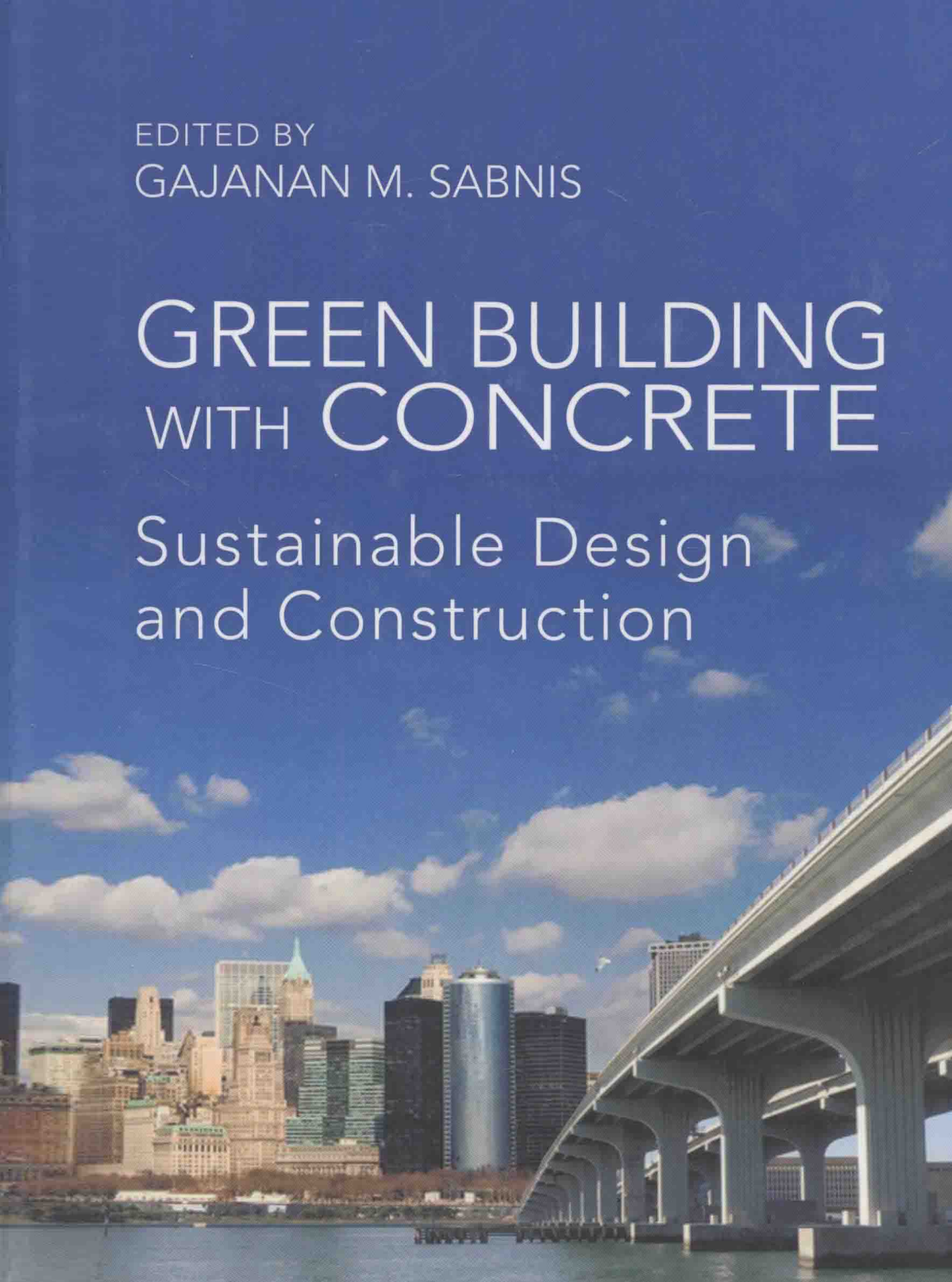
EDITED BY
GAJANAN M. SABNIS

GREEN BUILDING WITH CONCRETE

Sustainable Design and Construction



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Preface

This book provides the most recent information about concrete's history in the green building movement, state-of-the-art methodologies, and best practices. It will appeal to several major audiences. It may be considered as a textbook for use in university courses and industry education, as a handbook for use by building owners wanting to use concrete to assist in obtaining green certification, as a reference for industry professionals seeking an overview of the subject of concrete and green buildings, and as a guide to professionals in the building materials/products industries. The concept of green buildings is in the process of emerging from a decade-long effort to define its exact meaning. There have been research, white papers, articles, and seminars on the role of concrete in the green building effort. To date there has never been a book organized to provide an overview of all of the available information.

