

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

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 **Bond Behaviour of FRP in Structures**

J. F. Chen, J. G. Teng, 2005 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 Concrete Solutions 2011 Michael Grantham, Viktor Mechtcherine, Ulrich Schneck, 2011-09-08 The Concrete Solutions series of International Conferences on Concrete Repair began in 2003 with a conference held in St Malo France in association with INSA Rennes followed by the second conference in 2006 with INSA again at St Malo France and the third conference in 2009 in Padova and Venice in association with the University of Padova Now in 2011 the event is being held in Dresden in Germany and has brought together some 112 papers from 33 countries Whereas electrochemical repair tended to dominate the papers in earlier years new developments in structural strengthening with composites have been an increasingly important topic with a quarter of the papers now focusing on this area New techniques involving Near Surface Mounted NSM carbon fibre rods strain hardening composites and new techniques involving the well established carbon fibre and polyimide wrapping and strengthening systems are presented Seventeen papers concentrate on case studies which are all important in such conferences to learn about what works and what doesn't work on real structures Thirteen papers are devoted to new developments in Non Destructive Testing NDT Other topics include service life modelling fire damage surface protection methods and coatings patch repair general repair techniques and whole life costing This book is essential reading for anyone engaged in the concrete repair field from engineers to academics and students and also to clients who as the end user are ultimately responsible for funding these projects and making those difficult decisions about which system or method to use

Nondestructive Evaluation and Health Monitoring of Aerospace Materials and Composites III Peter J. Shull, Andrew L. Gyekenyesi, 2004 Proceedings of SPIE present the original research papers presented at SPIE conferences and other high quality conferences in the broad ranging fields of optics and photonics These books provide prompt access to the latest innovations in research and technology in their respective fields Proceedings of SPIE are among the most cited references in patent literature **Innovation & Sustainability of Structures**, 2005 *Fiber-reinforced Polymer (FRP) Reinforcement for Concrete Structures*, 2005 *Extending Performance of Concrete Structures* Ravindra K Dhir, Paul A J Tittle, 1999-10 Topics discussed in these papers include developments in materials and methods for repair of existing structures and use in

new construction The themes of the seminar are Materials Development and Practical Applications Dissertation Abstracts International ,2007 **Structural Integrity of RC Columns Wrapped with FRP Sheet Subjected to Various**

Environmental Conditions Including Corrosion ,2004 Although the short term performance of reinforced concrete RC columns wrapped with fiber reinforced polymer FRP composite materials has been widely studied research studies on the long term performance are limited The objective of this study was to evaluate the effects of various environmental conditions on the long term behavior of RC columns wrapped with FRP sheets The experimental program comprised two parts ambient environmental effect tests and corrosion tests The environmental conditions considered in the ambient environmental tests included 1 freeze thaw cycles 2 high temperature cycles 3 high humidity cycles 4 ultraviolet UV radiation and 5 saline solution while the corrosion tests dealt with the corrosion of steel reinforcement embedded in RC columns wrapped with FRP sheets RC columns were wrapped with carbon fiber reinforced polymer CFRP sheets and glass fiber reinforced polymer GFRP sheets and conditioned under the environmental conditions listed After the environmental conditioning uni axial compression tests were conducted in order to evaluate the effects on the mechanical properties such as column capacity stiffness and ductility ACI Materials Journal ,2003 **Case Histories and Use of FRP for Prestressing Applications**

Raafat El-Hacha,S. H. Rizkalla,2007 Fiber reinforced polymer FRP composite materials have been proposed for use in lieu of steel for prestressing applications The use of FRP has been growing rapidly in recent years FRP provides options and benefits not available using traditional materials The promise of FRP materials lies in their high strength lightweight noncorrosive nonconducting and nonmagnetic properties In 2005 ACI Committee 440 Fiber Reinforced Polymer Reinforcement published ACI 440 4R 04 Prestressing Concrete Structures with FRP Tendons as one of several guides in ACI s Emerging Technology Series to provide recommendation for the use of FRP materials based on available test data technical reports and limited field applications The aim of this document is to help practitioners implement FRP technology while providing testimony that design and construction with FRP materials systems is rapidly moving from emerging to mainstream technology **Transactions of the American Society of Civil Engineers** American Society of Civil Engineers,2006 Vols 29 30 contain papers of the International Engineering Congress Chicago 1893 v 54 pts A F papers of the International Engineering Congress St Louis 1904 *The Structural Engineer* ,1997 **Canadian Journal of Civil Engineering** ,2007

Fiber-reinforced-plastic (FRP) Reinforcement for Concrete Structures Antonio Nanni,1993 The 20 papers in this volume contribute to the advancing knowledge and acceptance of fibre reinforced plastic FRP composites for concrete reinforcement The book is divided into three parts reinforcement for concrete structures an international perspective and FRP reinforcement products **Report** ,1964

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