Committee Report : JCI- TC071A

Technical Committee on the Design and Utilization of Precast Concrete Products

Masahiro YURUGI, Masafumi KITATSUJI, Makoto HISADA, Yoshihisa NAKATA

Abstract

Despite the excellent properties and performance of precast concrete products, their usage has not appreciably increased with respect to the cement usage. Even a decreasing trend has been recognized recently. However, utilization of precast concrete products is essential in view of the foreseeable changes in the social circumstances. The Committee has therefore conducted research and investigation to confirm the problems and facts that the precast products have been facing and formulate technical materials that will contribute to their wide-spread use and development. This research revealed differences in the attitudes toward precast products between designer, constructor and precast manufacturers, problems related to the transition to performance-oriented design, and subjects to be addressed when using low quality materials, including recycled aggregate, for precast products.

Keywords: performance-oriented design, precast concrete, questionnaire survey, recycled material

1. Introduction

Because of production in plants under consistent quality control, precast concrete products are made to have stable qualities and contribute to the construction of structures having higher durability than those made of cast-in-place concrete. In regard to execution, they shorten the construction period while saving labor. For these reasons, labor-saving construction using precast and prefabricated concreting has long been expected to predominate over cast-in-place concreting. However, the amount of cement used for precast products has remained as low as 14 to 15% of the total cement production, with more recent data being even lower at 12 to 13%. This can be attributed to the following causes: (1) The excellence of the quality of precast products has not been fully understood; (2) their advantages including the short construction period have not been incorporated in the cost estimation, scarcely leading to an overall construction cost reduction; (3) product development has not responded to social changes and the present-day issues; and (4) technically, ensuring the performance of joints

involves difficulties. Nevertheless, the use of precast products will become increasingly necessary in consideration of the demand for highly durable infrastructure for constructing a recycling-oriented society and the social conditions in anticipation of the coming aging society. With this as a social background, JCI organized the Technical Committee on Design and Utilization of Precast Concrete Products for two years (2007-2008) to review subjects characteristic of precast products and formulate technical materials contributing to their spread and development[1].

Precast concrete products include a wide variety of items, such as general-purpose articles specified in JIS, large-scale products for specific civil structures such as bridges, specific modules for streamlined construction of individual buildings, such as walls, columns, and beams[2]. They are also used in various ways: as single members; in combination with other units to form a structure; and connected with cast-in-place concrete. For this reason, the Committee organized three working groups to investigate precast products: "Actual condition survey WG," which investigates their actual conditions in each of architectural and civil engineering fields; "Design method WG," which investigates the application of performance verification and the limit state design method; and "Recycled material utilization WG," which investigates the methods of utilizing recycled aggregate and low-quality aggregate for precast concrete products.

Table 1: Committee members

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Secretary	Yoichi TSUKINAGA	Hachinohe Institute of Technology
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	Hiroshi NAKANE	Ohki Corporation
	Yasuhiko FUJITA	Flowric Co., Ltd.
	Hiroshi MINAGAWA	Tohoku University
Cooperate Member	Teruo SHIROISHI	Japan Concrete Products Association

2. Questionnaire on the attitudes towards precast products

A questionnaire was conducted regarding the attitudes of designers, contractors and manufacturers towards precast products in order to clarify problems that they are facing and their actual development and wide-spread use. The questionnaire was directed to people engaged in work related to architecture and civil engineering. The former included designers, contractors, and manufacturers, whereas the latter included owners and manufacturers. This section reports on the results of the survey on the precast products for buildings, those for civil engineering structures, and the surface condition of such products. Note that the questionnaire was sent to respondents through respective trade organizations (the Building Contractors Society, Japan Prefabricated Construction Suppliers and Manufacturers Association, etc.)

(1) Results of questionnaire on precast products for buildings

The questionnaire conducted from July to September 2008 was directed to designers and contractors of building structures, as well as precast product manufacturers. Note that the procedure including the planning, design, transportation, and on-site installation of precast products is as a whole referred to as "precast concrete construction" in this paper, excluding the production process of such products.

