ABSTRACT

Formation and evaluation of sustainable concrete based on social perspectives in the Japanese concrete industry

日本のコンクリート産業における社会的視座に基づいた
サステナブルコンクリートの評価/形成

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Concrete is the primary material utilized for infrastructure construction. Globally, the usage of concrete has been increasing as developing countries have begun investing in their infrastructure. Further growth and urbanization will increase the demand for infrastructure and thus the usage of concrete will increase. However, this growth and urbanization is also responsible for environmental deterioration. The environment is one aspect of sustainable development, along with society and the economy. These three are not separate entities, but rather a hierarchy exists whereby changes in the environment affect society, and changes in society affect the economy. Sustainable development, therefore, is concerned with how to develop modern societies while reducing the negative impacts felt throughout these systems and allow future societies the same chance at development.

As part of the sustainability movement, the concrete industry has also begun to consider its environmental impact. Concrete's negative impact comes primarily from greenhouse gas emissions, consumption of natural resources, and waste disposal. Approaches to considering sustainable practice in the concrete industry include enhances durability, utilization of industrial waste, and recycling of construction demolition. Concrete materials form an important part of sustainable practice but, like sustainability itself, it is difficult to determine exactly what constitutes sustainable concrete. There is oftentimes a trade-off between different performance aspects, such as how increasing strength also increases CO_2 emissions. A definition for sustainable concrete which includes both a reference state and balance between evaluation criteria is necessary for the development and implementation of sustainable concretes. Just as concrete construction requires cooperation and interaction between many different groups, so too should the definition of sustainable concrete be developed considering the diversity of perspectives and goals within the concrete industry.

The objectives of this research are to develop a framework which can be used to define and evaluate the sustainability of concrete materials based on the perspectives of the relevant social groups; to investigate the perspectives on sustainable practice and materials in the Japanese concrete industry and the differences between social groups; and to apply these perspectives to the framework to establish a definition and weighted evaluation criteria for sustainable concrete.

Sociology of technology theory, which considers the technology development process as driven by the negotiation of differing perspectives on the technology, was combined with a technology formation model, which visualizes the formation of technology as the transcription of design information on media, to produce a framework which could transition from the undefined concept of sustainable concrete to a specific form and balance of criteria. This framework consists of three parts: the identification of relevant social groups, the evaluation of the social groups' perspectives on sustainable concrete, and the integration of the perspectives into the formation model.

To apply this framework for the Japanese concrete industry, relevant social groups were identified by considering the industry's structure and the relationship between social groups. The perspectives on sustainable materials were investigated using a top-down approach, via interviews with industry researchers, and a bottom-up approach, via surveys across a wide group of concrete industry members. Sustainable concrete practice and materials could be divided into two aspects: concrete performance and sustainability. The most importance was placed on durability, cost, and life cycle cost for concrete performance, and on atmosphere, land, consumption and production, and institutional framework for sustainability, and these were selected as key indicators for defining sustainable concrete. The concrete parameters were given higher importance than the sustainability indicators. Few differences between the social groups were observed; in the cases were conflict occurred, the contractor's viewpoint was selected as most appropriate.

To convert the importance factors for the key indicators into knowledge which could be applied to the formation of sustainable concrete, the multi-criteria decision-making tool Analytic Hierarchy Process was applied. Most of the weight was given to the concrete parameters, with cost and life cycle cost carrying the highest weight. These weights don't provide information about the absolute sustainability – only relative sustainability – so general-use concrete was set as the baseline which the concrete industry should aim to surpass. Sustainable concrete could therefore be defined as concrete which exceeds the performance of general-use concrete, and the evaluation of this performance could be conducted using the weights given to each indicator. An example calculation using this methodology and a simplified set of weights from the social perspectives was conducted using five concretes with different approaches to sustainability. It was found that durability was the key to achieving high

sustainable value, and the trade-off between reducing amount of recycled materials and increasing strength nearly balanced out overall. Normalizing these performances by the general-use concrete provided an easy-to-interpret means for understanding the trade-off between different performances.

The methodology proposed in this thesis can be used to overcome several barriers to the implementation of sustainable concrete. First, it provides a means for balancing different performance criteria by allowing that balance to be defined by the relevant social groups. In addition, this thesis directly addresses the problem of how to define sustainable concrete by a combination of social investigations, Analytic Hierarchy Process, and the establishment of general-use concrete as the baseline performance. These techniques may be useful to all members of the industry who are concerned with evaluating the sustainability of concrete materials.

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