Asian Concrete Federation E-Newsletter

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The theme of this edition of ACF E-Newsletter is High Performance Concrete (HPC).

In order to get a glimpse of the opinion on this topic from a specialist of this field, ACF E-Newsletter invited Prof. Ekasit Limsuwan who is an executive member of Asian Concrete Federation.

He is also a professor in the Dept of Civil Engineering at Chulalongkorn Univ. in the Thailand and has performed many researches on the topic of High Performance Concrete.

HIGH PERFORMANCE CONCRETE

THAILAND PRACTICE

Prof. Ekasit Limsuwan
Thai Concrete Association (TCA)

1. INTRODUCTION

High Performance Concrete (HPC) of normal practices in Thailand, has been defined slightly different than those of American practices. However, it may be categorized in accordance with the structural performance as a material or as a structural component. It is quite fortunate that industries, technical personnel, and researchers in Thailand have gained tremendous experiences from many countries all over the world. With association of natural resources such as cement, aggregate products, and manufacturing technology, have made this outstanding construction material to be used the successfully in of civil infra-structure projects. It is apparently acknowledged that construction industries of highly competitive in engineering services have induced some new products with special fabrication to accommodate its implementation to the real practices. Primary objective of this paper is to demonstrate some development from view point of researchers in cooperation with industrial personnel to enhance the implementation in real practices and to serve engineering services for consulting and construction. These achievements in HPC of Thailand practice can be exchanged or technology transferred to some other countries in Asia and all over the world.

2. DEVELOPMENT AND PRODUCTION

Early developments on high performance concrete, have been achieved first by reducing water to cement ratio (w/c) or increasing cement content. But in contradicting effect, it has lead to poor workmanship. Since the high range water reducing or super plasticizer are commercially available with reasonably reliable quality assurance, then specific performance improvements in strength, workability, durability and some specific properties have been archived. Principal characteristic of high performance can be Shown in Table 1. categories:

Table 1. Categories of High Performance Concrete

Outstanding Performance	Principal Indicators	Industrial Application
High Strength	- Cement Contents - Strength Based Gradation - Water to Cement Ratio - Workable Parameters	Precast Construction / Prestressing Concrete Members Highrise Structural Members / Pavement or Deck Repair
Workability	- Aggregate Gradation - Flow Ability - Workable Time - Slump / Slump Loss - Setting Time	Normal Construction / Congested Reinforcement / Column or Structural Members
Constructivity	- Special Form or Shuttle - Roll Compaction - Setting Time - Dimension Stability	Tunnel Lining / Box Section / Dam Construction
Temperature Rise	- Adiabatic Temperature - Dimension Stability - Micro Cracking	Mass Concrete / Mat Foundation / Large Volume Concreting

<u>High Strength</u> – HPC of high strength concrete, either with high early strength or final strength has concentrated on mix proportions to control the strengths. Principal factors to governing are the property the water to cement ratio, cement content and

aggregate gradation. The characteristic strengths would be expected to 150 MPa of normal manufacturing process and the higher strength can be achieved as ultra high strength of laboratory control. Flowability, workable period and early strength would be conformed to the HPC properties where the strength gradation would be one of the key factor. (Fig. 1)

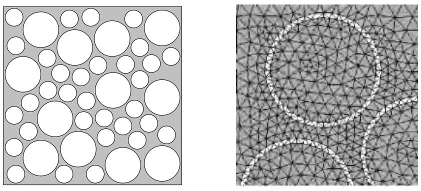

Fig. 1 FEA for Strength Based Gradation of High Strength Concrete

Workability – HPC of self compacted concrete would offer fluidity of concrete flow as self leveling, providing most effective concrete pumping, and supporting its filling ability in congested area of reinforcements. High performance aspect is achieving flow of more than 100% or slump of more than 21.0 cm. The most important factors would be emphasized on concrete mixed design and its optimum energy mixing of proper cement paste to cover the whole aggregate surfaces as which its aggregate gradation to optimize the cement paste. Reodology of the mixes can also be distinguished between its flowability and workability. (Fig. 2)

Fig. 2 Flowable Concrete

Constructability - HPC to support construction techniques can be done in various aspects. In Thailand, concrete for dam construction can be done by roll compacted concrete of which no formworks are required. The mixed design of such concrete can be zero slump, low cement content, retardation setting, low heat hydration and addition pozzalanic reaction. Primary properties are low heat, final high strength, low creep and shrinkage and reduced time dependent deformation. It is quite essential that dimension stability should be kept at the lowest possible to control micro cracking and the leakage. Figure 3 has shown the construction procedure by mean of roll compacted concrete; "Ta Dan" dam in Nakorn Nayok

Fig. 3 Roll Compacted Concrete with the Compaction

Temperature Rise – HPC of mass concrete construction or mat foundation would be developed toward low heat generation, uniform heat distribution, dry shrinkage control and micro cracking reduction. Major influences can be controlled by cement content, retarding chemical hydration, and aggregate gradation. Thermal characteristic of the mass aggregate and air entraining agents can contribute to heat transfer for controlling temperature rise.

Durability – HPC for long-term behavior can be altered by high strength, high permeability, and low alkality in accordance with its mechanical, physical and chemical durability properties. Development of the mixed design would pay attention to cement content, water to cement ratio, aggregate gradation and pozzalanic reaction. Service life in cooperation with material parameters to predict structural behaviors still requires for further studies.

Shrinkage Compensating – HPC for non-shrink properties or as a shrinkage compensating characteristic has emphasized on its dimension stability on dry shrinkage and its chemical composition. The essential parameters of HPC mixture associated with cement constituents would concentrate on ettringite formation due to cement constituents, hydration reaction, and pozzalanic reaction. To control its chemical production to contribute to dimension stability by means of shrinkage control, the amount of ettringite should have been sufficient to compensate for hydration of cement products. The ettringite formation is shown in Fig. 4.

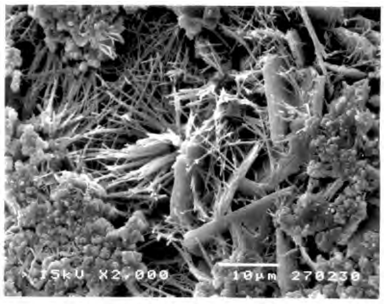

Fig. 4 Ettringite Formation of Shrinkage Compensating Concrete

3. INDUSTRIAL PERSPECTIVE

It is fortunate that concrete manufacturing has used some research outcomes to adopt their own products suitable for their construction industries. The industrial perspective has become effective only when the construction volume would be steady for manufacturing and supply with high quality and some technical supports for its customers. However, engineering services in building process of planning, design, construction, supervision, operation, and maintenance can easily be achieved by these collaborative approaches.

Precast and Prestressed Industries – First group of high strength concrete has been used remarkably for ready mixed industry since they can supply the concrete for precast industry, and prestressed construction especially for segmental construction requiring post-tensioning on the job site. Concrete strength for these types of construction requires compressive strength of normally higher than 30 MPa at 18 – 24 hrs. of ages and the characteristic strength would be higher than 60 MPa for 28 day strength. In many cases, the characteristic strengths would be expected to be 90 – 100 MPa. However, initial strength at stripping the formwork or prior to stressing sequence should be at least 50% of those specified strengths.

Highrise and Large Buildings – HPC for building construction would be emphasized for the performance of workability in congested reinforcement, high strength for column, and low temperature rise for mass concrete of mat foundation. In addition to large bored pile or diaphragm wall where compaction is impossible, then self compacted or self leveling concrete are commonly required. The concrete manufacturers can provide some technical assistance for those mixes to warrant quality assurance to all cases.

Civil Infra-structure Projects – HPC for civil infrastructure mega projects have always required special feature, for its concrete suitable for type of structures and construction method. Roll compacted concrete are required for dam construction to reduce the formwork and pumping or placing facilities. Self compacted concrete are one of the most appropriate for tunnel lining and diaphragm wall, especially for substructure construction. Similarly, mass concrete large mat foundations would also require low temperature hydration concrete (Fig. 5).

Fig. 5 Flowable Concrete

Pavement Repair and Grouting Work - HPC for large volume of concrete supply for repair work have indicated replacement concrete for highway pavement with high early strength at 4 – 6 hrs. of curing. Most repair work requires few hours for breaking an existing one, compacting base course, and placing concrete pavement in situ. The traffic may be closed few hours prior to mid night for execution and operations where it can be opened to the traffic right after 6 o'clock in the morning. The material cost of this high early strength concrete may be slightly higher than the normal concrete, but the cost for overall operation should be a lot less and become more economical.