♦ Items and methods of survey

In the questionnaire directed to the architectural field, the items related to precast concrete products/construction were classified as follows:

(a) Evaluation of precast concrete construction in comparison with conventional methods
  (1) Quality and promotion of precast products; utilization of recycled materials.
  (2) Period, cost, labor supply, execution plan, and execution control of precast concrete construction, environment, design, relevant parts of structures, and uses.

(b) Demands for promoting precast concrete construction

  Demands for the other groups; demands related to the use of recycled materials; demands for laws/standards.

The answer to each question was to be selected from five levels or written in the answer

space.

♦ Subjects of the questionnaires and numbers of respondents

The subjects of the questionnaire included (a) designers in charge of the approval of structural design or production design for precast concrete construction; (b) execution administrators in charge of the planning of design alteration of precast products and controlling their production and assembly; and (c) manufacturers producing and supplying precast products. The numbers of respondents totaled 96, which consisted of 20 designers, 41 contractors, and 35 manufacturers.

♦ Results

In regard to general items, the results were inventoried focusing on the differences among the attitudes/awarenesses by designers, contractors, and manufacturers. **Figure 1** shows an example of responses. The results are summarized as follows:

(a) Designers, contractors, and manufacturers similarly responded regarding to a question asking if the qualities of precast concrete products are more stable than those of concrete by conventional methods.

(b) Designers, contractors, and manufacturers have similar views in common that precast concrete construction requires a shorter construction period, is more helpful for solving labor supply problems, and more environment-friendly, than conventional methods.

(c) As to the construction cost, manufacturers think that precast concrete construction reduces the cost, whereas most designers and contractors do not think so. Designers and contractors also think that the composition of the price is unclear.

(d) In response to questions regarding parts for which the use of precast products is expected to increase, the respondents share a common view that a combination of cast-in-place concrete and precast products will predominate. In regard to a question as to whether precast products will be applied to uses other than collective housing, nearly half the respondents answer that they will be used for any type of building.

(e) Demands for other groups from owners, contractors, and manufacturers is as follows: It was desired by other groups that owners should have the comprehension to precast products; designers should standardize the member cross-sections; contractors should execute construction making most of the benefits of precast products; and manufacturers should reduce the cost and ensure the qualities of precast members.

(f) In regard to the use of recycled materials for buildings, all groups desire legislative preparations and recognize the necessity of durability verification.

