The mechanical property of a tunnel structure in wet granular layer

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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, 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)). The origin of this nonlinear response of wet granular matter to external loading has not yet been revealed sufficiently. Moreover, 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 deformed when it was uniformly loaded from the top of the layer with a very slow loading rate. By taking and analyzing the movies of deforming tunnel structures, we examined the temporal evolution of a projected cross section of the tunnel structure. Furthermore, based on the discussion of stability of tunnels in the soil (Knappett and Craig, *Craigs Soil Mechanics*, Spon Press (2012)), we estimated the maximum shear stress applied to the tunnel structure at each state. The experimental result showed that the mode of deformation depends on both liquid content and packing fraction. Particularly, the liquid-content dependence of the mechanical response is not monotonic. In addition, we defined two types of strengths characterizing a tunnel structure: yield and maximum stresses. As a result, we found that these strengths strongly depend on packing fraction. Besides, they show qualitatively different liquid-content dependence in relatively high liquid content regime. Finally, we briefly discussed a possible application of the experimental result for estimating the upper limit size of 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).

