CHARACTERISATION OF URBAN PATTERNS AT THE NEIGHBOURHOOD SCALE AS AN ENERGY PARAMETER. CASE STUDY: CASTELLÓN DE LA PLANA

[1]Braulio-Gonzalo, M.; [1]Ruá Aguilar, M.J.; [1]Bovea Edo, M.D.
[1]Departament d'Enginyeria Mecànica i Construcció, Universitat Jaume I
Avda. Sos Baynat, s/n, CP 12071 Castelló de la Plana
e-mail: braulio@uji.es; rua@uji.es; bovea@uji.es

ABSTRACT

According to the World Organization Prospects 2014 Revision (United Nations), the population in European cities has reached 73%, and 80% is forecast in forthcoming decades. Therefore, urban areas are large consumers of resources. Integrated Urban Regeneration (IUR) is implementing strategies to achieve a smart, sustainable and socially inclusive (Declaration of Toledo, 2010) urban development since the challenge is greater in existing urban environments, where it is not possible to act in the design phases. Therefore, an analysis of the characteristics of urban planning and building types that make up a city and its neighbourhoods is required to identify those typologies with energy vulnerability prior to implementing IUR.

This paper focuses on the energy factor as one of the items to consider in IUR. This will be useful in the decision making that determines which urban areas require more urgent intervention.

The urban morphology of a Mediterranean medium-sized city is characterized herein: Castellón de Plana (180,690 inhabitants, according to the Spanish National Statistics Institute (INE) 2010). Firstly, this city's historical urban development is analysed to determine different urban areas. Then existing building types are identified. Finally, these types are associated with the urban design and the results are represented by a Geographic Information System (GIS). The study results provide a number of urban morphology types with different layouts which represent the Mediterranean city, as well as the building typologies represented in each urban typology. Each presented set is likely to have different energy performance, and the findings can be extrapolated to other Mediterranean cities with similar characteristics to the city studied herein.

The collected information will be useful for further research to analyse the energy performance of the existing building stock in the city by taking into account the building type integrated into a consolidated urban design.

Keywords: Urban regeneration, urban design, building type, energy rehabilitation.

1.- Introduction

The World Organization Prospects 2014 Revision (United Nations) indicates that the population in European cities has reached 73%, and 80% is forecast for forthcoming decades. This scenario implies that urban areas are major consumers of resources and are progressively spreading, which means an increased built environment. This will entail future refurbishment and renewal needs to respond to more modern quality standards. According to Power [1], refurbishment of existing buildings is more environmentally sustainable than the development of new buildings because of the embedded energy they entail.

In Spain, the first Building Regulation on Thermal Conditions emerged in 1979, later than other countries. According to Spanish Statistical Office, 56% of all buildings have no thermal insulation [2]. In 2006, due to the transposition of the European Energy Performance of Buildings Directive [3] into Spanish Regulations, the Technical Building Code [4] came into being. Subsequently to ensure the European reduced emissions target, a new European Directive came about [5], which also centres on existing buildings. The EPBD's new more restrictive thermal insulation requirements in the building envelope led to a new update of the Spanish Building Code to accomplish transposition to existing buildings [6]. As a result, other than thermal insulation issues, factors such as orientation and location in an urban context should be considered for regulation requirements to be met.

In the Integrated Urban Regeneration (IUR) context in 2010, the Declaration of Toledo [7] suggested that diverse strategies should be implemented to achieve smart, sustainable and socially inclusive urban development since the challenge is more demanding in existing urban environments, where it is not possible to act in design phases. The aforementioned Declaration also emphasises the importance of urban areas to achieve the Europe 2020 objectives.

Some studies have analysed the energy performance of urban structures by considering the particular urban context, along with characteristics of the region in which the work was carried out. The influence of sun exposure on buildings has been studied by Yezioro, et al. [8] for urban blocks with a central courtyard, of latitudes between 26º and 34º. Košir, et al. [9] analysed the influence of insolation on five blocks patterns. Andreou [10] examined the effect of urban layout, street geometry and orientation in the Mediterranean region. Other authors have analyzed the urban form the energy consumption and greenhouse gas emissions. For example, Ishii et al. [11] analyzed it, in public buildings, in the Japanese city of Utsunomiya, for different building types. Wilson [12] related urban forms to the consumption of electricity in houses of Illinois.

