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Condition Assessment of Reinforced Concrete Bridges: Current Practice and Research Challenges

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Abstract: One quarter of bridges in Canada and the United States need repair. The present study provides a critical overview of the state-of-the-art existing condition assessment techniques for reinforced concrete bridges, with an emphasis on current practice in North America. The techniques were classified into five categories, including visual inspection, load testing, non-destructive evaluation, structural health monitoring, and finite element modelling. The potential applications of these technologies are discussed and compared, highlighting their primary advantages and limitations. The review revealed that quantitative assessment could be effectively achieved using several complementary technologies. It is shown that there is need for concerted research efforts to achieve automated data collection and interpretation analyses. Also, the configuration of monitoring systems was found to be paramount in effectively assessing bridge performance parameters of interest. The study suggests appropriate investigation methods for some bridge deterioration mechanisms. Knowledge gaps and challenges in this field are outlined in order to motivate further research and development of these technologies.

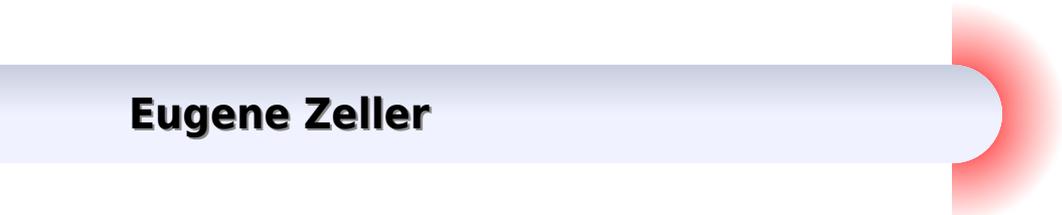
Keywords: concrete bridges; deterioration; condition assessment; visual inspection; load testing; non-destructive evaluation; structural health monitoring; finite element modelling

1. Introduction

Bridge failures can be catastrophic, both in terms of human life and economic loss. According to the Canadian infrastructure report card (2016), 26% of bridges are in fair, poor or very poor condition, and US \$50 billion needs to be invested for bridge replacement and maintenance. Likewise, about 25% of bridges in the USA are either structurally deficient or functionally obsolete, and \$70.9 billion is needed to address their maintenance [1]. Reinforced concrete (RC) bridges often deteriorate due to ageing, materials and construction defects, exposure to aggressive environments, lack of ductility, and excessive loads. The distinction among their major degradation causes is purely qualitative since such mechanisms can act in synergy. Different deterioration processes lead to different types of defects, which represent the main challenge in bridge inspection programmes. In addition, fire is one of the most severe hazards to which RC bridges may be subjected during its service life. Bridge management systems (BMSs) have been developed to assist decision makers in maximizing the safety, serviceability, and functionality of bridges within available budgets. The basic components of a BMS are illustrated in Figure 1. The architecture of a typical BMS consists of a database, condition and structural assessment modules, a deterioration prediction module, a lifecycle cost module, and a maintenance optimization module. The database stores inventory and appraisal data. The condition assessment module evaluates the existing health condition of the bridge(s). The deterioration prediction module estimates the future condition of bridge components. The life-cycle cost module calculates agency and user costs

Concrete Structures Condition Assessment Guidelines

Eugene Zeller



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Life-Cycle Civil Engineering: Innovation, Theory and Practice Airon Chen, Xin Ruan, Dan M. Frangopol, 2021-02-26 Life Cycle Civil Engineering Innovation Theory and Practice contains the lectures and papers presented at IALCCE2020 the Seventh International Symposium on Life Cycle Civil Engineering held in Shanghai China October 27 30 2020 It consists of a book of extended abstracts and a multimedia device containing the full papers of 230 contributions including the Fazlur R Khan lecture eight keynote lectures and 221 technical papers from all over the world All major aspects of life cycle engineering are addressed with special emphasis on life cycle design assessment maintenance and management of structures and infrastructure systems under various deterioration mechanisms due to various environmental hazards It is expected that the proceedings of IALCCE2020 will serve as a valuable reference to anyone interested in life cycle of civil infrastructure systems including students researchers engineers and practitioners from all areas of engineering and industry NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings Eugene Zeller, 2000-06 This document from the National Earthquake Hazards Reduction Program NEHRP was prepared for the Building Seismic Safety Council BSSC with funding from the Federal Emergency Management Agency FEMA It provides commentary on the NEHRP Guidelines for the Seismic Rehabilitation of Buildings It contains systematic guidance enabling design professionals to formulate effective reliable rehabilitation approaches that will limit the expected earthquake damage to a specified range for a specified level of ground shaking This kind of guidance applicable to all types of existing buildings in all parts of the country has never existed before Illustrated **Overview of Industry Guidance on Concrete Condition Assessment and Concrete Repair for Use Prior to Coating**, 2000 This Special Publication SP introduces a brief overview of concrete repair guidance offered by the American Concrete Institute ACI International the International Concrete Repair Institute ICRI the American Concrete Pavement Association ACPA the Aberdeen Group the Portland Cement Association PCA and work by authors considered experts in the field of concrete repair The publication is divided into two parts Part I *Selected Proceedings of the 2nd International Engineering Research Symposium; IERS 2024; 14 Aug; Colombo, Sri Lanka* T. Nilanthi Fernando, Manjula Siriwardhana, Ranjith Dissanayake, Meththika Vithanage, Jayathu G. Samarawickrama, Pradeep Gajanayake, 2025-03-03 This book presents selected peer reviewed articles from the 2nd International Engineering Research Symposium IERS 2024 held at Colombo in Sri Lanka under the theme of Engineering Innovations for Economic Transformation It highlights the latest advancements in engineering research innovations and technological principles aimed at driving economic changes and improvements within society and the industry IERS2024 covers the areas of Agricultural Engineering Chemical Engineering Civil Engineering Computer Science Engineering Electrical Engineering Electronics Telecommunication Engineering Mechanical Mechatronics Engineering Materials Science Engineering Manufacturing Process Engineering and other Engineering discipline relevant to the theme of IERS 2024 **Ninth International Symposium on Environmental**

