INNOVATIVE DESIGN TOOLS FOR SUSTAINABLE REFURBISHMENT OF LARGE BUILDING COMPLEXES

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Summary

The increase of energy costs will justify in the next future major investments on the refurbishment of existing building stock. Most of buildings built after the Second World War in Italy need cost-effective refurbishment measures considering both energy efficiency and improvement of architectural features.

The paper shows the results of a research project carried out at Politecnico di Milano aiming at the definition of a simple and useful design tool supporting decision makers. It points out different options and levels for refurbishment, in terms of type, value and quality. Beginning from the observation of transformation processes in the northern region, different strategies of refurbishment are considered adopting traditional or new technologies and low environmental impact materials. Holistic design issues supported the analysis of existing buildings, addressing architectural, technical and morphological characteristics. Reversible, light and flexible criteria pervade the identification of design strategies aiming at transformation of existing building stock according to changing housing demand.

Keywords: energy-efficient retrofitting, building technology, existing building stock, design tool

1 Improving energy-efficiency of the Italian social housing building stock

The renovation of existing building stock is a top priority of the European Union in order to reach the ambitious goal of decarbonization in 2050.

The EU final energy consumption for 2012 in the building sector (households and services) amounted to 460 Mtoe (39.9 % of the total EU-27 final energy use) of which 307.3 Mtoe in dwellings (26.6 % of the total EU-27 final energy use). Italy is the fourth state with the highest final energy consumption after Germany, United Kingdom and France. Nevertheless, compared to these, Italy is much more energy import dependent [1].

A great deal of research into sustainable refurbishment has been done in recent years, but it takes a long time for research findings to be adopted in a widespread practice of the construction sector, where several technical and non-technical barriers still persist [2].

In the case of social housing, economic constraints are prevalent. Moreover, most of the stock has no or few architectural and technical qualities, and design characteristics for energy savings are in general very low. Consequently, energy-efficient upgrade of these buildings should be one of more comprehensive refurbishment measures including new internal layouts and also neighbourhood renewal [3]. In addition, the target of reducing CO_2 emissions from the existing building stock means also considering low-carbon retrofitting strategies. Therefore, the adoption of low embodied energy materials and technologies should be properly evaluated [4].

In relation to the mentioned issues, the paper shows the results of a research project that is conducted in the framework of a national funded programme about the promotion of innovative strategies for sustainable refurbishment of the Italian building stock.

2 Research method

2.1 Geocluster approach

First of all, the Italian building stock was divided into “geoclusters”, i.e. groups or portions of the existing building stock sufficiently homogenous for being considered part of a system [5]. It can be also defined as an ensemble of indicators and variables common for each building. The method for the definition of the parameters derives from the individuation of which of them are very influential on the quality of the same buildings; once identified, these parameters would permit to define the geocluster.

The research helps to define a comprehensive knowledge of all the issues concerning the application of energy efficiency strategies to the refurbishment of the existing building stock, specifically:

- Energy assessment and classification of the existing building stock;
- Identification of innovative technological solutions for the energy efficiency and self-sufficiency;
- Integration of renewable systems, respecting the original historic, architectonic and environmental features.

For the specific purpose of the research, five geoclusters were selected in five Italian regions that can be representative of a wider context (**Fig. 1**):

- Large social housing complexes in Milan suburbs;
- Historical centres in the Italian Mediterranean area;

- Historical and modern buildings in the volcanic area of Etna;
- Historical buildings in the areas devastated by earthquake in Abruzzo Region;
- Vernacular buildings in Basilicata Region.

The characteristics of target building stock of each geocluster area are quite different, but the main research effort has been dedicated to the set up of framework for the collection and management of data in such a way to be compared.

Fig. 1 *The five Italian geocluster*

2.2 Case studies

The first step of the research work consisted of a collection of data for each building of the local geocluster which include building typology, building technology, load-bearing structure, environmental conditions and also input data for energy certificate [6].

