Naturwall: active timber wall for renovation of existent buildings

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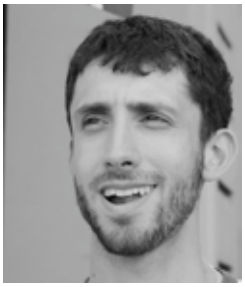

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Short Summary

The renovation of old buildings is actually the challenge to cope with increased effort in order to reduce climate global change, channeling more investment and awareness in this sense, defining more experimentations and find innovative solutions. The difficulty of carrying out an intervention on the existing buildings necessarily arise from the lack of information on the existing structure and the lack of coordinated processes between the multidisciplinary skills involved, as well as a difficulty to optimize the process that would make it even more competitive on the renovation work instead on the new construction.
Naturwall is an innovative energy saving system for existent buildings by using wood in multifunctional components able to mitigate the environmental effort in building management. The project meant to introduce an industrialized design method in the renovation of existing build environment that highlights opportunities gave by "off site" production and parametric design approach, without neglecting the aesthetical values and the possibility to change the architectural image of residential and non residential constructions. The project aims to create a representative model of solution that will be promoted in Italy and widespread in other similar context.

Keywords: wood, prefabrication, retrofit, building, urban renewal, renovation,

1. Introduction

The renovation of existing buildings is driven by new European rules and projects on energy efficiency. The recent Smart City program, EU climate action "20-20-20" or the last EPBD directive 2002/91/EC are promoting initiatives in the field of renovation, introducing new issues and perspectives in the use of materials and components performed for this goal.
The aim to achieve energy saving in buildings is a complex process, especially if buildings are very ancient. From the last report of Buildings Performance Institute Europe (BPIE), regarding the situation of building sector in EU 27 [1], are shown the performances of the amount of old construction characterized by poor energy saving potential. Our purpose has been the development of a whole process system in the field of renewal strategies to be used in every architectural field. Starting from the relief phase, we would optimize the process detailing envelope with digital data to be used in the entire process to define components that fit perfectly on the existent wall surface, reducing the risk of adaptability of the system and the work during the yard, We meant to achieve the reduction of energy cost optimizing the total cost of the operation, complying actual energy standards and reaching the opportunities related to renovation of social housing and industrial heritage, which needs smart solution in economic terms. In the report made by Copenaghen Economics for Renovate Europe in 2012 is highlighted how “energy savings associated with energy efficient renovation of buildings outweigh the up-front investment costs

needed to under-take the projects" [2]. The reducing of energy demand in public bills for example reflect a decrease in need for subsidies and permit the achievement EU's 2020 energy targets and reductions of greenhouse gases at a lower cost. Renovation opportunities could be a real benefit for EU economies and society, especially using a strategy that maximize the investment in energy saving convey an amount of extra benefits regarding the quality of health and urban climate (air pollution, etc...). Energy efficiency could seen as possibly the most cost effective way of reducing GHG emissions. Energy efficiency measures account for two-thirds of the 3.8 GT of abatement in 2020, with renewable energy contributing about 20 % [3]
Some economical studies [4] believed that efficiency offers an enormous "win-win" opportunity. Thus means that through an appropriate and strict energy conservation policies, it's possible both save money and reduce negative issues. This approach refers to the amount of externalities such as harm to human health, climate change and constraints on the foreign policy objectives of energy-importing countries that could be amplify with correct investments in energy efficiency. A true retrofit requires a fact-based, benchmarked, quantitatively oriented, energy efficiency retrofit with a clear payback analysis on an integrated multicomponent effort with performance guarantees. [5]

