Committee Report: JCI-TC171A

Committee Report: Technical Committee on Innovation of Systems for Production/Supply/construction of Concrete

Takafumi NOGUCHI, Akira HOSODA, Nobuhiro CHIJIWA, Ryo AOKI and Koji SAKAI

Abstract

To aid concrete-related industries in contributing to building a sustainable society in the near future, we focused on concrete production, supply, and construction systems. We thereby identified roadblocks to industrial conversion, studied the concrete technology and systems that will be used to build a sustainable society in an era of rapidly declining resources, the state of the next-generation supply chains that will be dealing with the changes in the social environment (population decline) surrounding the concrete industry, and innovations in fresh concrete production and supply systems suited to next-generation construction systems and changes in social conditions. We then made proposals based on our findings.

Keywords: Resource exhaustion, population decline, CO_2, specifications and standards, supply and sale, production and transport, toughening, quality assurance

1. Introduction

Progress has been made in technologies related to concrete owing to long-term advancements and energy saving in cement manufacturing technology, more efficient concrete manufacturing and construction technology, diversification of admixtures, higher-performance chemical admixtures, higher-performance concrete, and support through the establishment of legal systems, specifications, standards, and guidelines. Furthermore, there have been significant advancements in the design, operation, management systems, construction methods, and structural calculation methods for structures using concrete. Despite this, the construction field, especially the concrete production, supply, and construction fields, remain labor-intensive industries. Fresh concrete, which is a semi-finished product made in manufacturing plants, has a unique material flow, as it is transported to construction sites for final use and ultimately becomes part of a final structural product. It is governed by a peculiar trading system in Japan. With regard to future demand for technological development in production, supply and construction in concrete-related industries and their contribution to building a sustainable society, and conversion to highly productive capital-intensive industries, clearly fixed conventional technologies, systems, and business practices are proving to be roadblocks, and innovations are needed in order to satisfy a rapidly changing society.

Therefore, to introduce proposals for converting concrete-related industries from labor-intensive to capital-intensive industries that contribute to building a sustainable society, we focused particular attention on concrete production, supply, and construction systems, and studied 1) concrete technology and systems for building a sustainable society in an era of rapidly declining resources (WG1), 2) changes in the social environment (population decline) surrounding the concrete industry and the state of next-generation supply chains (WG2), and 3) innovations for production and supply systems for fresh concrete, suited to next-generation construction systems and changes in social conditions (WG3). We identified the focus areas for the concrete industry and made proposals for specific solutions. **Table 1** shows the list of committee members.

Table 1: Committee Members

Advisor	Koji SAKAI	Japan Sustainability Institute
Chairman	Takafumi NOGUCHI	The University of Tokyo
WG1 Chief Examiner	Akira HOSODA	Yokohama National University
WG2 Chief Examiner	Nobuhiro CHIJIWA	Tokyo Institute of Technology
WG3 Chief Examiner	Ryo AOKI	Aizawa Concrete Corporation
Committee members	Tetsushi KANDA	Kajima Corporation
	Koji KINOMURA	Taisei Corporation
	Yoichiro KUNIEDA	Tokyo Metropolitan University
	Hirohisa KOGA	Public Works Research Institute
	Hisako KOBAYASHI	East Japan Railway Company
	Jun SAITO	Hazama Ando Corporation
	Yoshimune SHIMIZU	Conqucid System Corp
	Toshio SUZUKI	Japan Testing Center for Construction Materials
	Masaki TAMURA	Kogakuin University
	Kenji NAMIKI	Obayashi Corporation
	Tadashi NISHIMURA	GCP Chemicals
	Tomoyuki HAYAKAWA	Japan Cement Association
	Kazuo FUJINO	East Nippon Expressway Company
	Toshiaki MABUCHI	National Institute for Land Infrastructure Management
	Masaki MUTO	Building Research Institute
	Kazuto YOSHIMORI	Zennama

2. Issues with fresh concrete production and supply systems and proposals for innovation

2.1 Purpose of activities and summary of results

We conducted a survey on various systems regulating concrete production and supply (JIS and Building Standards Act, etc.), identified the essential features of these regulatory mechanisms, and analyzed whether they are roadblocks to social change and necessary technological development. Furthermore, we studied and proposed mitigation measures to tackle any roadblocks, based on various social changes and the state of technological development.

2.2 Issues and proposals concerning manufacturing methods for "ready-mixed concrete", per JIS A 5308

2.2.1 Mixers and transport vehicles stipulated for manufacturing facilities

(1) Roadblocks to technological development

Considering a fresh concrete manufacturing and transport system using networked small-scale automated plants that commenced operation in 1998 in the suburbs of Sapporo City in Hokkaido, we conducted a survey on mixers and transport vehicles, stipulated for a JIS A 5308 manufacturing facility, which posed operational issues for this system. This system is a business model aimed at comprehensively dealing with fresh concrete delivery sites for large-scale building foundations involving the development and simultaneous operation of multiple networked small-scale automated plants. The small-scale automated plants consist of material storage and weighing facilities that utilize mixing trucks for the mixing and transport of fresh concrete.

According to the stipulations of Notification No. 1446 accompanying revision of Article 37 of the Building Standards Act in 2000, concrete used in primary structures that does not conform to JIS A 5308 must be certified by the Minister of Land, Infrastructure, and Transport. This revision, which is applicable for the foundations of ordinary wooden-frame houses in which non-JIS fresh concrete could previously be used, posed a major problem for the operation of this system. Per JIS, mixing is limited to fixed mixers, and transport vehicles are limited to agitator trucks.

(2) Changes in JIS standards concerning mixers and transport vehicles

JIS A 5308 was enacted by referencing the American Society for Testing and Materials (ASTM) standards in 1953 (Showa 28), and has since been revised (supplemented) 14 times, including a revision made in March 2019. The standards enacted in 1953 (Showa 28) contained two types of stipulations: mixers were referred to as fixed mixers and mixing trucks, and transport vehicles were referred to as mixing trucks and agitator trucks. However, the 1978 (Showa 53) revision eliminated mixing trucks from both mixers and transport vehicles, and limited mixers to the fixed type, and transport vehicles solely to agitator trucks. The reason for mixing trucks no longer being considered a type of mixer or transport method was that, at the time, there were very few mixing trucks among the mixers available in the country. Furthermore, according to written comments at the time of the revision, there were presumably no problems with the performance of mixing trucks.

(3) Proposal of mitigation measures for roadblocks

Mixing trucks that comply with ASTM standards are widely used in the US and Europe, and no problems have presumably been found in their concrete mixing and transport performance. Accordingly, we propose that manufacturing standards for mixers and transport vehicles, per JIS A 5308, be reverted to their original stipulations and include mixing trucks as they previously did.

