

In this issue ...

Prof Tamon Ueda, ICCMC Chairman gives the background on the development of the first Asian Concrete Model Code and the collaboration between ICCMC and ISO/TC71. ICCMC corporate members, Dr Kazuo Yamada of Taiheiyo Cement Corporation describes the advanced analytical technologies, EPMA for the evaluation of material transport and XRD/Rietveld method for the hydration analysis. Dr Minoru Morioka of Denki Kagaku Kogyo Kabushiki Kaisha introduces EIEN, the long-life concrete.

Harmonization of Design Code



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Background

Construction turnover in Asia constitutes one third of the world's market, while the remaining two thirds are shared equally by Europe and North America. Cement consumption in Asia, which is a good index to measure construction industry size, is now well above 50% of the world's total cement consumption. China is ranked first, followed by India. In 2005, consumption of cement by China was ten times greater than that in Japan. Besides the Asian construction industry's impressive size, it should also be noted that within Asia there are many large international construction projects, contracts being granted to European or North American companies as well as those from Asia. These facts imply the necessity of international codes for regulating the construction industry.

With this background, attention has been paid since the early 1990's to the internationalization of a code for structural concrete. The International Committee on Concrete Model Code for Asia (ICCMC) was established in 1994. This article introduces the Asian Concrete Model Code (ACMC) which was issued by ICCMC, and briefly describes the collaboration between ICCMC and ISO to propose ACMC as a basis for ISO codes.

International Committee on Concrete Model Code

Before establishment of ICCMC, Japan Concrete (JCI) Institute set up a Research Committee on Concrete Model Code, to conduct a feasibility study of a concrete model code in Asia, with

the collaboration of many Asian countries, in 1992. The JCI committee found that there were three types of countries

- Countries without any domestic code
- Countries with a domestic code, which was a copy of the corresponding code from a developed country
- Countries with a domestic code, which was developed within the country

Many countries in Asia showed both the necessity and feasibility of creating a concrete model code in Asia, like the Eurocode in Europe and the ACI Code in North America. The following reasons were presented:

- Nationalism
- Technological readiness
- Inappropriateness for adoption of existing codes in Europe and North America, due to differences in climate, material types and quality, level of technology, level of economy, and social systems for construction labor.

Considering the situation in Asia, a model code should be capable of

- allowing countries to develop their own codes
- Accommodating diversity within Asia in terms of available materials, and differences in climate, technological level, economic level, and social systems

ICCMC's history is summarized below:

1992	Establishment of JCI Research Committee on Concrete Model Code
1994	Establishment of ICCMC
1998	First Draft of ACMC
1999	Second Draft of ACMC
2001	ACMC2001 (2001 Edition of ACMC)
2003	Vietnamese Version of ACMC2001
2006	ACMC2006 (2006 Edition of ACMC)
2006	Chinese Version of ACMC2006

As of May 2007, ICCMC has over 80 individual members, 6 representative members (representing concrete related institutions) and 10 corporate members from the following 14 countries **and/or** economies: Australia, Bangladesh, China, India, Indonesia, Iran, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, and Vietnam.

ICCMC has been organizing committee meetings regularly with local institutional hosts. In total twenty-two meetings have been held in 12 countries **and/or** economies.

Asian Concrete Model Code

The latest version of ACMC, ACMC 2006, contains three parts (Part 1: Design; Part 2: Materials and Construction; and Part 3: Maintenance), which cover all types of concrete structures (plain

concrete structures, reinforced concrete structures, prestressed concrete structures, and composite structures with concrete). Its two main features are:

