SUSTAINABLE CONCRETE IN ASIA:
APPROACHES AND BARRIERS CONSIDERING REGIONAL CONTEXT

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ABSTRACT

Asia is home to a diversity of socio-economic and environmental conditions which directly affect concrete-related manufacturing and construction. The implementation of sustainable concrete in Asian countries is thus highly dependent on their regional conditions, but the regional context of sustainable concrete needs to be understood in order to connect generalized strategies with actual implementation. This paper summarizes the results and key findings from previous qualitative investigations carried out in Japan, Thailand, S. Korea, Mongolia, and Singapore, and compares the approaches and barriers to sustainable concrete in order to extract regional issues and their relationship with sustainable concrete. The results highlight the importance of institutional systems, economic factors, resource availability and recycling, geography and climate, technology level, stakeholder roles and relations, and social factors when considering the implementation of strategies for sustainable concrete in Asia.

Keywords: sustainability, Asia, concrete, institutional systems, resources, stakeholders, socio-economic conditions, climate

1. INTRODUCTION

Increased awareness of sustainable development has led the concrete industry to consider a practical interpretation of sustainability and climate change mitigation actions targeted at construction activities (Horvath and Matthews 2004). Within the concrete industry, discussions on sustainability have generally focused on the short- and long-term environmental impacts of concrete materials, construction, and structures, with particular emphasis on the large-scale emissions of greenhouse gases and particulate matter, massive consumption of natural resources such as water, sand and aggregates, and wide-spread waste generation from demolished concrete structures (Malhotra 1999; Mehta 2001; Sakai and Noguchi 2013).

In order to implement sustainable practices across all phases of the concrete life cycle, there have been a variety of actions taken at the national or multi-national levels. Some examples include the Concrete Joint Sustainability Initiative in North America, the Concrete Industry Sustainable Construction Strategy in the United Kingdom, and the Nordic Network "Concrete for the Environment." The Joint Sustainability Initiative was established to support and coordinate the actions of industry stakeholders towards improving sustainability in the North American concrete industry (ACI 2010), whereas the member countries of the Nordic Network chose to face environmental challenges in different ways: Denmark established a center for green concrete, while Norway developed an online, comprehensive database of important documents (Glavind et al. 2006).

However, while construction investment may be stabilizing in many developed countries, demand for and production of concrete-making materials is projected to grow in developing countries, particularly in Asia (Sakai and Noguchi 2013). Considering this growth – and the accompanying increase in negative environmental impacts – the Asian Concrete Federation (ACF) established a Sustainability Forum with representatives from a wide variety of countries, including India, Indonesia, Japan, S. Korea, Mongolia, Taiwan, and Vietnam, 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 towards the goal of sustainable development (ACF, 2013).

While ACF is moving towards a general framework for the Asian region, the actual implementation of sustainable strategies will necessarily vary between countries or regions. The concept of "regional context" can be derived from the United Nation's description of sustainability as being built upon the "interdependent and mutually reinforcing" social, economic and environmental pillars (United Nations, 2005): that is, 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. For the concrete industry, materials, construction, and structures are often region-specific and depend on climate, geography, availability of resources, level of development and technology, transportation and shipping systems, construction culture and stakeholders, and governing systems. These factors vary widely – particularly in Asia, which has a diverse range of conditions – and thus the regional implementation of strategies for sustainable concrete will also vary.

In order to understand region-specific issues related to concrete sustainability, investigations have been carried out in several Asian countries (Henry and Kato 2012a; Henry and Kato 2012b; Henry and Kato 2014). These investigations, which covered Japan, Thailand, South Korea, Mongolia, and Singapore (Fig. 1), sought to clarify the conditions in each country's concrete industry and relate those conditions to the strategies for sustainable concrete based on the perspectives of a diverse group of interviewed stakeholders. These five countries represent a wide range of development levels, climates, geographies, institutional systems, available resources, construction cultures, technology levels, and so forth (Table 1), and while their comparison is not indicative of Asia as a whole, it can provide some insights into the regional context of sustainable concrete.

This paper begins by presenting an overview of the general results and key findings from the previously conducted studies in Japan, Thailand, S. Korea, Mongolia and Singapore. It then focuses on and discusses the approaches to sustainable concrete and barriers to moving towards sustainability in the Asian concrete industry in the context of a broad range of regional conditions.