Specifying mixing systems used in trucks, through JIS, makes it more likely that there will be effective measures for “undersupplied rural areas”, which are a concern as the number of fresh concrete plants declines and becomes more concentrated in future. It is predicted that dry mix systems will need to be adopted at construction sites using mixing trucks when fresh concrete is required in areas where the current 1.5-hour JIS transport time standard cannot be met.

2.2.2 Stipulated methods for weighing materials

(1) Roadblocks to technological development

The mixed cement generally used in fresh concrete plants nationwide is limited to type B blast furnace cement. Concrete made using other mixed cements is very rare. We believe it is possible to increase mixed cement usage if type A, B, or C mixed cement can be included, depending on the performance required by a structure, to reduce CO_2 emissions.

Although it would be desirable for the substitution rate of admixtures to be altered in response to demand while utilizing existing fresh concrete plants around the country, the batching of different materials—cement and admixtures, for example—is not allowed per JIS, making this impossible for fresh concrete plants lacking weighing equipment for admixtures.

(2) Changes in JIS standards concerning batching

We surveyed changes in JIS A 5308 regulations concerning material weighing. The original standards (1953) stipulate, “containers used for weighing cement must be different from those used for weighing other materials." In the first revision (1968), the stipulation was changed to, "cement, aggregate, water and admixtures should each be weighed using separate weighing equipment." In addition, according to comments on standards written at the time of the first revision, "batching of fly ash and cement is allowed if unavoidable," and it appears that operations allowing for batching of cement and admixtures were being conducted at that time.

Thereafter, it appears that the fourth (1985) and seventh (1993) revisions allow for batching of aggregate and water, but batching of cement and other materials has not been allowed since the original JIS enactment.

(3) Proposed mitigation measures for roadblocks

To both ensure the performance of concrete structures and reduce CO_2 emissions, we propose the following concrete-manufacturing methods (high-mix–low-volume production) that use existing facilities in fresh concrete plants to properly alter the substitution rate of ordinary Portland cement with admixtures.

1) Storing only admixtures in storage facilities for type B blast furnace cement

Ground granulated blast-furnace slag or fly ash is conventionally stored as admixtures in storage facilities storing type B blast furnace cement. At many existing fresh concrete plants, this makes it possible to mix ordinary Portland cement and admixtures. As it is possible to properly alter the substitution rate of admixtures in accordance with required performance, increased admixture use is expected. In addition, manufacturing of type B blast furnace cement is unnecessary at cement plants. Thus, a reduction may be expected in the CO_2 generated from the transport of ground granulated blast-furnace slag to cement plants, and mixing of ordinary Portland cement and ground granulated blast-furnace slag.

2) Enabling batching of cement and admixtures through JIS standards

It is thought that if it is possible to weigh cement and admixtures with sufficient accuracy and implement printed record verification and other similar processes, it may be possible to manufacture concrete of consistent quality regardless, of whether weighing is done individually or in batches. Accordingly, we propose that JIS standards be revised to allow batching. Furthermore, since ensuring weighing accuracy for material units at existing facilities is sometimes difficult when batching significantly different materials, admixture substitution rates need to be determined within a range satisfying the accuracy of the weighing equipment.

2.2.3 Stipulated time for transport

(1) Roadblocks to technological development

Fresh concrete demand and supply (shipping volume and number of plants, respectively) are continuing to drop since peaking in 1990, and have remained low as a result of a slowdown in real GDP growth, sluggish investment in construction, and population decline. There are fears that if demand remains low, plants will be forced to close and "undersupplied rural areas" will emerge in areas with little demand for fresh concrete. Thus, the challenge for the fresh concrete industry is ensuring "stable supply" in the future, which requires the extension of transport time limits currently stipulated in JIS.

(2) Changes in JIS standards concerning transport time limits

The 1.5-hour time limit on the transport of fresh concrete was set forth under "Concrete mixing and transport" in the original JIS standards (enacted in 1953) and has yet to be revised. However, previously, transport times requirements were vague; hence, in a 2013 supplemental revision, the transport times were clarified with regard to the scope of responsibilities of fresh concrete producers. In a 2014 revision, the transport times were defined as "the time from when a producer commences mixing until a transport vehicle unloads at its destination, which should be within 1.5 hours," although the time limits could be modified through discussions with a buyer.

(3) Proposed mitigation measures for roadblocks

1) Estimated future number of fresh concrete plants (by 2045)

Figure 1 shows the estimated number of future fresh concrete plants, and **Figure 2** explains the estimation process. The number of fresh concrete plants is estimated to decrease from 3,406 (per 2015 results) to 2,769 in 2045, representing a 20% decline.

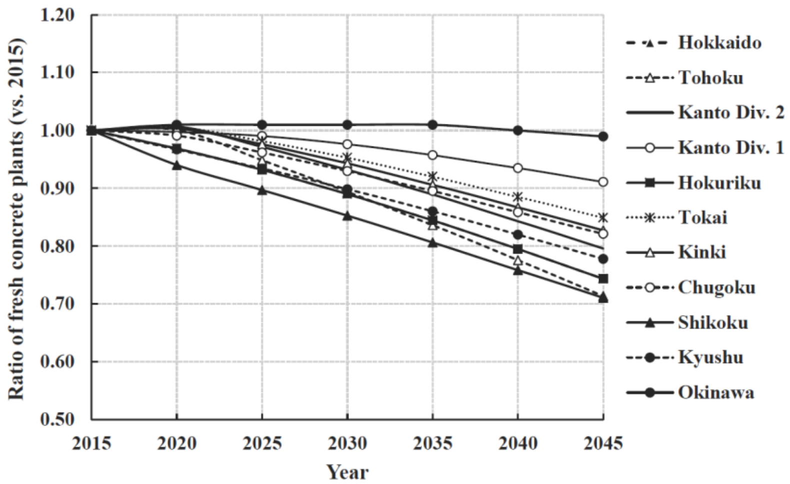

Fig. 1: Estimated number of future fresh concrete plants (sector average)

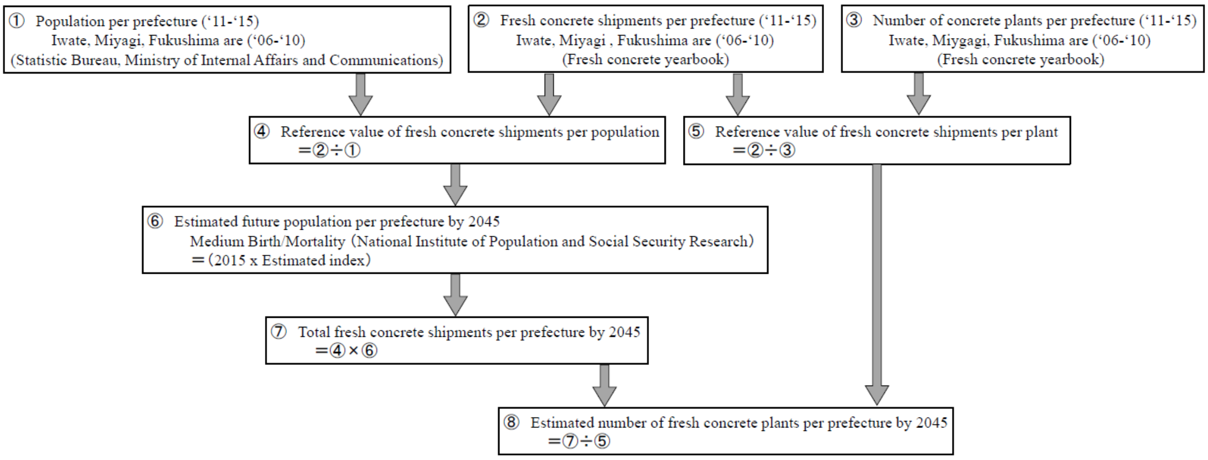

Fig. 2: Estimation process for future fresh concrete shipments and number of plants (by 2045)

2) Extended transport times through proper use of delayed chemical admixtures (delayed-type water reducers, etc.)