- Performance-based concept
- Multi-level document structure

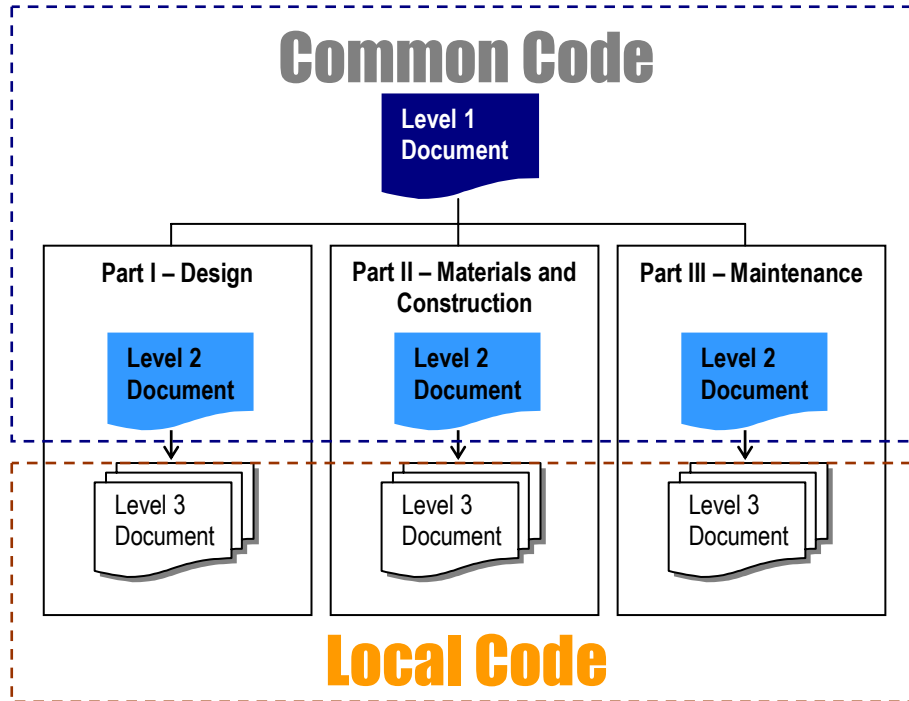


Figure 1. Multi-level document structure of ACMC.

The performance-based concept only specifies performance requirements, while a verification method for the requirement is not mandatory, meaning that any method can be used once it is proved appropriate. The multi-level structure (see Figure 1) allows the development of documents common to all countries and all structures (common code), and those specific to a particular country or a particular structure (local/specific code). Levels 1 and 2 documents are the common code, while a Level 3 document is a local/specific code. Both the performance-based concept and the multi-level document structure are suitable for the model code to deal with the great diversity in Asia.

ICCMC has been issuing Level 3 documents since 2001. There are two types of Level 3 documents: the national code type and the technical report type. Some representative Level 3 documents are given below:

- “An example of design for seismic actions – performance examination of RC building designed according to the Architectural Institute of Japan (AIJ) Guidelines”, 2001. (*Technical Report*)

- “Vietnam Construction Standard TCXDVN 318: 2004 - Concrete and Reinforced Concrete Structures - Guide to Maintenance”, 2004. (*National Code*)
- “Guidelines for Maintenance and Rehabilitation of Concrete Structures against Chloride Induced Deterioration”, 2004. (*Technical Report*)
- “The Standard Specification for Materials and Construction of Concrete Structures in Japan”, 2005. (*National Code Type*)

The third part of the 2006 ACMC code facilitates creation of a working national code written in compliance with ACMC2001.

Collaboration between ICCMC and ISO

ISO/TC 71 (Concrete, Reinforced Concrete and Prestressed Concrete) is a technical committee established to deal with all kinds of ISO documents related to concrete. There are six subcommittees under TC 71 (see Figure 2).

