

Durability of CFRP strengthened concrete structures under accelerated or environmental ageing conditions

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ABSTRACT: The durability of concrete slabs strengthened by bonded composite materials has been investigated in the framework of an international cooperation between two French and Japanese research institutes. Time evolution of the concrete/composite adhesive bond strength was studied under both controlled and environmental ageing conditions, by using different mechanical characterization methods. The first results of this ongoing experimental campaign are presented.

1 INTRODUCTION

Composite materials are commonly used worldwide for the strengthening and repair of civil structures. In Japan for instance, strengthening methods based on fibre reinforced polymer (FRP) have been intensively used for the seismic retrofit of bridge columns after the 1995 Kobe earthquake (Saito 2002), whereas in France, such methods are increasingly applied to the rehabilitation or upgrading of damaged concrete structures (Luyckx 1999). If the effectiveness of FRP strengthening techniques has been clearly demonstrated and is now commonly accepted, the durability of the adhesive bond at the concrete/composite interface is still a matter of investigation (Karbhari 2007, Marouani et al. 2008).

Several authors have reported substantial decreases in the adhesive bond strength of FRP strengthened concrete specimens submitted to accelerated ageing conditions, such as freeze-thaw/dry-heat cycles, immersion in salt solutions or exposure to humid environments (Karbhari 2007, Grace & Singh 2005). Saturated humidity was often found to be the most detrimental factor to the adhesive bond properties (Grace & Singh 2005). Beside the abundant laboratory studies, there are only few available data on the effect of long-term environmental ageing. Moreover there is still no reliable method to assess the field degradation rate on the basis of controlled laboratory exposures.

In this paper, the first results of two ongoing studies conducted by the French and Japanese Public Works Research Institutes (LCPC and PWRI, respectively) are presented. On the French side, concrete slabs strengthened by carbon fibre reinforced polymer (CFRP) have been exposed to accelerated laboratory ageing in saturated humidity. Time evolution of the adhesive bond strength was monitored by using either pull-off or shear loading tests. On the Japanese side, similar kind of specimens have been exposed to environmental ageing in the Tokyo City area for 14 years, and the residual adhesive strength was then evaluated by pull-off or peeling tests.

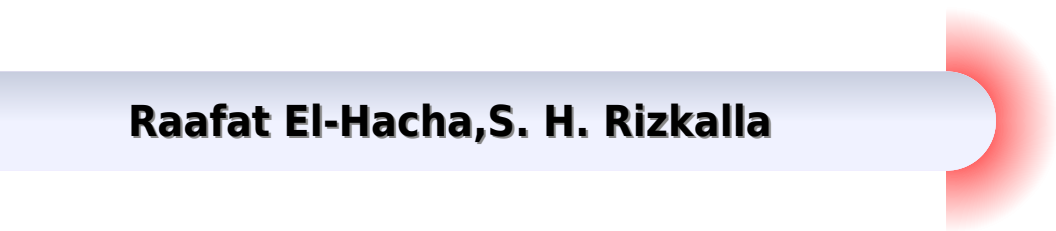
Data provided by these two complementary studies will offer a unique opportunity to compare the effects of laboratory and environmental ageing on the properties of the concrete/composite interface, and to discuss the validity of the various adhesive test methods.

2 EFFECTS OF ACCELERATED AGEING

The French Public Works Research Institute (LCPC) has selected specific laboratory ageing conditions for the durability assessment of adhesive joints: specimens are exposed to 95% relative humidity at a temperature of 40°C in a climatic chamber. Such a humid environment is supposed to be detrimental for the concrete/composite interface, since it may induce both plasticization