Figure 3 shows the results from trial calculations of the future supply area of fresh concrete plants from the estimated number of fresh concrete plants per prefecture and habitable area. The future supply area of fresh concrete plants will increase yearly. Furthermore, in terms of the ratio of the expanded supply area in 2045 to that in 2015, sectors will appear for which the ratio would be 1.3 times the national average; for sectors outside of metropolitan areas, the ratio would be 1.5 times the national average. Presumably, sectors will arise in which fresh concrete transport times will exceed the current 1.5 hours stipulated in JIS.

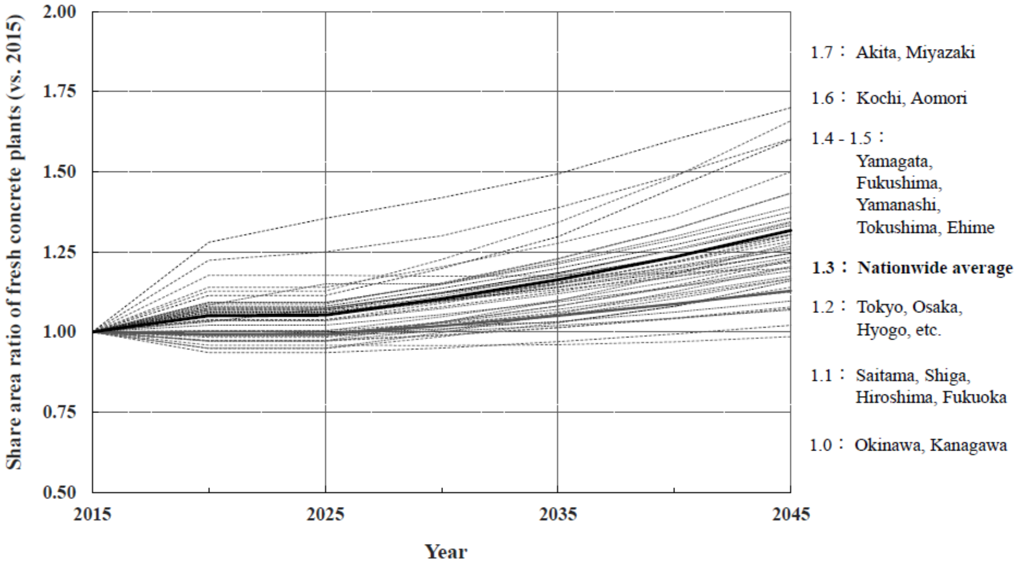

Fig. 3: Estimated supply area of future fresh concrete plans per prefecture

As a countermeasure to this, we propose extending the transport time from the current 1.5 hours to about 3 hours through the proper use of delayed chemical admixtures (delayed-type water reducers, etc.). In recent years, there have been remarkable developments in chemical admixture technology, including adjustment of fresh concrete setting times; thus, it appears possible to extend transport times without losing freshness. We believe that by properly using chemical admixtures and creating environments in which it is possible to extend transport times for fresh concrete (specifications, standards, criteria), it is possible to maintain a "stable supply" while consolidating plants and re-building a healthy fresh concrete industry with balanced supply and demand.

2.3 Issues and proposals for using new cement materials according to the Building Standards Act

2.3.1 Present state of using concrete under the Building Standards Act

The primary law governing the design and construction of buildings in Japan is the Building Standards Act (hereinafter, "Standards Act"), which demands proper compliance. Concrete is a specified building material stipulated in Notification No. 1446, which clarifies the details of Article 37 of the Standards Act. Specifications for ready-mixed concrete are also given in JIS A 5308, but non-conforming concrete may be used according to the Standards Act, by acquiring ministerial certification. Here, conformance includes being recognized as meeting the relevant JIS specifications, in addition to having a JIS mark displayed at the time of shipment from a ready-mixed concrete plant.

Ministerial certification for concrete, as shown in Article 37-2 of the Standards Act, generally presupposes the specification of a ready-mixed concrete plant, and strict stipulations for the raw materials, mixing, and quality-control methods used. Ministerial certification is essential when using cement having a quality not within the scope of JIS A 5308, for example, high-strength concrete. In addition, ministerial certification of concrete pursuant to Article 37 of the Standards Act will, in principle, involve a review based on JIS A 5308.

Typical examples of concrete receiving ministerial certification pursuant to Article 37 of the Standards Act are high-strength concrete and highly workable concrete. Such ministerial certification requires a considerable amount of certification material, including material properties related to concrete quality standards and statistical information, according to statements of operational procedures for the quality performance of building materials stipulated by designated performance evaluation organizations. Consequently, acquiring ministerial certification requires a large number of cases for evidence, and even high-strength concrete, which is routinely reviewed for ministerial certification, places a large burden on applicants in terms of cost, labor, and time.

2.3.2 Using new cement materials that are not specified building materials

If an attempt is made to use new cement materials for primary structure components, such as using ultra-high-strength–fiber-reinforced concrete (which has been increasingly used in the civil engineering field) for primary structure components in a building, there is a high likelihood that the materials will be deemed to not be concrete as they do not contain any raw aggregate; thus, they are unlikely to receive ministerial certification according to Article 37-2 of the Standards Act. In the absence of ministerial certification, new materials essentially cannot be used for primary structure components in buildings.

However, this does not make it impossible to use such new materials for primary structure components or the like. A possible route according to Article 20 of the Standards Act requires performance evaluation on the basis of individual buildings. This exception allows for the use of new materials not included in the specified building materials of Article 37 of the Standards Act, separate from the need for ministerial certification. Per Article 20, new materials may be used in an essential high-rise “individual building” over 60 m in height, after performance evaluation that includes a review of structural materials limited to that particular building. Consequently, this route presupposes time-history response analysis of a building for when an earthquake occurs, and it is generally felt that using this route for mid and low-rise buildings—not receiving time-history response analysis when applying for verification—would constitute design in excess of normal requirements.

