Energetic Enhancement in Built Heritage:
inner insulation of the building envelope

IRENE CALTABIANO[1], GIANFRANCO CAVAGLIÀ[1], MARIKA MANGOSIO[1], CORRADO CURTI[1]

[1] DIST, Politecnico di Torino, Turin, Italy

ABSTRACT: In the European context, in particular in Italy, the strategies to reduce the energy consumptions and to control the emissions responsible for climate change have to be focused on the energetic enhancement of the existing constructions. An increasingly widespread solution is to put the insulation in the inner side of the building envelope.
The aim of this paper is to present the targets, the methodology and the first results of an in progress research project, granted by E.U., through a call of the Italian Regione Piemonte. The general objective of the project is to design and to test an innovative solution for insulation to apply on the vertical inner side of the building. The project, called I.I.I. (Innovative Inner Insulation), is a national industrial research with an experimental part. In the project are involved six partners, three Universities and three private small and medium enterprises.
The system consists of a preassembled dry-laid panel, in which structure, thermal and acoustic insulation, heating plant and, optionally, finish coat are integrated: it is concerned with processing techniques of semi-finished and stratified products, as used in cooled transport. The design and testing of the system are presented through the analysis of a case study in Turin (Italy).

Keywords: inner insulation, building envelope, energetic enhancement

INTRODUCTION

Nowadays the new European energy strategy considers the achievement of the energy efficiency in the building sector as one of its main priorities. The actions to reduce the energy consumptions and to control the emissions responsible for climate change have been mostly focused on new buildings. Recently in the European context, rich of a relevant building heritage, the energy strategy started considering the existing building stock as a resource and not only as a problem. In Italy the 80% of the housing stock has been built before the approval of the first Italian regulation concerning the control of energy consumption in buildings (L. n. 373/1976). The widest part of this stock doesn't reach the minimum performance level in energy efficiency as required by law [2].

The energetic enhancement of the built heritage through refurbishment intervention programs can represent a concrete contribute to limit the general energy consumptions of our country. The choice of renovating the existing buildings leads also to an indirect saving. It must be considered the saving of embodied energy obtained reducing the production and the use of material and products and controlling the environmental impact of the intervention. It is important to underline also that the prevalent energetic retrofit interventions concern single housing units rather than the whole building.

The technical solutions which can offer the most significant contribution to the reduction of energy consumption concern especially the building envelope. In the energy renovation process of housing buildings the measures to improve the level of thermal insulation of the building envelope usually consist in the application of insulation layer on the external or the internal side of the envelope. In different cases, for example when the façade is characterized by decorations of relevant historical value or in those cases in which the restoration project doesn't involve the whole construction, it is not possible to apply effective solutions from the external side of the building. A significant solution is to put the insulation in the internal side of the building envelope. In many cases the internal insulation solutions borrow techniques and products from the most consolidated solutions of outer shell insulation, often revealing difficulties in execution and in control of the results.

Inner shell insulation is still a developing and improving intervention field, both at a technical and a commercial level. This technique presents an interesting operative margin in research field. As mentioned, it can be adopted by single homeowners even if a global intervention on the building has not been planned (e.g. due to the difficulty in coordinating the different phases).

AIMS

The paper aims to describe the focus, the methodology and the outcomes of a research project, granted by Regione Piemonte on E.U. funds, aimed to experiment an innovative, integrated and active insulation system applied to the inner side of the building envelope.

The I.I.I. (Innovative Inner Insulation) project is an industrial research and experimental development national project, which is conducted by three public research universities and three private technical partners selected between small and medium Italian enterprises. The goal of the experimentation is the integration between an inner insulation panel and a low temperature heating plant, providing an active contribution to the main heating system.

The research project aims to develop the potentialities and minimize the disadvantages existing at present in the inner insulation solution. The I.I.I. system can guarantee the continuity of the thermal insulation, the minimal amount of space, the reversibility of the intervention, the dimensional adaptability, the accessibility and disassembling for maintenance. The project also aims to develop a systematized technical solution in a flexible, integrated and active way in order to simplify the intervention.

The research starts from the firm belief that an efficient energy retrofit is not able to leave the knowledge of the built heritage out of consideration: it has always to get the embodied performances of the existing envelope and enhance them in the technical solution. Each building can be considered as a prototype and the technical solution can't be standardized.

THE I.I.I. PROJECT

The Innovative Inner Insulation (I.I.I.) project is funded by Regione Piemonte through the European Regional Development Fund (ERDF). The I.I.I. project is part of a regional initiative called "Industrial research projects and/or experimental development" launched to support Small and Medium Enterprises (SME). It promotes the cooperation and the competences exchange between regional companies (in particular SMEs) and research centres like Universities.