4. POTENTIAL DEVELOPMENT AND UTILIZATION

Some previous practical experiences in construction industry have shown some potential development for high performance concrete for the future utilization. Collaboration among academia who carried out most research work and practitioners who try to implement expertise to the industries by means of technical services are greatly appreciated. We have experienced the interaction among the owner, designer, and contractors to obtain the most suitable concrete for various construction projects. Now, many research projects are dealing with high performance concrete of ultra high strength, super workability, more durability, most appropriate for structural repairs and strengthening. So we would expect more adoption toward new construction industry, not only for new construction projects but also some repair or strengthening existing structures. Several projects are under way for assessment. They also can be used for design of repair and rehabilitation by patching, filling, overlaying, replacing as well as some postensioning needs. Some mixed or composite structures known as hybrid structures would also be built by high performance concrete with reinforced steel, prestressing tendons, and fiber reinforced plastic rebars such as Glass Fiber (GFRP) or Carbon Fiber (CFRP). Nevertheless, the Fiber Reinforced Plastic (FRP), would be very useful for active confinement, prestressing and postensioning effects. The interaction behaviors would not only be exercised on material behavior but also structural behavior for normal actions or abnormal loadings such as wind, earthquake, or unpredictable actions of blasting or accidental loading.

5. CONCLUSION

Those accumulative work done on HPC in Thailand practices, have been carried out first by research works at stage of development, then they are applied to real practices in construction industry. The interaction among involved parties may not be possible in every aspect but in technical approach can be adapted to some collaboration aspects of academia and practitioners. The code of practice for technical services as for design, construction, operation and maintenance of proper minimum warrantee of the commercial deal should be developed. The most effective functioning, proper serviceability of high performance indicators can accomplish technical and social to the same object. Hopefully, high performance concrete can be one of the most suitable materials for structural performance of its strength, serviceability and durability to be used as Performance based Concept or Code (PBC) in very near future.

Fig. 6 Pavement Repair with High Early Strength Concrete

On Engineered Cementitious Composites (ECC)

Review of the Material and Its Applications

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Abstract

This article surveys the research and development of Engineered Cementitious Composites (ECC) over the last decade since its invention in the early 1990's. The importance of micromechanics in the materials design strategy is emphasized. Observations of unique characteristics of ECC based on a broad range of theoretical and experimental research are examined. The advantageous use of ECC in certain categories of structural, and repair and retrofit applications is reviewed. While reflecting on past advances, future challenges for continued development and deployment of ECC are noted. This article is based on a keynote address given at the International Workshop on Ductile Fiber Reinforced Cementitious Composites (DFRCC) – Applications and Evaluations, sponsored by the Japan Concrete Institute, and held in October 2002 at Takayama, Japan.

1. Introduction

ECC is a class of ultra ductile fiber reinforced cementitious composites developed for applications in the large material volume usage, cost sensitive construction industry. Since the introduction of this non-proprietary material a decade ago, ECC has undergone major evolution in both materials development and the range of emerging applications. The discovery of ECC has benefited from pioneering research by the IPC group (Aveston, et al. 1971), one of the first groups which applied fracture mechanics concepts to analyzing fiber reinforced cementitious composite systems. The current advances in ECC technology could not have happened without the active participations of many organizations internationally The following sections describe important elements of research and development in ECC, from materials design to commercial applications. The importance of micromechanics in the role of materials design, optimization, and constitutive ingredient tailoring is emphasized. Reflections on material ductility, performance characteristics of reinforced ECC, or R/ECC, and cost considerations are examined. Future directions of ECC materials development and structural applications are indicated. At this point, it is clear that a milestone has been reached where there is a broad international community, involving academic, industrial and governmental concerns engaged in ECC science and technology development. ECC is no longer confined to the academic research laboratory. It is finding its way into precast plants, construction sites, and repair and retrofitting jobs. It is the hope of the author that by sharing knowledge as they are generated, ECC technologies will continue to accelerate in the next decade, benefiting society via the enhanced safety, durability, construction productivity and sustainable development of our physical infrastructures.

2. From Theoretical Materials Design to Commercial Applications

Since ECC was introduced about ten years ago, significant developments in research and commercialization of ECC technologies have occurred both in the academic and in the industrial communities. **Figure 1** shows a flow-chart of some important elements of ECC R&D, from basic materials design theory to practical commercial applications. Micromechanics relates macroscopic properties to the microstructures of a composite, and forms the backbone of materials design theory. Specifically, it allows systematic microstructure tailoring of ECC as well as materials optimization. This topic will be discussed further in the next section. For now, we recognize that microstructure tailoring can lead to extreme composite ductility of several percent in tension, a material property not seen before in disconti-

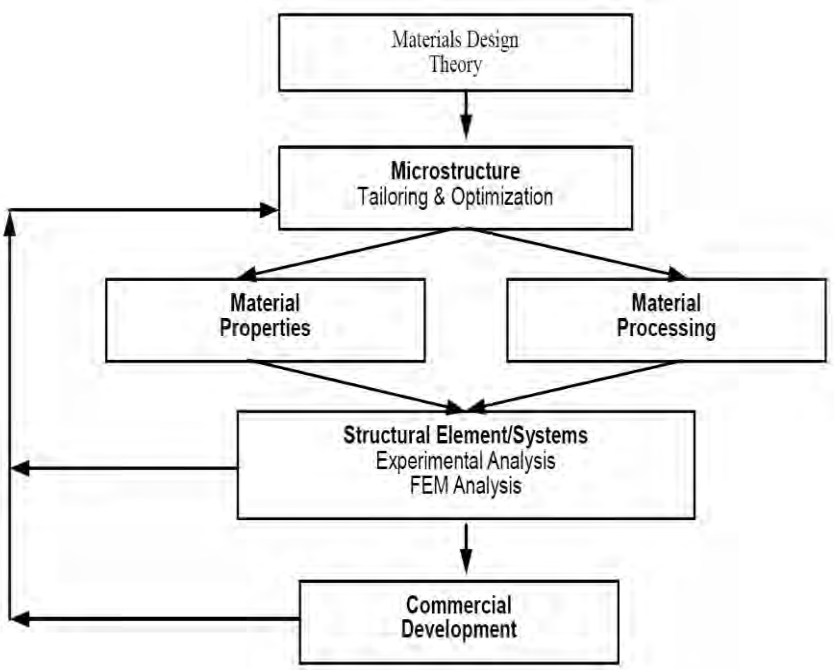

Fig. 1 Flow-chart of important elements of the research and development of Engineered Cementitious Composites.

nuous fiber reinforced cementitious composites. **Figure 2** shows an ECC with tensile strain capacity of 5% (Li et al. 2001), approximately 500 times larger than that of normal concrete or fiber reinforced concrete (FRC). An increasingly large database of mechanical (including tension, compression, shear, fatigue, and creep) and physical properties (including shrinkage, and freeze-thaw durability) of ECC is now being established. Materials optimization also leads to compositions (e.g. moderately low fiber volume fraction less than 2-3%, coupled with suitable matrix design)that make it possible for very flexible materials processing. ECC can now be cast (including self-compacting casting (Kong et al., 2003)), extruded (Stang and Li, 1999), or sprayed (Kanda et al., 2001; Kim et al., 2003a). It is the deliberate constituent tailoring and optimization methodology embodied in ECC that gives its name Engineered Cementitious Composite. The advantages of high composite ductility in the hardened state and flexible processing in the fresh state make ECC attractive for a broad range of applications. A variety of experiments have been performed to assess the performance of ECC at the structural level (see e.g. Fukuyama et al., 1999; Parra-Montesinos and Wight, 2000; Yoon and Billington, 2002; Fischer and Li, 2003a,b; Li et al., 2002) for both seismic and non-seismic structural applications. These experiments
provide new insights into how the material properties elevate the response performance of the structure. At the same time, constitutive models (Kabele, 2001; Han et al., 2002a) of ECC have been constructed and implemented into FEM codes for prediction of structural behavior. They should be useful for exploring the selective use of ECC in critical elements of a structural system, without excessive demands on expensive experimentation.
These activities are important in establishing rational means of designing structures made with ECC material. Commercial development of ECC technologies imposes additional considerations, in addition to those described in the previous paragraphs. The adoption of a new technology must be justified with advantages in cost-benefit ratio. While the initial raw