2.3.3 Issues and proposals of using new materials under the Standards Act

Use of non-specified building materials, such as new cement materials using fibers, for such things as primary structure components in buildings, is heavily restricted by laws. Regarding Article 37-2 of the Standards Act and the specified building materials subject to it, while there are well-established methods to evaluate performance for ministerial certification, there are no such methods for new cement materials that are not specified building materials, although it seems that an environment for such methods will be needed in future. For new cement materials not included in specified building materials, it is important to construct rational systems for evaluating performance in material units and providing a framework for ministerial certification, and thus enable new developments, considering their application to ordinary buildings for which time-history response-analysis-based structural performance evaluation is necessarily suitable, excluding structures such as high-rise and base isolated buildings.

3. Concrete technology and systems for building a sustainable society in an era of rapidly declining resources

3.1 Summary of activity goals and results

Concrete infrastructure has played a significant role in Japan’s post-Meiji-era modernization, post-WWII recovery, and Showa-era rapid growth. Although the Heisei era may generally be considered as one of deflation, it was also an era in which national and social vulnerabilities were laid bare by the Han﹣Shin Awaji Earthquake, the Great East Japan Earthquake, and successive heavy rains. Japan appears poised to face even more dangers in the new Reiwa era and beyond. Resource shortage, in particular, appears imminent and may force a major transformation in various systems. Humanity is entering a stage in which many resources that have been used indiscriminately thus far will rapidly decline, and it is feared that in extreme cases, they will be depleted soon. Here, we shall present the results of our analysis, and propose new technologies required for concrete, and the systems for putting them to use in order to build a strong, prosperous and sustainable society that is robust to severe resource constraints.

3.2 Analysis of the present state of Japan from a resource perspective

3.2.1 Trends in limestone as a cement raw material and aggregate

(1) Limestone as a cement raw material

Limestone is used in cement, concrete aggregate, roads, railways, and for lime. According to a publication by the Limestone Association of Japan, in 2016, approximately 140 tons of limestone were shipped nationwide, which included 44.1% for cement, 21.3% for concrete aggregate, 2.3% for roads, 13.8% for iron production, and 6.6% for lime.

According to the Survey of Reserve Ore by the Agency for Natural Resources and Energy, there were 27.1 billion tons of minable ore as of 2009, and the average production volume from 2009 to 2016, calculated from materials published by the Limestone Association of Japan, was 140 million tons. Hence, assuming continued recent production volume, is approximately 186 minable years are forecasted (2016 standard), and in approximately 200 years, limestone will be exhausted. Japanese Limestone is of very high quality and has a high degree of purity owing to geographical conditions. Thus, even its byproducts and waste products can be used as cement raw material. The challenge facing Japan’s engineers is to aim for a sustainable society by effectively using limestone—which is the only precious mineral resource Japan is capable of self-supplying—as a cement raw material, and thus, build strong and long-lasting infrastructure.

(2) Aggregate

Aggregate is inexpensive in terms of the unit cost of raw material, but is expensive to transport. Thus, local production for local consumption is ideal. The circumstances of aggregate differ depending on the region, but regions such as Kinki, Chugoku and Shikoku, which are poor in natural aggregate resources, have previously been largely dependent on sea sand from the Seto Island Sea. However, in recent years, the collection of sea sand has been prohibited in many prefectures; furthermore, China prohibited the overseas export of sand in April 2007, which has resulted in severe shortages of aggregate. In recent years, river gravel, land gravel, and mountain gravel have served as substitutes, and an increasing dependence on macadam has been witnessed. Data clearly show shortages of aggregate, which are now being felt worldwide. Approaches towards saving aggregate resources are being sought, as is concrete technology, to ensure quality of concrete and durability of structures when using various kinds of aggregate.

3.2.2 Resource exhaustion and decline problems, and carbon prices[1)]

There are concerns that not only concrete materials, but also other resources will be depleted or will decline. Limiting resource consumption is indispensable for human sustainability. One way to accomplish this is to realize a low-carbon economy on a global scale, if appropriate carbon prices are introduced. This may greatly increase tax revenues, and reduce other taxes.

The introduction of carbon tax, in particular, can address the crucial issue of total demand shortages, as companies make capital investments, increase tax revenues, and improve the environment. Countries that have not introduced carbon taxes could participate in voluntary agreements to reduce carbon emissions by allowing taxation at their borders, a system that would probably be legally recognized even by the WTO.

However, simply introducing a carbon tax would not be sufficient. Balanced and sensible mechanisms need to be created, including the healthy development of key industries. It is imperative to introduce technological development and innovations to reduce CO_2 emissions.

A green fund is a fund for reducing greenhouse gas emissions and dealing with the resulting effects, and for reducing the economic burden on developing countries that engage in such actions. For example, 20% of the income of advanced nations from introducing carbon prices may be directed to a green fund. If wealthy countries use a green fund when poor countries are participating in voluntary agreements and have set their carbon prices to the same level as other countries, then we may be able to live within planetary limits.

3.2.3 Role of stable power supply and hydropower

Sustainable power supply is essential not only for Japan, but for the entire world. As fossil fuels rapidly get depleted, Japan needs to seek the best mix of power sources suited to this era, while considering land conditions, technical capabilities, and global economic trends.

Sun and wind power would effective for only the near future, and are lacking when compared to thermal and nuclear power generation. They cannot deliver stable power to consumers, without a backup power source. Presently, their supply facilities contain excess equipment; about 2.7 times that needed for a maximum power demand of approximately 80 GW. Furthermore, thermal power generation is facing problems as profits decline. These problems require identification of underlying causes and rational solutions.

Proper use of nuclear power generation and intensified hydropower are considered essential for the future of Japan, due to declining resource availability and serious CO_2 problems. The blackout throughout Hokkaido that occurred in September 2018 would probably not have occurred if the Tomari Nuclear Power Plant were running, but the public opinion was that nuclear power generation was not viable. Therefore, sober discussions are first required for a reality-based community.

Hydropower represents a form of energy that can be produced purely domestically, and is a field in which Japan should actively invest, as slight improvements may yield several times the potential of present water power. Below, we summarize the opinions of Kotaro Takemura[2)].

- “Energy utilization” should be added to the objectives of Act I of the River Law, the water level of reservoirs that are only about half-full should be raised, and multipurpose dams should be used for energy operations.
- Concrete dams in Japan are sufficiently strong and could provide completely domestically-produced energy on a semi-permanent basis.
- Raising the number of existing dams would enable increased power supply with negligible sacrifice on the part of areas supplying water.

Per Takemura’s trial calculations, if the latent power-generating capabilities of Japan’s dams could be exploited, they could supply approximately 30% of the power demand.

