Energy and Buildings 62 (2013) 648–659

Contents lists available at SciVerse ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Sustainable restoration of traditional building systems in the historical centre of Sevilla (Spain)

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ARTICLE INFO

Article history:
Received 25 April 2012
Accepted 13 May 2012

Keywords:
Sustainable restoration
Traditional building systems
Revitalizing and conserving historical city centres

ABSTRACT

This study applies eco-efficiency and sustainability criteria to the restoration of a building, as an alternative to strict compliance with planning rules in this field.

The house we have studied dates from the 18th to 19th century and is located in the historical centre of the city of Sevilla, Spain. The main aim is to compare two different restoration plans from an eco-efficiency and sustainability perspective. We also assess the use of recently revived traditional construction systems for this type of building as a means to increase sustainability.

The results from the energy survey carried out in compliance with state building regulations show that a restoration project must be seen as an opportunity to make use of traditional construction systems as a tool for revitalizing and conserving historical city centres, and for promoting a new building model with sustainability as the centrepiece of architectural restoration.

1. Introduction

The idea behind "sustainable construction" is to minimize energy costs in the construction and maintenance of buildings. In its lifetime, a building will consume between 20 and 50% of the physical resources in its environment [1]. This fact, together with today's ecological pressures, requires a new approach to building, such that government agencies are moving rapidly to impose new mandatory standards [2] on energy efficiency for both new buildings and those under restoration.

Energy consumption is quantified as the energy used in the construction of the building and the maintenance required during the useful life of that edifice [3]. Energy saving in construction consists of:

- Reducing energy consumption during maintenance, by means of improving the insulation system of the building's envelope, which in turn will also cut cooling and heating costs.
- Reducing energy consumption during construction by using materials with a low-energy cost, such as recycled or recyclable materials, to guarantee the sustainability of the building.

Various authors have studied the effects of replacing certain materials with energy-sustainable materials in construction. Scheuer et al. [4] analysed the steel beams used for the roof at Oslo Airport and concluded that the energy cost for their construction was twice or three times higher than that for laminated timber beams, with fuel consumption 6–12 times higher. Buchanan [5] suggested that an increase in the use of wood as construction material could have a positive effect on global energy demand and the reduction of CO_2 emissions. Other research involving buildings in The Netherlands [6] show that greater use of wood in building construction could cut CO_2 emissions by 50% compared to traditional building materials.

The use of recycled or recyclable materials is a relatively new concept that aims to cut down on energy costs and maintain a building's energy balance in the long term. A Japanese study by Gao et al. [7] of energy saving in the construction phase of three buildings showed that energy consumption dropped by 25% when recycled materials were used. A similar study by Swedish investigators [8] modelled the construction of a house made almost exclusively with recycled materials against a similar residence built entirely with new materials. The results showed a 40% energy saving.

2. Objectives

This paper compares two restoration projects for a residential building in the historical city centre of Sevilla (Spain). Firstly, we analyse the developer's project, which follows current architectural methodology and complies with building regulations and budget limits. Then we present an alternative project that uses low-cost and recycled/recyclable materials to create a building with

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http://dx.doi.org/10.1016/j.enbuild.2012.05.009

