

19. Typological analysis of school centres to characterize the energy consumptions. The case of the city of Valencia.

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Abstract This paper presents the work developed like continuation of the European project TABULA-EIE (2010-2013), faced to characterize the types of the residential park of housings, to develop strategies of energy rehabilitation. The work now presented studies the centres of education, attending on the potential of saving that this type of buildings presents, many of them, constructed without regulation on energy efficiency. One of the main detected barriers has been the scarcity of energy information on the service industries. Other one has been the multiplicity of variables (uses, schedules...) that make difficult to establish systematical classifications. The challenge of the present investigation has been to propose a classification of types of constructions of educational centres in the city of Valencia, to help to establish possible progress strategies for groups and favor the energy saving. There are analysed the classification systems used in multiple energy studies on educational centres in Europe and, taking as a base the model of classification prepared in the project TABULA, the “matrix of buildings types”, a new matrix has been proposed for the centres of pre-school and primary education of Valencia. Finally, there appear the results of the theoretical energy study developed on one of the types of schools included in the proposed matrix. The used methodology can be replicable to other cities of Spain and can constitute the base to estimate the possible energy savings in school centres, in order to raise future stages of energy rehabilitation of an efficient way.

Keywords: International; TABULA; energy retrofit; schools; saving strategies

1. Introducción

Attending on the exemplary role that the public institutions should have on the subject of efficiency and energy saving, and to the demand of the European Directive 2012/27/EU that, in its article 5, paragraph 1, it establishes that the Member States, from January 1, 2014, must renew annually 3 % of the entire surface of the buildings with heating and/or system of refrigeration that occupy its central administration, institutions are working at the development of action plans that diminish the energy consumption and facilitate the attainment of the European targets.

In addition to the buildings of administrative, judicial or government use, there exists a wide variety of uses and activities developed in state buildings, like educational, sanitary and sports centres, hospitals, etc. , which are big energy consumers.

Unlike the residential sector, the energy study of the service industries presents a series of added barriers, as information scarcity, both at quantitative and qualitative level, as well as the existence of multiple variables that prevent from establishing a common system of classification (uses, schedules, facilities, etc.). As a result, the development of research about energy in this sector has to be realized by means of segmentation in order to obtain results that they facilitate to take decisions on the subject of energy rehabilitation of the buildings.

Every time are more numerous, both in Spain and in Europe, the studies on energy saving in educational buildings, in particular schools. As (Arambula et al. 2015) affirms, the increasing interest in school buildings, owes principally to the high energy consumption in this sector and at the inadequate level of comfort (so much thermal as of quality of the air). In particular, in Spain, the final energy consumption in buildings destined for education was promoting in 2014 to 599ktep, the 6,77 % of the entire consumption of energy in the service sector, percentage very similar to the 6.87 % corresponding to the energy consumption in hospitals (IDAE 2016).

This article is part of a study about energy saving strategies for primary schools, mainly focused on energy rehabilitation, which serves as tool to the public administrations at the time of planning actions of energy intervention in educational centres and being able to reach the targets marked by the European Union.

The first measurement, or strategy, has to be to know in depth the built park and make a classification by types in order to its further study and definition of realistic strategies for each group.

2. Methods

After analyzing the models of classification realized in other studies about energy in schools and of the residential sector in Europe, it has been taken as reference the european project "TABULA", adapting its classification system, the matrix of buildings types, to the educational centres of primary and applying it to the schools of the city of Valencia, Spain.

This matrix allows to group them easily and quickly according to on those characteristics or common factors that define their energy consumption, mainly those related to energy demand and systems performance.

The energy demand of a building depends principally on its envelope, its construction characteristics, location, climate, usage profile, activity schedule, etc. In order to delimit these aspects, it has been limited the study, inside the educational sector, to public buildings where infantile and primary education is taught. This makes that conditions and comfort needs, the schedules of functioning, program needs, etc., are similar.

In order to obtain a global classification criterion of the built park and obviating specific architectural design, buildings have been categorized bearing in mind their construction date and their volumetric characteristics. According to this date, it has been established what legislation was applicable to them and the requirements as for thermal isolation, as well as the constructive and architectural tendencies of the epoch.

From the volumetric point of view, a classification have been realized according to their compactness (envelope surface / volume).

From these two data, date of construction and compactness, it has been developed a matrix of buildings types of the city of Valencia, it has been defined the main characteristics of every typology and it has been selected a representative building of each group for its later analysis and detailed study.