3.3 Toughening of concrete structures for resource saving and a sustainable society

In an era of rapidly diminishing resources, resource conservation is essential. This makes it crucial to strengthen and increase the longevity of newly built structures and very large existing structures. Building long-lasting infrastructure will contribute greatly to improving productivity on the part of society owing to stock effects. This committee has surveyed and collated measures for resource conservation and reinforcement in construction, railways, roads, and pavement.

3.3.1 Sustainable construction systems

Resource conservation is essential to address the problems of large-scale earthquakes and global warming. Analyses are being conducted for debris generation and recoverability of buildings following a disaster, such as a Tokyo near-field earthquake or a Nankai Trough earthquake, and inquiries are being made into the effectiveness of preventive and post-disaster recovery measures, including socioeconomic systems corresponding to the degree of disaster severity. Presently, regarding the issue of post-disaster debris from buildings, while the Great East Japan Earthquake generated 22 million tons of debris, a Tokyo near-field earthquake would possibly generate 5 times as much, and a Nankai Trough earthquake might generate 11 times as much. The prompt disposal and effective use of debris from such large-scale disasters is key to rapid recovery and reconstruction. Such measures have been recognized as factors in creating sustainable construction systems.

Inorganic material found among disaster debris from the Great East Japan Earthquake was effectively utilized as implant and concrete material, which played a role in greatly reducing the environmental impact affecting both land use and resource circulation. However, there are still several problems with expanding its use in steel building frames. Future measures include making the functions and systems of buildings and the overall urban infrastructure more maintainable so that they can adequately respond to disasters. Therefore, there needs to be more specificity to the various measures concerned with the robustness of overall maintenance systems for buildings and urban areas, vulnerabilities considered synonymous with risk, and broadly-defined resilience encompassing all of these, in order to provide a framework for enabling preventive measures. We have, therefore, surveyed the latest trends and summarized them.

3.3.2 Resource-saving rail systems with superior strength and durability

Here, we summarize the innovation measures that could aid in creating a sustainable rail system for JR East Japan. This new system will have superior strength and durability against large earthquakes and will help reduce consumption of fossil fuels.

The JR East Japan Shinanogawa Power Station uses water power from the cities of Tokamachi and Ojiya in the Niigata prefecture. It is the overall name for three power stations: Senju Power Station, Ojiya Power Station, and Ojiya Power Station No. 2. These generate power by using water from the Shinanogawa River water system through aqueduct tunnels, using the Miyanaka catchment dam, three regulating ponds (Asakawara Regulating Pond, Yamamoto Regulating Pond, and Yamamoto Regulating Pond No. 2), and the difference in the elevation of a river terrace. The electricity generated here is delivered to the Tokyo metropolitan area, trains on the Joetsu Line and Shinkansen, and several rail facilities, and handles increased demand during daily morning and evening rush hours, by raising the water level of the regulating ponds. These stations manage approximately 20% of the power used by JR East Japan. Concrete structures built during the development of hydropower in 1931 continue to supply green energy. When thinking about sustainability in Japan, a lot can be learned from these comprehensive systems, which are equipped with redundancies accounting for maintaining operation while providing power (**Figure 4**).

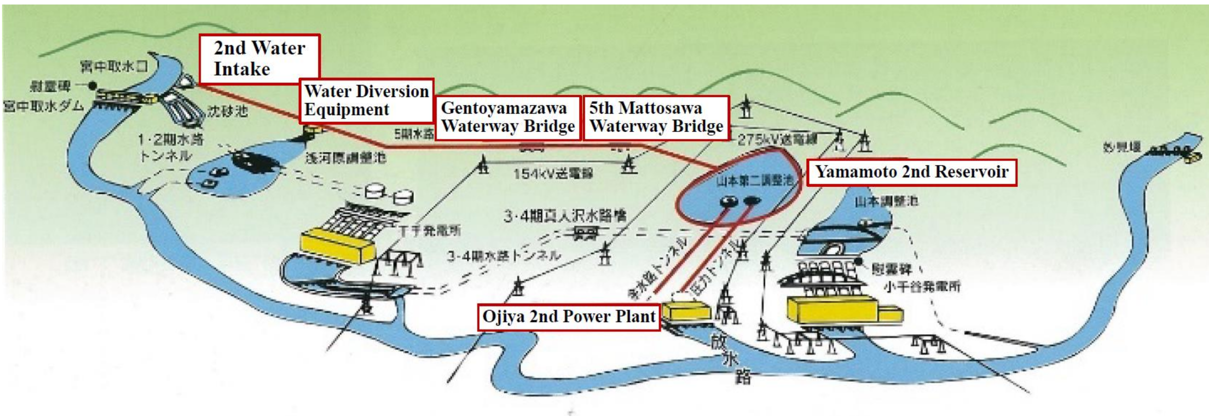

Fig. 4: JR East Japan Shinanogawa Power Station

Steps have been taken since the Han-Shin Awaji Earthquake to improve the transition to earthquake-proof concrete rail structures, and introduce innovative earthquake-proofing methods, and improve the earthquake resistance of newly built structures. In addition, work is being done to extend the life of newly built structures and conduct large-scale repairs to existing structures, including promoting the use of blast furnace cement and fly ash, both of which reduce the environmental burden and help control ASR.

3.3.3 Systems for ensuring the quality and durability of concrete road structures

The crack control and quality assurance system for concrete structures built by the Yamaguchi prefecture is an innovative system based on a special way of complying with basic construction requirements. It uses a database of compiled construction records at the design and construction stages, which has successfully controlled cracking in real structures, and made verifiable improvements in overall surface quality. Similar systems have been built in places such as the Gunma prefecture, and they are expected to produce longer-lasting concrete structures everywhere and improve the technical capabilities of engineers working in the industry, government, and academia, and also ensure continuous improvement of systems that evaluate technical standards and work results.

Adopting the Yamaguchi system promotes groundbreaking ways of ensuring the quality and durability of roads being rebuilt in Tohoku. Serious deterioration including sedimentation from the upper surfaces of highway bridge RC slabs is noticeable in open environments sprayed with large amounts of antifreezing agents. Hence, the proposed measures to increase durability, cracking control measures, and compliance with basic construction requirements, shown in **Figure 5**, are being systematized and implemented in trial construction projects. In environments sprayed with antifreezing agents, systems must both reduce the environmental burden and improve durability; thus, the use of blast furnace cement or fly ash is essential to preventing complex deterioration.

