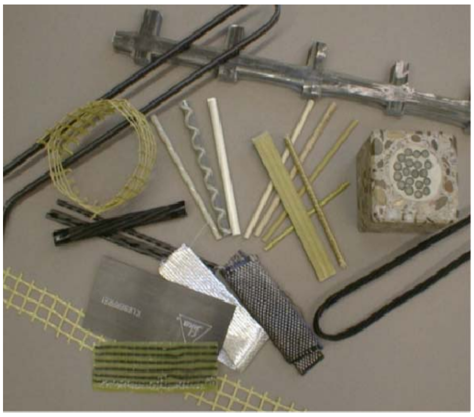
FINAL PUBLISHABLE SUMMARY REPORT

Much of the existing building stock in Europe, as well as in developing countries, has been designed according to old standards and has little or no seismic provision and often suffers from poor material and construction practices[1]. As a result, many existing buildings have deficient lateral load resistance, insufficient energy dissipation and can rapidly lose their strength during earthquakes, leading to collapse[2]. Retrofit of seismically deficient structures before earthquakes provides a feasible and cost-effective approach to improving their load carrying capacity and reducing their vulnerability[3].

Over the last decade, the use of externally bonded fibre composite materials (FRPs) has offered engineers a new solution for strengthening seismically deficient buildings (Figure 1). The initial cost of FRP for strengthening is usually higher than conventional structural materials. However, they are much easier to apply, and this is where composites offer significant economic benefits[4].

(a)



(b)

Figure 1: (a)- Different types of FRP composites; (b)- Strengthening of a RC columns with FRPs

Different optimum seismic design procedures for RC Buildings were discussed[5]. Optimum seismic design methods were categorized into different groups including conventional structural optimization methods, evolutionary and genetic algorithms-based strategies, using nonlinear push over analysis, and using concept of uniform deformation demands.

In this study, a practical method for optimum strengthening design of deficient RC structures using FRP composites was developed[6]. The proposed approach is based on the concept of uniform

---

1- Khan, S., **Hajirasouliha, I.**, Pilakoutas, K., Guadagnini, M., "A Framework for Earthquake Risk Assessment for Developing Countries", 9th US National and 10th Canadian Conference on Earthquake Engineering (EERI), Toronto, Canada, 2010.

2- García, R., **Hajirasouliha, I.**, Pilakoutas,K. and Guadagnini, M., "Seismic behaviour of EBR FRP retrofitted frames", Advanced Composites in Construction, Edinburgh, 2009.

3- Garcia, R., **Hajirasouliha, I.**, Pilakoutas, K. and Guadagnini, M., "Seismic Strengthening of RC Buildings Using CFRP", 9th US National and 10th Canadian Conference on Earthquake Engineering (EERI), Toronto, Canada, 2010.

4- Garcia, R., **Hajirasouliha, I.**, Pilakoutas K., "Seismic Behaviour of deficient RC Frames Strengthened with CFRP Composites", Engineering Structures, In press (2010).

5- **Hajirasouliha I**., Asadi P., Pilakoutas K., "Optimum Performance-Based Seismic Design of Reinforced Concrete Frames", Earthquake Engineering and Structural Dynamics, Submitted in March 2010.

6- **Hajirasouliha I.**, Pilakoutas K. "Optimal performance-based design of FRP jackets for strengthening of reinforced concrete structures", 14th European Conference on Earthquake Engineering, Ohrid, Macedonia, 2010.

distribution of deformation where the distribution of EBR FRP (i.e. the number of FRP layers) is modified so that inefficient material is gradually shifted from strong to weaker elements of a structure. This process is continued until a state of uniform deformation is achieved[7] . In such a condition, the dissipation of seismic energy in each structural element is maximized and the material capacity is fully exploited[8]. The optimisation procedure leads to a reliable and cost-effective design with the minimum amount of FRP materials.

To investigate the efficiency of the proposed optimisation technique, 5, 10 and 15 storey RC frames were designed. Analytical models were calibrated using the existing experimental results of a bare and strengthened full-scale two-storey RC frame. This frame was tested on a shake table as part of the EU-funded ECOLEADER Project[9]. It was shown that the analytical models can provide a reasonable estimate of the displacement demands for earthquake excitations with different PGA levels.

The efficiency of the proposed optimisation technique was demonstrated by using calibrated analytical models. The results indicated that the proposed method is capable of producing retrofit designs that reduce the total material cost of FRP by at least 20%[10]. Figure 2 shows the variation of rehabilitation cost from a conventionally designed model to the optimum model. It is shown that the proposed method practically converged to the optimum solution in less than 8 steps without any fluctuation.

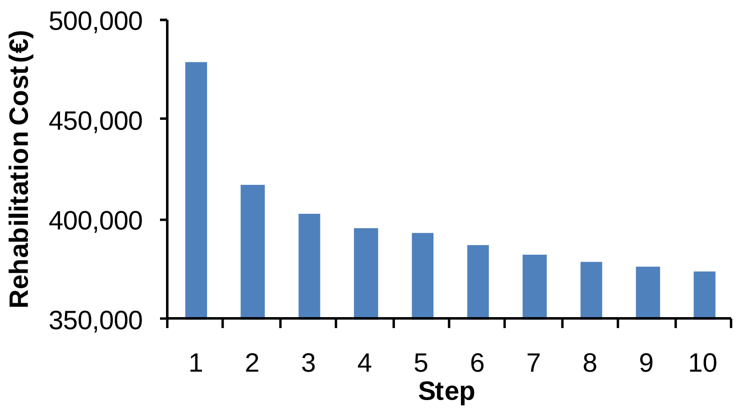


Figure 2: Variation of rehabilitation cost from a conventionally designed model to the optimum model

7- **Hajirasouliha I.**, Pilakoutas K., Moghaddam H. "Topology Optimization in Seismic Design of Truss-Like Structures", Computers & Structures, Submitted in May 2010.

8- **Hajirasouliha I.**, Pilakoutas K., Moghaddam H. "Optimum seismic design load distribution for height-wise irregular structures on different soil profiles", Soil Dynamics and Earthquake Engineering, Submitted in Jun 2010.

9- Garcia, R., **Hajirasouliha, I.**, Pilakoutas, K., Guadagnini, M. and Chaudat, Th., "Seismic Strengthening of RC Buildings Using Externally Bonded FRPs ", 14th European Conference on Earthquake Engineering, Ohrid, Macedonia, 2010.

10- **Hajirasouliha, I.**, Pilakoutas, K., "Optimal strengthening design of deficient reinforced concrete structures", Earthquake Engineering and Structural Dynamics, under preparation (will be submitted by Jan 2011).