2. RESEARCH METHODOLOGY

2.1. Interview contents and objectives

Conditions in the target countries' concrete industries were qualitatively investigated using in-depth, semi-structured interviews with a variety of industry stakeholders in each country. These semi-structured interviews followed a general outline but allowed for areas of interest to be explored in further detail (Punch, 2005). The interview contents used in the investigations covered three main areas, as summarized in Table 2, with the objective of understanding the regional differences in industry conditions and general sustainability issues, concept of sustainable concrete practice and materials, and barriers to implementing those practices and materials.

2.2. Interview sample

Over the course of the five investigations interviews were carried out with 42 people. The distribution of interviewees by general stakeholder groups is given in Table 3. The owner group includes representatives from government agencies, infrastructure developers, and real estate developers. Material interviewees came from cement manufacturers, ready-mix concrete producers, chemical manufacturers, and pre-cast producers. These interviewees were selected through professional contacts, with a focus on experts involved in the development, usage, and management of concrete so that general issues and their regional context could be identified. While some stakeholders groups were not represented in the original studies, their situations could be understood to some extent through their interactions with other stakeholders.

3. KEY FINDINGS FROM PREVIOUS INVESTIGATIONS

3.1. Japan

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.

3.2. Thailand

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.

3.3. South Korea

In South Korea, the government and major contractors are the major stakeholders, and sustainable materials and practices may be driven primarily at the construction level. The 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 towards CO_2 reduction, and there is action within the concrete industry towards 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.

3.4. Mongolia

The Mongolian concrete industry is characterized by strong demand for concrete, particularly for architectural applications, which peaks during the summer months and tapers off during the winter. During the summer peak, demand is so high that the industry experiences shortages, a problem which is compounded by the limited number of supply routes for importing cement. Natural resources for producing concrete are widely available domestically, except for anti-freezing admixtures. Management of curing during the colder winter months is critical to prevent concrete cracking. Important issues for sustainability include the conservation of natural resources and management of supply logistics due to the high demand for materials during the summer months, utilization of fly ash which is widely available from coal power plants but unusable at this time due to poor quality, and the implementation of quality control for materials and structures.

3.5. Singapore

As an island city-state with little natural resources, Singapore is heavily reliant on the import of materials such as cement, blast furnace slag, aggregates, and so forth. The industry is therefore very price-sensitive, and cost competition is very strong. The government is, however, working to promote green construction through programs such as the Building and Construction Authority's Green Mark system. Resource and energy conservation are important for moving towards greater sustainability, and concrete recycling is one opportunity which Singapore can take to promote sustainability in the concrete industry. However, it will be necessary for the concrete industry to build experience with sustainable and recycled materials and to overcome the increased cost for green construction.

4. DISCUSSION ON REGIONAL CONTEXT

4.1. Institutional systems

One commonality across all the countries was that the importance of country-specific institutional systems, such as standards, codes, regulations and so forth, was strongly identified, both as a barrier (as in, the lack of country-specific systems) and as an important action for moving towards more sustainable practice in the concrete industry. In the more developed countries such as Japan and South Korea, the lack of performance-based evaluation methods for both sustainability and durability was indicated as a barrier by interviewees, whereas in Thailand it was just durability which received mention. Furthermore, the need for laws and regulation for reducing the health and social impacts of cement- and concrete-related activities such as dust emissions and noise and water pollution was highly emphasized in Thailand, which may be attributed to the lack of governmental action in this area and the lower level of development. The need for institutional systems in Singapore tended to focus on the regulation of recycled aggregate, as the government has yet to take decisive action on the management of recycled materials. For Mongolia, one barrier to the development of the Mongolian concrete industry is the variation in quality of concrete materials and structures. Quality control is currently not specified in design and construction documents, and concrete production and construction relies on the competence of the ready-mix concrete supplier or the contractor, which results in inconsistent quality. Mongolia therefore has a need for quality management systems. There was little mention of environmental impact- or sustainability-related institutional systems from the results in Mongolia, suggesting that the industry is focused on developing other capabilities and environmental considerations are still down the road.