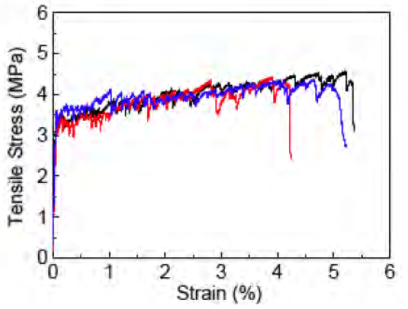

Fig. 2 Uniaxial tensile stress-strain curves of an ECC reinforced with 2% PVA-REC15 fibers

material cost of ECC is higher than normal concrete, the long term benefits are sufficient to potentially drive
this technology into the commercialization stage in the near future in a number of countries, including Japan, Korea, Australia, Switzerland and the US. Nonetheless, materials optimization for cost reduction of ECC remains important. It is expected that as investigations into structural response and commercial development of ECC technologies proceed, a feedback loop (**Fig. 1**) to microstructure tailoring for refinement in ECC materials will occur. In addition, special functionalities such as lightweight or high early strength will drive the development of specialized versions of ECC for different applications with unique demands. Each of the R&D elements and especially the feedback process will benefit from collaborations among researchers, material suppliers, precasters and design and construction contractors.

3. Micromechanics

Extensive research has shown that the most fundamental property of a fiber reinforced cementitious material is the fiber bridging property across a matrix crack, generally referred to as the $\sigma-\delta$ curve (Li 1992b; Li et al. 1993; Lin and Li 1997). This is the averaged tensile stress σ transmitted across a crack with uniform crack opening δ as envisioned in a uniaxial tensile specimen. The $\sigma-\delta$ curve provides a link between composite material constituents – fiber, matrix and interface, and the composite tensile ductility. To understand the fundamental mechanisms governing strain-hardening ECC behavior versus tension- softening FRC behavior, it is necessary to recognize the load bearing and energy absorption roles of fiber bridging. The $\sigma-\delta$ curve (**Fig. 3**) can be thought of as a spring law describing the behavior of non-linear springs connecting the opposite surfaces of a crack, representing the averaged forces of the bridging fibers acting against the opening of the crack when the composite is tension loaded. One of the criteria for multiple cracking is that the matrix cracking strength (including the first crack strength associated with the first crack) must not exceed the maximum bridging stress σ_{cu}. (The cracking strength is dominated by the matrix flaw size.) We may label this as the strength criterion for multiple cracking. A second criterion for multiple cracking is concerned with the mode of crack propagation which in turn is governed by the energies of crack extension. We may label this as the energy criterion for multiple cracking. fiber/matrix interface is too weak, pull-out of fibers occurs, resulting in a $\sigma-\delta$ curve with low peak strength σ_{cu}. When the interface is too strong, the springs cannot stretch, resulting in rupture and a small value of critical opening δ_p. In either case, the complementary energy shown as the shaded area C to the left of the curve in **Fig. 3** will be small. Steady state crack analysis (Li and Leung 1992) reveals that when the complementary energy is small (in comparison to crack tip toughness, the energy

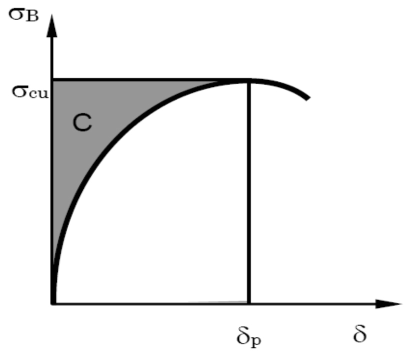

Fig. 3 The $\sigma-\delta$ curve and the concept of complementary energy

needed to break down the crack tip material to extend the bridged crack), the crack will behave like a typical Griffith crack. As the crack propagates, unloading of the springs will initiate at the middle of the crack, where the opening is maximum, when δ_m exceeds δ_p in **Fig. 3**. An expanding traction free or tension-softening region will follow the crack tip as the crack continues to propagate. After the passage of this crack, the composite will fail with reduced load carrying capacity, resulting in the tension- softening behavior of a normal FRC. In contrast, if the complementary energy is large, the crack will remain flat as it propagates so that the steady state crack opening $\delta_{ss} < \delta_p$, and maintains tensile load carrying capacity after its passage. As a result, load can be transferred from this crack plane back into the matrix and cause the formation of another crack, which may initiate from a different matrix defect site. Repetition of this process creates the well-known phenomenon of multiple cracking. The shape of the σ−δ curve therefore plays a critical role in determining whether a composite strain-hardens as in ECC, or tension-softens, as in normal FRC, under uniaxial tensile load. The strength and energy criteria for multiple cracking provide guidelines for tailoring the fiber, matrix and interface for ECC materials. provide guidelines for tailoring the fiber, matrix and interface for ECC materials. The shape of the σ−δ curve is governed by the fiber volume fraction, diameter, length, strength and modulus, in addition to the fiber/matrix interaction parameters that include the interfacial chemical and frictional bond properties (Lin et al. 1999). Controlling the shape of the σ−δ curve, therefore, boils down to controlling the fiber and fiber/matrix interaction parameters (Li et al. 2002b). This forms the tailoring strategy for the REC15 fiber now manufactured by Kuraray Co. Ltd. (Japan) for ECC reinforcements.

The σ−δ curve has a direct bearing on the constitutive law in general, and the tensile stress-strain curve of the composite in particular, since it determines whether strain-hardening will occur or not. This composite material constitutive law in turn governs the response of a structure built with ECC material. Hence, the σ−δ curve may be seen as a critical link between materials design (lower triangle, **Fig. 4**) and structural design (upper triangle, **Fig. 4**). From the above discussion, it can be seen that micromechanics serves as a useful tool to direct materials design for achieving desired structural performance. This is the concept behind the Performance Driven Design Approach (PDDA) (Li 1992a) proposed for materials engineering. As the structural design community moves away from traditional prescriptive design guidelines to a performance based design concept (PBDC) (SEAOC 1995), there will be significant opportunities for innovative use of materials. PDDA and PBDC can be combined to form the integrated structures-materials design (ISMD) scheme (Li and Fischer 2002) shown in **Fig. 4**. We expect that ISMD will serve as an important platform for collaborations between structural engineers and materials engineers, leading to innovative structural and materials designs. The common practices of adding fibers by trial-and-error and then testing for structural element response will not be an efficient approach to materials design, or for achieving deliberate levels of structural performance. Micromechanics also serves as a tool for materials optimization. The construction industry is a highly cost-sensitive industry. Any new material introduced must be cost-effective. Since fibers are much more expensive than cement, sand or water, it is imperative to minimize the amount of fibers used while maintaining the strain-hardening property. This concept is implemented in ECC in the form of minimizing the critical fiber volume fraction, the amount of fibers that just switch the material from a normal tension-softening FRC behavior to a strain-hardening ECC behavior. The critical fiber volume fraction can be determined based on knowledge of fiber, matrix and interface properties (Li and Leung, 1992; Lin et al. 1999). Using fiber conten below this critical value will lead to normal FRC tension-softening behavior. On the other hand, using fiber content greatly in excess of this critical value leads to not only high cost of material, but also creates difficulties in material processing. A fiber volume fraction at just above the critical value provides a composite optimal in performance, cost, and processability. It is clear that a low critical fiber volume fraction is desirable. Since this parameter is associated with fiber and interface properties, micromechanics provides guidelines to tailoring the fiber and the interface to minimize the critical fiber volume fraction. The tailoring is implemented via control of the surface coating of the PVA fiber. For this hydrophilic fiber, the untreated fiber has a too high chemical and frictional bond with cementitious material. A surface coating content between 0.8 and 1.2% by weight of fibers tends to lower the interface chemical and frictional bond properties to a level that causes the critical fiber volume fraction to drop to a minimum of about 2% (Li et al. 2002b). In the development of ECC, micromechanics serves multiple purposes:

