IRT survey for the quality control of FRP reinforced r.c. structures

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Abstract

Externally bonded Fiber Reinforced Plastics (FRPs) are widely used for strengthening of existing structures in recent years. However, the success of FRP reinforcement techniques is mainly subjected to the properly application of the FRPs, so a key role is played by the quality control of the application, to be performed by non-destructive techniques. At this aim, Cetma developed an InfraRed (IR) Thermography procedure and a post processing methodology able to detect and measure the area of bonding defects at the FRP – substrate interface. In this paper, the in – situ validation of the developed procedure on two r.c. structures retrofitted with FRP materials is presented.

Key words: Thermography, FRP, r.c. structures, quality control, bonding

1. Introduction

Fiber Reinforced Plastics (FRPs) materials, thanks to their mechanical and physical properties (excellent strength-to-weight and stiffness-to-weight ratios, high durability, corrosion resistance) are widely used for repairing, retrofitting and strengthening of existing structures in recent years. In fact, there may be several reasons for the need of strengthening and upgrading civil structures, such as changes in functionality, potential damage caused by mechanical actions and environmental effects, more stringent design requirements, original design and construction errors. However, in order to assure an effective FRP reinforcement, perfect adhesion between FRP and substrate (concrete or masonry) must be obtained; for this reason, it is essential to use Non-Destructive Testing (NDT) to assess the quality of bonding. Infrared thermography can be a reliable and confident non destructive testing technique for the evaluation of bonding defects in FRP – reinforced concrete structures. However, the set-up of IR technique for the detection of a particular defect (delamination, lack of bonding, …) in an FRP – reinforced r.c. structure needs a specific calibration, leading to the proper definition of the operational parameters (active/passive approach, distances, time-windows, …). Based on the results obtained from a large experimental program an IR yard-friendly methodology was calibrated; the in – situ validation of the technique was carried out on an r.c. structure externally reinforced with GFRP sheets and on a highway r.c. single span bridge structure retrofitted with CFRP materials. This step involved the transfer of the technique from the lab-scale to the real-scale, with the necessary adaptations in the operational parameters.

2. IRT procedure calibration

The IRT survey calibration was performed in the technological laboratory of CETMA; according to literature indications some FRP – reinforced concrete samples were accurately prepared, imposing acceptable defects with different shapes and dimensions at the FRP – substrate interface. Two types of defects with different dimensions were imposed (delamination, by the interposition of two bonded Teflon foils and lack of bonding of the FRP, by a simple Teflon foil). The experimental setups were meant to be as cheap as possible, in order to develop an experimental procedure that could be easily applied on the field and not only in research laboratories. The samples surface was analysed with the pulsed thermography (PT) method and four important set up parameters were investigated and defined in order to obtain the best defect visibility (thermocamera – sample distance; heating source – sample distance; “impulsive heating” time; time, after the heating step, at which the thermogram should be recorded). This extensive experimental campaign led to the calibration of an IR yard – friendly methodology, defining all the necessary operative parameters.

After the definition of acceptance criteria and reparation techniques for the defects, CETMA developed a post processing methodology in order to measure the area of bonding defects at the FRP - substrate interface. Only in this way it’s possible to establish whether a defects can be acceptable or not, and, in case, what is the best way to repair it.

3. IRT survey results

The developed IRT procedure was applied for quality control of two r.c. structures reinforced with FRP materials. The former, the ex Law Courts of Sant’Angelo dei Lombardi (in the municipal district of Avellino, Italy), retrofitted with GFRP sheets after the catastrophic Irpinia earthquake (magnitude 6.9) of 23rd November, 1980. The latter, an Italian highway r.c. single span bridge structure, seismic upgraded with CFRP materials according to the Italian law OPCM 3431. In both cases two approach were used: active, using a commercial halogen lamp with a nominal power of 1000 [W] lamp and passive, using solar heating. The adopted thermocamera was a commercial microbolometric FLIR System with a 320x256 Focal Plane Array. Thermographic data were processed with Almond’s half maximum contrast method; a particular Matlab routine was implemented in order to apply Almond’s procedure to the whole thermogram. In Fig.1 an example of thermograms of the GFRP reinforced structure is presented. For comparative testing, other traditional NDT techniques (visual inspection and coin – tap) were used for the quality control of the FRPs application. It can be pointed out that IR thermpography allows a quicker detection not only of all the defects detectable also with other traditional NDTs but also of a set of other smaller defects, otherwise not detectable, but anyhow potentially dangerous for structural safety.