1.1 Renovation problem in Italy

In Italy, the introduction of energy regulation, within standards coming from European energy legislation, has led to further actions oriented towards buildings retrofit. This approach is not well sustained by a renewal claim about functional and formal features, but only considering faster energy saving strategies. In the most case this has solved by installing a thermal insulation on the building envelope, which permit to fulfil the target points without valorise the economical and architectural value of building heritage.
The situation of built environment in Italy could be understood by the outcomes of two national studies. The first is an outline from ISTAT (National Institute for Statistic) survey in 2001, which shows the highest number of existing houses built before the energy crisis of the '70s (more than half of the total amount) and how much is the consumption of those buildings (about 250 kWh/m2 compared to 100 kWh/m2 of buildings built in the '90s).
Considering the improvement of energy efficiency of residential buildings built among 1950 - 1980 (resulting from a widespread housing development), may suggest the obvious benefits about reduction of climate-altering gases in Italian urban areas through retrofit strategies and the reduction of management cost for public administration.
The second important data coming from an EU project called TABULA [5], in which Italian part was conducted by Politecnico of Turin, it displays for Italian country an existing built environment not efficient, wide and varied to be tackled through redevelopment actions. This research defines the typology of Italian buildings heritage and their features, explaining some furthering action to improve their supply and energy performances.The last frame is a research conducted by Legambiente, and called "Tutti in classe A", which present the top level in Italian energy rating, confirming the worse insulation of buildings actually made in Italy.
All those documents explain us how much wide is retrofitting field of work in our country. Thus was highlighted by first international convention Re- Build, held in Riva del Garda (TN) in September 2012, which has shown the huge percentage of heritage to be restored and re-used, promoting governments initiatives in the recovery and regeneration assets, emphasizing the need to revise intervention processes on urban areas, stimulating the research of structured path between governance, business and local communities.

2. Naturwall – a sustainable way for the envelope retroffitting

The target of the Naturwall method is primarily focused on the building's energy efficiency improvement and, as direct consequence, the reduction of GHG emissions. "Energy efficient buildings poses special demands on the quality and performance capabilities of the facade" [6] In the field of renovation and refurbishment high energy retrofitting results and greenhouse gases reduction could be achieved by using multifunctional facade systems. Smart facade solutions using the surface of the building envelope as "active skin" confirm the increasing number of experience in this sense (TES EnergyFacade, enVELOP system, PHI-Wood façade, GAP façade system, etc..). The last number of Zuschnitt [7] shows some innovative way to recover buildings with wood prefab systems. Thus permit to reach to achieve high energy performances and sustainable features on existing buildings.

Our system would recover power from sun by using PCM systems or simple strategy to overstock renewable energy (PV, water, etc..). We verify the behaviour of Naturwall system with mathematical models by using energy evaluation software; after tested it on laboratory, we will prompted it on a real case study. The first application will be upon an industrial building envelope, which needs to be recovered and insulated. Finally, we study its application on a residential multi-storey building located in Turin (Italy) to verify the efficiency of the solution in terms of architectural renovation and energy saving.

