In the years to come, Korea will have the privilege to become the country presenting the most diversified bridge construction activities that will constitute precious case studies for the international bridge community. Until 2011, about 50 major bridges with various types will link some of the 3,000 islands of the peninsula to the mainland, which are taking place in the ambitious plan for building an efficient national transportation network and set the bases for the future strategic hub of Northeast Asia. In order to sustain this unprecedented construction activity of infrastructure systems and the encouraging technological accomplishments that have been acquired to date, the Korean R&D community agreed with the necessity to prepare for the next generation of construction technology. There is a clear need to develop and construct a new generation of high performance facilities by means of enhanced materials, advanced structural systems and technologies as well as upgraded or improved specifications or standards in a lifetime perspective.

This paper identifies some major technical issues and challenges for the next generation of bridge and addresses relevant and systematic construction-related R&D programs in Korea. Among them, the Korea Bridge Design & Engineering Research Center (KBRC) has been launched in 2004 as a national research program of the Ministry of Construction and Transportation to be the core of new research and technology transfer program in the area of bridge technology and expedite the process of full transition to the reliability- and performance-based bridge design codes and specifications in Korea. Other large R&D programs are also reviewed in terms of durability and lifecycle cost with lifetime perspective like the Bridge 200 R&D project of the Korea Institute of Construction Technology and high-performance materials like the High Performance Construction Material Research Center (HIPER CONMAT).

1. INTRODUCTION

Civil engineering projects were the backbone of the development and economic growth of Korea since the industrialization boom of the 1970’s. Massive investments were made to develop social infrastructures including the transportation and road networks. New expressways were constructed, national roads were enlarged and expanded, and metropolitan road networks were readjusted, leading to the construction of numerous bridges.

As a result, during the 3 decades following the economic boom of 1970’s, the volume of road bridges in Korea increased rapidly from 9,322 bridges for a total length of 268 km in 1970 to 22,937 bridges for a total length of 1,987 km in 2006.

The construction of long-span bridges also continuously increased, starting with Namhae suspension bridge in 1973, followed by Jindo and Dolsan cable-stayed bridges in 1984, and the completion of the second Jindo Bridge in 2005. During this short period, bridge engineering in Korea has achieved outstanding advances that resulted in the recent erection of several remarkable suspension and cable-stayed bridges. In the single year 2000, 3 major cable-supported bridges representative of the remarkable progresses realized in Korea were constructed. These bridges are Gwanggan suspension bridge, currently the longest bridge in Korea, Youngjong Bridge, the first three-dimensional self-anchored suspension bridge in the world, and Seohae Bridge, the longest cable-stayed bridge in the country).

Korea has a very ambitious plan for building strong and efficient national transportation network facilities...
2. RECENT BRIDGE CONSTRUCTION ACTIVITIES IN KOREA

The bridge construction activity has been recently revitalized by the ambitious plan of the government to link some of the 3,000 islands of the peninsula to the mainland. Ongoing projects intend to link some major islands of the southwestern coast with the mainland with an investment of approximately $10 billion until 2010 for the sole Province of Jeollanamdo. Additional investments for the construction of bridges are also foreseen until 2025 to promote economical and social balanced regional development all over the peninsula (Fig. 1).

In a social point of view, about 90% of the 3,158 islands of Korea is concentrated in the southern and western coastal areas of the peninsula, of which most are inhabited and located within a distance of 1 km from the continent. However, the aging and emigration of the working population to big cities as well as the poor accessibility is accelerating the desertion of remote and provincial areas. In an economical point of view, the governmental plan intends also to respond to the necessity to prepare for the large potential of future tourism inflow through seashore road belts following the adoption of 5-days work week. The scenes offered by the southern and western coasts will be a very profitable source of revenue for these regions. Moreover, the construction of bridges will reduce significantly the large detours caused by the sawtooth coastline, and improve the accessibility and transportability of products fabricated in the neighboring industrial complexes.

The construction of bridges in the coastal areas is involved in the national amendment promulgated in August, 2001. This amendment assigns the extension and construction of national roads No. 2, 24, and 77 and includes more than 65 km only in the maritime sections including about 50 major bridges. National road No. 2 linking Shinan to Busan will be extended by 96 km to reach 483 km, and national road No. 24 linking Shinan and Ulsan by 4.7 km to reach 457 km. The longest project concerns national road No. 77, which will link Busan to Incheon passing through Mokpo involving a first investment of $7.7 billion. The latter will see its length extended to 1,117 km of which 652 km will be modified or adjusted (Fig. 1).

