Comparative analysis of constructive solutions for thermal insulation by using computer applications in building rehabilitation in Mediterranean climate. The Spanish case

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ABSTRACT:
The new Spanish legislation in Energy Saving, similar to European regulation, provides new technical requirements to adequate technical solutions used in integral rehabilitation of existing buildings.

The aim of this paper is to present, analyze and discuss the main thermal insulation constructive solutions best suited to a Mediterranean climate, and conclude on their suitability under the legislation in Energy Saving.

The proposed methodology is based on the most usual constructive solutions in integral rehabilitation of buildings by analyzing their outstanding design features, by studying its construction details and then by applying the software provided by the Spanish legislation of energy efficiency in buildings.

The results of the study evaluate and classify several solutions for façade rehabilitation according to energy efficiency criteria and their suitability for this type of weather, verifying the necessity of using software applications in energy saving for the proper design of constructive solutions in building rehabilitation.

1INTRODUCTION

The new Spanish and European Energy Efficiency regulations represent a significant increase of thermal insulation requirements in new buildings and rehabilitation projects of the built heritage.

With the new software provided by the official government agencies, it can be increased the accuracy of calculations and dimensioning of insulation systems by considering not only the materials and building systems to be used or the type of climate but also the volumetric characteristics of the building and its orientation.

It is therefore appropriate to analyze how different building typologies and constructive characteristics of each period can have a significant bearing on the rehabilitation techniques used considering the new legal requirements and social demand for increasing the energy efficiency of existing buildings.

It is proposed a comparative study of different constructive solutions used in building rehabilitation to improve thermal insulation, through the application of computer tools mandatory in Spain. The investigation focuses on a series of representative type projects located in Mediterranean climate, classified according to the main constructive and volumetric characteristics of the architectural styles more developed during the twentieth century in Spain, whose buildings are currently under rehabilitation.

The significance of the study is to analyze and discuss the suitability of different technical solutions to improve thermal insulation according to the period and characteristics of the built heritage subjected to rehabilitation.

2MATERIALS AND METHODS

A comparison between different thermal insulation constructive solutions used in rehabilitation is proposed, calculating their energy efficiency in type projects located in different climatic zones of the Spanish Mediterranean coast, through the official version of the software of reference in Spain called LIDER (LImiting EneRgy Demand), which is considered to be an "Accepted Document" (Documento Reconocido) published by the Ministry of Housing of the Government of Spain.

2.1*Type of climate analyzed*

The designation of Mediterranean climate in Spain is applied to the strip of land between the northeast from Gerona to Almeria´s bay, since they share certain characteristics such as:
- Low and intense rainfall, mainly in fall, causing extended periods of summer drought.
- Annual average high temperatures ranging between 15°-18° C, with mild winters between 10°-12° C and summers exceeding 22° C.

Within this type of Mediterranean climate we can distinguish three zones: zones with a soft Mediterranean climate, dry Mediterranean climate and sub-desert or arid Mediterranean climate.

2.1.1.*Soft Mediterranean climate (Catalonia)*

It is characteristic of buildings in Barcelona. It is the most humid Mediterranean climate in Spain with rainfall exceeding 600 mm/year, rare times of drought, and a maximum rainfall in autumn and spring, coinciding with the dominance of westerly winds. It is characterized by mild winters and hot summers with a variation of about 15º C.

Snow episodes can be registered in winter, with at least 1 day of snow in a year on the coast and up to 10 in the inner margins and mid-mountain climate of this area.

2.1.2. *Dry Mediterranean climate (north and center of Valencian Community and Baleares Islands)*

It is characteristic of buildings in Valencia, with few, intense and irregularly distributed rainfall, decreasing from north to south and below 500 mm/year. The maximum rainfall is in autumn and spring, and in this case, no month suffer total drought as it happens further south.
The temperatures, which increase from north to south, have an annual average around 16-17° C, with mild winters of 10º C and long summers very dry and hot, with highs around 25º C.

2.1.3. *Arid or sub-desert Mediterranean climate (south of Valencian Community, Murcia and Almeria provinces)*

It is characteristic of buildings in Almeria and corresponds to the driest part of the Iberian peninsula and the entire European continent, with rainfall below the average of the Sahara as a whole.

The temperatures are very mild in winter, between 10°-13° C, and summers are long, dry and very hot with maximum temperatures over 30º C exceeding 40º C in situations of heat waves.

The rainfall is very low, ranging between 200 and 400 mm, and typically occur in the transitional seasons (autumn and spring).