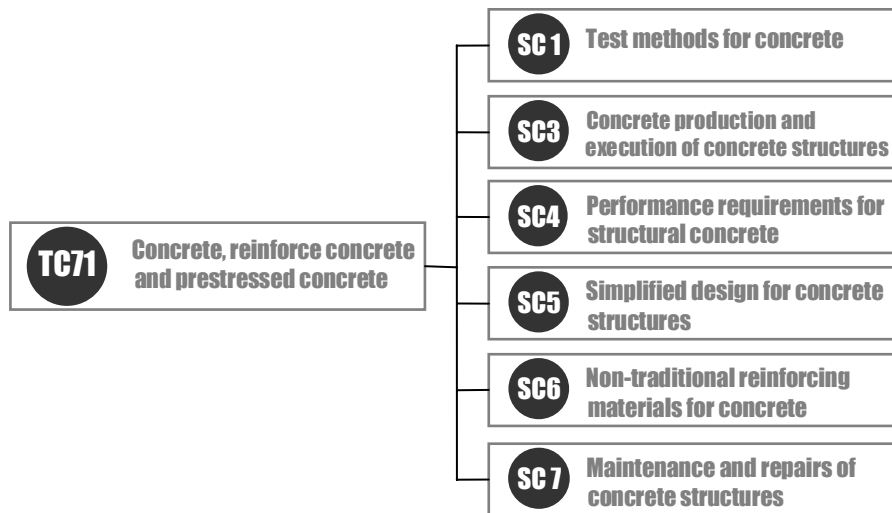


Figure 2 ISO/TC 71 and Subcommittees

In SC 4 there is an Ad-Hoc Working Group on a performance-based code, which was initiated by members from ICCMC, to study how to implement the performance-based concept and a regional code like ACMC, into the ISO system of codes. SC 7, proposed by the members from ICCMC, is currently chaired by Prof Ha-wong Song of Korea with the writer as Secretary. SC 7 is now drafting an umbrella code for maintenance based on ACMC.

The ICCMC network has successfully established an Asian team, working effectively to disseminate technology within Asia and to enhance the influence from Asia on ISO activities.

Note: This article is derived from a lecture given at the ACECC Workshop on "Harmonization of Design Codes in the Asian Region", Taipei, Nov. 4, 2006.

Advanced analytical technologies - EPMA for the evaluation of material transport & XRD/Rietveld method for the hydration analysis



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Design codes of concrete structures are now moving towards a performance-based type all over the world. Relating to this trend, advanced models estimating the durability of concrete have been intensively studied. The progress of these models is supported by advanced analytical technology. In this report, two methods are introduced. One is the electron probe microanalysis (EPMA) and the other is the X-ray diffraction (XRD)/Rietveld analysis.

EPMA (Fig. 1) gives precise information about the two dimensional distribution of elements. Recently, a draft standard on this method has been established by the Japan Society of Civil Engineers (JSCE). A working group in the concrete committee of JSCE (Chair: Prof. Koji Takewaka, Kagoshima Univ.; Secretary: Dr. Kazuo Yamada, Taiheiyo Cement Corp.) has been charged to carry out this activity. An English version of this standard "Area analysis method of elements distribution in concrete using EPMA" is now under preparation.

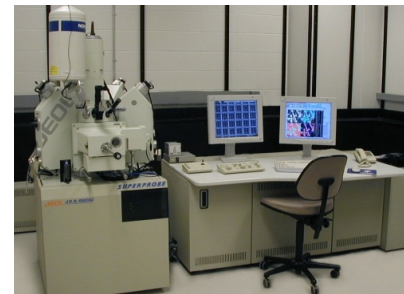


Fig. 1 Recent EPMA.

Characteristic points:

- Quantitative area analysis.
- High sensitivity and spatial resolution.
- Numerical processing.
 - >> Separation of paste part.
 - >> Calc. of Cl diff. coeff.
 - >> Phase analysis.

The first application of EPMA to area analysis was carried out by Prof. Emeritus Kazusuke Kobayashi of Univ. of Tokyo et al. (1988) showing the movement of chloride and alkalis in concrete by carbonation. After this application, the methodology for quantification of area analysis of concrete has been studied. Mori et al. (2006) reported the scientific background for quantification. This study received the JCI award 2007. A visual image of Cl concentration can be transformed in a quantitative concentration profile (Fig. 2).

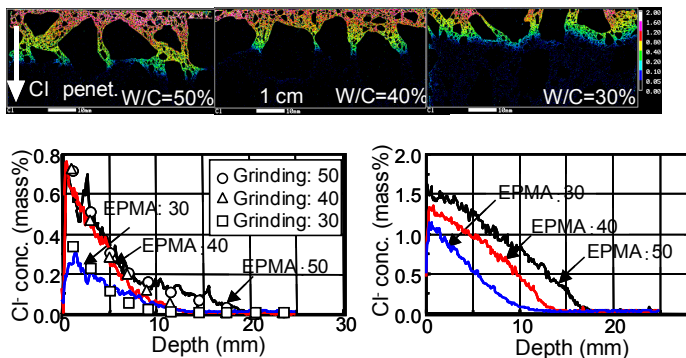


Fig. 2 Map images of Cl penetration (upper).

