Alternate Repair Material Systems for Application to Structural Concrete

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Summary

The study presents developments and applications of alternate material systems for repair that have evolved in recent years for application to structural concrete elements as a means of rehabilitation or retrofit. Firstly the widely used fibre reinforced polymer (FRP) of glass, or carbon in the form of a laminate or wrap with epoxy binding as a material in structural concrete applications is discussed. While its main attraction is high strength to weight ratio, the system has some limitations such as de-bonding due to progressive de-lamination at flaws or sudden brittle rupture. Moreover, its limitation in certain applications, particularly exposure to adverse environmental conditions such as moisture (if the binding epoxy is hygroscopic), high temperature (if the binding epoxy melts) such as due to fire is brought to light. The possibility of shielding the FRP repaired concrete in a ceramic or geo-polymer shell so as to offer a complete thermal shield together with a mechanical strengthening system is discussed. Merits of an alternate cement based systems such as fibre reinforced concrete with chopped short wire fibres made from steel, polyester, carbon and glass that are mixed into a concrete matrix, even with a self compacting concrete consistency at the time of casting as an alternate form of a repair system is then discussed. Experimental results and analytical procedures that have been developed to predict the capacity of the variously reinforced structural elements is presented to illustrate the merit of different approaches.

Keywords: Structural Concrete Repair, SCC with fibres, Carbon and Glass fibre reinforced polymer, high temperature, Geo-polymer

1. Introduction

Development of repair / rehabilitation or retrofit techniques in existing structures offers engineer / planner additional possibilities in deployment of funds in an effective manner. The initial development in retrofitting RC beams having damage in the tension region using FRP plates (Carbon, Glass and Aramid fiber plates) was encouraging A number studies on FRP based repair conclude that the surface preparation of the concrete, the selection of the adhesive, amount of tension steel and its effective cover in the concrete beam were some of the important factors affecting the overall performance of the retrofit.

The development of reactor powder concrete and with it the ability to tailor the concrete characteristics to the desired needs has led to investigations on the possible use of ultra high performance concrete (UHPC) for repair and strengthening of structural concrete elements. Studies have examined the micro-mechanical aspects of high performance fibre reinforced concrete.

Sustainability of the repair/ retrofit scheme against additional damage has been examined using thermally stable insulating materials. Some preliminary studies using geo-polymers as a thermal insulation along with mechanical retrofit with CFRP has been examined in this study.

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2. Details of the study

2.1 Experimental Program

The test program consisted of casting and testing of ten beams of 3m span. All the beams were tested over a simply supported span of 2.65m under four-point loading. The cross section of the beam consists of a flange of width 425 mm and depth 100 mm and a web of width 200 mm and depth 250 mm. The design parameters varied in the test were the zone of placement of the repair and the material used for repair. All the beams were cast using a normal strength concrete (40 MPa, characteristic cube strength). Five beams each designed to fail either in flexure or shear formed the test program. Each set of five beams had one of the beams as a control beam tested to failure.

Preliminary round of studies on effect of thermal exposure on concrete have been carried out on 25MPa and 35MPa normal concrete (compressive strength) containing granite-coarse aggregate.

2.2 FE Modelling

The FE analysis included modelling a concrete beam with the dimensions and properties corresponding to the experimental tested beams. For reducing computation time and computer memory required, only one quarter of the beam was modelled taking advantage of the symmetry in cross-section of the concrete beam and loading.

3. Results and Discussion

The two control beams (FF1 and SF1), which were tested, showed a classical flexure and shear failure, respectively. The flexure control beam FF1 failed at an ultimate load of 385 kN in a conventional ductile flexure mode with yielding of tension steel, followed by crushing of concrete in the compression zone at mid-span. The shear control beam SF1 failed at an ultimate load of 384.4 kN in a brittle manner, due to diagonal tension in the shear span, showing less deflection than the flexure control beam FF1. The finite element predictions for each of the two beams (FF1 and SF1) were found to closely predict the test results and indicated a strong influence of bond slip. The efficacy of SCC with fibre based repair in specimen FF2 (and SF2) was clear from the ductile failure obtained.

Plain concrete cylinders (25MPa compressive strength) subjected to various thermal exposures (temperature and duration) were cooled and tested under uni-axial compression to asses the strength degradation. The thermally damaged specimen were also first wrapped with CFRP and tested to assess improvement in strength.

4. Closing Remarks

The study has examined the use of different repair materials in reinforced concrete applications. The option of SCC for repair particularly with fibres offers considerable strength and ductility enhancements in comparison to GFRP or CFRP and has a lot of promise. Issues of de-lamination of the repair material are more easily addressed with cement-based materials. . The self-consolidating characteristics of concrete material offer easy repair possibilities in difficult to reach structural damage locations. Thermal insulation of CFRP using geo-polymer material was found to be an attractive option for repair applications when the structure is thermally vulnerable.

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