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This issue of ACF E-Newsletter contains the materials presented at ACF and ICCMC Special Session held at 2009 IABSE Conference in Bangkok, Thailand.
The title of the session was Concrete Technology in Asia. The session was co-hosted by ACF and ICCMC to promote the growing concrete technologies in Asia region.

Concrete Technology in Asia

Special Session for Asian Concrete Federation(ACF) and International Committee on Concrete Model Code for Asia(ICCMC)

Conjoiningly held with Public Session for 80th 2009 IABSE Anniversary.

Friday, September 11, 2009
Centara Grand at Central World
Bangkok Convention Center

Session Content

Role of Asian Concrete Federation

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Abstract

In the modern society, the border of each country is disappearing by the blocking of region, economy, and culture. Each regional block has their own characteristics which allow the countries to incorporate with each other. Asian Concrete Federation (ACF) was established for integration of concrete technology among the Asian countries and is executing work for unification of design concept. This paper introduces the background of establishment of ACF as comparing economic and concrete engineering block.

Keywords: Asian Concrete Federation, ACF, Engineering Block, Economic Block, EC, EU, ASEAN, APEC, NAFTA, Design Concept, Concrete Structure, LSD, USD, PBD, ICCMC

Introduction

Asian Concrete Federation (ACF) is a gathering organization for promotion of understanding of concrete technologies and structures among Asian countries and neighboring region. The ACF regularly organizes the ACF International Conference for exchange of useful information on new research results and practice in the field of concrete technologies and structures.

Economic Block

EU

In July 1967, France and Germany had established a European Economic block called the European Community (EC) in order to face the American economy. The founding member nations were of only six nations; France, Germany, Italy, Belgium, Luxembourg, and the Netherlands.

Fig. 1: Member nations of EU

But in 1973, the United Kingdom, Ireland, and Denmark joined the community, followed by Greece, Spain, Portugal, Austria, Sweden and Finland of Northern Europe in the 1980s. The EC is now joined by 15 countries. The population of the EC region is around 350 million. In 1994, the community changed its official name to the European Union (EU). The founding of EC is based on the term "Regionalism" in economics. Regionalism sets up a certain area as one whole market, and liberalizes intra-trade, and at the same time, differentiates external trade. The primary purpose of the EC was to gain profit from operating a big market by forming a huge common market through making a single block of intra-trade with unified economical system. But most recently, with its primary purpose in its background, EC aims at actualizing political union and finally accomplishing the European alliance. Carrying out this plan, Europe entered into contract in various customs unions, and an economic policy was enforced to give more freedom in the movement of capital and labor among member countries. The EC finally actualized the Economic and Monetary Union (EMU) by agreeing on a single monetary system called the "Euro".

ASEAN and APEC

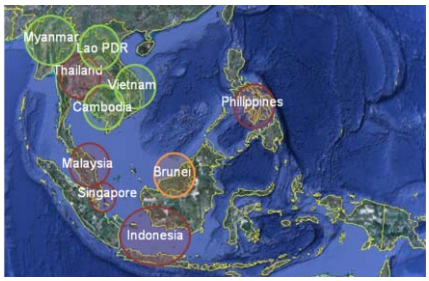

Fig. 2: Member nations of ASEAN

In August 8, 1967, in the same year of the founding of EC, the 5 Southeast Asian countries, Thailand, Indonesia, Malaysia, Philippine, and Singapore, gathered in Bangkok to form an economic block called the Association of Southeast Asian Nations (ASEAN). Brunei joined the group in 1984, Vietnam, Laos, Myanmar, and Cambodia in the 1990s, and now ASEAN is joined by 10 countries.

The population of the ASEAN region is around 500 million, and it includes an area of approximately 4.5 million square kilo meters. The purpose of ASEAN is to promote economic growth of the region, advancement of the community, and activation of cultural exchange by cooperating with the spirit of equality and partnership, and strengthen the foundation for the peace and prosperity among Southeast Asian countries.

Fig. 3: Member nations of APEC

Being aware of the foundation of the ASEAN, East Asian countries such as South Korea, Japan, and China extended the participation range, and established the Asia-Pacific Economic Cooperation (APEC) in 1989. Coming into the 1990s, Russia, USA, Canada, Mexico, Peru, and Chile joined the cooperation. This adds up to 21 countries taking part in the APEC. The population of the APEC region exceeds 2 billion, and occupies about 60% of the world's total GDP, making it the largest regional economic cooperation.

NAFTA

Fig. 4: Member nations of NAFTA

In 1994, the North American countries, USA, Canada, and Mexico agreed on the North American Free Trade Agreement (NAFTA) to promote an extensive range of free trade among the three counties. At the time of establishment, NAFTA was confident that it was the largest regional economic block with the population of around 370 million, and the GDP occupying 30% of the world's total GDP. The NAFTA was found with the purpose of accelerating each country's economical growth by forming a single trade market in the North American region with combining the capital strength and technology of USA, abundant resources of Canada, and cheap labor of Mexico. It can be seen that the establishment of NAFTA was a counter plan to deal with the movements of the European continent's EC and the Asiatic continent's ASEAN and APEC.

