

Durability and service life prediction for concrete structures – developments and challenges

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Abstract. The paper reviews developments in service life prediction for concrete structures. It indicates the difficulties inherent in rational service life design, in view of the multiple factors and variabilities involved in the process. The paper also emphasises the advantages of performance-based approaches to durability prediction, and considers performance testing, which is critical to achieving intended service life. Such approaches allow service life modelling, which the current prescriptive approaches do not. The concept of ‘durability indicators’ is covered, with a practical example showing how this can be used to improve concrete durability in construction. The paper also stresses the importance of an ‘integrated approach’ to durability specifications, performance-based predictions, and site quality control.

1 Introduction

Concrete remains the material of choice for the vast majority of construction activities around the world. The reasons are obvious: it is economical, easy to use, can be shaped into endless forms, is excellent structurally, and, despite the claims that it is not a ‘green’ material, has a very low carbon footprint – see Table 1

Table 1. Environmental indicators of concrete and other materials

	Concrete	Fired clay bricks	Steel
Embodied energy (MJ/kg)	~ 0.95	~ 3.00	~ 35
CO ₂ emissions (kg CO _{2,e} /kg)	~ 0.13	~ 0.22	~ 2.80

Concrete is also the ‘developmental material’ *par excellence*. Global development in infrastructure, housing, and so on is unthinkable in the absence of modern concrete. Further, concrete has today assumed a position of being a sophisticated material when used at the upper end of its technological usage scale, incorporating multiple binders, admixtures, fibres, various aggregates, and the like, to produce a composite material that can be tailored to almost any constructional requirement. At the other end of the technological scale, it remains accessible to the ‘common person’, helping her or him to improve their lives in meaningful ways.

Nevertheless, there are real challenges in taking concrete forward into future decades as the construction

material of choice. One of the most pressing is the question of lack of durability, coupled with ‘Design for Service Life’, with the associated concepts of ‘Performance-based design’, particularly for durability.

2 Design for service life

Design for service life implies that we can, rationally, perform the necessary range of design activities that will give reasonable assurance that the structure in question will fulfil its intended function for the required service life. This may be feasible when the service life is 20 or 30 years, or maybe even 50 years, but, practically, how do we design for a 100-y or 150-y service life? This is now being more regularly demanded by infrastructure owners. The following aspects need to be considered:

- Changing exposure environments (for example, global warming and related extreme weather events)
- Rapidly changing materials, especially with the pressure to reduce environmental impacts
- Inadequate knowledge and models
- The pervasive problem of variable construction quality
- Differing perceptions of what ‘service life’ means, particularly in terms of ‘end of service life’ criteria
- The physical impossibility of verifying our designs at an age much greater than 50 years!

Take for example the ‘Coignet House’ in Paris, built in 1853, and thought to be the first reinforced concrete house in the world, shown in Figure 1. It is clearly now in a poor state, with evidence of reinforcing corrosion and

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Gebrail Bekdaş, Sinan Melih Nigdeli

A red circular graphic with a gradient, appearing as a partial circle or a stylized arrow pointing to the right, located to the right of the authors' names.