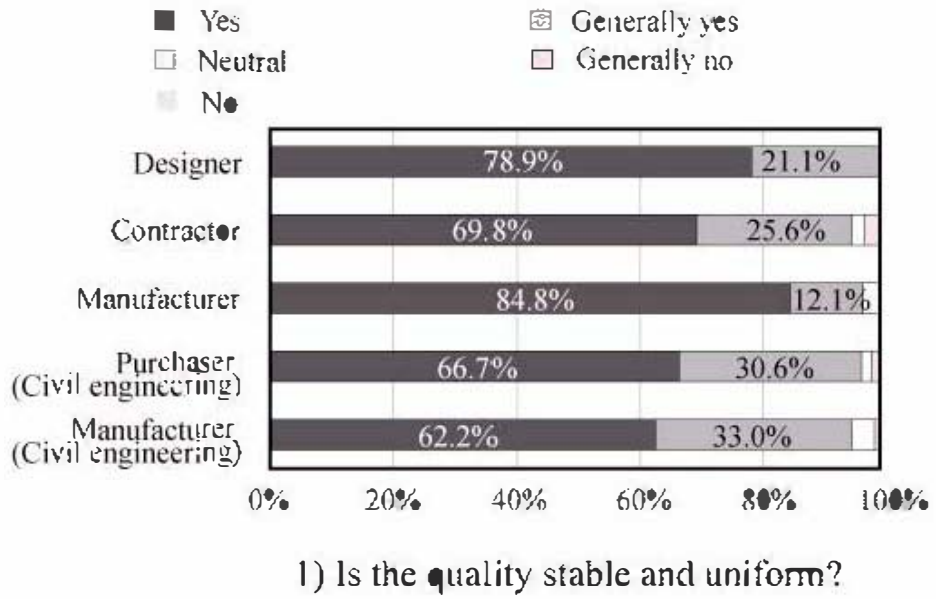

Figure 1: Answers by different standpoints

(2) Results of questionnaire on precast products for public works

A questionnaire survey was conducted from August 2008 to January 2009 to grasp the actual situation of the application of precast products to public works facilities, as well as to clarify the problems to be tackled to promote the use of such products. The questionnaire was directed to two groups: owners of public works facilities and manufacturers of precast products, focusing on the differences between the attitudes/awarenesses of both groups.

♦ Items and methods of survey

In the questionnaire directed to the civil engineering field, the items related to precast products were classified as follows:

(a) Evaluation of precast concrete construction in comparison with conventional methods

(1) Quality and promotion of precast concrete products; utilization of recycled materials.

(2) Period, cost, labor supply, execution plan, and execution control of precast concrete construction, environment, design, relevant segments, and uses.

(b) Demands for promoting precast concrete construction

Demands for the other group; demands related to the use of recycled materials; demands for laws/standards.

The answer to each question was to be selected from five levels or written in the answer space.

♦ Subjects of the questionnaires and numbers of respondents

The subjects of the questionnaire included (a) owners who can order for precast concrete construction and (b) manufacturers producing and supplying precast concrete products. The numbers of respondents totaled 335, which consisted of 86 owners and 246 manufacturers.

♦ Results

In regard to general items, the results were inventoried focusing on the differences between the attitudes/awarenesses by owners and manufacturers. The results are summarized as follows:

(a) Owners and manufacturers similarly regard the qualities of precast concrete products as being stable, with little difference between their views.

(b) Both owners and manufacturers have similar views in common that precast concrete construction requires a shorter construction period, is more helpful for solving labor supply problems, and more environment-friendly, than conventional methods.

(c) As to the construction cost, manufacturers think that precast concrete construction reduces the cost, whereas most owners do not think so.

(d) The issue of the use of recycled materials in the civil engineering field was controversial, though dependent on the type of precast product.

(3) Results of questionnaire survey on the surface condition of precast products

A questionnaire regarding the aesthetic appearance of the surface condition of precast products was conducted on manufacturers of precast products in the buildings and other civil engineering structures, contractors who carry out execution control of building construction, and designers of buildings.

♦ Contents of questionnaire

In regard to the aesthetic appearance of surface condition, the following points were asked:

(a) Aesthetic appearance of surface condition shown in sample images

(b) In-house standard for surface finish

(c) Rating of discoloration on members shown in sample images

The subjects were asked to rate sample images on their PC screens downloaded from a website to minimize the effect of difference in vision due to printer resolution, etc.

♦ Aesthetic appearance rating of surface finish shown in sample images

Since the degree of partial discoloration on concrete surfaces can be evaluated in terms of

the average and standard deviation of lightness[8], the questionnaire survey was carried out using sample images having different lightness values. The survey items included the following:

- Effect of the lightness of concrete surfaces on sub-consciousness
- Surface colors that appear to need repair with respect to the certain lightness of the surface
- Lightness differences that mar the aesthetic appearance and need repair
- Lightness values that appear to need repair when the standard deviation of lightness is constant
- Relationship between the area ratio of surface air voids and the necessity for repair

No physical value on the concrete surface was indicated in each question. The respondents were asked to answer by subjective ratings of the sample images.

♦ In-house standard for surface finish condition

In this survey, the respondents were asked if there is an in-house standard regarding the color shading, partial discoloration, and surface air voids of precast products to clarify how the aesthetic appearance of surface finish condition is controlled in their production. The reasons for establishing the in-house standard and evaluation methods were also asked in the questionnaire.

