# INVESTIGATION OF VOLUMETRIC CHANGE OF CEMENTITIOUS MATERIALS AT DIFFERENT TEMPERATURE AND RELATEIVE HUMIDITY BASED ON PORE-LIQUID INTERACTION

Saitama University Regular Member ○Nirmal Raj Joshi
Saitama University Regular Member Asamoto Shingo

## 1. INTRODUCTION

The phenomenon of concrete shrinkage has been under investigation since the time of L'Hermit (1950s) and followed by a number of researchers such as Powers, Bazant and others. It has now been well established that shrinkage occurs mainly due to evaporation of moisture from pores of hardened cement paste matrix. There are mainly three types of phenomena that have been developed to explain the volumetric changes related with moisture behavior in fine pores: a) capillary tension, b) disjoining pressure and c) solid surface energy.

The study on the volume changes of cementitious materials with different pore distributions under various temperatures could lead to understanding the phenomena based on temperature dependent moisture behavior in fine pores. The response to the infiltration of different liquids into the pores will give a valuable insight on the internal pore-liquid interaction related with the above mentioned phenomena. This understanding will enable to predict the behavior at nano scale pores which ultimately leads to the macroscopic phenomena of shrinkage, deflection and other mechanical properties. In this study, dimethyl sulfoxide (DMSO) is used as the infiltration solvent because it has favorable properties such as higher dipole moment than water and readily soluble in water. The specimens of Auto-claved Light-weight Concrete (ALC) and hardened cement paste are dried and then submerged in DMSO to focus on the sudden volumetric change due to the DMSO infiltration from a viewpoint of capillary tension, disjoining pressure and solid surface energy. This experiment will be continued to study the behavior of porous material and the results will be included in upcoming symposium.

## 2. METHODOLOGY

In the experiment, specimen of size 10mm*25mm*25mm was selected. The material used for the test was auto-claved light weight concrete (ALC) and hardened cement paste (w/c=0.4). In the case of ALC, commercial sample obtained from the manufacturer was used and cut in the required dimension. Then the sample was wetted in water for 24 hours at 20$^o$C in a climate controlled room before starting to measure shrinkage. In the case of cement paste, the form was removed 24 hours after casting and then the specimen was cured in water at 20$^oC$ for 7 days of age.

After the preparation of the specimens, it was put in controlled chamber to accurately maintain 40 °C and 80% relative humidity (RH). The length change due to the drying was recorded for 24±0.5 hours at 5 minutes interval using data logger and displacement transducer with an accuracy of 0.001 mm as shown in Photo 1. Next, the solvent was filled in the container holding the specimen. The volume change was recorded for next 24 hours. Furthermore, to account for thermal expansion of measuring device due to temperature fluctuations, the length change of a glass with very low thermal expansion coefficient was measured simultaneously. Similar experiment was also done for 20$^o$C at 80% RH.


Photo 1 Experimental setup with specimen in the first two container(from left), the third container has a glass to account for thermal expansion of transducers.

## 3. RESULTS AND DISCUSSIONS

The results of the experiment are shown in Figure 1a and b. In the experiment, the distinct volumetric changes between ALC and cement paste were observed. It was observed that at 40 $^o$C shrinkage is smaller than that at 20$^o$C for ALC samples. Furthermore, at 40$^o$C it can be seen that there is some increase in volume even during drying process (initial concave part). This is ascribed to the different pore size distribution on each of the sample (Figure 2a). This may be due to the inkbottle effect caused by trapped condensed water (Ishida et al.). The entrapped water is thermodynamically unstable and can escape the bottle neck at high temperature. The dispersion of the water reduces the area where the capillary tension works (Figure 2b) and leads to the decrease of the shrinkage stress to cause the volume increase during drying. When DMSO was added it was observed that the specimen suddenly swells at 20°C but at 40°C the specimen goes on sudden shrinking. The swelling may be because water can easily mix with DMSO to disappear capillary tension in relatively large pores as shown in Figure 3 (a). In the case of 40 °C, only condensed water in fine pores due to severer drying can be extracted by DMSO to cause sudden shrinkage. Such extraction of water will result in decrease of disjoining pressure and also increase in surface energy resulting in shrinkage Figure 3 (b). After the sudden volumetric change, the gradual shrinkage and swelling occur at 20°C and at 40°C, respectively. The shrinkage could be attributed to the extraction of water in fine pores but the swelling is caused by the vapor absorption in DMSO at high temperature.

