

Analogue experiments of reproducing morphological features of entablature in columnar joints

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There are various types of morphological features in columnar joints, i.e. column width, column configurations (straight or curved) and the directions of developed columns. We have conducted analogue experiments by use of potato starch and water mixture to reproduce morphological characteristics of entablature and we have found the following two results: 1) when the desiccation rate increases instantaneously on the half way of columns development, the number of columns increases by column nucleation, 2) the direction of developing columns is perpendicular to the isopleth surface of the same water concentration with the exception under particular circumstances of stress field. In order to observe the time evolution of column development in the case of the spatially inhomogeneous desiccation rate, we used the X-ray CT (MCT 225 made by Nikon, owned by Fukuoka Industrial Technology Center) at a certain interval of time during the development of columns. We prepared potato starch and distilled water mixture with the same mass 150g each in a plastic cylindrical container. The light source (60 W lamp) is located at 3 cm above the surface of mixture thereby the thermal heterogeneity on the surface is made due to the highest desiccation rate just below the lamp and the lowest desiccation rate at the edge of circular sample surface. We took the X-ray CT images every 2 or 3 hours during the daytime to observe the change of water distribution by the gray scale intensity together with crack developments in the mixture with time. As a result, there is a higher brightness area like a crescentic shape at upper part of the mixture, which indicates lower concentration of water than at lower part, before the initial generation of cracks on the surface of the mixture. The area in which cracks develop coincidentally take a similar crescentic shape. The lower area below the crack front indicates homogeneous brightness. The crack front advanced to the depth with keeping its crescentic shape and cracks developed not perpendicular to the crack front, indicating the discrepancy with the theoretical prediction for the crack direction under the simple condition. This discrepancy may be caused by the mechanical effect at the edge of the plastic container. In addition, we conducted the experiments in the case of drying from 3 non-parallel surfaces which provide spatially homogeneous desiccation rate each. We put the mixture into a triangular prism shaped metal frame. Two sides are dried through the membrane (surface B and C) and the other top side is dried directly on the air (surface A). We conducted experiments in the cases that the angle θ between surfaces B and C is 60 degree and 90 degree each. As a result, when θ is 90 degree, columnar joints developed from surface A, B and C simultaneously merge in the center of the mixture with curved structure which are fan-like structure at the edge of the triangle. From the comparison with the theoretical results, the characteristics of curved structure can be explained by the condition that a crack propagates perpendicular to the iso-concentration surface. We will investigate the interaction of columns developed from different directions in terms of angles between the desiccation surfaces as a parameter.

Keywords: columnar joints, analogue experiment, entablature, morphological features