Force Reflecting Porous Media with Dynamic Elasticity Change

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1 Introduction

Liquid absorption affects the behavior of objects. Rain absorbed in the barrage can weaken its structure and cause the dam failure. A wet sponge ball bounces differently from a dry one. Porous media is a material that has internal pore space and is able to absorb liquid (e.g. a sponge or soil). Liquid absorption changes not only geometrical properties, e.g. volume, but also mechanical properties, e.g. elasticity. The aim of this study is to physically model the structural change of a porous media due to liquid absorption. Previous studies have focused on liquid flow inside the media[Lenaerts et al. 2008]. In contrast, this paper proposes a porous model that is able to simulate elastic change in a real sponge.

2 Simulating elastic change of porous media

As shown in Fig. 1, the particle system represents porous media and allows elastic representation with the real-time dynamic change of mechanical properties. Porosity ϕ_i refers to volume fraction of pore space within the volume of particle i. Saturation S_i refers to volume fraction of liquid in the pore volume.

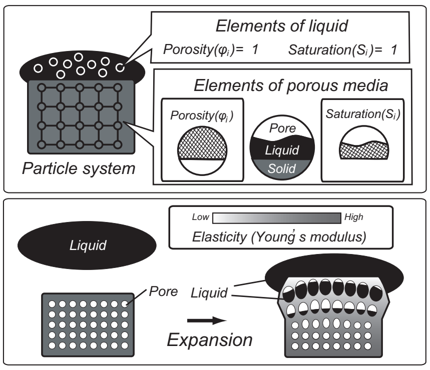

Figure 1: *Simulation framework for porous media*

The principle of effective stress divides the total stress σ_i into effective stress σ_i' and pore pressure u_i [Terzaghi 1936].

$$\sigma_i' = \sigma_i - u_i. \tag{1}$$

Pore pressure is the pressure of the liquid in the pore space. The effective stress, which is the stress acting on the solid, decreases when the pore pressure increases due to liquid absorption.The proposed porous model considers non-linearity between the pore pressure u_i and the saturation $S_i$to represent the rapid decrease of elasticity in the beginning of liquid absorption. (k_*: coefficients)

$$u_i = k_1 S_i + k_2 S_i^2 + k_3 S_i^3 \tag{2}$$

A decrease in effective stress σ_i' increases the pore space (porosity ϕ_i). In material physics, the elastic change is modeled as the change of the porosity as follows:

$$E_i(t) = E_i(0)(1 - \beta\phi_i(t)) \tag{3}$$

where E_i^0, E_i^t are the Young's modulus at initial state and at time t, respectively, and β is a constant.

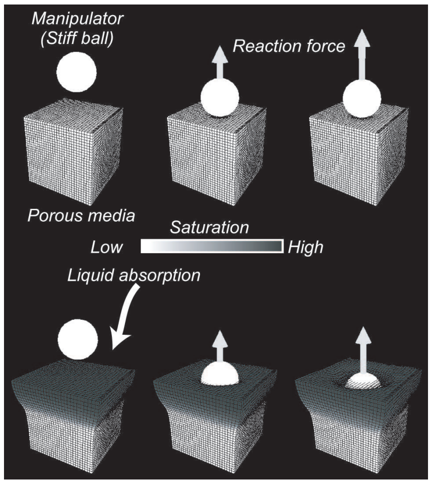

Figure 2: *Simulation results (liquid absorption: 0ml and 0.8ml)*

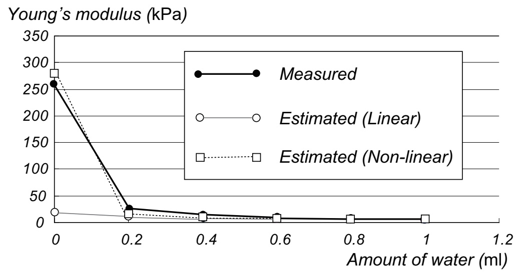

Figure 3: *The measured and estimated elastic change*

Fig. 2 shows the deformation of the porous model by unified applied forces for several conditions of liquid absorption. The model was deformed to a larger extent when the liquid absorption increased. Fig. 3 shows the measured Young's modulus via the compression test of a real sponge and the estimated Young's modulus via linear and non-linear pore pressure models. The results confirm the proposed model's ability to simulate the elastic change of the real sponge.

Acknowledgments

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