On the whole, 43 buildings were catalogued and analysed. Three main building technologies were identified: brickwork masonry, cavity walls and prefabricated concrete panels (**Fig. 2**).

For each one, two representative buildings were selected. They reveal a shortage of general performances, high energy demand and, above all, inadequate internal layout.

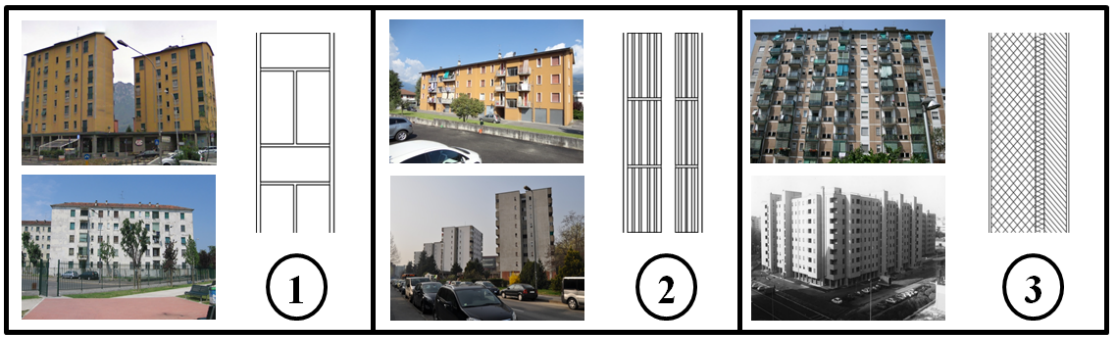

Fig. 2 *Building technologies identified during the analysis of the existing building stock in Lombardy: 1) single-layer brickwork masonry; 2) cavity wall; 3) precast concrete panels.*

Four refurbishment scenarios were taken into account from simple envelope retrofitting (without modifying internal layouts) to more complex measures, including building addictions (**Fig. 3**). The different scenarios were applied to the six selected building and evaluated in accordance with three indicators that were considered significant of a sustainable refurbishment: reduction of energy demand, reduction of CO_2 emissions and improvement of architectural quality.

