

# Advances in serviceability and strength of normal- and high-strength concrete structures

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## Summary

Serviceability and strength of concrete structures have been a topic of intense research for many years. Reported herein is the work conducted in this area, especially in the past decade, which ranges from the development of the layered finite element method and the associated theoretical studies to elaborate laboratory tests of high-strength concrete elements. In particular, serviceability studies reviewed include natural frequency, cracking and crack patterns, deflection and damping characteristics; strength investigations reviewed cover beams, slabs and walls, as well as the punching shear strength of

flat plates. A long-term on-site study of column shortening in an 80-storey residential building recently completed at Gold Coast in Southeast Queensland, Australia is also reported. In addition, a separate section discusses the serviceability studies specific for high-strength concrete structures. Summarized herein is the review of research findings published during the period spanning mainly from 1995 to 2005. Relevant formulas and analytical procedures which may assist practising engineers in the design of concrete structures are reported for completion.

**Key words:** axial shortening of columns; cracking and crack control; deflection; damping characteristics; punching shear strength of concrete flat plates; serviceability of high-strength concrete structures; ultimate loads of walls and slab panels

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## Introduction

For a concrete structure to be considered serviceable, cracking must be controlled and deflections must be within specified limits. Also, it must not vibrate excessively. Concrete strength characteristics play a major role in each of these three aspects of the service load behaviour. Serviceability, like the strength characteristics of concrete structures, is therefore of paramount importance, especially from a design perspective.

During the past decade, various researchers have conducted a considerable amount of research in the broad area of serviceability and strength characteristics of concrete structures. These covered both reinforced and prestressed concrete structures as well as different structural elements constructed of both normal- and high-strength concrete. This paper attempts to review and present a summary of the findings from these research efforts. A significant number of papers and reports in the subject area published by different researchers are discussed

herein. A brief description is given of each of these works which were published mainly between 1995 and 2005 with some earlier ones included for completeness.

The main purpose of this paper is to acquaint the reader with the considerable body of research work and relevant findings in the topical area. The publications reviewed herein are classified and described under the following headings:

- Cracking and crack control
- Deflection
- Damping characteristics
- Axial shortening of columns in tall buildings
- Punching shear strength of concrete flat plates
- Ultimate loads of walls and slab panels

High-strength concrete (HSC) being a relatively new material, the discussion on the serviceability studies of HSC structures has been presented in a separate section.

To cover a large collection of publications in a restricted number of pages, the description of each, by

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## **Longterm Serviceability Of Concrete Structures:**

*Long-term Serviceability of Concrete Structures* Anis Farah, American Concrete Institute, 1989      Management of Concrete Structures for Long-term Serviceability Ewan A. Byars, Tony McNulty, 1997 This book presents the proceedings of the international seminar organised by the Centre for Cement and Concrete at the University of Sheffield to bring together information on the major issues concerning through life management of major concrete structures      *Long-term Serviceability of Concrete Structures* Anis Farah, Committee 348 "Structural Safety", American Concrete Institute, 1989

Long-term Serviceability of Concrete Structures ,1989      **Serviceability Limit State of Concrete Structures** FIB - International Federation for Structural Concrete, 2019-09-01 Serviceability limit states are essential for appropriate function and durability of concrete structures The attention is paid especially to the stress limitation crack width analysis and deflection analysis The document provides supplementary information to the fib Model Code 2010 MC2010 where a limited space did not allow for a detailed description of individual procedures The principles used in MC2010 in chapter 7.6 are explained in detail within this document The stress analysis is focused on stresses in concrete and steel including the stress redistribution due to the long term load and cracking of reinforced concrete and prestressed concrete elements Crack width analysis explains the mechanism of cracking under mechanical loading and due to deformation restraint Cracks in prestressed concrete elements are also discussed Deflection analyses with different levels of accuracy are described including the shear effects Examples illustrate the practical application of rules defined in the MC2010 of individual serviceability limit states Simplified and more general methods are used An important part of the bulletin shows the development and extension of the serviceability limit states after publishing of the MC2010 and alternative approaches Special attention is paid to deflections of prestressed concrete beams shear effects on deflection slenderness limits and influence of the concrete cover The final part deals with an application of numerical simulations      *Long Term Durability of Structural Materials* P.J.M. Monteiro, K.P. Chong, J. Larsen-Basse, K. Komvopoulos, 2001-08-29 Long Term Durability of Structural Materials features proceedings of the workshop held at Berkeley CA in October 2000 It brought together engineers and scientists who have received grants from the initiative NSF 98 42 to share their results on the study of long term durability of materials and structures The major objective was to develop new methods for accelerated short term laboratory or in situ tests which allow accurate reliable predictions of the long term performance of materials machines and structures To achieve this goal it was important to understand the fundamental nature of the deterioration and damage processes in materials and to develop innovative ways to model the behavior of these processes as they affect the life and long term performance of components machines and structures The researchers discussed their approach to include size effects in scaling up from laboratory specimens to actual structures Accelerated testing and durability modeling techniques developed were validated by comparing their results with performance under actual operating conditions The main

mechanism of the deterioration discussed included environmental effects and or exposure to loads speeds and other operating conditions that are not fully anticipated in the original design A broad range of deterioration damage such as fatigue overload ultraviolet damage corrosion and wear was presented A broad range of materials of interest was also discussed including the full spectrum of construction materials metals ceramics polymers composites and coatings Emphasis was placed on scale dependence and history of fabrication on resulting mechanical behavior of materials

