Quality-Oriented Façade Systems: Initial Investments vs. Global Cost Approach

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Abstract: An analysis applied to an existing building considering the whole service life, regulated or, if any, measured, of energy/technological upgrading action does not only require initial investments to be taken into account. Of course, such investments are significant and will have to be considered at a first stage, but it is not the only aspect to be considered. Provisions of Construction Procurement Guidance, No.7 Whole Life Costs state: “All procurement must be made solely on the basis of value for money in terms of the optimum combination of global costs—and not only initial investment costs—and quality to meet the user’s requirements”.

Key words: Facade system, initial investments, global cost approach, quality, convenience.

1. Introduction

When renovating a pre-existing council building, with reference of the insulating product on the vertical supporting layer, three functional models can be identified:

- opaque vertical enclosure with insulating product laid on the external side;
- opaque vertical enclosure with insulating product laid in hollow space;
- opaque vertical enclosure with insulating product laid on the internal side.

This simple consideration may benefit: (1) public and private organisations in identifying opportunities to decrease costs and increase efficiency in exploiting available resources; (2) designers, who could draw up classifications in order of priority to support decision-making and cope with budget limitations; (3) experts in carrying out assessment procedures. In scientific terms, identification of functional models could be vital to develop a policy aimed at applying scientific findings to real cases, also in view of improving existing products and techniques or patenting new ones.

In the present work, opaque vertical enclosure with insulating product laid on the external and internal sides have been introduced, while the cavity wall insulation option has not been presented. In fact, hollow space insulations are not always easily feasible nor cost-effective when renovating a pre-existing council building, which can be seen in the case study of the present work (Fig. 1).

All that stated above, external and internal insulation options have been put in comparison in terms of preliminary assessment (Tables 1-3), so as to select the functional model to adopt for upgrading the case study (Fig. 1). Then, alternative functional homogeneous systems and alternative upgrading combinations referred to the selected functional model have been put in comparison in terms of both initial investments and global costs. Conclusions will be drawn from the end of the manuscript.

2. Performance Benefits and Drawbacks of Alternative Strategies

Advantages and disadvantages of a given insulating strategy can be clearly highlighted using a benefit-cost analysis. In this view, a preliminary estimate of the
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initial costs could help choose the most appropriate strategies to be first adopted in the case at hand (Fig. 1).

A performance benefits and drawbacks of alternative strategies usable for upgrading are reported in Table 1.

A preliminary assessment may reasonably include a compared estimate of the cost involved in creating internal insulation vs. external insulation. An estimate of the initial costs could help choose the most appropriate strategies to be first adopted in the case at hand even if it is not the only thing that counts. Of course, all the preliminary analyses have been carried out to verify that the minimum legal requirements for thermal insulation have been met. The analysis has shown that, in terms of initial investment, the difference between unit pricing for internal vs. external insulation—which allows us to estimate the overall cost of the project—lies in the supply-cost analysis.

The non-part market survey we conducted revealed that, as of 2012–2015, the unit prices for internal vs. external installation are virtually identical. In order to carry out a preliminary financial analysis, it is necessary

| Upgrading strategy | Internal insulation |
|---------------------|---------------------|
| **Benefits** | |
| Reduction of thermal bridges; Reduction of thermal stress; Thermal inertia; Decreased risk of interstitial condensation and formation of mildew; Viability in laying great insulation material thicknesses without construction problems; Viability in working without limitative spatial and/or temporal interference(s) with users during the construction phase; Unchanged internal marketable area; Viability in shaping pilasters | Unchanged of external finishing coat; Contribution to the building’s inertial behaviour; Increase in soundproofing level of the wall package; Quick installation of the thermal insulation system; System integration |
| **Drawbacks** | |
| Low impact resistance; High thermal inertia; Comprehensive limitations in housing installations (not strictly necessary); Low possibility to diversify coating; Increased laying costs due to skilled labour | Lack of continuity of the insulating layer (thermal bridges); Thermal stress on the wall structures and supports; Extremely prone to wall damp; Interstitial condensation; Prone to mould formation; Defective planarity of the wall support reveal surface area; Low impact resistance; The insulated wall cannot accommodate any suspended weights (poor resistance to suspended loads); The insulating layer offers little mechanical resistance. As for sheetrocks, weights may be hooked on. However, this is subject to the type and pitch of the substructure; Reduction in internal marketable area |
| **Economics** | |
| The cost-effectiveness of the use of the external strategy must be assessed beforehand | The cost-effectiveness of the use of the internal strategy must be assessed beforehand |

![Front view No. 1: Wall surface: 605.071 m²](image1)

![Front view No. 2: Wall surface: 237.624 m²](image2)

![Front view No. 4: Wall surface: 237.624 m²](image3)

![Front view No. 3: Wall surface: 625.629 m²](image4)

Fig. 1 The case study, geometrical configuration.