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Prediction of Concrete Durability J. Glanville, A. Neville, 1997-06-12 Poor durability of concrete is a continuing concern to owners of structures and their professional advisors Advances in methods of assessing and predicting durability are being made in many areas and this book provides a state of art review of the current situation Contributions from leading researchers and consultants make it a valuable guide f *Prediction and Evaluation of Hardened Concrete Strength* Yidong Xu, Jianghong Mao, Weijie Zhuge, Xiaoniu Yu, Ping Wu, 2025-08-30 This open access book monitors the development of the temperature field within concrete structures and based on the Arrhenius equation constructs F P maturity equations applicable to different temperature ranges It investigates the impact of hydration rate on the strength prediction method of the maturity equation Furthermore the book employs artificial neural network theory to improve the accuracy of early concrete strength predictions optimizing the neural network model to develop a more precise and widely applicable prediction model An intelligent program is developed using MATLAB facilitating rapid strength prediction and assessment on construction sites using measured parameters **Prediction of Concrete Durability from Thermal Tests of Aggregate** E. C. Higginson, D. G. Kretsinger, 1953 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 **Durability of Building Materials and Components 8: Performance, service life prediction and sustainable construction** Michael A. Lacasse, Dana J. Vanier, 1999 This set of conference proceedings focusses on topics related to integrating existing knowledge together with more recent contributions on service life life cycle costing performance and life cycle analysis sustainable durable design Includes author subject indexes **Recent Advances in Civil Engineering for Sustainable Communities** N. Vinod Chandra Menon, Sreevalsa Kolathayar, Hugo Rodrigues, K. S. Sreekesava, 2024-03-25 This book presents select proceedings of the International Conference on Interdisciplinary Approaches in Civil Engineering for Sustainable Development IACESD 2023 The topics covered include geographic information systems GIS and building information modeling BIM integration of numerical methods for fluid flow modeling and the revolutionary potential of 3D printing within the construction industry This book serves as a resource material for researchers and industry professionals interested in developing solutions for sustainable and resilient infrastructure that aims for communities with Net Zero Targets **Bridge Maintenance, Safety, Management, Life-Cycle Sustainability and Innovations** Hiroshi Yokota, Dan M. Frangopol, 2021-04-19 Bridge Maintenance Safety Management Life Cycle Sustainability and Innovations contains lectures and papers presented at the Tenth International Conference on Bridge Maintenance Safety and Management IABMAS 2020 held in Sapporo Hokkaido

Japan April 11 15 2021 This volume consists of a book of extended abstracts and a multimedia device containing the full papers of 571 contributions presented at IABMAS 2020 including the T Y Lin Lecture 9 Keynote Lectures and 561 technical papers from 40 countries The contributions presented at IABMAS 2020 deal with the state of the art as well as emerging concepts and innovative applications related to the main aspects of maintenance safety management life cycle sustainability and technological innovations of bridges Major topics include advanced bridge design construction and maintenance approaches safety reliability and risk evaluation life cycle management life cycle sustainability standardization analytical models bridge management systems service life prediction maintenance and management strategies structural health monitoring non destructive testing and field testing safety resilience robustness and redundancy durability enhancement repair and rehabilitation fatigue and corrosion extreme loads and application of information and computer technology and artificial intelligence for bridges among others This volume provides both an up to date overview of the field of bridge engineering and significant contributions to the process of making more rational decisions on maintenance safety management life cycle sustainability and technological innovations of bridges for the purpose of enhancing the welfare of society The Editors hope that these Proceedings will serve as a valuable reference to all concerned with bridge structure and infrastructure systems including engineers researchers academics and students from all areas of bridge engineering

Durability of Building Materials and Components 8 National Research Council Canada,1999 This volume provides a selected overview of approaches methods techniques tools systems and technology used to develop knowledge of the service life durability of construction and building materials **Advances in Non-Destructive Evaluation (NDE)** Bikash Ghose,Venugopal Manoharan,Ravibabu Mulaveesala,2024-09-30 This book comprises the proceedings of the Conference and Exhibition on Non Destructive Evaluation NDE 2021 organised by the Indian Society for Non destructive Testing ISNT This book covers topics from wide domains from conventional to advanced NDE including conventional and advanced NDE methods drone based inspections thermal wave imaging NDT data fusion material characterization waveguide sensors inspections of civil structures medical applications such as bone density and cancer diagnosis periodic maintenance life estimation as well as structural integrity and related areas This book serves as a useful reference for students researchers and practitioners alike **20th International Probabilistic Workshop** José C. Matos,Paulo B. Lourenço,Daniel V.