Concrete Engineering Block

Production Statistics of Cement

As mentioned before, the global economy is being divided into blocks of continents based on "Regionalism". Especially, it is necessary to keep close attention to the recent activities of the economic block centering in the Asiatic continent. According to the production statistics of cement, which stands as the symbol for construction work, the total world output reaches up to 2.3 billion tons based on the 2005 data. If we classify this data to each continent, the Asiatic continent produced 1.56 billion tons, and this number occupied 68% of total world output. 390 million tons were produced in the European continent, and 240 million tons from the American continent. The growth of production rate in the Asiatic continent arises from the rapid increase of output from East Asia, which includes China, and from Southwest Asia, where India is located. According to the Top 10 Cement Producing Countries in 2005, China ranked 1st with 1 billion tons, India ranked 2nd with 140 million tons, and USA ranked 3rd with 100 million tons of production, respectively. The ranks are followed in the order of Japan, Spain, Russia, South Korea, Italy, Turkey, and Brazil.

Table 1: The statistics of top 10 cement producing countries

Rank	Nation	Output (1000 ton)	Rank	Nation	Output (1000 ton)
1	China	1,038,300	6	Russia	48,739
2	India	136,672	7	Korea	47,195
3	USA	100,000	8	Italy	46,411
4	Japan	68,652	9	Turkey	45,572
5	Spain	50,347	10	Brazil	36,673

Table 2: An annual output of cement by continent (Unit: 1 million ton)

	'97	'98	'99	'00	'01	'02	'03	'04	'05
Asia	961	941	994	1,018	1,101	1,186	1,307	1,444	1,564
Europe	302	313	314	327	326	336	353	374	391
America	210	215	218	218	217	216	220	228	240
Africa	64	66	69	75	76	80	83	90	96
Oceania	9	9	9	9	8	9	9	10	11
Total	1,546	1,544	1,604	1,647	1,728	1,827	1,972	2,146	2,302

The Design Concepts for Concrete Structure

The movement of the formation of blocks based on regionalism in the economic field is very similar to the movement in the engineering field. There are three different concepts of structural design in the Concrete Engineering field. The foundation of these three concepts coincides with the foundation of the world economic block. There are the Ultimate Strength Design Method (USD) of NAFTA in the American continent, the Limit State Design (LSD) of EU in the European continent, and the Performance Based Design (PBD) in the Far East and Southeast Asian countries. The PBD produced with ICCMC, is called the "Concrete Model Code of Asia". The international organization to promote this concept is "Asian Concrete Federation (ACF)". The ACF is currently participated by 11 countries including South Korea, Japan, Taiwan, Thailand, Vietnam, Malaysia, Indonesia, Philippine, India, Singapore and Australia, and there are countries such as USA, Russia, Mongolia, and even Egypt, expressing their willingness to participate in the federation.

Role of ACF

The social, cultural, environmental and technological background of Asian countries, though diverse, is different from that of western counterparts. Therefore, it is thought expedient to formulate a gathering organization for discussion and information sharing of research, design, construction and maintenance of concrete structures commensurate with the needs, practices and aspirations of Asian countries. The objectives of ACF shall be to promote understanding of concrete structures and services to the society through concrete structures in countries in the Asia and neighbouring region through. Detailed contents are as following.

- Initiation and support of international collaborative activities for development of research and technology relating to various aspects of concrete and concrete structures.

- Dissemination of useful information on concrete and concrete structures by way of publications, conferences, symposia, workshops and/or seminars.

- Promotion of updating and revising concrete codes/standards on structural design, materials, construction and maintenance through development of new knowledge to meet the latest needs.

- Interaction with the members and keeping them aware of the activities of the Federation.

Main Work

The scope of activities of the Federation shall encompass all aspects of structural concrete engineering including design, construction, materials, monitoring and inspection, testing, preservation, production of concrete elements, exchange transfer of concrete technology, rehabilitation, and demolition of concrete structures taking into consideration the technological, social, economical, environmental, aesthetic and cultural aspects of countries in the Asian and neighboring region. The main work of ACF is explained to below.

- Promotion of international standardization relating to test methods, properties of material, and guidelines for design, construction and maintenance

- Hold international conferences

- Information dissemination through the Internet (e-newsletter and homepage)

- International collaboration on advanced technology and/or hot topics Offer an international engineering license

- Publication of an international journal.

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Contribution of ICCMC and ACMC to Sustainable Development in Asia

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Abstract
This paper summarizes the activities of the International Committee on Concrete Model Code for Asia (ICCMC) which is an international organization set up initially for drafting a common concrete code for Asia. Since its establishment in 1994 until now, ICCMC has published a number of useful documents, generally referred to as the Asian Concrete Model Code (ACMC). At the moment, four working groups are responsible for publishing the ACMC documents which are separated into 3 areas i.e. 1) design, 2) materials and construction and 3) maintenance. ICCMC classifies the documents into 3 levels i.e. level 1, level 2 and level 3. Some documents have been adopted as references or templates for drafting national codes and standards. ICCMC is now attempting to publish more documents which are not only in the categories of codes and standards but also technical reports and references in various specific topics based on research and studied results of countries in Asia. It is expected that these documents will become useful and be appropriate to countries in Asia. In addition to the documenting activity, ICCMC also provides opportunity for members to have information exchange and member interaction as well as provides support on research and study in conjunction with the Asian Concrete Federation (ACF). It is expected that closely working between or integration of ICCMC and ACF will be an essential step for both organizations to be able to offer more contribution to the sustainable development in Asia.
Keywords: ICCMC, ACMC, model code, Asian concrete model code, design, materials and construction, maintenance