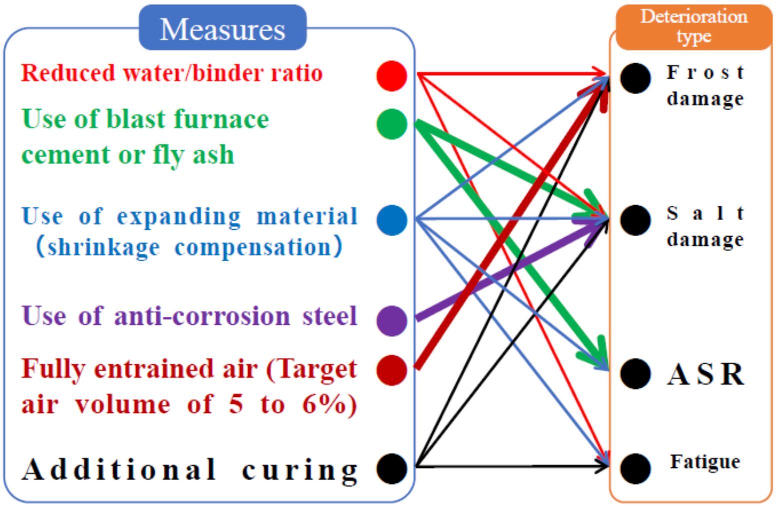

Fig. 5: RC slab durability-increasing measures (Tohoku road reconstruction)

3.3.4 Present status of concrete pavement and its expected future role

In Japan, the percentage of pavement made with asphalt is quite high, but the advantages of a concrete pavement are being considered, to address the need to save petroleum resources and reduce running costs, and it is highly likely that it will be used to a greater extent in the future.

The fraction of highways constructed using concrete pavement is approximately 7% (as of December 2016). As concrete pavement was first adopted for the tunnel portion of Japan's first high-speed road, the Meishin highway—made possible by extensive test construction and the development of engineering and construction laws for the issues that arose—road pavement has been developed combining the features of both concrete and asphalt. This is referred to as composite pavement, which consists of continuous reinforced concrete and asphalt, as shown in **Figure 6**. This was used extensively in the construction of the Shin-Tomei Expressway and Shin-Meishin Expressway. This committee looked at the background of the development of composite pavement. These steps taken to improve the slip resistance of concrete pavement and resolve problems with noise and dust. Furthermore, we looked at the development of composite pavement that combines the high durability benefits of concrete pavement, and the high slip resistance and low noise and vibration of asphalt pavement.

In addition, we analyzed the features of asphalt, composite, and concrete pavement, as well as the technical issues that arise with the use of concrete pavement.

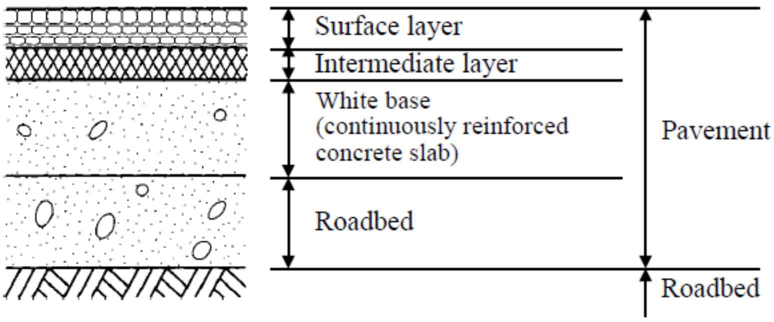

Fig. 6: Composition of composite pavement in a highway

3.4 Extending life of virgin resources by using demolished concrete material and recycled aggregate

In the past, a lack of area for the disposal of material left from the demolition of concrete structures posed a social problem; hence, the reuse of demolished material was researched. As a result, the rate of demolished concrete material reuse has reached a level of 99% or higher. However, most of this is reuse of subbase coarse material, and whether this high reuse rate can be maintained remains to be seen. On the other hand, regarding aggregates, it is difficult to secure high-quality virgin resources from specific regions, so resources transported from other regions are used. It is felt that reusing demolished concrete material as recycled aggregate is important for building a sustainable society.

While studies have been made regarding concrete using recycled aggregate on the technical level, such as the establishment of JIS, the actual use is still low. Therefore, to understand how to use recycled aggregate, we surveyed overseas legislation regarding waste, technical standards for recycled aggregate, and case studies of recycled aggregate use, and then compared them to the situation in Japan. From the results, we obtained the following findings.

In Europe, targets have been provided based on the Council Directive on Waste (2008/98/EC) for the reuse, recycling, and recovery of 70% or more building waste, by 2020. In addition, European countries have introduced landfill taxes as an incentive for effective use of recycled aggregate. As of December 2017, landfill taxes were introduced in 24 out of the 28 member states of the EU, and 18 member states have passed legal prohibitions against the use of certain materials in landfills. However, landfill taxation rates vary depending on the country, state, and local government, and the material in question.

Overseas technical standards for recycled aggregate generally stipulate the mixed use of recycled and natural aggregate. Regarding changes in the mixture ratio (according to the environments in which concrete is used and their strength ranks), overseas standards differ from those in Japan, in that they clearly differentiate between recycled aggregate concrete and concrete using virgin materials.

Most of the recycled aggregate used overseas is subbase coarse material as it is in Japan, so it is felt that its use in structures is restricted.

3.5 Use of information in the concrete field for a sustainable society

Improving productivity and building a sustainable society amid increased worldwide competition between countries demands the use of information and the incorporation of critical information into databases.

This committee has surveyed and collected examples of using information in the concrete field.

The Council on the Study of Improving Productivity in Concrete has been involved in the digitization of information on fresh concrete, streamlining testing through its use, and conducting trial construction projects with an aim towards systemization. We have compiled the statuses thereof.

The Yamaguchi prefecture cracking control system uses a database compiling the records of construction that has been properly accomplished, and can thereby improve productivity by making preliminary temperature stress analysis unnecessary. We have compiled the merits of building and of using a high-quality database.

One method for achieving traceability is a fresh concrete quality control system using IC tags. We have compiled possibilities for certifying the quality of fresh concrete delivered as a semi-finished product, and providing safety and security through clarification of responsibilities.

4. Virtual study of effects of population decline on concrete study systems

4.1 Purpose of this study

Today, social conditions previously unseen are rapidly approaching. These include accelerating population decline/rate of aging, concentrated population in cities and regional depopulation, and the emergence of remote communication, autonomous operation, and artificial intelligence (AI) based on IT. Concrete will presumably continue to be a primary building material, so with the idea that today's concrete production and supply systems are closely related to how the country will look in the future, we have decided to study what type of concrete production and supply systems may exist in future. The future does not simply lie in following the present. Its form will change according to a variety of factors, including attitudes towards national planning, disasters, and international circumstances. Therefore, our study here does not aim to narrow down what the future might bring; rather, it aims to discuss how the future might look by examining the possibilities, considering information that has been collected as objectively as possible.

4.2 Effect of shifting fresh concrete demand due to demographics on supply systems

We conducted a survey on future concrete supply with changing demographics, focusing on shifts in demand for fresh concrete. First, we analyzed the correlations between building investments and population, as well as current fresh concrete plan distribution and shipping results, and then built a base for predicting future fluctuations. Based on this, using GIS, we estimated the effects on supply systems according to future demographics in Hokkaido. This demonstrated the possibility of a quantitative approach to supply models.