The history of cement manufacturing and the use of concrete are discussed to provide a context for today's current practices. Continuing pressures on the construction industry to reduce waste have resulted in an increase in the amount of concrete that is recycled or reused. Refurbishing or reusing structures is the least-waste option. This book outlines the variety of ways that concrete is easily and affordably reused. Work is under way within the precast industry with the aim of making it possible to lease concrete products so that they can be returned and/or reused.

The newly emerging green building delivery system now differs sharply from conventional building delivery systems. The result of this evolution has been new development and building delivery systems that emphasize a far wider collaboration among all parties to the construction process, including owners, developers, architects, engineers, constructors, facility managers, real estate professionals, and materials/product manufacturers. New quality-control systems with unique requirements are one of the outcomes of the green building process and this book will inform the reader about these requirements and the appropriate use of concrete products.

For example, LEED* buildings must have a building commissioning component, a construction waste management system must be in place, erosion/sediment control plans must be provided and enforced, and stringent construction process requirements must be followed to ensure excellent indoor air quality for the completed building. Concrete plays a role in each of these important green building components. The USGBC's LEED green building assessment standard will be referenced often and covered in detail because it is the key to green building delivery in the United States and is also being adopted in many other countries. Environmental life cycle assessment (LCA) methods conducted in accordance with ISO 14040† are described regarding their role as important emerging green building tools. This book will highlight research on the economic analysis, in particular the application

* US Green Building Council, Leadership in Energy and Environmental Design.

† International Organization for Standardization. Environmental Management—Life Cycle assessment—Principles and Framework.

of life cycle costing, to provide a full picture of the economic benefits of concrete for a green building.

As one examines the changes and growth in infrastructure taking place around the globe, a book of this type should be based not only on the experiences in the United States and Canada, but also on experience gained in Japan, Southeast Asia, and other parts of the world. With this thought, the editor looked beyond the original idea of a North American focus to find contributors from around the world. These contributions are valuable because they not only bring the international flavor, but also truly embrace the concept of global sustainability. It must be affirmed that the idea of sustainability has taken on much more meaning in Southeast Asia, where countries have seriously considered this concept for centuries, compared to the few decades it has been considered in the developed world.

This book was originally written as a textbook for university classes and for the concrete industry continuing education courses taught by the National Ready Mixed Concrete Association (NRMCA) in the new course: Green Building with Concrete. This course will be available to concrete industry members all over the nation through the NRMCA's extensive network of certified instructors. NRMCA also plans on partnering with state affiliates to deliver this course with member instructors who have gone through their extensive "train the trainer" program. This book will be an instrumental part of this special certification. The American Concrete Institute and the Portland Cement Association are both developing similar efforts. As the book took shape, the focus changed and became more global, as did the contributions. The book thus became a handbook providing diverse viewpoints from various international experts more closely matching the global nature of the sustainability movement.

This book will find its way as a textbook for courses emerging at universities on topics related to sustainable construction. California State University, Chico, offers a course* for which this book will serve as the primary textbook. The course is part of the larger concrete industry management (CIM) program, which is a relatively new 4-year degree program dedicated to meeting the employment needs of the concrete industry in the United States. Currently, four CIM programs are taught in universities in Tennessee, New Jersey, and Arizona. It is expected that they will all eventually add concrete sustainability courses.

In addition, this book serves as a tutorial for owners and developers who procure commercial and institutional buildings, including healthcare corporations, universities, school boards, manufacturers, high-technology firms, and many more entities that are recognizing the value of shifting to green building procurement and learning how to use versatile and available concrete to better meet their goals. Many green building and other green activist groups will find this book very informative and useful. These include those interested in land development, urban sprawl, brownfield recovery, and many other problems connected to industrial activity and the built environment.

Environmental Building News, Worldwatch magazine, and publications by organizations such as the American Institute of Architects (AIA) and the Urban Land Institute would be pertinent outlets for information about this book. National

* CIMT 363. Sustainability in the built environment: The role of concrete.

agencies such as the US Environmental Protection Agency, the US Department of Energy, the US Department of Defense, the US Department of Interior, and the General Services Administration are conducting research into green buildings, promoting green buildings, and/or procuring green buildings. As a consequence, the many managers and technical staff engaged in these activities are a potential audience for this book. Additionally, the equivalents of these agencies at the state and local government levels throughout the country should have significant interest in this book because many of these organizations are procuring green buildings and writing laws and ordinances supporting the procurement of green buildings.