Table 1 Comparative preliminary assessment of the benefits and drawbacks of adopting a certain strategy involving the use of a sealing product which must meet the minimum thermal insulation standards (actual system status: the case of a traditional multi-layer opaque main wall).
Table 2 Preliminary comparative analysis of supply costs (from price lists) to ensure the project meets minimum thermal insulation requirements.

| External insulation | Internal insulation |
|---------------------|---------------------|
| General description: $t$: thickness; $\lambda$: thermal conductivity | General description |
| Unit price | Unit of measure and impact on functional unit | Unit price | Unit of measure and impact on functional unit |
| Base coat together with reinforcement | | Preparation of door and window frames and waterproofing of door and window frames | 0.08 | EUR/m² |
| Insulation—white SEP: $t$: 8 cm; $\lambda$: 0.036 W/mK | 70.00 | EUR/m³ | 8.75 | EUR/m² |
| Insulation—grey SEP: $t$: 8 cm; $\lambda$: 0.032 W/mK | 110.00 | EUR/m³ | 12.50 | EUR/m² |
| Primer | $\approx$ 1.00 | EUR/m² | Slate fastening by means of hammer | 10.62 | EUR/m² |
| Top coat—organic coat | 2.72 | EUR/kg, 3 kg/m² | Primer | 4.32 | EUR/m² |
| Top coat—siloxane coat | 5.91 | EUR/kg, 3 kg/m² | Reinforcement | 5.87 | EUR/m² |
| Neoprene gasket strips | 1.56 | EUR/ml | Smoothing | 0.36 | EUR/m² |
| Plugs | $\approx$ 1.50 | Each 5 ÷ 6 plugs/m² | Key coating | 1.33 | EUR/m² |
| | | | Plaster for indoor use | 4.58 | EUR/m² |
| | | | Hydro paint for indoor use | 0.98 | EUR/m² |

Source: an Italian insulating company price list [5].

Table 3 Static testing of existing support.

| Need class | Requirement class | Description of residual specific requirement | Control criteria | Viability |
|------------|-------------------|---------------------------------------------|------------------|-----------|
|            |                   | Static resistance to locked-in loads brought to bear by the installation of a façade system onto a pre-existing support | Structure documentation consistency; Overall bearing capacity of reference sample structure measured by means of adequate instruments; Structural project | Yes/No Yes/No Yes/No |
|            |                   | Movements of the main structure | Structural project | Yes/No Yes/No Yes/No |
|            |                   | Differential dropping control | Structural project | Yes/No Yes/No Yes/No |
|            |                   | Plugs suitability to the supporting structure | Type of existing structure; Type of existing support | Yes/No Yes/No Yes/No |
|            |                   | Verticality, horizontality and flatness tolerance control | On-site checks; Good design practice | Yes/No Yes/No Yes/No |

To understand how to make a fair comparison of the various costs involved in supplying both internal and external insulation strategies. Following are some useful points to bear in mind in this respect. Of course, when considering options to retrofit external insulation, solutions that will meet at least the minimum thermal insulation requirements must be taken into account. At a preliminary stage, the incidence of the external insulation strategy must be calculated to include the total volume.

The preliminary financial analysis must account for the use of either white SEP (sintered expanded polystyrene) insulation panels (thickness: 8 cm; thermal conductivity: 0.036 W/mK) or grey SEP insulation panels (thickness: 8 cm; thermal conductivity: 0.032 W/mK). The latter requires an
initial investment, that is 30%~40% higher than the white SEP insulation option.

With reference to the supply of the entire façade system only, this analysis concludes that the supply costs of grey SEP insulation panels are 12% higher than the supply costs of white SEP insulation panels.

In case of external insulation, neoprene is not always accounted for. In the case at hand, the incidence of neoprene has been calculated.

By contrast, when computing the incidence rate of internal insulation strategies, neoprene must be taken into account without fail so as to allow for preparation and treatment of windows and door frames.

Table 2 shows, in preliminary terms, in terms of initial investments, the external thermal insulation composite system is of course more appealing compared to internal insulation.

3. Functional Configuration Referred to External Insulation

Now, alternative functional homogeneous systems and alternative upgrading combinations referred to the functional model—opaque vertical enclosure with insulating product laid on the external side, are put in comparison in terms of initial investments. The functional homogeneous systems are the ETICS (external thermal insulation composite system) [1] and the external cladding system [2].