4.2. Economic factors

Many economic factors were also similar across the investigated countries. Focus on initial cost in bidding systems, the increased cost of sustainable construction, and the effect of sustainable practice on profits were identified as barriers in Japan, Thailand, South Korea, and Singapore. In order to move towards more sustainable (and, particularly, durable) concrete, it's necessary to consider the costs and environmental impacts of a concrete structure over its entire life cycle, rather than focusing purely on the initial costs and impacts. The background and difficulties related to this necessary action, however, varied by country. Japan's need for more durable concrete stems in part from the decreasing availability of public funding for construction and maintenance. This means that existing and future infrastructure will have to be maintained for longer with less financial resources – thus, current concrete construction and maintenance should attempt to address this future financial difficulty now by providing infrastructure which will carry less economic burden in the future. However, as the industry is already facing cutbacks due to the shrinking domestic market, many stakeholders are reluctant to invest in new environmentally-friendly technologies as it is difficult to balance the company needs with societal needs. South Korean will also be facing a drop in domestic demand in the future as the volume of infrastructure stock stabilizes, and Korean companies are also hesitate to invest in sustainable practices which may reduce the profits from construction companies.

Thailand's industry, however, is facing a significantly different economic situation and market. Most concrete-making materials are locally available and very cheap, and labor costs are also extremely low. As a result, competition in the industry is intensely focused on cost and the majority of government projects rely on initial cost only. This makes it difficult to introduce new materials or construction processes if they don't reduce cost or construction time, and there is little consideration of additional value such as durability or environmental impact. Singapore also has a highly cost-competitive environment due to the free market mechanism, and the industry is very price sensitive. Cement is imported as a finished product and the price is low, which makes it difficult to use alternative cementitious materials which could reduce environmental impacts such as CO_2 emissions. As a result, reducing the cost of sustainable materials and technologies would be an important step for both Thailand and Singapore, as would be greater consideration of life cycle costs over initial cost only.

4.3. Resources availability and recycling

The relationship between local availability of resources and the importance of recycling for sustainable concrete was clearly found in the investigations. The importance of recycling was highest in Japan and South Korea, countries which, although they have enjoyed abundant natural resources in the past, are now facing a decreasing supply. However, there are many barriers in both countries related to the usage of recycled materials, particularly the perception of recycled materials as low quality amongst both industry stakeholders and the general population. Singapore is almost wholly dependent on the import of construction materials, but relies on the free market mechanism to balance out import costs. This results in high cost competitiveness which makes it difficult to promote the usage of recycled materials. Disposal of waste is another environmental issue related to recycled materials which Singapore is facing, as there is limited land available for disposal. Improvement of recycling technologies would thus not only reduce waste disposal but also help reduce reliance on imports.

Both Thailand and Mongolia have abundant resources and there is little drive to implement recycling technologies at this time. Concrete construction in Thailand – similar to Singapore – is highly price competitive, and it's currently cheaper to throw away demolition waste and leftover concrete from construction sites and RMC plants than it is to recycle it, as the cost of recycling technologies is still high. In Mongolia, recycling could possibly contribute to reducing the reliance on imported materials during the peak summer construction months, but due to the low industry level and high cost there is little motivation to utilize such materials at this time.

4.4. Geography and climate

Geography and climate have a clear effect on the approaches to sustainable concrete. In countries with long coastlines and high exposure to saline environments, such as Japan, Thailand and South Korea, durability of concrete was strongly emphasized in the interview investigations. Singapore, although surrounded by the ocean, has a much shorter coastline and much less infrastructure stock to manage, whereas Mongolia has no coastline at all. Thailand and Singapore, however, both have to deal with warm tropical temperatures and high humidity, and structural durability has to be assured considering these conditions. Japan and South Korea face a much wider range of durability issues, as they have widely varying annual temperatures and climates and thus a wider range of deterioration mechanisms. Conversely, deterioration of infrastructure in Mongolia is driven primarily by freeze-thaw and temperature-related mechanisms.

Geography also affects the supply of resources. Two extreme examples of this can be seen for Singapore and Mongolia; Singapore, while small and almost entirely reliant on imported materials, is a major shipping center with extensive port facilities, making it easy to manage the import of concrete- and construction-related materials. Mongolia, on the other hand, has an ample supply of natural resources but is somewhat reliant upon imports during the peak summer months, and the limited number of routes for importing materials – primarily from China – often results in a bottleneck in the supply chain during the construction peak. Thailand also has a large amount of natural resources but is reliant upon its river ways to ship construction materials from the mountainous northern areas to the more densely populated central regions around Bangkok. Long-term sustainability of concrete in these countries is thus dependent on the geographic features which enable the steady supply of resource, but the level of development also has an influence, as countries with more developed infrastructure systems are better able to handle the transport of the materials necessary for concrete construction, both over long distances (such as across borders) and short distances, which are more common when local availability of natural resources is high.

