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Understanding the regional context of sustainable concrete in Asia: Case studies in Mongolia and Singapore

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ABSTRACT

In order to improve the sustainability of the Asian concrete industry, it is important to understand the effect of regional context considering the widely varying socio-economic conditions present in Asia. This research in Mongolia and Singapore was conducted as a continuation of previous studies in Japan, Thailand and South Korea in order to further contribute to understanding regional context, particularly geographic, climate, and economic factors. Geography and climate were found to strongly affect the means by which durability should be assured in each country, as Singapore has a tropical climate whereas Mongolia experiences a large temperature variation with extremely cold winters. The ability to access construction materials and resources was also related to geography, as Singapore, while resource poor, is an international shipping center, whereas Mongolia has abundant resources but few access routes for imports. Quality control issues in Mongolia could be understood in the context of the lower level of economic development, whereas in Singapore the high level of development has lead to an emphasis on green construction, with the government taking the lead in implementing new systems and technologies.

1. Introduction

1.1. Sustainability and concrete

Concrete is the most widely used construction material on the planet and serves as the primary material in constructing the infrastructure necessary to provide society with basic safety and living requirements. The usage of concrete has been increasing as developing countries have begun investing in infrastructure systems such as highways, bridges, tunnels, and so on, with the result that concrete has become the second most-used resource in the world after water (Sakai, 2009). As human populations continue to grow and urbanize, so too will the demand for infrastructure increase, resulting in increased utilization of concrete to meet that demand. Growth and urbanization has, however, also been a primary driver of environmental deterioration, from destruction of ecosystems to increased emissions of greenhouse gases and other air-born pollutants. Observed changes in the global climate have increased awareness of the impacts of human activities on environmental systems and led to the formation of international committees on how to reduce environmental deterioration and mitigate future climate changes (IPCC, 2007).

Increased awareness of the environment has also led the concrete industry to consider its environmental impact and explore strategies for mitigation actions targeted at construction activities (Horvath and Matthews, 2004). Concrete's negative impacts come in several forms, from large-scale emissions of greenhouse gases and particulate matter to massive consumption of natural resources such as water, sand and aggregates. The production of cement – the main binder in concrete – alone is estimated to be responsible for up to 10% of global CO_2 emissions (Malhotra, 1999; Sakai, 2009), with over 50% of world cement production emissions coming from Asia (Humphreys and Mahasenan, 2002). Cement production also consumes large quantities of natural resources such as clay and limestone, and concrete production was estimated to consume more than 11 billion tons of sand, gravel and crushed rock per year in addition to over one trillion liters of water (Mehta, 2001). By some estimates, the cement and concrete industries are the largest consumers of these resources in the world, and while construction investment may be stabilizing or even shrinking in some developed countries, demand for and production of concrete-making materials is projected to continue to grow in many developing countries – particularly China and India (Sakai and Noguchi, 2013).

Proposed strategies for improving the sustainability of concrete include reducing resource consumption by utilizing waste and recycled materials; reducing CO_2 emissions by consuming less

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concrete in new structures, less cement in concrete mixtures, and less clinker when making cement; enhancing the durability of new construction; extending service life through maintenance management; selecting low-impact construction methods; and taking a holistic approach in concrete technology and education (Malhotra, 1999; Mehta, 1999, 2001, 2009; Sakai, 2009). These strategies, however, only suggest generalized guidelines and concepts. In order to practically implement sustainability in the concrete industry, there have been a variety of actions taken at the national or multi-national levels. One prominent example is the Concrete Joint Sustainability Initiative (JSI) in North America, an industry-wide Memorandum of Understanding which provides a framework and principles for supporting and coordinating the actions of industry stakeholders toward improving sustainability in the concrete industry (ACI, 2010). Other examples include the Concrete Industry Sustainable Construction Strategy in the United Kingdom or the Nordic Network "Concrete for the Environment." In the case of the Nordic Network, Glavind et al. (2006) noted that Nordic countries had chosen to face environmental challenges in different ways: Denmark established a center for green concrete whereas Norway developed an online, comprehensive database of important documents. The Asian Concrete Federation (ACF) has also established a sustainability forum with representatives from a wide variety of countries, including Japan, S. Korea, Thailand, Taiwan, Vietnam, Indonesia, India, and Mongolia, to tackle sustainability-related issues in Asia and to pursue the goals laid out in the 2010 ACF Taipei Declaration on Sustainability. This declaration includes six items: recognizing the importance of the Asian concrete society's role in achieving sustainable development; realizing the need for sustainable development by reducing resource consumption and carbon footprint; encouraging the concrete industry to provide safe, serviceable, and environmentally-friendly structures for the good of society; promoting the use of the best technologies and technological innovations for sustainability; informing the concrete industry and the public of the role concrete plays in sustainable development; and collaborating with other international associations toward the goal of sustainable development (ACF, 2013).

