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Improving Recycled Aggregate by CO2 Fixation

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Introduction

Following a boom in construction during Japan's period of high economic growth, we are no in an era when the aging of those structures now has to be managed, and demolition and renewal are becoming more and more common. Generally, demolished concrete has so far been reused as roadbed material or for backfilling. However, as demolitions increase and the demand for subgrade material falls, the recycling of demolished concrete may stagnate in the future. As a result, there is a desire for greater use of demolished concrete as aggregate in new concrete. In addition, there is a concern about the increase in the amount of returned concrete, etc., and its use as recycled aggregate is also desired in its treatment. In Japan, recycled aggregate is classified into three qualities (H, M, and L) according to its absolute dry density and water absorption. Low-quality recycled aggregate (L) can be used where high strength and durability are not required, using less energy and costing less to produce than M and H quality aggregate, and it generates less fine powder as a by-product. On the other hand, the quality of the aggregate itself is generally inferior, and concrete using these low-quality recycled aggregates has lower strength and greater length change due to drying shrinkage compared to normal concrete, which is a problem. Further, there are few plants capable of producing recycled aggregate in Japan. Therefore, given the desire to expand the use of recycled concrete, a technology for improving low-quality recycled aggregate without the need for special equipment is required.

Looking at the problem from a different perspective, there are initiatives aimed at adsorption and immobilization of carbon dioxide (CO_2) in concrete as part of a carbon neutral society. It has been reported that when cement hydrates in concrete are carbonated, the voids in the mortar become denser. If the mortar voids in recycled aggregate could be densified by carbonation, then low-quality recycled aggregate may find other uses. To look into this possibility, we have been investigating a low-energy, low-cost method of modifying recycled aggregate by forced carbonation using CO_2 gas. If it proves possible to use this technology to manufacture a modified recycled aggregate that fixes CO_2, the widespread use of recycled aggregate would be promoted.

Technology for Modification of Recycled Aggregate by Carbonation

When CO_2 from the atmosphere penetrates concrete, it is adsorbed by calcium hydroxide, one of the cement hydration products in concrete, to form calcium carbonate. This phenomenon, known as carbonation, means that concrete has the ability to absorb carbon dioxide. However, carbonation is not necessarily considered a good thing in concrete engineering. The steel reinforcing bars used in concrete usually have a thin oxide surface layer called a passivation film, which prevents corrosion under alkaline conditions. The carbonation of concrete through absorption of CO_2 causes a gradual shift from alkaline conditions in the concrete to neutral, leading to loss of the passivation film. The reinforcing bars can then corrode, given a suitable supply of water and oxygen, leading to a decrease in bearing capacity of the structure.

However, the calcium carbonate formed by carbonation has a greater volume than the original calcium hydroxide, so the chemical reaction has the effect of densifying the voids. It is known that densification of coarse voids improves the strength and mass transfer resistance of the concrete itself. By densifying the mortar in the recycled aggregate as shown in Fig. 1, it may be possible to overcome the disadvantages of recycled aggregate concrete, such as reduced strength and low mass transfer resistance.

In this experimental study, we prepared various types of recycled coarse and fine aggregates and checked the dry density and water absorption after modification by carbonation. In typical results, as shown in Fig. 2, dry density increased and water absorption decreased for all the prepared coarse aggregates. The porosity of the aggregate was also measured, confirming that it had decreased.

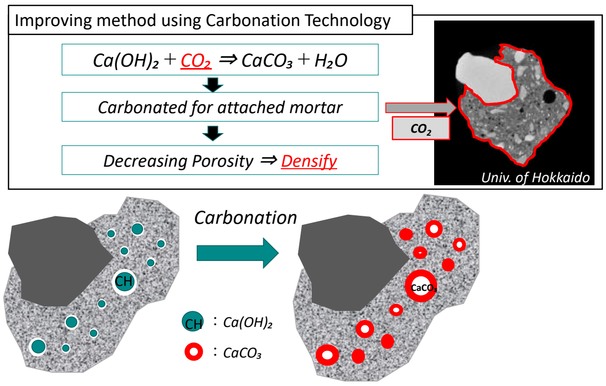

Fig. 1 Mechanism of aggregate modification by carbonation

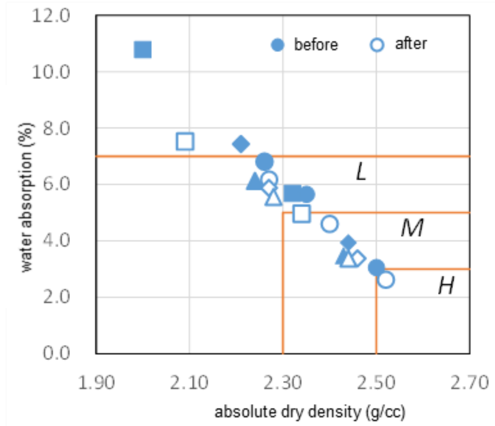

Fig. 2 Example of results of modification by carbonation

Concrete using Modified Aggregate

Concrete samples were produced with aggregates modified by forced carbonation. The porosity, compressive strength, and drying shrinkage were measured, as shown in Fig. 3. The porosity of the concrete decreased for all modified aggregates. Compressive strength increased and drying shrinkage decreased in most of the concretes. The tendency was that the quality of the recycled aggregate was better than L of JIS standard.

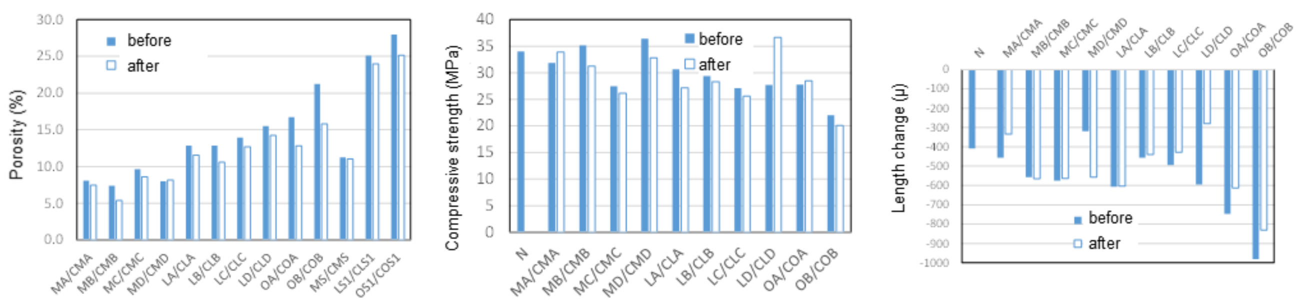

Fig. 3 Performance of concrete with recycled aggregate before and after modification

(porosity, compressive strength, drying shrinkage)

Conclusion

As a contribution to the desired carbon-neutral society of the future, we suggest that recycled aggregate from the demolition of concrete structures as recycled aggregate improved by CO_2 fixation could be modified by carbonation technology to improve it for the production of new concrete. If the carbonation system were to use CO_2 obtained, for example, from the exhaust gas of a cement plant, this technology would lead to an overall reduction of CO_2 emissions by the concrete industry. Further, since structures built with this concrete will fix atmospheric CO_2 throughout their lifespan, we believe that this technology can further contribute to a carbon-neutral society. Future work on this technology will aim to quantify the amount of CO_2 adsorbed during carbonation and construct a system for actual implementation.