Urban Rehabilitation of the Coimbra's "Baixinha" Historical Centre – Portugal

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Abstract

Rehabilitation is, in cultural and social terms, an alternative to the substitution of buildings, as an assertion of the urban space's memory and the established social relationships making a unique space within a more global one which is the city as a whole. However we see that the energetic policies are, in a way, more oriented towards a more recent construction, bringing a constant challenge to the rehabilitation being made, also motivated by the complexity involving energetic rehabilitation and the fact that it is still a fairly recent process in our country. The present work exposes studies, its analysis and the evaluation of the measures that should be taken. These should join together rehabilitation and renovation to the carrying out of the energetic-environmental measures, keeping in mind the increase of the buildings energetic performance, the comfort and liveability conditions and the fulfilment of the current legislation without changing the image or the historical and architectural features of old buildings. Researches were made to establish the comfortable thermo conditions and tests to understand the typologies, morphologies and constructive systems influence on the achievement of those conditions. The gathered information was analysed, adjusted and tested in the rehabilitation of historic centre of the Baixa area of Coimbra in order to help the city's administration to accomplish one of their goals: "to assure the environmental and energetic sustainability".

Keywords: rehabilitation, energetic performance, historical centre, sustainability, comfort

1. Introduction

In Portugal during the 20th. century, rehabilitation work was essentially carried out on monuments. It was only after the Revolution of 25 April 1974 that conservation practices began to change, with the recognition of the importance of the idea of that cities should integrate the socioeconomic, cultural and environmental aspects of rehabilitation work and ensure that it was not restricted only to monuments but also included other groups of buildings. Rehabilitation is an important alternative to the replacement of buildings and prevents urban sprawl. In addition, given the impact of buildings in terms of energy consumption, they will now have to comply with minimum energy performance requirements, adapted to local climate conditions. Good practice, in this context, must therefore be aimed at the best possible use of the relevant factors to reinforce energy performance by increasing thermal levels and installing alternative energy supply systems.

Despite the fact that energy policies are not particularly directed towards old buildings and that there are ongoing difficulties involved in implementing domestic energy rehabilitation measures, it is imperative that concerns about energy and thermal comfort are incorporated into rehabilitation, restoration and renovation projects for existing buildings and measures are taken to optimise cost efficient energy-environmental behaviour.

Improving the overall energy performance of an existing building does not necessarily mean total renovation but may be limited to the most important elements of energy performance and those which are cost-effective. Therefore, the search for tools to assess the best building solutions from the point of view of comparative thermal analysis is also very important.

Within this context, this paper presents an assessment of corrective thermal measures implemented through two studies which tested out various thermal corrections applied to two properties, a T0/T1 (studio/one-bedroom flat) (Study 1) and T2/T3 (2/3-bedroom flat) (Study 2) in two separate old buildings in the historic centre of the Baixa area of Coimbra that were due to undergo different rehabilitation strategies.

2. Thermal-energy correction strategies

2.1 The urban environment – climate factors and data

The historic centre of Coimbra stands between nineteen and one hundred and five metres above sea level.

The climate in Coimbra has the typical characteristics of the Beira Litoral region, being temperate and Mediterranean, with moderate temperatures in summer and winter and rainfall throughout the year.

According to Thornthwaite the climate in the area is classified as B1, B'2 s a′, or in other words, humid and mesothermal [1], with moderate water deficiency and little or no concentration of thermal efficiency in the hot season. As classified by Koppen it is a Csb [2] climate, i.e. temperate, humid (Mediterranean) with dry and not very warm summers.

The average annual temperature is 14.8º with slight monthly variations (19.9ºC in July and 9.7ºC in December). Average annual rainfall amounts to 913.8 mm and 75% of the annual total falls between October and March. The relative humidity is high, with an annual average of 82%. The lowest monthly average is 73% in July and August. Annual insolation amounts to 2,392 hours, a value which is not particularly high, and morning fogs and mists are very common. The average wind speed is 10.5 Km/h, with prevailing winds from the south and southwest in autumn and winter and from the northwest in spring and summer. Frosts are rare, occurring only 3.6 days of the year between October and April (Nunes, 2002). The water temperature of the River Mondego varies from 6º C in the coldest months of December and January to 19º C in the hottest months of July and August, averaging 16º C in the Coimbra and Lower Mondego zones and 10º C in the Serra da Estrela and Caramulo zones.

