In-situ X-ray computed tomography characterisation of 3D fracture evolution and image-based numerical homogenisation of concrete

Z. Yang, W. Ren, R. Sharma, S. Mcdonald, M. Mostafavi, Y. Vertyagina, T.J. Marrow

PII: S0958-9465(16)30597-2

DOI: 10.1016/j.cemconcomp.2016.10.001

Reference: CECO 2724

To appear in: *Cement and Concrete Composites*

Received Date: 15 February 2016

Revised Date: 24 August 2016

Accepted Date: 1 October 2016

In-situ X-ray Computed Tomography Characterisation of 3D Fracture Evolution and Image-Based Numerical Homogenisation of Concrete

Z. Yang[1]*, W. Ren[2], R. Sharma[3], S. Mcdonald[4], M. Mostafavi[5], Y. Vertyagina[6] and T.J. Marrow[6]

[1]Centre for Low Impact Buildings, Faculty of Engineering & Computing, Coventry University, UK
[2]College of Water Resources and Architectural Engineering, Northwest A&F University, China
[3]School of Engineering, Indian Institute of Technology Mandi, India
[4]Manchester X-ray Imaging Facility, School of Materials, the University of Manchester, UK
[5]Department of Mechanical Engineering, University of Bristol, Bristol, UK
[6]Department of Materials, University of Oxford, UK

Abstract: In-situ micro X-ray Computed Tomography (XCT) tests of concrete cubes under progressive compressive loading were carried out to study 3D fracture evolution. Both direct segmentation of the tomography and digital volume correlation (DVC) mapping of the displacement field were used to characterise the fracture evolution. Realistic XCT-image based finite element (FE) models under periodic boundaries were built for asymptotic homogenisation of elastic properties of the concrete cube with Young's moduli of cement and aggregates measured by micro-indentation tests. It is found that the elastic moduli obtained from the DVC analysis and the FE homogenisation are comparable and both within the Reuss-Voigt theoretical bounds, and these advanced techniques (in-situ XCT, DVC, micro-indentation and image-based simulations) offer highly-accurate, complementary functionalities for both qualitative understanding of complex 3D damage and fracture evolution and quantitative evaluation of key material properties of concrete.

Key words: X-ray computed tomography, Fracture, Segmentation, Digital volume correlation, Homogenisation, Concrete

1 INTRODUCTION

Quasi-brittle multiphase composite materials, such as concrete, bones, fibre-reinforced plastics (FRP) and ceramic/metal matrix composites are widely used in engineering structures of many industries. A better understanding of their mechanical behaviour can lead to development of materials with higher load resistance, cost-effective manufacturing processes and optimal structural designs. Due to the random distribution of multiple phases from the nano-, micro-, meso- to macro-

*Corresponding author: Prof. Z Yang, Email: ac1098@coventry.ac.uk