(1) Micromechanics enables ISMD,

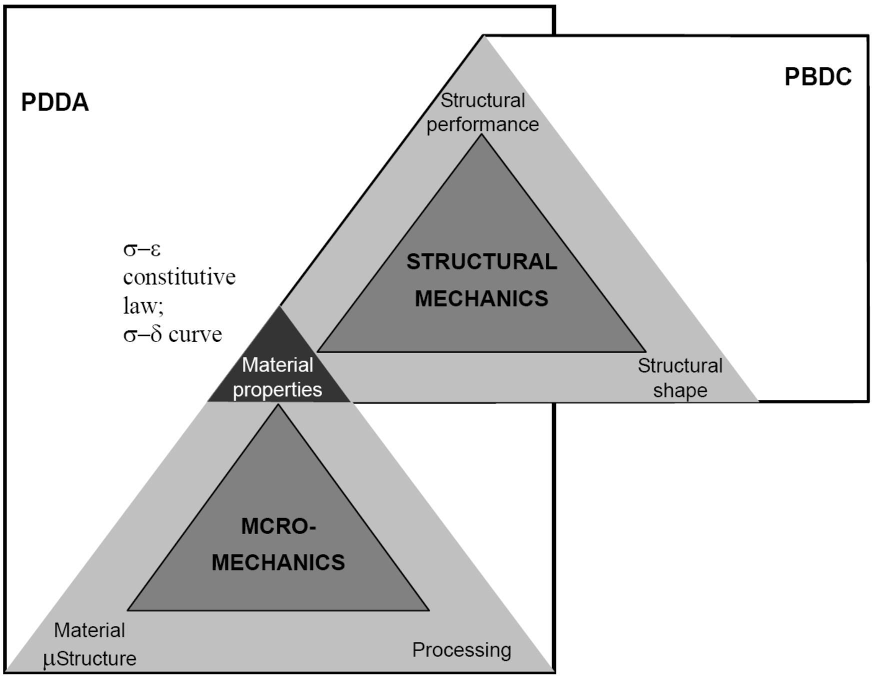

Fig. 4 Concept of Integrated Structures and Materials Design (ISMD).

(2) It creates an analytic tool for composite optimization, making it feasible to achieve high performance and flexible processing at minimum fiber content, and

(3) It creates a systematic approach to materials tailoring, resulting for example, in the rapid development of the REC15 fiber. For these reasons, ECC is not only a cementitious composite with high ductility performance; it is a micromechanics based design concept.

4. Strength vs. Ductility

The unique feature of ECC is its ultra high ductility. This implies that structural failure by fracture is significantly less likely in comparison to normal concrete or FRC. In traditional R/C structural design, the most common and most important material parameter of concrete is its compressive strength. For this reason, structural strength (and more generally, structural performance) is often perceived to be governed by material strength. This means that higher material strength (usually referred to compressive strength in the concrete literature) is expected to lead to higher structural strength. This concept is correct only if the material strength property truly governs the failure mode. However, if tensile fracture failure occurs, a high strength material does not necessarily mean higher structural strength. Rather, a high toughness material, and in the extreme, a ductile material like an ECC, can lead to a higher structural strength. A number of recent experimental observations (Lim and Li, 1997; Kanda et al., 1998; Kesner and Billington, 2002) provide support for the above concept. For example, precast in-fill wall panels for seismic retrofitting of buildings have been studied experimentally and numerically. Fully reversed cyclic shear load tests (Kesner and Billington, 2002) confirmed that a panel with a concrete of compressive strength of 50 MPa attained a structural strength of 38 kN, while a similar panel made with ECC material of lower compressive strength (41MPa) achieved a higher structural strength of 56 kN. The over 35% structural strength gain in the R/ECC panel can be attributed to the material ductility of the ECC that maintained integrity of the panel to a larger drift level. Similarly, detailed numerical analysis (Kabele 2001) of a wall panel made with ECC demonstrated a structural strength three times larger than that of the panel made with FRC, despite the fact that both materials had the same tensile and compressive strengths.

5. Performance of R/ECC Elements

Experimental and FEM investigations have revealed a number of unique behaviors of ECC in structural applications. These behaviors are expected to have direct impact on infrastructure safety, durability and construction productivity. When ECC replaces concrete in reinforced structures, we refer to these as R/ECC structures or R/ECC elements. Below we describe some general characteristics observed in R/ECC structural elements and broad targets of ECC applications.

5.1 General Characteristics of R/ECC Structural Behavior

Reduction or elimination of shear reinforcement: ECC has excellent shear capacity, as demonstrated by Ohno shear beam tests (Li et al. 1994). Under shear, ECC develops multiple cracking with cracks aligned normal to the principal tensile direction. Because the tensile behavior of ECC is ductile, the shear response is correspondingly ductile. As a result, R/ECC elements may need less or no conventional steel shear reinforcements. For example, test results of flexural members (Fischer and Li 2002b) subjected to cyclic loading confirm that the load carrying capacity and the energy absorption of R/ECC without shear stirrups exceed those of a standard R/C with stirrups. Similarly, ECC beams without shear reinforcement demonstrate superior performance to HSC beams with closely spaced steel stirrups, suggesting that elimination of shear reinforcement is feasible when concrete matrix is replaced by ECC (Li and Wang 2002). Experiments on the cyclic response of unbonded post-tensioned precast columns with ECC hinge zones (Yoon and Billington 2002) and R/ECC columns (Fischer et al. 2002) also confirmed that the column integrity could be maintained better when concrete is replaced by ECC without any seismic shear detailing. Sustaining large imposed deformation: With tensile strain-hardening and ultra high tensile strain capacity, ECC can sustain very large deformation without damage localization. This behavior can be utilized in a number of situations where the imposed deformation on a structure is expected to be high. As an example, ECC may be used in link-slabs that replace conventional joints in concrete decks. The ECC can then accommodate the deck movements induced by shrinkage, temperature variation or creep. Zhang et al. (2002) demonstrated this idea by applying a strip of ECC sandwiched between concrete segments. Uniaxial tensile test of this arrangement confirms that large deformation (1.3% strain) can be imposed without causing any cracks in the concrete segments. All the deformation was absorbed by the ECC strip. Full scale test (Kim et al. 2003b) demonstrated that the ECC link-slab technology is feasible. Compatible deformation between ECC and reinforcement: In R/ECC with steel reinforcement, both the steel and the ECC can be considered as elastic-plastic material capable of sustaining deformation up to several percent strain. As a result, the two materials remain compatible in deformation even as steel yields. Compatible deformation implies that there is no shear lag between the steel and the ECC, resulting in a very low level of shear stress at their interface. This phenomenon is unique in R/ECC. As a result of low interfacial stress between steel and ECC, the bond between ECC and reinforcement is not as critical as in normal R/C, since stress can be transmitted directly through the ECC (via bridging fibers) even after microcracking. In contrast, in R/C members, the stress must be transferred via the interface to the concrete away from the crack site. After concrete cracks in an R/C element, the concrete unloads elastically near the crack site, while the steel takes over the additional load shed by the concrete. This leads to incompatible deformation and high interface shear stress responsible for the commonly observed failure modes such as bond splitting and/or spalling of the concrete cover. The compatible deformation between ECC and reinforcement has been experimentally confirmed (Fischer and Li 2002a). **Figure 5** shows the contrasting behavior of R/ECC and R/C near the interface revealed in a cross-sectional cut of tension-stiffening specimens. Synergistic interaction with FRP reinforcement: The use of fiber reinforced plastic (FRP) reinforcement in R/C structural elements is often met with difficulty (Fukuyama et al. 1995) due to the premature failure of FRP after the brittle concrete cracks, especially under compression loads when the structure is subjected to reverse cyclic loading. Such failure of FRP is prevented in R/ECC (Fischer and Li 2003a) since the ECC does not form

