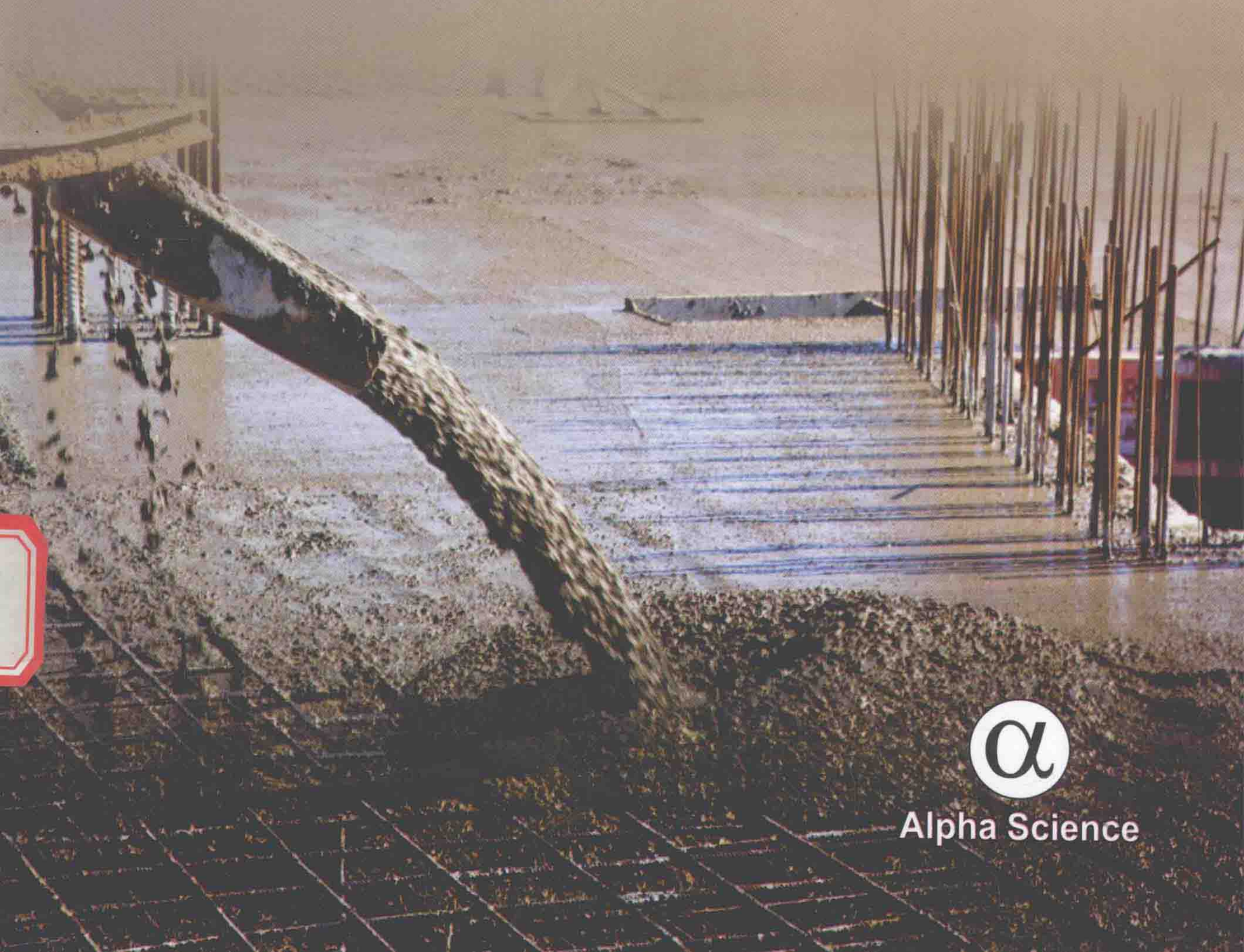
CONCRETE TECHNOLOGY PRACTICES

Aminul Islam Laskar



Alpha Science

CONCRETE TECHNOLOGY PRACTICES

Aminul Islam Laskar

Alpha Science International Ltd.
Oxford, U.K.