Fig. 2 illustrates Incheon Bridge, an offshore circular expressway with a total length of 12.343 km that will link Incheon International Airport to the new city of Songdo in the southern of Incheon South Port. Its construction began in October, 2004 and the bridge will be completed in October, 2009. The bridge has been designed to secure a navigation clearance of 715 m and overhead clearance of 74 m for the passage of shipping, and will rank at the 5th position among the longest cable-stayed bridges in the world.

Fig. 3 depicts the Busan-Geoje fixed link project
in the southeastern coast. The project will connect Geoje Island to Busan City via Gadeok Island and will create a U-type road network of 60 km that will replace the former 140 km. The new road network, which comprises 2 cable-stayed bridges (222 + 475 + 222 and 108 + 2@230 + 108) with H-shape towers and the first Korean immersed traffic tunnel (3.7 km), at a depth of 40 to 50 m, for a total length of 8.2 km, began in April, 2004 and will be completed in March, 2010.

 Particularly, the coastal area of the Province of Jeollanamdo has a length of 603 km studded with 1,965 islands for which the local government established road plans involving 102 sea-crossing bridges. Currently, 32 bridges have already been built and 21 are under construction and 48 under planning. Fig. 4 depicts the sea-belt road that will be constructed in the area of Goheung in the extension of road 19. This project will link the district of Goheung, the county of Hwayang and Dolsan Island by 11 bridges presenting diverse features as can be seen in Fig. 4\textsuperscript{1,3}.

Fig. 5 presents a rendering of 1545 Bridge of which construction started in 2008 and to be completed in 2012. This suspension bridge will have a central span length of 1545 m that will make it the 3rd longest bridge in the world. 1545 Bridge will connect the cities of Gwangyang and Yeosu that are located at both sides of Gwangyang Bay in the southern seashore. The superstructure will be a twin-box girder and the towers will rise at a height of 265 m. High-strength cables of 1860 MPa will be adopted to sustain the deck.

3. TECHNICAL ISSUES OF RECENT BRIDGE CONSTRUCTION

Recent bridge construction activities are mainly taking place in the coastal areas of the peninsula with a preference for cable-supported bridges\textsuperscript{2}. The locations and functions of these bridges made them subject to harsh environmental conditions like strong winds, typhoons, and higher salinity. Being also
The use of innovative materials is also a current trend in bridge construction. High performance materials are introduced to secure maintainability, durability and allow bridges to be more slender. These are high strength concrete like the example of Seonyu pedestrian bridge in Seoul, which is a simple span fixed concrete arch of 120 m made with ultra-high strength concrete, or high strength steel adopted for Youngjong Bridge.

Response-control techniques are becoming more common to secure safety and serviceability since the construction stage and all along the service life of the structure. Several examples can be found in the introduction of tuned mass dampers (TMD) in footbridges to improve the comfort of the pedestrians4).

Environmental preservation and aesthetics are also rising as important issues in the construction of bridges. The choice of materials like weathering steel in water resources protection area has been conducted with such concern about nature. After the industrialization period of 1970s, citizens become more sensitive to aesthetic features, especially in terms of harmony with landscape and cultural history. Typical examples can be found in the urban renewal project of Cheonggye Stream in Seoul, which restored a stream that has been buried in concrete during more than 40 years. The restoration project involved the construction of 21 new bridges that have been design to reflect the character of the neighborhood and to agree with Korean building patterns.

As was noted in the current features in recent bridge constructions, modern bridge structures must be smart and flexible enough to exhibit durability, reliability, adaptability and functionality as well as being aesthetically pleasing. As a bridge project is undertaken, planning and designing requirements on lifetime longevity require a perspective involving multi-disciplinary technologies and techniques. The needs for a universal set of design specifications and engineering technologies are also critical in establishing a unified transportation system.

The followings are major technical issues currently faced or to be faced by the Korean bridge community in the construction and design of bridge.

**Universal design specifications**

Despite of the needs and trend to build such new generation of bridges as defined above, many domestic bridge designers are still applying simple analyses based on classical methods. However, the behavioral characteristics of this new generation of bridges with longer spans and specialized features differ significantly from previous bridges. Since time dependent and nonlinear behaviors become dominant as design parameters, need is to set up measures to pre-view the transient behavior produced by the higher flexibility and vulnerability to external excitations. In addition, performing fatigue design strengthening of endurance, life cycle-cost (LCC) analysis arising as absolute prerequisites, such processes will constitute core technologies indispensable for the extension of the lifespan of the bridges of the next generation.