1.2. Considering the regional context

The differing approaches to concrete sustainability may arise from a more fundamental aspect of sustainability itself – that it is a human vision with human values, and thus the perception of or values applied to sustainability may vary, particularly by region or by culture (Bell and Morse, 2008). By extension, as sustainability has been famously described as being built upon the "interdependent and mutually reinforcing" social, economic and environmental pillars (United Nations, 2005), then strategies or activities which may be sustainable in one region of the world under a given set of social, economic, and environmental conditions may not be sustainable in a different region of the world under different conditions.

Concrete construction and materials are also often region-specific, as the activities and challenges faced by concrete industries depend on a variety of factors such as climate, geography, availability of resources, level of development and technology, transportation and shipping systems, construction culture and stakeholders, governing systems such as codes, guidelines, and specifications, and so forth. The implementation of sustainability in the concrete industry must therefore also take into account the actual regional and socio-economic conditions in which concrete construction will occur. Some research has applied life cycle assessment (LCA) to examine the effect of different regions and climates in the United States on energy savings of concrete buildings (Ochsendorf, 2010; NRMCA, 2011). However, these studies were limited to a single developed country and focused primarily on the environmental benefits of concrete usage. In order to further understand region-specific issues and their relationship with concrete sustainability across a broader selection of countries and conditions, investigations were conducted in Japan, Thailand and (South) Korea through interviews with a wide variety of concrete industry stakeholders (Henry and Kato, 2012a,b).

In Japan, the importance of durability for sustainable concrete was repeatedly emphasized in the investigation, which can be understood in the context of a decreasing and aging workforce with decreasing natural and economic resources. In addition, as the efficiency level of the Japanese cement industry is already high, enhancing durability is one strategy to reduce transportation- and construction-related CO_2 emissions. The importance of recycling in Japan could also be understood not as a means to further reduce waste generation, as Japan already enjoys a 96% recycling rate for concrete, but rather as a means for reducing the consumption of natural resources by utilizing recycled concrete as raw material in new construction instead of down-cycling it as backfill. Barriers to the implementation of sustainable concrete practice and materials may be the most specific to Japan's conditions. As noted by Chong et al. (2009), this may be due to that fact that sustainability in Japan is more driven by government forces whereas in the USA the private sector is expected to take the lead.

Thailand represents a unique case for sustainable concrete due to widespread adoption of fly ash concrete, which contributes to reducing the environmental impact of concrete materials. Investigation results found that, due to the low cost of labor, price serves as the most important criteria for concrete, which makes it difficult to test or adopt new technologies due to high cost competition. Most technology is diffused through the cement companies, which have the highest investment in R&D, although foreign consultants also provide such support. Finally, the lack of sustainability education makes it difficult to convince customers of additional value such as environmental impact reduction – thus education should form the base of promoting sustainable practice. Since environmental technologies cannot compete on cost, criteria for additional value are also necessary to concretely evaluate these characteristics.

In Korea, the government and major contractors are the major stakeholders, and sustainable materials and practices may be driven primarily at the construction level. The importance of utilizing contractors' construction knowledge toward reducing environmental impact was also identified in a previous study by Son et al. (2011). The Korean industry has to contend with domestic issues such as a shrinking domestic market, which may drive domestic contractors overseas where they can obtain greater experience with sustainable construction, and reduction in natural resources, which can be seen driving changes in the country's mindset regarding waste management and recycling. Usage of recycled aggregates in concrete structures will, however, need to overcome barriers such as negative public perception. While the government has taken measures toward CO_2 reduction, and there is action within the concrete industry toward a labeling system for ready-mix concrete and cement, increased cooperation among stakeholders will be necessary to move sustainable technologies from the laboratory to practice.

1.3. Research objectives

These previous investigations highlighted some general key issues related to the regional context of sustainable concrete such as the role of major stakeholders in developing and implementing new technologies as well as the creation and enforcement of standards and regulations, the importance of recycling considering resource depletion, the effect of negative social perception on the usage of recycled materials, the importance of durability considering changes in society, and the need for sustainability education and consideration of additional value criteria. However, the effect of