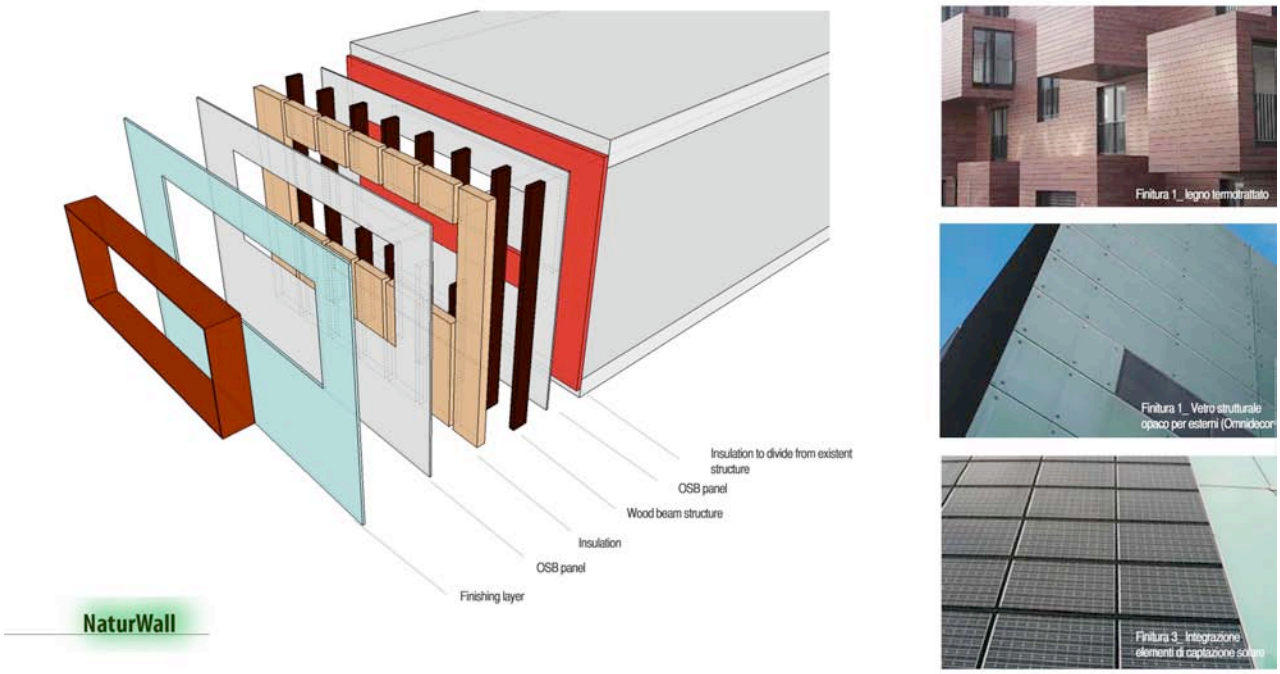


Fig 1: Naturwall facade system schematic design

The main target of that element are:

- Self supporting timber frame structure, coming from local forestry management
- Precision and quality of a customized prefabricated building system
- Application of different cladding materials – especially use of solar active systems (PCM, Photovoltaic, etc..
- Spatial intervention or expansion in a coherent modular system
- Integration of technical systems and sensor for monitoring performances
- Static behavior: wood elements are lighter than other construction material and guarantee better seismic performances.
- Responsive design to project objectives, an off-site process permit to control the quality of the final result, elements are industrialized products (made by using CNC machinery);
- Management of the yard: the setting in construction phase is more simple and there is the possibility to work, in the case of retrofit projects, without move outside the users, reducing implementation cost.
- Use of local material, especially wood coming from certified forest

A core task of energy efficient building design is to reach the required indoor environmental quality with a minimum of primary energy demand and a simple energy supply system. [8] Naturwall have several advantages, especially in the use of natural and local material, which reduce the embodied energy in the process and the carbon footprint of the products.

2.1 Multidisciplinary integrated workflow

Naturwall research meant to introduce a new settlement in renovation design approach maximizing benefits of integrated design and off-site production. This means achieving energy requirements

paying attention on the whole process. It is almost different from simple "recovering" strategy, Naturwall aims to define housing components able to activate dynamic and adaptive processes referred to the stresses coming from the external environment.
Facades play a fundamental role in the city renovation projects especially if the intervention runs up on buildings without remarkable architectural meaning and poor energy saving quality.
Naturwall prefab elements combine a self-supporting structure with insulation infill and panelling, which can be made by wide range of cladding materials (e.g. timber boards, timber panels, glass, aluminium etc.). High precision components like windows are easily integrated due to the modularity.

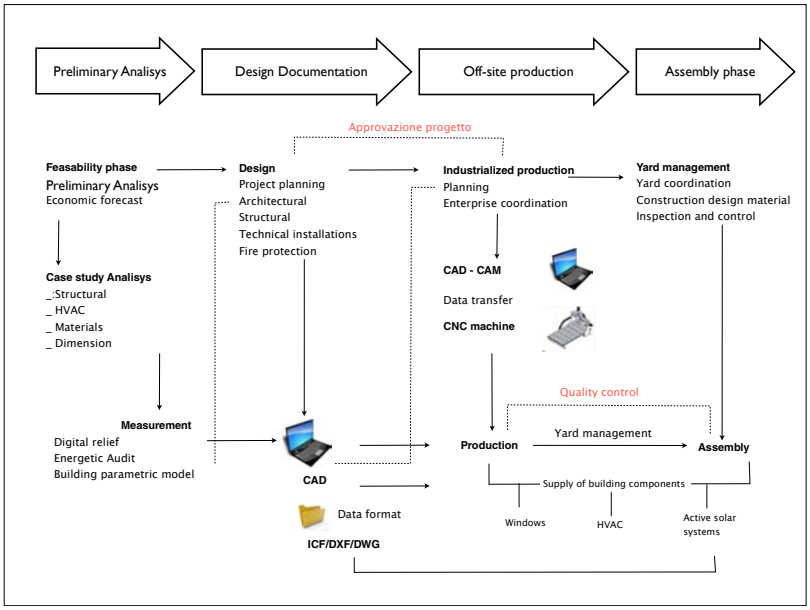


Fig 2: Naturwall workflow process (A. Spinelli, 2012)