2.2 Identification of main problems

The buildings in the area covered by the study have a low comfort level, independently of its type, due to the poor thermal quality of the building external envelope (walls, frames and coverings) and the actual spatial structure of some of the buildings, which makes it difficult to control natural ventilation and consequently the speed and quality of air in the interior. Their relationship to the outline and width of the streets also affects comfort, since most of the year no direct sunlight comes through the windows, thus reducing solar gain in summer (a positive point) and practically eliminating it in winter (which is very disadvantageous to the performance of the building).

Certain problems related to condensation are also found, either due to the poor quality of the building envelope and lack of heating and ventilation control, or due to climatic factors (with high levels of relative humidity registered). In buildings whose walls have lime-based coatings, the situation is less problematic due to their hydroscopic inertia, which is more permeable to water vapour and releases it more slowly.

2.3 Passive solar strategies

This type of strategy aids the natural heating or cooling down of buildings according to the needs of users. It involves studying the spatial organisation which best favours interior thermal comfort, including constructional mechanisms integrated into the buildings through various measures, namely:

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[1] Humid climate with little water deficiency
[2] Csb – Temperate Humid Climate with dry, temperate summers

1. The use of buffer zones (technical and service areas) to protect living space in terms of solar gain and undesirable losses;
2. Making use of passive solar gains: south-facing collectors to aid insolation in winter and offer protection against the sun in summer;
3. South and north facing openings in opposite facades to allow for cross ventilation in summer and blind facades in the east and west to provide better solar protection in summer;
4. Entrances or interior courtyards to promote passive cooling and provide light for interior areas in summer;
5. Cooling by natural night ventilation or through water evaporation systems;
6. The use of active technologies for transparent or translucent facades to accommodate the relationship between thermal solar gains and natural lighting, favouring gains during the hours of winter insolation and reduction in summer.

Whenever possible passive solar strategies must be applied in rehabilitation work, and even active strategies as well, whilst recognising that their application is limited, given that this involves a built-up area with a defined shape and size. Given these adverse factors and the fact that groups of buildings with great heritage value are involved, various hypotheses and intervention strategies should be tested out from the point of view of increasing comfort and thermal, energy and environmental performance, in order to find the best solution without interfering with the architectural image. For this reason thermal correction applied to the exteriors of walls and external shading are not included in this study;

3. Case study 1

Case study 1 involves a building due to undergo extensive rehabilitation and renovation work, maintaining the facades and altering the entire constructional system and organisation of the interior. It was chosen because it is typical of the cases found in the historic centre of the Baixa area of Coimbra, given the high level of degradation in buildings, which at times leads to maintenance of the facades only and, in addition, because rehabilitation projects are in the applications phase.

3.1 Description of the building

The building stands in Rua na Moeda nº 84-92 / Largo das Olarias, Santa Cruz and was probably constructed at the end of the 19th. century. There is a commercial establishment on the ground floor and residences (7 T0 – studio flats) on the 1st. and 2nd. floors.

Figure 1: Photos / Study 1 localization

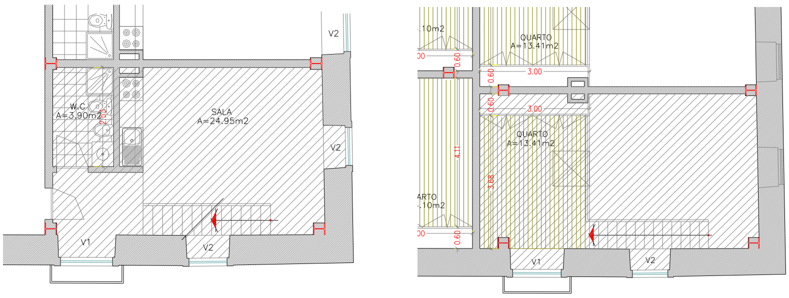

Figure 2: Study 1 target fraction

3.2 Study methodology

In order to assess the most suitable thermal intervention strategies that do not clash with the architectural style of the building, 12 tests were carried out involving the application of the new thermal regulations (DL 80/2006):

3.2.1 Test 1 – existing situation (starting point)

This test served to calculate the thermal performance of the building after alterations to the divisions and the materials stipulated in the architect's plan, without carrying out any thermal correction.