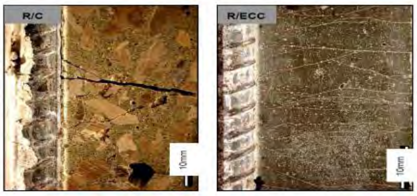

Fig. 5 Compatible deformation between ECC and steel reinforcement (right*)*

major fracture planes and continues to provide a protective concrete cover even when strained to the inelastic stage. This phenomenon removes a major concern of using FRP as reinforcement, while allowing the exploit tation of the unique properties of FRP in R/ECC structures, including the large elastic deformation range and corrosion resistance of FRP. In addition, extensive test results of R/ECC beams reinforced with FRP (Li and Wang 2002) revealed significant improvement in flexural performance in terms of ductility, load-carrying capacity, shear resistance and damage control (crack width, spalling) compared with the counterpart high strength concrete (HSC) beam with the same reinforcement configurations. *High damage tolerance and reduction*: Damage tolerance is a measure of the residue strength of a material or structure when damage is introduced. The damage tolerance of ECC has been investigated (Li 1997). Tensile loading of a specimen with deliberately introduced notches of different lengths demonstrated that ECC is remarkably notch insensitive. The high damage tolerance of ECC is reflected in the failure mode, e.g. under an indentation test (Kanda et al.1998), where the high stress concentration at the edge of the indent did not lead to fracture failure. Indeed, the high damage tolerance of ECC makes this material highly suitable for use in structural elements where high stress concentration is difficult to avoid. As an example, the interaction of the steel beam with an R/C column in a beam-column connection test (Parra-Montesinos and Wight, 2000) leads to high stress concentration where the steel flange bears on the concrete material when the assembly was subjected to repeated cyclic loading. No fracture failure was observed when ECC was used, despite delibe rate removal of all shear stirrups. In contrast, severe spalling results in the case of conventional concrete. Under fully reversed cyclic loading, a set of orthogonal cracks is formed. In R/ECC specimens of different geometries tested (Fukuyama et al. 1999; Parra Montesinos and Wight, 2000; Yoon and Billington, 2002; Fischer and Li, 2003a,b; Kanda et al., 1998; Kesner et al., 2002), these orthogonal cracks do not lead to surface spalling as often observed in R/C specimens after large load reversals, resulting in significant reduction in damage. *Tight crack width control*: When an ECC structural element is loaded (flexure or shear) to beyond the elastic range, the inelastic deformation is associated with microcracking with continued load carrying capacity across these cracks. The microcrack width is dependent on the type of fiber and interface properties. However, it is generally less than 100 micron when PVA fiber is used. **Figure 6** shows the crack width development as a function of tensile strain in a uniaxial tension specimen. The crack width first increases, but reaches a more or less steady state value beyond about 1% strain. For this specimen using 2% of REC15 fiber with 0.8% surface coating content, the crack width stabilizes at about 80 micron. The tight crack width in ECC has advantageous implications on structural durability (more below), and on the minimization of repair needs subsequent to severe loading of an ECC member.

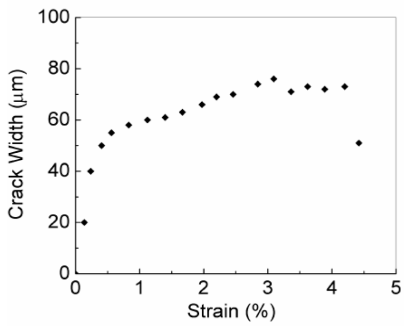

Fig. 6 Crack width development in a ECC with 2% REC15 fibers

5.2 Classes of Target Applications

The observed characteristics of R/ECC structural elements described above suggest at least three broad classes of target applications. These include structures requiring collapse resistance under severe mechanical loading, and structures requiring durability even when subjected to harsh environmental loading. Finally, ECC is expected to support enhanced construction productivity. Safe infrastructure subjected to severe mechanical loading: The most investigated group of structures in this category is seismic resistant structural members tested under fully reversed cyclic loading. Investigations have been carried out in beam elements (Fukuyama et al. 1999; Kanda et al. 1998), in column members (Fischer et al. 2002), in hybrid steel beam-concrete column connections (Parra-Montesinos and Wight 2000), in ECC smart frames which self-center subsequent to seismic loading (Fischer and Li 2003b), in precast infill retrofit of open frame walls (Kanda et al. 1998; Kesner and Billington, 2002; Horii et al., 1998), in precast segmental concrete bridge pier systems (Yoon and Billington, 2002), and in damping elements (Fukuyama et al., 2002), amongst others. These studies demonstrate superior seismic resistant response as well as minimum post-earthquake repair requirements when R/ECC is used in place of R/C. While it may be intuitively appealing to associate observed high energy absorption of R/ECC members under cyclic loading directly with the material ductility of ECC, the real situation is more intricate than this. Fischer and Li (2002a) showed that the high energy absorption in R/ECC members derived from the extended use of the steel reinforcement both in the sense of a longer segment of the reinforcement undergoing plastic yielding in tension and compression and in the sense of more stable hysteretic loops. These phenomena are directly related to the compatible deformation between steel and ECC as described in the previous subsection. Durable infrastructure subjected to severe environmental loading: The most investigated applications in this category belong to repair of infrastructures using ECC. These include planned repairs of a dam (Japan), the underdeck of a bridge (Japan), a sewage line (Korea), tunnel linings (Switzerland) and concrete bridge decks (US). There are a number of characteristics of ECC that make it attractive as a repair material. ECC can eliminate premature delamination or surface spalling in an ECC/concrete repaired system (Lim and Li 1997). Interface defects can be absorbed into the ECC layer, and arrested without forming spalls, thus extending the service life. Suthiwarapirak et al. (2002) showed that ECC has fatigue resistance significantly higher than that of commonly used repair materials such as polymer mor tar. ECC also has good freeze-thaw resistance and restrained shrinkage crack control (Li et al. 2002a). There is increasing evidence that a crack width of 100 micron represents a threshold above which water flow through cracks becomes appreciable (Tsukamoto 1990; Wang et al. 1997; Lawler et al. 2002). Since the crack width of ECC can be kept below this limit (**Fig. 4**), it is likely that ECC would serve as an excellent "concrete-cover" in R/ECC structures. The low transport rate of aggressive agents through ECC may delay steel corrosion leading to extended service life in, e.g. structures in coastal regions. Further research is needed to directly confirm this expectation. Infrastructure construction productivity: ECC may lead to enhanced construction productivity in several ways. The most direct means is by elimination of labor-intensive installation of shear reinforcing bars in seismic structures. As discussed earlier, the high shear capacity of ECC decreases or even eliminates the need for shear reinforcement. The flexible processing routes of ECC also lend themselves to efficient methods of application of ECC in construction sites or in precast plants. For example, for many repair applications, or in tunnel lining construction, the use of spray processing can speed up the construction process. Similarly, extrusion of ECC can provide a continuous method of manufacturing high quality ECC products with low waste (Stang and Li, 1999; Takashima et al., 2003). Self-compacting ECC lends itself to challenging construction conditions, including where horizontal formwork or "concrete" filled tubes are utilized, with potentially significant reduction in labor requirements.

6. Cost of ECC

The additional cost of ECC over normal concrete derives mostly from the use of fibers and higher cement content. This is the reason why optimization of the composite to minimize the fiber content is so important, as pointed out in Section 2 above. In comparison to steel fibers used in many FRCs, polymer fibers such as PVA may be more expensive on a unit weight basis. However, it should be noted that polymer fibers have density six to seven times lower than that of steel, and it is the volume content of fibers and not the weight content which governs the performance of the cementitious composite. Partial substitution of cement with industrial by-products such as flyash should further reduce the cost of ECC, although the resulting change in interface and matrix properties and their effects on composite strain capacity should be carefully examined. Finally, the cost of ECC in comparison to other high performance construction material such as polymer mortar currently in use for repair of infrastructure can be much lower. Ultimately, the economics of ECC should be based on cost/benefit analyses. The potential benefits of using ECC have been discussed in the previous sections. The life cycle cost of a structure includes not only the initial material cost, but also the construction cost (labor and speed) and maintenance cost. By reducing or eliminating shear reinforcement, there will be cost advantages in constructing infrastructure with ECC material, associated with the reduction of steel as well as reduction of on-site labor, while speeding up the construction process. The durability of ECC and ECC structures should extend the service life of infrastructures while reducing maintenance cost. A full analysis should take into account social and environmental cost and benefits of using ECC. Such life-cycle assessment has important ramifications in the broad adoption of ECC and in the sustainable development of this material (Li et al, 2004).

7. ECC Technology Network

ECC is a relatively new material emerging from laboratory to precast plants and construction sites. The material continues to evolve, and new material characteristics continue to be uncovered. More and more applications are being found for ECC. There is a need to exchange evolving information between academic, industrial and governmental concerns. For this reason, the ECC Technology Network was established in 2001. The ECC Technology Network is an informal organization composed of members that are interested in developing and promoting ECC technology. A web site hosted by the University of Michigan provides an international platform for sharing news and knowledge of ECC materials and application technologies. There is no cost to joining this organization, just a commitment to further advances of ECC.