Oliveira,Jorge Branco,Dirk Proske,Rui A. Silva,Hélder S. Sousa,2024-07-05 This volume presents the proceedings of the 20th International Probabilistic Workshop IPW which was held in Guimar es Portugal on May 8 10 2024 Probabilistic methods are currently of crucial importance for research and developments in the field of engineering which face challenges presented by new materials and technologies and rapidly changing societal needs and values Contemporary needs related to for example performance based design service life design life cycle analysis product optimization assessment of existing structures and structural robustness give rise to new developments as well as accurate and practically applicable probabilistic and

statistical engineering methods to support these developments These proceedings are a valuable resource for anyone interested in contemporary developments in the field of probabilistic engineering applications **Advances in Structural**

Engineering K. V. L. Subramaniam, Mohd Ataullah Khan, 2020-05-13 This book contains selected papers in the area of structural engineering from the proceedings of the conference Futuristic Approaches in Civil Engineering FACE 2019 In the area of construction materials the book covers high quality research papers on raw materials and manufacture of cement mixing rheology and hydration admixtures characterization techniques and modeling fiber reinforced concrete repair and retrofitting of concrete structures novel testing techniques such as digital image correlation DIC Research on sustainable building materials like Geopolymer concrete and recycled aggregates are covered In the area of earthquake engineering papers related to the seismic response of load bearing unreinforced masonry walls reinforced concrete frame and buildings with dampers are covered Additionally there are chapters on structures subjected to vehicular impact and fire The contents of this book will be useful for graduate students researchers and practitioners working in the areas of concrete earthquake and structural engineering *Advances in Civil Engineering and Infrastructural Development* Laxmikant Madanmanohar Gupta, Maya Rajnarayan Ray, Pawan Kumar Labhasetwar, 2020-11-13 This book comprises selected proceedings of the International Conference on Recent Advancements in Civil Engineering and Infrastructural Developments ICRACEID 2019 The contents are broadly divided into five areas i smart transportation with urban planning ii clean energy and environment iii water distribution and waste management iv smart materials and structures and v disaster management The book aims to provide solutions to global challenges using innovative and emerging technologies covering various fields of civil engineering The major topics covered include urban planning transportation water distribution waste management disaster management environmental pollution and control environmental impact assessment application of GIS and remote sensing and structural analysis and design Given the range of topics discussed the book will be beneficial for students researchers as well industry professionals **Second International Conference on Durability of Building Materials and Components,**

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engineering Among those papers received we have eventually chosen about a hundred to be presented and included in this proceeding These papers generally represented the current research status in this field and the future trend We sincerely believe that these papers could be valuable to the future work of yours Finally on behalf of the committee I would like to deeply express our gratitude to those who have supported the EPE2014 especially the international experts who helped reviewing papers the DEStech Publications help publish the conference proceedings and last but not least the authors of these inspiring papers Without the help from these people EPE2014 would not be as half successful as it is now Here welcome to EPE2014 and let s hope that it will be a great success Tim Chou

New Advances in Soft Computing in Civil Engineering Gebrail Bekdaş, Sinan Melih Nigdeli, 2024-08-07 Soft computing applications plays a crucial role in civil engineering applications with engineers striving to create outstanding designs that prioritize safety aesthetics cost efficiency and environmental considerations Advanced optimization techniques are especially valuable for complex systems including multi constraint problems multi objective problems and control problems needing iterative processes in solving differential equations Throughout history people have used their creativity to enhance designs in everyday tasks and this is where metaheuristics come into play drawing inspiration from nature to develop novel algorithms These artificial intelligence based algorithms possess distinctive attributes and leveraging various features from different algorithms can enhance the effectiveness of optimization improving precision computational efficiency and convergence This book serves as a timely resource summarizing the latest advancements in civil engineering optimization encompassing both metaheuristic approaches and emerging trends that integrates artificial intelligence and machine learning techniques to predict optimal solutions streamlining lengthy optimization processes The book s chapters cover a wide range of civil engineering applications with the primary goal being to introduce fundamental concepts and advanced adaptations This comprehensive resource is designed to provide undergraduates and graduate engineering students with a solid understanding of materials and content making it a valuable reference for university courses in various civil engineering disciplines The book will be edited and the editors will contribute to most of the chapters Depending on the availability of high quality papers the editors may increase their contributions by sharing recent research projects and postgraduate students theses

