VERTICAL STRAIN AND BREAKAGE BEHAVIOUR OF CREEP LOADED CRUSHED MUDSTONE UNDER EXPOSING DRY/WET CYCLE AND WATER GRADIENT.

Institute of Industrial Science, University of Tokyo, Student member Mohamed NIHAAJ
ditto Kiyota, T., Munoz, H., Mohsan, M., and Katagiri, T.

Introduction

Mudstone is one of the widely available materials for construction of dam embankment, which are exposed to wetting and drying cycles (hereafter denoted as W/D cycle) due to the occurrence of fluctuation of the water level. Mudstone strength and deformability characteristics are dependent on dry and wet cycle, known as slaking. The settlement is the major problem in dam embankment as experienced at Ataturk dam at Turkey (Cetin et al., 2000). Previous study (Zhang (2014)) analysed the vertical strain behaviours without considering the suffusion effect. The Present paper focuses the settlement and the breakage behaviour of the crushed mudstone, which subjected to W/D cycle along water gradient. To capture the real condition, W/D cycle coupled with temperature such as wetting at room temperature (25^{0}c) and fully dry (Wc<1%) at 56^{0}c. To provide above conditions, oedometer was modified.

Development of Weathered Mudstone Apparatus

For this experiment oedometer to be modified to control the variant of water content, temperature, and water gradient.

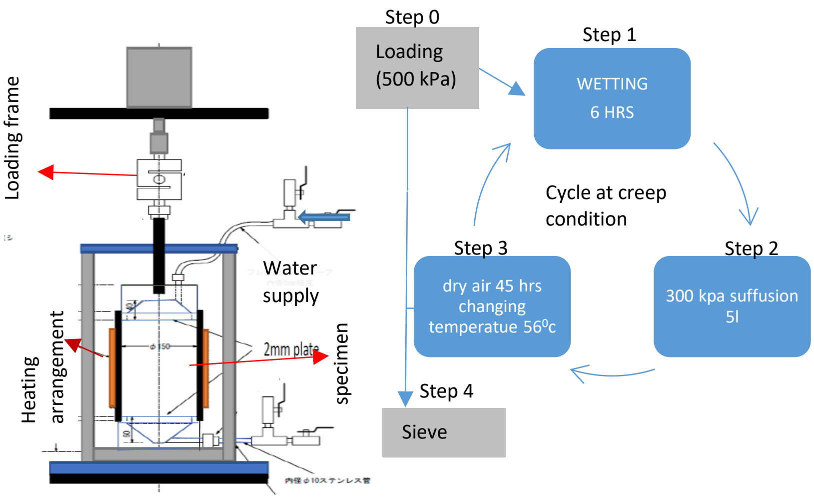

Fig 1. (a)Diagram of apparatus (b) Typical steps in a cycle

Table 1: Type of specimen

Speci Name	No cycle	Test Steps in order
Cycle0 Loading	0	0-4 (only loading)
Cycle1	1	0→(1→2→3)→4
Cycle3	3	0→(1→2→3) *3cycle*→4
Cycle5	5	0→(1→2→3) *5cycle*→4
Cycle12	12	0→(1→2→3)*12cycle*→4

**(1-2-3)-one cycle of wet and dry

Fig 1 (a) shows the modified oedometer, consists of four components. **1)** Vertical loading frame, which is able to apply up to 500 kPa axial stress. **2)** Heating arrangement- specimen mold is wrapped with heater and an insulating cover for minimizing heat loses. **3)** The wetting arrangement, the top cap is annexed with a water tank which is able to supply the water with pressure. **4)** Water collecting system, which embedded at bottom of the specimen mold to drain out the water and collect the washed out the particle.

Sample Preparation & Testing Procedure

The mudstone specimen (φ=75mm & h=150mm), was prepared by oven dried and crushed Hamamatsu mudstone (2-4.75mm). The specimen was prepared as five layers by applying external vibration to avoid breakage. Initial density of 12.16 kN/m^3 (Dc=78% of the initial material) was kept constant for all specimen. The Hamamatsu mudstone, which can be categorized as medium durable rock according to the test result, conducted herein. Slaking durable index are Id1=92.13%, Id2=73.75%, slaking index JGS 2125-2006 is 3, slaking ratio (NEXCO-100,2006) is 0.87% and water absorption (ASTM method C97) is 12.7%.

Tests were conducted through following steps (as shown in Fig. 1(b)); **steps-0** applying 500 kPa as axial stress, keep it as constant for the entire test. **Step-1** after the axial strain is stable at step-0 (which calibrated as 6 hours) wetting stage to be started. Water is applied to top cap by inducing negative pressure (-98kpa) inside the specimen and wait until the vertical strain becomes stable (at calibration, the wetting time defined as 6 hours). **Step-2** water gradient (300kpa) applied through the top cap and collect the water and washout particle through the 1mm mesh. Each cycle was applied 5 litres of water at this stage. In the drying phase as **step-3**, pressurized dry air has been applied through the top cap. At the same time, the heater maintained the inner specimen's average temperature as 56^{0}c. The required duration of applying dry air and heating arrangement were calibrated for reducing the water content less than 1% (45 hours, as calibrated). **Step-4** After finishing 5 experiments as explained in Table 1, remaining material was sieved and analysed the breakage.

Results and Discussion

Five samples were prepared and exposed to W/D cycle as mentioned in Table1. In a cycle, the vertical strain was measured immediately after wetting (W) & drying (D).