8. Outlook & Conclusions

While rapid progress has been made in ECC technological development over the last decade, it may be expected that the coming decade will be even more exciting. As research advances, we will continue to discover more favorable characteristics of ECC that lend themselves to new infrastructure applications. It may be envisioned that a new generation of ECC material embodying the advantages of both steel (ductility) and concrete will be developed. These new materials will be

- designable for achieving targeted structural performance levels
- sustainable with respect to social, economic and environmental dimensions
- self-healing when damaged
- functional to meet requirements beyond structural capacity

Associated with this material, a new generation of infrastructure systems that have one or more of these characteristics will emerge:

- safe with minimum repair needs even after subjected to severe loading conditions
- smart with self-adapting ability
- mega-scale but without size-effect drawback

· zero-maintenance even when exposed to severe environment

· constructable at high speed and with low waste Meanwhile, attention is needed in the following R&D areas:

(1) Standardized mix design: Improved versions of ECC will continue to evolve for some time. While this is a natural consequence of research, the user community may benefit from a "reference" standard mix. Consideration of cost and ingredient material availability should be taken into account to establish this standard mix. These considerations are as important as those for ECC performance and material processability. The standard mix can provide a baseline for property assurance.

(2) Pre-mix ECC: It is not reasonable to expect the user community to conduct micromechanics calculations to create suitable mix composition. Apart from standardized mix design, another step towards user-friendliness is to create pre-mix ECC with specific but simple instructions of applications.

(3) Basic material supply: The construction industry is a high volume but also highly cost-sensitive industry. Widely available material supply at competitive pricing is important to the ECC user community. Micromechanics remains to be a central tool for tailoring fiber and matrix materials suitable for ECC applications.

(4) Material performance specifications: For structural designers, there should be a minimum material performance specifications for ECC so that structures designed with ECC would behave as expected. The fundamental material performance specification may be based on tensile strain capacity, tensile strength and the presence of multiple cracking.

(5) Standardized test methods: An increasingly complete material database is being established for the properties of ECC under various mechanical loading, including tension (Li, 1998; Li et al., 2001), compression (Li, 1998), shear (Li et al. 1994), cyclic loading (Fukuyama et al. 1999; Kesner et al. 2002), fatigue (Suthiwarapirak et al. 2002), creep (Billington and Rouse 2003) and fracture (Li and Hashida 2003). The responses of ECC to environmental loading such as drying shrinkage (Weimann and Li, 2003), freeze-thaw cycles (Lepech et al., 2003), hot and humid weather cycles (Li et al., 2003), are being documented. There is a need to develop standardized test methods, particularly for the fundamental uniaxial tensile stress-strain curve, for ease of comparisons of ECC materials. Careful examination of the potential influence of specimen size and geometry on the measured material properties should be included.

(6) Numerical tools: Robust numerical tools are needed for simulation of structural systems containing ECC materials. Constitutive models capable of capturing the essence of ECC behavior under complex stress-states embedded into industrial strength FEM codes should help structural designers take full advantage of ECC material in infrastructure system design.

(7) Consolidation of knowledge in specific application fields: Broad categories of ECC applications, such as seismic applications, or repair and retrofitting, are emerging, as described in Section 5. Valuable knowledge is being accumulated. They should be periodically consolidated and shared, in order to further advance each application field.

(8) Sustainable development: As an emerging infrastructure construction material, ECC is in an excellent position to embrace sustainable development of infrastructures. Both the cement (Battelle Memorial Institute 2002) and concrete (Mehta 2002) industries are moving in this direction. Sustainable development addresses sustainability indices of social, economic and environmental. The gain in performance (safety, durability, and construction productivity) must be balanced with the ecological impacts of raw material ingredients usage. Adoption of suitable recycled material, including flyash and waste fibers, should be considered. Detailed life-cycle assessment of ECC should be conducted.

(9) Structural innovations: ECC can be viewed as a ductile metal-like material on the macroscopic scale, with an essentially bi-linear tensile stress-strain curve. The significant difference from the property of normal concrete makes designing structures with ECC more challenging as traditional design guidelines for R/C may not be adequate (and probably too conservative). Innovative structural design concepts are needed to fully exploit the unique behavior of ECC. As an example, Fischer and Li (2003b) developed an auto-adaptive frame which took advantage of the distinct behaviors of R/ECC with steel and R/ECC with FRP reinforcements, allowing the frame to automatically switch to a lower stiffness at large drift level to limit the force acting on the frame, while providing a self-centering characteristic after earthquake loading.

(10) Integrated Structures and Materials Design: As described in connection with **Fig. 4**, the micromechanics theory behind the design of ECC enables the vertical integration of structural and materials design. Examples of this two-way feedback are being created (e.g. Kim et al. 2003b). Research is needed to further demonstrate and elucidate the feasibility and advantages of this new approach. ECC has enjoyed broad based support from developers and users, material suppliers and construction/design companies, and academic research groups and commercial enterprises. There are a variety of social needs that create an exciting environment for continued ECC developments. These include greater infrastructure security (against both man-made and natural hazards) and sustainability and the continuing movement towards performance based design. Together, the ECC technology community can contribute to improving the quality of life in our modern society through innovations in materials and structures technologies.

The 5th ACF Executive Council (EC) Meeting

8 December, 2009
Hosted by APFIS 2009 Local Organizing Committee

The 5th ACF Executive Council (EC) Meeting was held at Seoul, Korea on December 8, 2009. The meeting was hosted by APFIS 2009 LOC and attendees express sincere appreciation for their hospitality. The meeting details are follows.

1. Introduction

On 8th December 2009, the 5th ACF Executive Council Meeting was held in Sheraton Grand Walker Hill Hotel, Seoul, Korea.

2. Attendees

The attendees of the meeting are as follows.

J. Sim (ACF President)
T. Ueda (ACF Vice President)
L.Q. Hung (ACF Vice President)
C. Park (ACF Secretary)
H. Noguchi (ACF EC)
T. Uomoto (ACF EC)
Y.W. Chan (ACF EC)
F.X. Supartono (ACF RM)
W. Kim (ACF RM)
C.K. Cho (ACF CM)
H.S. Cho (ACF CM)
S.J. Kwon (ACF CM)
D.U. Choi (Observer)
J.K. Kim (Observer)
S.B. Shin (Observer)
S.G. Oh (Observer)
S.G. Hong (Observer)
J.H.J. Kim (ACF Member)
S.H. Song (ACF Staff)
Y.J. Kim (ACF Staff)

3. Agenda

1. Opening Remarks by Prof. Sim, President of ACF

Prof. Sim opened the 5th Executive Council Meeting.

2. Short Message from Prof. Kim, the President of KCI

Prof.Kim welcomed all the EC members and participants who have come to Seoul to attend the ACF EC meeting.

3. Roll call of the Delegates and Declaration of Quorum

Prof. Park, Secretary of ACF, took a roll call of the EC members and confirmed the attendance of more than 50% of all EC members.

4. Adoption of the Agenda

The Secretary presented the draft agenda for the meeting. The draft was approved without dissent.

5. Briefing on the main contents of the 4th EC meeting

The Secretary read up the draft minutes of the last meeting which was held in Ho Chi Minh City, Vietnam, on 10 November 2008.

5a. Revised Constitution and Byelaws

Prof. Park stated the important issues of the revised Constitution. They include amendment of EC member increasing from 10 to 14.

6. President Report

6a. Settlement of ACF HO in Korea

Prof. Sim briefly reported the establishment of ACF Head Office in Ansan, Korea.

6b. Homepage Revision

Prof. Sim reported the ACF Homepage revision, which started its service since 1 May 2009.

6c. Report of P & VP's Meetings (Hanoi and Bangkok Meeting)

Prof. Sim reported the P & VP's Meetings held in Hanoi and Bangkok. Prof. Sim also suggested that from year 2010, the IM membership fee should pay for two years.

6d. Membership Status and Extension of RM and CM

Prof. Sim reported the current Membership Status and the future expected RM and CMs. f. Sim commented that not all RM members are active in ACF activities. Prof. Sim reported that Mongolia agreed to be the RM of ACF. Prof. Sim will also continue to contact Egypt who has shown interest in applying for RM of ACF. Prof. Hung is now in contact with China, Laos, Cambodia. Prof. Ueda suggested local chapters of ACF for Sri Lanka, Banladesh and Pakistan.