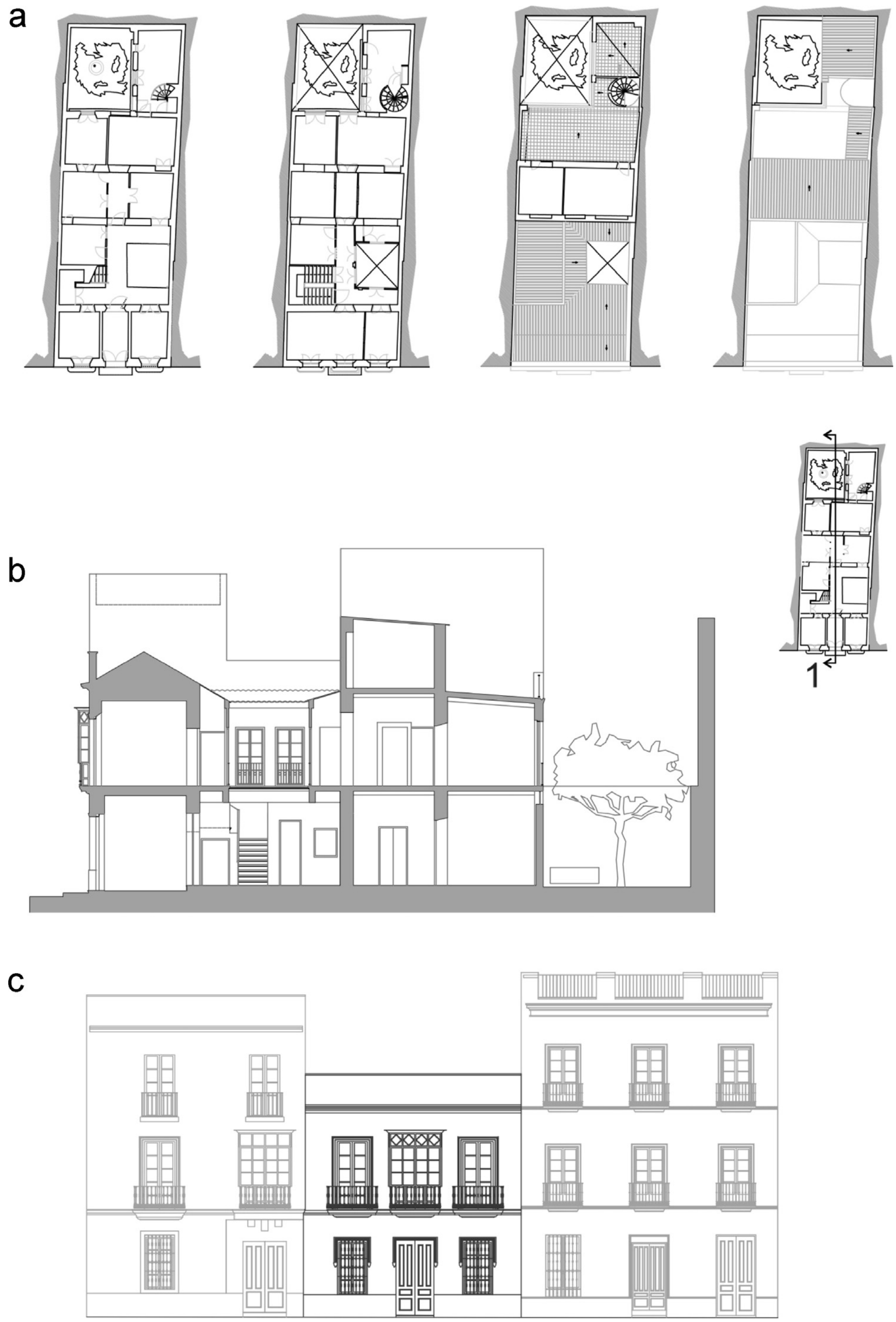


Fig. 1. Model A. (a) Plans, (b) Section 1 and (c) elevation.

an energy balance, with an energy efficiency that will reduce the building's power consumption during its lifetime.

3. The study

This work forms part of the research project *Interventions in Historical Buildings*, be they classified as monuments or not, and the processes of adapting these edifices to a sustainably developed cultural and economic reality.

This study focuses on residential buildings in the historical city centre of Sevilla [9], in particular a single-family house on two floors which is a typical example of the architecture of houses constructed in the 18th and 19th centuries in the city.

These types of buildings have been, and still are, undergoing restoration in a process of adaptation to a new social and cultural reality in the city.

3.1. Analysis of the original building (Model A)

It was originally a two-storey house, with five supporting walls and two patios (Fig. 1a and b), both traditional features of residential architecture in Sevilla in the 18th and 19th centuries, with

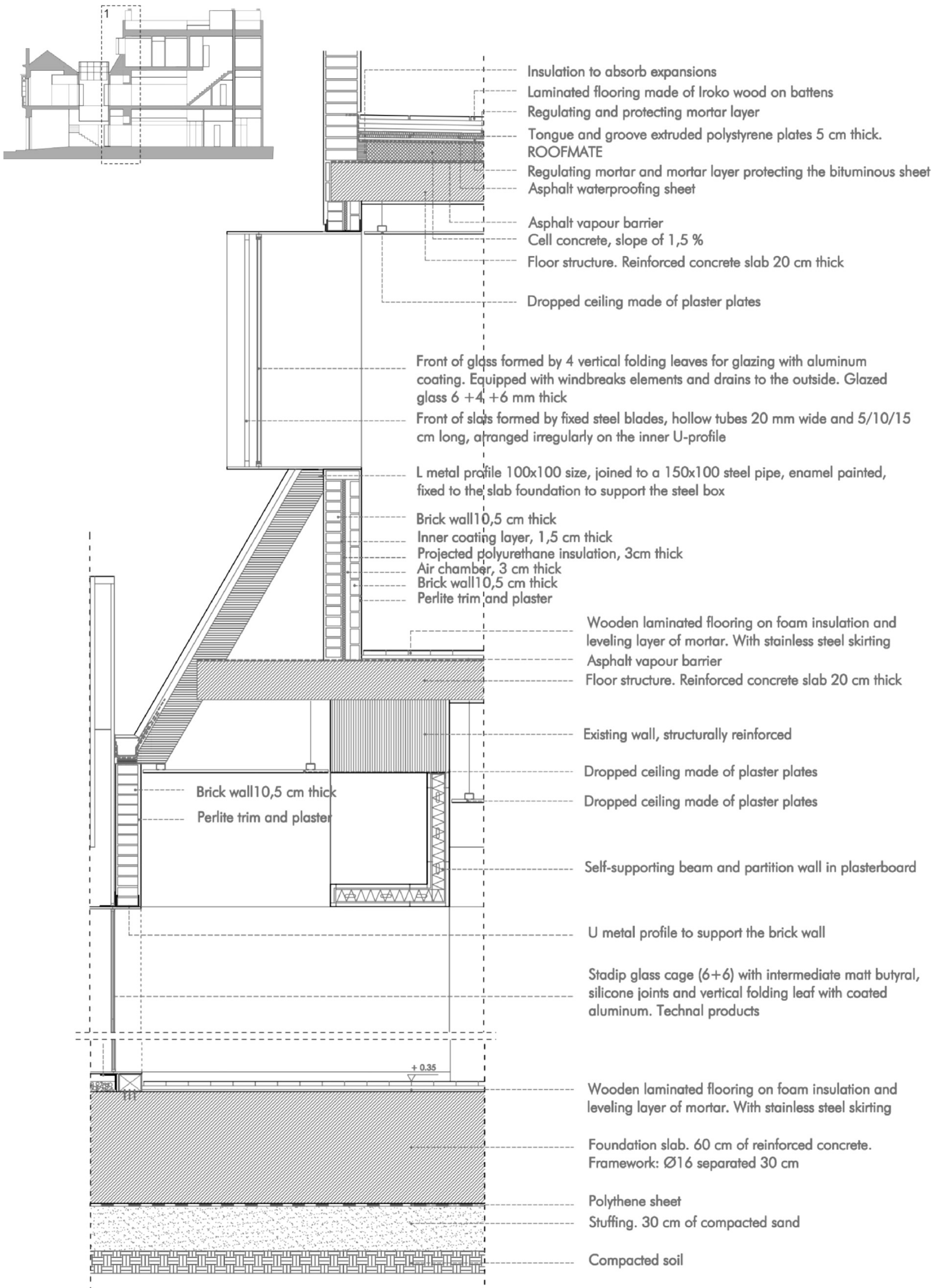


Fig. 2. Construction Section 1, Model B.