2.2*Building typology analyzed*

2.2.1.*Eclecticism*

Nineteenth and early twentieth century projects respond to an eclectic aesthetic of historicist character that feeds on the past solutions as a mixture of different historical styles.

It was used in almost any architectural style as urban extensions, domestic and industrial architecture, but materialized with special intensity in institutional and municipal public buildings, ministries, hospitals, markets and stations, since many of the eclectic architects were municipal architects who gave a unitary character of the local architecture in which they worked.

The enclosures of the buildings of this period usually consisted of a layer of lime plaster of 3 cm (1), limestone wall of 50 cm (2) and plaster of 1.5 cm (3). In some buildings, the stone wall cladding was replaced for solid brick wall on the upper floors.

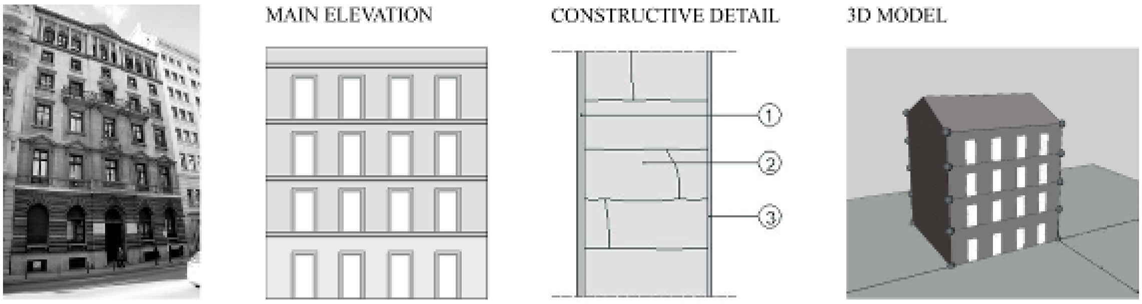


Figure 1. Barcelona.1931-32. Casal del Metge. Via Laietana, 31. Architects: Adolf Florensa & Enric Catá.

2.2.2.*Rationalism*

Later, in the 30s, architectural rationalism emerges, characterized by an architecture with more simplicity, stripped of ornamentation, without commitment to academic or historical past and with a strictly functional basis.

It is a decorative architecture without ornament, with material sincerity, pure geometries and a desire for simplicity, betting on western modernity.

The enclosures of the buildings of this period usually consisted of a layer of lime plaster of 2 cm (1), solid brick wall of 30 cm (2) and plaster of 1 cm (3).

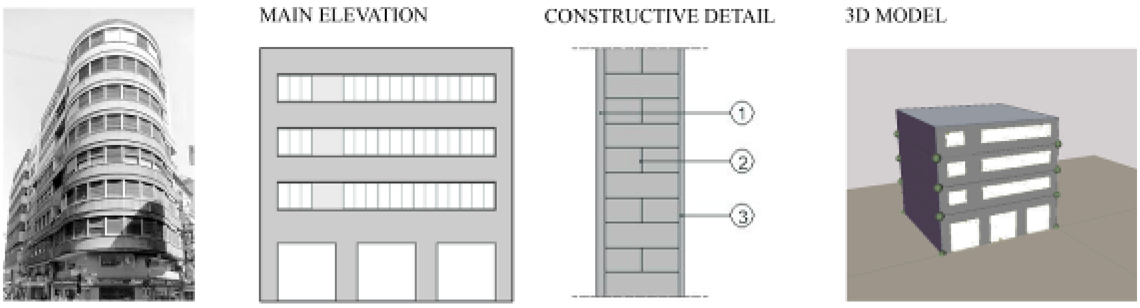


Figure 2. Alicante. 1935. Roig Building. C/ Coronel Chapulí, 3. Architect: Miguel López González.

2.2.3.*Neotraditionalism*

After the Spanish Civil War and World War II, many architects are exiled and those who remain abandon the progressist line. A regionalist traditionalism architecture appears, an exaltation of rural forms based on a return to the languages in the twenties. It is necessary to solve urgently the housing shortage caused by the destruction of the Civil War, which drives to a policy of cheap houses.

The official pomposity remains for the show of power, while for the household sector it will attend a regional approach, with practical and inexpensive materials.

The enclosures of the buildings of this period usually consisted of a layer of lime plaster of 2 cm (1), solid brick wall of 30 cm (2) and plaster of 1 cm (3).