A result has already been achieved through the addition of an optimum design procedure for seismically isolated bridges based on LCC concept in the 2004 new version of the Korean Seismic Design Specifications of Highway Bridges. The new design concept adopts seismic fragility analysis to compute failure or damage probability of critical components considering low to moderate seismicity5).

Along with such researches, recognition of potentially devastating disruption of infrastructure systems, typically bridge structures, due to natural hazards such as typhoons and earthquakes, and man-made hazards through the exponential growth of the traffic volume has been emphasized through the growing seismic activities and increasing scale of the typhoons crossing the peninsula since the last decade6). Identification of the local characteristics of failure mode or limit-state due to these loadings represents thus a critical task in the development of consistent specifications or standards.

Reliability-based bridge design specifications should be developed under general consensus on the target level of reliability attributed to the structure and structural components. Most of advanced countries are or already have been transferring their bridge design concept onto limit-state or reliability-based design method. USA already recognized the need to reflect reliability-based design concept since 1986, and developed the AASHTO-LRFD Design Specifications, which are applied on all new bridges since 2007. Europe is currently unifying the Eurocode applying limit-state design method of which Eurocode 1, 2 and 4 are under implementation stage. Germany is also under transition stage to unify the German codes (DIN) to the Eurocode. UK applies its own bridge standards (BS5400), which adopt unilaterally the limit-state design.

The advancement of structural analysis methods is also critical to implement practical design. For example, numerous structures are recently using ultra-thick plate, but their design remains still performed by means of modified thin plate analysis, while more advanced analysis concepts should be employed. In addition, the development of various types of reliability assessment techniques or probabilistic analysis methods is a prerequisite to secure practicable reliability-
Durability

Korea like most advanced countries is seeing the maintenance costs of its bridge stock exceeding the construction costs of new bridges since a large portion of the current stock has been built during the industrialization period of 1970’s. A review of the bridge stock reveals that the lifespan of bridges in Korea reaches merely 30 years, that is about the half of the 50 to 75 years lifespan of bridges in advanced countries with 50 years in Japan, 70 years in UK and USA, 76 years in Sweden and 75 years in Finland. Regard to the bridge stock recorded in the late of 2006, this means that approximately 700 bridges have to be reconstructed or completely retrofitted yearly. It should be noted that the reduced lifespan of the domestic bridges is essentially due to functional defects, which are related to the reconstruction or retrofit of the bridges to respond to more strict design loads according to the tremendous increase of traffic\(^1\).

Such short lifespan induces direct construction costs rising to billions of dollars and leads to tremendous indirect social costs due to subsequent traffic congestion since, differently from the construction of new bridges, the reconstruction of existing bridges requires the installation of temporary facilities to secure traffic flow. In addition, since bridges are often constituting the unique access to isolated areas, the socio-economic consequences brought by the closure of the bridge to be reconstructed are incommensurable.

A review of the design life of recent major bridges is representative of this trend: 100 years for the Confederation Bridge in Canada, Youngjong Bridge and Seohae Bridge in Korea, Oresund Bridge linking Sweden and Denmark and Donghai Bridge in China, 120 years for Millau Viaduct in France, Vasco da Gama Bridge in Portugal and Rion Antirion Bridge in Greece, and a record of 200 years for Akashi Kaikyo Bridge in Japan\(^1\). A recent survey of the Precast/Prestressed Concrete Institute (PCI) also revealed that the most important feature selected by bridge designers and engineers is durability and long-life rate\(^6\).

Durability stands thus as a fundamental problem to be dealt with by structural engineers who are pursuing sustainability for their structures. Durability can be approached in several aspects from which material durability and structural durability can be seen as the major ones. Material durability is the ability of the material like concrete or steel to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different materials require different degrees of durability depending on the exposure environment and desired properties. Besides, structural durability stands for the ability of the structure to withstand the applied loads within the prescribed criteria of serviceability or comfort for the users.

This means that durability must be understood in terms of serviceability and maintenance for the extension of the service life and design life of bridge structures. Therefore, researches should provide long-term solutions through the use of high performance materials, response-control technology, relevant design specs, and rehabilitation and retrofit technologies.

Optimized structural systems

The exploitation of high performance materials such as high performance concrete and steel, FRP and FRC is now common in the construction and repair of bridge structures. The use of emerging new materials like FRP for the repair and rehabilitation of structures has been seen to result in significant cost-savings and more efficient construction with less traffic disruption. The use of high performance materials has also been seen to result in more slender structures with optimized cross-sections and reduce the amount of materials needed during construction. Requirements are thus the development of design and construction standards based on optimized materials, details and structures so as to take full advantage from these systems.