Introduction
With the rapid development of the countries in Asian region during 1980's to 90's, experts in the field of concrete sensed the necessity of having close cooperation among each other and the result turned up in the form of the establishment of the International Committee on Concrete Model Code for Asia (ICCMC) in 1994 [1]. Since that time, ICCMC has been positioning itself in conducting academic activities especially on developing model code for concrete practices (Asian Concrete Model Code, ACMC). Four working groups (WG's) i.e. WG1 on Design, WG2 on Construction and Materials, WG3 on Maintenance and WG4 for document editorial work had been established for this purpose. Though this international code drafting organization is still in its teenage period, it has already published a number of useful documents which have already been used as references or even adopted by some countries to draft their national codes or standards. The activities of ICCMC are not only limited to the code drafting issue but also others like arranging workshop and seminar sessions in various international conferences and providing research grants related to the code making and drafting activities with the support from the Asian Concrete Federation (ACF) and issuing newsletters to distribute information to members. In fact, ACF and ICCMC are currently kinds of closely related organizations in such a way that ICCMC acts as the academic body for ACF whereas ACF support ICCMC in term of funding projects related to code establishment. Not only concentrating its activities in Asia, ICCMC also conducts some cross-regional activities such as setting up a task force to link with the ISO/TC71 in order to have the ISO/TC71 recognize the ACMC. ICCMC has been increasingly receiving recognition from countries and regions in Asia and then this paper is aimed to liberate the past, present and potential future contributions of the ICCMC and the ACMC to the sustainable development in the field of concrete construction in Asia.

Situation of ACMC in Asia
It is obviously known that recently more than half of the world construction activities are concentrated in Asia which is a big region with complicated varieties. In regard of concrete construction, there are varieties in terms of climate, local materials, standards and ways of practice, level of technology and culture. Many countries in Asia have been directly or indirectly adopting foreign codes and standards for their practices. Some adopt single code but some apply many foreign codes. Such large complicacies and varieties caused difficulties in unification of the code and standard of practice. ICCMC recognized this situation and finally came up with the solution to make a model code which can be adopted by each country as the framework in which local conditions no matter in terms of climate, materials, ways of practice or level of technologies can be integrated into the country code. The ACMC code was, therefore, separated into 3 levels of document as follows

Level 1: Frame work of the code
Level 2: Frame work with description and commentaries
Level 3: National codes, national standard

In addition to national codes and standards, ICCMC also approved technical reports or references on some specific topics as one of the types of the Level 3 document.
For the ACMC Level 1 and Level 2 documents, the first draft appeared in 1998 with the revised 2nd draft published in the following year (1999). After that the model code had been improved twice in 2001 and the latest version in 2006 (see Fig.5 for the 2006 version [2]).

ACMC Level 3 documents can be classified into 2 categories which are national codes/standards and technical reports or technical references. National codes/standards which are classified as the Level 3 documents are those drafted based on the ACMC Level 2 documents with incorporated local conditions and information which are compatible to the situations of that country or region. Examples are such as the "Vietnam National Standard TCXDVN 318: 2004- "Concrete and Concrete Reinforced Structures - Guide to Maintenance" which is the first national ICCMC level 3 document drafted by the cooperation among committee members of ICCMC together with the Vietnamese local committee [3]. This standard had been approved for being applied in Vietnam by the Vietnamese Ministry of Construction in July 2004. Another kind of similar Level 3 documents is the translated or summarized version of national codes or standards made conforming to the ACMC structure. These are such as the "Guidelines for materials and construction based on Japanese Standard Specifications" [4], "Design for Seismic Action - An example of seismic performance examination for RC building designed according to the Architectural Institute of Japan (AIJ) Guidelines" [5], "Maintenance for Chloride Attack - Guidelines for maintenance and rehabilitation of concrete structures against chloride induced deterioration" [6], the "Thai Standard Specification for Materials and Construction of Concrete Structures (being prepared by Thailand Concrete Association) [7], "Thailand Maintenance Code and Standard" (being prepared by Thailand Concrete Association) and the Philippine National Code on Materials and Construction (being prepared).

In the near future, in addition to the national codes and standards, various documents in the form of technical reports or technical references will be published as the Level 3 documents of the ACMC. Examples are such as technical references on High Strength Concrete, Self-Compacting Concrete, Mass Concrete and Recycled Aggregates, etc.

Fig. 5: 2006 version of ACMC (Level 1 and Level 2 Documents)

Fig. 6: Vietnam National Standard TCXDVN 318: 2004- "Concrete and Concrete Reinforced Structures - Guide to Maintenance

Fig. 7: Design for Seismic Action - An example of seismic performance examination for RC building designed according to the Architectural Institute of Japan (AIJ) Guidelines

Fig. 8: Guidelines for maintenance and rehabilitation of concrete structures against chloride induced deterioration

Contribution of ICCMC and ACMC to Development in Asia

The main contribution of ICCMC to the development in the field of concrete in Asia may be categorized into the following topics.

