Dissertations

A Study on the Practical Application of Low Carbon High Strength Concrete

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In response to recent global movements to prevent climate change, recent years have seen efforts to develop low-carbon technologies accelerate, aimed at reducing the carbon emissions of the construction industry. Cement is one the primary components of concrete, and its manufacture is the primary source of CO_2 emissions during concrete production. Therefore, utilizing low-carbon concrete—in which some cement is replaced with admixtures, such as ground-granulated blast-furnace slag or other industrial byproducts—should be a useful strategy to help fight global warming.

However, the properties of low-carbon concrete can vary depending on admixture type, cement replacement ratio, strength level, and other factors, and relevant literature data on the material, especially for high-strength mixtures, are far from adequate. Investigations aimed at determining the feasibility of low-carbon concrete in environmentally friendly designs should first ensure the material's performance is sufficient for its intended application, then gather more evidence on high-strength varieties of low-carbon concrete to maximize the reduction of CO_2 emissions.

The present study was conducted to test the performance of a high-strength low-carbon concrete for use in practical applications in consideration of the above, with the aim of expanding its potential scope of use. The test material was created from blast-furnace cement with fly ash replacement, a mixture chosen based on preceding research to ensure both versatility and durability. Both laboratory experiments and full-scale simulations were conducted to validate its performance, adopting a cement manufacturing process that could be applied in real construction projects. The resulting high-strength concrete exhibited suitable carbonation resistance, and an excellent ability to suppress the generation of heat, which effectively controlled thermal cracking. However, specimens subjected to a temperature history similar to conditions experienced by actual members exhibited severe reductions in long-term strength. Additional verification experiments were performed to elucidate the responsible mechanism, as strength reductions due to environment effects could complicate the material's real-world application. The results showed that one major cause was spalling at the coarse aggregate–mortar interface due to differences in strain, a phenomenon due to differences between the linear expansion coefficients of the mortar and coarse aggregate. Effective countermeasures were proposed based on these findings.

It is also important that the individuals who order and supervise construction projects appreciate the advantages of employing low-carbon concrete in building projects. Accordingly, another investigation was conducted with the aim of establishing a quantitative method to demonstrate how much the CO_2 emissions of entire buildings could be reduced by applying low-carbon concrete, in a way understandable to ordering parties and managers involved in construction alike. These efforts centered on the carbon footprint system, already widespread in other industries in Japan and overseas. The result was the system's first-ever application to buildings in Japan, which demonstrated the method's usefulness. Furthermore, a case study was run on how applying low-carbon concrete, primarily to real buildings, could help to reduce CO_2 production, and it was quantitatively demonstrated how improvements to the long-term strength behavior of the concrete itself could help to reduce CO_2 emissions.

This series of efforts established a connection between the core technology of low-carbon concrete and a method for evaluating the CO_2 emissions of buildings: in doing so, this thesis provides the field with a measurable index for building a sustainable society based on environmental friendly design.