Quantified data application for Cl concentration profile (lower left, good match with chemical analysis), and for paste (lower right)

Every durability issue relates to cement hydrates. Therefore, the quantification of cement hydration is important. Hoshino et al. (2006) reported on the effectiveness of applying the XRD/Rietveld method for hydration analysis of cement systems, including blast furnace slag. The Rietveld method gives quantitative information by pattern fitting of measured and theoretical profiles (Fig. 3). In hydrated slag cement, there are two amorphous phases. The Rietveld method quantifies it as a single phase. Unhydrated slag was quantified by a selective dissolution method and C-S-H is assumed to remain. The Rietveld method shows the progress of hydration clearly. Moreover, the estimated porosity in cement paste showed a good correlation with strength and this suggests the effectiveness and accuracy of this method.

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- (3) Mori, D., Yamada, K., Hosokawa, Y. and Yamamoto, M. (2006), "Applications of electron probe micro analyzer for measurement of Cl concentration profile in concrete", Journal of Advanced Concrete Technology, 4, 3, 369-383.
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- (5) Hoshino, S., Yamada, K., Hirao H. (2006), "XRD/Rietveld analysis of the hydration and strength development of slag and limestone blended cement", Journal of Advanced Concrete Technology, 4, 3, 1-11.

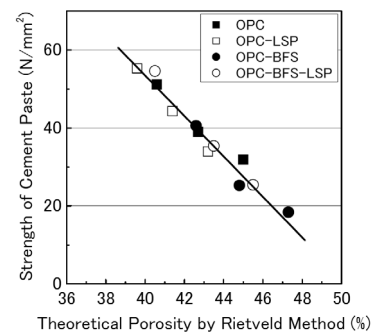
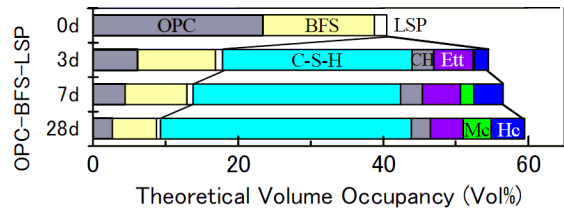
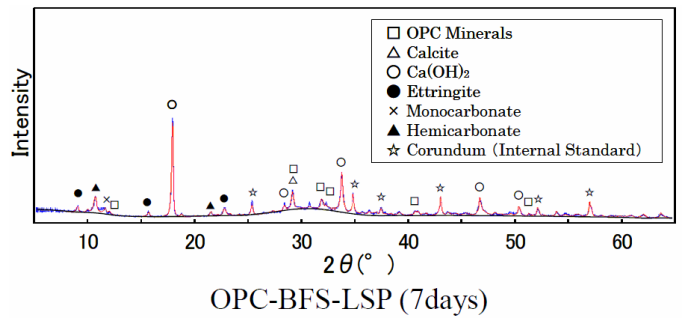


Fig. 3 Example of XRD/ Rietveld analysis.

Upper: pattern fitting, middle: phase composition of hydrated slag cement, lower: Estimated porosity based on the results by Rietveld method and compressive strength.



Taiheiyo Cement Corporation has been supporting the activities of ICCMC as a corporate member since 2001. For more information about the company visit <http://www.taiheiyo-cement.co.jp/english/index.html>

Long-life concrete “EIEN”



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As a result of pushing the life extension of concrete to the utmost limit, the long-life concrete “EIEN” has been developed. EIEN was named after “Earth, Infinity, ENvironment.” In keeping with this name, EIEN is an earth-friendly and environment-friendly long-lived concrete. EIEN can be said to have been born from a combination of ideas contrary to what was previously believed, because this concrete was born from the “material” and “curing method” that cannot be applied from common sense on conventional concrete. This article introduces EIEN.

Outline of “EIEN”

Before starting development of long-life concrete, the author searched for hints by surveying the relics of ancient Rome, Egypt, and China. It became clear that the common factor shared by all of these ancient concretes, from diverse areas of the world, which remained in place for extremely long periods of time, was advanced carbonation. Carbonation had been considered an undesirable phenomenon in the past, since it neutralizes concrete of alkalinity and induces the corrosion of reinforcing steel. However, the author found that by adopting a technique to actively carbonize concrete through blending it with a specific additive (γ -2CaO·SiO₂), it was possible to greatly increase the density of the concrete and suppress penetration of carbon dioxide and chloride ions. This technique could also remarkably

reduce the leaching of calcium ions as described below, resulting in remarkable life extension. The physical properties of EIEN in comparison with common concrete are shown in Table 1.

