Study on Aggregate Restraining Effect on Drying Shrinkage of Model Concrete

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Introduction

Aggregates that taken from demolished concrete and use again to produce new concrete are known as recycled aggregate. Until now a lot of research has been done to find out the physical and mechanical properties of recycled aggregate concrete. From that knowledge it is established that recycled aggregate that has absorption less that 3% shows good mechanical properties and sufficient durability performance against single deterioration mechanism (Ref. 1). But most of the real concrete structures are experience of combine deterioration mechanism induced by mechanical and climatic load. The performance of recycle aggregate concrete under combined deterioration mechanism is inferior even if the absorption is less than 3%

This is easy to understand that, due to the existence of bonded mortar leads to complex combined deterioration mechanism of recycled aggregate concrete. Because the porous nature of the bonded mortar, recycled aggregate has higher absorption rate that natural aggregate. Due to this higher absorption capacity of the RA the concrete produce from RA shows higher permeability hence lower durability and also due to higher absorption of RA the evaporation of water from concrete body leads to the drying shrinkage of RAC. On the other hand, the drying shrinkage of concrete has significantly affected by the aggregate restraining effect. In conventional concrete aggregate volume is varying about 50 % to 80% of total concrete volume and total shrinkage of concrete is depend on the shrinkage of aggregate phase and paste phase. So is the volumetric shrinkage of the paste phase is greater than that of the aggregate then the aggregate restrain the shrinkage of paste (Ref.2). It means that the drying shrinkage strain is depend on the restraining effect of aggregate and aggregate restraining effect can be varied depending on the percentage of attachment of bond mortar in case of recycled aggregate concrete. So for that it is very important to clarify the rule of aggregate restraining effect on the shrinkage of concrete.

In this context model-concrete (Will be describe in Chapter 2) specimen was examined with mortar specimen to find the influence of aggregate restraining effect on drying shrinkage of concrete. Among many deterioration mechanism drying shrinkage has significant influence to reduce mechanical properties of RAC and damaged are found in the RAC due to alternate drying and wetting. As a time dependent phenomenon after several cycle of drying and wetting crack can occur in RAC structures as a representation of damage. Once crack occurred in concrete structures it also accelerates in the reduction of mass transfer characteristics of RAC. So due to the inferior mechanical properties the mass transfer properties of RAC also get reduce hence combined deterioration mechanism can initiate in RAC due to the drying shrinkage strain. So in this study the basic mechanism of drying shrinkage of RAC was investigated.

Trial experiment

The objective of the trial experiment is to find that is there any influence of temperature on strain development during the experiment. Also to find a suitable mix proportion and boundary condition for the original experiment the trial experiment was done. To evaluate the influence of drying condition in strain development, 57% relative humidity was set as drying relative humidity constantly until the end of the measurement of strain. Temperature was set as 20°C. Initial condition of the specimen was saturated. So the specimen was exposed to drying from saturated. The specimen details are shown in Fig. 1. The specimen was 150 mm x 150mm in size and 25 mm in thick. To measure the strain under drying condition, strain gages were installed on the upper face of the specimen as shown in Fig. 1.

Fig. 1: Specimen details

Original experiment

The objective of the original experiment is to observe the influence of presence or absence of aggregate in strain distribution. To achieve the objective presence or absence of aggregate was chosen as the parameter of the study. Since the presence or absence of bond mortar influence aggregate restraining property so it is very important to know the influence of aggregate itself. 50% water-cement was chosen as the W/C ratio for the original experiment. To clarify the influence of presence or absence of aggregate in the original experiment the
specimen size was same as trial experiment but one steel aggregate was use in one specimen which is defined as model concrete specimen in this study. The size of the aggregate was 50 mm in diameter and 25 mm in height and the aggregate was set in the middle of the specimen as shown in Fig. 2. The other specimen was simple mortar specimen.

**Experimental setup and boundary conditions:**

To evaluate the influence of drying condition in strain development, 57% relative humidity was set as drying relative humidity constantly until the end of the measurement of strain. Temperature was set as 20°C. Initial condition of the specimen was saturated. So the specimen was exposed to drying from saturated. To create such environmental condition highly sophisticated controlled environment chamber setup was used under in house lab facilities. The chamber can controlled the relative humidity as specified under certain temperature. Specimens were kept inside the chamber for 30 days in a drying condition. The wires of the strain gages were connected with the data loggers to take the data for every 10 minutes. The data was recorded by using commercial software and personal computer as shown in Fig. 3.

**How to get strain without the influence of temperature**

From the trial experiment it is found that temperature influences the strain development of the specimen. So to find strain without the influence of temperature a quartz cube was used to find the strain due to temperature variation in the experimental room. The strain development due to temperature variation is measured by quartz cube. So once the measured strain for any position is known and the temperature influenced strain is known, by subtracting the temperature influenced strain from the measured strain of the specimen the strain due to drying can be achieve. This methodology is followed in this study. From all the measured strain the temperature influenced strain is excluded to find the strain due to drying only.