This work presents a methodology to characterise the urban morphology of the residential building stock in medium-sized cities in the Mediterranean region according to two main parameters, block pattern and building type, from the energy viewpoint. To validate the methodology as a case study, an urban morphology characterisation was conducted in one of the neighbourhoods in the city of Castellón de la Plana (east Spain), which has 180,690 inhabitants. This allowed us to present the residential block patterns in both neighbourhoods. The results form part of a larger study and can be used as a starting point for future research, where the energy performance of the existing building stock will be analysed on a city level by considering the building type integrated into a consolidated urban design.

2.- Methodology

This work is structured as follows. The urban layout of the Mediterranean cities is firstly analysed to obtain block patterns. In order to deal with this issue, the study

started from the biggest scale (the city) and moved towards the neighbourhood level. Finally, it worked on the block scale.
Next building types were identified and classified according to their use (single family house (SF) or multi-family house (MF)), number of storeys and location of the building in relation to other buildings.
With gvSIG [13], a Geographic Information System software, building types were linked to blocks patterns, which gave a set of characteristic urban systems of the Mediterranean city, and permitted us to standardise urban morphologies. This also allowed us to obtain the area built for every building type in a given urban area. . Other authors have previously used GIS to represent different spatial coordinates associated parameters. Specifically, with respect to the energy performance of historic buildings Fabbri et al. [14] used GIS in different regions of Italy.This methodology can be used in the context of Mediterranean cities. The results of the set of urban blocks can be extrapolated to the city scale as proposed by bottom-up approaches [15]. Figure 1 shows the methodology flow chart:

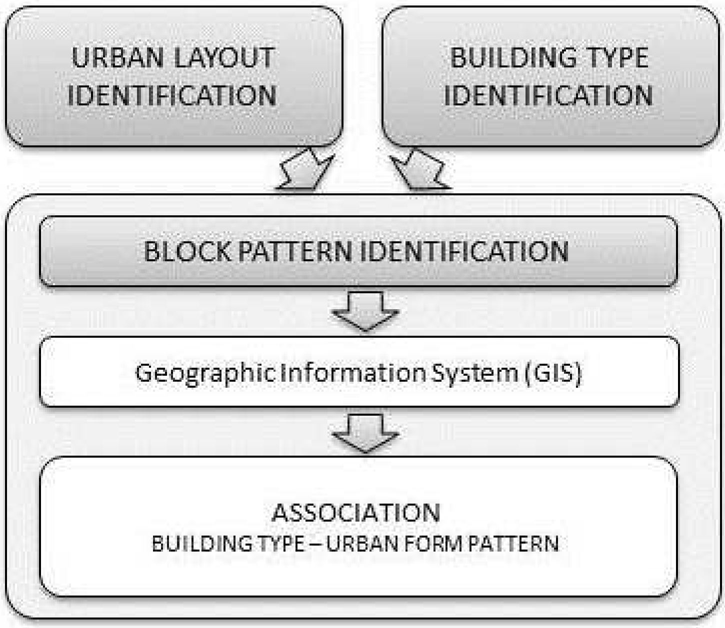


Fig. 1 “Methodology for characterising building types in urban morphology patterns”. Source: the authors

Table 1 shows the seven block patterns identified for the Mediterranean city, their location in the city and building type, together with a brief description.

