Final Report Summary - PROHITECH (Seismic protection of historical buildings by reversible mixed technologies)

The project PROHITECH tackled the very important subject of the seismic protection of historical and monumental buildings, namely of constructions dating back from the ancient age up to the mid of the 20th century. Its main objective was to develop sustainable methodologies for the use of reversible mixed technologies in the seismic protection of existing constructions, with particular emphasis to buildings of historical interest. Reversible mixed technologies exploit the peculiarities of innovative materials and special devices, allowing ease of removal if necessary. At the same time, the combined use of different materials and techniques yields an optimisation of the global behaviour under seismic actions. The endpoint of the research was a proposal of codification for the use of such technologies in the seismic protection of existing constructions, which will meet the most up-to-dated codification issues at European level and will comply with layout, language and philosophy of structural Eurocodes.

As well known, several countries and many cities in the southern part of Europe, namely the Mediterranean and Balkan area, are greatly exposed to seismic hazard, which causes its large and
valuable building heritage to be strongly at risk of severe damage or even destruction due to earthquake occurrences. This problem mostly stands for historical and monumental constructions, due to the fact that most of them frequently lack basic anti-seismic features and/or were never fitted with adequate provisions against earthquake actions.

The research program involved 16 academic institutions coming from 12 countries mostly belonging to the South European and Mediterranean area. The work plan was based on 12 scientific work packages, plus 3 management work packages.

Within the technical field of seismic rehabilitation, two aspects are receiving an increasing attention by engineers and researchers, namely:

- preservation of ‘structural integrity’ of existing buildings under severe or exceptional seismic actions (SI);
- improvement of building seismic performance by means of 'reversible mixed technologies' (RMT).

Both these aspects are closely interrelated between each other, in the sense that the application of RMT is, in some cases, the only tool to achieve a satisfying level of SI under severe earthquake actions. The concept of SI relies on the necessity to ensure seismic protection against collapse also in case of destroying events. In this view, it can be properly framed within the advanced concept of 'Performance based design' (PBD). As well known, the PBD is a new way to approach the structural design against seismic actions, having the purpose to ensure a proper degree of structural reliability under any specified working conditions, including both serviceability and ultimate limit states. Till now, the PBD has been applied only to new structures, which can be easily designed complying with relevant behavioural thresholds set by PBD itself. No applications exist in the field of existing constructions, yet. In particular, neither criteria nor methodologies are available for achieving a satisfying design level against strong intensity earthquakes. This is indirectly confirmed by most of national seismic codifications, which, as a matter of fact, allow avoiding a rigorous seismic retrofit in case of historical constructions.

This approach, of course, tends to preserve the monumental value of the construction, but causes this to be not adequately protected against severe earthquakes. It is evident as this aspect deserves great attention not only in the perspective of saving human lives, but also in the light of preserving invaluable artefacts from complete destruction. The use of innovative materials and mixed technologies is the most appropriate answer of ensuring an adequate performance, and hence the structural integrity, under strong seismic actions.

‘Reversible mixed technologies’ (RMT) are based on the integration of structural members of different materials and/or construction methods into a single construction. The basic feature of RMT is that their application should be always completely recoverable, that is reversible, if required. This is considered as an essential design requirement in order to prevent historical and monumental buildings from unsuitable rehabilitation operations. The main aim of RMT is the best exploitation of material and technology features, in order to optimise the structural behaviour under any condition, including very severe limit states involved by strong seismic actions. This practice, initially concerned with new, technologically advanced buildings, is now being looked up with increasing interest in the field of structural rehabilitation, too, due to the greatest possibilities of structural optimisation and, hence, performance improvement, achieved for thanks of mixed technologies. In a few words, the use of reversible mixed technologies would involve the best exploitation of each material and/or technology used in the intervention, providing in such a way the best
exploitation of each material and/or technology used in the intervention, providing in such a way the best performance from both technical and economical point of view.

Specific objectives to be pursued, aimed at:
1. drawing the attention of industry, research centres, engineers and competent authorities of European and Mediterranean countries on the problem of safeguard of construction heritage from seismic risk, in particular when historical buildings are concerned;
2. improving the awareness of operators listed above about the importance of using advanced materials and technologies in the seismic up-grading of constructions;
3. improving the average knowledge of practising engineers about innovative systems of seismic protection, so as to contribute to the institution of specialised skills in the field of seismic rehabilitation;
4. promoting the use at a wide scale of reversible and environmentally friendly technologies, in order to fit existing constructions with easily removable and modifiable seismic protection systems;
5. supporting the adoption of 'smart' materials and special techniques for the seismic protection of constructions as a cheap and effective alternative to traditional, highly intrusive strengthening methodologies, especially when historical constructions are faced;
6. advancing the state-of-the-art in the field of seismic protection of constructions, by adding new information about the behaviour of structures fitted with special systems and/or using advanced materials or devices for improving the seismic performance;
7. allowing engineers to use simple and reliable tools for analysing the behaviour of constructions provided with advanced systems for seismic protection, as well as for detailing up-grading interventions;
8. developing advanced, PBD-complying guidelines for the practical application of innovative materials and technologies in the field of seismic restoration.

The project was structured into eight work packages (WPs), as follows:

WP 1 Overview of existing techniques
Main objectives of WP1 have been:
- establishing a commonly agreed background and terminology to base studies on structural typologies, condition references and retrofit requirements;
- comparing the current design approaches and past design practices and codes;
- reviewing the current practice in retrofit methods.

WP 2 Damage assessment
The aim of this part of the research was to prepare an overview of damage assessment methodologies followed in various Mediterranean countries in the PROHITECH project. The focus was mainly on the Mediterranean region, a part of the world which unfortunately is no stranger to earthquakes.

WP 3 Risk analysis
The first objective consisted in reviewing the current approaches to damage assessment and definition of vulnerabilities of structural types, based upon observed damages due to recent earthquakes that occurred in some Euro-Mediterranean countries. The second objective was to help to define problems that require an approach based on innovative technologies.

WP 4 Intervention strategies
The contents and objectives of WP4 were established as follows:
1. terminology in the field of intervention work on historical buildings;
2. intervention solutions and criteria for seismic upgrading and rehabilitation of constructions;
3. options for intervention strategy;
4. country seismic legislation and actions for seismic intervention on constructions;
5. reversible intervention for cultural heritage constructions.

WP 5 Innovative materials and techniques for seismic protection
The main scope of WP5 was the individuation of innovative materials and devices on the basis of their mechanical features, in order to select suitable materials for creating both strengthening systems and special devices aimed at the optimisation of the structural behaviour.

WP 6 Set-up of advanced reversible mixed technologies for seismic protection
The aim of WP6 has been to complement and complete the work performed in WP4 and WP5 by providing the information necessary to the proper use of innovative materials and mixed technologies in strengthening interventions, as well as the definition of special systems for seismic protection to be applied to existing buildings. For this reason, the mechanical properties of materials and relevant features of innovative seismic protection systems have been studied in order to set-up adequate solutions for both intended purposes.

WP 7 Experimental analysis
The experimental analyses maybe represent the actual core of the PROHITECH research project. They have provided a very important contribution in the development of RMT to be applied for the seismic protection of historical buildings. The work has been carried out with the main aim of assessing and setting-up new mixed techniques for the repair and strengthening of historical buildings and monuments belonging to the cultural heritage of the Mediterranean basin.

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