3. Built park classification for its energy study

The EU demands to member states, in annex 3 of Directive 2010/31/EU, to define representative buildings as models, distinguished by its functionality and geographical situation, both residential and not residential, new and existing, in order to study them later and to define measurements of energy intervention and to calculate its cost.

Although every time energy studies about educational centres are more numerous, the information scarcity make that only few research works establish a system of previous classification to identify the most representative.

It is the case of (Arambula et al, 2015), that, in its study, seeks to identify few buildings as representative of a set of 60 schools of the province Treviso (Italy).

For it, he identifies a number of architectural and energy parameters, such as the envelope and roof surface, liveable area, ratio between window area and facade, ratio between area of windows and opaque surface, the average transmittance envelope, etc. After analysing these parameters, he obtains as a result five types of representative buildings of the set.

Other studies, like (Gaitan et al. 2010), normalize the data collected from more than a thousand Greek schools and applying an algorithm, establish a school "pattern" to compare savings margins, etc.

Nevertheless, most of the studies do not develop a classification system that identifies a representative building, they study straight a series of buildings, or the whole set, of a region or city, establishing later stages of intervention and energy progress or other conclusions according to the approach of the investigation.

It is the case of (Santoli et al. 2014) that, taking from energy certificates the energy consumption data and the location of the schools inside the city of Rome, analyse and compare by districts diverse energy parameters. Finally, they classify the primary schools park as historical buildings, buildings built between 1860-1940 and buildings built in the post-war period, and propose a series of improvements for every group.

(Dall'O' and Sarto 2013) realized an energy audit campaign in 49 school complexes located in the region of Lombardy, Italy, proposing a set of intervention stages and concluding that not always it is necessary an excessive intervention in heating improvements.

In other occasions, besides the location and the quantity and quality of the data that it is had about the schools, it is used as a selection criterion the period in which they were constructed or rehabilitated and consumption level when it is above or below the average. For example, (Thewes et to. 2014) analyses the real consumption of 68 school buildings of Luxembourg (of infantile, primary, secondary education and sports) built, expanded or completely renewed after 1996.

In addition to specific studies about schools, it has been developing diverse European and national programs, which were compiling information and were studying energy characteristics of buildings for its later classification and proposal of interventions. Some of these projects are E-RETROFIT-KIT, DATAMINE and TABULA-EPISCOPE, as well as works of other research groups as GTR, which realizes a classification of the residential sector identifying representative groups of dwellings (Cuchí 2011).

TABULA project, taken like model in this study, which developed between 2010 and 2013, had as its main target to study and to characterize the types of existing apartment houses to raise common performance strategies in the residential area, on the subject of energy efficiency, allowing to compare the parks of residential buildings of the different countries, exchange experiences and to learn from each other about good practices on energy rehabilitation (IVE 2015).

About not residential buildings, only is gathered data of five countries, this owes to the big variety of buildings and uses that comprise the tertiary sector and the limited information about them, both in quantity and quality. Schools appear in

most cases like a category, but without going so depth in their studio or type (Stein et al. 2012)








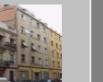







	Region	Construction Year Class	Additional Classification	SFH	TH	MFH	AB
				Single-Family House	Terraced House	Multi-Family House	Apartment Block
1	Mediterranean climate (Clima Mediterráneo)	... 1900	generic	 ES.ME.SFH.01.Gen	 ES.ME.TH.01.Gen	 ES.ME.MFH.01.Gen	 ES.ME.AB.01.Gen
2	Mediterranean climate (Clima Mediterráneo)	1901 ... 1936	generic	 ES.ME.SFH.02.Gen	 ES.ME.TH.02.Gen	 ES.ME.MFH.02.Gen	 ES.ME.AB.02.Gen
3	Mediterranean climate (Clima Mediterráneo)	1937 ... 1959	generic	 ES.ME.SFH.03.Gen	 ES.ME.TH.03.Gen	 ES.ME.MFH.03.Gen	 ES.ME.AB.03.Gen
4	Mediterranean climate (Clima Mediterráneo)	1960 ... 1979	generic	 ES.ME.SFH.04.Gen	 ES.ME.TH.04.Gen	 ES.ME.MFH.04.Gen	 ES.ME.AB.04.Gen
5	Mediterranean climate (Clima Mediterráneo)	1980 ... 2006	generic	 ES.ME.SFH.05.Gen	 ES.ME.TH.05.Gen	 ES.ME.MFH.05.Gen	 ES.ME.AB.05.Gen
6	Mediterranean climate (Clima Mediterráneo)	2007 ...	generic	 ES.ME.SFH.06.Gen	 ES.ME.TH.06.Gen	 ES.ME.MFH.06.Gen	 ES.ME.AB.06.Gen

Fig. 1 TABULA. Matrix of building types: Spain, Mediterranean climate (IVE 2012)

3.1. Classification according TABULA

TABULA project realizes a buildings matrix for every country and climate (Fig. 1). Every matrix includes two variables: construction year and the size or building type. While the first factor changes according to the regulation of every region, the second one is common to all, so that buildings can be: simple family houses, terraced houses, multi-family houses and apartment blocks.