♦ Results

The number of respondents to the questionnaire regarding the aesthetic appearance of surface condition totaled 173.

The selected target color of concrete surfaces tended to be light, while the respondents became subconsciously less sensitive to color shading and partial discoloration as the color lightness increased. Also, they felt uncomfortable when the surface void area ratio exceeded 0.5%. Few in-house standards were found to have been established regarding the color shading and partial discoloration of surface condition. The evaluation methods adopted in such standards were mostly visual evaluation.

3. Problems related to the design of precast products

(1) Apprications and problems of precast concrete products/structures

The characteristics of precast products in comparison with cast-in-place concrete include the following: (a) produced at plants with strict control over the materials, placing, and curing; (b) produced mostly as high strength concrete; (c) careful inspection is possible due to

being produced at plants; (d) generally produced with a small cover depth; (e) recently include imported products (prestressed concrete shield segments, for instance); (f) large-size products are difficult to transport; and (g) may require a large crane for installation; (h) the degree of freedom in designing cross-section is low (however, repeated use of molds can improve the profitability).

The characteristics and benefits of construction using precast products include the following: (a) shortens the construction period; (b) saves labor (workforce); (c) ensures quality stability; (d) ensures safety of construction; (e) facilitates the use of recycled materials; (f) reduces the generation of construction waste; (g) allows careful surface finishing; (h) allows partial replacement; (i) reduces the number of construction control items; and (j) allows confirmation of member performance.

Despite these characteristics, precast products used for construction may not always lead to success, but may cause defective events. Members of the Committee interviewed their company staffs to collect examples of successful cases and cases involving defective events.

In most of the 56 successful cases of using precast products, shortened construction period and streamlined construction were cited as the factors of success. These included the following: precast box culverts having a large cross-section for expressway underpasses to shorten the construction period and improve the qualities; arch-shaped precast members with a wall thickness of 500 mm for an open cut tunnel to simplify the construction and reduce the construction cost; the use of precast products that shortened the restoration period; and the use of precast greening blocks that enabled the formation of vegetation bases having complicated shapes.

On the other hand, interviews with precast product manufacturers revealed the following typical defects: (a) cracks; (b) dimensional errors; (c) air pockets **(Fig. 2)**; (d) partial discoloration; (e) chipping/fracture; honeycombs; (g) paste exudation; (h) efflorescence; and (i) pop-outs **(Fig. 3)**.

Figure 2: Example of defect
(Insufficient filling at connection fitting)

Figure 3: Example of defect
(Popout due to deicing salt)

Joint-related defects included a case of cracks 0.5 mm or more in width in the joints dividing the upper and lower segments of box culverts. This was attributed to the internal pressure from water-swellable rubber used as water-stops for the joints. Other defects included the deterioration of concrete in the joints of tiles used for precast curtainwalls and the contamination of sealing compounds used for joints in buildings.

Defects related to subsequently placed concrete included cases involving stay-in-place forms or seismic retrofitting with reinforced concrete lining. Other defects include a case of high embankment where unsymmetrical earth pressure acted on the structure of the precast products and a case where the subgrade reaction was not constant due to changes in the ground conditions.

(2) The use of precast products in foreign countries

The Committee conducted a literature survey of overseas specifications for precast products and presented the abstracts of the following documents along with the construction conditions for using precast products:

- BS EN 13369: Common rules for concrete products (U.K.)
- Building Code 318, PCI manual, AASHTO, etc. (U.S.A.)
- DIN 1045 (Germany)

In these specifications, provisions for the performance of structures built using precast products are well developed rather than the technical standards for manufacturing the products. They include technical requirements particularly for the connection of precast units in constructing the structures, which are considered to become necessary in Japan in the future.

It should be noted that, despite the elaborate requirements to ensure the performance of precast products and the resulting structures, the acceptance criteria for their appearance, which scarcely has a direct effect on their functions of the structures, are less stringent than in Japan.