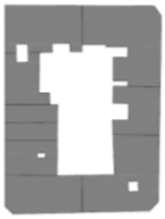
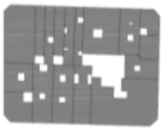
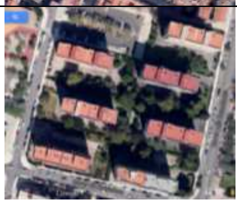
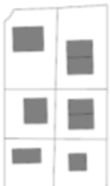
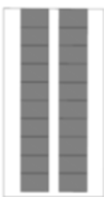
Urban layout	Urban block pattern	Location	SF/ MF	Density	Description
	BLOCK 1 	Historical centre Suburban districts	SF/ MF	Medium	Irregular shape, narrow streets, low-rise buildings Mainly single family terraced houses
	BLOCK 2 	Expansion district near the city centre	SF/ MF	High	Rectangular Medium and high-rise multifamily houses with big courtyards.
	BLOCK 3 	Expansion district near the city centre	SF/ MF	High	Rectangular Medium- and high-rise multifamily houses. Buildings with light well
	BLOCK 4 	Expansion district near the city centre	MF	High	Linear block Medium- and high-rise multifamily houses, buildings facing two streets and with light well.
	BLOCK 5 	New development districts	MF	Medium	Detached buildings in condominiums (gated communities). The block comprises a group of buildings with an open inner plot. Medium- and high-rise multifamily detached houses.
	BLOCK 6 	New development districts Suburban districts	SF	Low	Terraced low-rise buildings. The block comprises a group of buildings with an open inner plot. Detached or semi-detached single family houses
	BLOCK 7 	New development districts	SF	Low	Terraced low-rise buildings. The block comprises a group of buildings with a free inner plot. Terraced single family houses

Table 1 “Urban layout typologies and characteristics”

Building types in the Mediterranean city define the urban landscape. When we consider the energy performance viewpoint, different types work distinctly. For example, a MF building and a detached SF house present different form factors. Hence the thermal envelope that comes into contact with the external environment significantly influences their energy performance [16]. A classification of the residential building stock is provided according to two factors: (a) year of construction period and (b) building type (detached/terraced and height). The age of the building represents one of the most important aspects in the energy rating, as the date of construction determines aspects such as the existence of insulation in the thermal envelope, type of carpentry and glass and other features. The division into time periods is complex, because of both normative and legislative context, and due to historical reasons that have defined the constructive evolution. We found temporary classifications, adapted to the particularities of the analysed area in different sources. For example, in Greece, Dascalaki et al. [17] and Theodoridou et al. [18]; in Italy, Caputo et al. [19]; in Germany, Bradley and Kohler [20]; in Denmark, Kragh and Wittchen [21]; and in Spain, in the region of Catalonia, Garrido-Soriano et al. [22]. At European level, the EPISCOPE [23] study, which was launched in 2013 as a continuation of TABULA project, integrates the action of some European countries. Among its objectives, they classify building types according to building periods. In Spain, the classification has been made by the Valencian Institute of Building (IVE, Instituto Valenciano de la Edificación, in Spanish), specifically in the area of Alicante and Valencia. The IEE Project TABULA is accessible from the http://www.episcope.eu/ link.

The results of our classification is quite similar to the one performed in TABULA. It results in a matrix of 30 building classes as shown in Table 2.

Construction period		Building type					
		A	B	C	D	E	F
		MF Detached ≤4 floors	MF Detached >4 floors	MF Terraced ≤4 floors	MF Terraced >4 floors	SF Detached/ Semi-detached	SF Terraced
1	<1940	A1	B1	C1	D1	E1	F1
2	1940-1959	A2	B2	C2	D2	E2	F2
3	1960-79	A3	B3	C3	D3	E3	F3
4	1980-2006	A4	B4	C4	D4	E4	F4
5	>2006	A5	B5	C5	D5	E5	F5

Table 2 “Matrix of building classes”

Having identified block patterns and building types, they are represented by a GIS to find their relation. This allows the built area for every building type in an urban area to be obtained, and the average block pattern in an urban area under study to be identified. Information from the Cadastre Office (cadastral plot reference number, year of building construction, building type, height and built area) is inputted into the tool. Then building types are linked to urban layouts to obtain the typical residential block patterns.

3.- Case study

The methodology set out in Section 2 was applied to Castellón de la Plana (east Spain), a medium-sized city on the coast. One neighborhood was selected with different block patterns and different building types, previously identified (see Table 1). Data were provided by the Cadastre General Office [24]. Non-residential buildings were ruled out to implement the suggested methodology.