Code and standard establishment
Information exchange and member interaction
Research project funding and conducting

The code and standard making activity had been described with the details given in section 2. The code establishment activity is now considered the main activity of ICCMC. It is quite obvious that the ACMC has started to be recognized little by little within the region. This can be seen by the adoption of level 2 documents to draft national codes/standards in some countries [3, 7]. One of the major advantages of the ACMC lines in its easiness to allow local conditions to be incorporated. The ICCMC hopes that more countries in the region will show their interests to adopt the concept of ACMC for their country codes and standards in the near future.

In regard of the information exchange and member interaction, ICCMC has published 1 to 2 issues/year of newsletters since the year 2000. The newsletters are distributed to all ICCMC members. Conferences, workshops and committee meetings are also regularly organized, usually in line with international conferences in Asian region to allow information exchange and also interaction of members and non-members who are academicians and professionals in the field of concrete.

Though not so financially healthy, ICCMC recently started to sponsor research projects with the support from the Asian Concrete Federation. It is realized that an ideal model code which can incorporate local conditions requires sufficient amount of information obtained from various countries and regions. As the commencing stage, due to the reasons of budget limitation and adoption facilitation, all granted projects are targeted for the development of ACMC Level 3 documents (related to the establishment of national codes or technical

references). Some information on the granted projects can be found in the website of ICCMC (www.iccmc.org).

ICCMC also recognizes the importance of international collaboration with other regions. One of the steps was the setup of a task force, IS-TF, to cooperate with the ISO committee(s). The ICCMC's ISO-TF has been encouraging ISO/TC71 to recognize the present situation and significance of Asian countries in the field of concrete technology. Main activities of ISO-TF involve; 1) leading ISO/TC71/SC7 to implement ACMC Part3 into a main part of ISO code on maintenance and repair of concrete structure, and 2) encouraging ISO/TC71/SC4 to include the contents of ACMC Level 1 and Level 2 into the umbrella code under SC4.

The full committee of ICCMC has regularly gathered and met since its establishment especially during major international conferences in Asia. This IABSE 2009 Bangkok Colloquium is another opportunity for the full committee of ICCMC to gather to conclude the progress of activities done since the previous meeting and to plan for future ones. All interested academicians and professionals in the field of concrete are welcomed to join the meeting which will be held on 12 September 2009 (please contact the colloquium organizer of any ICCMC committee members for more information).

Conclusions

Brief history and activities up to now of ICCMC are summarized in this paper. At present, the major activities of ICCMC are categorized into 3 areas which are code and standard establishment, information exchange and member interaction and research projects funding and conducting. One of the most dominant tasks of ICMC is the establishment of the Asian Concrete Model Code (ACMC). The ACMC documents are separated into 3 areas which are 1) design, 2) materials and construction and 3) maintenance. ICCMC classifies the documents into 3 levels i.e. level 1, level 2 and level 3. Some documents have been adopted as references or templates for drafting national codes and standards. ICCMC is now attempting to publish more documents which are not only in the categories of codes and standards but also technical reports and references in various specific topics based on research and studied results of countries in Asia. It is expected that these documents will become useful and be appropriate to countries in Asia. In addition to the documenting activity, ICCMC also provides opportunity for members to have information exchange and member interaction as well as provides support on research and study in conjunction with the Asian Concrete Federation (ACF). It is believed that closely working between or integration of ICCMC and ACF will be an essential step for both organizations to be able to provide more contribution to the sustainable development in Asia.

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ACMC–Performance Based Code for Design,Construction and Maintenance

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Abstract
Asian Concrete Model Code (ACMC) is the first international code in the region as a performance based code, whose first version appeared in 2001. ACMC consists of design, construction and maintenance parts, which deal with concrete structures from birth to death. The required performance, whose verification method is provided, is safety, serviceability and reparability. ACMC introduces the multi-level document structure. Level 1 and Level 2 documents are the common code, while Level 3 document is the local/specific code. Since its birth ACMC has been serving to not only to Asia but also the whole world through ISO activities. It is believed that ACMC would be a good model for sustainable international model code because of its performance based nature and multi-level document structure.
Keywords: Performance-based code, international model code, multi-level document structure

Introduction
Asia is a fast growing region in the world. In Asia the size of construction market is much greater than one third of the whole world market and the consumption of cement is far more than a half of the world consumption. After constructing abundant structures in Asia, we are responsible to maintain them for a long period for the sustainable world. In order to construct new structures and maintain them with good quality and reasonable cost the role of structural code is vital. Since structures themselves are supposed to be of long life, structural codes should be sustainable. International Committee on Concrete Model Code for Asia (ICCMC) established in 1994 is a sole international body for concrete structures in Asia with the aim of developing and maintaining Asian Concrete Model Code (ACMC), which is a good example of a sustainable code.

Sustainable code and Asian Concrete Model Code
A sustainable code is universal and user-friendly. There are two keywords to make codes sustainable. They are “performance-based concept” and “multi-level document structure”.