In the case of Spain, segmentation establishes in TABULA project, realizes a first classification of residential buildings, applicable to non-residential, according to the climate zone in which they are: North-Atlantic, Continental and Mediterranean. With regard to the construction date they are set six periods, based on the application regulation in this epoch about thermal conditions and constructive-

structural system: before 1900, from 1901 to 1936, from 1937 to 1959, from 1960 to 1979, 1980 to 2006 and from 2007.

The milestones that mark the change of epoch are the changes of economic period of the country, as well as, the appearance of regulation that influenced the constructive methods, as the norm of Thermal Conditions of Buildings of 1979 and Technical Code of the Building of 2006.

Both classification criteria, based on climate zone or on construction year, are applicable to segment all tertiary sector buildings, as hospitals, office buildings, commercial, educational, etc. However, the size or buildings type must be defined depending on the specific segment of the tertiary park that it is going to be studied.

So much the classification criteria according to the climatic zone, as according to the year of construction, are applicable to segment all the buildings of the service industries, be already hospitals, office blocks, commercial, educational, etc. Nevertheless, the size or type of building is necessary to define it according to the segment of the tertiary park that he goes to study.

4. The matrix of building types applied to public schools of Valencia.

Valencia City is provided with 90 public preschools and primary schools, composed by about 215 buildings. Many of these buildings are extensions, small lecture halls, offices, libraries, gyms, locker rooms, warehouses, etc., built in an independent way to the main building and, in many cases, they belong to different epochs.

Available classification data has been:

- Schools list of obtained from the Centres Guide GV.
- Cadastral data, with general geometric characteristics, surfaces, construction date, number of floors, etc.
- Plans, historical and graphic documentation of schools, obtained from literature, files or in situ.

The adaptation of the matrix model of building types to the schools park has been carried out keeping the variables of climatic zone and construction year and including compactness (surface facades / v) as a factor of classification of the building size. In spite of the different architectural designs and the scarce information that we have about these constructions, this parameter allows us, objective and quickly, to sort of buildings according to their size and form, in turn, provides data about its energy performance, since the more compact is a building more energy efficient it is.

In spite of the different architectural designs and the scarce information that we have about these constructions, this parameter allows arranging, on an objective and quick form, the buildings by its size and, in turn, it provides information on its energy behaviour, because as more compact is a building more efficient is.

4.1. Classification of the schools according to their compactness

The segmentation of the schools by types according to its compactness has been carried out in three steps: calculation of the compactness, analysis of the buildings and to establish levels.

Firstly, the calculation of the compactness has been realized obtaining from the cadastre the envelope surface (fronts, soil and covering) and the built surface, taking three meters height as an average value by floor to the calculation of the volume. In the cases that it has been possible, it has been consulted maps and graphic papers of the buildings, it has been discarded those schools without enough information.

For example, a building with a built surface of 1800 m² and a surface of its surrounding one of 2800 m², will have a compactness of 0,528, obtained of dividing the envelope surface between the volume of the building (surface constructed multiply by three meters high).

As soon as the compactness was obtained, they have been discarded the buildings with a value superior to one, because they are mostly small constructions that lodge warehouse, toilets, changing rooms, etc. , and those buildings with a compactness higher than one because they are gymnasia or pavilions.

As a result we have the compactness of 79 schools and 135 buildings, which correspond with buildings of classrooms and buildings of administration, libraries, canteens, etc.

Secondly, the results have been divided by intervals of 0,1 (Table 1) and the relation has been analysed, on one hand, the relationship between compactness and form of the schools that have the same surface in all its floors, and, as other, those in which the surface in every floor changes relative to others.

Table 1 Compactness by intervals of 0.1 and the number of buildings per interval

Compactness	<0,3	0,31 a 0,4	0,41 a0,50	0,51 a 0,60	0,61 a 0,70	0,71 a 0,80	0,81 a 0,90	0,91 a 1,00
N° buildings	0	10	32	41	13	2	10	27

After observing that there are buildings with different shapes and heights that have the same compactness (Fig. 3), and bearing in mind its epoch of construction, it has been identified and analysed six forms, or building types, which represent the 86.67 % of the studied buildings. The rest are colleges with a singular design that is not possible to frame inside a specific group.