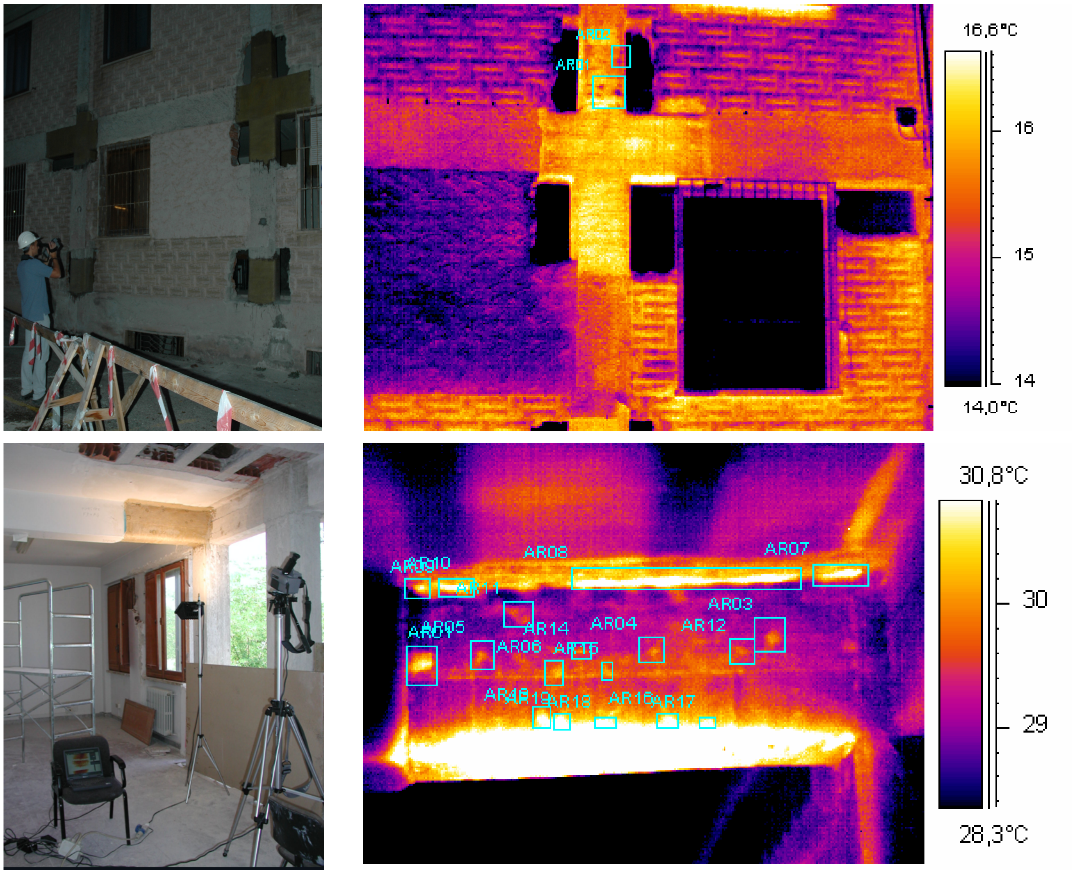

Fig. 1. *IRT survey of an r.c. structure reinforced with GFRP sheets*

REFERENCES

[1] Corvaglia P., Manni O., Largo A., Caponero M.A., Galietti U. “Termografia e smart patch in FRP/fibra ottica per la diagnostica ed il monitoraggio di strutture in c.a. rinforzate con FRP” Materiali ed Approcci Innovativi per il Progetto in Zona Sismica e la Mitigazione della Vulnerabilità delle Strutture, Università di Salerno, Febbraio 2007

[2] Corvaglia P., Manni O., Largo A., Caponero M.A., Galietti U. “Soluzioni innovative per la diagnostica ed il monitoraggio di strutture ed infrastrutture civili: termografia e sensoristica ottica” Monitoraggio di edifici strategici, ponti, gallerie, Napoli, Novembre 2006

[3] P. Corvaglia; U. Galietti; A. Largo; S. Nenna; L. Spagnolo, “Feasibility of different thermal analysis of FRP – reinforced concrete”, QIRT’ 06 Padova, June 2006.

[4] CNR-DT 200, “Istruzioni per la progettazione, l’esecuzione ed il controllo di interventi di consolidamento statico mediante l’utilizzo di compositi fibrorinforzati - materiali, strutture di c.a. e di c.a.p., strutture murarie”, 2004.

[5] ICC Evaluation Service, Inc., “Interim criteria for inspection and verification of concrete and reinforced and unreinforced masonry strengthening using fiber-reinforced polymer (FRP) composite systems”, 2004.

[6] ICBO; “Acceptance criteria for inspection and verification of concrete and reinforced and unreinforced masonry strengthening using fiber-reinforced polymer (FRP) composite systems”; ICBO Evaluation Service, INC, 05/2001.

[7] Peters S.T., Handbook of Composites, Chapman & Hall, London (UK), 1998.

[8] X.P.V. Maldague; “Theory and Practice of Infrared Technology for Nondestructive Testing”; A Wiley-Interscience Publication, John Wiley & Sons Inc.; N.Y. 2001.

[9] D.P. Almond, R. Hamzah, P. Delpech, Peng Wen, M.H. Beheshty, M. B. Saintey; “Experimental investigations of defect sizing by transient thermography”; QIRT 96-Eurotherm Series 50 ETS ed., Pisa 1997, pp.233-238.

[10] “Infrared methodology and technology”; edited by X.P.V. Maldague, Gordon and Breach Science Publishers; 1994.