The performance based code is the latest type and most suitable for any code, especially for international code. The concept of performance base is also accepted by ISO. The performance based concept is to specify the required performance but the method to achieve the required performance. With this concept any national and regional code can apply its suitable method for design, construction and maintenance of a structure, if it is proved that the structure satisfies the required performance, which can be universally adapted. Especially this concept is necessary for the part of the world, such as Asia, in which the big diversity of economical and technological level, climatic and social condition and available material and facility exists.

The performance-based design is with more general methodology than the rest of the design methodologies (Allowable Stress Design, Ultimate Strength Design and Limit State Design). PBD clearly describes the required performance often in wording easily understood by ordinary people. Presently the following required performance is considered in various codes with PBD:
Safety*
Serviceability*
Maintainability and Repairability (or Restorability)*
*: Durability
Constructability
Sustainability (or Environmentability)
Economy

The way to make a structural code sustainable is to have a common code and local (or specific) code as a set (see an example in Fig. 9).

The common code provides the basis of design, construction and maintenance, including the required performance, which should be applied to any local (or specific) code. The local code is a code of practice to provide all necessary technical guidance which can be different among different local codes to fit for any local condition.

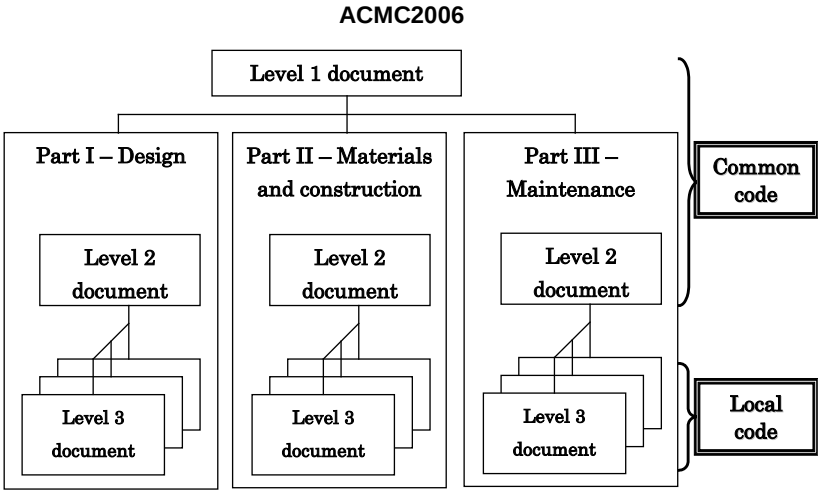

Fig. 9: Multi-level Document Structure of Asian Concrete Model Code

As shown in Fig. 9. ACMC 2006 consists of Level 1 and Level 2 Documents, both of which are the common code, while Level 3 Documents are local (specific) codes. Level 2 Document consists of three parts; Part I – Design, Part II – Materials and Construction and Part III – Maintenance. ACMC covers all kinds of concrete structure from its birth to death. As the required performance, only safety, serviceability and reparability (restorability) are dealt with. ISO/TC71/SC7 (Maintenance and repair of concrete structures) are drafting an umbrella code for maintenance and repair of concrete structures with Part III of ACMC as its basis. One of Level 3 Documents is the Vietnam National Standard for maintenance of concrete structures.

Conclusions

In order to make structures sustainable, structural codes should cover not only design and construction but also maintenance and repair. A sustainable code is universal and user-friendly. The performance-based concept and multi-level document structure are the key issue for the sustainable code. Asian Concrete Model Code is the first attempt in this kind in the region and shows a good example of the sustainable code.

Research and Development of Roller-Compacted Concrete for Dam in Vietnam

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Overview of hydropower dam construction in Vietnam by Roller Compacted Concrete

The plan for electric-power development for Vietnam up to 2015 with extended forecast up to 2025 show that in order to satisfy the demand in electric energy the total capacity of all electricity generating equipments is set at 59,144 MW. Out of this capacity of 15,315 MW must come from hydro-power plants. The number of major hydro-power plants is 46 and 20 of them is to be constructed with concrete. It is planed to use Roller-Compacted Concrete to construct about 80% of concrete dams.

Table 3: Roller-Compacted Concrete dams in Vietnam

No.	***Project name***	***Max. height*** *(m)*	***RCC Volume*** *($10^3 m^3$)*	***Location***	***Notes***
1	*PleiKrong*	*71*	*290*	*Kon Tum Province*	*Construction completed*
2	*Se San 4*	*68.4*	*753*	*Gia Lai Province*	*Construction completed*
3	*A Vuong*	*82*	*267*	*Quang Nam Province*	*Construction completed*
4	*Dong Nai 3*	*108*	*1,140*	*DakNong - Lam Đong Province*	*Under construction*
5	*Dong Nai 4*	*128*	*1,288*	*DakNong - Lam Dong Province*	*Under construction*
6	*Ban ve*	*136*	*1,519*	*Nghe An Province*	*Under construction*
7	*Binh Dien*	*75*	*300*	*Thua thien Hue Province*	*Construction completed*
8	*Huong Dien*	*82.5*	*260*	*Thua thien Hue Province*	*Under construction*
9	*Song Tranh 2*	*97*	*1,025*	*Quang Nam Province*	*Under construction*
10	*Dak Mi 4*	*90*	*720*	*Quang Nam Province*	*Under construction*
11	*Dinh Binh*	*53*	*180*	*Binh Dinh Province*	*Construction completed*
12	*Son La*	*138*	*3,082*	*Son La Province*	*Under construction*
Total			***10,824***		