The aim of the Regional project is to support the local economic recovery through the promotion of research and the valorisation of the potentialities of Small and Medium Enterprises (SME). The distribution of the funds is followed by the Innovation Pole Polight, a research and development cluster dedicated to sustainable building technologies and hydrogen. Polight is a coordination structure among the innovation actors (companies, research institutions and public authorities) and it is design to support the research development and industrial innovation activities.

The I.I.I. project has been thought to give interesting and innovative answers to the need to improve the thermal performances of existing buildings also in case of small projects carried out by small companies.

The attention is focused on the building enclosure where it is common to identify thermal bridges: areas in which is registered a non-uniform heat transfer between the interior and exterior parts. The theme of the elimination, or reduction, of thermal bridges represent an important field of research, because they can produce the physical decay of the building. The I.I.I. project gives the chance to investigate different solutions to reduce the heating dispersions monitoring thermal bridges. They can be searched in the building sector using existing products and systems, but also looking at other kind of experiences in other fields. In the project specific attention is given to the possibility to find solutions to use in historical buildings and in all that cases in which it is difficult, or inappropriate, to use solutions applied in the external part of the building.

The project is coordinated by professor Gianfranco Cavaglià of the Politecnico di Torino and involves three university departments and three SMEs. Each partner has a specific role bringing his own experience in the project.

The Interuniversity Department of Regional and Urban Studies and Planning (DIST) of Politecnico di Torino follows all the aspects related to the technological solutions (design of the system and its components, connection among them, anchoring systems, etc.); the Department of Energy (DENERG) of Politecnico di Torino is involved in the thermal analysis and is responsible for the modelling of the thermal performance of the insulating and radiant system; the Department of Science and Technological Innovation (DSIT) of Università degli Studi del Piemonte Orientale collaborates to develop the energy aspects and manages the thermal monitoring on site; Boschis S.p.A, a company specializes in the manufacture and installation of wood finished components, is charged to design and to produce the wooden parts of the system and the mechanical components of the insulating and radiant system; NTS Group S.r.l., a company specializes in the sale and installation of technical components for heating and cooling plants, provides know-how and components related to the active radiant part of the system; Cluster Srl, a building company, gives the manufacturer's point of view and has made available a part of one of its construction sites as case study, giving the chance to have a real experimentation in the field.

The I.I.I. project consists of two parts: the first is theoretical and is focused on the analysis of the building envelope and on the thermal bridges up to the conception and design of an insulating and radiant system; the second includes the assembly of all the parts of the system and its test in the field.

The research has been developed using different case studies with the aim to verify as much problems as possible and to look each time for effective answers applicable in the inner part of the envelope walls of a construction. As usual in the building sector, it has been necessary to be conscious that each construction represents a single prototype that needs specific solutions.

Four dwellings have been analysed with a qualitative approach and for each of them have been designed a specific insulating solutions. Each case study has been useful to notice different problems to solve in relation to specific geometrical conditions, but also to requests and needs of the users. For the dwellings the attention has been focused only on the possible geometrical solutions to give answers to the need to improve, with inner insulation, the thermal performance of the external walls of the buildings.

In one of the four case study the insulation project has been manufactured in site and the thermal performance of the external insulated walls has been verify through thermographic images. The result has been very interesting and satisfying because of the improvement of the thermal performance registered and evaluated in comparison with the adjacent flat (Fig. 1).

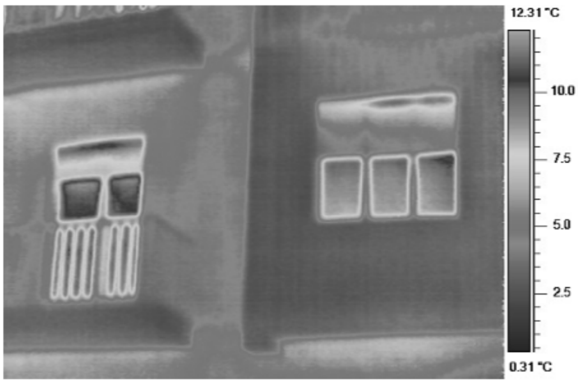

Figure 1: Thermographic image of the case study: on the right the apartment with the insulating panels in the inner side of the wall, on the left the adjacent flat without insulation.

The principal case study chosen for the I.I.I. project, object of the research work of the group of partners involved, is an historic building in the centre of Turin which occupies an entire block and has a big internal court. The construction, made of several adjacent buildings with different formal values and structural characteristics, is being transformed into a hotel. The main part of the block is facing Piazza Carlo Emanuele II and is called "ex Casa Gramsci". In the future hotel two rooms have become the case studies for the project. In both of them the thermal performances of the external walls have been monitored and in one the insulating and radiant system has been installed and tested (Fig. 2).

