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Effect of corrosion pattern on the ductility of tensile reinforcement extracted from a 26-year-old corroded beam

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Abstract. Tension tests were carried out to investigate the effect of the corrosion pattern on the ductility of tension bars extracted from a 26-year-old corroded reinforced concrete beam. The tensile behavior of corroded bars with different corrosion patterns was examined carefully, as were two non-corroded bars extracted from a 26-year-old control beam. The results show that corrosion leads to an increase in the ratio of the ultimate strength over the yield strength, but reduces the ultimate strain at maximum force of the reinforcement. Both the corrosion pattern and the corrosion intensity play an important role in the ductile properties. The asymmetrical distribution of the corrosion around the surface is a decisive factor, which can influence the ultimate strain at maximum force more seriously.

Keywords: corrosion; tensiontest; ductility; ultimate elongation; steel bar

1. Introduction

The corrosion of reinforcement, which commonly happens in a chloride environment, is considered to be one of the major problems for the deterioration of reinforced concrete structures, which has been the object of great attention from both researchers and engineers (Care *et al.* 2008, Zhu *et al.* 2012, Bhargavak *et al.* 2006). Corrosion damage of the reinforcement can not only reduce the cross-section of the steel bar but also produce stress in the concrete around the bar which can gradually result in cracking or even spalling of the concrete cover as the volume of the corrosion products increases (Wong *et al.* 2010). Considerable resources are expended to repair and rehabilitate deteriorating concrete structures (Kreit *et al.*). It has been reported that, in the USA, such repair and rehabilitation costs over $20 billion per year (Strategic High Research Program 1989).

Much research work has been done to deal with this corrosion problem, especially the corrosion of reinforcement. Ahmad (2003) has reviewed reinforcement corrosion in concrete structures and assessed the causes and extent of corrosion of reinforcements, so as to predict the residual behavior of a corroded structure exposed to an aggressive environment. Apostolopoulos *et al*. (2006) have noted the increase in steel stress at corroded cross-sections, and also observed reduction of the ductility. Stewart (2009), Maslehuddin *et al*. (1990) have also investigated the

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Bhargava, K., Ghosh, A.K., Mori, Y. and Ramanujam, S. (2006), "Model for cover cracking due to rebar corrosion in RC structures", *Eng. Struct.*, **28**(8), 1093-1109.
BS EN 1992-1-1 Eurocode 2, Design of concrete structures-Part 1-1: General rules and rules for buildings, October 2005.
Cairns, J., Plizzari, G.A., Du, Y.G., Law, D.W. and Franzoni, C. (2005), "Mechanical properties of corrosion-damaged reinforcement", *ACI Mater. J.*, **102**(4), 256-264.
Caré, S., Nguyen, Q.T., L'hostis, V. and Berthaud, Y. (2008), "Mechanical properties of the rust layer induced by impressed current method in reinforced mortar", *Cem. Concr. Res.*, **38**(8), 1079-1091.
Castel, A., François, R. and Arligue, G. (2000), "Mechanical behaviour of corroded reinforced concrete beams—Part 2: Bond and notch effects", *Mater. Struct.*, **33**(9), 545-551.
Coronelli, D. and Gambarova, P. (2004), "Structural assessment of corroded reinforced concrete beams: modeling guidelines", *J. Struct. Eng. ASCE*, **130**(8), 1214-1224.
Cosenza, E., Greco, C. and Manfredi, G. (1998), *An Equivalent steel Index in the Assessment of ductility Performances of the Reinforcement*, CEB Bulletin No. 242.
François, R., Khan, I. and Dang, V.H. (2013), "Impact of corrosion on mechanical properties of steel embedded in 27-year-old corroded reinforced concrete beams", *Mater. Struct.*, **46**(6), 899-910.
Khan, I., François, R. and Castel, A. (2011), "Mechanical behavior of long-term corroded reinforced concrete beam", *Model. Corr. Conc. Struct.*, **5**(10), 243-258.
Kreit, A., Al-Mahmoud, F., Castel, A. and François, R.(2011), "Repairing corroded RC beam with near-surface mounted CFRP rods", *Mater. Struct.*, **44**(7), 1205-1217.
Lee, H.S. and Cho, Y.S. (2009), "Evaluation of the mechanical properties of steel reinforcement embedded in concrete specimen as a function of the degree of reinforcement corrosion", *Int. J. Frat.*, **157**(1-2), 81-88.
Maslehuddin, M., Ibrahim, I.M., Al-Sulaimani, G.J., Al-Mana, A. and Abduljauwad, S.N. (1990), "Effect of rusting of reinforcing steel on its mechanical properties and bond with concrete", *ACI Mater. J.*, **87**(5), 496-502.
Palsson, R. and Mirza, M.S. (2002), "Mechanical response of corroded steel reinforcement of abandoned concrete bridge", *ACI Struct. J.*, **99**(2), 157-162.
Stewart, M.G. (2009), "Mechanical behaviour of pitting corrosion of flexural and shear reinforcement and its effect on structural reliability of corroding RC beams", *Struct. Safety*, **31**(1), 19-30.
Strategic High Research Program (1989), *Concrete and structure: Progress and product update*, Washington DC, National Research Council.
Vidal, T., Castel, A. and François, R. (2004), "Analyzing crack width to predict corrosion in reinforced concrete", *Cem. Concr. Res.*, **34**(1), 165-174.
Wong, H.S., Zhao, Y.X., Karimi, A.R. and Jin, W.L. (2010), "On the penetration of corrosion products from reinforcing steel into concrete due to chloride-induced corrosion", *Corros. Sci.*, **52**(7), 2469-2480.
Zhang, R.J., Castel, A. and François, R. (2009), "The corrosion pattern of reinforcement and its influence on serviceability of reinforced concrete members in chloride environment", *Cem. Concr. Res.*, **39**(11), 1077-1086.
Zhu, W.J. and François, R. (2012), "Corrosion of the reinforcement and its influence on the residual structural performance of a 26-year-old corroded RC beam", *Proceeding of the 3rd International Conference on Concrete Repair, Rehabilitation and Retrofitting*, Cape Town, South Africa, September.
Zhu, W.J., François, R. and Coronelli, D. (2012), "Effect of corrosion of reinforcement on the coupled shear and bending behaviour of reinforced concrete beam", *Proceeding of the 6th International Conference on Bridge Maintenance*, Safety and Management, Stresa, Lake Maggiore, Italy, July.

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