EIEN has high mechanical strength and high bending toughness, and it also displays a small rate of change in length and a small diffusion coefficient. Its striking feature is solubility, which is less than that of common concrete by a factor of four digits. EIEN has received carbonation curing, which forces modification of the CaO component to sparingly-soluble calcium carbonate, thus its solubility level is remarkably low. The leaching phenomenon of Ca ions becomes a fatal defect, when long-term durability of concrete is considered. In addition, this phenomenon causes change to the environment surrounding the concrete, to high alkalinity levels, which may affect vegetation, aquifers, and other aspects of the ecosystem. EIEN, whose CaO component has been converted to neutral calcium carbonate, does not generate such problems. In addition, EIEN confines CO₂, a greenhouse effect gas, within the concrete when carbonation curing is applied. This is the reason why EIEN is earth-friendly and environment-friendly.

Application Cases and Usage of EIEN

Because of its high salt interception performance and leaching resistance, EIEN has been applied for the repair of piers, which are under severe conditions of a salt-laden environment. The cases of buried form and pier repair using EIEN are shown in Photo 1. In addition, to make use of the features of low pH and leaching resistance, applications to build vegetation concrete, water utilization facilities, and water supply facilities, are planned. Great expectation is also given to EIEN in the construction field of radioactive waste treatment plants which demand very long and durable life.

Table 1 Physical properties of EIEN

	Compressive strength	Tensile strength	Bending strength	Bending -toughness	Length change	Cl diffusion coefficient	Solubility / Ksp
Unit			N/mm ²		10 ⁻⁶	cm ² /y	(mol/L) ³
EIEN	130	8.0	11.5	9.0	83	0.012	10 ^{-8.27}
Concrete	57	4.4	6.4	0.1	694	0.782	10 ^{-4.97}



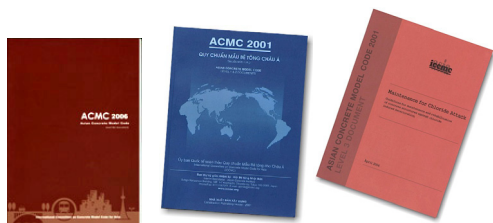
Photo 1 Application of EIEN.
 (L-R) Buried form of EIEN, repair of pier soffits using buried form, protective layer upper surface of pier

EIEN is an innovative concrete that has been born by combining two well-known ideas previously considered wholly negative, viz the utilization of carbonation reaction, which had been considered to be a “poison” for concrete, and γ -2CaO·SiO₂, which had been abhorred as a “nuisance”, to create a new product that not only resists degradation over time but can be called ‘environmentally friendly’. As a final comment, EIEN has been developed by the cooperation amongst three firms, the Kajima Corporation, Ishikawajima Construction Materials Co., Ltd., and Denki Kagaku Kogyo Kabushiki Kaisha.



Denki Kagaku Kogyo Kabushiki Kaisha has been a corporate member of ICCMC since 2001. For more information about the Denka Group of which Denki Kagaku Kogyo Kabushiki Kaisha forms, visit <http://www.denka.co.jp/eng/top.htm>

ICCMC publications



2001 ACMC 2001

An example of design for seismic actions – performance examination of RC building designed according to the Architectural Institute of Japan (AIJ) Guidelines

ACMC 2001, Vietnamese version

2004 Vietnam Construction Standard TCXDVN 318: 2004 - Concrete and Reinforced Concrete Structures - Guide to Maintenance

Guidelines for Maintenance and Rehabilitation of Concrete Structures against Chloride Induced Deterioration

2005 The Standard Specification for Materials and Construction of Concrete Structures in Japan

2006 ACMC 2006

2007 Design for Fire Actions – Guidelines for the Design of Reinforced Concrete Buildings against Fire Actions

Next ICCMC meeting

Next meeting will be held in conjunction the 3rd ACF International Conference, 11-12 November 2008, Ho Chi Minh City, Vietnam.

Joining ICCMC

ICCMC membership is open to anyone interested in concretes. Visit our website to apply on-line or write to Mrs Naoko Masaki (admin@iccmc.org) for more information.

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