Concrete Technology Practices
500 pgs. | 391 figs. | 38 tbls.

Aminul Islam Laskar
Department of Civil Engineering
National Institute of Technology Silchar
Assam

ALPHA SCIENCE INTERNATIONAL LTD.
7200 The Quorum, Oxford Business Park North
Garsington Road, Oxford OX4 2JZ, U.K.

www.alphasci.com

ISBN 978-1-84265-942-7

To

My parents *Habib Ali Laskar* and *Sahera Begum Laskar*,
Wife *Begum Wahida*, and
Sons *Asif and Arif.*

PREFACE

Concrete is generally preferred for desired compressive strength and excellent durability during the service life of the structures. A good concrete is a maintenance free construction material unlike structural steel when exposed to atmosphere. Concrete is the second largest material consumed by human civilization now-a-days just after water. Over the recent years, there is a huge increase in the concrete production throughout the world. Current world total annual production of cement is about 2 billion tons and is sufficient to make about 2.5 metric tons per year per person. Greatest producer of cement in the world today is China, which produces 49% of total world's production, India being the 2^{nd} largest country which produces about 20% of the world's production. The subject 'Concrete Technology" has therefore been incorporated in various institutes to make this material familiar to students. Present book is an attempt to elaborate the concrete fundamentals as well as recent developments of the subject so as to make students familiar with the topics during undergraduate and postgraduate study.

The present book '*Concrete Technology Practices*' contains fundamentals of the subject concrete technology such as *hydration of cement, cement types, concrete making materials, workability, hardened properties of concrete, durability, mix design, chemical and mineral admixtures, and non-destructive testing*. Recent developments in concrete science and engineering such as *self compacting concrete, high performance concrete, fiber reinforced concrete, ultra-high performance concrete, rheology of concrete* have also been appended as individual chapters. Special topics like some sophisticated and special techniques in concrete technology such as *mercury intrusion porosimetry, nitrogen adsorption test, impact echo test, ground penetration radar, XRD, SEM, impact testing* etc., have been covered. The unique feature of the book is inclusion of some of the latest topics in this subject such as *geopolymer concrete, pervious concrete, radiation shielding, concrete at cryogenic temperature, nanotechnology and nano-materials in concrete*. It will provide up to date information on the subject and ready reference of the relevant Codal provisions. The book will serve as a textbook at undergraduate and postgraduate level in Civil Engineering Universities, NITs and IITs. It will also serve as a ready reference for the construction engineers in various executing agencies.

Any suggestion by the readers regarding the improvement of the book will be highly appreciated.

Aminul Islam Laskar

ACKNOWLEDGEMENT

I would like to express my sincere thanks and gratitude to following eminent personalities, organizations and publishers for allowing me to reproduce extracts from their books and technical reports and notes:

Dr. Salim Barbhuiya, Curtin University, Perth, Australia,
Dr. C. F. Ferraris, National Institute of Standards and Technology, USA,
US Bureau of Reclamation, US Department of Interior Design,
Portland Cement Association, Skokie, USA
Prof. D. Fowler (University of Texas at Austin),
Ms. Nel van der Werf (Springer, Germany),
Prof. J. J. Beaudoin (NRC Ottawa, Canada),
Dr. Thierry Sedran (LCPC, France),
Dr. François de Larrard (LCPC, France),
Dr. Peter Domone (University College, London),
Rosemary Bavister (Taylor & Francis Books, UK).

I gratefully acknowledge Bureau of Indian Standards (New Delhi) for giving me permission for the reproduction of illustrative and tabular materials. Finally, thanks are due to my undergraduate student Er. Rituraj Shukla (2013 passed out batch) for preparing the questions which have been appended at the end of this book.