Despite the use of wood in construction is increasing in Italy, the use of lightweight components in the intervention on the built environment remains an area of interest and research in our country. The aim of this project it's to propose a reflection about the opportunity gave by using industrialized system in the retrofitting approaches in urban spaces. permitting a deep renovation of the heritage that now shows problem of maintenance. The situation of the context, especially in urban dense areas, is very important to define a strategy that conceive the operative condition and time costing of the retrofit operation. One of the purpose of this research is the connection among design phase and construction, through the re-organization of the whole process with: digital measurement, planning off-site fabrication, on-site assembly, defining the instruments and phase necessary to bring the renovation to the end, evaluating all the issue and pay-back return. The Naturwall project take into account different ways for the application of that innovative component on the building. In particular, three main installation type have been considered: components applied on exiting envelope, components applied instead the existing envelope or components added to extend the building. All these types of installation request a preliminary survey of the building in order to put in evidence the critical points and study the best solution for the building renovation.

2.1.1 The role of relief phase

A specific relief phase, based on a dedicated methodology able to investigate in details the starting condition of the building, is necessary in order to collect important features and parameters necessary to conceive the component with respect to its performance, but also in order to reduces cost, resources and times in the whole design and fabrication process. During the production phase is important the availability of reliable and detailed measurements regarding the building. Since precision and reliefs devoid of errors are at the base of each solid design and correct inventory of the current state of a building, nowadays the simple 2D representations are no longer sufficient to serve the purposes of the field of architecture especially in the detailed metric measurement of the external facades. In the last few years, the employment of 3D laser scanning systems for the survey of exiting building - also complex - have been considerably increased due

to the advancement achieved by the recent hardware and software solutions. This technical improvements has boot a consequent decrease in the laser scanning services cost, that today are almost comparable with the traditional survey techniques. In addition, comparing the traditional survey techniques, the high level details achieved by laser scanning survey permits the correct dimension of the components during the off-site production phase achieving high precision (as an example, technical compartment for windows could be measured with a total error less than 5mm). Because the digital fabrication process based on CAD/CAM programs work mainly in two-dimensional mode, the 3D scan data allows the generation of any number of 2D representations such as plans, sections or views to understand the possible critical points during the fabrication process and design the component correctly. It is therefore possible to compare the measured data with the desired renovation project, detecting early warning of potential design errors and eliminating them even before the construction phase. This reduces the high liability risk of the requalification project, while the stringent requirements in terms of accuracy and profitability become calculable. In addition, the relief data could be directly imported in CAD/CAM programs and directly charged into CNC production machine, reducing the time necessary for the fabrication. Another advantage of the adopted method is given by the deformation analysis conducted on the façade, which allows to extract different important parameters in order to plan the most suitable installation program and conceive the proper support structure devoted to the component installation (bracket, trestles, etc.) with a consequent reduction in terms of resources and time

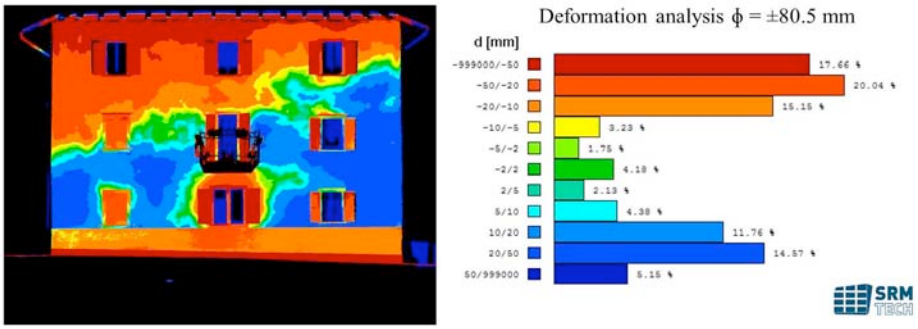


Fig 3: Deformation analysis of the west façade of an existing building (traditional '900 architecture) in Trentino, Italy.

during the place on the yard due to unforeseen critical points. As an example, in figure 3 is reported the deformation analysis on an existing building in Trentino Region where façade planarity error is higher than 20 mm in the 84% of the total surface.