3.1.- Analysing the historical development of the studied city

Urban development is influenced very much by physical conditions (climate, orography, etc.), and by the socio-economic and historical features of all urban areas. Based on the many references reviewed, urban fabric and building types are decisive factors when considering the energy performance of an urban system. This section briefly describes the urban development of Castellón de la Plana. This helps understand the current urban design and contributes to identify differences in urban morphology and building types when considering several neighbourhoods.

Castellón de la Plana began as a 13th-century city. This Middle Age village was formed by small groups of detached and spread houses. It was later surrounded by a defensive wall, which is identified with what is today’s historic centre. The wall remained until the beginning of the 19th century when the suburbs near the historical centre were included, which had developed due to demographic and economic growth. The wall was knocked down and new land became available, with new plots of 4-m façades that were 20 m deep, and buildings reached a height of 6 m. This led to new buildings near the historical centre, which remain today and are characteristic of the city centre [25].

In the early 20th century, the city was formed by ten neighbourhoods and three urban areas: inner area, first expansion area near the city centre and new expansion area. When the Spanish Civil War ended in 1939, new squares and avenues shaped the city, but the concept of compact growth and integrated green areas was lost. Quick demographic growth disproportionally brought about higher buildings and, therefore, increased building density. Disparate heights were seen given the mixture of 3-4-storey buildings with newly built constructions occupying 8-14 floors. This urban landscape is characteristic of the historical centre today.

In the 1980s and 1990s, the urban layout was vastly transformed and became a more structured layout. New big urban plans for residential use, SF or MF houses, were built in the areas surrounding the city where a more regular urban pattern is found.

Figure 2 illustrates how this city evolved according to a GIS map. The evolution of built areas is linked to year of construction. Six time intervals are seen. The lines represent the different neighbourhoods that exist in the city today.

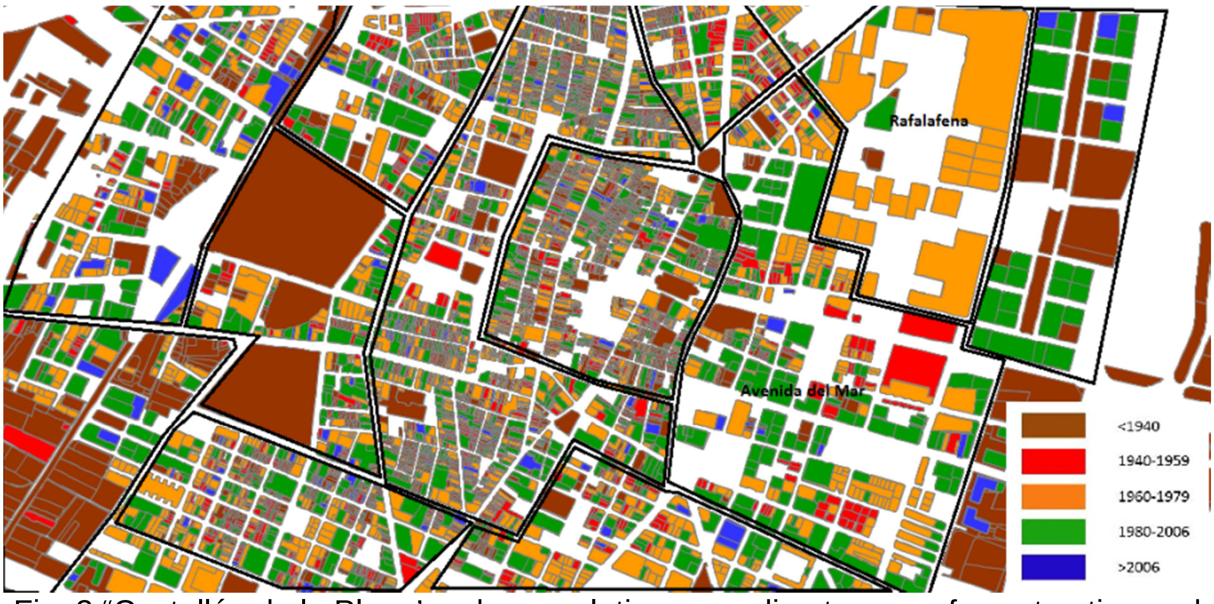


Fig. 2 “Castellón de la Plana’s urban evolution according to year of construction and areas with different urban fabrics”. Source: the authors

As Figure 2 shows, Castellón de la Plana has several urban layouts in each considered area. The historical centre shows an irregular pattern, while traditional and new expansion areas present an orthogonal-grid pattern.