CONTENTS

1

INTRODUCTION

The use of various cements in structures is an ancient practice. Some of the earliest use of true mortar was in ancient Egypt, Greece and Crete. In Greece and Crete, lime mortars were made from burning of limestone. Some foundations from ancient Egyptian Buildings made use of gypsum concrete. The Romans mixed lime (i.e. burnt limestone) with volcanic ash from Mount Vesuvius near the village of Pozzouli. This ash became known as Pozzolana after the name of that village. Structures made with pozzolana during entire Roman Empire showed remarkable durability, the best known surviving example of which is the Pantheons in Rome (Fig. 1.1). The wall and dome thickness is 6 m and is made of lime-pozzolana concrete.

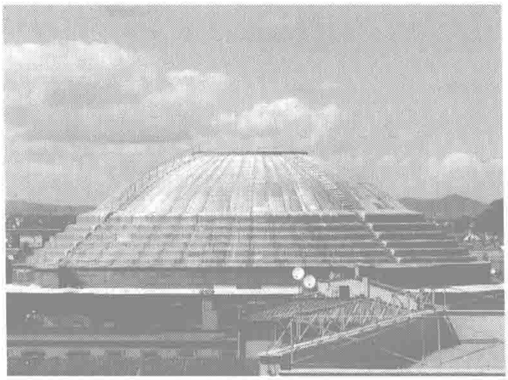


Fig. 1.1 *Ancient roman pantheons (Temple of Gods); built in 128 AD, it has 43.2 m diameter dome, a record for 1800 years*

In the 18th century, active research into improving the quality of cements was becoming fairly widespread in Western Europe. In 1756, John Smeaton discovered that strong lime mortar could be obtained by burning limestone. Subsequently, James Parker in England (1796), Edger Dobbs in England (1810) did major breakthrough in the understanding of hydraulic cements. It was not until the year of 1824 that the hydraulic cement (now commonly known as Portland cement) became popular when it was patented by a Leeds builder named Joseph Aspdin. The name "Portland cement" was given originally due to the resemblance of the color and quality of the hardened cement to Portland stone (limestone quarried in Dorset). Joseph Aspdin set-up the 1st Portland cement plant at Wakeland (UK) but the production cost was high. His products therefore, could not catch up the market. Marketing of Portland cement received a major boost in 1938 when it was chosen for the prestigious project to construct the Thames River tunnel (Fig. 1.2). Today, the most widely used modern construction material is concrete that is made by mixing Portland cement with sand, crushed rock and water. The name 'Portland cement' has been retained by the industry because the present day cement is still produced from limestone and argillaceous raw materials and because the name has an unrivaled prestige, distinction and reputation. Man consumes no material except water in such tremendous quantities. Current world total annual production of cement is about 2 billion tons and is sufficient to make about 2.5 metric tons per year per person on the planet. Greatest producer of cement in the world today is China, which produces 49% of total world's production, India being the 2nd largest country which produces about 20% of the world's production.

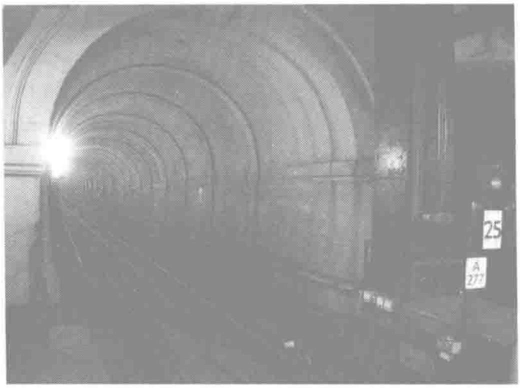


Fig. 1.2 *Thames river tunnel (England) where Joseph Aspdin's cement was used (completed in 1843)*

Concrete is neither strong nor tough as steel, but it is the most widely used engineering material. Because concrete is stable in water. The ability of concrete to withstand the action of water without serious deterioration makes it an excellent material for building structures to control, store and transport water. Structural concrete elements can be formed into a variety of shapes and sizes. This is because freshly made concrete is of a plastic consistency, which allows the material to flow into the formwork. Further, it is usually the cheapest and most readily available material in the site. Principal ingredients for making concrete viz., Portland cement and aggregates are relatively cheap and are more commonly available in most areas of the world. In addition, large amounts of many industrial wastes such as fly ash, ground blast furnace slag can be used as a substitute for the cementitious material or aggregates in concrete. Therefore, in the future, considerations of energy and resource conservation are likely to make the choice of concrete as a structural material even more sustainable.

