Infrastructure Renewal and Management Research in Taiwan

Tony C. Liu[1] and Jenn-Chuan Chern[2]

ABSTRACT

Infrastructure is the underlying foundation of national economy and public quality of life. In the past 50 years, Taiwan invested heavily in dams, freeways, airports, rapid mass transit systems, and high-speed railways. Many of these infrastructure systems are now approaching or exceeding their design life. In addition, excessive demand, severe natural environment (i.e., frequent earthquakes and typhoons), misuse, inadequate maintenance, and poor management policy and practices take their toll. In 1999 Ji-Ji earthquake and recent major floods and landslides caused by typhoons illustrated the fragility of Taiwan's infrastructure. Therefore, there is an urgent need to renew and to extend the service life of these infrastructure systems and to enhance infrastructure management systems in Taiwan. It is obvious that we must move quickly to put existing knowledge about repair and rehabilitation of public works facilities to work and generate new and innovative technology through comprehensive and holistic research.

This paper proposes some broad-based, multidisciplinary research areas, including evaluation tools and modeling technologies, new repair materials and systems, field process technologies, management systems, and technology transfer plan for infrastructure renewal and management in the hope that it will provide a catalyst that encourages a major national investment in infrastructure renewal and management research that is critical to Taiwan's sustainable economic development and national competitiveness.

Keywords: Infrastructure, management system, nondestructive testing, rehabilitation, repair, sustainable development, technology transfer

INTRODUCTION

Infrastructure is the underlying foundation of a national economy and public quality of life. In the past 50 years, Taiwan invested heavily in dams, freeways, airports, rapid mass transit systems, and high-speed railways. (Figure 1)

Figure 1 Examples of Infrastructure Investments in Taiwan

Many of these infrastructure systems are now approaching or exceeding their design life. In addition, excessive demand, severe natural environment (i.e., frequent earthquakes and typhoons), misuse, inadequate maintenance, and poor management policy and practices take their toll. In 1999 Ji-Ji earthquake and recent major floods and landslides caused by typhoons illustrated the fragility of Taiwan's infrastructure. Therefore, there is an urgent need to renew and to extend the service life of these infrastructure systems and to enhance infrastructure management systems in Taiwan. It is obvious that we must move quickly to put existing knowledge about repair and rehabilitation of constructed facilities to work and generate new and innovative technology through comprehensive and holistic research and implementation plans.

Although Taiwan's National Science Council and many public agencies have been funding infrastructure evaluation and repair research, these R&D activities are fragmented, narrowly focused, and suffer from lack of a well-organized and focused strategy to implement the research results. A continuing under-investment in infrastructure renewal related R&D and a reluctance to address long-term goals have resulted in limited and questionable benefits.

This paper presents some broad-based, multidisciplinary research areas for infrastructure renewal and management in the hope that it will provide a catalyst that encourages a major national investment in infrastructure renewal and management research (Reference 1) that is critical to Taiwan's future economic progress and national competitiveness.

RECOMMENDED RESEARCH AREAS

EVALUATION TOOLS AND MODELING TECHNOLOGIES

A major problem in repairing and rehabilitation of infrastructure is inability to assess accurately the causes of deterioration and its state of health. Current methods for assessing constructed facilities are relatively primitive and unreliable. Research needs in this area include deterioration science and damage processes, improved forensic analysis methods, improved nondestructive techniques, long-term health monitoring, advanced instrumentation, optical fiber-based sensor technology, wireless sensor network technology, prediction of service life, risk assessment methodology, and artificial intelligence.

The research is also needed for developing performance-based durability design code that may include numerical modeling and accelerated laboratory test methods specifically devoted for predicting degradation of concrete structures subjected to various aggressive chemicals (e.g., chlorides, sulfates, etc) and loading. In addition, application-specific models must be developed for the repair industry. Some areas needing research include: life-cycle cost modeling for alternative repair materials and methods and expert system for condition evaluation and for repair technologies.