Fig. 3. Model B. (a) Plans, (b) Section 1, (c) Section 2 and (d) elevation.

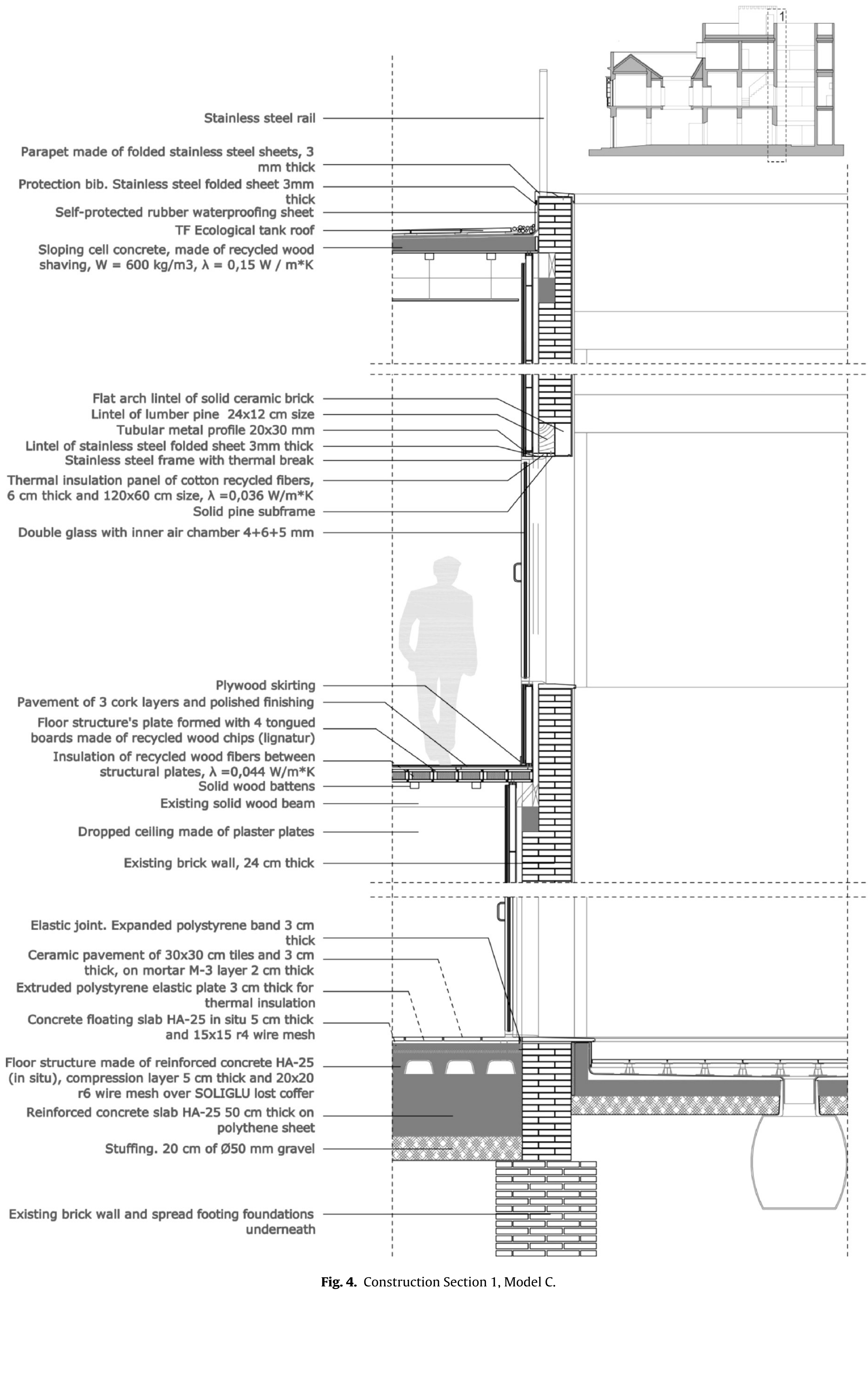


Fig. 4. Construction Section 1, Model C.

Table 1
Study of materials.

Material	Recycled	Recyclable	Impact on production	Transport	Solid waste generation	Lifespan
Metal						
Recycled glass railing	Yes	Yes	Low	National	None	Long
Recycled copper sheet	Yes	Yes	Low	Local	Low	Long
Aluminium frames	No	Yes	Medium	Local	None	Long
Reused wooden frames	No	No	None	None	None	Medium
Waterproof material						
EP honeycomb expand sheet	No	Yes	Medium	National	Low	Long
PE recycled sheet	Yes	Yes	Medium	National	Low	Long
Resin injection moulding	No	No	High	Local	Medium	Long
Concrete						
c. lighten with recycled EPS	Yes	Yes	Low	National	None	Long
Soliglú system	Yes	No	Medium	National	None	Long
Ytong porous concrete	No	Yes	Low	National	None	Long
Insulation materials						
Recycled wood grain	Yes	Yes	Low	National	Medium	Long
Cotton grain	Yes	Yes	Low	National	Medium	Long
Cork	Yes	Yes	Low	National	Medium	Long
EPS panels	No	Yes	Medium	Local	Low	Long
Wood						
Recycled tetra brik panels	Yes	Yes	Low	National	Medium	Medium
From sustainable woods	No	Yes	None	National	Medium	Long
Lignatur system	No	Yes	Low	International	Low	Long
Coating						
Naturfloor bamboo pavement	No	Yes	Low	National	None	Long
Plaster ceiling with secondary structure	No	No	High	Local	High	Medium
Reused 30 × 30 ceramic tile pavement	No	No	None	None	None	Medium
Recycled plastic tiles	Yes	Yes	Medium	National	Low	Long
Reused roof tiles	No	No	None	None	None	Long
Thermochip sandwich panel (plaster–cork–plaster)	No	No	Medium	Local	Low	Long
Aislacork	No	No	Low	Local	None	Medium
Other						
Aluminium blind box	No	Yes	Medium	Local	None	Long
Recycled concrete gravel	Yes	Yes	Low	National	None	Long
Biogas bricks	No	Yes	None	National	Medium	Long
Zinc green roof	Yes	Yes	Medium	National	Medium	Long
EPS joint treatment	No	Yes	High	Local	Low	Long

the house built around a main patio, with load-bearing walls made of brick and limestone mortar. The narrow facade adjoins two restored buildings each with three floors (Fig. 1c).

