DEFORMATION OF MORTAR AROUND AN AGGREGATE IN A TRIAL SPECIMEN UNDER COMPRESSIVE STRESS USING X RAY CT AND DVC

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Summary: In this study, as the first step towards understanding the behavior of the mortar around an aggregate, comparisons have been made between the strain distributions, just prior to sample fracture, around different aggregates in mortar specimens containing just a single aggregate particle. We calculated the displacement field inside each specimen by Digital Volume Correlation (DVC) analysis of tomography images acquired first before loading and the second under maximum loading. The DVC was performed with the program "TomoWarp2". The study showed that if a particle is inserted into the mortar, the shrinkage strains are inhibited and the shear strains occur around the surface of particles. The regions of elevated shear strain become cracks at sample fracture. The region of elevated shear strain is larger for softer particles.

1. INTRODUCTION

In concrete, aggregates are important for strength, controlling volume change and durability. In Japan, many kinds of waste particles have been tested as the aggregate for concrete to limit the use of natural resources. Therefore, it is important understand the behavior and influence of particles in concrete under various environmental conditions. However, until recently there have been few methods for directly measuring the behaviour of aggregates within concrete.

X-ray computed tomography (CT) is a useful method for visualizing inside of materials and has been used in many studies indifferent some engineering fields. A special X-ray CT apparatus has been developed at Kindai University with an integrated mechanical loading system. This X-ray CT apparatus can provide three-dimensional reconstructed images inside concrete under compressive loads up to 300 kN. Therefore, it is possible to study the internal strains of concrete by X ray CT images acquired at different loads complemented by digital volume correlation (DVC).

In this study, as the first step in understanding the behavior of mortar around an aggregate, we compare strain distributions, just before sample fracture, in mortar specimens with different, single aggregate particles.

2. EXPERIMENTAL METHOD

In this study, the mortar specimens with a single particle of approximately 40 mm in diameter in the centre of each specimen were prepared. The strain distribution inside these specimens under the load, just before sample fracture, were measured by X-ray CT and DVC.

The mortar was made by mixing, in a small mixer, tap-water, a high early strength Portland cement, a high performance thickener, and mountain sand, plus marker particles. The marker particles were a zirconia balls of 0.3 mm in diameter. The water cement ratio was 0.6. Mixed mortar was poured into a cylindrical mould of 75 mm in diameter and 150 mm in height, first up to one third of its volume. Next, a single aggregate particle was hung in the centre of the mould from the upper surface by a thread. Subsequently, the mould was filled in two further pouring stages (to two-thirds and then to full); this avoided any joints in the specimen at the centre-height of the specimen. In this study, a stone and a brick particle were considered, plus a sample without an aggregate particle. After one day, the specimens were removed from the moulds and were put in the water of 20°C for curing during 14 days.

A compressive strength test was carried out, following JIS A 1108, with three specimens after curing. The stress-strain relationship was measured by strain gauges attached to the sides of the specimens. Based on these results, the strain just before breaking was estimated. Next, new specimens of each type in turn, with strain gauges,

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were placed in the X-ray CT apparatus. A first CT scan was made of the specimens under 5 kN compressive load. Next, the load was increased at 0.5 mm / minutes until the estimated strain then the loading was stopped and the specimen was scanned again. The loading was then gradually increased until sample destruction and stopped, then the specimen was scanned a final time. The radiographic parameters were 210 kV and 100 microA, the exposure time was 0.5 seconds and 2000 projections were made over 360° rotation of the sample. The voxels in the recontrusted images were cubic with 0.123 mm in the side length.

We calculated the displacement field inside the specimens by DVC analysis, with e code “TomoWarp2”, using the image of the first scan and the second scan. The volume and shear strain fields were calculated from the displacement fields and compared with the cracks visible in the third scan image.

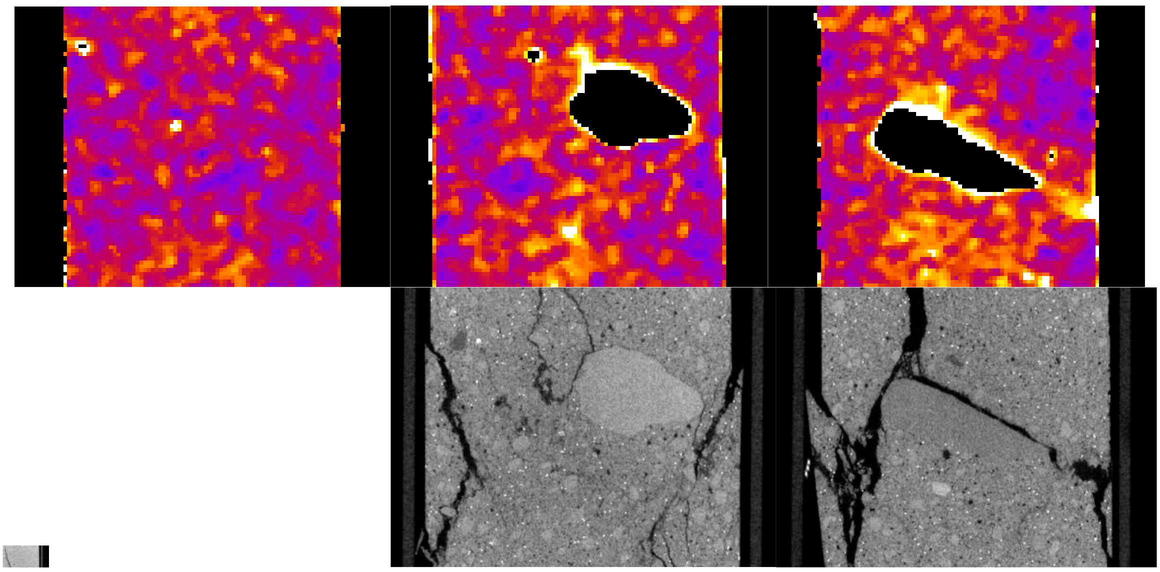
3. RESULTS

Figure 1a shows the volume strain distribution inside the mortar specimen without an aggregate by comparison between the first scan and the scan just before breaking. Regions of shrinkage strain are distributed uniformly in this cross section and are not especially concentrated. Correspondingly, many cracks that can be seen in the image after sample breakage were broadly distributed.

Figure 1b shows the volume strain distribution inside the mortar specimen with the stone aggregate. The volume strain distribution in the bulk mortar shows the same tendency as in the only-mortar specimen. However, around the immediate surface of the stone, a one of elevated expansion strain can be seen as a white area. After breaking, large cracks can be seen in the regions where there was high shear strain prior to sample failure.

Figure 3c shows the shear strain distribution inside the mortar specimen with the brick aggregate. The shear strain around surface of the brick particle appears to be wider than in the mortar specimen with a stone aggregate. A high shear strain region can be seen in the area between the right lower part of the brick particle and the specimen surface. These high shear strain areas lead to large cracks when the sample broke.

This study has shown that aggregate particles inserted into mortar inhibit shrinkage strains and elevated shear strains will occur around the surface of the particles. These zones of elevated shear strain evolve to cracks at sample breakage. The magnitude of strain in these regions of elevated shear strain are seen to be larger in the case of a softer particle.



(a) Mortar (b) Stone (c) Brick

Figure 1: (top) Cross sections extracted from the volume strain DVC volumes and cross sections through the CT images of the sample after breaking, for (a) just mortar specimen, (b) the mortar sample with a single stone particle and (c) the mortar sample with a single brick particle.

References

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