Since 2003, the Electricity Generating Authority of Vietnam (EVN) has invested in research and application of RCC for construction dams, as applied to Pleikrong dam in Kon Tum province with the volume of concrete 290 thousand cubic meters. With the consultancy of COLENCO (Switzerland), the final mix proportion consists of 290 kg of binder (80 kg of cement, 210 kg of Puzzolanic), coarse aggregate with Dmax 40mm. Since then, many dams were constructed by RCC, such as Dinh Binh dam, A Vuong dam, Se San 4 dam, etc… Especially, Son

La hydroelectric dam which is the biggest dam in Southeast Asia with the volume of concrete over 5 million cubic meters, 60% of that is RCC. Up to now, 12 RCC dams have being constructed in Vietnam with the volume of RCC about 11 million cubic meters (see table 3 and fig. 10). In addition, many RCC dams are going to be constructed.

Experiences of dam construction in Vietnam

1. Materials

The requirement of material for RCC is almost the same as for Conventional Concrete (CVC). However, some differences need to take into consideration.

a) Coarse aggregate

Some differences in properties of aggregate for RCC, CVC and mass concrete which need to consider are: gradation and maximum size of coarse aggregate (Dmax). In mass concrete, maximum size of coarse aggregate can reach up to 100-150 mm, whereas, for RCC, maximum size of coarse aggregate varies from 38 mm to 75 mm. According to recommendation of EM 1110-2-2006, maximum size of coarse aggregate for RCC should be smaller than 75 mm. In Vietnam practical experiences show that maximum size of coarse aggregate for RCC varies from 40 mm to 60 mm.

Gradation: coarse aggregate with continuous aggregate gradation should be used. In Vietnam, not only solid basalt but also hollow basalt can be used for RCC.

b) Fine aggregate:

When low cementitious material content is used in RCC, the required amount of material passing through the 0,075 mm sieve for RCC (7,2 – 15%) is greater than for conventional concrete (<10%). The larger percentage of fines is used to increase the paste content in the mixture to fill voids and contribute to workability.

c) Mineral admixtures

Mineral admixtures was used in order to increase fine content, to improve workability, to reduce cement content and to reduce heat of hydration. Mineral admixtures shall conform to the requirements of ASTM C 618-03. In Vietnam, there are plentiful sources of

