GREEN CONCRETE MATERIAL DESIGN PHILOSOPHY FOR USE IN PORT STRUCTURES

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1. Introduction

Coastal concrete structures are subjected to severe environmental conditions, and often undergo premature structural deterioration due to reinforcing steel corrosion caused by chloride penetration. This causes an increase in life cycle cost due to the increase in costs related to inspection, maintenance, and repair operations needed to maintain acceptable performance. Repair operations for piers in particular are difficult and expensive due to location, time restriction, limited working space, and so forth. Iwanami et al. (2007) proposed a new method for constructing open-type piers by utilizing pre-cast slabs connected by replaceable joints to the pier super structure (Fig. 1). This method can reduce repair and maintenance costs since deteriorated slabs can be easily removed and repaired or replaced. Furthermore, utilizing pre-cast concrete can realize cost savings during construction and produce higher quality concrete, improving durability.

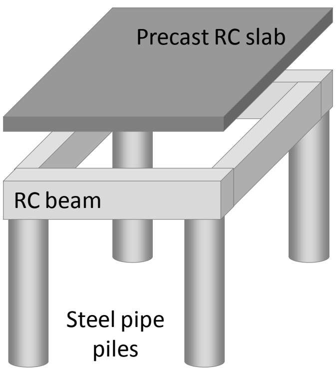

Figure 1 Replaceable slab system for open-type piers as proposed by Iwanami et al.

While this system may reduce economic cost, ways to reduce environmental and social cost also need to be considered in the context of promoting sustainable practice in the concrete industry. "Green" concrete should be developed which reduces CO_2 emissions and consumption of natural resources by replacing virgin materials with industrial waste and recycled materials. Furthermore, the development process should emphasize durability, as premature deterioration results in higher life cycle cost. By applying green concrete to the pre-cast slab used in this new system, the sustainable value – measured as the "triple bottom line" (TBL) of economic, environmental, and social impacts – can be enhanced, producing infrastructure which not only lasts longer, but helps serve a benefit to society by reducing CO_2 emissions, preserving raw materials, and reducing the disposal of waste to landfills.

2. Green concrete material design

2.1 Development framework

The framework shown in Figure 2 provides the basic design philosophy for the development of green concrete. In this framework, sustainable information such as TBL criteria needs to be combined with traditional engineering knowledge, and materials should be selected based on their sustainable value (Henry et al., 2008). Practically, this translates into the need to emphasize durability-based material design (engineering approach) while minimizing the economic, environmental, and social impact of that material (sustainable approach).

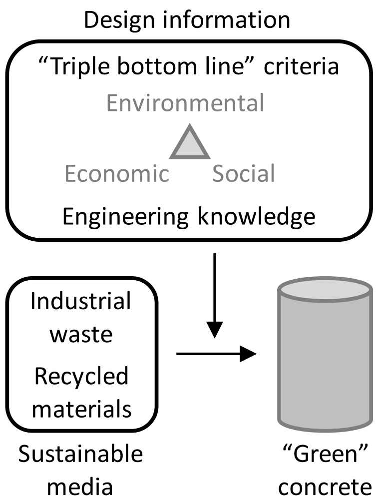

Figure 2 Framework for developing green concretes

2.2 Durable material design

The primary cause of deterioration in port structures is corrosion of reinforcing steel due to chloride penetration. The ingress of chloride ions occurs through the pore structure of the concrete material or cracks at the surface. In order to enhance the material durability and

Keywords: sustainability, green concrete, fly ash, recycled aggregates, durability, port structures
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delay the onset of chloride-induced corrosion, durable material design should focus on a dense pore structure and crack reduction.

Part of this solution is provided by the use of pre-cast concrete, which can reduce the potential for early-age cracking by factory quality controls and higher-grade construction works. The addition of fibers to the matrix can reduce tensile stresses and crack propagation. Next, self-compacting capability can provide durable material performance at each material stage, as well as reduce manufacturing cost. Since self-compacting concrete typically requires a low water-binder ratio, this results in a denser pore structure. Finally, replacing Portland cement with fly ash can help increase durability through the reaction of fly ash with the weaker hydration products, resulting in a more homogeneous cement paste matrix and reducing defects in the microstructure.