Identification and characterisation of existing construction solutions:

- Outer walls in soft limestone masonry (20 cm thick in the areas below the windows and 70 cm thick in the remaining areas), with traditional coatings on both sides.
- Frames – Glazing with wooden frames, two-pane windows, simple glass and night-time screening with low air permeability (entrance);
- Floors – One-way floor with ceramic filler blocks (0.35 m), levelling cement screed, loose-laid floor covering in the sitting room, mosaics in wet areas and ceiling covering of plaster with metallic finish;

- Coverings - One-way slabs with ceramic filler blocks (0,30m), discontinuous covering of ceramic tiles with well-ventilated area beneath, plastering in interior;

- Water heating system– gas heater.

In this test the effects of installing three different water heating systems were analysed, whilst the remaining features were maintained, in order to determine which was most advantageous.

3.2.1.1 Existing situation + Electric hot water storage heater (TAE)

3.2.1.2 Existing situation + Gas hot water storage heater (TAG)

3.2.1.3 Existing situation + Solar collectors (CS)

3.2.2 Test 2 – Compliance with minimum requirements imposed by new thermal regulations

In this test specific thermal corrections were applied to ensure compliance with minimum regulatory requirements. The corrections made in order to comply with minimum requirements which involved replacing the water heating system with a more efficient one were also tested.

3.2.2.1 Test 2.1 - Minimum requirements + Gas hot water storage heater (TAG)

3.2.3 Test 3 – thermal correction 1

In the test the aim was to comply with the minimum requirements stipulated in the thermal regulations by replacing the frames with more efficient ones and introducing specific corrections which did not significantly reduce indoor space. Certain thermal corrections were therefore carried out, the water heating system was replaced with an electric hot water storage heater with less than 50 mm of thermal insulation and solar collectors were installed in accordance with the Portuguese regulatory programme for the analysis of solar system performance (Solterm).

3.2.4 Test 4 – thermal correction 2

The aim of test 4 was to comply with thermal regulation requirements without replacing framing. Thermal corrections were therefore introduced using thicker insulation material, replacing the existing water heating system with a gas hot water storage heater with 50 mm of thermal insulation and installing solar collectors in accordance with the Solterm programme.

3.2.5 Tests 5, 6, 7 and 8 – thermal correction 3, 4, 5 and 6

In these tests more intrusive and wide-ranging thermal corrections were introduced in order to comply with (and exceed) the thermal regulation requirements by replacing the water heating system an electric hot water storage heater with less than 50 mm of insulation and installing solar collectors in accordance with the Solterm programme.

Table 1 – Summary table with carried out corrections

Test	Frame (glass)	Sealed doors	Ventilation grid	Walls 20 (insulation)	Walls 70 (insulation)	Floor slab (insulation)	Roofing (insulation
1, 1.1, 1.2, e 1.3	Existing	No	No	Without	Without	Without	Without
2 e 2.1	Existing	No	No	60mm	Without	Without	60mm
3 - Correction 1	Double special	Yes	Yes	60mm	Without	60mm	60mm
4 - Correction 2	Existing	Yes	Yes	60mm	60mm	60mm	60mm
5 - Correction 3	Double	Yes	Yes	60mm	30mm	30mm	30mm
6 - Correction 4	Double	Yes	Yes	60mm	30mm	60mm	60mm
7 - Correction 5	Double	Yes	Yes	60mm	40mm	60mm	60mm
8 - Correction 6	Double	Yes	Yes	60mm	60mm	60mm	60mm

4. Results

Using a spreadsheet the thermal regulations were applied to the tests named before and the values for Nic, Nvc, Nac and Ntc in Kwh/m^2.year were calculated. The obtained results are presented in Table 2:

Table 2: Obtained results from the calculation of the thermal regulation

Tes	Ap (m^2)	RPH	Nic	Ni	Nvc	Nv	Nac	Na	Ntc	Nt
1 - Existing	44.89	1.00	187.02	73.47	1.70	18	68.09	52.69	11.30	7.94
1.1 - Exist.+TAE	44.89	1.00	187.02	73.47	1.70	18	42.56	52.69	17.78	7.94
1.2 - Exist.+TAG	44.89	1.00	187.02	73.47	1.70	18	48.63	52.69	9.62	7.94
1.3 - Exist.+CS	44.89	1.00	187.02	73.47	1.70	18	65.16	52.69	11.04	7.94
2 -. Mín Req.	44.89	1.00	138.98	73.47	2.85	18	68.09	52.69	9.91	7.94
2.1 - Mín Req. + TAG	44.89	1.00	138.98	73.47	2.85	18	48.63	52.69	8.24	7.94
3 - Correction 1	44.89	0.85	105.55	73.47	3.97	18	39.62	52.69	14.59	7.94
4 - Correction 2	44.89	0.85	73.42	73.47	3.98	18	45.70	52.69	6.10	7.94
5 - Correction 3	44.89	0.85	84.47	73.47	3.88	18	45.70	52.69	6.42	7.94
6 - Correction 4	44.89	0.85	73.42	73.47	4.60	18	45.70	52.69	6.10	7.94
7 - Correction 5	44.89	0.85	70.37	73.47	4.72	18	45.70	52.69	6.02	7.94
8 - Correction 6	44.89	0.85	66.33	73.47	3.32	18	45.70	52.69	5.89	7.94