6e. International Partnership Agreement with ACI

Prof. Sim reported on the International Partnership Agreement with ACI.

6f. Approval of New EC Members (Prof. W. Kim)

Prof. W. Kim, Vice President of KCI, was accepted as the EC member.

7. Vice President Report (Technical Dept.)

7a. TG Activities (TG2 and TG3: Final Reports)

Prof. Ueda reported on the Final Reports of TG2 on Maintenance for Leakage due to Cracking and TG3 on Seismic Assessment and Retrofit. Both reports were reported in Ho Chi Min City, Vietnam, and were officially announced as ISO documents. Prof. W. Kim suggested the formation of a formal process of an official system in approving AFC documents. Prof. Noguchi suggested division of the type of publications such as report/code and suggested to set up regulations for all ACF publications. Prof. Ueda and Prof. Park will work together with the formation of byelaws for publication.

7b. TG Activities (TG4, TG5, and TG6: Intermediate Reports)

Prof. Supartono reported on the activities of TG4 on Identification of Shrinkage and Creep of High Strength Concrete in Humid Tropical Weather. The research will take of approximately 2 years and it now has arrived at the end of the 2nd Stage out of 5 stages. Prof. Ueda reported on the activities of TG5 on Complete Set of Level 3 Documents for ACMC. It can be divided in to three parts: Design, Construction, and Maintenance. Prof. Noguchi reported on the activities of TG6 on Survey on Statistical Data of Constituent Materials and Production of Concrete in Asian Countries.

7c. Activities of ICCMC

Prof. Ueda reported on the activities of ICCMC. There has been an ICCMC Proposal for the Merger between the ACF and ICCMC. The ICCMC consists of 80 Individual Members and 10 Corporate Members. Prof. Sim commented he had no objection on the official proposal. Prof. Chan commented that the ACF and ICCMC should be merged in a proper manner. Prof. Sim concluded that to make it official, the decision will be made at the next GA and this discussion will be discussed after Prof. Ueda prepares an official proposal in the next EC meeting.

7d. Report of Promotional Session (Bangkok)

Prof. Sim reported on the ACF promotional session held at the 80th IABSE Anniversary.

8 Vice President Report (Policy Dept.)

9. Newsletter Updates

Prof. Jay Kim reported on the updates of the latest Newsletter. Also, Prof. Jay Kim reported on the future plans for the next Newsletters.

10. Discussions on Organization Management

10a. Budget Plan and Expenditure Items

Prof. Park reported on the Budget Plan and Expenditure Items. Prof. Sim noted that KCI is under consideration of changing its subcategory from B to A Prof. Sim also announced that the travel expense of the P & VP members will be supported by Korea's CMs for the 5th ACF EC meeting.

11. Planning on Next Meetings

11a. P & VP Meetings (Sapporo)

Prof. Ueda reported on the next P & VP Meeting held in Hokkaido University, Sapporo, possibly near end of June 2010.

11b. Promotional Session (CECAR)

CECAR 5 will be held from August 8~12, 2010, in Sydney, Australia. ACF promotional session will be planned.

11c. 6th EC Meeting in 2010 (Taipei)

The 6th EC Meeting will be held during the 4th ACF Conference on November 29 ~ December 1, 2010, in Taipei International Convention Center, Taipei, Taiwan.

11d. General Assembly (Taiwan)

The General Assembly will be held during the 4th ACF Conference on November 29 ~ December 1, 2010, in Taipei International Convention Center, Taipei, Taiwan

12. Update of the 4th ACF Conference

Prof. Chan reported on the 4th ACF Conference on November 29 ~ December 1, 2010, in Taipei International Convention Center, Taipei, Taiwan

13. Other Businesses

13a. ACF Environmental Declaration of Concrete

Prof. D. Choi reported on the ACF Environmental Declaration of Concrete. The formation of TG7 on the ACF Environmental Declaration of Concrete has been approved. TG7 will invite each RM members to be part of the group.

14. Future Activity Suggestions and Reports from JCI

Prof. Noguchi reported on the future activity suggestions and reports from JCI. Prof. Noguchi proposed to organize seminars co-sponsored by JCI and ACF. Prof. Noguchi will communicate by e-mail with the responsible person in detail and also decide on the sharing percentage of profit.

15. Adjournment

The meeting was adjourned by the President at 18:30, 8 Dec 2009.

What's ACF objective ?

- 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.

ACF Corporate Member (CM) Advertisements

SAMSUNG E&C

(082-C-00005)

Since 1978, in only 30 years after the start up of a mid-size company with $17 million in sales, Samsung E&C has become a world-wide construction firm that represents Korea with the world's best building techniques. And with 4 core businesses – architecture, plant, engineering, and housing – as a basis, Samsung E&C continues to grow through selective and concentrated management plans. Customer satisfaction and quality control are always the first priority. And through the outstanding execution of its material works as well as its management processes, Samsung E&C has raised its entire business structure to even higher standards. Samsung E&C will continue to excel as one of the world's top construction companies.

BUILDING WORKS

In the field of construction works, Samsung E&C takes pride in its many developments in high-tech construction engineering and in design optimization. Especially in the construction of today's towering skyscrapers, which require high-tech core technologies in structural design, optimization of installation systems, high strength concrete, etc. Furthermore, by having attained so many accomplishments in semiconductor clean rooms and other high-tech business facilities, business, airports, convention center, medical, education & research, leisure/distribution, hotel/housing and SOC related facilities, Samsung E&C has also attained the stature of being a top world-class competitor.

CIVIL WORKS

Samsung E&C is focused on the nation's infrastructure construction such as, roadways, bridges, tunnels, rail ways, ports, airports and dams, which will improve the quality of life for all Koreans. In addition, by taking part in infrastructure construction in the Middle East, South East Asia, and throughout the world, Samsung E&C also helps to raise the living standards for people throughout the world. As a major participant in large scale SOC businesses such as harbor and bridge construction, Samsung E&C has gained a competitive edge in large scale civil engineering projects. By recruiting and training the best in the engineering and construction fields, and expanding our investment in technological advancements, Samsung E&C continues in the efforts to secure the civil engineering industry's premier position.

PLANT WORKS

Samsung E&C is making great progress with projects in a variety of industries such as power plant, nuclear power plant, energy storage and transportation facilities, environmental facilities, etc. These undertakings require the highest levels of technology and construction precision and are of the utmost importance as they form the core for the power plant (EPC) and energy (EPC) construction industry's design, procurement, construction, maintenance, and repair. Samsung E&C will continue to make great strides forward as a global EPC contractor.

HOUSING WORKS

Samsung E&C leads in setting housing and cultural trends by introducing of a brand competition to the national housing market. With the introduction of the name branded apartments „Raemian' and with the construction of the first housing development that combines living quarters, commercial spaces, Tower Palace and Trapalace, Samsung E&C has set a new standard in building quality homes. Samsung E&C has established quality management and customer satisfaction as the basis of its business, and will raise its brand value through providing a variety of programs and benefits for clients.

Already a world famous global company that is trusted, respected, and admired, we will continue to develop innovative solutions to our increasingly crowded world, We will design and build healthy and comfortable living spaces for people, while protecting the environment for the generations to come. For this, we remain determined to always serve our clients with the highest principles, and ensure that each and every employee of Samsung E&C values the relationship with every single customer as being the most important. We will devote our efforts endlessly into creating a better world where human beings can coexist peaceably with each other and with the Earth itself.

Hyundai E&C

(082-C-00003)

HYUNDAI ENGINEERING & CONSTRUCTION

Since its inception in 1947, Hyundai E&C has been taking the leading role in the nation's development initiatives such as the post-war recovery during the 1950's and government-led growth policies during the 1970 are firmly positioning itself as industry bell-wether in Korea.

In this regard, the history of Hyundai E&C can be said to be that of the country's building industry.

In 2008, it posted record high results in contract awards, sales and earnings. In 2009, it was selected as the No. 1 builder in construction capabilities which are comprehensively assessed based on factors like project experience, financial position, technological ability and credit ratings.

The remarkable performance comes from the entrepreneurship of Chung Ju-yung, the late founder of Hyundai Group. At the heart of the entrepreneurship, ceaseless challenge and creative wisdom will continue to help Hyundai E&C make changes and innovations across the company, thus leading Hyundai E&C to become one of the world renowned companies.