3.2.- Selected Neighbourhood

One neighbourhood, *Avenida del Mar*, in the city was chosen to implement the suggested methodology. It is located in the eastern part of the city and it has an orthogonal pattern. The district corresponds to an expansion area from the 1930s and represents four of the seven block patterns (Blocks 2, 3, 4 and 6; see Table 1) and the five building types identified (B–F), presented in Section 2. Those not selected are no so representative of the entire city pattern because they correspond to the historical city centre and to new developments that have emerged in recent years. Most of the urban expansion districts near the city centre have the same urban layout as *Avenida del Mar*.
Table 3 presents the number of buildings per building type. Figure 3 shows in a map the building type distribution in both neighbourhoods.

		Building type					
		A	B	C	D	E	F
Construction period	1	-	-	15	-	-	60
	2	-	34	99	10	26	60
	3	-	-	61	256	6	22
	4	-	7	58	259	-	33
	5	-	-	2	26	-	5

Table 3 “Number of buildings per building type in *Avenida del Mar*”

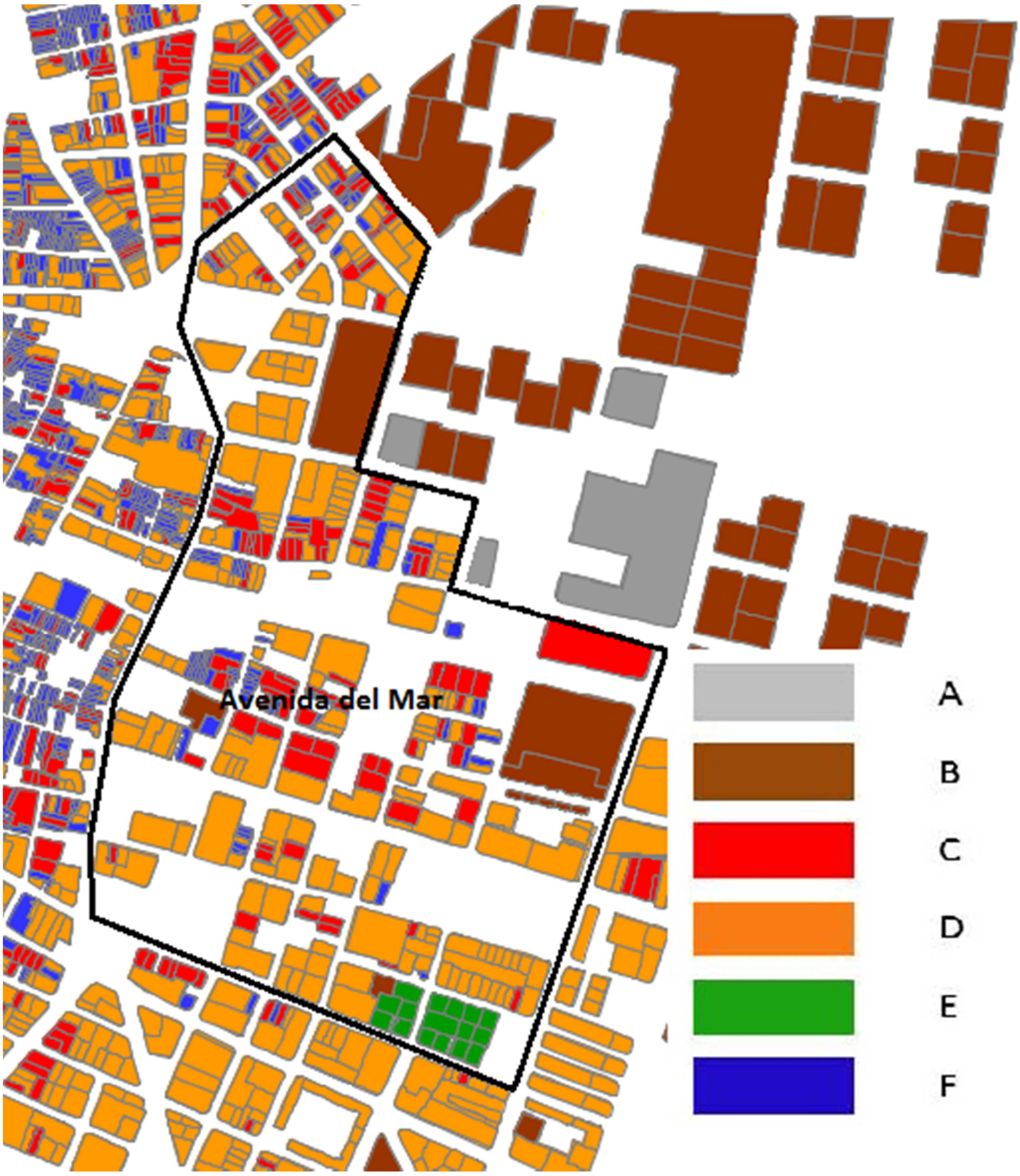


Fig. 3 “Distribution of building types in the selected neighbourhood”. Source: the authors

Using gvSIG, both variables were crossed to obtain the percentage of building types included in each block pattern, as seen in Table 4. This allowed us to standardise the building types in an average block. Table 5 indicates the sum of the built area (in m2) for each building type.

	Building type			
Residential block pattern	C	D	E	F
Block 2	8.63%	89.28%		2.09%
Block 3	8.63%	89.28%		2.09%
Block 4		100.00%		
Block 5				
Block 6			100.00%	

Table 4 “Crossing building type and residential block pattern (% percentage of built area per building type)”

	Building type					
	A	B	C	D	E	F
Avenida del Mar	-	64165	96794	1001582	4319	23477

Table 5 "Built area per building type (m^2)"

The methodology was applied to the selected neighbourhood and resulted in the standard residential block pattern and the percentage of built area per building type. Figure 4 shows the configuration for the four blocks considered in the case study.