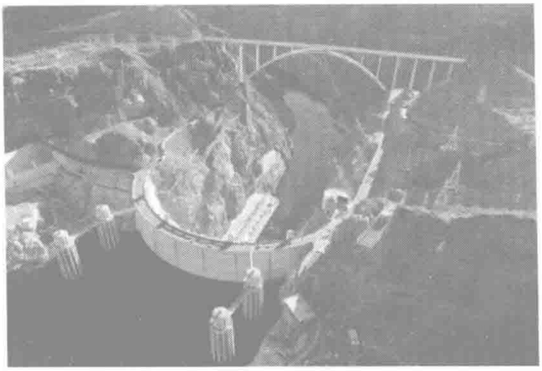


Fig. 1.3 *Boulder dam in USA (Completed in 1948)*

Although the fundamental cement types have been unchanged over the years, certain cement properties have changed significantly. Most changes emanate from the new cement manufacturing methods. Broadly speaking, ordinary Portland cement manufactured during the last 25 years gains strength more rapidly than that produced 40 years ago. Formwork can be stripped off earlier and construction can proceed more rapidly.

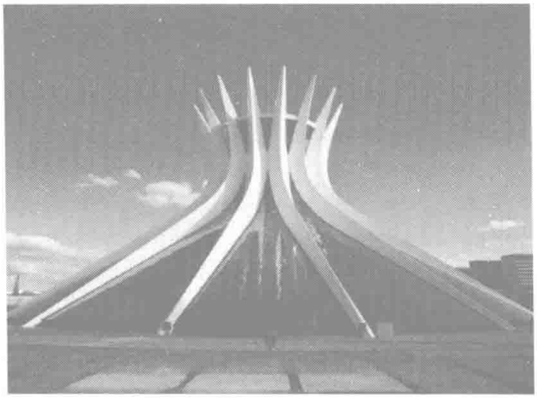


Fig. 1.4 *Brazilian cathedral is made-up of sixteen parabolic concrete columns reaching-up towards the sky*

The attempt of developing new materials from the locally available raw materials like agricultural and industrial wastes is worldwide. Studies showed that the use of waste materials to produce different kind of building materials would not only reduce the construction cost but also contribute to cleaner environment of the developing countries. Moreover, there has been an increasing demand for the use of cement in modern days. The cost of cement is high and cement manufacturing is localized in the areas where raw materials are abundant. The cost of transportation adds substantially to the cement cost for the consumer at any distance from the point of manufacturing. Many industrial wastes are now-a-days used in cement and construction sector. Fly ash is one such by-product and is an excellent material for cement and concrete. Pulverized Fly Ash (pfa) is described now-a-days as a by-product, but 40 years ago it was considered to be a waste product. Other siliceous materials such as microsilica, rice husk Ash (RHA) and metakaolin are also used in some parts of the world.

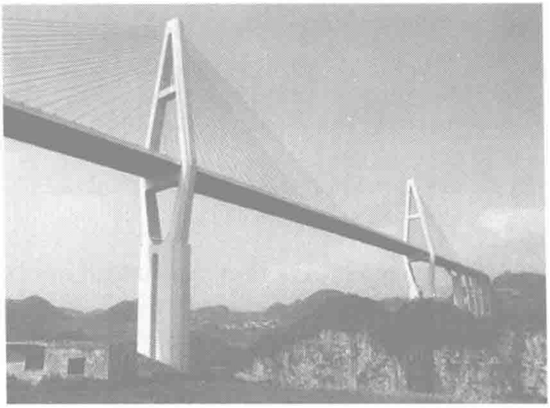


Fig. 1.5 *Malinghe River Bridge is a 241 m high cable-stayed bridge near Xingyi, China. As of 2012, it is among the 25 highest bridges in the world*