A survey of the building found that:

- The walls were made of two rows of bricks with limestone mortar, with a 2-cm overlay of limestone mortar above and below. The original walls were in good condition, with a flat-jack tested compressive strength of 0.85 N/mm^2.
  The facade has serious rising damp.
  The framework varied in condition depending on the storey. There were three different structures:
- The first floor framework consisted of 13 cm × 20 cm wooden beams with an offset to support a curved ceramic piece that forms the arches, an alcatifa filling, brick and hydraulic pavement with an undercoating of limestone mortar.
- The flat roof framework was made of wooden beams measuring 11 cm × 20 cm, with a wooden bandlet, solid brick, filling, auxiliary paving and finished with pressed ceramic tile.
- The sloping roof structure had wooden boards and tiling with corrugated fibrocement sheets.

These frameworks were found to be in excellent condition following ultrasound testing [10] except for the flat roof structure where the beam heads had been damaged by damp and xylophagous insects.

3.2. Analysis of the constructed restoration model (Model B). Compliance with regulations: materials and building systems used

The PGOU-2004 [11] town planning regulations were in force in Sevilla when the restoration plans were drawn up, which obliged the architects to preserve the facade as it was originally constructed, allowing for any necessary reinforcements and consolidation but prohibiting modifications. Spaces could not be altered without prior justification. Likewise the first supporting wall had to be retained along with its typological elements.

The current town planning legislation (PGOU-2008 [12]) underlines the public authorities' increasing interest in the conservation and restoration of city centres. However, the study of this model reveals that the typical sustainability measures to minimize a building's energy consumption and adapt it to current ecological requirements are lacking. Rather it aims to preserve a visual image of a historical centre based on facades but without taking into account other traditional elements such as wooden framework structures and brick walls. These materials are replaced by concrete and steel, which is contrary to the idea of sustainability.

In this context the project that was carried out by the developer, Model B, complied with regulations in force at the time, which converts the building into a piece of contemporary architecture in which steel and glass are the predominant aesthetic and structural materials. The main characteristics of the construction are (Fig. 2):

- *Foundations*: A concrete slab is cast as the new foundation of the building, and also acts as the ground floor pavement.
- *Structure*: The structure built on the new foundation consists of pillars and steel frameworks. Demolition and the construction of the new foundation took up more than 70% of the original surface area. The only insulation built into the frameworks on each floor is a high-density polyurethane sheet beneath the wooden flooring.
- *Envelopes*: The old dividing walls have been replaced by new ones made of bricks with a width of 11.5 cm, and the load-bearing walls