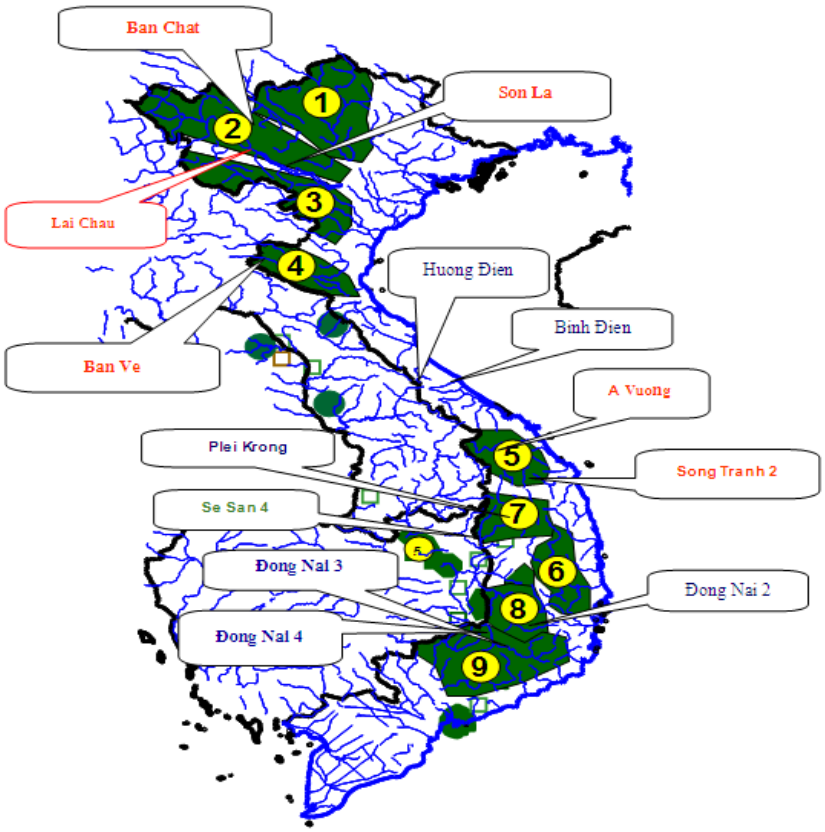

Fig. 10: Location of RCC dams in Vietnam

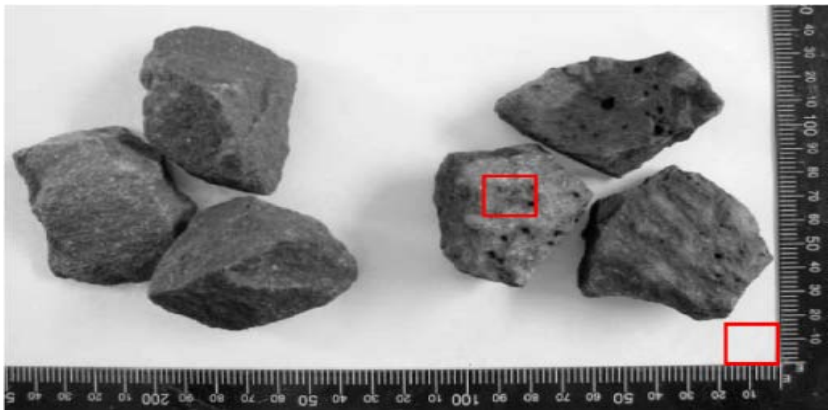

Fig. 11: Solid basalt and hollow basalt in stone mine C – Dong Nai 3

Fig. 12: Fly ash after unbured carbon separation in Pha Lai thermalpower plant

fly ash and nature puzzolan.
Production of fly ash in Vietnam is very big about 5 million ton per year. However, the L.O.I. of Vietnamese fly ash is very high (>15%), while the required L.O.I. according to ACI M618 is smaller than 6%.
In Vietnam there are several production lines in operation separating unburned carbon by floating method.

d) Chemical admixture
For RCC, chemical admixtures can be used to improve workability, to delay time of setting.

e) Cement
In Vietnam, Almost all cement types for RCC is Portland cement (PC)

2. Mixture proportion
The RCC mixture proportion depends largely upon the strength and durability requirements of the structure. However, RCC mixture proportion may also be greatly influenced by project-specific requirements such as material availability, hauling and conveying methods, spreading and compacting equipment, etc.
The RCC mixture proportion procedure is normally separated into two main steps: in laboratory and at construction site.
Some typical mix proportions of RCC in Vietnam was showed in table 2,

Table 4: Some typical mix proportion of RCC in Vietnam

No.	*Project name*	*D_{max} (mm)*	*Unite power content, kg*		*Type of mineral admixture*
			Cement	*Mineral admixture*	
1	*DakMi 4*	*50*	*95*	*125*	*Natural Puzzolan*
2	*Se San 4*	*50*	*80*	*160*	*Natural Puzzolan*
3	*PleiKrong*	*40*	*80*	*210*	*Natural Puzzolan*
4	*Dong Nai 3*	*50*	*75*	*160*	*Natural Puzzolan*
5	*Dong Nai 4*	*50*	*85*	*95*	*Natural Puzzolan*
6	*Song Tranh 2*	*63*	*70*	*110*	*Natural Puzzolan*
7	*A Vuong*	*60*	*90*	*150*	*Natural Puzzolan*
8	*Ban ve*	*50*	*80*	*120*	*Natural Puzzolan*
9	*Dinh Binh*	*60*	*105*	*140*	*Fly ash*
10	*Son La*	*50*	*60*	*160*	*Fly ash*

3. Construction Technology
- RCC Production plants: The RCC plant includes the mixers, the aggregate stockpiles, the materials feed system, and the discharge system. Practical experimence show that th conventional concrete production line can be applied for the production of RCC.

- RCC Transportation Systems: RCC is transported from plant to the placement area as quickly as possible by using the suitable method to reduce segregation, contamination and drying. Conveyor system was used to transport RCC from mixers to suitable location, then is transported to the tank with end gates to put RCC into the dump truck. At the end of belt conveyor, a partition and a duct were arranged to reduce segregation of RCC. Then, RCC is transported from the tank at left hand side of dam to placement area by dump truck with capacity of 8-10 m3 (see Fig.13).
- Spreading RCC
RCC is spread on un-compacted edge of RCC lane surface within 10 minute. For most applications, RCC lift thickness of 300 mm is suggested.

RCC spreading is carried out with bulldozer equiped with hydrolic lifting equipment. The bulldozer body should be U-shape in order to eliminate the RCC seregation.

Rubber – tyre bulldozer should not be use for RCC spreading and the travelling of such equipment on RCC surfaced is prohibited.

Those bulldozer using for RCC spreading should not cause any contamination of RCC with leaked oil and dust.The spreading of RCC is carried in such maner so that the RCC separation can be minimized. Separated aggregate must be treated with suitable mixture carrection or disposed (see fig. 14).

Fig. 13: Belt conveyor and transportation system vehicles


Fig. 14: Spreading and compaction of RCC

- Compaction RCC

RCC is compacted with a vibrating steel-wheel roller. It has been determined from various test sections and actual construction projects that RCC can be adequately compacted using a variety of vibratory roller.

Compaction should be accomplished as soon as possible after the RCC is spread. Typically, it is specified that compaction is to be completed within the time of the initial setting of RCC which is determined by experiment.

Wet density of RCC after compacting in different location is showed in construction drawing. Compaction must be ensured the wet density after compacting not less than 98 percent of design value.

Wet density of RCC was determined by nuclear equipment. Over 6 hour after compacting, heavy duty construction equipment should not be allowed to travel on the surface of dam.