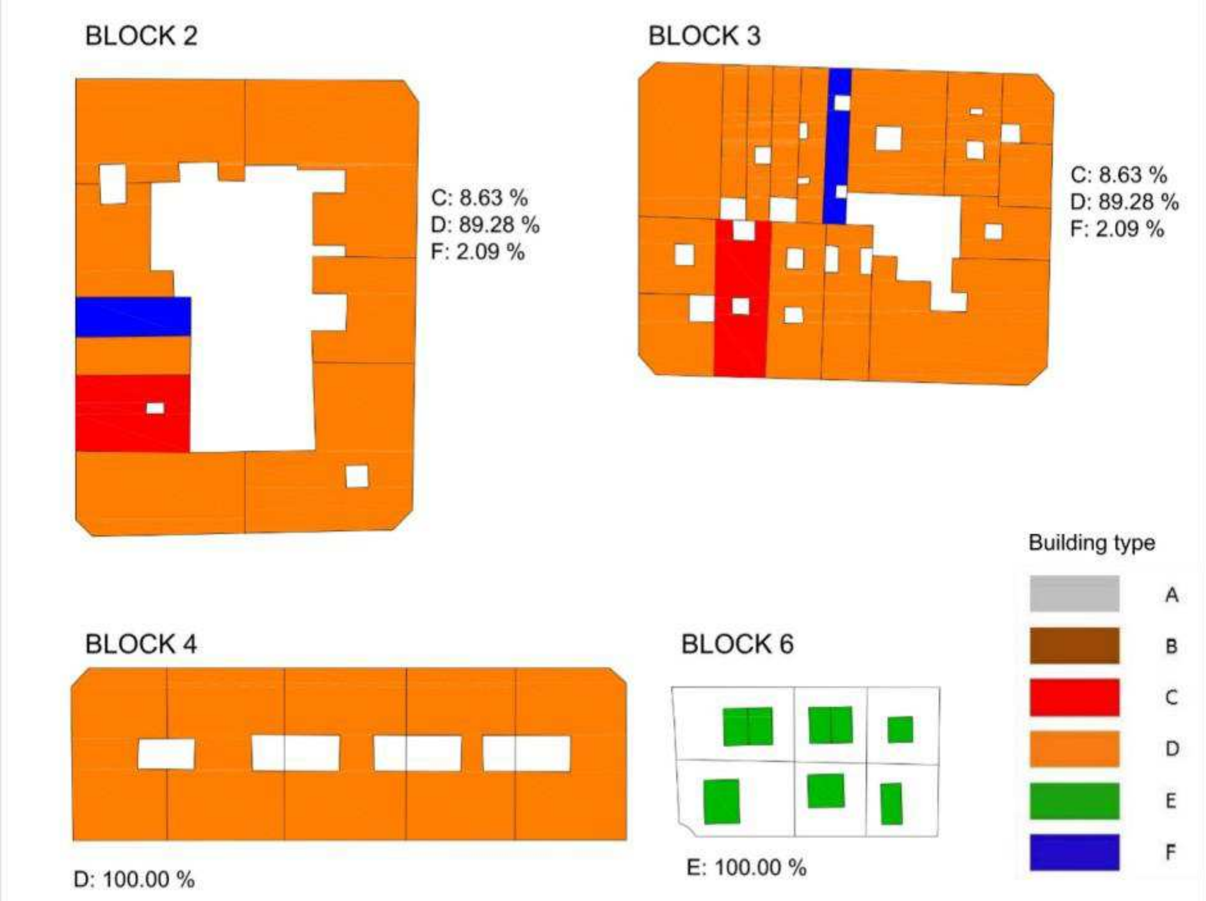


Fig. 4 "Residential block pattern in the neighbourhood under study and % of built area for each building type". Source: the authors

4.- Conclusions

This study proposes a methodology for classifying and characterising the urban layout of the residential building stock in medium-sized Mediterranean cities from an energy perspective. For this purpose, two variables were considered. Firstly, the urban layout was analysed to obtain block patterns. Then building types were identified. Thirdly and lastly, those data were crossed by the GIS software. This meant that both the building and the location of that building were considered a part of an urban context. This factor can strongly condition its energy performance.
We applied the proposed methodology to the city of Castellón de la Plana (E Spain). One neighbourhood was chosen as the basis for a case study. It represented four of the seven block patterns and five of the six building types (previously identified in this work). Crossing data gave the percentage of built area of each building type for all the block patterns. This provided a representative configuration of the complete neighbourhood, which becomes a representative average block.

This study contributes to standardise urban block configurations and will make energy modelling simulation attainable for estimating the energy performance of a specific residential building stock. From a bottom-up approach, the results can be extrapolated to a large scale, these being the neighbourhood, and ultimately the city.
This methodology can be implemented in similar Mediterranean cities and can prove to be a very valuable tool for local administrators, energy planners and other stakeholders for evaluating priority neighbourhoods to undertake building refurbishment or urban regeneration plans.