Hyundai E&C consists of nine divisions : civil & environment division, division of building works, division of housing works, plant division, power & energy division, investment &business development division, domestic business division, overseas business division and management & corporate business division.

Currently, the construction industry has shifted its focus from labor-intensive works to technology intensive works that are combined with sophisticated finance and cutting-edge IT expertise. In these circumstances, Hyundai E&C will lead the shift in paradigm with relentless challenging spirit.

As a first step, Hyundai E&C will reorganize the company from top to bottom, getting it prepared to play a leading role in future building industry by reinforcing its competencies in design engineering, procurement, construction management and project management.

Hyundai E&C is managing the Institute of Technology & Quality Development and supporting engineers to conduct research and development initiatives for the construction sites around the world of Hyundai E&C.

Hyundai E&C's landmark Institute of Technology & Quality Development consists of three buildings: the Structural Engineering Laboratory building, Environment Building and Research Building. The Structural Engineering Laboratory which is used to test the performance of cutting-edge structures like super bridges. It has five labs for wind tunnels, concrete & asphalt materials, rock mechanics, soils and dredging. Also the Environment Building has six labs for acoustics, artificial climates, construction facilities, indoor air quality (IAQ), water quality & wastes and in-depth environmental analyses.

As the forerunner in low carbon green technology, Hyundai E&C will have all of our resources available to explore opportunities to develop renewable energy, such as nuclear power, desalination, wind, hydro, tidal, bio-energy, and solar power.

Hyundai E&C is developing technologies to help reach CO2 emission reduction levels which are rapidly becoming the bases for world-wide environmental regulations. For example, "carbon-zero ambient temperature asphalt mixture paving method" is an environmentally friendly construction method that can reduce CO2 emission levels by 0.52 million tons annually. Hyundai E&C are also focusing on the development of cutting-edge materials to replace cement which is a primary source of CO2 emissions.

In addition to being a leader in the development of core technologies for high-rise buildings and human resources training programs, the Institute specializes in the production of forward-looking technologies (including hybrid systems for "zero energy buildings" that utilize optimal element technologies and engineering and new and renewable energy) and such infrastructures as the Smart Grid. It is also working on technologies that produce bio gas and hydrogen from organic wastes, purify polluted soil and remove environmental hazards.

Working with its unparalleled technological capabilities, Hyundai E&C is constantly pursuing the commercialization and globalization of its R&D efforts and is committed to strengthening its competitiveness in the burgeoning future-oriented construction sector.

SAMBU Construction

(082-C-00009)

SAMBU CONSTRUCTION CO.,LTD.

Since its inception on 1948, SAMBU Construction Co., Ltd. has always been committed to executing projects faithfully and responsibly with artisanship, and has played a pivotal role in advancing the structure of Korea's construction industry with its abundant experience and know-how accumulated in diverse fields of works.

In particular, SAMBU demonstrated Korea's construction technological prowess by capturing the Gold Medal for Civil Engineering Construction for its successful completion of the Under-Riverbed Subway Tunnel Project at the 28th IFAWPCA Convention in Seoul. The technological scheme applied to the Under-Riverbed Subway Tunnel, shortening the construction period and lowering the cost, was the first of its kind in Korea. SAMBU's technological repute is not confined to the domestic market. The company has been involved in civil engineering, architecture, plant and various other works around the globe, including Saudi Arabia, Malaysia, Nepal and Pakistan, with a sense of accountability as Korea's representative contractor.

Vision of SAMBU

SAMBU engages in continuous self-assessment, research and setting new challenges to create a better space in the future, where man and the environment can coexist in perfect harmony. Through innovative and motivating management with Human-oriented, Customer-oriented and Technology- oriented, SAMBU has set a firm goal of becoming a world-class construction company in the 21st century. Creative Challenge Toward a Better Future!

Civil Works

BRIDGES

SAMBU has always followed only one path as a contractor. Careful Planning and responsible workmanship have earned SAMBU a reputation for reliability and experience. It successfully built the Hwangsan Bridge, Asia's longest ILM(Incremental Launching Method) bridge(1,050m), Geumnam Bridge, the nation's first-ever concrete box bridge, Baekje Bridge, based on he Well scheme, and Yeonyuk Bridge of Anheung Port,

TUNNELS

The technological know-how that SAMBU has accumulated in civil works is well evidenced in its expertise in building tunnels. In particular, the Han River Tunnel, the nation's first-ever under-riverbed tunnel(Yeoido Section #5-18), was awarded the Gold Medal for Civil Engineering Construction at the 28th IFAWPCA Convention in Seoul, as its new construction paradigm significantly reduced the construction period as well as the cost. The recognition by such a prestigious international forum was a confirmation of Korea's advanced level of engineering and construction technology. SAMBU's tradition of flawless construction has continued with the Yu River Oepal Bridge Tunnel, Sillim-Anyang Tunnel, Hamyang Tunnel, etc.

Architectural Works

OFFICE . COMMERCIAL BUILDINGS

SAMBU, Totally committed to stability and reliability, has followed a single path of an expert contractor for more than five decades. Its works ranging from towering high-rise office buildings to public facilities have impressed customers both at home and abroad. The MBF Finance Headquarters building, which changed the skyline of Malaysia, has been acclaimed as a masterpiece wrought by SAMBU's artisanship. The high-tech intelligent building with optimized IT business efficiency showcases the future-oriented, corporate ideals of SAMBU.

Housing

CONDOMINIUMS

Since it delved the condominiums construction business in Yeoido in the 1960s, SAMBU has built a reputation as the strongest condominiums contractor through steady efforts toward improvement in housing. SAMBU is now determined to take the lead in the nation's housing industry by supplying the so-called "cyber condominiums" equipped with high-tech communications facilities, quality finishing materials, nature-friendly landscape architecture and outstanding designs, befitting the information and high-tech era. SAMBU has accepted the challenge of providing the people a comfortable living environment that serves as a haven in this hectic, modern life. The pioneering and creative spirit that began with the construction of the SAMBU Condominiums buildings in Yeoido, Seoul, has been revived with the SAMBU Renaissance Condominiums. The creation of more fulfilling residential spaces through redevelopment and reconstruction has also contributed to a balanced urban development.

Plant Works

POWER PLANTS

SAMBU boasts of a long of building hydro, thermal and combined heat & power plants, as evidenced by the Yeongnam Thermal Power Plant, Bucheon Combined Heat and Power Plant, Sancheong Pumping-up Power Plant, North Jeju Thermal Power Plant, etc. SAMBU builds power plants with a solemn sense of mission, responsibility and artisanship. Drawing on its past experiences and expertise, SMABU is actively involved in power plant construction and is fully qualified participate in atomic power plant construction.

INDUSTRIAL PLANTS

SAMBU has long been involved in quality construction of the nation's major industrial facilities, including cement plants, iron & steel works, oil storage facilities, oil pipes, etc. It is also involved in heat-generating facilities, another important source of energy. Drawing on accumulated technologies, experiences and know-how, SAMBU is firmly resolved to take the lead in construction of industrial facilities both at home and abroad with faith, sincerity and incessant efforts.

Advertisement of the 4th ACF Conference

Conference Information

Date
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Venue
Taipei International Convention Center (TICC)
No.1, XinYi Road, Sec. 5, Taipei, Taiwan

Organized by
Taiwan Concrete Institute (TCI)
National Taiwan University (NTU)
National Taiwan University of Science and Technology (NTUST)
National Taiwan Ocean University (NTOU)

Hosted by
Asian Concrete Federation (ACF)

Official Language
The official language of the Conference is English.

Conference Secretariat
If you would like to be on our mailing list to receive the further information on the Conference, please email the Conference Secretariat with your contact information (Name, Affiliation, Mailing Address and E-mail)!

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Main Theme

- Ecology, Environment and Engineering
- Sustainable Construction
- Design and e –Concrete
- Code and Standards
- Life Cycle Management
- Repair, Maintenance and Rehabilitation
- Innovative Technology and Modern Management
- Mega Project and International Cooperation

Program Topics

- Engineering for Ecology and Environment
- Eco-cement, Eco-concrete, and Green Concrete
- Durability
- Supplementary Cementitious Materials
- RPC, ECC, and other Special Concrete
- Architectural Concrete and Esthetics

Taiwan, Taipei, Nov. 28 --Dec. 01 , 2010

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