- Technical Report -

CURRENT STATE AND SUSTAINABLE PROSPECTS IN THE MONGOLIAN CONCRETE INDUSTRY

Michael HENRY[*1]

ABSTRACT
This investigation in Mongolia was conducted to identify sustainability issues faced by a developing country and to compare them to Japan considering differing regional conditions. The Mongolian concrete industry is faced with challenges such as limitations on construction due to cold winter temperatures, a peak in demand leading to shortages of concrete-making materials during the summer months, and the need for quality control of materials and structures. The level of development, geographic location and climate can help explain the sustainability issues in each country.
Keywords: sustainability, Mongolia, developing country, material supply, fly ash, quality control

1. INTRODUCTION

Increased awareness of sustainability has led the concrete industry to consider strategies for improving the sustainability of concrete materials, construction and structures, and globally there have been a variety of actions taken at the national or multi-national levels to implement sustainability. One example is the Concrete Joint Sustainability Initiative in North America, an industry-wide Memorandum of Understanding which provides principles and a framework for supporting and coordinating the actions of industry stakeholders towards improving sustainability [1]. 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, the member countries chose to face environmental challenges in different ways: for example, Denmark established a center for green concrete whereas Norway developed an online, comprehensive database of important documents [2]. These differing approaches suggest an important point related to concrete sustainability: that concrete materials and construction are often region-specific, and thus the implementation of sustainability in the concrete industry will also vary depending on regional conditions. This problem can be seen to arise from the fundamental issue that sustainability is a human vision with human values [3], and what may be sustainable in one region of the world under a given set of conditions may not be sustainable in a different region of the world under different conditions.

In order to better understand the region-specific issues related to concrete sustainability, investigations on concrete sustainability have been conducted in Japan, Thailand, and South Korea. In the case of Japan, the emphasis on recycling, durability, and life cycle cost and CO_2 emissions can be understood in the context of an ageing population, decreasing interest and investment in the construction field, and a steadily aging and deteriorating infrastructure system [4]. For Thailand, it is necessary to reduce focus on cost competition through education in order to develop the market for new technologies and promote understanding of the additional value of concrete, as well as reduce social and health impacts such as dust, noise, and water pollution. South Korea is faced with domestic issues such as a shrinking market and reduced natural resources, which could be seen as factors driving changes in the country’s culture and mindset regarding sustainability, but increased cooperation among stakeholders and more government support will be necessary to move sustainable technologies from the laboratory to practice.

Although the results of these investigations provide insight into regional issues, they do not consider the conditions of a country at a low level of development. In order to understand the regional context of sustainable concrete in Asia considering more widely varying conditions, an investigation was carried out in Mongolia. Mongolia was selected for this investigation as its level of development and regional conditions are vastly different than those of the previously investigated countries.

The objectives of this investigation were to summarize the current state of the Mongolian concrete industry, explore how conditions in Mongolia affect the potential for moving towards sustainable concrete, and compare issues in the Mongolian concrete industry with those in Japan.

2. ABOUT MONGOLIA

Mongolia is a land-locked country located in Northern Asia (Fig. 1) between Russia (to the north) and China (to the west, south, and east). Its landscape is characterized mainly by steppes and plains, with mountains and desert regions in the west and south, and although summers are generally hot, winter temperatures may reach as low as -40°C.

*1 Project researcher, ICUS, Institute of Industrial Science, The University of Tokyo, JCI Member

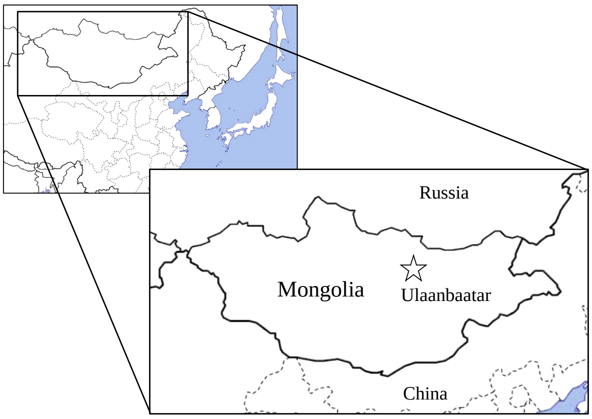

Fig.1 Geographic location of Mongolia

Although it is the 19th largest country in the world by area, Mongolia is very sparsely populated, with a total population of only 3.13 million (Table 1), of which roughly 1 million people reside in the capital city of Ulaanbaatar. Economically, Mongolia has both a low gross domestic product (GDP) and GDP per capita, but its level of development is expected to rise dramatically in the future, primarily due to investment in mining of untapped natural resources.