(3) Points to consider in design, production, execution, and maintenance of precast concrete products and structures

When manufacturing precast products, it is necessary not only to prevent the above-mentioned defects but also to establish rational methods of production. To this end, the manufacturer should hold thorough discussions with the owners regarding the product specifications before production and reach an agreement beforehand. A prior agreement about partial discoloration and crack width/amount, for instance, eliminate complaints at the time of delivery, prevent extra work processes not in the production plan, and eliminate delay in construction due to replacement of precast units.

Points that precast product manufacturers and contractors consider in design, execution, and maintenance include the following:

♦ <u>Points to consider in design</u>

(a) Earth pressure control

Unsymmetrical pressures in constructing high embankment or skew crossing, etc., should be thoroughly considered in the design.

(b) Measures against foundation settlement

Thorough investigation into the foundation ground should be carried out during the design phase. Design of structures incorporating certain settlement may be necessary

in some cases.

(c) Connecting methods

Design considering the performance for the connections should be required depending on the using conditions of the structure. Since connections can be critical weaknesses particularly during an earthquake, ease of restoration should also be considered in the design.

(d) Joints structures between precast units

When using precast products in combination, joints and connections between them are necessary. Performances required for connections include the capability of transferring forces, watertightness, durability, and deformability to follow the displacement of the ground. A joint structure should therefore be selected so as to meet these performance requirements. For sealing joints of curtainwalls, the fatigue resistance of joints provided at corners should be carefully considered[3]. Other points to consider when designing sealing joints include that the joint size should be determined so as to be safe against their deformation and that the safety factor should be large enough against indeterminate external forces[4].

(e) Effects of subsequently placed concrete

When using half-precast products or stay-in-place forms, the effects of subsequently placed concrete

subsequently placed concrete is expected to act on slabs made of precast units, for instance, the bending stress resulting from both the weights of subsequent concrete and precast members should be examined. When the lateral pressure of subsequently placed concrete

placing conditions should be determined in consideration of the rate of placing and the depth of each lift. In the case where stay-in-place forms serve as cover concrete, it is necessary to monolithically combine the forms with subsequently placed concrete and to take measures to avoid early cracking of precast forms due to the temperature stress or drying shrinkage of subsequently placed concrete.

(f) Control of construction loads

It is important to improve the accuracy of the assumption of indeterminate construction loads, such as the eccentricity of jacking reaction on shield segments, the lateral pressure on such segments due to butting, and frictional forces. In designing stage using thin-wall precast unit, other points to be considered include the establishment of technology for verifying strength and crack width during

construction as well as the treatment of long-term residual stress resulting from construction loads.

◆ Points to consider in execution

(a) Control of the accuracy of installation/assembly

For installation of precast products, the construction machines and methods should be suitably selected for the job site conditions. Also, the accuracy of assembly should be controlled to meet the tolerances for construction in consideration of the tolerances for individual products.

(b) Connection

Large sized precast products are generally connected using such jointing materials as prestressing steel and metal fittings. Precast products should thus be connected basically by methods and materials to meet the performance requirements for the resulting structure, giving due consideration to the performance of connections required by the design.

(c) Joints (watertightness)

The joints between panels for precast concrete curtainwalls used for the exterior walls of buildings play an important role in inhibiting the infiltration of rainwater. These are made by the filled joint method using a joint sealant or the open joint method in which a barrier is formed with gaskets. Since both methods have advantages and disadvantages regarding the durability, running cost, etc., either of the two should be selected with due consideration to the performance of the resulting structure. It is advisable to refer to the Technical Guidelines for Watertight Design and Construction of Exterior Wall Joints[4] published by Architectural Institute of Japan (AIJ) when designing and executing joints.

(d) Subsequently placed concrete

Important points to consider when placing subsequent concrete include that the concrete should be placed according to the execution plan at the design stage and that particular care should be exercised for the placing rate and fluidity of concrete, which can affect the concrete lateral pressure. When pumping concrete, the discharge end should be moved to avoid excessive differences between concrete levels.