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Concrete Repair, Rehabilitation and Retrofitting II Mark G. Alexander, Hans-Dieter Beushausen, Frank Dehn, Pilate Moyo, 2008-11-13 The Second International Conference on Concrete Repair Rehabilitation and Retrofitting ICCRRR 2005 was held in Cape Town South Africa from 24-26 November 2008. The Conference followed the very successful First International Conference also in Cape Town in 2005 and continued as a collaborative venture by researchers from the South African Research Programme in Concrete Materials based at the Universities of Cape Town and The Witwatersrand and The Construction Materials Sections at Leipzig University and MFPA Leipzig in Germany. The background in industry and the state of national infrastructures continues to be highly challenging and demanding. The facts remain that much of our concrete infrastructure deteriorates at unacceptable rates that we need appropriate tools and techniques to undertake the vast task of sound repair, maintenance and rehabilitation of such infrastructure and that all this must be undertaken with due cognisance of the limited budgets available for such work. New ways need to be found to extend the useful life of concrete structures cost effectively. Confidence in concrete as a viable construction material into the 21st century needs to be retained and sustained, particularly considering the environmental challenges that the industry and society now face. The conference proceedings contain papers presented at the conference and classified into a total of 12 sub-themes which can be grouped under the three main themes of: i) Concrete durability aspects, ii) Condition assessment of concrete structures and iii) Concrete repair, rehabilitation and retrofitting. The major interests in terms of submissions exist in the fields of innovative materials for durable concrete construction, integrated service life modelling of reinforced concrete structures, NDE, NDT and measurement techniques, repair methods and materials, and structural strengthening and retrofitting techniques. The large number of high quality papers presented and the wide range of relevant topics covered confirm that these proceedings will be a valued reference for many working in the important fields of concrete durability and repair and that they will form a suitable base for discussion and provide suggestions for future development and research.

Repair, Rehabilitation, and Retrofitting Mr. Rohit Manglik, 2024-09-24 This book offers a detailed exploration of repair, rehabilitation and retrofitting focusing on key concepts, methodologies and practical implementations relevant to modern engineering and technology practices.

10th International Conference on FRP Composites in Civil Engineering Alper Ilki, Medine Ispir, Pinar Inci, 2021-11-26 This volume highlights the latest advances, innovations and applications in the field of FRP composites and structures as presented by leading international researchers and engineers at the 10th International Conference on Fibre Reinforced Polymer (FRP) Composites in Civil Engineering (CICE) held in Istanbul, Turkey, on December 8-10, 2021. It covers a diverse range of topics such as: All FRP structures, Bond and interfacial stresses, Concrete filled FRP tubular members, Concrete structures reinforced or pre-stressed with FRP, Confinement, Design issues, guidelines, Durability and long term performance, Fire impact and blast loading, FRP as internal reinforcement, Hybrid structures of FRP and other materials.

Materials and products Seismic retrofit of structures Strengthening of concrete steel masonry and timber structures and Testing The contributions which were selected by means of a rigorous international peer review process present a wealth of exciting ideas that will open novel research directions and foster multidisciplinary collaboration among different specialists

Maintenance, Safety, Risk, Management and Life-Cycle Performance of Bridges Nigel Powers, Dan Frangopol, Riadh Al-Mahaidi, Colin Caprani, 2018-07-04 Maintenance Safety Risk Management and Life Cycle Performance of Bridges contains lectures and papers presented at the Ninth International Conference on Bridge Maintenance Safety and Management IABMAS 2018 held in Melbourne Australia 9-13 July 2018 This volume consists of a book of extended abstracts and a USB card containing the full papers of 393 contributions presented at IABMAS 2018 including the T Y Lin Lecture 10 Keynote Lectures and 382 technical papers from 40 countries The contributions presented at IABMAS 2018 deal with the state of the art as well as emerging concepts and innovative applications related to the main aspects of bridge maintenance safety risk management and life cycle performance Major topics include new design methods bridge codes heavy vehicle and load models bridge management systems prediction of future traffic models service life prediction residual service life sustainability and life cycle assessments maintenance strategies bridge diagnostics health monitoring non destructive testing field testing safety and serviceability assessment and evaluation damage identification deterioration modelling repair and retrofitting strategies bridge reliability fatigue and corrosion extreme loads advanced experimental simulations and advanced computer simulations among others This volume provides both an up to date overview of the field of bridge engineering and significant contributions to the process of more rational decision making on bridge maintenance safety risk management and life cycle performance 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 students researchers and engineers from all areas of bridge engineering

Durability of Composites for Civil Structural Applications Institute of Materials, Minerals, and Mining, 2007-07-25 Provides practising engineers decision makers and students with a useful and fundamental guide to the use of FRP composites within civil and structural engineering A P Mouritz RMIT Australia