3. RESEARCH METHODOLOGY

This investigation was conducted in two phases consisting of a quantitative data-gathering phase and a qualitative interview phase. The data-gathering phase focused on collecting information related to the production of concrete-making materials and concrete and education on concrete materials and structures at the university level. This data was collected from both government and university sources.

The interview phase focused on understanding general industry conditions such as industry culture and stakeholders, technologies and materials, evaluation criteria, codes and regulations, and environmental impacts and issues. Six interviews were conducted in total, with two interviewees representing the academic field, one from a ready-mix concrete plant, one from a pre-cast concrete factory, one from a government agency related to construction, and one serving as a project manager of a large construction project.

4. CURRENT STATE OF CONCRETE INDUSTRY

4.1 Brief history

Concrete does not have a long history in Mongolia. Until the late 1940s, lime was the primary binder utilized for masonry and plaster mortars. However, from the late 1940s, Portland cement began to be imported from the Soviet Union. Industrialization of Mongolia occurred between 1965 and 1970, during which the first Portland cement factory was constructed in 1967 with the support of Czechoslovakia. This was followed by the construction of two more cement plants in 1984 and 1999 using Russian technology.

From 1990, Mongolia shifted to a market economy, leading to the privatization of many state factories and companies. Of the two cement factories in operation at that time, the 1967 factory shifted to private ownership whereas the 1984 factory remained state-owned. During the decade following the shift to the market economy and into the 2000s, there was a sharp downfall in the construction sector, but the industry began to grow strongly again from 2005.

4.2 Stakeholders

The concrete industry in Mongolia is composed of materials manufacturers, general contractors, private developers, and the government. The type, number and capacity of materials manufacturers are summarized in Table 2. As of 2010 there were 8 cement factories, 46 sand and aggregate producers, 69 ready-mix batch plants, and 96 factories manufacturing precast reinforced concrete products. The majority of these are domestically owned and operated.

Table 1 Select characteristics of Mongolia in comparison with Japan [5]

Characteristic	Mongolia	Japan
	GEOGRAPHIC	
Area	1,564,116 km^2 (19)	377,915 km^2 (62)
Coastline	0	29,751 km
Climate	desert; continental (large daily and seasonal temperature ranges)	varies from tropical in south to cool temperate in north
Terrain	vast semidesert and desert plains, grassy steppe, mountains in west and southwest; Gobi Desert in south-central	mostly rugged and mountainous
	PEOPLE	
Population (July 2011 est.)	3,133,318 (135)	126,475,664 (10)
Urbanization	62%	67%
	ECONOMY	
GDP (2010 est.)	$11.02 billion (148)	$4.31 trillion (4)
GDP per capita (2010 est.)	$3,600 (161)	$34,000 (38)
	TRANSPORTATION	
Railways	1,908 km (74)	26,435 km (11)
Roadways	49,249 km (81)	1,203,777 km (5)

Note: numbers given in parentheses are world rankings

Table 2 Statistics of concrete-related materials manufacturing in 2010

Type	No. factories	Annual output
Cement	8	770,000 tons
Fine & coarse agg.	46	5,241,000 m^3
Ready-mix	69	11,823,800 m^3
Precast	96	1,139,650 m^3

There are also many general contractors operating in Mongolia. The larger contractors have some vertical integration, including basic research, and are also involved in materials manufacturing, such as the production of precast concrete elements. While most of the contracting companies are domestic, there is growing participation from overseas companies, particularly from China and South Korea.

In addition to the large materials and construction companies, the Mongolian government also serves as one of the major stakeholders, generally in an advisory and supervisory role, such as when to halt construction during the cold winter season.

4.3 Materials

The cement used in Mongolia is either produced domestically or imported from China by train. It comes in a variety of quality levels, indicated by the cement "mark," and higher quality concretes generally require the usage of higher quality cements. River sand is the typical fine aggregate, and crushed granite is used for coarse aggregate. In the past, mountain stones were used for coarse aggregate, but this limited the concrete strength due to the smooth aggregate surface. Once the usage of angular, crushed aggregate became more common, however, this allowed for higher strength concretes to be achieved (in conjunction with higher quality cements), and the current maximum strength is around 45 MPa. Chemical admixtures are imported from China.