The book covers topics ranging from cement manufacturing to the design of concrete systems and other related topics, including rehabilitation of concrete, as they relate to sustainability. The original focus was on North American practice, but, as discussed, it was determined that the inclusion of global expertise and efforts adds substantially to the value of the text.

Following the Introduction, Chapter 2 deals with cement and its production from the sustainability perspective toward the future including an Appendix that deals with admixtures, which have become an integral part of concrete. Chapter 3 is concerned with the design practice in concrete structures independent of their origin. Chapter 4 discusses the importance of concrete's thermal mass and how using special concrete can enhance overall sustainability. Chapter 5 deals with another major application of concrete in the pavements, including new development in pavements using roller compacted concrete, the subject of Chapter 6. Chapter 7 addresses surface runoff through the application of pervious concrete for sidewalks and parking areas, where water percolation prevents flooding and maintains the level of water in soil to conserve the balance of nature. Chapter 8 focuses on how concrete applications in large metro cities can be used to mitigate the urban heat island effects. Chapter 9 uses the major case study to discuss the application of sustainability in the various applications presented in earlier chapters. Chapter 10 discusses rehabilitation and the use of 3R principles, namely reuse, recycle, and renewal, so that the balance is maintaining by providing insight in sustainability and rehabilitation. Finally, Chapter 11 concludes with a global look at the sustainability.

It should be mentioned with some pride that this book is unique in some respects. With the contributions from India, it shows the global relevance of sustainability, indicating that good practice is not just relevant to North America or Western Europe, but also to a large country like India, where the need is even greater. Finally, the contributors have collected a large number of references in electronic form to share with the readers. More than 500 references, which add much value to the book, are available at http://www.crcpress.com/product/isbn/9781439812969. I hope that readers will acknowledge the use of these references through proper citation in their future work.

Gajanan M. Sabnis

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I cannot overlook Dr. Kenneth Derucher, professor of civil engineering and former dean at California State University at Chico, who introduced me to Kristin and proved to be the link after 25 years of our personal friendship when he was at the University of Maryland. Unfortunately, he could not contribute to this text, but I still owe him a debt of gratitude for this project.

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Gajanan M. Sabnis

About the Editor

Gajanan M. Sabnis, PhD, PE, is emeritus professor at Howard University in Washington, DC, and presently an international consultant in project management and related fields. With his diverse cultural background and experience in the United States and India, he spends considerable time in India to assist infrastructure projects there. Large infrastructure development is taking place in India and the Middle East, and he finds it rewarding to provide such advisory service. He is a strong proponent of sustainability in civil engineering—particularly in the cement and concrete industry. He participated in the initial development of the policy on sustainability in ASCE and has built his own home in Silver Spring, Maryland, as an experiment in the principles of sustainable construction.

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Contents

1 Introduction

Gajanan M. Sabnis

CONTENTS

1.1 BACKGROUND

The advances of sustainable construction and the green building movement of the past decade have spurred a detailed examination of building materials and practices worldwide. The Portland cement and concrete industries have an invaluable role to play in achieving the goals of reducing society's environmental footprints on the earth and in the atmosphere. Cement and concrete sustainability are measured in many ways. They are measured upstream during the manufacturing process and downstream in how construction projects are built and operated.

This book offers insight into new legal, technological, and social developments guiding the introduction of green buildings and their effects on the construction industry. This includes an in-depth evaluation of carbon dioxide and other emissions associated with the manufacture of cement, the attributes that concrete has to offer the green building movement, and the effect that emerging life-cycle analysis has on concrete's role in this important revolution in the building industry. The chapters to follow explore the benefits of thermal mass, increased water supply, and improving water quality; reducing urban heat island effects; reducing construction waste and the use of supplementary cementitious materials to gain a better understanding of how concrete can contribute to sustainable construction; leadership in energy and environmental design (LEED); and the green building movement in general. This book outlines clearly how to make the most of concrete in sustainable design, with an emphasis on environmental impact and occupational and consumer health and safety.

1.2 INTRODUCTION

Sustainability, in general, was given a political definition by the United Nations as follows: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs—by attempting to balance social, economic and environmental effects."

One can start with this definition and work on its applicability in any field. One can hardly argue with this definition. In Section 1.3, this definition is discussed in detail. A later section covers civil engineering aspects of this definition in light of the American Society of Civil Engineers (ASCE) and the policies approved by it. Various organizations, such as the American Concrete Institute (ACI), Portland Cement Association (PCA), Concrete Reinforcing Steel Institute (CRSI), and Precast/Prestressed Concrete Institute (PCI), have also adopted a unified approach by establishing a coalition to pursue sustainability in the context of concrete. The Concrete Joint Sustainability Initiative is a coalition of industry associations representing companies who make or maintain concrete structures. The main goal is to educate the members of organizations at large and their clients about use of concrete in sustainable development.