Key: Ap (m2) – Floor area in m2; RPH – Renovations per hour; Nic – Nominal energy needed for heating; Ni – Maximum value for nominal annual energy needed for heating; Ncv - Nominal energy needed for cooling; Nv - Maximum value for nominal annual energy needed for cooling; Nac – Nominal energy needed for sanitary hot water; Na – Maximum value for nominal energy needed for sanitary hot water; Ntc – Nominal overall primary energy needs; Nt – Maximum value for nominal overall primary energy;

5. Case study 2

Case study 2 involves a building due to undergo extensive rehabilitation and renovation work, maintaining the facade, floors, support structure and constructional system and only restoring the existing area by implementing thermal correction systems and a specific rearrangement of the interior divisions in order to improve comfort conditions. It was chosen because it is also very typical of the Baixa area of Coimbra, given the poor state of repair of the building and the need to preserve all its features.

5.1 Description of the building

The building stands in Rua da Moeda nº 60-64, Santa Cruz and was probably built at the end of the 19th century. The ground floor serves as a commercial establishment, whilst the 1st. 2nd. and 3rd. floors are residential (3 T3s – three-bedroom flats). In this test we studied the 1st. floor.

Figure 3: Photos / Study 2 localization

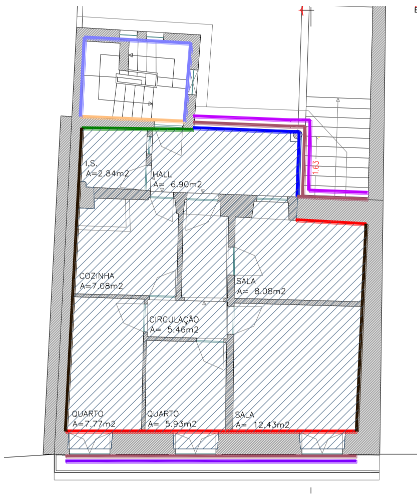

Figure 4: Study 2 target fraction

5.2 Study methodology

In order to assess the most suitable thermal intervention strategies that do not clash with the architectural style of the building, 17 tests were carried out involving the application of the new thermal regulations:

5.2.1 Test 1 – existing situation (starting point)

This test served to calculate the current thermal performance of the property, without introducing any thermal corrections.

Identification and characterisation of existing building solutions:

- Outer walls in soft limestone masonry (15 cm thick in the area below the windows and 60 cm thick in the remaining area), with traditional coatings on both sides (0,25*2).

- Dividing wall with adjacent building on the other side, in soft limestone (50 cm thick) with traditional coatings on both sides (0.25mm*2).

- Dividing wall with stairwell, in soft limestone (22 cm thick) and traditional coatings on both sides (0,25 mm*2).

- Floors – One-way wooden floor (0.35 m) and ventilation space, floor covering (0.03 cm) and wood lathing ceiling (0.02 cm);

- Frames:

  1- Glazing with wooden frames, two-pane windows, plain glass and night-time screening with low air permeability (entrance), south facing (1.10 m x 2.06 m);

  2- Glazing with wooden frames, four-pane windows, plain glass and night-time screening with low air permeability (entrance), north facing (2.66 m x 1.90 m);

  3 - Glazing with wooden frames, three-pane windows, plain glass and night-time screening with low air permeability (entrance), east facing (1.64 m x 1.90 m);

- Water heating system – gas heater (piped, no insulation);

This test also analysed the effects of installing three different water heating systems whilst the remaining features were maintained, in order to determine which was the most advantageous.