Proceedings of CEE 2025 Zinoviy Blikharsky, Dušan Katunský, Lech Licholai, 2025-10-29 This book gathers the latest advances innovations and applications in the field of effective methods of calculation resource saving technologies and advanced materials in civil and environmental engineering as presented by leading international researchers and engineers at the XIX International Scientific Conference Current Issues of Civil and Environmental Engineering Lviv Ko ice Rzesz w held in Her any Slovakia on September 24-26 2025 It covers highly diverse topics including structural shaping and optimization aspects of structural behavior and modeling advanced analysis methods experimental tests and numerical simulations design codes in particular Eurocodes and other national and regional limit state codes and highway and bridges engineering It also discusses modern architectural and structural solutions innovative materials and products durability and

maintenance fabrication and erection sustainability in construction renewable energy sources heat gas and water supply ventilation and air conditioning ecological and energy saving technologies modern water purification and treatment technologies and the protection of water ecosystems This book which was selected by means of a rigorous international peer review process highlights numerous exciting ideas that will spur novel research directions and foster multidisciplinary collaborations

FRP Composites in Civil Engineering - CICE 2004 R. Seracino, 2004-12-15 The range of fibre reinforced polymer FRP applications in new construction and in the retrofitting of existing civil engineering infrastructure is continuing to grow worldwide Furthermore this progress is being matched by advancing research into all aspects of analysis and design The Second International Conference on FRP Composites in

Hydraulic and Civil Engineering Technology VIII Mijia Yang, Pijush Samui, João C.G. Lanzinha, Jianhui Hu, 2023-12-15 All of us are dependent on a built environment constructed and maintained by civil and hydraulic engineers and for those working in these fields keeping up to date with the latest technological developments is vital for the safe and efficient design and operation of this infrastructure This book presents the proceedings of HCET 2023 the 8th International Technical Conference on Frontiers of Hydraulic and Civil Engineering Technology held from 25-27 September 2023 in Wuhan China HCET is an international conference which aims to enhance the development of hydraulic and civil engineering in China with a focus on high end intelligent and green technologies It seeks to do this by consolidating global wisdom and achievements and providing scientific support HCET also offers an excellent opportunity for scientists researchers and engineers from around the world to exchange their findings and discuss developments establishing a basis for national and international collaboration A total of 316 contributions were received for the 2023 edition of which 187 were ultimately accepted after a rigorous review process and checks for quality and plagiarism Topics covered include the research and development of concrete structure design and analysis structural mechanics and structural engineering building and future materials hydraulic engineering geological exploration and earthquake engineering building technology urban planning road bridge and traffic engineering energy infrastructure environmental engineering and advanced engineering technologies and interdisciplinary sciences and applications Covering a wide range of subjects related to hydraulic engineering and civil engineering technology and associated transdisciplinary sciences the book will be of interest to all those working in the field

Long-Term Durability of Polymeric Matrix Composites Kishore V. Pochiraju, Gyaneshwar P. Tandon, Gregory A. Schoeppner, 2011-09-25 Long Term Durability of Polymeric Matrix Composites presents a comprehensive knowledge set of matrix fiber and interphase behavior under long term aging conditions theoretical modeling and experimental methods This book covers long term constituent behavior predictive methodologies experimental validation and design practice Readers will also find a discussion of various applications including aging air craft structures aging civil infrastructure in addition to engines and high temperature applications

Dictionary of Concrete Technology Natt Makul, 2025-06-04 The Dictionary of Concrete Technology is a

thorough resource encapsulating the progressions in concrete technology which connects traditional methodologies with contemporary innovations With over 1 000 meticulously selected terminologies it provides clear definitions context and cross references catering to professionals students and researchers This dictionary addresses the necessity for an updated lexicon to keep pace with the swift advancements in materials science and civil engineering Compiled through years of collaboration with scholars engineers and industry specialists it ensures precision and relevance Organized alphabetically with detailed elucidations the dictionary is straightforward to navigate supported by an extensive index and references for further exploration Focusing on both current methodologies and emerging trends such as sustainability and digital construction it offers insights into the future of the discipline Designed as an essential instrument it continues evolving with updates supporting its users quest for knowledge and excellence

Advanced Polymer Composites for Structural Applications in Construction L C Hollaway, 2004-04-22 Over the past three decades advanced polymer composites have emerged as an attractive construction material for new structures and the strengthening rehabilitation of existing buildings and bridges The techniques associated with the technology analysis and design of polymer composites in construction are continually being researched and the progress made with this exciting material will continue at an ever increasing rate to meet the demands of the construction industry This volume of proceedings is from the Second ACIC 2004 International Conference which focused on the application and further exploitation of advanced composites in construction The conference allowed practising engineers asset managers researchers and representative of regulatory bodies to promote the active exchange of scientific and technical information on the rapidly changing scene of advanced composites in construction This volume focuses on the presentation of new concepts techniques and case studies which will lead to greater exploitation of advanced polymer composites and FRP materials for civil engineering infrastructure rehabilitation and renewal Presents new concepts techniques and case studies