These forms or types are: narrow buildings with masonry walls, rectangular buildings with very elongated plant and masonry walls, rectangular and narrow buildings, with big height and the corridors of access to classrooms in the rear facade, buildings with plant in X, rectangular buildings with a central corridor and buildings with different surface in every floor.

Thirdly, they have been fixed compactness levels, common to all the types, with which the schools can be classified (Table 2).

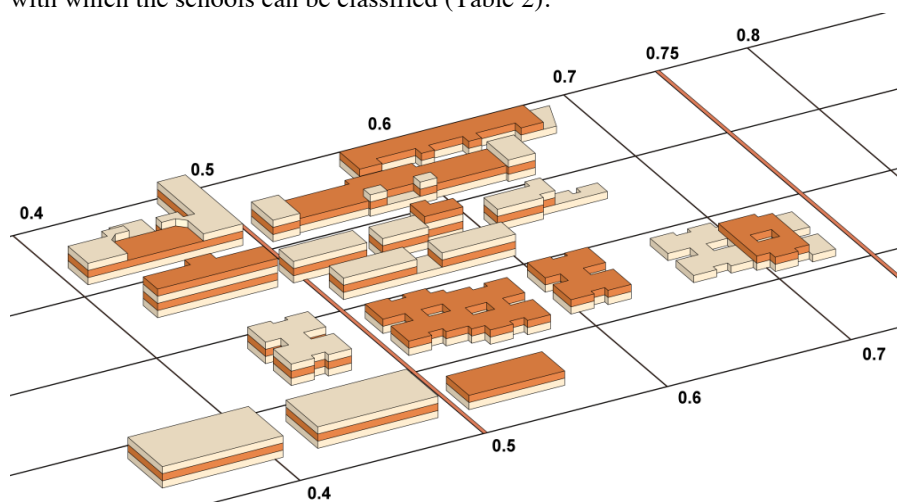


Fig.2 Perspective diagram of compactness variation depending on the shape and size of the building

Table 2 Compactness levels in relation to the height and shape of the building

Compactness	Buildings with the same surface in every floor	Buildings with different surface on every floor
< 0,25	*	*
0,26 a 0,50	<ul style="list-style-type: none"> • 4 floors in rectangular, narrow and high-rise buildings • 3 floors 	<ul style="list-style-type: none"> • To 0,26 : Buildings where the second floor surface is practically the same as the ground floor . • 3 and 4 floors in rectangular, narrow and high-rise buildings • To 0.50: Buildings where the deck area of second floor is equal to the sum of the areas covered ground floor and first floor.
0,51 a 0,75	<ul style="list-style-type: none"> • 2 floors in rectangular, narrow and high-rise buildings • 2 floors 	<ul style="list-style-type: none"> • To 0.5 : Buildings where the deck area of first floor is practically the same as the ground floor . • 1 and 3 floors in rectangular , narrow and high-rise buildings • To 0.75 : Buildings where the deck area of first floor is less than or equal to the ground floor .
0,76 a 1	<ul style="list-style-type: none"> • 1 floor 	<ul style="list-style-type: none"> • Building with a small first floor area

* As it is shown in Fig.2, in Valencia there are not buildings with less compactness than 0.30.

4.2. Matrix of building types


From the above data, it has been developed a matrix of buildings types with six periods (A- F) and four levels of compactness (I- IV). Some periods have been subdivided, because at that time schools were built with some of the forms or building types mentioned in the previous section. Finally, we have obtained a matrix with eight rows and four columns (Fig.3).

	Región	Año de construcción	Compacidad (A/V)			
			I. 1 a 0.76	II. 0.75 a 0.51	III. 0.50 a 0.26	IV. < 0.25
A	Clima Mediterráneo	...1900	A.I	A.II	A.III	A.IV
B	Clima Mediterráneo	1901 ... 1936	B.I		B.III	B.IV
C1	Clima Mediterráneo	1937 ... 1959				C1.IV
C2	Clima Mediterráneo	1937 ... 1959	C2.I			C2.IV
D	Clima Mediterráneo	1960 ... 1979				D.IV
E1	Clima Mediterráneo	1980 ... 2006				E1.IV
E2	Clima Mediterráneo	1980 ... 2006	E2.I			E2.IV
F	Clima Mediterráneo	2007...	F.I	F.II	F.III	F.IV

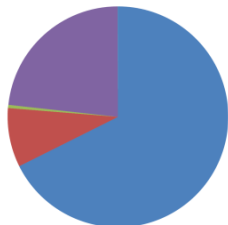
Fig. 3 Matrix of building types applied to public schools in Valencia

In the case of Valencia, not all the types have a real model, for example, there are not public schools built before 1900, or they are scarce and with a unique de-

sign, for example, those built after 2007. Some of the buildings types spanning several periods of the matrix, as C2 type, which includes buildings built in the 1950s and 1960s, or type D, built between the 1970s and the early 1980s.