5.2.1.1 Existing Situation + Electric hot water storage heater (TAE)

5.2.1.2 Existing Situation + Gas hot water storage heater (TAG)

5.2.1.3 Existing Situation + Solar collectors (CS)

5.2.2 Test 2 – compliance with minimum requirements imposed by new thermal regulations (DL 80/2006)

In this test specific thermal corrections were introduced in order to comply with minimum regulatory requirements. Another correction was introduced: replacement of the water heating system by a more efficient one

5.2.2.1 Test 2.1 - Minimum requirements + Gas hot water storage heater (TAG)

5.2.3 Tests 3 and 4 – thermal correction 1 and 1.1

Tests 3 and 4 aimed to comply with the requirements stipulated in the thermal regulations by replacing the frames by more efficient ones, introducing specific corrections which did not significantly reduce indoor space, replacing the water heating system with an electric hot water storage heater with less than 50 mm of insulation and installing solar collectors in accordance with the Portuguese regulatory programme for analysis of the performance of solar energy systems (Solterm).

5.2.4 Tests 5, 6 and 7 – thermal corrections 2, 2.1 and 2.2

Tests 5, 6 and 7 aimed to comply with the thermal regulation requirements without replacing framing. Thermal corrections were therefore introduced involving the use of thicker insulation, replacing the existing water heating system with a gas hot water storage heater with 50 mm of thermal insulation and installing solar collectors in accordance with the Solterm programme.

5.2.5 Tests 8, 9, 10 and 11 – thermal corrections 3, 3.1, 3.2, 3.3

In tests 8, 9, 10 and 11 other more intrusive and wide-ranging thermal corrections were introduced in order to attempt to comply with (and exceed) the requirements stipulated in the thermal regulations by introducing various thermal corrections, replacing the water heating system with a gas hot water storage heater with at least 50 mm of thermal insulation and installing solar collectors in accordance with the Solterm programme.

5.2.6 Tests 12 and 13 – thermal corrections 4 and 4.1

The aim of tests 12 and 13 was to achieve maximum thermal performance and comfort in the property and exceed the requirements stipulated in the thermal regulations by introducing various thermal corrections, replacing the water heating system with a gas hot water storage heater with less than 50 mm of insulation and installing solar collectors in accordance with the Solterm programme.

Table 3 – Summary table with the carried out alterations.

Test	Frame (glass)	Sealed doors	Ventilation grid	Walls 20 (isol)	Walls 65 (isol)	Staircase walls. (isol)	Walls separating from other. buildings (isol)	Floor slab 1 (isol))
1, 1.1, 1.2, e 1.3	Existing	No	No	Without	Without	Without	Without	Without
2 e 2.1	Existing	No	No	30mm	Without	30mm	Without	30mm*
3 - Correction 1	Special double	No	No	60mm	Without	30mm	Without	60mm
4 - Correction 1.1	Special double	Yes	Yes	60mm	Without	30mm	Without	60mm
5 - Correction 2	Existing	Yes	Yes	30mm	30mm	30mm	Without	40mm
6 - Correction 2.1	Existing	Yes	Yes	40mm	40mm	40mm	Without	60mm
7 - Correction 2.2	Existing	Yes	Yes	60mm	60mm	60mm	60mm	60mm
8 - Correction 3	Existing	Yes	Yes	30mm	30mm	30mm	Without	30mm
9 - Correction 3.1	Double glass	Yes	Yes	30mm	30mm	30mm	Without	30mm
10 - Correction 3.2	Double glass	Yes	Yes	40mm	30mm	40mm	Without	60mm
11 - Correction 3.3	Double glass	Yes	Yes	60mm	30mm	60mm	Without	60mm
12 - Correction 4	Double glass	Yes	Yes	30mm	30mm	30mm	30mm	30mm
13 - Correction 4.1	Double glass	Yes	Yes	60mm	30mm	30mm	30mm	60mm

*Only the flooring slabs above an unheated/ exterior area were insulated (excluding the part above the commercial establishment)

6. Results

Using a spreadsheet the thermal regulations were applied to the tests named before and the values for Nic, Nvc, Nac and Ntc in Kwh/m^2.year were calculated. The obtained results are presented in Table 4:

Table 4 – Obtained results from the calculation of the thermal regulation

Test	Ap (m^2)	RPH	Nic	Ni	Nvc	Nv	Nac	Na	Ntc	Nt
1 – existing	61.12	1.00	135.04	72.90	1.18	18	125.02	77.40	14.68	11.27
1.1 - exist.+TAE	61.12	1.00	135.04	72.90	1.18	18	71.44	77.40	24.65	11.27
1.2 - exist.+TAG	61.12	1.00	135.04	72.90	1.18	18	76.94	77.40	10.54	11.27
1.3 - exist.+CS	61.12	1.00	135.04	72.90	1.18	18	69.56	77.40	9.91	11.27
2 – Mín. Req.	61.12	1.00	104.71	72.90	1.68	18	125.02	77.40	13.80	11.27
2.1 – Mín. Req.+TAG	61.12	1.00	104.71	72.90	1.68	18	76.94	77.40	9.67	11.27
3 - Correction 1	61.12	1.00	74.83	72.90	2.93	18	15.98	77.40	6.83	11.27
4 - Correction 1.1	61.12	0.85	70.18	72.90	3.49	18	15.98	77.40	6.70	11.27
5 - Correction 2	61.12	0.85	70.96	72.90	2.48	18	21.47	77.40	3.93	11.27
6 - Correction 2.1	61.12	0.85	65.80	72.90	2.75	18	21.47	77.40	3.78	11.27
7 - Correction 2.2	61.12	0.85	50.30	72.90	2.83	18	21.47	77.40	3.33	11.27
8 - Correction 3	61.12	0.85	73.56	72.90	2.33	18	21.47	77.40	4.00	11.27
9 - Correction 3.1	61.12	0.85	67.93	72.90	2.82	18	21.47	77.40	3.84	11.27
10 - Correction 3.2	61.12	0.85	61.13	72.90	3.31	18	21.47	77.40	3.65	11.27
11 - Correction 3.3	61.12	0.85	60.20	72.90	3.34	18	21.47	77.40	3.62	11.27

Test	Ap (m^2)	RPH	Nic	Ni	Nvc	Nv	Nac	Na	Ntc	Nt
12 - Correction 4	61.12	0.85	57.54	72.90	2.82	18	21.47	77.40	3.54	11.27
13 - Correction 4.1	61.12	0.85	50.54	72.90	3.34	18	21.47	77.40	3.35	11.27

Key: Ap (m2) – Floor area in m^2; RPH – Renovations per hour; Nic – Nominal energy needed for heating; Ni – Maximum value for nominal annual energy needed for heating; Ncv - Nominal energy needed for cooling; Nv - Maximum value for nominal annual energy needed for cooling; Nac – Nominal energy needed for sanitary hot water; Na - Maximum value for nominal energy needed for sanitary hot water; Ntc – Nominal overall primary energy needs; Nt - Maximum value for nominal overall primary energy;

7. Discussion of results / conclusions

On the basis of the results of the 2 studies, the following conclusions may be drawn:

- The buildings which were tested have very low comfort levels, presenting high values for nominal energy needed for heating (Nic) and nominal energy needed for sanitary hot water (Nac);

- The existing properties and those renovated whilst maintaining the constructional system (Study 2) responded better, from a thermal, energy and environmental point of view, than the properties in which the facades and walls were maintained but the constructional system was altered (Study 1);

- The most advantageous water heating system is the one that uses gas as a source of energy, is the most cost effective and uses solar collectors as a support;

- It is possible for buildings in the historic centre of Coimbra to comply with thermal regulations by using various processes, methodologies and levels of intervention. Methods should be chosen on an individual case basis, in accordance with the budget available, the level of intervention required and the desired thermal and energy performance;

- Thermal correction which involves replacing frames by other, better-sealed ones with low emission double panes does not, in itself, meet the thermal regulation requirements. Moreover, if thermal correction is applied to the surrounding walls, floors and coverings whilst preserving the frames, it is possible to comply with these requirements;

- The installation of ventilation grids with self-regulating openings is a very important corrective measure, as it controls damp, prevents condensation and the appearance of pathologies, and reduces overall energy needs (Ntc) and heating needs (Nic) and, although the values for cooling needs (Nvc) rose, they were still insignificant in terms of the values stipulated in the thermal regulations;

- From a comparison and analysis of the base values and those resulting from the corrections that were introduced it may be concluded that, if care is taken, light intervention introducing improvements within the range of restrictions affecting comfort and energy consumption can produce good results from a thermal point of view and a considerable reduction in consumption;

- The alterations introduced in order to comply with minimum requirements fell considerably short of thermal regulation requirements;
- •The inertia of the properties remained high even when thermal correction was applied to the inside of all the exterior walls;
- It is difficult to make value judgements on which of the tests were most advantageous, although the most balanced studies in terms of cost effectiveness appear to be Test 4 (Study 1) and Test 6 (Study 2), if the intention is not to replace the frames. If a higher level of intervention is intended, Test 9 (Study 1) and Test 11 (Study 2) are best.

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