Structural systems shall be approached by understanding the advantages and limitations of traditional, newer and emerging materials in terms of safety, durability and economy. As a result, relevant structural systems can be developed exhibiting optimized materials, details, components and foundations that are able to exploit these newer optimized materials to assure safer structures with extended service life and minimum maintenance.

Accelerated construction

Annual costs for repair and retrofit of infrastructures have surpassed those of new construction in Korea. USA also faces such situation. The ASCE recently reported that to repair all deficient bridges it will cost in excess of $180 billion over the next 20 years, while poor roads are presently costing US drivers $54 billion annually in additional vehicle repair and operating costs.

Innovative construction and repair methods, materials and systems are needed to reduce on-site construction time while ensuring long-lasting structures. Bridge design enabling reduced construction period...
create structures exhibiting reliable and extended lifecycle.

Research shall thus be started to analyze and manage the huge volume of data collected through the numerous instrumented long-span bridges in operation. This will help to (1) gather information on the actual conditions of the bridges built according to the current design specifications that will enable to revise sometimes excessively conservative items, (2) enhance future SHM system and reduce significantly the costs and size of measurement instrumentation allowing the extension of its application to common bridges and, (3) promote more effective bridge monitoring improving the credibility of inspections and ratings through less subjective data and, allowing more rational maintenance schedule with optimized cost-savings \(^2\),\(^3\).

Management of knowledge

The development of all the aforementioned technologies will not have sense without recognition and understanding of all the parties involved from design, construction and maintenance of bridges.

The quality of the bridge depends on the speed of adoption of the latest technologies including codes. Each bridge is unique and its design and construction rely to a large extent on past experience, particularly in the case of long-span cable-supported bridges. Interactive sharing of knowledge being thus essential, cooperation and exchange between academia and industry, domestically as well as internationally, shall be promoted to enhance the practicability of these technologies. Ongoing dissemination and management of emerging technologies and bridge-engineering knowledge to the bridge community shall be addressed as fast as the advancement of new technologies. Therefore, in parallel with technological advancement, continuous education and communication consistent with industry needs shall be implemented.

4. CONSTRUCTION-RELATED TECHNOLOGY ROADMAP

It has been seen that unprecedented bridge construction projects are actually under way and remarkable technological accomplishments have been achieved in Korea. In order to support such enterprise and sustain the next generation of bridges to be constructed in the peninsula, the Korean R&D community agreed with the necessity to develop and construct a new generation of high performance facilities by means of enhanced materials, advanced structural systems and technologies as well as upgraded or improved specifications or standards in a lifetime perspective.

Accordingly, the Ministry of Land, Transport and
Maritime Affairs (MLTM) launched the “Program for 5 Years Plan for Construction Technology Innovation (2003~2007)” to strengthen and systematize R&D programs as well as improve R&D management system. According to the program, 25 technology roadmaps (TRM) for the innovation of construction technology were established by experts from academia, research institutes and various fields of construction industry with respect to 6 directions: (1) analysis and design technologies, (2) construction materials, (3) maintenance and productivity, (4) natural hazards and accidents, (5) environment-friendly energy-saving technology and, (6) space utilization. Medium to long-term TRMs were established according to the TRM of MLTM and other research-related institutes. The two following chapters address a review of major in-house and national R&D programs related to bridge engineering implemented in accordance with the TRM.

5. BRIDGE R&D ACTIVITIES IN KOREA: IN-HOUSE PROGRAMS

(1) Bridge 200 and Super Bridge 200 of Korea Institute of Construction Technology (KICT)

Bridge 200 was a comprehensive research project of KICT (2002~2006) intending to secure bridge technologies that extend the lifespan of bridge to 200 years and to develop ultra high-strength concrete exhibiting strength 5 times larger than current concretes through 5 key technologies related to the durability of concrete, development of high-durable structures, and reinforcement techniques of existing bridges. This project having been successfully completed in 2006, Super Bridge 200 has been launched in 2007 as a succeeding project involved in the top-brand projects of the Ministry of Sciences and Technology. Super Bridge 200 targets the development of bridge sustainable for 200 years by exploiting the so-developed ultra-high strength concrete to cable-stayed bridge structures. The expected outcomes are reduction of the maintenance costs by 20% and extension of the lifespan of the bridges by 200%. The technologies developed through Bridge 200 are briefly summarized.