Advances in FRP Composites in Civil Engineering Lieping Ye, Peng Feng, Qingrui Yue, 2012-02-01 Advances in FRP Composites in Civil Engineering contains the papers presented at the 5th International Conference on Fiber Reinforced Polymer FRP Composites in Civil Engineering in 2010 which is an official conference of the International Institute for FRP in Construction IIFC The book includes 7 keynote papers which are presented by top professors and engineers in the world and 203 papers covering a wide spectrum of topics These important papers not only demonstrate the recent advances in the application of FRP composites in civil engineering but also point to future research endeavors in this exciting area Researchers and professionals in the field of civil engineering will find this book is exceedingly valuable Prof Lieping Ye and Dr Peng Feng both work at the Department of Civil Engineering Tsinghua University China Qingrui Yue is a Professor at China Metallurgical Group Corporation

Advances in Structural Mechanics and Applications José António Fonseca de Oliveira Correia, Satyabrata Choudhury, Subhrajit Dutta, 2022-06-02 The proceedings of the conference is going to benefit the researchers academicians students and professionals in getting

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Structural Engineering and Materials Science **Proceedings of the 6th International Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures** Xiang-Lin Gu, Masoud Motavalli, Alper Ilki, Qian-Qian Yu, 2024-01-20 This book is a compilation of selected papers from the 6th International Conference on Smart Monitoring Assessment and Rehabilitation of Civil Structures SMAR 2022 The work focuses on the state of the practice and recent advances in testing and monitoring technology in structural modeling and assessment methods and in the application of advanced materials for structural rehabilitation The contents make valuable contributions to international professors research scientists professional engineers postdoctoral fellows and postgraduate students *Strengthening of Reinforced Concrete Structures* L C Hollaway, M Leeming, 1999-03-05 The in situ rehabilitation or upgrading of reinforced concrete members using bonded steel plates is an effective convenient and economic method of improving structural performance However disadvantages inherent in the use of steel have stimulated research into the possibility of using fibre reinforced polymer FRP materials in its place providing a non corrosive more versatile strengthening system This book presents a detailed study of the flexural strengthening of reinforced and prestressed concrete members using fibre reinforced polymer composite plates It is based to a large extent on material developed or provided by the consortium which studied the technology of plate bonding to upgrade structural units using carbon fibre polymer composite materials The research and trial tests were undertaken as part of the ROBUST project one of several ventures in the UK Government's DTI LINK Structural Composites Programme The book has been designed for practising structural and civil engineers seeking to understand the principles and design technology of plate bonding and for final year undergraduate and postgraduate engineers studying the principles of highway and bridge engineering and structural engineering Detailed study of the flexural strengthening of reinforced and prestressed concrete members using fibre reinforced polymer composites Contains in depth case histories *Computational Mechanics, Materials and Engineering Applications* Jian Rong Yang, Min Yu, 2011-12-22 Selected peer reviewed papers from the 2011 International Workshop on Computational Mechanics Materials and Engineering Applications CMMEA 2011 July 23 24 2011 in Kunming P R China **Water Conservancy and Civil Construction Volume 1** Saheed Adeyinka Oke, Fauziah Ahmad, 2023-08-17 Water Conservancy and Civil Construction gathers the most cutting edge research on Water Conservancy Projects Civil Engineering Construction Technology and Process The book is aimed at academics and engineers in water and civil engineering *Insights and Innovations in Structural Engineering, Mechanics and Computation* Alphose Zingoni, 2016-11-25 Insights and Innovations in Structural Engineering Mechanics and Computation comprises 360 papers that were presented at the Sixth International Conference on Structural Engineering Mechanics and Computation SEMC 2016 Cape Town South Africa 5 7 September 2016 The papers reflect the broad scope of the SEMC conferences and cover a wide range of engineering structures buildings bridges towers roofs foundations offshore structures tunnels dams vessels vehicles and machinery and engineering materials steel

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