4.2.1 Demographics and building investment

To identify correlations between demographics and building investment, we conducted a literature survey of both statistical data and estimation predictions. Based on the results, it was clear that demographics can be explained primarily by regional population inflow into the three metropolitan areas in Japan, and that stagnant inflows due to economic recession and population fluctuations in urban areas other than Tokyo are slowing down. We found that building investments have been following a downward trend since 1995, and the three major metropolitan areas are tending toward a decline in percentage growth. It has been predicted that population will decline to about ¼ to ½, by 2100, owing to the birth rate, which will accelerate as the contemporary metropolitan population decreases. It is believed that building investment will peak in 2018, and then, owing to population shifts, it will fall.

4.2.2 Fresh concrete plant distribution and shipping results

To identify the geographical features and shipping volumes of fresh concrete supply, we examined fresh concrete plant distribution and plant occupancy maps of each region. In particular, with regard to present circumstances in which the operating rate of local plants is less than 10%, it was shown that decreased concrete demand due to population decline is an urgent issue that needs to be addressed.

4.2.3 Effect of demographics on fresh concrete supply models

We examined how changes in fresh concrete demand due to demographics affect the supply infrastructure (fresh concrete plants).

Although both consolidation and decentralization have been suggested as policies for national resilience regarding population, here, we referenced moderate estimation results by a cohort method. The subject region was limited to Hokkaido; using concrete demand per unit population and shipping needed to maintain plants as variables, we verified the results through multiple scenarios. Based on the results, the population distribution in Hokkaido is uniform, which shows the possibility that the regional demand percentage and transport distances may increase (**Figure 7**). It is thought that overall, demand in Hokkaido will decline significantly, so there will be several fresh concrete plants facing maintenance issues, and measures will need to be taken at the national level from the perspective of infrastructure maintenance.

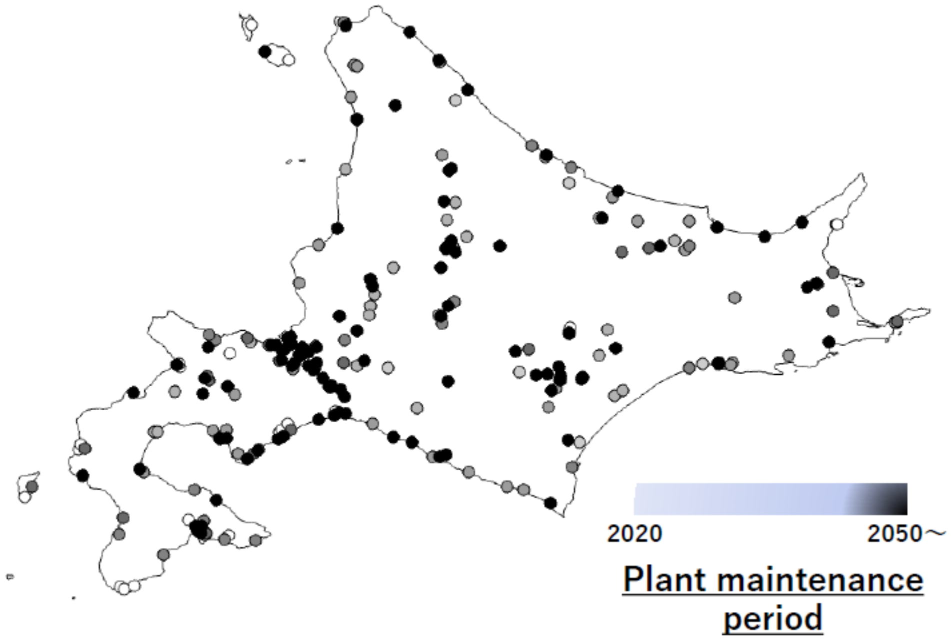

Fig. 7: Map of estimated plant distribution (scenario showing relatively gradual population decline, and plants closing with a ¼ decrease in revenues)

4.3 Effect on precast concrete supply system

Expectations are growing for precast concrete (hereinafter, PC) as a solution for improving productivity in response to population decline. Therefore, we discussed the effects of PC on future concrete supply systems. Furthermore, committees and associations have been established for different types of PC products, and hence, obtaining an overall idea is difficult. Therefore, we made an analysis based only on public information available on the Internet.

4.3.1 Present status of precast concrete

From the sales volume per cement shipping volume demand, we found that the percentage of PC has remained stable in the mid-10% range since the 1960s. Considering that ready-mix concrete use has increased from approximately 5% to 70% between the 1960s and the 1990s, it seems that manufacturing technology for PC had undergone major innovations by the 1960s.

4.3.2 Company size and status of membership in committees and associations

Surveys confirm the presence of 822 companies and 1335 plants nationwide. About 20% of these plants could not be confirmed as being registered for JIS certification. In addition, 75% of corporations own only one plant; only 4% of the corporations own five or more plants.

In addition, although industry committees are formed for every manufactured product, we found that more than half of the companies do not belong to any committee.

4.3.3 Plant location situation

If plants are located near a high-demand area, then they should be concentrated in a densely populated area or a prefecture with major building investment. However, based on the results of our analysis, such trends are not seen, but a high correlation with road extensions appears. A common relationship was seen nationwide in which there was about one plant per 909 km of road extension (**Figure 8**). As it is thought that raw material transport and product shipments are mainly done using trucks, locating plants in places having well-developed road networks could enable efficient operation. In addition, this also indicates that road-building and any nearby road construction would stimulate demand.

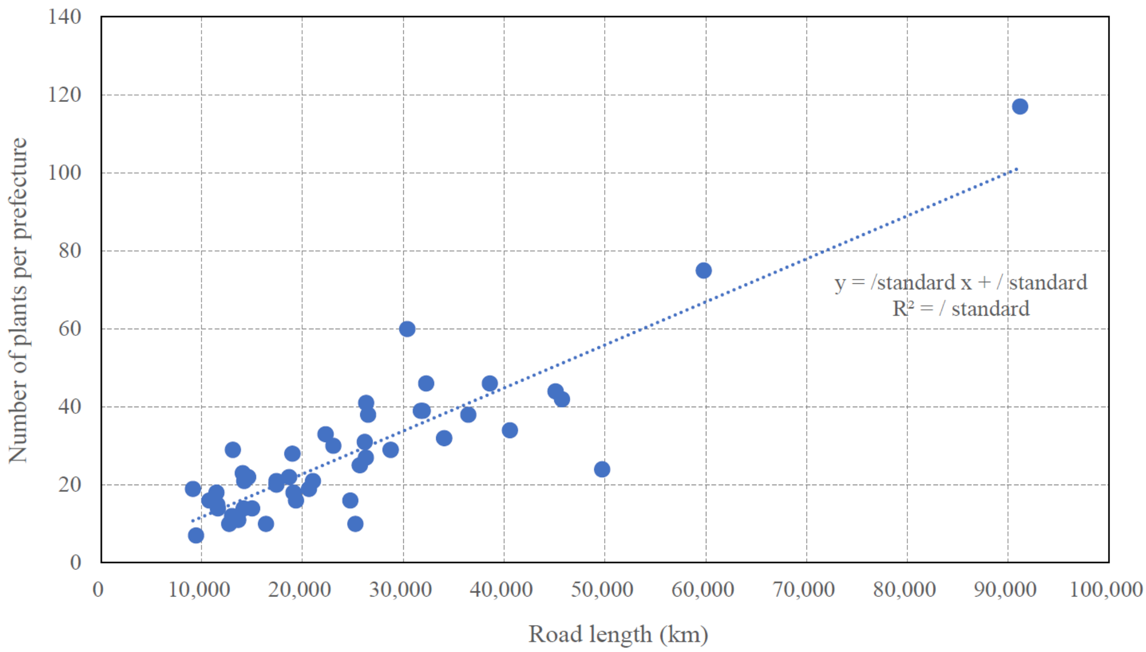

Fig. 8: Relationship between the number of plants per prefecture and road extensions