Concrete materials are primarily specified and evaluated by their compressive strength, which is measured using 100 millimeter cubes. Fresh properties such as slump and air content are also specified and evaluated but, although they are assured at the ready-mix concrete plant, they may not necessarily be measured upon delivery at the construction site.

One unique aspect of concrete materials in Mongolia is the widespread usage of anti-freezing admixtures. As the outdoor temperature is below 0°C for several months of the year – usually beginning around late autumn – anti-freezing admixtures are essential for continuing construction operations into the winter months.

4.4 Construction

Most concrete is used for architectural purposes such as buildings. There are not many applications of concrete for civil construction, as there is less demand for civil infrastructure relative to the demand for buildings. Architectural structures are generally concrete frames with masonry walls (Photo 1), and precast elements (Photo 2) are often used to speed up the construction process or to continue construction into the colder winter months.

Management of concrete curing is an important issue for concrete construction in Mongolia due to the large temperature differences which occur between the concrete inner core (70°C) and the outside air (-15°C to -25°C). During the coldest months, this difference may reach 100°C and result in severe cracking of the new concrete unless proper measures are taken. This usually entails covering the fresh concrete with plastic and felt and curing it with heaters inside a tent (Photo 3) in order to reduce the temperature differential. When concrete is cast and cured in cold weather, accompanying test specimens are generally cured under the same conditions in order to ensure the development of the required performance.

4.5 Education

The Mongolian University of Science and Technology (MUST) is the largest institution in Mongolia providing a university education in the field of civil engineering. MUST has experienced explosive growth over the past few decades, with the total number of students increasing from just 3083 in 1992-1993 to more than 36,000 in 2010-2011.

Photo 1 A concrete-framed building with masonry walls

Photo 2 Precast reinforced concrete floor elements

Photo 3 Curing of a concrete slab-on-grade cast in November

The MUST School of Civil Engineering and Architecture (SCEA), founded in 1959, was the first department of engineering in Mongolia. The school has also grown steadily over the past years (Fig. 2), and undergraduate and graduate students enrolled in SCEA made up 9.4% of the total number of students in MUST in the 2010-2011 academic year. Within SCEA, there are five programs related to the fields of concrete and construction – structural engineering, structural analysis, construction materials technology, road construction, and construction management – and undergraduate and graduate students in these programs have made up roughly 55% of the total number of students enrolled in SCEA each year from 2007 to 2011.

For undergraduate students, there are many courses related to concrete and construction required in the SCEA curriculum, such as construction materials; reinforced concrete structures; technology of construction processes; construction technology; metrology, quality control, and certification; and organization of building production.

5. PROSPECTS FOR SUSTAINABILITY

Although awareness of sustainability in the Mongolian concrete industry is currently low, there are many possibilities for moving towards more sustainable materials, construction, and structures. Perhaps one of the most promising indicators is that the pace of change is very high, in part due to the mining boom, which is helping to raise interest in the construction field and promote the development of new and better construction technologies and practices. This trend is helped by Mongolian engineers who have studied or worked outside Mongolia and are now trying to help improve the domestic industry based upon their experiences in other countries.

5.1 Resource usage and material supply

Mongolia is fortunate in that it has an abundant supply of natural resources for making concrete (excluding water), and – although demand is high – there is little concern that these resources will be exhausted in the foreseeable future. However, due to the stoppage of concrete construction work during the winter, the summer months are characterized by a construction frenzy. As a result, there ends up being a shortage of many concrete-making materials, particularly cement.

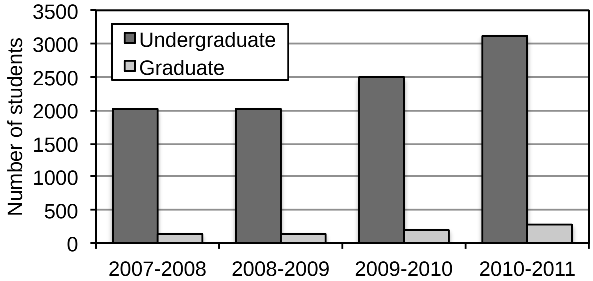

Fig.2 Undergraduate and graduate students in the School of Civil Engineering and Architecture

This highlights Mongolia's vulnerability to its limited number of supply routes and the difficulties of supply logistics. As there are no seaports, imports such as cement must be shipped via train from China, creating a bottleneck in the concrete construction supply chain during the high-activity summer months. While this places strain on domestic resources, it may also provide an opportunity for the utilization of waste materials to supplement raw materials.