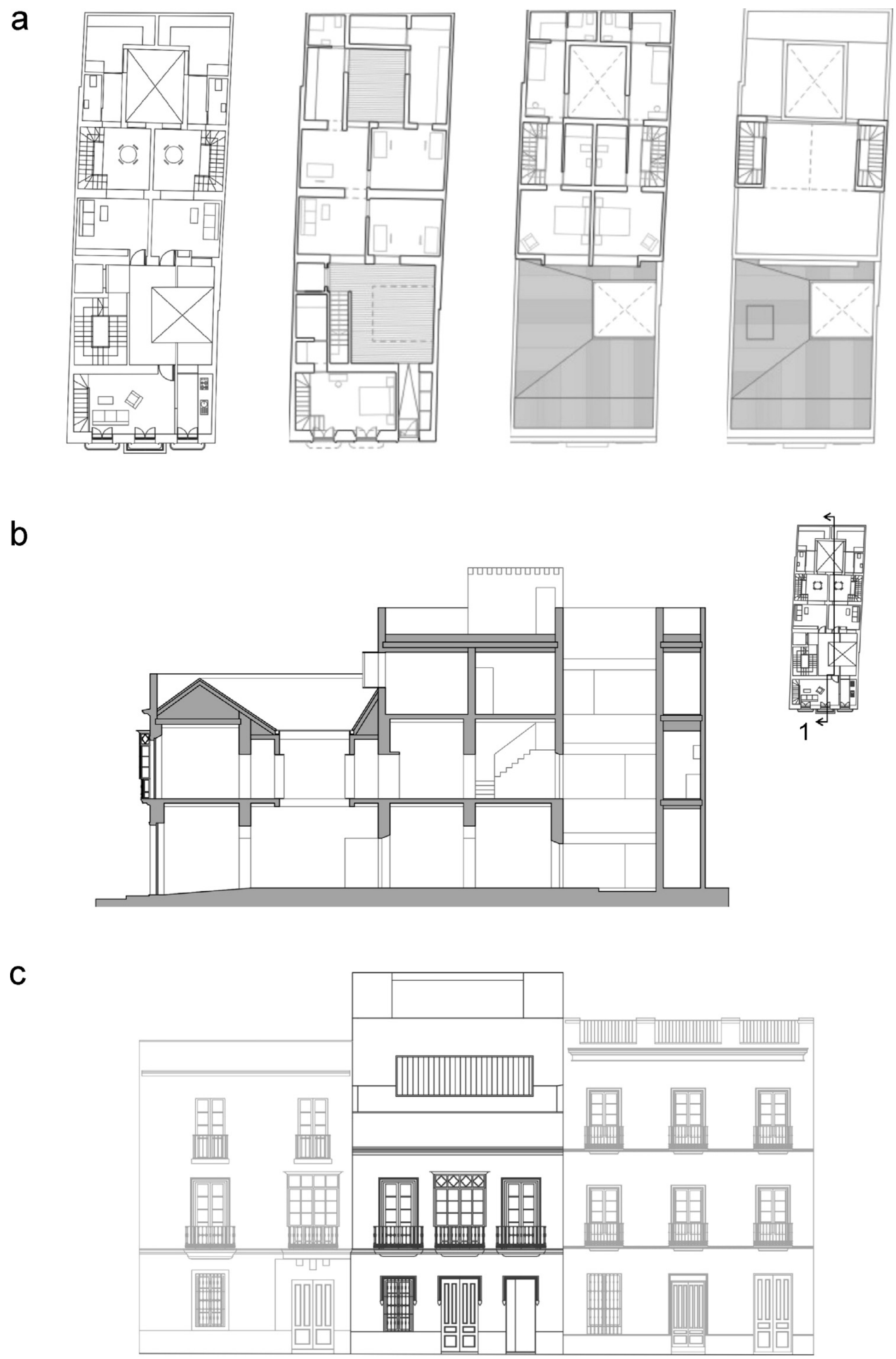


Fig. 5. Model C. (a) Plans, (b) Section 1 and (c) elevation.

with the typical envelope of cavity and partition walls, which do nothing to improve the building's overall energy efficiency.

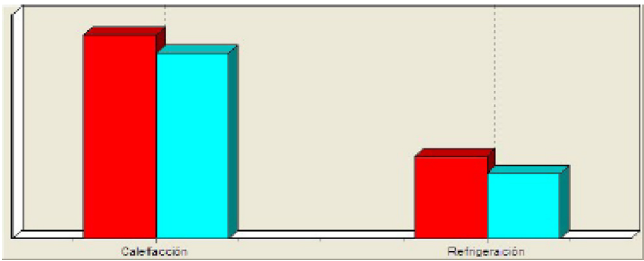
The project does not include a ventilation system to rid the facade of its rising damp.

The restoration plan adhered to the developer's requirements of three apartments each containing three bedrooms, and two offices (Fig. 3a–d). As a result, an extra floor was added, with the supporting wall maintained, as required by the regulations.

3.3. The proposed sustainable restoration model (Model C). Study of materials and construction system: proposal for materials and construction systems

As a contrast to Model B, we developed our Model C as an alternative which not only aims to comply with building regulations but also to preserve traditional construction systems and use of materials, as well as applying techniques to make the building sustainable and eco-efficient. With this in mind, we examined building materials taking into account seven sustainability parameters, such as

Table 2
Model A in accordance with standard (LIDER results).



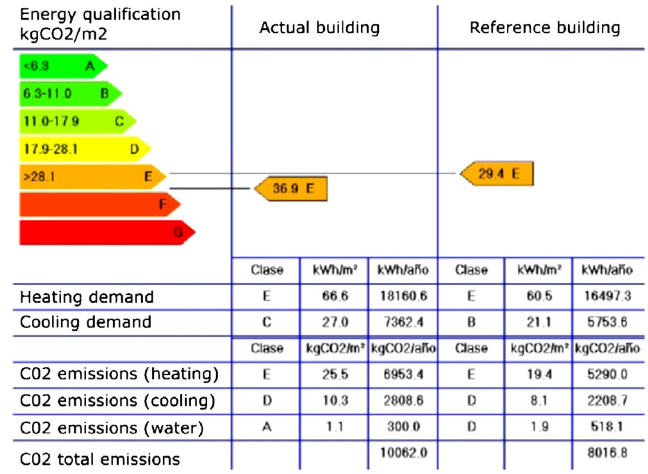
whether they are recycled, recyclable, reused, their impact on production and transport, solid waste generation during construction and building lifespan (Table 1).

Our project also includes new systems for sustainable insulation and use of rain water, and a study of sunlight exposure and ventilation, etc., to minimize the building's energy consumption.

The study makes the following proposals (Fig. 4):

- *Demolition*: In model C, demolition is limited to some bracing walls. As a result, demolition is reduced from 71% in Model B to 12% in Model C, meaning a 59% saving in waste, labour, budgetary and environmental costs.
- *Foundations*: Model C proposes a ventilated floor structure set on the concrete slab foundation based on recycled PVC panels. This will eliminate the rising damp at the base of the old brick walls by means of a cross-ventilation system which will be wind-powered via shafts on the roof.

Table 6
Model A energy qualification values obtained from CALENER VYP.



Energy qualification kgCO2/m2	Actual building			Reference building		
	Clase	kWh/m²	kWh/año	Clase	kWh/m²	kWh/año
Heating demand	E	66.6	18160.6	E	60.5	16497.3
Cooling demand	C	27.0	7362.4	B	21.1	5753.6
	Clase	kgCO2/m²	kgCO2/año	Clase	kgCO2/m²	kgCO2/año
C02 emissions (heating)	E	25.5	6953.4	E	19.4	5290.0
C02 emissions (cooling)	D	10.3	2808.6	D	8.1	2208.7
C02 emissions (water)	A	1.1	300.0	D	1.9	518.1
C02 total emissions			10062.0			8016.8

- *Frameworks*: the floor structure is to be made of wood set on wooden beams with wooden grooved and tongued boarding and interior rigidizer squares and holes filled with recycled wood fibres, which make an ideal acoustic and thermal insulation.
- *Building envelope*: The existing woodwork should be preserved after treatment.

Materials that are expensive to produce like steel, reinforced concrete and glass are replaced by cheaper alternatives. Steel is

Table 3
Model A, compliance with CTE-DB-HE 1 requirements in *U*-values (climatic zone, B4).