Degradation of Materials in Nuclear Power Systems Steve Bruemmer, Peter Ford, Gary Was, 2013-10-18 This collection presents an exchange of ideas among scientists and engineers about the economic and safety concerns surrounding environmentally induced materials problems which lead to nuclear power plant outages Scientists and engineers concerned with the environmental degradation processes corrosion mechanical and radiation effects present their latest results on such topics as life extension relicensing and materials problems associated with spent fuel storage and radioactive waste disposal This collection will be of interest to utility engineers reactor vendor engineers plant architect engineers researchers concerned with materials degradation and consultants involved in design construction and operation of water reactors

Case Studies of Rehabilitation, Repair, Retrofitting, and Strengthening of Structures Mourad M. Bakhoun, 2010 *ACI Manual of Concrete Practice* American Concrete Institute, 2002 [Guideline for Structural Condition Assessment of Existing Buildings](#) American Society of Civil Engineers, Structural Engineering Institute, 2000-01 Changing economic conditions concern for historic preservation emphasis on fully utilizing conveniently located structures space shortages and increasing cost of materials and products used in the construction of new buildings have resulted in a need to evaluate and more fully utilize the existing building inventory To this end this revision of the ASCE Standard *Guideline for Structural Condition Assessment of Existing Buildings* a replacement of ASCE 11 90 provides the design community with guidelines for assessing the structural conditions of existing buildings constructed of combinations of material including concrete masonry metals and wood It consists of an overview of preliminary and detailed assessment procedures of materials properties and test methods and of evaluation procedures for various physical conditions of the structure This information has been compiled and subjected to a consensus review and approved by the ASCE Standards Committee on Structural Condition to provide a much needed resource standards on building condition assessment for selected materials and for other areas related to the structural performance of buildings Professional engineers building owners and regulatory officials will find this Standard *Guideline* invaluable

Failure, Distress and Repair of Concrete Structures N. Delatte, 2009-11-24 Many concrete structures around the world have reached or exceeded their design life and are showing signs of deteriorating Any concrete structure which has deteriorated or has sustained damage is a potential hazard *Non-destructive Testing of Wisconsin Highway Bridges* Alireza Ghorbanpoor, Neal Benish, 2005 **Guide for Evaluation of Concrete Structures Prior to Rehabilitation** ACI Committee 364, 1993 **Report on Aging of Nuclear Power Plant Reinforced Concrete Structures** D. J. Naus, 1996 The Structural Aging Program provides the US Nuclear Regulatory Commission with potential structural safety issues and acceptance criteria for use in continued service assessments of nuclear power plant safety related concrete structures The program was organized under four task areas Program Management Materials Property Data Base Structural Component Assessment Repair Technology and Quantitative Methodology for Continued Service Determinations Under these tasks over 90 papers and reports were prepared addressing pertinent aspects associated with

aging management of nuclear power plant reinforced concrete structures Contained in this report is a summary of program results in the form of information related to longevity of nuclear power plant reinforced concrete structures a Structural Materials Information Center presenting data and information on the time variation of concrete materials under the influence of environmental stressors and aging factors in service inspection and condition assessments techniques repair materials and methods evaluation of nuclear power plant reinforced concrete structures and a reliability based methodology for current and future condition assessments Recommendations for future activities are also provided 308 refs 61 figs 50 tabs