(a) Long-life deck systems for bridges

Bridge deck is one of critical elements being the most exposed to potential damage among the major structural members. The average lifespan of the bridge decks in Korea runs around 13 years despite of the intended design lifetime of 30 years. This project achieved the extension of the actual lifespan of decks by more than 100% by developing various new types of decks like precast deck, steel-concrete composite deck, steel-free deck and FRP deck to replace former cast-in-place RC concrete decks.

(b) Strengthening methods for deteriorated concrete bridges

This project established constructable and cost-efficient strengthening techniques through enhanced load carrying capacity of the deck-girder-substructure system so as to improve lifespan and performance by more than 50% compared to conventional methods. The developed items are the establishment of bonded strengthening method, the development of unbonded strengthening method, wedge-type mechanical anchor for unbonded method, and near surface mounted reinforcing method.

(c) Technology for durable concrete bridges

This project developed low heat-high durable concrete, low shrinkage-low cracking concrete, high toughness concrete, innovative materials inhibiting degradation together with durability design method for concrete.

(d) Technology for durable bridge foundations

The number of collapsed small to medium-size bridges due to scouring during flood reaches annually an average of 100. This project established technologies that prevent efficiently scour and strengthen bridge foundations so as to extend the lifespan of foundations.

(e) Design methodology for durable bridge deck pavement

This project developed design technologies and high durable pavement materials considering the domestic climatic conditions, the moving vehicle characteristics, the structure of the bridge deck and material characteristics so as to extend the service life of bridge pavement, reduce pavement construction costs and increase the safety of the road. The major results are the development of serviceability assessment technique for pavement and technologies improving the durability of bridge pavement.

(2) TRM of Korea Expressway Corporation (KEC)

KEC, a public corporation established in 1969, is responsible for the construction, operation, repair and maintenance of the expressway network. Affiliated to KEC, the Highway Research Center (HRC) is a leading road research institute and is engaged in active research in 6 fields including traffic, road pavement, and infrastructure.

KEC and HRC also undertook medium to long-term TRM in 6 major domains, which are road design and survey, pavement, structures, tunnels and foundations, environment, and construction management. Among these programs, the TRM related to structure targets specifically technologies that will be of practical use to provide the next generation of bridges and includes no more than 10 development
projects. The first two projects, (1) long-duration concrete and (2) recycling of construction wastes focus on high-performance and nature-friendly materials technologies. The remaining 8 projects aim directly bridge construction technology also in a lifetime perspective. These are: (3) construction technology for the next generation of PSC bridges with optimized LCC, (4) construction and design technology for precast bridges, (5) construction technology for composite FRP bridges, (6) rationalization of limit-state design for bridges to replace allowable stress design, (7) construction and design technology for long-span bridges, (8) construction of bridges integrated with probabilistic and optimized LCC concepts, (9) design technology using high-performance steel materials for the next generation of bridges and (10) integration of advanced digital IT technologies in design and construction of bridges. KEC is also a participating member of Korea Bridge Design & Engineering Research Center, the core of new research and technology transfer program in the area of bridge technology, presented in the subsequent chapter.

6. NATIONAL RESEARCH PROGRAMS

In order to manage and evaluate comprehensively the numerous R&D programs of MLTM, the Korea Institute of Construction & Transportation Technology Evaluation and Planning (KICTEP) was launched on 2002. KICTEP is supporting the establishment of short and long-term R&D plans related to construction and transportation technology as well as their management and evaluation. The Institute also copes with technology transfer through the analysis and implementation of research results, marketing and the distribution and management of R&D projects.

The major R&D projects managed by KICTEP can be classified into 2 fields that are construction and transportation. In the transportation field, R&D are typically oriented toward urban transportation systems like urban rail transit systems, railroad safety, light rail transit system and high-speed railway, and comprise also the national transportation core technology R&D.

To pursue and increase the impact of the results of the aforementioned program, MLTM set up a new program called VC-10 (Value Creator-10) in 2006. VC-10 targets the creation of added values rising up to $40 billion until 2015 through 10 mega projects that are: U-Eco city, Ultra-high rise building system, Cubic urban renovation, Safe sustainable smart highway, Super high-speed railway KTX, Urban Maglev, Global top desalt system, Intelligent spatialization of land information, Certification technology of small to medium aircrafts, and Super-long-span bridge. Huge investment of $6.5 billion will be poured during 10 years and the programs will be operated in the form of R&BD (Research and Business Development).

In the case of the Super-long-span bridge program, detailed TRM is currently under preparation and it is expected that the program will be launched in a short delay according to the release of budget from the government. The main targets of this program are to develop sustainable technologies enabling the construction of cable-stayed bridges and suspension bridges longer than 1500 m and 3000 m, respectively.