5.2 Fly ash and other waste materials

Mongolia relies heavily on coal-fired power plants for electricity generation. These plants generate large amounts of fly ash by-product which could potentially be utilized as a supplementary cementitious material in concrete. However, the quality of fly ash produced from these power plants is poor and the fly ash is ultimately dumped. In addition, while other countries (most notably Thailand) are experienced with the use of fly ash in concrete, the Mongolian industry is unfamiliar with it and people are not aware of the benefits of fly ash concrete or how to design for it or build with it. Therefore, although there is a steady supply of fly ash available, it will require significant research investment and effort in order to produce a usable material and to educate the industry.

There are other recycled materials, such as recycled glass, which could also contribute to reducing resource consumption in Mongolia. As the labor cost in Mongolia is low, glass can be produced cheaply; however, it may still have a higher cost relative to raw materials, and thus it may require some incentive from the government in order to promote its usage.

5.3 Quality control of materials and structures

One barrier to the development of the Mongolian concrete industry is the variation in quality of concrete materials and structures. Quality control is generally not specified in design and construction documents, which instead focus mostly on strength, and thus the batching, mixing control, casting, curing, and so forth rely on the competence of the ready-mix concrete supplier or the contractor, which results in inconsistent quality across the industry. Quality is also affected by the summer-time supply issues, as ready-mix concrete suppliers, in the case of a shortage, may mix-and-match whatever materials they have on hand, rather than strictly follow the design documents. On the project site, the know-how of contractors is important for assuring the structural quality, as they have to verify that the actual site conditions are following the design documents or contracts. Even on very large projects, however, quality control can be loose and low-quality surface conditions observed (Photo 4), which then require extensive patching operations.

There are some efforts underway to ensure the quality of concrete materials and structures. However, quality control comes second to cost, and the implementation of conformation codes or other regulatory oversight by the government or public agencies may be necessary to encourage the industry to implement quality control practices.

5.4 Codes & standards

Due to Mongolia's location and history, a wide variety of codes and specifications are in use, such as modified Russian codes or Chinese codes. The industry is currently, however, migrating to European design codes, and there are calls to implement ISO standards or a Mongolian National Standard for conformation codes to ensure material and structural quality. None of these codes, specifications, or standards address environmental impact, which is a barrier to moving towards sustainability in the concrete industry.

5.5 Air and noise pollution

One large environmental issue, especially in Ulaanbaatar, is air quality. A large population of Mongolians live in yurts and rely upon the burning of coal to generate heat, which creates low-hanging smog during the winter months. The government is thus working to construct buildings for these people to live in and reduce the amount of coal burning. In addition to yurts, there are also a large number of factories and manufacturers located within Ulaanbaatar who are also contributing to the air and noise pollution. Relocation of these facilities to outside the city would help improve the air quality and reduce dust and noise.

5.6 Others

One means for making concrete construction more sustainable in Mongolia would be to increase the strength of the reinforcing steel. Currently, the highest grade available is G390, but if higher grade steel was utilized it would allow for a reduction of the overall amount of reinforcing steel, which would also reduce the associated labor costs.

On-site generation of construction waste such as waste timber is another sustainability issue. Timber framework is widely used for concrete construction, particularly by Chinese contractors, but after the project completion this material is usually disposed of (Photo 5). The usage of steel framework, such as that used by South Korean contractors, reduces the amount of waste generation and can be reused, but also costs more than timber framework and would be more difficult for local companies to purchase.

The low level of technology in the Mongolian concrete industry is also 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. However, as the economy develops, the local research base and know-how will also grow and contribute to better implementation of new technologies.

5.7 Comparison with Japan

When comparing the issues related to concrete sustainability in Mongolia with those in Japan, it is clear that the differences in economic development level and geographic location and climate strongly affect how the two countries should move forward with implementing sustainability in the concrete industry.