(e) Backfilling

It is necessary to establish the tolerances for the unsymmetrical earth pressure as well as the control methods in backfilling of the structures. These include the permissible difference between the backfill levels on both sides of the structure, the materials for

backfilling, compaction method, degree of compaction, and the control values and control method for fluctuations in the density. It is also necessary to improve the accuracy of the design impact load from the compaction machine and establish the method of compaction near the structure and its control. The observation of dynamic state and control method during execution are also important considerations.

♦ Points to be considered in securing durability and maintenance of concrete

Long-range deterioration of structures made using precast products is primarily caused by frost damage, abrasion, drying shrinkage, and alkali-silica reaction (ASR).

Among the ASR-induced deterioration cases, there were cases where deterioration occurred in precast products made using aggregates judged as being "innocuous" by alkali-silica reactivity testing as specified in JIS A 1145 (Chemical method) or JIS A 1146 (Mortar bar method). This can be attributed to the fact that the alkali content of precast products tends to be high due to the high cement content and that the use of blended cement, which is effective in inhibiting ASR, is difficult for precast products. In view of this situation, ASR testing methods for precast concrete different from those for ready-mixed concrete should be investigated. Issues to be addressed in the future include the establishment of technology related to testing methods for ASR potential and judgment criteria for steam-cured concrete and methods of identifying natural aggregate that is judged as being safe by the chemical method but actually causes ASR (applicability of the ACI method and Canadian method).

The relationship between the cracking and watertightness/airtightness of joint sealants, weather resistance of sealants, and exterior wall contamination due to sealants should also be investigated in the future, in order to evaluate the durability of joints/connections and to establish appropriate maintenance methods for them.

(4) Issues related to the design of structures using precast products

While existing recommendations and guidelines can be referred to regarding the structural design of precast concrete products, new guidelines should be formulated for their material design including investigation for their durability. Along with the methods of design and production of precast products, the establishment of a method of designing structures as an assembly of precast units is particularly anticipated. It is also considered important to categorize precast products not by their size but by the using conditions, for example easily replaceable products, such as curb blocks, and those that are not easily replaceable, such as articles embedded in the ground. It is also important to characterize designing concept according to these using conditions. These guidelines should include requirements for specific

uses and localities, such as those for use in marine environments, cold climate specifications, and acid-resistant specifications.

(5) Examples of design calculation for structures using precast units

The Committee took up an L-shaped retaining wall as an example of a concrete structure using precast units and conducted safety verification by the limit state design method in accordance with the JSCE *Standard Specifications for Design and Construction of Concrete Structures*[5] and the *Design Standard for Railway Structures*[6]. The structure under study was an L-shaped retaining wall 3.0 m in height and 100 to 220 mm in thickness designed by the allowable stress design method[7]. As a result, the structure was found to be safe both in the serviceability and ultimate limit states, rather showing a possibility of reducing the reinforcement content. Issues to be addressed in the future include the following:

(1) The validity of coefficients in the equation for calculating the bending crack width of thin-section members.

(2) The applicability of the limit values for bending crack width to members with a cover depth of 30 mm or less.

(3) The variances in the judgment criteria between standards.

4. Utilization of recycled materials for precast products

Precast products have several advantages in utilizing recycled materials. To begin with, JIS A 5308 (Ready-mixed concrete) requires that the cement and aggregate to be used for ready-mixed concrete (RMC) must meet their respective JIS requirements. For this reason, low quality materials and recycled materials (not standardized) cannot be used for RMC. Even currently standardized recycled aggregate and municipal solid waste (MSW) slag cannot be used for RMC accredited to JIS.

On the other hand, JIS A 5364 (Precast concrete products -- General rules of materials and product methods) requires that the materials should have qualities equal to or higher than those conforming to JIS. This is at least not more stringent than the requirements for RMC, and the use of recycled aggregate and MSW slag for precast products is explicitly permitted. Such a difference may result from the forms of delivery. The materials of RMC are strictly restricted, as the product to be delivered is not finished (hardened) products and therefore its performance cannot be verified at the time of delivery. However, the performance of precast products can be tested as hardened concrete in accordance with JIS A 5363 (Precast concrete products -- General rules for methods of performance test). In other words, how and from what the products are made, including the materials, consolidation method, and curing

method, are not important as long as the requirements. This is an instance of a change from 'specification-oriented' requirements to 'performance-oriented' requirements, which are vital for utilizing recycled materials.