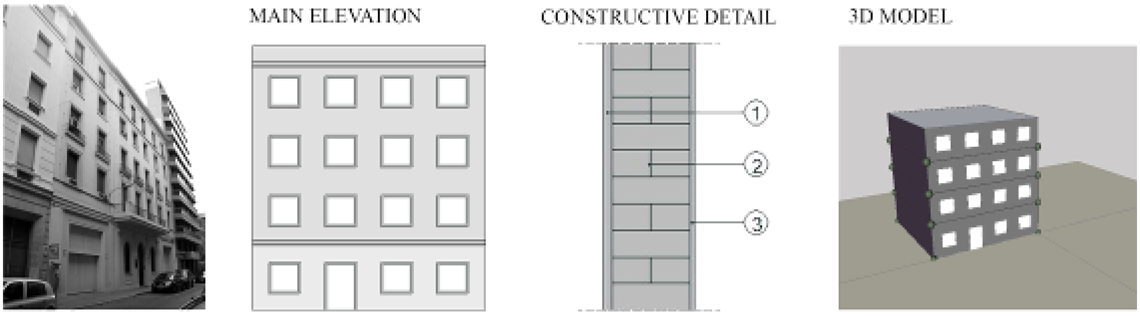


Figure 3. Alicante.1965. Cámara Agraria Provincial de Alicante. C/ Pintor Lorenzo Casanova, 4.

2.2.4.*60-70 Years*

During these years, architects who were betting on the continuity of rationalism coexist with others who bet on alternatives to the "International Style", which spread globally talking about the form and function.

It coincides with rising living standards and purchasing power of the population of Spain, allowing the possession of a second temporary residence, and increasing the demand of tourist accommodation in coastal areas.

The enclosures of the buildings of this period usually consisted of a layer of brick wall of 14 cm (1), air camera of 10 cm thick (2), hollow brick wall between 4 and 7 cm (3) and plaster of 1 cm (4). The brick enclosure used at this time was mostly facing brick.

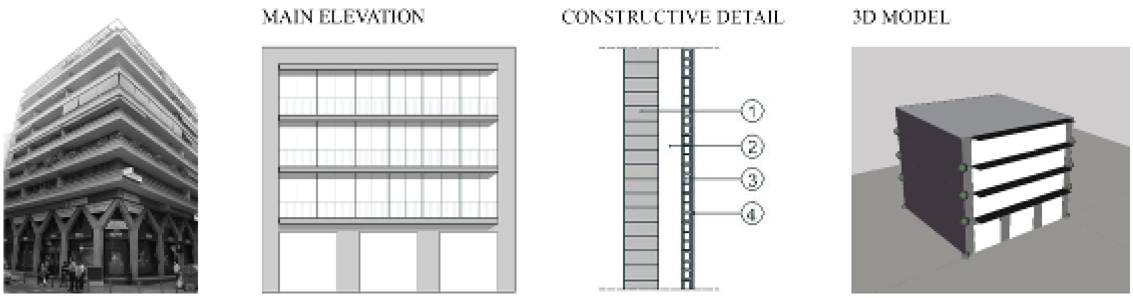


Figure 4. Alicante.1965. Housing Building. C/ Reyes Católicos. Architect: Juan Guardiola Gaya.

3RESULTS AND DISCUSSION

3.1*Results*

The results obtained, calculated for different climatic variations of the Mediterranean climate in Spain, help verify the need to improve the energy efficiency of the built heritage analyzed, but also show the different heating and cooling needs of the building types studied, according to their architectural typology and orientation