Non-destructive Testing of Materials in Civil Engineering Krzysztof Schabowicz, 2019-11-19 This book was proposed and organized as a means to present recent developments in the field of nondestructive testing of materials in civil engineering For this reason the articles highlighted in this editorial relate to different aspects of nondestructive testing of different materials in civil engineering from building materials to building structures The current trend in the development of nondestructive testing of materials in civil engineering is mainly concerned with the detection of flaws and defects in concrete elements and structures and acoustic methods predominate in this field As in medicine the trend is towards designing test equipment that allows one to obtain a picture of the inside of the tested element and materials From this point of view interesting results with

significance for building practices have been obtained

Decision Based Design Vijitashwa Pandey, 2013-08-26 In a presentation that formalizes what makes up decision based design Decision Based Design defines the major concepts that go into product realization It presents all major concepts in design decision making in an integrated way and covers the fundamentals of decision analysis in engineering design It also trains engineers to understand the impacts of design decision The author teaches concepts in demand modeling and customer preference modeling and provides examples This book teaches most fundamental concepts encountered in engineering design like concept generation multiattribute decision analysis reliability engineering design optimization simulation and demand modeling The book provides the tools engineering practitioners and researchers need to first understand that engineering design is best viewed as a sequence of decisions made by the stakeholders involved and then apply the decision based design concepts in practice It teaches fundamental concepts encountered in engineering design such as concept generation multiattribute decision analysis reliability engineering design optimization simulation and demand modeling This book helps students and practitioners understand that there is a rigorous way to analyze engineering decisions taking into consideration all the potential technical and business impacts of their decisions It can be used in its entirety to teach a course in decision based design while selected chapters can also be used to cover courses in subdisciplines that make up decision based design

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Sustainable Traffic and Transportation Engineering in 2023 Andrii Bieliatynskyi, Dmytro Komyshev, Wen Zhao, 2024-07-30 This open access book discusses modern cutting edge techniques and theoretical research in the domain of transportation engineering As China's Belt and Road Initiative BRI gains momentum over these years the construction of transport routes between China and its neighboring countries has seen an unprecedented rise which draws increased attention from researchers to the theoretical advances and technological innovation in the construction of transportation facilities It will be an invaluable asset for the development of transport infrastructure construction technologies worldwide Among the landmark engineering projects in the initiative are the Piraeus Port in Greece the 100 MW photovoltaic power plant in Hungary Kauposberg and the Monnet Railway in Kenya each of which stands out with its innovative highlights in theoretical research and technological advances The book is expected to share with global experts and engineers in the field of transportation advanced research results and technologies in construction from China discuss new research topics and explore feasible solutions in the realm of transportation engineering The main topics discussed in this book include a New theories and technologies for the construction of roads railroads subways airports bridges tunnels and other infrastructure b Advanced theories and technologies for the construction of ports dams reservoirs sluices hydraulic tunnels canals and other infrastructure c Novel materials and innovative application of these materials to the construction of transportation facilities This book is intended for graduate and doctoral students experts and engineers in the field of transportation engineering

Life-Cycle and Sustainability of Civil Infrastructure Systems Alfred Strauss, Dan Frangopol, Konrad

Bergmeister,2012-09-18 Life Cycle and Sustainability of Civil Infrastructure Systems contains the lectures and papers presented at the Third International Symposium on Life Cycle Civil Engineering IALCCE 2012 held in one of Vienna s most famous venues the Hofburg Palace October 3rd 6th 2012 This volume consists of a book of extended abstracts 516 pp and a DVD ROM **Advanced Manufacturing and Automation XI** Yi Wang,Kristian Martinsen,Tao Yu,Kesheng

Wang,2022-03-07 The proceedings collect selected papers from the 11th International Workshop of Advanced Manufacturing and Automation IWAMA 2021 held in Zhengzhou Polytechnic China on 11 12 October 2021 Topics focusing on novel techniques for manufacturing and automation in Industry 4 0 are now vital factors for the maintenance and improvement of the economy of a nation and the quality of life It will help academic researchers and engineering to implement the concept theory and methods in Industry 4 0 which has been a hot topic These proceedings will make valuable contributions to academic researchers engineers in the industry for the challenges in the 4th industry revolution and smart factories

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