Another advantage is the small amounts of precast unit production, which make the plants the largest potentials for accepting recycled materials are precast units for roads and concrete blocks for revetments. Their annual shipments amount to around 5.5 million and 2.3 million tons, respectively, with the annual shipment per plant ranging from 5,000 to 10,000 tons. Since such plants use small machinery and equipment with small batch sizes, they can flexibly accept small amounts of recycled materials. The relative smallness of most precast products also makes such plants adaptable to recycled materials. The case of defective events is another advantage of precast products.

The assessment by lifecycle analysis (LCA), and new technologies/methods for precast concrete products. Three draft guidelines are also proposed in the report for using Class M recycled coarse aggregate, ground granulated blast-furnace (GGBF) slag, and fly ash for precast products.

(1) Use of recycled aggregate for precast products

Annual waste concrete discharge amounts to 35 million total waste from the construction sector. Though most is reused for the crusher-runs of roads, the expected increase in the amount of future concrete waste will outgrow the demand for concrete debris for crusher-runs. Recycling of waste concrete as aggregate for concrete is thus anticipated from the standpoint of formulating a resource-recycling society.

Recycled aggregate for concrete were classified into three ranks, H, M, and L, and JIS specifications were established in 2003 to 2007 for Class H recycled aggregate itself and concrete made using Class M and Class L recycled aggregates. However, these standards impose strict limitations, assuming their use for RMC.

Despite the highest expectations placed on its wide use, the standard limits the use of Class M recycled aggregate to underground structures in order to weed out problems with drying shrinkage and freezing and thawing action. However, precast products are advantageous that their small member size minimizes drying shrinkage-induced defects and facilitates replacement in case of defective events. Also, a simple method of testing the resistance of aggregate to freezing and thawing action has been developed, enabling easy judgment for use in precast products.

For these reasons, the Committee decided to propose draft guidelines for the procedures of ensuring the qualities/performance when using Class M recycled aggregate for precast products.

(2) Low quality aggregate

Alkali-silica reactive aggregate, which is distributed nationwide, is scarcely used in certain regions, and non-reactive aggregate is transported to these regions over a long distance, sometimes from more than 100 km away. Local production for local consumption is desired from the aspects of the effective use of resources, cost saving, and environmental load mitigation. Active utilization of reactive aggregate for precast products is particularly anticipated, as such products can be sufficiently protected from ASR through anti-ASR measures taken during production processes at strictly controlled plants.

Clinker ash is a porous material having properties (particle size) similar to sand. The strength properties of concrete containing clinker ash varies depending on the overall grading of the clinker ash and the other aggregate used. Such a concrete should therefore be proportioned by trial mixing beforehand at the present stage.

(3) Blended cement and admixtures

GGBF slag is used for precast products with the aim of improving the performance of resulting concrete, such as improving the chloride-shielding performance, improving the chemical resistance, and inhibiting ASR. Also it is used as an admixture for self-compacting concrete aiming for saving labor and reducing the vibration/noise during placing. When using a binder containing GGBF slag, the curing conditions should be selected by testing beforehand, as its setting time generally tends to be retarded and the temperature dependence of its strength development tends to be high. It is desirable to conduct verification testing using full-scale models. When such a concrete is subjected to accelerate curing, the post-demolding strength gains generally tend to decrease as the pre-curing time decreases, as the temperature rise rate increases, and as the maximum temperature increases. Moreover, a high maximum temperature can lead to insufficient cooling of products by the time of retrieval from the curing chambers, ending up in cracking due to rapid cooling.

