide and 0.5 m high current-wave flume (SeaTech, University of Toulon, France). A gentle sloping beach was located at the downstream end of the flume to maximize the dissipation of the transmitted wave energy and avoid spurious reflection. Porous media are constituted by a dense array of emerging vertical cylinders. These tubes of same diameter are regularly disposed along two perpendicular axes forming a 45° angle with the longitudinal axis (Fig. ). Three porous media are built with three different diameters D, respectively 0.020, 0.032 and 0.050 meter. The porosity γ of porous structures is constant and equal to 0.7. Nevertheless the specific surface s, previously defined in the introduction section, depends on cylinder diameters and thus takes the respective values 52, 33 and 22 m⁻¹. The lengths of porous media were adjustable from 1.20 m to 4.80 m depending on the experiments.