2.1.2 The role of design phase

The designing phase could be focused as the main part of the process; the modern methods for measuring described above (i.e. Photogrammetry and 3D laser scanning) generate precise data of the target buildings in 3D-models, which could used for designing prefabricated components for renovating, and finally, for maintenance program. The dataflow matches the requirements of the digital process chain, from site measuring, planning to prefabrication. To exploit the best value of industrialized process we need to improve our instruments of investigation and communication. BIM method, for example, is an intelligent model-based process that helps professionals and enterprises achieving business results by managing more accurate, accessible, and actionable insight throughout project execution and lifecycle.

"The digital age has radically reconfigured the relationship between conception and production, creating a direct digital link between what can be conceived and what can be built", [7] the use of control machines within help of computer code permit to overcome the limit of standardization, variable information flow coming from design allows the manufacturing of components of various shapes, without any loss of time in production phase. The easy machinability of wood account this material for digitally controlled processes, thus provide an opportunity to incorporate the properties of material and inputs coming from construction and fabrication requirements, as parameters into the process. [8]

Timber design can be defined as the most modern method of construction in the market in terms of contemporary 'information society'. No other systems could explain better the relationship between technology, fabrication methods and architecture. [9] With an integrated design, you not only

evaluate the systems by themselves, but also as part of the overall energy consumption picture so that every action reinforces the others.

2.1.3 The role of production phase

When we manage a retrofit process, a shorter assembly on-site and fewer restrictions due to construction work compared to conventional renovation methods is a valuable quality for owner-occupied flats or buildings under operation. Some case studies made in Europe shows how it's possible to make a renewal project within inhabitants living in the "under construction" building.
In the timber construction sector, advanced methods of prefabrication are very successfully used in a contemporary practice to make new energy efficient buildings, and are consistently gaining market share.
Prefabrication allows the integration of building components such as windows, building services systems and ready-made surfaces of the facade elements in the controlled and ergonomic working environment of the factory. A flexible workflow from design to production allows for customised fabrication of single building parts to take into account the specific needs of individual buildings, e.g. size, unevenness etc.
Builders are actually prepared to achieve higher work productivity and manage rapidly the entire process, especially the assembly that is controlled from a strict design phase, which define the dimension of all pieces and modules. All parts of the system could be optimised in the workshop, e.g. material flow and efficiency, machine employment, etc . The work load on-site is minimised to the handling of just-in-time provided parts. This avoids organisational work, unproductive time, preparation work and enhances the productivity of the whole process.

2.1.4 The role of monitoring phase

In combination with an accurate metric measurement and deformation analysis of the building façade, a thermal analysis is conducted in order to evaluate environmental condition and characterize the building from the energy point of view. These analysis is important not only for the proper refurbishment of the façade in order to improve energy saving performances of the building, but also to realize a measurement campaign that characterize the performances of the installed components during their lifecycle. The survey methodology combines the most recent techniques for survey and modelling of the existing buildings with the thermal analysis (eventually merged on the 3D data volume), giving a sort of structural analysis and performance estimation of the building that will be suitable for a correct production of the components as cited before. By this way, a continuous improvement of the product in function of the different building environment conditions and landscape characteristics could be done.
In the economics of the operation, get feedback on the functioning of these modules and their performance, in order to improve their features on subsequent projects, is a key point; through the insertion of sensors it's possible to evaluate the parameters in a dynamic and active way, changing the characteristics of the housing envelope and the management system refer to geographical site and also provide real-time assessments of behaviour in various situations of intervention. This would ensure a performance audit of the housing within dynamic systems, allowing managing more accurately the service life of the building.