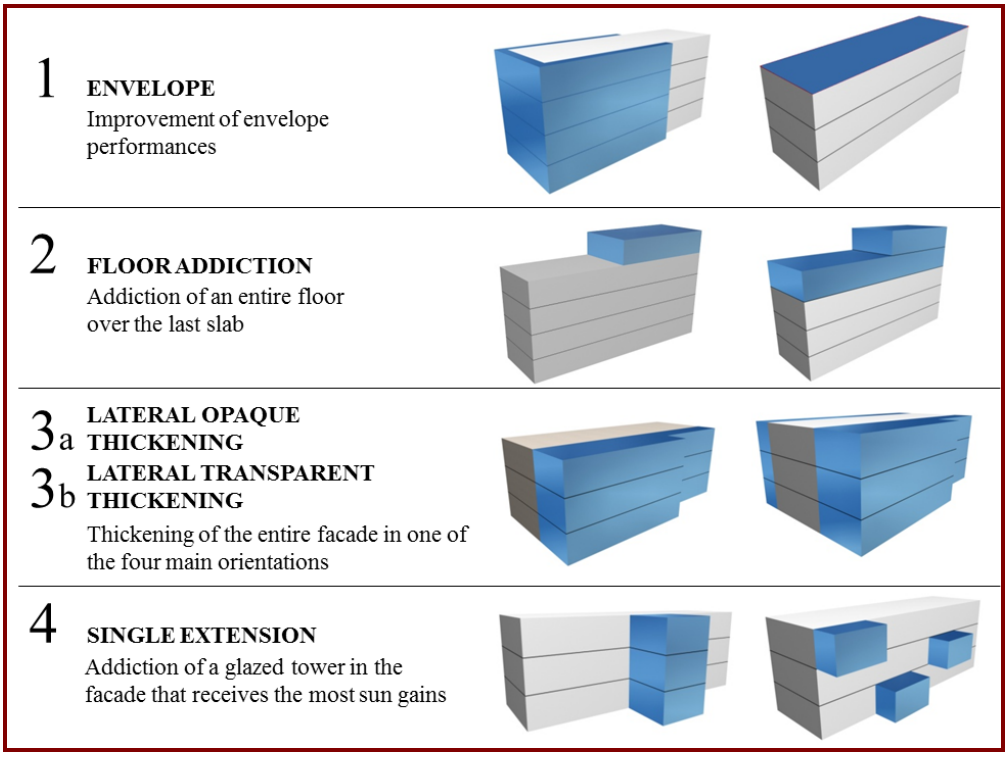

Fig. 3 *The four refurbishment scenarios considered in the project.*

The reduction of energy demand was evaluated according to the achievement of three fixed targets: C, B and A-rated energy performances. Obviously, the retrofit measures include not only substantial improvements to the thermal performance of the external fabric, but also changes to the building services. More than 270 energy simulations were carried out on case studies, allowing for each target the identification of U-value of the building envelope after refurbishment, in order to reach the three performance targets with or

without changes to internal and external layouts. Considering the reference U-values, actually, different technological solutions are being identified and evaluated by means of a Life Cycle Assessment. Opportunities for extensions and addictions will be evaluated following a sample survey on the selected case studies by means of questionnaires to inhabitants and housing organizations.

3 Design tool

All data collected are being implemented into a design tool that will support designers and housing organizations during decision-making process. Starting from the characteristics of an existing building subject to a retrofitting programme, the pre-evaluation tool will help identify the best retrofitting options in accordance with the three indicators: reduction of energy demand (from G to C, B and A-rating), carbon reduction (considering the environmental impact of materials and technologies) and improvement of architectural layout (extension of living area, new balconies or loggias, etc.) (**Fig. 4**). The tool takes into account the architectural, technical and morphological features of the existing building and suggests light reversible technologies enabling optimum performances, time and site operations rationalization, cost savings and adaptability to future changes. Further development will include payback time of the different proposed retrofit measures.

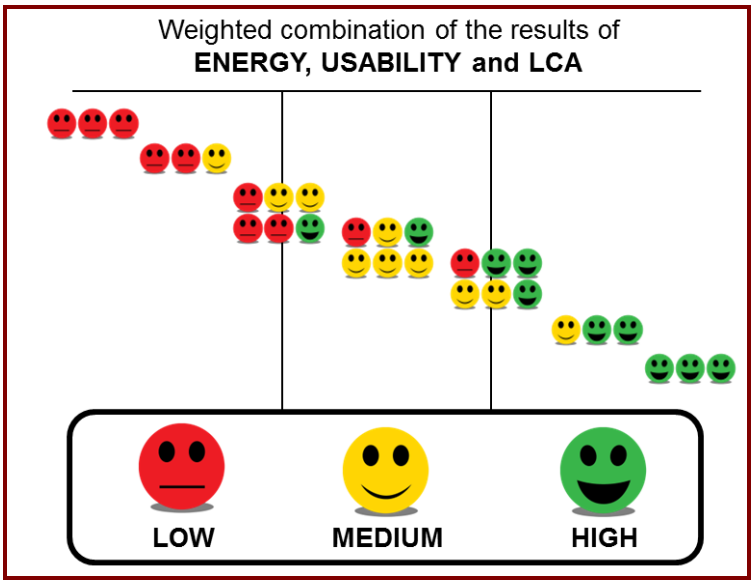

Fig. 4 *The design tool.*

4 Conclusions

The evident conditions of obsolescence of social housing complexes in Lombardy point out the need of refurbishment measures considering, at the same level and time, functional and general performance requirements. The upgrade of spatial quality and life conditions must go hand in hand with energy efficiency and resource savings. Nevertheless, due to economic constraints, integrated measures could be not cost-effective so strong efforts in policies and investments are still necessary. The proposed tool, based on a geocluster

approach, allows going beyond a single building's study. It should be feasible and replicable on a mass scale, giving usefull indications for an holistic refurbishment.

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