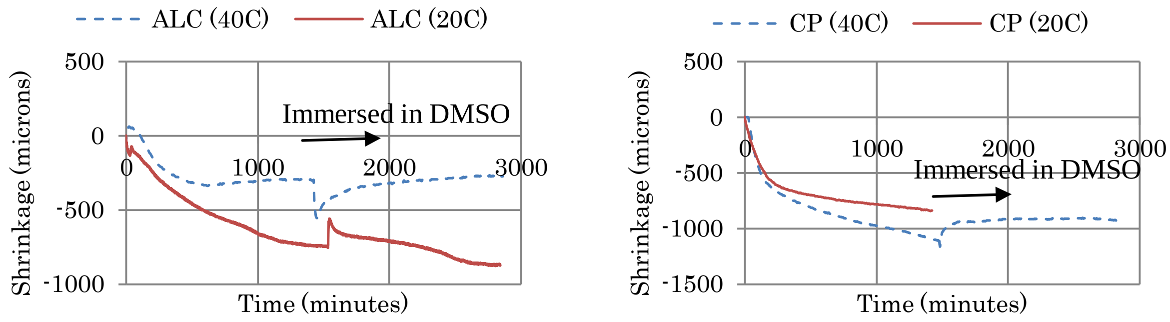


Figure 1. Behavior of (a)ALC and (b) cement paste treated at 20°C and 40°C and 80%RH

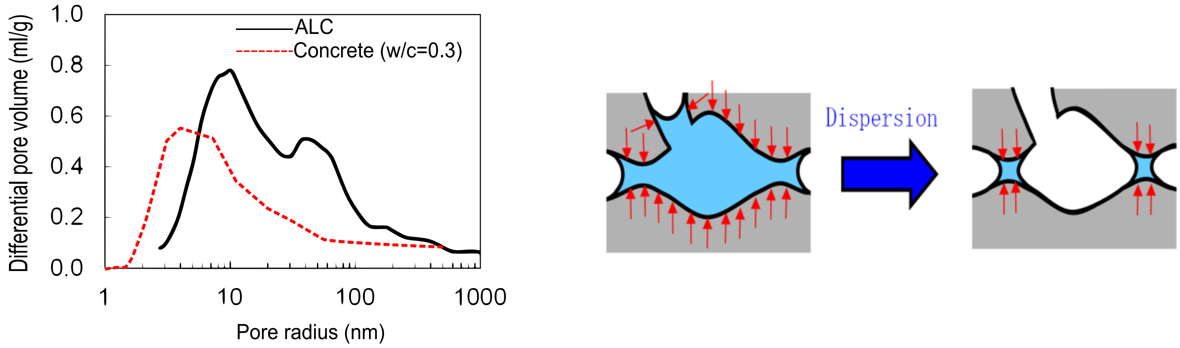


Figure 2. (a) Pore volume distribution in ALC and cement paste and (b) Inkbottle effect in smaller pores

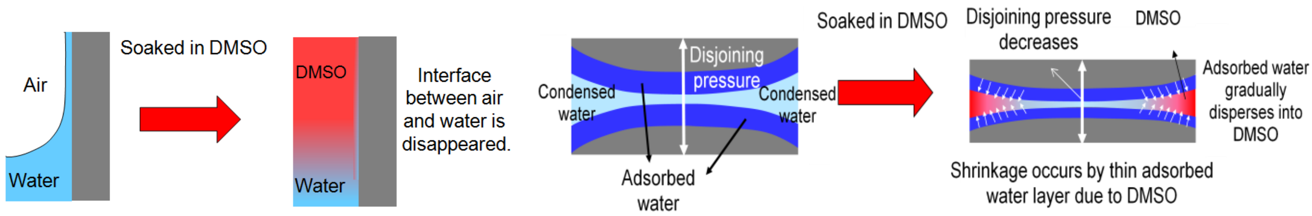


Figure 3. Behavior of (a) Release of capillary tension (b) release of disjoining pressure

On the contrary, in the case of cement paste, it did not show any increase in volume while drying in either temperature. The sample which was dried at 40°C showed higher shrinkage than at 20 °C. It could be because the trapped water in the inkbottle-shaped pores is more stable due to the connection with finer pores than in the case of ALC and does not disperse even at 40°C. When DMSO was added, swelling tendency was observed at both of temperatures. However, the data for 40°C was distorted and has not been presented in the figure. This uniform shrinkage may be attributed to the release of capillary tension in relatively large pores and the increase of disjoining pressure in fine pores.

## 4. CONCLUSION

The result obtained gives insight of interesting phenomenon that occurs due to f liquid-pore interaction. It was also observed that this interaction changes with temperature and humidity. The result for ALC showed very high fluctuations while cement paste sample gave relatively stable results. Thus, a detailed research is still ongoing to explain such phenomenon in porous materials. Currently, this research will be continued and the progress will be included in the next JSCE symposium.

## REFERENCES


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