**Short-Term and Long-Term Behaviour of Reinforced Self-Compacting Concrete Structures** Farhad Aslani, 2014-06-24 Volume is indexed by Thomson Reuters BCI WoS Self Compacting Concrete SCC refers to a highly flow able non segregating concrete that can be spread into place fill the formwork and encapsulate the reinforcement without the aid of any mechanical consolidation SCC is regarded as one of the most promising developments in concrete technology due to significant advantages over Conventional Concrete CC In this study cracking caused by external loads in reinforced SCC and FRSCC slabs is examined experimentally and analytically The mechanisms associated with the flexural cracking due to the combined effects of constant sustained service loads and shrinkage are observed One of the primary objectives of this study is to develop analytical models that accurately predict the hardened mechanical properties of SCC and FRSCC Subsequently these models have been successfully applied to simulate time dependent cracking of SCC and FRSCC one way slabs

Creep, Shrinkage and Durability Mechanics of Concrete and Concrete Structures, Two Volume Set Tada-aki Tanabe, Kenji Sakata, Hirozo Mihashi, Ryoichi Sato, Kochi Maekawa, Hikaru Nakamura, 2008-09-01 CREEP SHRINKAGE AND DURABILITY MECHANICS OF CONCRETE AND CONCRETE STRUCTURES contains the keynote lectures technical reports and contributed papers presented at the Eighth International Conference on Creep Shrinkage and Durability of Concrete and Concrete Structures CONCREEP8 Ise shima Japan 30 September 2 October 2008 The topics covered

**Durability of Concrete Structures** G.C. Mays, 1991-11-14 This book is concerned with the long term durability of concrete as a structural material as used in the construction of buildings bridges roads marine and civil engineering structures It discusses the fundamental reasons for the deterioration of concrete over time and available techniques for detecting remedying and preventing the deterioration

Durability of Building Materials and Components J.M. Baker, Howard Davies, A.J. Majumdar, H. Davies, P.J. Nixon, 2006-05-18 This book is the Proceedings of the fifth in the major series of triennial international conferences on the Durability of Building Materials and Components It includes reports on current research into the causes mechanisms and rates of deterioration of building materials reliable means of repair and prevention of early failure and new materials which can reduce construction costs

**Frontier Technologies for Infrastructures Engineering** Alfredo H.S. Ang, Shi-Shuenn Chen, 2009-04-21 An exclusive collection of papers introducing current and frontier technologies of special significance to the planning design construction and maintenance of civil infrastructures This volume is intended for professional and practicing engineers involved with infrastructure systems such as roadways bridges buildings power

generating and dis

**Durability of Concrete**, 2000 **DESIGN OF CONCRETE STRUCTURES** BANDYOPADHYAY, J. N., 2008-07-07 This text primarily analyses different methods of design of concrete structures as per IS 456 2000 Plain and Reinforced Concrete Indian Standard Code of Practice 4th revision Bureau of Indian Standards It gives greater emphasis on the limit state method so as to illustrate the acceptable limits for the safety and serviceability requirements of structures Besides dealing with yield line analysis for slabs the book explains the working stress method and its use for designing reinforced concrete tension members theory of redistribution of moments and earthquake resistant design of structures This well structured book develops an effective understanding of the theory through numerous solved problems presenting step by step calculations The use of SP 16 Design Aids for Reinforced Concrete to IS 456 1978 has also been explained in solving the problems KEY FEATURES Instructional Objectives at the beginning of the chapter highlight important concepts Summary at the end of the chapter to help student revise key points Sixty nine solved illustrative examples presenting step by step calculations Chapter end exercises to test student s understanding of the concepts Forty Tests to enable students to gauge their preparedness for actual exams This comprehensive text is suitable for undergraduate students of civil engineering and architecture It can also be useful to professional engineers