2.3 Sustainable material design

Portland cement is the primary contributor of CO_2 in concrete by several orders of magnitude. Replacement of cement with fly ash, a waste by-product from the coal industry, can not only reduce CO_2 emissions significantly, but also provide an alternative means of disposal, diverting usable material from landfills. Simply replacing Portland cement with alternative cementitious materials is, however, not enough. The volume of Portland cement itself must be reduced as much as possible. By reducing this volume, several beneficial effects can be achieved: environmental impact is reduced, and early-age cracking potential decreases due to lower heat generation during the hydration phase, improving durability. Mixing water can also be reduced by optimizing the use of chemical admixtures, but careful mix design will be necessary to reduce these volumes while maintaining durability and constructability.

In addition to fly ash, utilizing recycled materials as replacements for virgin materials will further reduce disposal to landfills. Normal aggregates can be completely replaced with recycled aggregates produced from construction waste, and fibers made from recycled PET bottles can help improve durability.

3. Development process

The successful development and application of green concrete relies not only on thorough investigation of material properties, but on the ability of the innovators to construct the social network necessary to bridge the gap from laboratory to construction site. To this end, a heterogeneous engineering approach is necessary to consider the needs of the relevant social groups (Henry et al, 2008). Many different groups are involved in the construction of port structures, such as the owners, designers, contractors, and concrete manufacturers. Each of these groups has a unique perspective on the application of green concrete, so for the material to be implemented successfully, these perspectives must be understood and considered during the development process in order to produce a material which best balances the different viewpoints.

4. Conclusion

In this paper, the characteristics of green concrete for pre-cast slabs in a replaceable open-type pier construction system are proposed. The design of green concrete was broken into two parts, durable and sustainable design, and is summarized in Figure 3. Durable design aims to extend the service life of the structure by reducing the risk of damage from chloride-induced corrosion. Sustainable design specifies the reduction of CO_2 emissions and disposal to landfills by utilizing replacement materials for Portland cement, aggregates, and fibers.

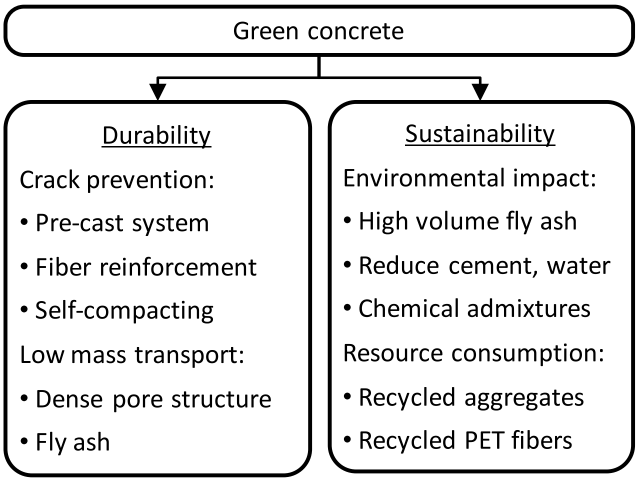

Figure 3 Green concrete design parameters

In order to successfully implement this material, the perspectives of the relevant social groups need to be considered, and their input used to guide the development process towards a material which best meets a compromise between the various groups.

References

[1] Henry, M., Kato, Y., and Yokota, H., “Developing sustainable technologies for concrete infrastructure construction and maintenance in coastal regions,” 2nd LCMCCS, Hangzhou, China, pp. 47-51, 2008.

[2] Iwanami, M., Yokota, H., and Terauchi, K., “Structural performance of RC members connected by replaceable joint for superstructure of open-type piers,” 32nd Conference on Our World in Concrete and Structures, Singapore, pp. 241-248, 2007.