3.1.1 *South-North facing*

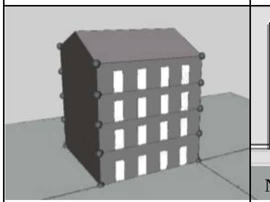
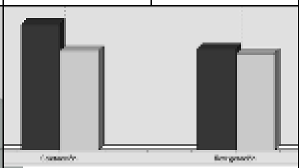
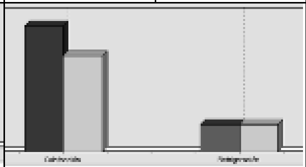
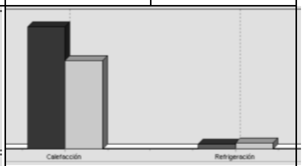
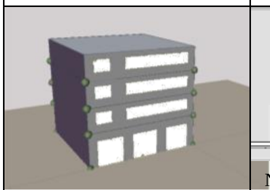
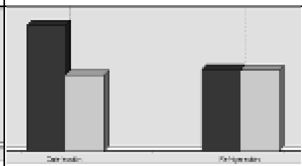
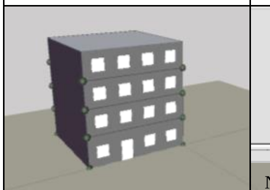
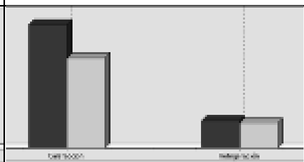
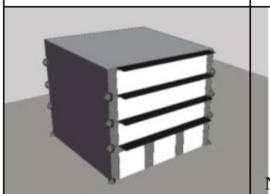
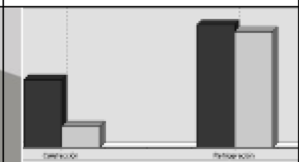
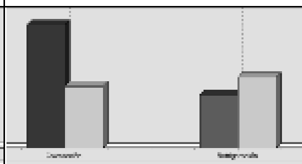
3D MODEL	**ALMERIA**		**VALENCIA**		**BARCELONA**	
	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING
 ECLECTICISM	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	COMPLY	 NOT COMPLY	COMPLY
 RATIONALISM	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	COMPLY
 NEOTRADITIONALISM	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY
 60s	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	COMPLY	 NOT COMPLY	COMPLY

Figure 5. Results obtained for South-North facing
*Right bar marks the maximum energy consumption allowed

3.1.2 *West-East facing*

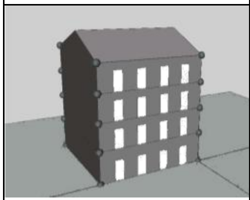
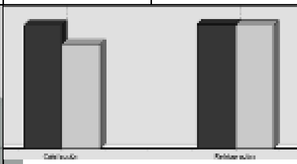
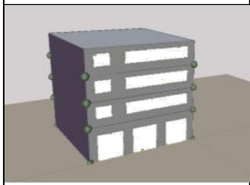
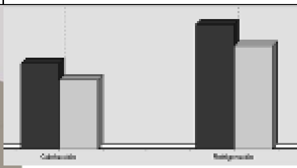
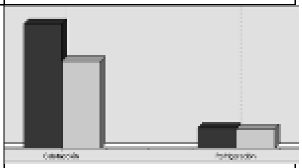
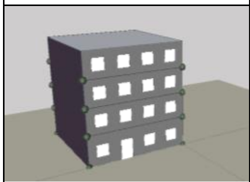
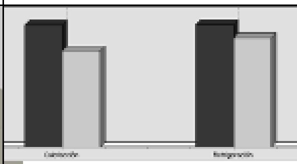
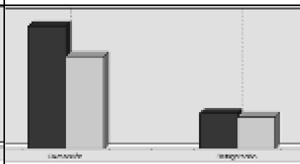
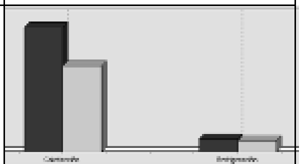
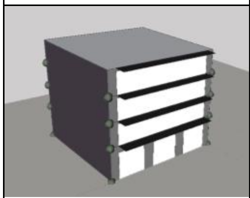
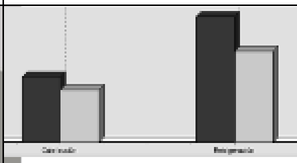
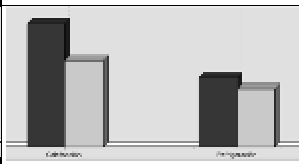
3D MODEL	ALMERIA		VALENCIA		BARCELONA	
	HEATING	COOLING	HEATING	COOLING	HEATING	COOLING
 ECLECTICISM	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY
 RATIONALISM	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY
 NEOTRADITIONALISM	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY
 60s	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY	 NOT COMPLY	NOT COMPLY

Figure 6. Results obtained for West-East facing
*Right bar marks the maximum energy consumption allowed

4DISCUSSION

The results obtained show the main differences in the calculation of energy efficiency of the buildings analyzed, according to its architectural and constructive typology characteristic of the different periods studied, and their orientation.

The different calculations of the thermal transmission of building envelopes and window spaces with computer programms according to the Código Técnico de la Edificación (Technical Building Code), allow verifying the relatively good thermal performance of the façade walls of early century buildings even with bad thermal behavior of the windows glass.