	U_{max} (W/(m^2 K)) CTE-DB-HE 1 (climatic zone B4)	*U* obtained (W/(m^2 K))	Conclusions
Supporting exterior walls made of solid bricks	1.07	1.28–1.47	Ok as from 70 to 75 cm thickness
Supporting exterior walls made of 24 cm bricks	1.07	1.76	Extra insulation needed
Dividing walls made of solid bricks	1.07	2.34	Extra insulation needed
Flat roof	0.59	2.16	Extra insulation needed
Pitched roof	0.59	0.59	Ok
First metre of ground floor less than 0.50 m deep	1.07	2.27	Extra insulation needed
Interior horizontal partition in contact with a uninhabitable room	1.07	–	–
Glass	5.70	2.60	Ok
Frames	5.70	2.60	Ok

Table 4
Model A locations with higher heating demand.

Ref.	% higher than reference *U*-value	Location	Cause
P01-E01	108.2	Back patio enlargement	Insufficient insulation
P01-E03	96.1	Room between fourth and fifth supporting walls, next to the patio	Lack of direct sunlight
P02-E01	183.8	Back room enlargement	Insufficient insulation
P02-E02	186.2	Room between fourth and fifth supporting walls	Lack of direct sunlight
P02-E03	187.6	Room between fourth and fifth supporting walls	Lack of direct sunlight
P02-E06	112.6	Room between second and third supporting walls, next to the patio	Insufficient insulation
P03-E01	173.8	Tower	Insufficient insulation

Table 5
Model A locations with higher cooling demand.

Ref.	% higher than reference *U*-value	Location	Cause
P01-E08	206	Room between second and third supporting walls, next to the patio	Insufficient insulation
P01-E010	193	Hall	Inadequate insulation and facing east
P02-E01	159.1	Back patio enlargement	Insufficient insulation
P02-E04	160.5	Room between second and third supporting walls, next to the patio	Insufficient insulation
P02-E06	293.7	Room between second and third supporting walls, next to the patio	Insufficient insulation
P03-E01	160.4	Tower	Insufficient insulation

Table 7
Model B compliance with CTE-DB-HE 1 requirements in *U*-values (climatic zone B4).

Element	U_{max} (W/(m^2 K)) CTE-DB-HE 1 (climatic zone B4)	*U* obtained (W/(m^2 K))	Conclusions
Exterior walls made of two rows of bricks and insulating material between them	1.07	0.66	Ok
Supporting exterior walls conserved, made of solid bricks	1.07	1.28–1.47	Ok above 70–75 cm thickness
Dividing walls made of perforated bricks and inner coating	1.07	2.35	Extra insulation needed
Flat roof	0.59	0.30	Ok
Pitched roof	0.59	0.91	Extra insulation needed
First metre of the ground floor less than 0.50 m deep (concrete slab and wood or marble coating floor)	1.07	1.45 wood 2.06 marble	Extra insulation needed
Partition wall in contact with an uninhabitable room (brick wall 11.5 cm wide and coating)	1.07	1.96	Extra insulation needed
Interior floor structure in contact with a uninhabitable room (one-directional roof structure, ceiling and wood floor)	1.07	1.04	Ok
Double glass (4-6-4)	5.70	3.00	Ok
Frames	5.70	5.70 aluminium 2.00 wood	Ok

Table 8
Model B in accordance with standard (LIDER results).

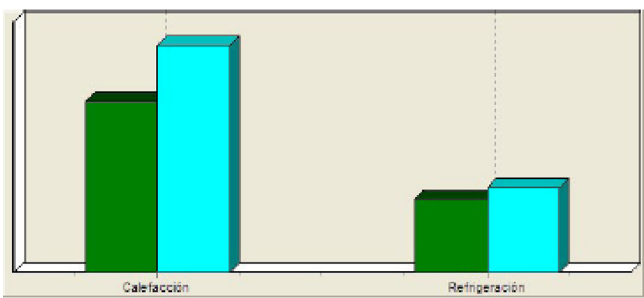


Table 9
Model B locations with higher heating demand.

Ref.	% higher than reference *U*-value	Location	Cause
P02-E06	101.2	Right-side apartment at the bottom of the building	Insufficient insulation in partition wall, and contact with unused covered, ventilated patio
P02-E01	98.3	First supporting wall on first floor	Lack of insulation in the roof

substituted for aluminium and recycled copper when not required for the support structure.

This project is also innovative in its use of the rear patio for collecting rain water for reuse within the building. The water flows under the raised pavement to an underground tank. The design of the roofs on the fourth and fifth supporting walls has also been altered to act as cisterns.

Table 10
Model B locations with higher cooling demand.

Ref.	% higher than reference *U*-value	Location	Cause
P02-E01	105.3	First supporting wall on first floor	Lack of insulation in roof, west facing
P02-E06	114.9	Right-side apartment at the bottom of the building	Insufficient insulation in partition wall, and contact with unused covered, ventilated patio

The Model C design includes the developer's three individual properties and two offices to dimensions very similar to those actually built (Fig. 5a–c).

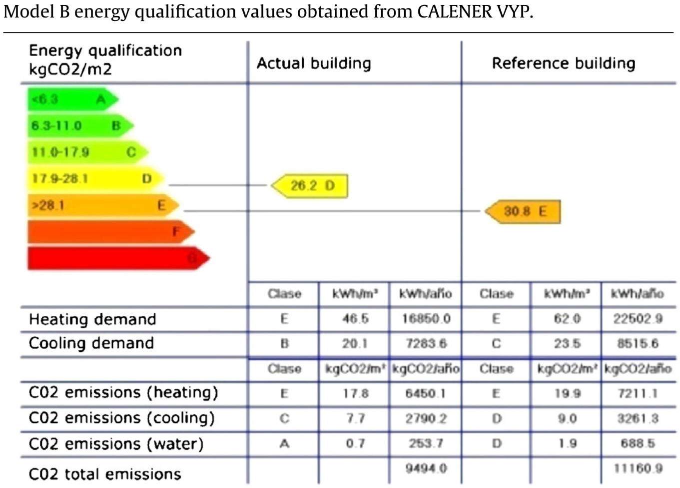
4. Results

In order to evaluate the construction solutions of Models B and C, and the energy efficiency proposals put forward in this study, we analysed all three models (Model A – the original building; Model B – the building materials and systems used in the intervention; Model C – the alternative proposed by this research) according to the CTE-HE-1 [13] state regulation, with the use of official computer applications such as LIDER [14] and CALENER VYP [15].