**Innovation, Communication and Engineering** Teen-Hang Meen, Stephen Prior, Artde Donald Kin-Tak Lam, 2013-10-08 This volume represents the proceedings of the 2013 International Conference on Innovation Communication and Engineering ICICE 2013 This conference was organized by the China University of Petroleum Huadong East China and the Taiwanese Institute of Knowledge Innovation and was held in Qingdao Shandong P R China October 26 November 1 2013 The conference received 653 submitted papers from 10 countries of which 214 papers were selected by the committees to be presented at ICICE 2013 The conference provided a unified communication platform for researchers in a wide range of fields from information technology communication science and applied mathematics to computer science advanced material science design and engineering This volume enables interdisciplinary collaboration between science and engineering technologists in academia and industry as well as networking internationally Consists of a book of abstracts 260 pp and a USB flash card with full papers 912 pp *Advanced Sensing, Materials and Intelligent Algorithms for Multi-Domain Structural Health Monitoring* Liang Ren, Gangbing Song, Qingzhao Kong, Chun-Xu Qu, Yang Zhang, Yunlai Zhou, 2022-01-07

**Incorporating Sustainable Practice in Mechanics and Structures of Materials** Sam Fragomeni, Srikanth Venkatesan, 2010-11-18 Incorporating Sustainable Practice in Mechanics of Structures and Materials is a collection of peer reviewed papers presented at the 21st Australasian Conference on the Mechanics of Structures and Materials ACMSM21 Victoria University Melbourne Australia 7th 10th of December 2010 The contributions from academics researchers and practisin

**Long-term Performance and Durability of Masonry Structures** Bahman Ghiassi, Paulo B. Lourenco, 2018-11-27 Long Term Performance and Durability of Masonry Structures Degradation Mechanisms Health Monitoring and Service Life Design focuses on the long term performance of

masonry and historical structures The book covers a wide range of related topics including degradation mechanisms in different masonry types structural health monitoring techniques and long term performance and service life design approaches Each chapter reflects recent findings and the state of the art providing practical guidelines Key topics covered include the theoretical background transport properties testing and modeling protective measures and standards and codes The book s focus is on individual construction materials the composite system and structural performance Covers all issues related to durability including degradation mechanisms testing and design monitoring and service life design Focuses on different masonry construction types Presents a one stop reference for advanced postgraduate courses that focuses on the durability of masonry and historical constructions

#### **Bridge Maintenance, Safety, Management and Life Extension**

Airong Chen,Dan Frangopol,Xin Ruan,2014-05-27 Bridge Maintenance Safety Management and Life Extension contains the lectures and papers presented at IABMAS 2014 the Seventh International Conference on Bridge Maintenance Safety and Management IABMAS 2014 held in Shanghai China July 7 11 2014 This set consists of a book of abstracts and a DVD containing the full papers of 396 contributions presented at IABMAS 2014 including the T Y Lin Lecture nine Keynote Lectures and 386 technical papers from about 40 countries All major aspects of bridge maintenance safety management and life extension are addressed including advanced materials aging of bridges assessment and evaluation bridge codes bridge diagnostics bridge management systems damage identification design for durability deterioration modeling earthquake and accidental loadings fatigue field testing health monitoring load models life cycle assessment maintenance strategies non destructive testing prediction of future traffic demands repair and replacement residual service life safety and serviceability service life prediction and sustainable bridges among others This set provides an up to date overview of the field of bridge engineering as well as the recent significant contributions to the process of making rational decisions in bridge maintenance safety management sustainability monitoring long life strategy and resources optimization deployment for the purpose of enhancing the welfare of society It will serve as a valuable reference to all concerned with bridge structure and infrastructure systems including students researchers engineers consultants and contractors from all areas of bridge engineering

#### **Proceedings fib Symposium in Dubrovnik Croatia** FIB – International Federation for Structural

Concrete,2007-05-01 **American Environmentalism** J. Michael Martinez,2013-06-20 Protecting the natural environment and promoting sustainability have become important objectives but achieving such goals presents myriad challenges for even the most committed environmentalist American Environmentalism Philosophy History and Public Policy examines whether competing interests can be reconciled while developing consistent coherent effective public policy to regulate uses and protection of the natural environment without destroying the national economy It then reviews a range of possible solutions The book delves into key normative concepts that undergird American perspectives on nature by providing an overview of philosophical concepts found in the western intellectual tradition the presuppositions inherent in neoclassical economics and

anthropocentric human centered and biocentric earth centered positions on sustainability It traces the evolution of attitudes about nature from the time of the Ancient Greeks through Europeans in the Middle Ages and the Renaissance the Enlightenment and the American Founders the nineteenth and twentieth centuries and up to the present Building on this foundation the author examines the political landscape as non governmental organizations NGOs industry leaders and government officials struggle to balance industrial development with environmental concerns Outrageous claims silly misrepresentations bogus arguments absurd contentions and overblown prophecies of impending calamities are bandied about by many parties on all sides of the debate industry spokespeople elected representatives unelected regulators concerned citizens and environmental NGOs alike In lieu of descending into this morass the author circumvents the silliness to explore the crucial issues through a more focused disciplined approach Rather than engage in acrimonious debate over minutiae as so often occurs in the context of green claims he recasts the issue in a way that provides a cohesive look at all sides This effort may be quixotic but how else to cut the Gordian knot

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