Contributions of concrete to sustainability come from its components, such as cement, aggregate, and even water, and their impact on its properties during the life of the produced structure. Concrete should be desirably strong and durable and preferably immune to any environmental factors causing its damage or deterioration. It has the ability to withstand temperature to insulate the interior, not to mention its

ability to provide sound insulation in many cases, which makes it an ideal construction material anywhere the ingredients are available in the world. This raises various key issues for its sustainability, which are presented here as the main backbone for the rest of this book. They can be termed "ten commandments" to maximize concrete's sustainability. Effectively leveraged, reinforced concrete can contribute a great deal to creating sustainable buildings, bridges, and other infrastructures necessary for a successful future of any country.[1]

1.3 OVERVIEW OF THE SUSTAINABILITY MOVEMENT*

The goal of sustainability is to leave the world a better place for future generations. Companies are learning that they are more profitable and more sustainable if they think in terms of a triple bottom line: *economic, social, and environmental or profits; people; and the planet.* This approach enables business development to meet the needs of the present without compromising the ability of future generations to meet their own needs. This section provides the critical review of various historical approaches to environmental regulation and the emerging principles of sustainability.

1.3.1 Environmental Sustainability

Sustainability starts with environmental performance. While they are only one of three foundations of sustainability, environmental concerns typically get the most attention. In fact, the concepts of sustainable development and sustainability were born of environmentalism. In 1987, the United Nations World Commission on Environment and Development presented a document, commonly called the Brundtland Report, to the UN General Assembly. This report addressed concerns for historical development paths, which led to depleted natural resources, including clean air and water. It called for future economic development that could be sustained without depleting natural resources or harming the environment. The report famously defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[1]

The Brundtland Report was primarily concerned with global equity and the sustainable economic growth of developing nations. This concept spread through the 1990s and was expanded to the broader concept of sustainability, which can guide the philosophies and actions of individual countries, communities, industries, companies, facilities, and people, regardless of their development status.

1.3.2 Historical Command-and-Control Regulation

Before Brundtland, environmentalism relied on an adversarial system in which government entities required industrial facilities, automobiles, and communities to utilize processes or technological controls to limit air emissions, solid waste, and water discharges. This command-and-control approach sought to filter or capture pollution rather than limiting its creation. In many countries, including most in North America

* This section was contributed by Thomas B. Carter, also the author of Chapter 2.

and Europe, this approach was effective in removing most pollution from the most significant sources. For example, requiring US cement plants to install particulate matter controls reduced those emissions by more than 99%.

Most observers agree that the command-and-control approach was appropriate in the first stage of the environmental movement. From the industrial revolution of the nineteenth century until the advent of environmental awareness in the mid-twentieth century, most industries and individuals envisioned natural resources, fresh air, and clean water as limitless. By the time that humankind realized that this was not the case, dramatic steps were necessary. In the early 1970s many governments established environmental ministries, agencies, and laws. In the last three and one-half decades, industrialized countries achieved significant gains in reducing air emissions and water discharges. The initial challenge of sustainable development was to ensure that developing countries learned the lessons of the past and developed in a smarter and more environmentally aware manner.

Now that old facilities generally include emissions controls—at least in developed countries—the challenge is to ensure that new facilities are designed to reduce the need for such controls. Sustainability looks beyond command-and-control measures to ensure that future development and industrialization are conducted wisely.

1.3.2.1 Beyond Compliance

One element of sustainability is that environmental policy—whether at the government or corporate level—should not be based on the rigid structure of legal requirements. Rather, these decisions should consider the long-term welfare of the people with a stake in a company or a country. As this broader approach has gathered momentum, industry and government are increasingly turning to voluntary measures to minimize environmental impacts. Often these measures are accompanied by market-based mechanisms for ensuring that overall emissions of a given pollutant are kept to a sustainable level.

1.3.2.2 Social Sustainability

Gaining less attention than environmental concerns but equally important are the social impacts of sustainability. Sustainable industries must strive to maximize positive effects on society through education, employment, economic welfare, stakeholder empowerment, and other factors. Negative social impacts should be minimized. Social sustainability can be seen as a series of concentric circles expanding around a company of other entities.