The analysis was carried out in two phases:

- Analysis of cooling and heating requirements based on a building model of similar characteristics provided by LIDER, which is also adjusted to the planning regulations in force.
- Analysis, using CALENER VYP, of the building's energy qualification as provided by the kg CO_2/m^2 indicator. This quantifies CO_2 emissions arising from heating, cooling and water usage.

Table 11
Model B energy qualification values obtained from CALENER VYP.

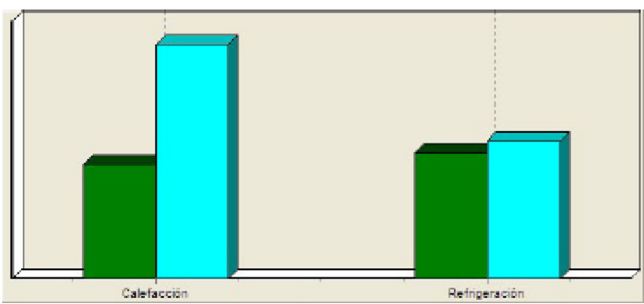


	Actual building			Reference building		
	Clase	kWh/m²	kWh/año	Clase	kWh/m²	kWh/año
Heating demand	E	46.5	16850.0	E	62.0	22502.9
Cooling demand	B	20.1	7283.6	C	23.5	8515.6
	Clase	kgCO2/m²	kgCO2/año	Clase	kgCO2/m²	kgCO2/año
C02 emissions (heating)	E	17.8	6450.1	E	19.9	7211.1
C02 emissions (cooling)	C	7.7	2790.2	D	9.0	3261.3
C02 emissions (water)	A	0.7	253.7	D	1.9	688.5
C02 total emissions			9494.0			11160.9

Table 12
Model C compliance with CTE-DB-HE 1 requirements in *U*-values (climatic zone B4).

Location	U_{max} (W/(m^2 K)) CTE-DB-HE 1 (climatic zone B4)	U obtained (W/(m^2 K))	Conclusions
Exterior walls (bordering the patio) made of two rows of bricks and insulating cork between them	1.07	0.94	Ok
Exterior walls made of two rows of bricks, insulating cork between them and a plaster panel as inner coating	1.07	0.49	Ok
Supporting exterior walls conserved, made of solid bricks and cork added	1.07	0.70	Ok
Dividing walls made of perforated bricks and cork insulation	1.07	0.99	Ok
Flat roof (concrete with wood aggregates and recycled cotton for insulation. Floor structure: oriented strand board)	0.59	0.20	Ok
First metre of the ground floor less than 0.50 m deep (floor structure with XPS insulation)	1.07	0.80	Ok
Partition wall in contact with an uninhabitable room (plaster panel and recycled cotton for insulation)	1.07	0.56	Ok
Interior floor structure in contact with a uninhabitable room (oriented strand board and recycled cotton for insulation, plaster ceiling and expand cork floor)	1.07	0.27	Ok
Double glass (4-12-6)	5.70	1.60	Ok
Frames	5.70	3.20 aluminium 2.20 wood	Ok

Table 13
Model C in accordance with standard (LIDER results).



4.1. Energy analysis: Model A

The energy requirements of Model A sometimes score higher than those of the reference building, specifically 10.1% higher for heating and 27.8% for cooling (Table 2).

A more detailed analysis of the transmittance values (*U*-values) shows that very few elements in the envelope satisfy the CTE-DB-HE 1 regulations (Table 3). The wooden roof of the first supporting walls scores best in terms of transmittance as a result of the thermal

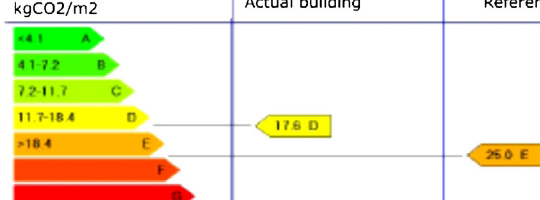
Table 14
Model C locations with higher heating demand.

Ref.	% higher than reference *U*-value	Location	Cause
P03-E01	65.7	Right-side apartment at the bottom of the building on the second floor	Due to big roof area and walls facing north
P03-E02	71.0	Left-side apartment at the bottom of the building on the second floor	Due to big roof area and walls facing north
P04-E02	72.8	Tower right apartment on the second floor	Because all the elements that border it belong to the building envelope
P01-E02	60.1	Between the facade and the following supporting wall	Due to being on the ground floor, contact with an uninhabitable patio and lack of direct sunlight

Table 15
Model C locations with higher cooling demand.