Photo 4 Example of low-quality surface concrete conditions in a large building under construction

Photo 5 Large volume of waste timber at a construction site

Among the issues in Mongolia, the need for quality control of cement, aggregates, concrete and structures was strongly focused upon. As the Mongolian concrete industry is still relatively young, and there has been only limited investment in research until now, construction specification focuses on the required material performance such as strength rather than the quality of the materials or structure. In Japan, however, there is a strong system in place for ensuring material and structural quality, which has been developed through extensive investment and experience. As the Mongolian industry is expected to continue to grow strongly into the future, such systems for managing quality will surely be developed as the industry itself develops.

The effect of geographic location and climate on sustainable concrete in both countries can be understood fairly directly. In the case of Japan, durability is considered one of the most important means for moving towards sustainability, whereas in Mongolia very little mention was made of durability aspects. As detailed in Table 1, Japan has a dense population, lengthy coastline, and mountainous terrain, which has led to extensive concrete infrastructure; conversely, in Mongolia there is much less need for civil construction due to the smaller population and gentler terrain. Furthermore, infrastructure in Japan is exposed to a wide variety of harsh environments, whereas in Mongolia the primary deterioration mechanism of concrete is generally freeze-thaw. Due to the harsh winters, however, Mongolia experiences a much more tumultuous construction period, with high construction activity leading to material shortages during the summer. This is compounded by the limited supply routes into Mongolia. Japan, however, has milder seasonal differences, with construction work generally continuing year-round, and extensive port facilities around the country serve to maintain the import of necessary materials.

Mongolia and Japan do share some similar issues for sustainable concrete. First is the need for resource conservation. While the investigations in both countries highlight this issue, the underlying context is significantly different – in Mongolia, resource conservation is important due to shortages during the high construction activity period, whereas in Japan it is driven by the diminished availability of domestic natural resources. The need for codes and standards is also a similar issue but, again, the underlying context differs. The Mongolian situation is driven by the need for quality control-related conformation codes, whereas in Japan durability specifications are necessary considering the need for enhanced durability. In both countries, however, some form of governing code or standard is necessary to outline environmental practices for the concrete industry.

6. CONCLUSIONS

(1) This research investigated the current state of the concrete industry in Mongolia, explored the relationship between conditions in Mongolia and the prospects for sustainable concrete, and compared some of the issues faced by Mongolia with those in Japan.

(2) 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, particularly of cement, and this problem is compounded by the limited number of supply routes for importing cement from China. Natural resources for producing concrete are widely available domestically, except for anti-freezing admixtures, which are imported from China. Management of concrete curing during the colder winter months is critical to prevent concrete cracking.

(3) 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 to reduce variation across the concrete industry. Other issues include the development of conformation codes and reduction of air pollution and waste generation.

(4) When comparing the Mongolian concrete industry with Japan's, the level of economic development was said to affect the progress towards quality control management, whereas social conditions, geographic location and climate affected the demand for civil infrastructure, focus on durability, and the importance of supply logistics for concrete-making materials due to the limited construction period. However, resource conservation and codes and standards are important for both countries to move towards more sustainable concrete.

ACKNOWLEDGEMENT

This research was funded by The Foundation for the Promotion of Industrial Science, Japan.

The author would like to thank Dr. Peljee Otgonbayar, Director and Professor, and Dr. Enebish Ninjgarav, Associate Professor, both of the School of Civil Engineering and Architecture, Mongolian University of Science and Technology, and Mr. Yasuyoshi Ichihashi, Visiting Professor, ICUS, IIS, The University of Tokyo, for their generous support of this investigation.

REFERENCES

[1] American Concrete Institute, "Unifying for a sustainable future," Concrete International, Vol. 32 No. 3, 2010, 16-17.

[2] Glavind, M., Mehus, J., Gudmundsson, G., Fidjestol, P., "Concrete – the sustainable construction material," Concrete International, Vol. 28 No. 5, 2006, 41-44.

[3] Bell, S., Morse, M., "Sustainability indicators: measuring the immeasurable?," London: Earthscan, 2008.

[4] Henry, M., Kato, Y., "Perspectives on sustainable practice and materials in the Japanese concrete industry," ASCE Journal of Materials in Civil Engineering, accepted for publication, 2012.

[5] Central Intelligence Agency, "The World Factbook," (online), retrieved 2011 Jan. 11: https://www.cia.gov/library/publications/the-world-factbook/