Caracterización energética del tipo: Colegio C2-II Período 1937-59 Clima mediterráneo					C2-II
Zona climática	Clima mediterráneo				
Período de construcción	Período 1937-59				
Tipo de construcción	Colegio, tipo c2, comp. II				
S. Habitable (m2)	Volumen (m3)	Compacidad S/v (m-1)	Nº de plantas	Nº de unid. escolares	
1051.30	3364.16	0.55	4	16	

Características: elementos constructivos e instalaciones			Análisis del consumo y las emisiones	
Elemento	Descripción	U(w/m2 K)	Demanda (kWh/m2)	
Cubierta plana (C1)	Baldosa cerámica de 20mm Capa de Impermeabilización Hormigón áridos ligeros Forjado unidireccional entrevigado de hormigón 250mm Enlucido de yeso	1.79	Global	452.37
Cubierta plana ventilada (C2)	Baldosa cerámica de 20mm Capa de impermeabilización Tablero de bardos cerámicos Cámara de aire horizontal de 200 mm Forjado unidireccional hormigón 250mm Enlucido de yeso	2.33	Calefacción	70.25
Fachada principal (F1-F2-F4)	Enfoscado de mortero de cemento Ladrillo cerámico h. doble de 115 mm Cámara de aire 50mm. Ladrillo cerámico h s 40 mm Enlucido de yeso	1.33	Refrigeración	25.44
Fachada posterior (F3)	Enfoscado de mortero de cemento Ladrillo macizo de 115 mm Enlucido de yeso.	1.94	Emisiones (kg CO2/m2)	
Suelo	Baldosa de terrazo Forjado losa hormigón armado 200 mm	0.3-0.86	Global	112.37
Ventanas	Madera Vidrio simple	2.2 5.7	Calefacción	75.99
Puertas exteriores	Metálica Vidrio simple	5.7	Refrigeración	9.71
Sistema	Descripción		ACS	0.52
Calefacción	Radiador eléctrico Potencia 1500w 3 radiadores/aula. 1 rad/despacho.		Iluminación	26.10
A.C.S.	Termo-acumulador eléctrico en cocina		Otros	



Detalle de emisiones de CO2

- Calefacción
- Refrigeración
- ACS
- Iluminación
- Otros

Fig. 4 Model information document and analysis of consumption and CO² emissions of a building type C2.II

As a result, the 135 buildings studied has been reduced to 14 representative types, about them it has been performed a theoretical analysis of energy consumption and CO² emissions. Following the methodology of TABULA, the results have

been gathered in individual cards with general information of the building (period, living area, volume, number of floors, compactness, number of school units, etc.), the characteristics of the construction elements and installations and energy consumption and CO² emissions (Fig.4).

These cards serve as an energy consumption reference for other buildings with the same type, and like a base to prepare proposals and intervention strategies of energy rehabilitation for every type and for groups.

5. Conclusions

From three factors that influence the energy consumption, date of construction, compactness and form, it has been obtained a model of matrix of building types that allows grouping them quickly and easily. After its application to the public schools of the city of Valencia, we obtain a matrix of eight rows and four columns, which classifies the 135 studied buildings, corresponding to 79 of the 90 schools, in 14 representative types for its later study and calculation of their energy savings potential levels of intervention.

It has been noted the absence of organization and difficulty of access to information about energy consumptions of the public park of schools, for this reason we propose to create a computer hardware that allow to manage actively energy data of the public sector.

The matrix has allowed developing a segmentation of the schools park with energy criteria, knowing the most representative and numerous types, allowing thus, estimating potential energy savings in schools and posing efficiently future scenarios for energy rehabilitation. It is essential to know how it has been built in the past to improve efficiently in the future.

Acknowledgments The authors acknowledge to the Generalitat Valenciana, the Town Hall and the County Council of Valencia and public primary schools of Valencia, for their time, for its time, for allow us the access and for all the information that they have given us, without which a big part of this study would not be possible.

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