Fig. 15: Curing RCC

- Curing RCC

Immediately after final rolling and compaction testing, the surface of the RCC surface shall be kept continuously moist for 28 days or until the other lift is spread. Water cure shall be applied by fog spray nozzles, soaking hoses, sprinkler system or other means that will ensure a uniform moist condition to the RCC. Application of this moisture must be done in a manner that will not wash out or damage the finished surface of RCC (see Fig. 15)

4. Joints

Joint is the contact surface between an adjacent RCC lift and the previous RCC lift. It is necessary to minimize the appearance of vertical joint.

- Hot joints: A joint is to be considered a hot joint when an adjacent RCC lift is placed before the initial setting of the previous RCC lift. Hot joints do not require any special treatment.

- Warm joints: A joint is to be considered a warm joint when an adjacent RCC lift is placed before the final setting of the previous lift. In this case, the surfaces of the previous RCC lifts need to be cleaned and bedded with a layer of mortar with the thickness of 10-15 mm.

- Cold joints: A joint is to be considered a cold joint when an adjacent RCC lift is placed when the previous RCC lift is hardened. In this case, the surfaces of the previous RCC lifts need to be roughened by high pressure water jet (40 MPa) and steel brush. After that, the surface was covered by bedding mortar with the thickness of 10-15 mm before placing a new RCC lift.

Table 5: The criteria, standard and frequency of test for RCC in the construction process

Materials	*Experimental*	*Standard of testing*	*Confining standard*	*Frequency of test*
Cement	*Chemical, mechanical properties*	*14TCN67-2002*	*14TCN66-2002*	*Every batch of cement*
Mineral admixture	*Chemical, physical, mechanical properties*	*ASTM C 311-98b*	*ASTM C 618-03*	*Every batch of mineral additives*
Retarding admixture	*Chemical, physical properties*	*ASTM C 403*	*According to requirement*	*Every batch of additives*
Aggregates	*Mechanical properties and gradation*	*14TCN70-2002*	*14TCN71-2002*	*1 time/day*
		14TCN69-2002	*14TCN68-2002*	
		ASTM 1141	*ASTM 1141*	
Water	*Chemical, physical properties*	*14TCN73-2002*	*14TCN72-2002*	*According to requirement*
RCC	*Workability*	*ASTM C 1170-91*	*According to requirement*	*1 time/shift or every 750m^3*
	Density	*ASTM C1040*	*According to requirement*	*1 time/hour or every 25m^3*
	Temperature of RCC	*ASTM C 1064*	*According to requirement*	*1 time/hour or every 200m^3*
	Sampling	*ASTM C 1176-92*		*1 time/shift or every 750m^3*
	Compressive strength	*ASTM C 1176-92*	*According to requirement*	*1 time/shift or every 750m^3*

5. Quality control

The quality control program for RCC must be set up before commencement of construction. Base on this program, the procedure will implement the activities related to the quarrying, production, storage materials and batching to produce RCC and perform evaluation of tests. All quality material must be stored according to regulations.

Fig. 16: Nuclear testing equipment

Fig.17: Experiment to determine modulus of elasticity and compressive strength of RCC

6. Some technical problems arising

- *Cracking problem of RCC:* In a small number of constructed RCC dams, crack of concrete appears after approximately 1-2 months. The cause of the cracking is said due to the drying shrinkage and thermal shock of concrete and other causes (Fig. 19).

Fig. 18: RCC Cracking after construction 2 months

Water leaking problem: After ponding, in some dams water leaking is observed through the dam corridor with flow rate approximately 30 l/s. This problem will be solved by the effort of constructor and designers.

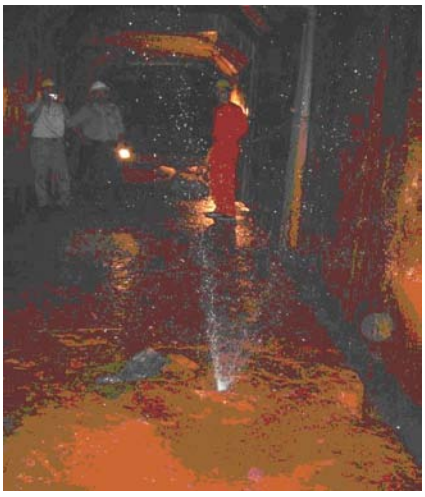

Fig. 19: Water leaking in the dam corridor

Conclusions

RCC technology for dam construction in Vietnam has just been applied for 6 years, but it is considered to be successful so far. Advantages of RCC technology are: fast construction speed, guarantee of good quality. Maximum speed of RCC construction in Vietnam over 150.000m^3/month, when concrete construction speed by conventional concrete technology (CVC) is about 60.000m^3/month.

Materials for RCC production are available in many locations with profuse reserves. Especially, Vietnamese engineers have successfully developed the technology to separated unburned carbon from fly ash.

However, in Vietnam RCC is still facing some technical problems such as heat development in the concrete, cracking of concrete and water leaking etc. These problems should be carefully studied and solved. Moreover, the current research and application of RCC technology are carried out mainly in construction engineering. It is advisable for the professional researchers to strongly engage with research and development of RCC technology in order to apply it in near future. . Therefore, this is the subject which scientists interested in and need more researches to develop and apply RCC technology in Vietnam.