Mode of tunnel deformations induced by loading in wet granular layer

*Ayuko Shinoda[1], Shin-ichi Fujiwara[2], Hiroaki Katsuragi[1]

1. Graduate School of Environmental Studies, Nagoya University, 2. Museum, Nagoya University

Stable burrows in wet sediments dug by tidal and shore animals play important roles not only in the ecological behaviors of the animals, but also in material circulation in the substrate and the sediment conditions. Thus, the burrow stability problem has been a challenging topic in the fields of sedimentology and biology. Modern ocypodid crabs are known to dig deep burrows in a sandy beach (Seike and Nara, *Palaeogeog., Palaeoclimat., Palaeoecol*, 252 (2007) 458). However, it has not been clarified that how stable these burrow structures are against the external loading.
For the quantitative understanding of strength of a burrow in sandy beach, we modeled it by a tunnel structure in wet granular layer, and focused on mechanical property of wet granular matter. According to the previous works, its mechanical property shows complex behaver. For example, tensile strength of wet granular column nonlinearly depends on liquid content (Scheel et al., *Journal of Physics: Condensed Matter*, 20 (2008) 494236, Herminghaus, *Wet Granular Matter: A Truly Complex Fluid, World Scientific* (2013)). However, little is known about the strength of a tunnel structure formed in wet granular layer.
In this study, we conducted a simple experiment to investigate the mechanical property of a tunnel structure in wet granular layer. In the experiment, we observed how the tunnel structure was deformed by slow uniaxial compression. During the compression, the projected cross section of the deformed tunnel was filmed by a CMOS camera. The compression force was also measured by a testing machine. In this experiment, we mainly varied following parameters: liquid content, packing fraction, initial diameter of the tunnel, and grain size. By analyzing the acquired movies, we examined the temporal evolution of a projected cross section of the tunnel structure. We found that the mode of tunnel deformations can be classified into three types: continuous shrink, shrink with collapse, and subsidence by collapse. The experimental result indicates that the mode of deformations is principally determined by the initial diameter of a tunnel and grain size.
Furthermore, based on a simple model of the force balance for tunnels in soil (Knappett and Craig, Craigs Soil Mechanics, Spon Press (2012)), we estimated the maximum shear stress applied to the tunnel structure. In addition, we defined two types of strengths characterizing a tunnel structure: yield and maximum stresses. As a result, we found that these strengths show qualitatively different dependences on experimental parameters.
Finally, we briefly discussed the condition to maintain a tunnel structure in a sandy beach environment by using the experimental result and information obtained in previous works (Seike, *Marine Biology*, 153, (2007) 1199-1206, Sassa and Watabe, *Report of the Port and Airport Research Institute*, 45, 4,(2006) 61-107).