Reference of geometrical configurations are reported in Table 4.

3.1 Detailed Design and Engineering of Façade Systems

Façade systems have been engineered in advance by the author in compliance with applicable regulations [1-4].

The following items were prepared to estimate initial investments: (1) a list of components, services or activities to be carried out; (2) for each item, basic measurements carried out on specified areas; (3) total amount and, if applicable, sketches for additional information; (4) for each item, unit price, quantity and amount; and (5) a list of materials, rented equipment and accomplished works that might be necessary, if any.

Before introducing results, some remarks on the amount of necessary components to build façade systems should be specified. For this purpose, simplifications have been carried out. Furthermore, some remarks on preliminary viability analyses have been reported in Table 5.

3.2 External Thermal Insulation Composite System

Calculation of quantities for individual components of the shell system (Fig. 2) has been carried out in compliance with the provisions of the CORTEXA Handbook [3]. In particular: (1) The system to lay adhesive beds to fix insulating panels to walls and, consequently, calculation of quantities, emissions and consumption has been calculated according to the bead/spot method (minimum contact surface: 40% of panel), for rock wool, glass wool and sintered expanded polystyrene; (2) Calculation of fixing equipment has been carried out in compliance with fixing diagrams in the abovementioned handbook [3]. Other particular measures and specific activities to be carried out comply with the provisions of the abovementioned handbook. Figs. 3 and 4 show economic

Table 4  The case study, numerical configuration.

| View position                      | Front view No. 1 (Fig. 1) | Front view No. 2 and front view No. 4 (Fig. 1) | Front view No. 3 (Fig. 1) |
|-----------------------------------|---------------------------|-----------------------------------------------|----------------------------|
| Wall surface                      | 605.071 m²               | 237.624 m²                                   | 625.629 m²                 |
| ETICS involved surface            | 553.304 m² of insulating panels, scrap excluded; 719.881 m² of insulating panels, scrap included | 207.689 (each) m² of insulating panels, scrap excluded; 224.489 (each) m² of insulating panels, scrap included | 207.689 (each) m² of insulating panels, scrap excluded; 224.489 (each) m² of insulating panels, scrap included |
| External cladding systems involved surface | 657.709 m² of reinforced-concrete panels, laid | 208.041 (each) m² of reinforced concrete panels, laid | 530.297 m² of reinforced concrete panels, laid |
Table 5  Viability analysis: type of constraints and opportunities to depart from constraints (an exemplification, the Italian case).

| Italian type of constraints | Level | Description | Reference and remarks (*) | Actual system status | Legal constraint may apply but can be waived | Legal constraint may apply but can be monetized |
|-----------------------------|-------|-------------|---------------------------|----------------------|---------------------------------------------|-----------------------------------------------|
|                             | Town planning | General | Ministerial Decree No. 1444 of April 2, 1968 (published in OG (official gazette) No. 97 of April 16, 1968): mandatory constraints on building density, heights, distance between buildings and maximum ratio, between areas allocated to housing and production, and public areas or areas allocated to collective activities, public green spaces or parking spaces. The abovementioned mandatory constraints must be observed for the purpose of creating new town planning tools or revising the existing ones (Article 17, Law No. 765 of August 6, 1967 (in force since April 17, 1968)). | Actual Yes No | Yes No | Yes No |
|                             |       | Related to architecture | Prime minister’s decree of 12 December, 200: identification of documents required to check for compatibility between landscape and suggested works (Article 146, Subsection 3, Cultural Heritage and Landscape Code, Legislative Decree No. 42 of January 22, 2004 (OG No. 25 of January 31, 2006). | Actual Yes No | Yes No | Yes No |
|                             | Building | Architecture | Reference sanitary regulations approved by means of Town Council Resolution No. 268/90, regional council resolution, updated to title III of the reference local sanitary regulations (Regional Council Resolution No. 4/45266 of July 25, 1989). | Actual Yes No | Yes No | Yes No |
|                             | Building | Related to net area | Reference sanitary regulations approved by means of Town Council Resolution No. 268/90, regional council resolution, updated to title III of the reference local sanitary regulations (Regional Council Resolution No. 4/45266 of July 25, 1989). (*) Calculation method to be checked according to municipalities. | Actual Yes No | Yes No | Yes No |
|                             | Building | Related to ownership | (1) Italian civil code; (2) condominium regulations; (3) private agreements, if any. | Actual Yes No | Yes No | Yes No |
|                             | Building | Historical, related to façade | Legislative Decree No. 42 of January 22, 2004, cultural heritage and landscape code (Article 10, Law No.137 of July 6, 2002 (published in OG No. 45 of February 24, 2004, ordinary supplement No. 28). | Actual Yes No | Yes No | Yes No |
|                             | Building | Technological, related to composition | About compatibility (*) (*) Criticality, not constraint, depending on the architectural features and on composition of the built object. | Actual Yes No | Yes No | Yes No |
|                             | Building | Structural | Ministerial decree of January 14, 2008 (OG No. 29 of February 4, 2008, ordinary supplement No. 30, technical building regulations). | Actual Yes No | Yes No | Yes No |