Major long-term national R&D programs related to the advancement of bridge design and engineering technologies are reviewed.

(1) Korea Construction Engineering Development Collaboratory Program (KOCED)

KOCED was launched in 2004 to establish a comprehensive base for construction-related testing, research and education. The program has been developed to overcome difficulties induced by the lack of large-scale testing facilities that are prerequisite for the advancement of state-of-the-arts technologies in civil engineering. The program was inspired by the NEES program in USA but instead of being limited to earthquake engineering, it encompasses the entire civil engineering field.

The “collaboratory” concept has been adopted to build economically the 12 large-scale research facilities planned in the program. Six of them that are the hybrid structure test, wind tunnel, marine environment simulation, centrifuge test, advanced construction material test and multi-support shaking table test laboratories, are currently under construction in major universities all over the country and will be connected using high performance information network integrated into a grid system (Fig. 6). This grid architecture using leading information technology will also integrate high-performance computing facility and digital data repository to gather the facilities functions and make them working as a single
laboratory, i.e. collaboratory.

(2) Korea Wind Engineering Research Center (KWERC)

KWERC was established in July of 2005 at Mokpo National University as a research program involved in the Regionally Characterized Construction Technology R&D Project according to the TRM of MLTM. The objectives of the Center are to develop key technologies related to wind engineering for the bridge construction projects undertaken in the southwestern coast of the peninsula, develop technologies to reduce wind-induced disasters in the southwestern coastal area and establish relevant prevention system during the 5 years of the program. KWERC is a unique program in that it is targeting wind engineering essentially for cable-supported bridge structures. The Center also intends to promote its activities through collaboration with the Boundary Layer Wind Tunnel Laboratory of the University of Western Ontario in Canada.

(3) High Performance Construction Material Research Center (HIPER CONMAT)

HIPER-CONMAT is a new-born research center established at the Research Institute of Industrial Science and Technology (RIST) in the form of a research institute-industry cooperative program extending for a period of 5 years. The Center together with KBRC are involved in the Construction Core Technology R&D Projects established according to the TRM of MLTM.

The vision of the center is summarized by the term BEST, standing for Beautiful, Economical, Sustainable, Totalized Infrastructure.

Since technologies exploiting high performance construction materials are the most effective and basic means to construct, repair and maintain high quality social infrastructures with economical efficiency, this program intends to develop materials and corresponding applications for 3 fields of construction materials that are high performance steel, FRP/FRC and innovative materials for the creation of new space (Fig. 7).

An itemization of the goals can be done through the 3 fields mentioned above: development of high performance steel of 500, 600 and 800 MPa and corresponding application technologies on infrastructures; implementation of hybrid bridge system exhibiting high performance, accelerated construction and reduced LCC through the exploitation of FRP/FRC; development of recyclable, nature-friendly and high performance construction materials for the creation of new space and corresponding application technologies.

(4) Korea Bridge Design & Engineering Research Center (KBRC)

KBRC, currently in the last year of its program, was established at Seoul National University through a national research program launched in 2004 by MLTM according to the long-term TRM for the advancement of bridge technology. A total of 413 researchers and engineers, including 60 professors from 35 universities and institutes, are participating in the Center. Twenty-six companies, KICT and KEC are also joining in this industry-university cooperative program.

KBRC in partnership with industry, academia and research institutes aims to develop and implement more durable, economical and safer bridge structures. The products of the program will be intelligent bridges of the next generation that last longer in a lifetime perspective and have lower maintenance demands or maintenance free bridges in harmony with innovative and advanced technologies, and ecological requirements. Another outcome of the program will be the establishment of reliability-based code and standards in accordance with the international codes. The ambition of the KBRC is to bring Korea into the top-ranking of the bridge-builder nations in the near future through such advanced analysis and design technologies.

a) Objectives of KBRC with a lifetime perspective

The rapid evolution of computational structural analysis together with the rise of IT technology made it possible to perform more complex computation for bridge structures. In addition, high performance and high strength materials also begin to take larger place in the construction of bridges. The combination of such various technologies allowed the construction of longer span bridges since the late of the last century with records of lengths approaching 2,000 meters. One can predict that this tendency will continue in the years to come to create a new generation of bridges that will break records of length and longevity.

The next generation of bridge will present extended lifetime with resilient and long-term perfor-
Fig.8 Features of the next generation of bridge technology with a lifetime perspective.