Figure 2: Experimental room in the building called "ex Casa Gramsci"

If compared with the dwellings previously analysed, in the solution thought for this case study the insulating solution is enriched with an active part made of a radiant coil. The solution, developed with the collaboration of all the partners of the project, aims to reduce the heat transfer through the external walls of the building with a high performance insulation and provides the room heating with a vertical integrated system of radiant pipes (Fig. 3).

Figure 3: Anchorage of the insulating/radiant panels in the experimental room

The experimental part of the I.I.I. project, conducted between January and May 2013 in the hotel case study, can be divided in four phases. At the beginning two rooms have been monitored with thermal sensors to register and analyze the heating performance of their external walls. The second phase of the monitoring has been done in one of the room after the installation of the insulating and radiant system to verify its insulating performance in a passive condition. In the third phase the radiant elements have been activated and the monitoring activity has been useful to control both the wall and the plant performances. During the last period of the monitoring have been tested different types of coating panels to verify their impact on the heat transmission from the heating coil located inside the *insulating/radiant panel* to the case study room. This final part represents an interesting field of research to deeper in future studies.

In all the phases the control of the performance of walls of the room and of the system was made also by thermographic photos (Fig. 4). They has given the possibility to have an instant outline of the thermal situation of the surfaces.

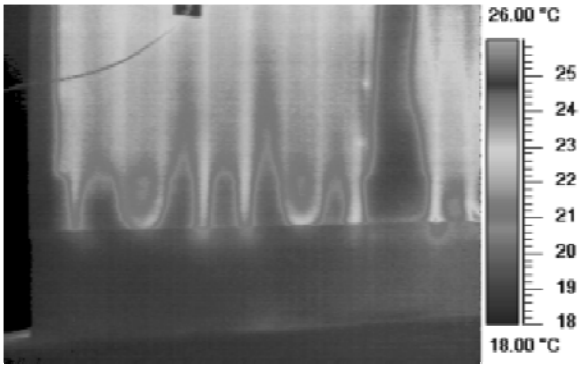

Figure 4: Thermographic photo in the experimental room during the third phase of the monitoring

The experimental part of the project has been useful to experience strengths and weaknesses of the system. When it was necessary, in the phases of its design, assembly and test it has been possible to propose and verify different solutions.

METHODOLOGY

The research project presents three different levels of successive in-depth analysis. These levels concern: the general structure of the research, the definition of the thermal insulation system assembled with the radiant system, the setting up and the management of the experimental phase. The methodological approach has been different for each of these levels.

The research has been structured according a cross-curricular method. The organization of the activities has correlated the academic world, the production world and the construction field. The cooperation of three different scientific areas was carried out by operating mainly along the disciplinary border areas in a spirit of mutual technology transfer. The synergy between university and small and medium enterprises has been finalized to give a concrete technical answer to the new requests of the building sector.

The general structure of the research involved the identification of a significant case study as field of application and verification of theoretical knowledge and of collection of experimental data. Besides it, other four cases with similar characteristic has been analyzed. They have been useful mainly to guide the project phase as a collection of situations to consider.

As a second step we have to recognize that the built heritage is mostly composed by prototypes and represents a complex reality. From a methodological point of view defining the ensemble of technical components as a system means working in the field of the complex systems. The system has to be able to provide, to control and to absorb every variations induced by the change of the boundary conditions of each building.

In the setting up and the management of the experimental phase both deductive and inductive method have been applied. The research questions, the scope of data collection and the analysis techniques have been determined and defined throughout the theoretical framework setting. The early settings have been fine-tuned by means of data analysis and the partners' contribution of experience, generalizing and systematizing what has been observed on site.

INSULATING AND RADIANT SYSTEM

The insulating and radiant system developed in the I.I.I. project is conceived to be prefabricated through the dry assembly of modular components. The production of the single elements and their assembly in a factory would make possible the minimization of the impact of the installation (dust, noise, undefined duration,...) in the building where the system is installed.
In order to guaranty an easy and quick setup, the system has been conceived made of modular elements with few special pieces to solve specific parts (corners, window frames, ceiling,…). It is especially thought for single applications in a wide number of buildings.

The insulating and radiant system includes different functions: physical resistance, thermal and acoustic insulation, heating and finish. It is made of several parts: a dry laying of a pre-assembled insulating/radiant panel, an anchorage system and a coating panel on its front. The insulating/radiant panel is composed of different layers and contains a water circulating system. It integrates in a single component the high performance of insulating elements, that ensure a passive thermal protection, with low temperature radiating elements (Fig. 5). The insulating/radiant panel has been developed as a reinterpretation of the techniques used in cooled transport, associated with the systems with radiant panels utilized in the heating/cooling floor plants.