The case of the Region of Lombardy (northern Italy)—opportunities to depart from constraints

| Level | Description | Reference and remarks | Yes | No |
|-------|-------------|-----------------------|-----|----|
| Building | Energy efficiency | In compliance to Article 11, Legislative Decree No.115 of May 30, 2008 on energy efficiency, the region of Lombardy provides for some exceptions on minimum distances between buildings, on minimum distances for road protection and on maximum building heights, while no reference is made to distances from borders. The purpose is clearly fostering building projects providing for buildings with increased energy performance, thus leading to drawing up regulations that, in concrete terms, depart from the existing ones. To be more specific, sections of Article 11 concerning distances and heights are applied in Lombardy, since these two topics are not dealt with in Regional Law No. 26/1995. | Yes | No |
Fig. 2  Comparison of alternative supply costs (free delivery to the construction site analysis).
As for Solutions 1-3: (01) siloxane coating (finishing coat); (02) primer; (03) base coat (together with reinforcement); (04) butterfly plugs complete with end caps. And for Solution 1: (05) sintered expanded polystyrene in panels, size: 100 × 60 cm, thickness: 8 cm; for Solution 2: (05) rock wool in panels, size: 100 × 60 cm, thickness: 8 cm; for Solution 3: (05) glass wool in panels, size: 100 × 60 cm, thickness: 7 cm.
As for Solutions 4-5: (01) fiber-reinforced concrete panels, thickness: 0.8 cm; (02) extruded profile in aluminium alloy EN 6060 T5; (03) single and double tile-retaining hooks in 10/15 thick, enameled stainless steel EN 14310 (AISI 301); (04) springs to fix hooks on extruded profile, in stainless steel EN 14310 (AISI 301); (05) single, double and special double load-bearing stirrups, from extruded profile in aluminium alloy EN 6060; (06) nuts, bolts and stainless steel class A2 Grover washers to fix extruded profile on the stirrups; (07) fixed-point mounting screws; (08) anchors to fix the stirrups on the wall, mechanical or epoxy-resin based, as needed; (09) neoprene gasket strips, to gauge the tiles, the hooks and the aluminium profile, in different thickness as needed; (10) springs in tempered stainless steel, to support the insulating panels and press them on the wall surface; (11) butterfly plugs complete with end caps; (12) rock wool in panels; size: 100 × 60 cm, thickness: 8 cm.
Incidence of the three insulating products reported in Fig. 2 (1 of 2), a global cost approach. As far as the laying costs concerned, rock wool and glass wool are more expensive than sintered expanded polystyrene.

5. Initial Investments vs. Global Costs

In synthesis, global cost analyses [1] are reported in Figs. 5 and 6. Results are shown in form of compared bar charts. Please consider that in the global cash flow analysis, no tax deduction have been included for energy upgrading. From an exclusively monetary point of view, initial investment represents a cash outflow...
that might lead an investor to tend to select an upgrading solution instead of another one. It is evident that initial investment for an external cladding system are more superior than that would be necessary for an external thermal insulation composite system (Figs. 2 and 5-8).

6. Conclusions

We have already discussed about the fact that it is not only the monetary aspect that makes the
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difference [5, 6, 7]: Optimisation of choices is not only a matter of cash-flow analyses [8, 9].

Choices should not be made only according to the lowest costs but also considering several aspects that can be brought back to the concept of “technical sustainable value”, which mainly derives from competent functional and environmental assessments [5] of the reference analysis system. Furthermore, unexpectedly, we have already discussed about the fact that considering a LCC (life cycle costing) approach [10, 11], convenience in funding solutions that are convenient in terms of quality, but less convenient in terms of initial investments, may be reasonably pursuable for an individual property owner of a flat in a condominium (multi-owner property) [7], such as our case study (Fig. 1).

Acknowledgments

Technical data here presented have been collected/elaborated within a non-market, non-party research carried out by the author autonomously on the Italian market from 2009 to 2015.

Technical data here presented are partially drawn, then at a later stage elaborated, from the already defended Ph.D. thesis, where all sources and information used or quoted have been indicated and acknowledged by means of a dedicated reference list.

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