Fig.9 Strategic objectives of KBRC.

mance, provide optimized structural efficiency and cost-effectiveness all along its life-cycle, and combine high-performance materials with innovative construction and design methods. Therefore, performance objectives and priorities to be met are: reliability-based design together with aesthetic design considering ecological constraints; shortened construction time; extended lifetime with reduced LCC, at the most, maintenance free management; immunity against natural or accidental hazards; functional adaptability; and nature-friendly materials recyclable after decommissioning (Fig. 8).

In order to prepare for the next generation of bridge technology, the Center has set five strategic objectives, which are (1) establishment of advanced analysis methods and design technology, (2) development of reliability-based bridge design codes and specifications, (3) development of sustainable bridge design technology based on a lifetime perspective, (4) innovation of bridge design technology integrating leading technologies such as IT and (5) promotion of international exchange and collaboration program, as illustrated in Fig. 9.

b) Summary of research directions in KBRC

Significant progresses in detailed and advanced 3-dimensional analysis have already been and are continuously realized by the domestic researchers, especially in the domain of structural analysis methods considering all types of nonlinearities and construction stages. Complicated dynamic analysis under the action of traffic loads, earthquake and wind, and response control analysis are now common in the research sector. However, the process of putting research outcomes into practice still remains tremendous task. Most of field engineers still continue to apply linear or simplified structural analysis due to the lack of collaboration with academia and research sector, and such gap often results in inappropriate solutions during the design and analysis of large-scale or special bridges.

Therefore, advanced analysis and design technologies are currently developed and being implemented for long-span bridge systems including cable-supported bridges\(^7,8,9\). The development of analysis tools highly dedicated to special topics such as probabilistic analysis of fatigue cracking in structural design\(^10\) and detailed analysis of ultra-thick plate structures are also implemented to fulfill the needs of engineers on field. KBRC intends to encourage the development of such powerful advanced analysis and design methods so as to reduce the gap between research and practice, and establish technology transfer program to form experts and widespread advanced analysis and design technology to engineering consultants. Through such program, it will be possible to put the research outcomes into practice, which in turn will activate relevant researches. In this loop, the Center will play an essential role by providing the engineer the analysis and design tools he needs and furnishing research guidelines to the developers.

Major leading countries in construction technology have progressively introduced reliability-based or limit-state bridge design codes and specifications like the AASHTO-LRFD specifications in USA and Eurocode in Europe. Due to the globalization of the construction market and the rationality and consistency of the reliability-based design concept, the Center focuses on the research for the transition of current Korean bridge design codes into reliability-based ones\(^11\).

The Center will propose a final draft for the reliability-based bridge design codes in 2008. The proposal of reliability-based design specifications is expected to provide the bases to prepare for the opening of the construction market and help us to find market overseas. In order to help and promote the future adoption and widespread of these new specifications, the Center started ongoing educational programs to the engineers and designers since 2006.

The Center also promotes researches on new sensing techniques using leading technologies like IT and, activate and develop applications of the SBBMS to a large panel of representative bridges in order to obtain database for future constructions and produce maintenance free bridges. Results obtained through such
monitoring will help the development of design technology integrating LCC concept.

Also in such lifetime perspective, structural response control algorithms related to wind, traffic, earthquake and other dynamic loadings have been developed and have already found limited applications. The transition of such technological and theoretical knowledge to systematic practical applications will indeed extend the life-cycle, reduce or optimize LCC in a long-term, increase the reliability and durability of the bridge system.

Digital technologies are already massively applied for design in the construction sector. Apart from sensing technologies, the exploitation of IT or CAD resources is no more marginal in structural design, construction processes and execution and management of design drawings. Works to implement global design standards are also carried out to create design information for the domestic highway bridges\(^{(12)}\). This will help to manage the whole construction and design process optimally, like the management of on-shore and off-shore construction processes in the new bridges of the coastal areas.

The next step fixed by the Center is to promote the advancement of modeling and analysis through the integration of various leading technologies such as IT and communication technologies. Information technologies adopting GPS, GIS, RS or LBS will help to realize integrated management of bridges in a lifetime perspective. Other advanced fields, like new materials, structural response control technologies, LCC and value engineering are continuously developed and will soon find practical use in a large scale. SHM with advanced sensors such as MEMS-based sensors and wireless sensing techniques are also examples of research area for the innovation of bridge design technology integrating leading technologies. The integration of such technologies since the design stage also constitutes a major objective of the KBRC.

7. CONCLUSIONS

In the years to come, bridge design and maintenance will be driven by requirements to keep traffic moving, increase capacity and reduce delays, respect ecological exigencies and keep both initial and long-term costs as low as possible. Therefore, in the future, creating sustainable and maintenance free bridges will be the foremost and exciting challenge bridge designers and engineers will face.