4.5. Technology level

Technology-related issues were found to be more critical in countries with lower levels of development, such as Mongolia and Thailand. The low level of technology in the Mongolian concrete industry is a barrier to sustainability, and will require more research, testing, and coordination of industry efforts. Furthermore, advanced technologies currently in use are usually imported, either from China or South Korea, and there is a lack of skilled workers who can maintain those advanced technologies. In Thailand, the development and usage of higher-level technologies is impeded by the high cost competitiveness in the industry, which makes it difficult to invest in new technologies with uncertain value of return. Singapore also faces high cost competitiveness, but there is high investment in research and development particularly among government agencies and the larger concrete suppliers. New technologies are often introduced either through the government's promotion of initiatives and public funding or by overseas companies, but the easiest or most cost-effective means in Singapore may be to purchase and modify a new technology rather than directly develop it.

Some barriers to sustainable concrete related to technology level were also found in the more developed countries. In particular, in Japan there was a higher emphasis on durability as an aspect of concrete sustainability, and as a result the lack of durability evaluation technologies was identified as a barrier in moving towards more sustainable concrete. In South Korea and Singapore (and Japan as well), lack of research and advancements on recycling technologies were identified as barriers. These countries are facing greater challenges related to natural resource supply than Mongolia or Thailand, and thus the utilization of recycled and waste materials in concrete and the development of more advanced recycling technologies are important for moving the concrete industry towards greater sustainability.

4.6. Stakeholder roles and relations

Stakeholders' roles also play an important role in the approach to sustainable concrete. In countries such as Japan, South Korea and Singapore, the government is actively involved in policy-making towards changing practices in the construction industry. Examples include the South Korean government's mandate on CO_2 emissions reduction and Singapore's Green Mark system, certification of which is becoming mandatory for an increasing number of projects. The Japanese government has also been historically shown to take the lead in industry initiatives. In Thailand, the lead stakeholders are the major cement companies, and improvements to sustainability focus on a materials approach; conversely, in South Korea the lead stakeholders include not only the government but also the major general contractors, and movement towards sustainability tends to come from a construction perspective. Japan, on the other hand, has greater vertical integration, and a wider variety of stakeholders are involved in strategies to improve sustainability.

The relationship between stakeholders can also be a difficult barrier to moving towards sustainable concrete materials. In Japan, the RMC belong to a centralized association which handles the allocation of work; thus, the contractors do not directly select the RMC provider themselves and there is a level of security for the work conducted by RMC. South Korean contractors, however, can directly select an RMC for their project, but they do not provide a guaranteed minimum cost and thus, when they try to cut project costs by reducing material costs, the RMC has to reduce their cost even lower while still meeting minimum quality and performance requirements. This environment makes it difficult for RMC to utilize more environmentally- friendly technologies, as they have to consistently adjust to the cost-cutting from contractors.

One similarity across Japan, Thailand and South Korea is the strong role academic and professional associations have taken in moving their respective concrete industries towards sustainability. In these countries, these groups have already begun technical activities such as technical committees and cooperative research works. In Singapore similar activities can also be seen, but they are much more strongly driven by government directive than in the other three countries.

4.7. Social factors

Many of the social factors related to sustainable concrete relate to a lack of motivation to use sustainable materials, reluctance to utilize new technologies, and perception of recycled materials as low quality. These barriers were strongly identified in Japan, Thailand, South Korea, and Singapore. However, some unique social conditions which affect sustainable concrete were also found. In Japan, the aging and decreasing population could be seen as a significant factor in driving the concrete industry towards more durable concrete materials, construction and structures. Japan is very unique in this regard in that it must manage an increasingly aged infrastructure stock with decreasing human resources. Thailand, unlike most of the other countries studied in these investigations, is faced with political instability and corruption in the government, leading to frequent changes in government policy which make it difficult to establish confidence in the longevity or stability of new policies related to environmental issues. Finally, although few sustainability-specific issues were found in Mongolia, one large health issue is poor air quality due to the reliance of poor Mongolians living in yurts on coal burning to generate heat during the winter months. The government is working to construct buildings for these people to live in and reduce the amount of coal burning.