3. A refurbishment case study in Piedmont

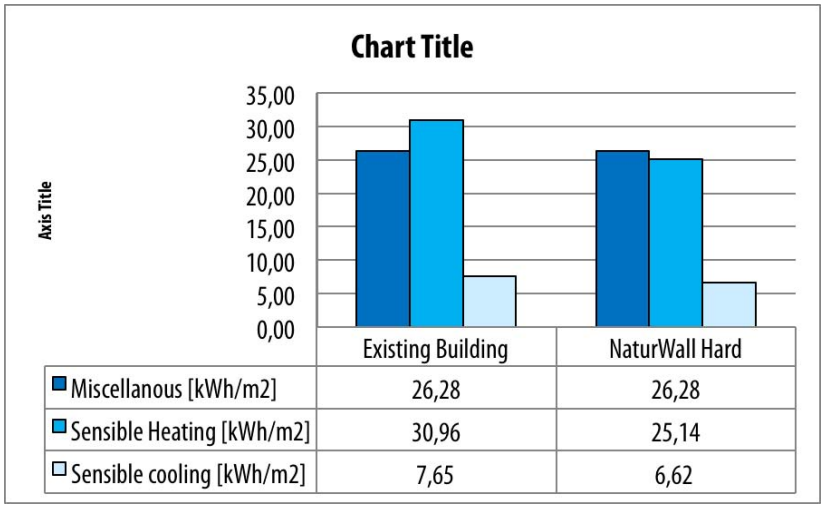
Fig 1: 4 Naturwall Case study model. Located in via Pietro Cossa in Turin. On the right the plan of the main floor.

Naturwall becomes a real program of intervention within Territorially Agency of Home (ATC) endorsement that has sustained our initiative permitting to develop some case study models to verify the feasibility of this retrofit strategy. Choosing a building more responsive to the average characteristics of the buildings made in the post Second World War period, we define a smart requalification process that combine Naturwall with other renewable systems to reduce the impact of those buildings towards "Net Zero Energy" home goal. The building is part of an expansion project in the suburbs of Turin in the '60 and are characterized by a poor energy saving envelope and low architectural value. By using Autodesk Design Builder© software tool we put in the baseline data coming from a preliminary energy audit and we studied the behaviour after introducing our new envelope system. The scope is to analyse how it works before and after the application of the Naturwall façade system. Evaluating the apartments of one floor, after calculating their annual consumption related to heating, cooling and electricity consumption, we simulated the addition of the new facade.
We use in this Naturwall system composed with local timber structure, cellulose insulation and ventilated glass facade (for external layer). Our intervention as be considered as a passive way to reduce consumption without using active systems, like as new technical installations or renewable energy.

The main results shows immediately a considerable percentage reduction of heating and cooling consumption and the increase of performances in energy saving envelope.

	Without retrofit	With Naturwall = Transmittance= 0,138 W/m^{2}K)
U_ Wall 1	0,486	0,11
U_ Wall 2	0,563	0,113
U_ Wall 3	0,561	0,113
U_ Wall 4	0,49	0,113

The table above shows the differences between transmittance values of the walls (that define the perimeter of the apartment) before and after installation of Naturwall system, the new partition have a behaviour in line within standards of new energy regulations in Italy.



The table above shows instead the reduction in term of energy consumption for square meter before and after the installation of Naturwall system. The amount of decrease it's around 15% of total energy consumed for square meter. Considering only the annually cost referred to heating and cooling consumption it represents an added value gain of 321 € for apartment. If we consider

electrical costs (Miscellaneous) the percentage drops to 6%.

4. Conclusion

Naturwall is a retrofit technological system that means to achieve energy savings requirements and restore contemporary building architectural aspect. Our building needs a restoration process to upgrade their performances and reduce the management costs and impact on the environment. With a deep preliminary study on the existing it's possible to make a detailed frame for the requalification process, inside of which can be define some work scenarios, finding the best solution for restoring quantifying the added value of regeneration. Materials, products, components and building techniques used in new buildings need to be further developed and adapted to the constraints of existing buildings. In terms of added value, the new envelope introduce a permanent solution that can be evaluate on a long financial term and achieving some incentives from Government, like as photovoltaic installations, we could widespread that practice of intervention. Multifunctional elemnts, including energy production installations, distribution and storage technologies, shall be integrated into the envelope system for building retrofitting.
For the final step of this research we are defining the cost of the component and its assembly phase on the yard, to develop a real payback return plan of the investment. Naturwall is an eco sustainable system, by using local wood materials to increase the ecological amount of the product and give new opportunities for woodworking local chain on out territorial land and develop a model for other country and define new business for enterprises in retrofit programs.

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