REFERENCIAS

[1] Power, A. (2008). *Does demolition or refurbishment of old and inefficient homes help to increase our environmental, social and economic viability? Foresight Sustainable Energy Management and the Built Environment Project*,**36**(12), 4487–4501. doi:http://dx.doi.org/10.1016/j.enpol.2008.09.022
[2] INE. (2015). Spanish Statistical Office. Retrieved from http://www.ine.es/
[3] EPDB. European Directive 2002/91/EC on the energy performance of buildings (2002). Retrieved from http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0091
[4] CTE. Código Técnico de la Edificación. Real Decreto 314/2006 (2006). España.
[5] EPDB. European Directive 2010/31/UE on the energy performance of buildings (2010). Retrieved from http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32010L0031
[6] CTE. Actualización DB HE del Código Técnico de la Edificación. Orden FOM/1635/2013 (2013). España. Retrieved from http://www.boe.es/diario_boe/txt.php?id=BOE-A-2013-9511
[7] Presidencia Española. Declaración de Toledo, Reunión informal de Ministros (2010). España.
[8] Yezioro, A., Capeluto, I. G., & Shaviv, E. (2006). Design guidelines for appropriate insolation of urban squares. *Renewable Energy*, **31**(7), 1011–1023. doi:10.1016/j.renene.2005.05.015
[9] Košir, M., Capeluto, I. G., Krainer, A., & Kristl, Ž. (2014). Solar potential in existing urban layouts—Critical overview of the existing building stock in Slovenian context. *Energy Policy*, **69**, 443–456. doi:10.1016/j.enpol.2014.01.045
[10] Andreou, E. (2014). The effect of urban layout, street geometry and orientation on shading conditions in urban canyons in the Mediterranean. *Renewable Energy*, **63**, 587–596. doi:10.1016/j.renene.2013.09.051
[11] Ishii S., Tabush S., Aramaki T. & Hanaki K.,(2010), Impact of future urban form on the potential to reduce greenhouse gas emissions from residential, commercial and public buildings in Utsunomiya, Japan, *Energy Policy*,**38**, 4888–4896.
[12] Wilson B, (2013), Urban form and residential electricity consumption: Evidence from Illinois, USA,*Landscape and Urban Planning*,**115**, 62– 71.
[13] Asociación gvSIG. (2014). gvSIG. Retrieved from http://www.gvsig.com/
[14] Fabbri K., Zuppiroli M. & Ambrogio K. Heritage buildings and energy performance: Mapping with GIS tools, *Energy and Buildings*,**48**, 137–145.
[15] Moffatt, S. (2001). Methods for the evaluation of the environmental performance of building stock. Canada: Editorial review by Illari Aho, Findland.
[16] Okeil, A. (2010). A holistic approach to energy efficient building forms. *Energy and Buildings*, **42**(9), 1437–1444. doi:10.1016/j.enbuild.2010.03.013
[17] Dascalaki, E. G., Droutsa, K. G., Balaras, C. A., & Kontoyiannidis, S. (2011). Building typologies as a tool for assessing the energy performance of residential buildings – A case study for the Hellenic building stock,*Energy and Buildings*, **43**(12), 3400–3409. doi:http://dx.doi.org/10.1016/j.enbuild.2011.09.002
[18]Theodoridou, I., Papadopoulos, A. M., & Hegger, M. (2011). A typological classification of the Greek residential building stock,*Energy and Buildings*, **43**(10), 2779–2787. doi:http://dx.doi.org/10.1016/j.enbuild.2011.06.036
[19]Caputo, P., Costa, G.& Ferrari, S., (2013). A supporting method for defining energy strategies in the building sector at urban scale. *Energy Policy*,**55**, 261-270.

doi:http://dx.doi.org/10.1016/j.enpol.2012.12.006
[20]Bradley P.E. & Kohler N., (2007), Methodology for the survival analysis of the urban building stocks, *Building Research and Information*, **35**(5), 529-542.
[21]Kragh J. & Wittchen K.B., (2014), Development of two Danish building typologies for residentialbuildings, *Energy and Buildings*,**68**, 79–86
[22]Garrido-Soriano N., Rosas-Casals M., Ivancic A.& Álvarez-del Castillo M.D., (2012), Potential energy savings and economic impact of residential buildings under national and regional efficiency scenarios. A Catalan case study, *Energy and Buildings*, **49**, 119–125.
[23] IEE Project TABULA accesible desde el enlace http://www.episcope.eu/.
[24]Comes, A. E. (2012). *Paseando por las calles de Castellón*. 1ª edición. Editorial Creamos talentos literarios, Castelló de la Plana.
[25] DGC. (2014). Dirección General del Catastro. Retrieved from http://www.catastro.meh.es/