1.3.2.3 Occupational Health and Safety

At the center of sustainable industries and companies are individual employees. The health, safety, and welfare of employees and the communities in which they live and work are essential components of economic, environmental, and societal factors by which sustainability decisions are weighed.

1.3.2.4 Community Health and Safety

Controlling emissions, waste, and discharges is essentially a community health and safety program—and, in the case of greenhouse gases or other pollutants with broader

consequences, a global health and safety program. Therefore, the environmental sustainability steps discussed before are directly relevant to community concerns.

Other community health and safety issues include safe quarry operations and safe driving and rail operation guidelines. Less direct but equally important contributions include sponsorship of local youth athletic programs and health-care benefits for employees and their families. Finally, the very act of employing community members contributes to their ability to obtain good nutrition and medical care and to their general physical and mental health. All of these are factors by which the cement industry creates sustainable communities.

1.3.2.5 Customer Health and Safety

The next ring of social sustainability includes the customers and users of cement. One form of outreach to this group is sharing of information on the contents of the product. For example, in the United States, manufacturers provide their customers with a material safety data sheet (MSDS) with detailed information on any health or safety concerns associated with ingredients in cement.

1.3.2.6 Community Involvement

A mark of social sustainability that extends beyond health and safety is stakeholder involvement. Many companies have established community involvement committees to give their neighbors a voice in major decisions that might affect the community. An informed and participatory community can make the right decisions to become a sustainable community.

1.3.3 Economic Sustainability

The final leg is economic sustainability. For a company to remain a valuable member of the community in which it operates and to contribute to environmental and social sustainability, it must remain in business. This requires operating at a long-term profit.

1.3.3.1 Cost Savings

Many of the measures taken to achieve environmental and social sustainability directly benefit the financial bottom line and therefore contribute to economic sustainability. Air emissions, solid waste, and water discharges are the results of inefficiencies in an industrial system. An ideal system would produce no waste or by-products. While generally unattainable, this is still the ultimate goal of a sustainability program. Enhancing energy efficiency, minimizing waste, and utilizing industrial by-products as fuels or raw materials improve both profits and the environment.

1.3.3.2 Stakeholder Satisfaction

Another means by which a company can ensure financial sustainability is to maximize the satisfaction of its employees, customers, communities, shareholders, and other stakeholders. Taking care of employees and being a good community member are two ways to achieve stakeholder satisfaction. Having a strong record of striving toward environmental and social sustainability is increasingly

important in attracting and pleasing customers, communities, shareholders, and other stakeholders.

1.4 SUSTAINABILITY AND CIVIL ENGINEERING

Civil engineers looked at sustainability as a policy and principle of practice. For the first time after years of debate, as a professional body, ASCE has revised its Code of Ethics to make the principles of sustainable development part of the canon of civil engineering practices and introduced it as a policy statement that is continuously updated.

The concept of sustainability deals primarily with sustainable development as defined by the ASCE in 1996: "Sustainable Development is the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development."[2]

Sustainability in the developed as well as in the developing world requires scientific and technical innovations to create designs that enable the earth and its inhabitants to prosper and therefore should be considered a universal phenomenon.

ASCE encourages the use of *life-cycle cost analysis (LCCA) principles* in the design process to evaluate the total cost of projects. The analysis should include planning, design, construction, operation, maintenance, regulatory, environmental, safety, and other costs reasonably anticipated during the life of the project, whether borne by the project owner or those otherwise affected. When the cost of a project is estimated only for design and construction, the long-term costs associated with maintenance, operation, and retiring of a project are overlooked. One of the most significant elements for the planning and designing of facilities is the determination of the total effect of life-cycle costs on a project. The rationale in the use of LCCA is to raise the awareness of owners, clients, and the public of the total costs of projects and promote quality and comprehensive engineering solutions. Short-term design cost savings that lead to high future costs will be exposed as a result of the analysis.[3]

1.5 SOME MYTHS ABOUT SUSTAINABILITY[4]

The sustainability and green building movements have given rise to more discussion on the topic and created some critical issues, which may or may not be significant. This section takes a critical, hard look at some myths about sustainability and concrete from a global perspective.

1.5.1 Sustainability Is a New Phenomenon

Sustainability as introduced now in our life may be new, but it was always part of our engineering works. Thus, if the structure is designed well and the constructors (both engineers and builder) follow certain engineering guidelines, it will be sustainable. Sustainability has moved into our lives and will remain with us. Professionally speaking, ASCE was the first to adopt sustainability as a policy in 1996 to provide civil engineering principles for the profession to follow. In 2010, the US GSA established the position of chief greening officer, who is responsible for pursuing innovative