NEW REPAIR MATERIALS AND SYSTEMS

Durability of infrastructure repair and rehabilitation, to a large degree, depends on the correct selection and use of repair materials. Selection of repair materials requires an understanding of material performance in anticipated service and exposure conditions. At present, there is little information on the durability of repair systems and the choice of material is made largely on manufacturer provided information that is often misleading and incomplete. Research on durability of repair systems will improve the selection of materials and will result in repairs being carried out more efficiently. Since each of the broad categories of repair materials has a wide variation of properties, research on the development of performance criteria on broad categories of repair materials will provide valuable basic information on the parameters controlling durability (Reference 2).

Because nonmetallic reinforcements (fiber-reinforced plastic, FRP) have come on the scene more recently than traditional steels, the use of these materials has been hampered by the lack of standard test methods, specifications, and design guides. There is a pressing need for attention to these issues before non-metallic reinforcements can achieve full potential as repair materials. Other research opportunities include self-repairing (damage insensitive) materials, smart materials and systems, engineered cementitious composites

(ECC), nano-materials for repair applications, and new automatic systems for strengthening materials.

FIELD PROCESS TECHNOLOGIES

Perhaps the most important area of research in the infrastructure renewal arena involves field process technologies. Repair techniques that work in the laboratory quite often do not scale up to the field for the most basic reasons, including restricted access to the repair area, general site conditions, power requirements, safety considerations, and non-availability of skilled technicians. Understanding a repair method or having an advanced technology available is of little use if a repair cannot be physically and economically achieved in the field. Research is warranted to overcome those site problems and to produce field-expedient repair technologies. Research in these areas may include: practical and field-expedient corrosion-protection technologies, mitigation of alkali-silica reactivity in existing structures, corrosion-canceling technologies (Reference 3), laser techniques for non-impact methods of demolition, robotic technology for construction and repair of structures. In addition, detailed application guidance that clearly establishes the limitations and long-term effectiveness of various repair techniques is needed.

MANAGEMENT SYSTEMS FOR EXISTING INFRASTRUCTURE

Infrastructure management involves political, social, environmental, economic elements as well as technical elements. The elected officials are often reluctant to support infrastructure renewal projects because of high and uncertain direct cost, budget constraint, and less political incentives. These situations can lead to inadequate maintenance of existing infrastructure systems, over-investment in inefficient new systems, inability to achieve the best use of existing facilities, and lack of appropriate and timely information for decision making. Current management systems (e.g., planning, budgeting, execution, and evaluation, etc) in Taiwan are primarily for new projects and the management systems for existing infrastructure are inadequate or non-existence especially in the rural public works agencies. For example, some rural public works agencies have very limited or no funds are budgeted for periodic safety inspection, maintenance, and repair of bridges and roads under their jurisdiction. Consequently, some of these public works facilities in the rural regions have been poorly maintained.

To ensure infrastructure safety and operational adequacy, comprehensive national infrastructure management system must be developed. This infrastructure management system should include, but not be limited to, appropriate policies and regulations for planning, prioritizing, budgeting, and performance monitoring and evaluation requirements for existing infrastructure, the development of a comprehensive internet-based national public works database system. This database system may include infrastructure inventories, condition assessment, maintenance records, and a variety of other items that provides appropriate and timely information for decision making. Total life-cycle costs principle rather than on those of capital investment costs alone will help to avoid biases favoring new infrastructure investment over operational improvements of existing infrastructure.

The recommended infrastructure renewal research needs are summarized in Table 1.

TECHNOLOGY TRANSFER AND IMPLEMENTATION PLAN

There will be no effective improvement in the nation's infrastructure if the research projects remain in the laboratories or are restricted to the text of a report that stays on the bookshelves. The proposed infrastructure research program must include the following measures to facilitate the implementation of the research program.

1. DEVELOP AN INTEGRATED KNOWLEDGE SYSTEM

Large amount of information already exist relating to repair and rehabilitation activities. This information is a result of both research and field experience gained in day-to-day work. Unfortunately, this information is mostly fragmented, scattered, and unevaluated. Because there is no systematic means for bringing such useful information together and making it available to the users, full advantage is frequently not taken of what has been previously learned in seeking solutions to current problems. Consequently, costly research findings go unused and valuable experience is overlooked. To correct this situation, a continuing effort to search out and synthesize useful information from all possible sources should be initiated. To aid in information retrieval and analysis, an integrated knowledge system (e.g., a computerized database) for repair and rehabilitation must be planned, built, and maintained at a national level.