NEHRP Guidelines for the Seismic Rehabilitation of Buildings, 1997 *Guide for Nondestructive Evaluation Methods for Condition Assessment, Repair, and Performance Monitoring of Concrete Structures* International Concrete Repair Institute, 2009 *Codes and Standards and Applications for Design and Analysis of Pressure Vessel and Piping Components*, 1991 Robert F. Sammataro, 1991 **Repair and Renovation of Concrete Structures** Ravindra K. Dhir, M. Roderick Jones, Li Zheng, 2005 Preface Introduction Organising Committee Scientific and Technical Committee Collaborating Institutions Sponsoring Organisations with Exhibition Exhibiting Organisations Supporting Institutions Opening Paper Getting it Right From Testing Through Diagnosis to Lasting Repair THEME 1 DEGRADATION OF CONCRETE STRUCTURES Keynote Paper On the Role of Moisture in Degradation of Concrete Structures Condition Survey of Romanian Prestressed Concrete Bridges The Use of Air Entrainment in Bridges and Highway Structures of the USA Influence of Design and Construction Details on Localized Degradation of Concrete Structures Diagnosis and Repair of a Cement Concrete Structure A Case Study of a Residential Building Degradation of Concrete in Structures Water Treatment Infrastructure Models for Environmental Actions on Reinforced Concrete Structures Influence of Desulfurised Combustion Gases on Durability of Cooling Towers Studying the Bond Between Repair Materials and Concrete Substrate Mathematical Modelling of Strike Penetration Processes into Concrete and Sandy Barriers THEME 2 DEVELOPMENTS IN DIAGNOSTIC TECHNIQUES Keynote Paper Cover Concrete Evaluation The Contribution of GRP Techniques Experimental Studies and Field Measurements Cost Effective Testing of Concrete Structures Defeating Alkali Aggregate Reaction Worldwide Temperature Variations in Concrete Subjected to Cyclic Compressive Loads Consequences for Diagnostic Applications A Study About the Rehabilitation Method of Electrochemical Chloride Extraction in Brazil Loading Tests Practical Experiences Possibilities of Optical Fibre Sensors to Monitor Strength in Concrete Structures Durability of Marine and Coastal Structures The High Quality Cover and Monitoring Approach New Suggestions to Measure the Corrosion Level of Reinforcement Using Infrared Thermographic Technology Fracture Energy of Ultra High Performance Concrete Beams Using Infrared Thermographic Technology Development of an Automatic Crack Recognition System for Concrete Structures A Non Destructive Test to Measure Concrete Permeability Ultrasonic Inspection of Concrete Structure New Steps Towards Transparent Concrete On Bonding Repairing Steel Fibre Reinforced Concrete to Hardened Concrete Condition Assessment of RC Structures by Electro

Chemical Method Linear Polarization and Accelerated Carbonation Experiments THEME 3 REPAIR MATERIALS AND METHODS Keynote Paper New Materials Concepts and Quality Control Systems for Strengthening Concrete Construction Repair of Foundation for Large Compressor On the Use of Non Adequate Primers to the Reinforcing Steel in Concrete Localised Repairs Evaluating External CFRP Strips and Internal MFR Steel Shear Bars for Shear Strengthening of Precast Concrete Channel Beams Evaluation of Corrosion Inhibitors for Remediation of St Mary s Multi Storey Car Park Colchester Improving Efficiency in the Galvanic Cathodic Protection of Concrete Structures Re alkalisation of Carbonated Concrete by Alkalline Solutions Absorption and Diffusion Mechanisms External CFRP Tendons for Bridge Strengthening in Austria Anchorage of Additional External Prestressing Tendons Determination of Ductility and Deformability Undeces for FRP Strengthened RC Slabs Use of FRP Materials for Strengthening Concrete Structures Effect of Temperature on the Durability of Systems of Strengthening of Concrete Structures Axial Compressive Strength of Reinforced Concrete Columns Wrapped with Fibre Reinforced Polymers FRP Efficiency of Hybrid FRP Sheets in Strengthening Concrete Beams Embedded Fibre Bragg Grating Sensors for Monitoring the Health of Concrete Structures Performances of Bonded An *Concrete International* ,2004 *Assessment and Renovation of Concrete Structures* Ted Kay,1992 Part of the Concrete Design and Construction series this text considers the assessment and renovation of concrete structures It covers such areas as deterioration process testing techniques interpretation of results repair and renovation techniques and contract documents

Structural Condition Assessment Robert T. Ratay,2005-01-17 In Structural Condition Assessment editor in chief Robert T Ratay gathers together the leading people in the field to produce the first unified resource on all aspects of structural condition assessment for strength serviceability restoration adaptive reuse code compliance and vulnerability Organized by the four main stages of a structural evaluation this book provides an introduction to structural deterioration and its consequences the business and legal aspects of conducting an evaluation initial survey and evaluation techniques for various structures and specific tests for five of the most common structural materials concrete steel masonry timber and fabric

Handbook of Corrosion Engineering 2/E Pierre R. Roberge,2012-01-26 THE MOST COMPLETE UP TO DATE CORROSION CONTROL REFERENCE Fully revised throughout Handbook of Corrosion Engineering Second Edition discusses the latest advances in corrosion resistant materials methods and protective coatings This comprehensive resource covers all aspects of corrosion damage including detection monitoring prevention and control Written by a world renowned expert on the subject the book helps you to select materials and resolve design issues where corrosion is considered a factor Understand predict evaluate mitigate and correct corrosion problems with help from this authoritative guide Coverage includes Aqueous corrosion High temperature corrosion Atmospheric water seawater soil concrete and microbial environments Modeling life prediction and computer applications Identifying and inspecting corrosion failures Corrosion maintenance through inspection and monitoring Corrosion testing Selection and design of engineering materials Protective

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