The reduction of the thickness of the envelopes of rationalism and Neo-traditionalism buildings have effects on a progressively greater thermal transmittance, and thus, on worsening the overall building insulation.

Finally, in the buildings of the sixties, the increasing of the glazing proportion penalizes even more the poor insulation of their facades because solar control glazing and double glazing were still not used. Its use began to generalize from the eighties. However, the appearance of important overhangs on the facades of the buildings of that period, reduces significantly the solar incidence on the glazing when they are facing south, penalizing significantly the setting sun when the glazing are facing west.

The calculations of the different rehabilitation constructive solutions studied, applied on the same buildings analyzed, allow us to verify that in the early-century buildings, we obtain a remarkable improvement in the overall building thermal behavior with the improvement of the glazing and only a minimum increase of the thermal insulation in the facade walls.

However, in rationalist and neotraditionalism buildings it is necessary the improvement of the insulation in the facade walls, and buildings of the sixties require an important increase in the insulation of both the brick walls and glazing, especially when they are facing west and the facades have no overhangs.

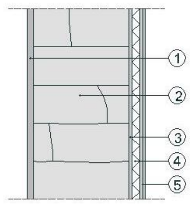
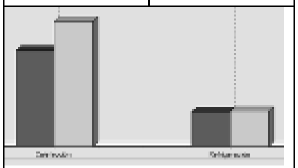
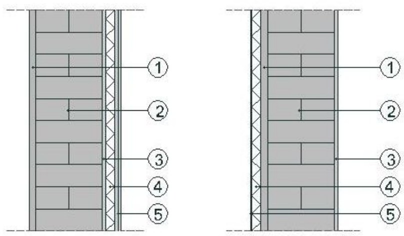
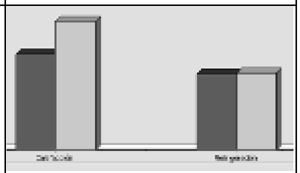
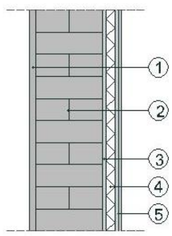
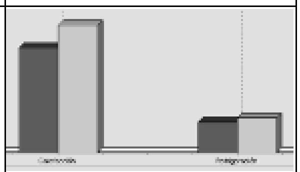
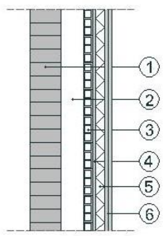
CONSTRUCTIVE DETAIL		ALMERÍA VALENCIA BARCELONA	
		HEATING	COOLING
	ECLECTICISM 1.Lime plaster (3 cm) 2.Limestone (50 cm) 3.Plaster (1.5 cm) 4. Thermal Insulation (2 cm) 5. Plaster panels (3 cm)	 COMPLY	COMPLY
	RATIONALISM Insulation on the inside and outside 1.Lime plaster (2 cm) 2.Brick (50 cm) 3.Plaster (1 cm) 4. Thermal Insulation (4 cm) 5. Plaster panels (3 cm)	 COMPLY	COMPLY
	NEOTRADITIONALISM 1.Lime plaster (2 cm) 2.Brick (50 cm) 3.Plaster (1 cm) 4. Thermal Insulation (4 cm) 5. Plaster panels (3 cm)	 COMPLY	COMPLY
	60s 1.Facing brick (14 cm) 2.Air camera (10 cm) 3.Hollow brick partition (4 cm) 4.Plaster (1.5 cm) 5. Thermal Insulation (5 cm) 6. Plaster panels (3 cm)	 COMPLY	COMPLY

Figure 7. Results for constructive solutions in rehabilitation of twentieth-century buildings in Valencia (South-North facing)
*Right bar marks the maximum energy consumption allowed

5CONCLUSIONS

The study helps confirm the significant differences in the energy performance of existing buildings, according to their age, architectural style and construction.

Using the latest computer programs, according to the new energy efficiency standards for buildings in Spain, has allowed us to determine the different thermal isolation needs in existing buildings thanks to the calculations made about thermal transmittances of different types of building envelopes.

From the discussion we can conclude that the comparative analysis of the main architectural and constructive typologies of the built heritage of the twentieth century facilitates the correct choice and design of the most appropriate constructive solutions for their rehabilitation and climate conditioning in terms of architectural and constructive typology of the building, as well as the position of the insulation on the inside or outside the building, improving the appropriate prescription of materials and the adoption of technical solutions for facade insulation best suited to increasing the performance of existing buildings according to the new Spanish regulations for energy efficiency in buildings and the demands of society.

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