This paper presented an overview of bridge related activities in Korea, including construction projects as well as national and in-house research programs aiming the integration of LCC and lifetime performance for the next generation of bridge design and maintenance. Past and current experiences of the Korean bridge engineering community have been reviewed to highlight technical issues of bridge construction from which challenges for the next generation of bridge technology has been derived. Accordingly, ambitious programs have been launched and are taking place in a context of unprecedented bridge construction projects and technological accomplishments.

Focus has been done especially on KBRC involved in a long-term TRM for the advancement of bridge technology established in 2003 by the MLTM, which will be the core of new research and technology transfer program in the area of bridge technology. The Center intends to innovate for the next generation of bridge by integrating leading technologies of diversified fields such as IT, develop sustainable bridge technology optimized with lifetime perspective and promote the transition of design process to reliability and performance-based bridge design codes and specifications in Korea. Globalization being a leitmotif in the new century, KBRC is leading researches for global standards and attaches particular importance on international collaboration and exchanges.

Future R&D programs have also been briefly introduced. Among them, the program of MLTM dedicated to long-span cable-supported bridges involved in the program VC-10 is under planning in order to develop sustainable technologies and promote technology fusion for long-span bridges of the next generation.

ACKNOWLEDGMENT: This work is part of a research of the Korea Bridge Design & Engineering Research Center (KBRC) at Seoul National University. KBRC is supported by the Korea Ministry of Land, Transport and Maritime Affairs through the Korea Institute of Construction & Transportation Technology Evaluation and Planning (KICTEP).

REFERENCES

1) Koh, H. M. : Recent research and development of bridge technology in Korea, Proc. of Intern. Symposium on Sea-Crossing Long-Span Bridges, Invited Lecture, Korean Group of IABSE, Mokpo, Korea, pp. 81–101, February 15–17, 2006.

2) Koh, H. M. and Choo, J. F. : Preparing for the future: National research programs for the next generation of bridge design and maintenance in Korea, Second Intern. Conf. on Bridge Maintenance, Safety and Management, IABMAS '04, Kyoto, Japan, October 18–22, 2004.

3) Koh, H. M. and Choo, J. F. : Advanced bridge research and monitoring activities in Korea, SAMCO Summer Academy 2005, Invited Lecture, Zell am See, Austria, September 5–9, 2005.

4) Koh, H. M., Park, W., Choo, J. F., Ha, D. H., Kim, Y. S., Joo, S. J. and Seo J. W. : State-of-the-art on application, R&D and design rules for seismic isolation and energy dissipation for civil structures in Korea,
State-of-the-art, 9th World Seminar on Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures, Kobe, Japan, June 13–16, 2005.

5) Koh, H. M. and Hahn, D. : Risk-based optimum design of seismically isolated bridges in a region of low to moderate seismicity, IABSE Symposium, Structures and Extreme Events, Lisbon, Portugal, pp. 170–172, September 14–17, 2005.

6) Roads & Bridges : Durability, long life are most important characteristics of a bridge, April 19, 2004.

7) Kim, N. I., Kwon, S. D., Kim, H. K. and Kim, M. Y : Free torsional behavior of suspension bridges considering warping-torsional shear effects, J. Steel Structures, Vol. 5, pp. 119–132, 2005.

8) Kyung, Y. S., Kim, M. Y. and Chang, S. P : Determination of effective buckling lengths of cable-supported bridges using inelastic system buckling analysis, J. Korean Soc. of Civil Engineers, Vol. 25 (4A), pp. 627–636, July 2005.

9) Park, K. S., Koh, H. M., Ok, S. Y. and Seo, C. W. : Fuzzy supervisory control of earthquake-excited cable-stayed bridges, J. Engng. Structures, Vol. 27, pp. 1086–1100, 2005.

10) Kang, S. C., Seo, J. K., Koh, H. M. and Park, K. S. : Fatigue reliability evaluation of steel-composite high-speed railway bridge with tuned mass damper, J. Earthquake Engng. Soc. of Korea, Vol. 9 (45), pp. 1–10, October 2005.

11) Shin, D. K., Park, Y. S. and Chung, T. J. : Reliability-based calibration of dynamic load allowance, J. Korean Soc. of Civil Engineers, Vol. 25 (3A), pp. 545–553, May 2005.

12) Lee, S. H., Jeong, Y. S. and Kim, B. G. : Sharing of steel bridge information using CAD system with ACIS solid modeler, J. Korean Soc. of Civil Engineers, Vol. 25 (4A), pp. 677–687, July 2005.

(Received May 23, 2006)