Fly ash is used for precast products to improve the finish appearance of products by enhancing the filling performance of concrete, to reduce cracking by inhibiting shrinkage (autogenous and drying shrinkage), and to improve the production performance including water-reducing effect and suppression of heat generation. It is also used to improve the durability by increasing the chloride-shielding performance and chemical resistance due to

pozzolanic reaction, which densifies the microstructure of hardened cement, as well as for its excellent ASR-inhibiting effect. Fly ash also serves as an admixture to ensure the fluidity of self-compacting concrete, which is used for precast products to save labor and reduce vibration/noise during placing, as well as to prevent cracking of high strength products by reducing the shrinkage and heat generation. Another use of fly ash for high quality products is as a substitute for silica flour for forming tobermorite in autoclave-cured products.

Though its setting time is normally retarded, a binder containing fly ash is generally advantageous for steam curing because of the temperature dependence of fly ash concrete strength development. Nevertheless, curing conditions must be determined after verifying the strength development by preliminary testing similarly to general concrete. It is desirable to conduct such testing on full-scale models.

(4) Environmental assessment

Enviromnental load assessment was conducted on two box culverts to be constructed as underground road structures. The structures under study were precast and cast-in-place box culverts 7.7 m in height and 9.8 m in width, which were assumed to be made using Type B blast-furnace slag cement and normal portland cement respectively. As a result of calculation, no marked difference was found between the enviromnental loads derived from their materials. One of the significant advantages of using precast members is a shortened construction period. The assessment results including the loads due to traffic congestion during the construction periods are as given in **Table 2**. The environmental loads from the construction of the box culvert made of precast members were found to be reduced to approximately 60% of those from the cast-in-place box culvert in all emission items.

(5) New technologies/methods

(a) Double mixing method

Numerous studies have been conducted on the double mixing method whereby mixing is carried out by dividing the amount of mixing water into two stage with optimum ratios, reporting reduced amounts of bleeding water, accelerated early hydration of cement, and shortened setting times. It has been confirmed on a laboratory level that this method, when applied to the production of precast products, shortens the pre-curing time before normal pressure steam curing. Though items remain to be confirmed before applying to production in actual plants, this method has a potential to shorten the curing process in the production of precast products involving normal pressure steam curing, which is used in most precast concrete plants.

(b) Preformed air-entraining admixtures

Active use of fly ash is desired from the standpoint of effective utilization of resources. However, unburnt carbon contained in fly ash impairs the foaming function of air-entraining admixtures, making the air content control difficult when using a normal air-entraining admixture. Meanwhile, a preformed air-entraining admixture, which is added during mixing after being foamed into fine air bubbles of a dense mousse, is capable of reducing the adverse effect of unburnt carbon. Preformed air-entraining admixtures reduce the space factor between these bubbles in the concrete and increase the frost resistance of concrete. It also reduce the defoaming ratio during vibratory consolidation of precast products.

Table 2: Comparison of environmental loads incorporating construction period

	CO_2 (t)	SOx (t)	Nox (t)	Dust (kg)
Cast-in-place concrete	10,440	5,613	23,004	2,728
Precast concrete	6,620	3,508	14,378	1,705

5. Summary

The activities of the Committee over two years have clarified to a certain extent the current issues related to precast products and subjects to be addressed for widening their use. However, a number of issues have also been left undiscussed, since this is the first committee that deals with precast concrete products in JCI and precast products are produced in a wide variety of forms for various usages as stated in the 'Introduction.' In contrast to European precast products under intensive study by numerous institutions including public organizations, research activities on precast concrete are not so active in Japan. It is hoped that the activities of this Committee will mark the beginning of continuous investigation into precast concrete construction. Note that the activities of this Committee will be reported in detail at the following debriefing session/symposium:

Debriefing session/symposium "Technical Committee on the Design and Utilization of Precast Concrete Products"

Date: Friday, August 7, 2009

Place: CST Hall, Surugadai Campus, Nihon University

Program: Working Groups' activity reports, Panel discussion

References

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