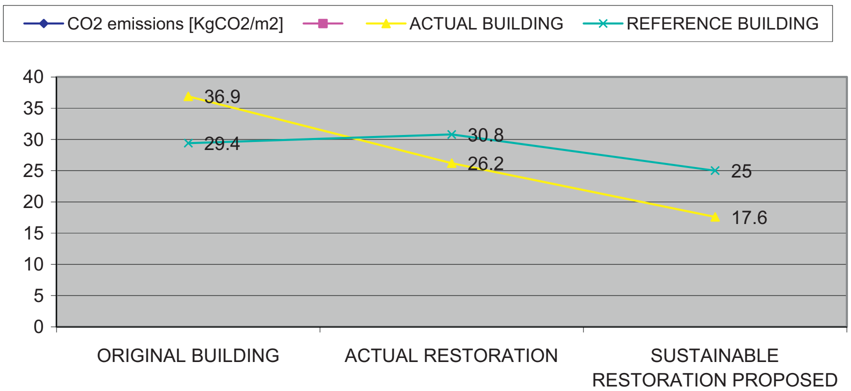
Ref.	% higher than reference *U*-value	Location	Cause
P02-E02	115.2	Kitchen between the facade and the following supporting wall on the first floor	Due to numerous windows
P02-E05	113.5	Living room of the left-side apartment at the bottom of the building on the first floor	Due to contact with the two patios
P02-E06	108.2	Living room of the left-side apartment at the bottom of the building on the first floor	Due to contact with the two patios
P04-E01	121.5	Headframe left-side apartment on the second floor	Because all the elements that border it belong to the building envelope

Table 16
Model C energy qualification values obtained from CALENER VYP.



Energy qualification kgCO2/m2	Actual building			Reference building		
	Clase	KWh/m²	KWh/año	Clase	KWh/m²	KWh/año
Heating demand	D	21.1	6602.9	E	43.4	13581.3
Cooling demand	D	23.3	7291.3	D	25.5	7979.8
	Clase	kgCO2/m²	kgCO2/año	Clase	kgCO2/m²	kgCO2/año
C02 emissions (heating)	E	8.1	2534.8	E	13.9	4349.8
C02 emissions (cooling)	E	8.9	2785.1	E	9.7	3035.5
C02 emissions (water)	A	0.6	187.8	D	1.4	438.1
C02 total emissions			5507.6			7823.3

Table 17
Comparison of CO_2 emission evolution in the reference building and each case analysed.



resistance from the partially ventilated air shaft which is the space under the roof.

An analysis of the different parts of the building revealed that the biggest heat loss in winter was in the supporting walls at the bottom of the property (Tables 4 and 5). Here extensions have been built due to clogging in the patios, which are insufficiently insulated and reduce exposure to sunlight. The biggest heat gains in summer were recorded in the patio of the second supporting wall. This is covered by a glass roof with very little heat resistance, so it becomes a semi-outdoor space with almost no ventilation, creating a kind of greenhouse effect due to the direct capture of sunlight via convection.

For energy classification, Model A is a type E with a kg CO_2/m^2 indicator of 36.9 against 29.4 for the reference building (Table 6).

4.2. Energy analysis: Model B

The energy analysis of Model B reveals that there are elements which do not comply with DB-HE-1 requirements regarding the building envelope (Table 7).

Despite some of the elements of the building envelope falling short of insulation standards, Model B global energy demand is in line with CTE limits, with 25% less heating and 14.5% less cooling required than in Model A, which were 10.1% and 27.8% higher respectively (Table 8).

The areas with greatest energy demand both in terms of heat loss and heat gain are found in the apartment built on the first supporting wall on the first floor, and in rooms at the bottom of the building divided by partition walls. This is due to insufficient insulation of some elements that form part of their envelope (Tables 9 and 10).

Model B's energy classification is type D, with a kg CO_2/m^2 indicator of 26.2, 14.9% less than the reference building's value. Model A's energy requirements were greater than the reference building's, which scored a type E. We observe that this parameter is significantly improved (Table 11).

Model B is very similar to the original building. In fact, it only differs in better cooling due to greater insulation of the thermal envelope. The compactness of the building in its original state and after restoration are similar as a result of urban planning requirements that oblige volume and free spaces to be retained in similar fashion to the original configuration of the building.

4.3. Energy study: Model C

The final part of this research looks at the proposed sustainable building Model C and its energy values.

The analysis of the thermal envelope shows that Model C easily complies with all the transmittance stipulations in the CTE-DB-HE 1 Technical Building Code for energy requirements (Table 12), unlike the two other models.

Furthermore, Model C's global energy demand is also within CTE limits. Heating demand is only 48.8% of the reference building's, as opposed to 110.1% in Model A and 75% in Model B. The demand for refrigeration is 91.6% for the reference building, compared to 127.8% for Model A and 85.3% for Model B (Table 13).

The analysis of energy demands shows that the greatest demand for both heating and cooling is in those rooms whose walls and roofs form part of the building envelope. The demand for heating is not related to insufficient or lack of insulation (as in Models A and B) but due to orientation and subsequent lack of direct sunlight (Table 14).

The areas requiring most cooling are in rooms where the adjoining building is broadest and where the windows are exposed to greater sunlight. Demand for cooling is also high in a non-ventilated covered patio on the second supporting wall due to heat gain by thermal capture and convection that cause a kind of greenhouse effect. This is unavoidable because this kind of glass roof is under heritage protection and cannot be altered (Table 15).

The energy efficiency study classifies this building as a type D with a kg CO_2/m^2 indicator of 17.8, 28.8% lower than that of the reference building (Table 16).

The graph below shows the evolution of CO_2 emissions in the three models (Table 17). The Model C design yields a reduction of 51.7% compared to Model A and 32% to Model B.

5. Conclusions

We have carried out an analysis of the energy cost of two different projects for the restoration of a residential building, and the conclusions are:

- The sustainable restoration project proposed is significantly better in terms of heat loss in winter and cooling in summer.
- The passive solutions in this proposal such as a good design for the building envelope, suitable positioning of the windows, a good orientation plan and ventilation system, can all help to balance the energy demand throughout the year. This energy efficient design can reduce CO_2 emissions by more than 50% during the useful life of the building compared to the original structure and is 30% more efficient than the restoration achieved in Model B.
- A quantitative study was not carried out, but the use of recycled materials or materials with a lower energy production cost can cut energy costs during construction when compared to projects that are not eco-efficient.

Apart from the advantages gained from sustainability and eco-efficiency, this type of project also contributes to the restoration of buildings that adhere to traditional materials and construction systems.

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