5. CONCLUSION

This paper summarized five studies conducted in Japan, Thailand, South Korea, Mongolia, and Singapore which investigated the relationship between region-specific issues and sustainable concrete. Regional context was discussed considering areas such as institutional systems (level of development and government involvement), economic factors (cost competitiveness of markets and balancing company profits against societal benefits), resource availability and recycling (reduced resources and reliance on imported materials), geography and climate (range of deterioration mechanisms for durability of concrete structures and resource supply), technology level (level of development and cost performance of new technologies), stakeholder roles and relations (lead stakeholders and project economic risk), and social factors (population age, political stability, and health effects).

While these countries encompass a wide variety of conditions, continued research in other Asian countries – especially China and India, the two major developing countries in Asia – will be necessary to build a deeper, more comprehensive understanding of the regional context of sustainable concrete. Ultimately, a stronger, more diverse knowledge base on regional context could contribute to a roadmap towards concrete sustainability in Asia which considers the unique characteristics and needs of each country while identifying shared issues which countries could cooperatively improve upon together.

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Table 1: Select characteristics of investigated countries (adapted from CIA 2013)

Characteristic	Japan	Thailand	South Korea	Mongolia	Singapore
Geographic					
Area (km^2)	377,915 (62)	513,120 (51)	99,720 (109)	1,564,116 (19)	697 (192)
Coastline (km)	29,751	3,219	2,413	0	193
Climate	Varies from tropical in south to cool temperate in north	Tropical; rainy, warm, cloudy southwest monsoon (mid-May to Sep.); dry, cool northeast monsoon (Nov. to mid-March); southern isthmus always hot and humid	Temperate, with rainfall heavier in summer than winter	Desert; continental (large daily and seasonal temperature ranges)	Tropical; hot, humid, rainy; two distinct monsoon seasons; inter-monsoon – frequent afternoon and early evening thunderstorms
Terrain	Mostly rugged and mountainous	Central plain; Khorat Plateau in the east; mountains elsewhere	Mostly hills and mountains; wide coastal plains in west and south	Vast semidesert and desert plains, grassy steppe, mountains in west and southwest; Gobi Desert in south-central	Lowland; gently undulating central plateau contains water catchment area and nature preserve
People					
Population (July 2012 est.)	127,368,088 (10)	67,091,089 (20)	48,860,500 (25)	3,179,997 (135)	5,353,494 (114)
Urbanization	67%	34%	83%	62%	100%
Economy					
GDP (2011 est.)	$4.497 trillion (5)	$609.8 billion (25)	$1.574 trillion (13)	$13.43 billion (142)	$318.9 billion (40)
GDP per capita (2011 est.)	$35,200 (36)	$9,500 (114)	$32,100 (40)	$4,800 (155)	$60,500 (5)
Transportation					
Railways (km)	27,182 (11)	4,071 (42)	3,381 (51)	1,908 (73)	-
Roadways (km)	1,210,251 (5)	180,053 (28)	103,029 (41)	49,249 (81)	3,356 (163)

Note: numbers given in parentheses are world rankings; currency units are US dollars

Table 2: Outline of interview contents

Theme	Description
Concrete industry conditions	Identify stakeholders, relationships, technology level, research investment, institutional characteristics, materials and resources, general environmental and sustainability issues
Sustainable concrete practice and materials	Identify changes needed to achieve sustainability, evaluation criteria, and opportunities for each country to improve concrete sustainability
Barriers to sustainable concrete	Clarify barriers to sustainable concrete practice and materials

Table 3: Interviewees by country & stakeholder group

Group	Jap.	Thai.	Kor.	Mon.	Sing.
Owner	2	1	2	2	2
Contractor	3	0	2	0	2
Materials	4	4	1	2	2
Academic	4	2	4	2	1
Total	13	7	9	6	7

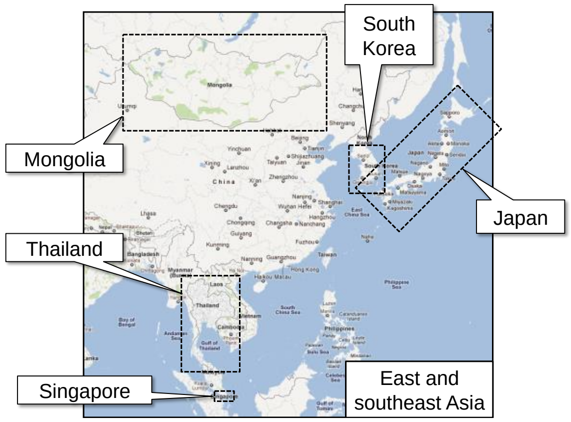

Figure 1: Geographic location of investigated countries