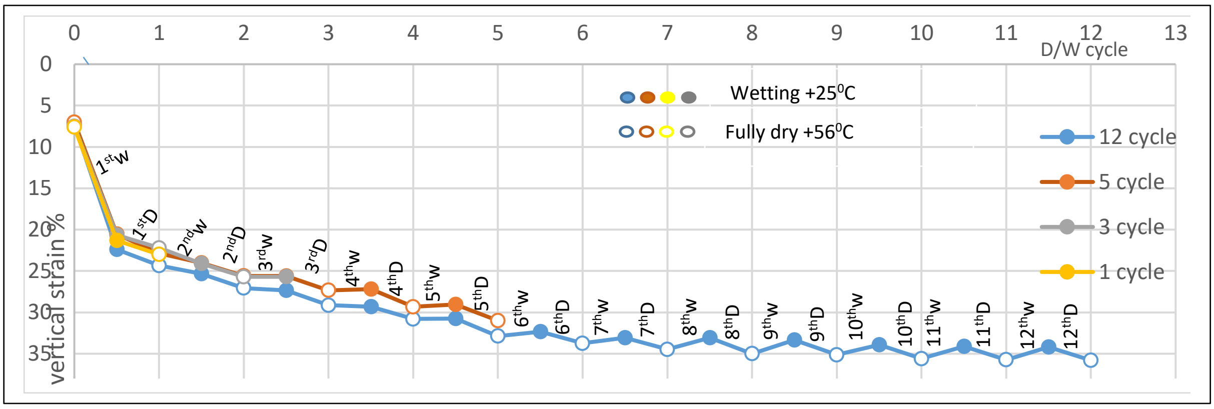

Fig 2. W/D cycle vs vertical strain

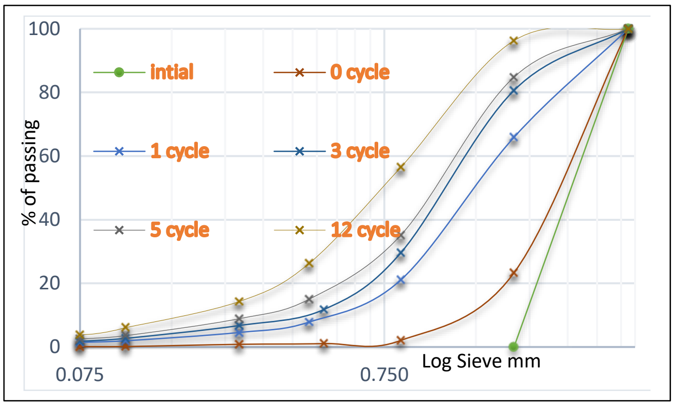

Fig 3. Breakage with cycle

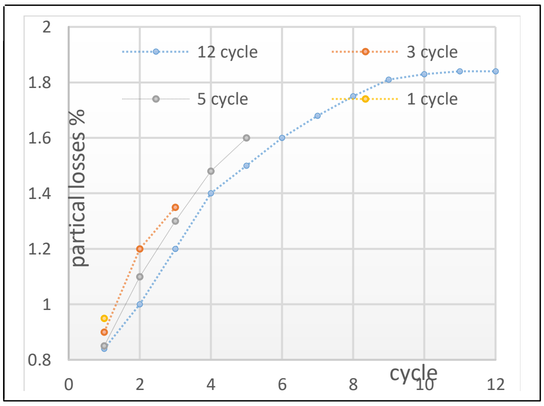

Fig 4. Cycle vs particle losses

Vertical strain behaviour along W/D cycle is depicted in Fig 2, in which wetting state representing by filled circle whereas, dry state representing by the open circle. Vertical strain induced by wetting at nth cycle denoted by nthW, as well as drying strain donated by nthD at Fig 2. Wetting at 1st W/D cycle causes higher vertical strain (about 15%) compare with consecutive W/D cycle due to the collapse behaviour. The vertical strain becomes stable after the 9th W/D cycle. Further induced settlement densifies the specimen (more than 35% of initial density) up to 9th cycle.

Wetting causes settlement in only first three cycles. After 5th cycle it shows an expansion behaviour, because swelling potential increases with W/D cycles. Finally, the expansion behaviour becomes stable after 7th cycle.

The remaining material in five samples were sieved and particle size distribution was plotted as depicted in Fig 3. The particle size distribution severely changed by breakage that triggered by W/D cycle compared with initial state (cycle 0) at Fig 3. This breakage increases the percentage of the finer particle.

Particle losses (%) along W/D cycle is explained by Fig 4. Washout particles by water gradient were collected and measured. After the 9th cycle particle losses were limited. It can be explained as densification was caused by settlement (as shown in Fig 2) and finer particle produced by the breakage (as shown in Fig 3) made the clogging effect, by which the finer particles retained and trapped in between bigger particles. Thus, particle losses limited after the 9th cycle.

Conclusion

Experimental results show that W/D cycle caused an increase in vertical strain as well as particle breakage. The particle losses by the water gradient also increased along with W/D cycle. However, the vertical strain and particle losses by the water gradient became stable in increasing W/D cycles.

References:

1. Cetin, H., Laman, H. and Ertunc, A. (2000): Settlement and slaking problems in the world’s fourth largest rock-full dan, the Ataturk Dam in Turkey, *Engineering Geology*, 56(3-4), 225-242.
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