The most common problem with concrete is shrinkage, which results in cracking. Shrinkage takes place within the hydrated cement paste (*hcp*), and so the cement is responsible. Creep not always harmful, but usually has undesirable effects, notably a time-dependent increase and deflection and also a loss of prestress. Alkali-silica and alkali-carbonate reactions are induced by the alkalis in cement; sulfate attack involves tricalcium aluminate in the cement. Some other types of chemical attack involve leaching of calcium hydroxide, which is a major product of the cement hydration and corrosion of reinforcement.

Portland cement concrete is considered to be a relatively brittle material. Apart from its excellent properties, concrete shows a rather low performance when subjected to tensile stress. When subjected to tensile stress, unreinforced concrete will crack and fail. The traditional solution to this problem is reinforced concrete, where reinforcing bars or prestressed steel bars inside the concrete elements are capable of absorbing the appearing tensile stresses. Another rather recent development is steel fiber reinforced concrete (SFRC). By adding steel fibers while mixing the concrete, a so-called homogeneous reinforcement is created. This does not notably increase the mechanical properties before failure, but governs the post failure behavior. Thus, plain concrete, which is a quasi-brittle material, is turned to the pseudo ductile steel fiber reinforced concrete.

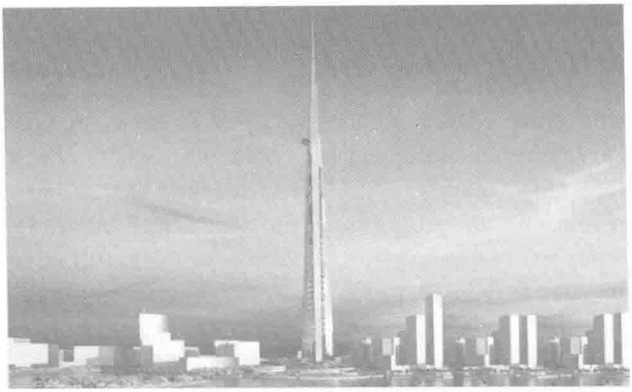


Fig. 1.6 *Proposed 1 km high tower in Jeddah, Saudi Arabia; it will require half million cu.m of concrete*

The use of high strength concrete and high performance concrete has become a common practice in many applications throughout the world for many decades, especially for high-rise buildings, long span bridges and repair and rehabilitation works. Moreover, during the last decade, developments in mineral and chemical admixtures have made it possible to produce concrete with relatively much higher strength than was thought possible. High strength concrete is not a revolutionary material; rather, it is a development of normal strength concrete. Today, we have RCC framed high rise buildings and long span bridges with very high performance concrete. The constant endeavor of technologist during last decade yielded still stronger materials and these are ultra-high performance concrete. Examples of such high-tech materials are reactive powder concrete (RPC), engineered cementitious composites (ECC), compact reinforced composite (CRC) etc.

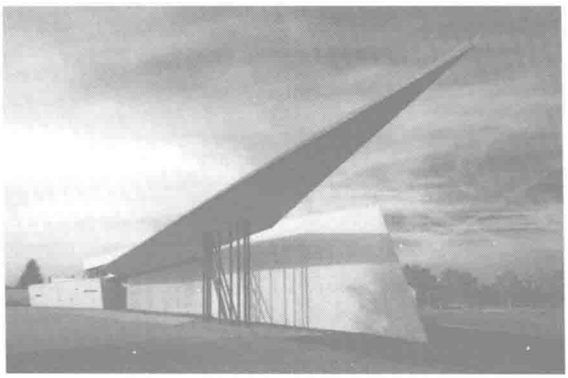


Fig. 1.7 *The Vitra fire station in Germany uses concrete planes that bend, tilt, and break according to the conceptual, dynamic forces connecting landscape and architecture*