4.3.4 Proposal to improve the precasting rate

Although the main focus has been on using precast concrete to improve productivity, its technical maturity has already reached a high level, and there is a high probability that the current precasting rate has achieved the best mix. Measures to further improve these conditions include innovations through sharing between plants for different products, stabilizing concrete supply chains and plant management through flexible product manufacturing, supplementing supply systems with PC plants that can ship read-mix concrete, and steps to make obtaining certification for both ready-mixed concrete and PC easier.

4.4 Effect of changes in the social fabric on sales systems

A cooperative selling system for fresh concrete has enabled the delivery of concrete of prescribed quality within prescribed delivery times in response to the expansive needs of postwar recovery and rapid economic growth. Furthermore, it has greatly contributed to land development. However, as the population declines in the future, there may be significant changes in the volume and distribution of building demand. Here, we consider two extreme future population distribution models: an intensive society and a distributed society. We examined which fresh concrete sales model will be superior, and what steps can ensure that the country remains strong.

4.4.1 A possible urban model and the features thereof

In an intensive society, it is possible to develop intensive infrastructure and efficiently maintain and operate that infrastructure. However, there is a concern that its high density will make redevelopment difficult, and cause widespread damage from disasters. A regional distributed society utilizes IT and facilitates the movement of people and things through virtual space and automated operating technology. As the population is spread widely, there is little damage at the local level when disasters strike, which is thought to increase the nation’s resilience against disaster. However, the infrastructure usage rate is lower, and thus, there are concerns that maintenance and operating costs will be higher.

4.4.2 Building demand density and sales models

One factor strongly influencing sales models is the density of building demand. If this density is low, multiple plants cannot be established, and, naturally, a small number of plants in a non-cooperative sales system will manage manufacturing and sales. When the demand density is a little higher, multiple plants may be established and will start to compete, but the competition will be stiff, so a cooperative sales system will emerge to ensure stability. As the demand density increases further, plants will arise that do not belong to the cooperative sales systems and that operate on their own. Therefore, both cooperative and non-cooperative systems will exist. However, fresh concrete has restricted shipping times; the commercial area of one plant is narrow; and the overlap between commercial areas is not large. Therefore, it is felt that non-cooperative plants may coexist by establishing technological distinctiveness, the antithesis of neighboring cooperative-type plants. Furthermore, more people will gather, and local demand density will increase. Competition will increase as plant commercial areas completely overlap. Fresh concrete is characterized by having a small range of price adjustment and difficulty in establishing technological distinctiveness. Therefore, it is felt that consolidation into large plants with lower raw material procurement costs will proceed, and presumably, non-cooperative sales-type plants capable of flexibly dealing with changes will dominate.

4.4.3 Ensuring resilience in possible sales systems

The demand density is based mainly on market principles. Therefore, we examined ways to ensure national resilience. In the case of a distributed society with very low demand density, a non-cooperative sales supply is considered to be excellent. However, if a problem occurs at a base plant, there will be widespread supply stoppages. Thus, it is possible that supply via site plants may be effective as a policy to ensure robustness and efficiently secure a commercial area. On the other hand, in the case of an intensive society with very high demand density, problems at a base plant will have serious effects. Therefore, it is felt that ensuring a system close to a cooperative sales model, not concentrating production at a single plant guided by market principles, is necessary. This system can allow for multiple coexistent plants, that is, it can establish cooperation between non-cooperative operators.

5. Conclusion

The concrete industry can essentially be considered mature. Its uses simple materials. Concrete is manufactured by mixing cement, water, and aggregate, and is then transported to a site, and then, is hardened through placement, compaction, and curing. Mixing to achieve a prescribed strength is not a difficult task. However, although the materials are simple, concrete still has a “weakness,” in that slight differences in conditions can greatly vary its quality. Against this background, quality assurance has largely been limited to imposing several restrictions. Originally, performance was determined only by material and structural requirements, so there was no need for “standards” enumerating “nitpicky” details. Regardless, instructions would often be given for things to done in specific ways. Hence, several related specifications and standards have been created. Once established, they become obstacles to technical innovation and often consume energy and increase costs on a practical level.

The basis for all technological and system specifications and standards ultimately goes back to the law. The law leads ways to stipulate the scope of the work of each ministry.

Naturally, if the fundamentals of society change, these need to be changed as well, but it is difficult to say if this is always done appropriately, and if it blunts the competitive will of potential innovators. How jurisdictions are divided between ministries also complicates problems. On the other hand, the fact is that years of accumulated efforts have played a critical role in preventing catastrophes. For example, many of the solutions to problems that arise are turned into stopgap measures. A patchwork of stopgap measures complicates problems even more, and creates a negative cycle of new barriers. In other words, if all events are not handled systematically, then they cannot be handled appropriately. Presently, the most pressing challenge facing society is how to deal with problems systematically and effectively. However, this sort of consciousness is rare in the industrial sector, which is increasingly bloated with an “unwillingness to change.”

This technical committee initially approached its objective from the aforementioned viewpoint, but as it proceeded with its discussions, it found that there was little self-awareness in the concrete and construction fields, though their problems will be significant barriers in the future. In order to ensure the future sustainability of society, in addition to global warming and resource depletion, we recognized that how Japan will deal with its population decline is a major issue, and it is important to directly confront how it is connected to the concrete and construction industries. We should not have to reiterate it, but for us, the population problem is quite serious, since it will reorder infrastructure based on the demands of society. A dangerous situation is starting to emerge that has never been experienced in human history. Dealing with it will take more than just stopgap measures.

Against this background, this technical committee has proposed familiar examples of barriers and their countermeasures, examined technology and systems for a sustainable society (based on resource exhaustion), and examined what might happen in the concrete industry in future, due to population decline. Of course, these proposals are not adequate. Emphasis must be placed first on the need to identify the root problems facing near-future society, and how society might have to adjust based on various social demands. The presence of such a system will give birth to “innovation.”

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