2. IDENTIFICATION OF RELEVANT FOREIGN DEVELOPMENTS

Significant advancements in repair and rehabilitation research and technology have occurred in foreign countries, notably in the United States, Japan, Canada, Germany, and the United Kingdom. We must ensure that knowledge of foreign developments is regularly obtained and disseminated. Such a commitment will avoid redundant research and permit our researchers to sustain an active dialogue with their foreign counterparts. Accordingly, a national technical clearinghouse should be established to collect, review, analyze, publish, and distribute relevant information on repair and rehabilitation of constructed facilities.

3. TECHNICAL EDUCATION AND TRAINING OF ENGINEERS AND CONTRACTORS

The potential benefits of this infrastructure renewal and management research areas cannot be realized without a knowledgeable workforce. Regularly scheduled training courses and workshops should be conducted for engineers and contractors in the repair industry. The educational system must keep pace with the new knowledge being generated and pass the information on to engineers and contractors. Curricula and training materials must be regularly updated to reflect the changing knowledge base. These training materials should be targeted for use in academic and vocational programs to ensure that the work force will be able to apply the new and innovation technology in all phases of repair and rehabilitation activities.

4. PROTOTYPE DEMONSTRATION PROJECTS

A key element of the infrastructure research is prototype demonstration and evaluation projects, documenting the real-world benefits of using the new and innovative repair technology and systems (Reference 4). The demonstration projects will be in a wide range of applications, including bridges, buildings, dams, port facilities, and other constructed facilities. Active participation by the government and public works agencies is essential to the success of prototype demonstration projects.

5. DEVELOP INTERNATIONAL COOPERATION AND PARTNERSHIP

Some research and development studies related to infrastructure renewal and management have been or are being conducted in many foreign countries. International cooperation and partnership with these countries should be pursued.

CONCLUSIONS

1. There is an urgent need to renew and to extend the service life of the infrastructure systems and to enhance infrastructure management systems in Taiwan. Major national investment in infrastructure renewal and management research is critical to Taiwan's sustainable economic development and national competitiveness.
2. The broad-based, multidisciplinary research areas for infrastructure renewal and management are proposed. They include evaluation tools and modeling technologies, new repair materials and systems, field process technologies, and management systems for existing infrastructure.
3. The technology transfer and implementation plans are important components of the infrastructure research. The proposed technology transfer and implementation plans include development of integrated knowledge system, identification of relevant foreign developments, technical education and training of engineers and contractors, prototype demonstration projects, and international cooperation and partnership.

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Table 1. The Recommended Infrastructure Renewal Research Needs

Evaluation Tools and Modeling Technologies	● Deterioration science and damage processes ● Improved forensic analysis methods ● Improved nondestructive testing techniques ● Long-term health monitoring of structures ● Advanced instrumentation ● Optical fiber-based sensor technology ● Wireless sensor network technology ● Prediction of service life ● Risk assessment methodology ● Artificial intelligence ● Life-cycle cost model for alternative repair methods ● Expert-system modeling ● Performance-based durability design
New Repair Materials and Systems	● Durability of repair systems ● New repair materials and applications techniques ● Performance criteria for repair materials ● Self-repairing (damage-insensitive) concrete ● Non-metallic reinforcements (FRP) ● Smart materials and systems ● Engineered cementitious composites (ECC) ● Nano-materials for repair applications ● New automatic systems for strengthening materials
Field Process Technologies	● Field-expedient corrosion protection technologies ● Mitigation of alkali-silica reactivity in existing structures ● Corrosion-canceling technologies ● Laser techniques for non-impact methods of demolition ● Robotic technology for construction and repair of structures ● Field guidance on existing repair techniques

Table 1. The Recommended Infrastructure Renewal Research Needs (Cont'd)

Management Systems	● Internet-based database system (including inventories, condition assessment, maintenance records and other items) ● Improved policies and regulations on planning, prioritizing, budgeting, performance monitoring, and evaluation requirement for existing infrastructure ● Life-cycle cost minimization principles