Figure 5: Insulating/radiant panel

The insulating panel is completed and stiffened on its back and front faces by two plastic glued laminates. The front side of the panel is milled with numerical control machines in order to produce the vertical conduits necessary to wedge the heating elements of the system and the structure useful for the anchorage of the covering panels. In the circle section millings are glued the aluminium bent sheets in order to obtain an homogeneous distribution of the heat provided by the radiant coils slotted located in direct contact with them and to increase the heat transmission towards the internal space of the room. The aluminium bent sheets have a specific Ω shape useful to block the pipes which contain.

The square section millings contain the aluminium structure for the anchorage of the covering panel. It is connected with the insulating panel through self-tapping screws which reaches the back of the *insulating/radiant panel* where are fixed wooden horizontal slats (Fig. 6). They are part of the anchoring system which includes other slats screwed in the wall. The wood elements are connected through a mechanical dry joint.

The third part of the system is the covering panel prefinished or completed on site. It can be thought in wood, aluminium, glass, ceramics or using traditional or innovative products according to the formal chooses defined in the project. Nevertheless it is important to choose solutions which don't compromise the transmission of the radiant heating through it. The covering panels is connected with the *insulating/radiant panels* with screwed metallic hooks.

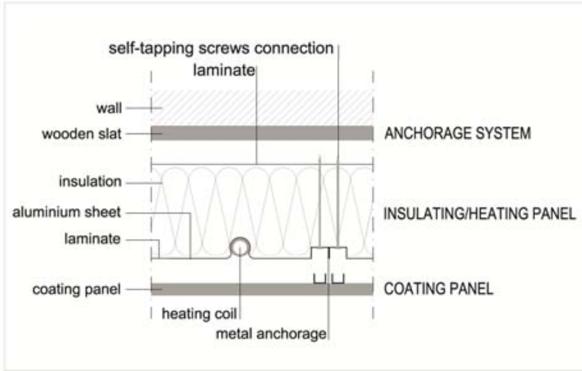

Figure 6: Exploded view drawing of the insulating/radiant system

The insulating and radiant system has to be completed realizing the hydraulic connections of the pipes in order to power its active part up to provide the necessary passage of water (Fig. 7). The combination of passive and active actions can guarantee a good comfort. When the assembly process of all the components of the system is ended, it is possible to complete it with the definition of all the finish elements and the integration of the plants.

Figure 7: Hydraulic connections of the pipes

The result of the I.I.I. project is the creation of a solution that integrates in the *insulating/radiant panels* different functions in order to simplify the procedures of intervention during the upgrade of the existing buildings. The characteristic of the panel can change (thickness and type of insulation, diameter of the pipes, shape of the aluminium sheets, etc.), but the idea of the product remains. All the technical chooses elaborated by the partners of the project have been made going in the direction of the maximum flexibility of the system. When it has been possible the connections have been thought with dry systems to ensure the characteristics of reversibility and inspectability.

CONCLUSION

The I.I.I. project is a challenge started with some hypothesis examined in depth and tested by the partners during the activities developed. Each solution has been verified with the aim to use the critical results as incentive to enrich the research. The attention has been focused on the general argument of the project (building envelope, thermal bridges and energetic enhancement of the historical construction) also through the analysis of the dwellings case studies; on the insulating and radiant system and on its components; later on its application to the principal case study of the hotel.

The work developed in the practical field has been a relevant chance to be aware of the real difficulties that can arise in a project focused on the buildings enhancement.

The project has given the possibility to discuss problems and solutions among researchers and technicians with different know-how and back ground and the concrete experience has brought out new problems, divergent points of view and possible new solutions. The discussion has been interesting and useful to reach the aim of the project: conception, design, prototyping, installation and monitoring of the insulation and heating system.

The results achieved at the moment are concerning to the different solutions designed to fit the system in the existent room used as case study. The theoretical hypothesis have been verified and some initial solutions, like the hanging system of the finishing panels with the insulating and radiant panels or the window frame connection, have been redesigned to give more suitable results. Data related to the thermal performance of the insulating and radiant systems have been collected and now are analyzing by those partners of the I.I.I. project working on the physic of buildings. Through their considerations we will understand the impact that the presence of passive or active insulation can give on the thermal performances of the external walls of the building.

In addition to the described tangible results it is important to notice that there are many others intangible results like the possibility to make working together the academic world, the production and the construction reducing the gap among sectors often in conflict or that simply neglect each other. The I.I.I. project has brought, furthermore, the opportunity to promote professional partnerships, to subsidize the working world related to the SME and to confirm the practical utility of the experimentation in the field.

The system made of the insulating/radiant panels developed in the project can also be promoted as a possibility to reduce the energetic impact of the buildings on the environment. The solution can be applied in new and existing buildings and the first results of the research have showed it guaranties a good performance.

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