Preface

With the rapid consumption of more and more resources, the quality of energy stored in resources decreases to cause the relentless increase in entropy on the earth. Due to material performance, degeneration and external action failures are inevitable during the service of structures. Material and structure system sinks into a crisis of entropy increment, i.e., availability loss. With the advance of science and technology and the upgrading of social demand, materials have been driven to further develop toward material/structure integration, structure/function integration, and multifunctionality/intelligence integration for defusing this crisis. Smart and multifunctional material is an area of technology that is integrated with sensing and actuation functionality, and those functions are combined with control elements. It usually has one or more properties which can be changed in a controlled fashion by external stimuli, such as stress, temperature, moisture, pH, electric or magnetic fields. Depending on the changes in external conditions, smart and multifunctional materials can change either their properties (mechanical, electrical, appearance), structure, composition, or their functions. They therefore possess strong and effective capability to control entropy for adapting external environment and avoiding availability reduction. Many new applications of smart and multifunctional material technology have been found in civil infrastructures, and they represent an emerging research field. These applications include condition/health monitoring, damage assessment, structural control, structural repair and maintenance, integrity assessment and more recently asset management, preservation, and operation of civil infrastructures. The relative technologies possess many potential benefits such as improved infrastructure reliability and longevity, enhanced structural performance and durability, improved safety against natural hazards and vibrations, and reduced life cycle costs in operating and managing civil infrastructures.

Concrete is the most widely used material for infrastructures because it has excellent mechanical strength and is resistant to water, easily formed into various shapes and sizes, and cheap and readily available everywhere. Twice as much concrete is used in infrastructures around the world as the total of all other building materials, including wood, steel, plastic, and aluminum. Production and application of concrete have significant impact on resources, energy, and environment. Although the production of concrete binder (e.g., cement, asphalt) needs intensive energy, concrete has more excellent ecological profile than other construction materials such as metal, glass, and polymers. Compared with other construction materials, the production of concrete consumes the least amount of materials and energy, produces the least amount of harmful by-products, and causes the least amount of damage to environment. Concrete is a responsible choice for sustainable development. In the foreseeable future, concrete will continue to play an important role in infrastructure construction. However, the development of concrete is encountering enormous problems and challenges. (1) Binder manufacturing has a direct and visible negative impact on the world's resources, energy consumption, and environment. For example, making 1 ton of cement requires about 2 tons of raw material (limestone and shale); consumes about 4 GJ of energy in electricity, process heat, and transport (energy equivalent to 131 cubic meters of natural gas); and produces approximately 1 ton of CO_2, about 3 kg of NO_X (an air contaminant that contributes to ground-level smog), and about 0.4 kg of PM10 (an airborne particulate matter harmful to respiratory tract when inhaled). (2) Increasing attention has been paid to security of infrastructures since concrete is a brittle material and it usually works with cracks. (3) The durability of infrastructures becomes an increasingly important issue. Due to the degeneration of concrete materials, complex interaction between concrete materials and their service environment, absence of advanced design and condition assessment tools, and timely maintenance, many concrete structures are in a state of utter disrepair. It is therefore needed to render the failing infrastructures back to a serviceable and safe state. (4) Concrete belongs to a primary and complex composite in nature. The behaviors of concrete during the life cycle should be able to be controlled through mass, energy, or information exchange with external environment. (5) Multifunctional and smart concrete is required since traditional concrete just serving as structural materials cannot meet the upgrading requirement in terms of safety, longevity, and function of advanced engineering infrastructures. (6) The complex composition and structure of concrete has not been completely understood yet, which limits the utility and predictability of concrete in critical applications, but offers opportunities for formulation of additional control. Smart and multifunctional concrete provides a suite of capabilities to address these unmet needs in the infrastructure field, by developing materials with improved performance, better durability, and reduced environmental impact.

Smart and multifunctional concrete is an intelligent system with properties different from those of conventional concrete, such as self-sensing, self-healing, electrically conductive, thermal, and electromagnetic properties, or the ability to react upon an external stimulus, such as stress and temperature. The "smartness and multifunction" of concrete is achieved through material composition design, special processing, introduction of other functional components, or modification of microstructure. The basic principle of smart and multifunctional concrete is based on biomimetic design, and multiscale and multicomponent compositization. The concept of smart and multifunctional concrete was developed in the late 1980s.

In the past nearly four decades, much work has been done on the development and deployment of smart and multifunctional concrete. This book provide a summary report on current researches on smart and multifunctional concrete to help people working on this particular aspect to their job better.

This book covers theory, techniques, and applications of smart and multifunctional concrete containing its design, fabrication and processing, test and characterization, properties and their control method, mechanisms and models, application in infrastructures, and future development. This book is organized as shown below. The first part provides a general introduction to the smart and multifunctional concrete (Chap. 1). The second part presents some specific smart or multifunctional concrete involving self-compacting concrete (Chap. 2), self-expanding concrete (Chap. 3), self-curing concrete (Chap. 4), self-shaping concrete (Chap. 5), self-sensing concrete (Chap. 6), self-healing concrete (Chap. 7), self-adjusting concrete (Chap. 8), damping concrete (Chap. 9), anti-spalling concrete (Chap. 10), wear resisting concrete (Chap. 11), aircraft arresting concrete (Chap. 12), electrically conductive concrete (Chap. 13), electrothermal concrete (Chap. 14), light-transmitting concrete (Chap. 15), light-emitting concrete (Chap. 16), photocatalytic concrete (Chap. 17), electromagnetic wave shielding/absorbing concrete (Chap. 18), radiation shielding concrete (Chap. 19), hydrophobic/superhydrophobic concrete (Chap. 20), permeable concrete (Chap. 21), nondispersible underwater concrete (Chap. 22), and energy harvesting concrete (Chap. 23). Finally, the third part discusses the future challenges for continued development and deployment of smart and multifunctional concrete (Chap. 24).

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