**Comparison of moisture distribution of model concrete and mortar specimen**

The moisture distribution of model concrete and mortar specimen has been recorded automatically by sensors for throughout the experiment period and the results of the distribution are shown in Fig. 4 and Fig. 5. If the moisture distribution of the position D is observed, it can be said that due to the presence of aggregate in the model concrete specimen the moisture distribution change is less than mortar specimen after 30 days but if the moisture distribution for the position A is observed, it can be said that the distribution is almost same for both of the specimen after 30 days of exposure.

The phenomenon can be explained that even if having aggregate due to the presence of two open surface moisture movement is not obstructed for both of the specimen in this position which results same moisture distribution for model concrete and mortar specimen. On the other hand, at position D for of model concrete and mortar specimen the moisture distribution shows significant difference after 30 days of exposure. The phenomenon can be explained from the view point of
having aggregate in the model concrete specimen the moisture movement is slower than mortar specimen. Because the aggregate gives restrain to the moisture movement. So the moisture movement is different in that position for both of the specimen.

Comparison of observed model concrete strain with observed mortar strain

The comparison of strain between model concrete and mortar specimen for different position with same exposure condition is shown in Fig. 6 and Fig. 7. Between two specimens for the position D the model concrete specimen shows significantly less shrinkage strain than mortar specimen. After 30 days of exposure mortar specimen for that position shows about -220 micro strain. On the other hand model concrete shows -20 micro strain of drying shrinkage strain.

The result can be evaluated from the view point of aggregate restrain between two specimens. Since there was aggregate in model concrete specimen, which restrain the shrinkage strain for model concrete specimen and vice versa. The strain rosette for the position A as shown in Fig. 6 shows almost similar trend of results for both of the specimen. From the start of the exposure of the specimen both of the specimens in this position starts to shrink due to drying which can be explained from the view point of the experimental condition and having no influence of aggregate restrained effect. Because, this position was near from both of the open faces. So for that even having the aggregate in the model concrete specimen, it cannot influence the results due to the availability of two open faces whose are responsible for the evaporation of moisture from this position. So the result of this position and position D is almost two different trends for both of the specimen due to restrained effect of the presence of the aggregate in the model concrete specimen. This phenomenon is supported by the moisture distribution of the model concrete and mortar specimen for the position of A and D. If the moisture distribution both of the specimens is observed for position A, we can see that there is almost no difference in moisture distribution and if we see the moisture distribution of the position D we can see that the moisture distribution shows big difference. It means that the presence of aggregate can restrain moisture movement as well. Once the moisture movement is affected the strain development is also affected.

Schematic diagram of maximum and minimum principal strain

Maximum and minimum principal strains were measured from the observed strain of the exposure test. The maximum and minimum principal strain of model concrete and mortar specimen are shown in Fig. 8 and Fig. 9 by schematic diagram. In mortar specimen the maximum and minimum principal strain for position A, B, D and E all are showing compression state. In case of model concrete specimen the maximum and minimum principal strain of position A shows compression but the other positions of model concrete specimen like position B, D, E shows presence of tensile strain. So it means that the presence of aggregate can generate tensile strain around the aggregate. The phenomenon can be
explained from the view point that when aggregate present strain are restrained by the aggregate and create tensile strain.

Comparison of maximum principal strain from moisture distribution view point

The maximum principal strain for both of the specimen is compared from the view point of moisture distribution of the specimen as shown in Fig. 10 and Fig. 11. The results of the maximum principal strain can be explained by moisture distribution. In position A the maximum principal strain of model concrete and mortar specimen are showing almost same trend of strain development. The moisture distribution of this position can clarify the reason of this kind of strain development for both of the specimen. Both of the specimens show almost same moisture distribution after 30 days of exposure. Since the moisture distribution was same, so the strain development for both of the specimen was same even after having steel aggregate in the model concrete specimen. Because two available open surfaces was near from this position and moisture can easily pass through these surface. On the other hand, the maximum principal strain in the position D for both of the specimens shows significant difference. So once again the moisture distribution of this position for both of the specimen can clarify the result. The presence of aggregate in model concrete specimen significantly influences the moisture movement in this position. So the moisture movement is slower in model concrete specimen in this position.

Fig. 8 and Fig 9: Schematic diagram of principal strain

Fig. 10 and Fig 11: Comparison of maximum principal strain

Conclusion

1. The presence of aggregate can restrain strain and moisture movement in porous medium.
2. From the experiment, it is observed that due to the presence of aggregate strain of model concrete specimen were restrained.
3. From the experiment it was also found that aggregate can restrained the movement of moisture. Due to presence of aggregate moisture cannot move directly through the aggregate.
4. Due to presence of aggregate tensile strain generate around the aggregate.

References