'CONS' AT THE MOMENT OF INTRODUCING NEW ECO-EFFICIENT TECHNOLOGIES TO BUILD A DETACHED HOUSE. CASE STUDY: A HOUSE IN PALOMARES DEL RIO (SEVILLE)

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ABSTRACT

The need for construction and restoration of buildings within an ecological and sustainable manner is highlighted in this increasingly aware global world; so it is very easy to fail thinking on how simple it could be to execute certain eco-efficient constructive proposal in any project, no matter its size.

Despite having previous experiences in construction of several prefabricated buildings (fire stations, offices, schools), and participating in some important research projects on studying new eco-efficient constructive proposals for dwellings, as the Patio 2.12 project for Solar Decathlon Europe 2012, that was the mistake our team failed into when we decided to incorporate a new more efficient constructive system in a private promoted detached house project.

This works shows, by means of a real and built example, that kind of things that is not usually told in a congress or an article: all those problems found during the incorporation process which have to be controlled to improve the viability of any building project which pretends to apply new solutions.

In this case, the problem was to move from a traditional detached house project based on a system of structural walls with 3cm of insulation, plastered and painted, floor slabs with beams and concrete slabs, balustrades and small windows, pitched roofs... (private promoter's first idea) to a contemporary house project based on a Steel Frame system with 14cm of insulation, and multiple eco-efficient architectural strategies, with mezzanine floor, double height and large windows(final project) ... at the same price and lesser execution time.

All those problems our team had to face and the different constructive proposals and professional decisions we reached out during the different phases of this project, from first stages to the end of the building process, to obtain at the same price a detached house executed in less time and with more material and environmental quality than a traditional one through the incorporation of eco-efficient proposals are shown in this paper by adding real budgets, time programs, comparative studies, sketches, drawings and photographs.

In spite of the economical crisis, this house has risen 50% in value.

Keywords: Eco-efficient proposals, Steel frame, Viability, Rise in value

1.-Introduction

The world of the construction in particular and the society in general is, fortunately, increasingly aroused by the need to construct and rehabilitate following an ecological and sustainable speech [1]. Architecture is been complemented with adjectives that try to describe a course to the change (ecological, green, sustainable, eco-efficient, bioclimatic, environmental …) in spite of the fact that still we do not know the differences between the different meanings of those adjectives.

The market is been filled with patents commercialized by huge companies, constructive or structural solutions, regarding hygrothermal conditioning, energy efficient alternatives, that assure to improve the quality of life minimizing their environmental impact [2].

Eco-efficient constructive solutions are necessary, this is well-known and few people will question this reality. Nevertheless we are not always conscious about the difficulty an architect has to face with at the moment of wanting to introduce one of these constructive alternatives in any architectural project.

Facing this panorama it is easy to fall down in the mistake of thinking how easy it could be to execute certain eco-efficient solutions in any project [3] [4], for small that it could be, especially when the developer companies are anxious to obtain clients and to demonstrate their scientific progresses and that's why they will provide architects any help they need.

In spite of previous experience at the execution of different prefabricated buildings (fire stations, offices, schools, housings) and participation in some important research projects focused on finding new eco-efficient constructive solutions for dwellings (as the Patio 2.12 project for the Solar Decathlon Europe 2012 competition) this one was the mistake we did when we decided to apply a new more efficient construction system when a private promoter ask us to design and build an single-family house.

2.-Objectives

The aim of this work will be to show by means of a real and executed case study, those aspects that is not usually told in an article or in a conference: all the disadvantages of these processes that need to be controlled to provide viability to any project trying to apply new eco-efficient solutions. Firstly this work will compare the traditional and habitual constructive systems with their eco-efficient alternatives highlighting the advantages, but noticing the disadvantages that arise during the whole building process (from the preliminary design up to the end of the execution of the building).

3.-Methodology

The case study is a building project which architects are two of the authors of this work (Dr. David Moreno Rangel and Manuel Fernández Expósito). The tasks done and the difficulties found will be described in a sequential process for each stage of the architectural project.

Provided that this case study has served as base for the elaboration of a Master Thesis of the student Enrique Ramos Torres titled 'alternative constructive systems: prefabrication and industrialization' supervised by Dr. David Moreno Rangel, some of his research results will be shown to support some considerations and conclusions of this communication.

The main objective of this work is to bring to light currently in existence alternative constructive systems showing their characteristics and basic specifications: materials, constructive sections, assembly, execution times, economical aspects, technical difficulties among others aspects.

Although some exemplifications are made based on this project, this experience is acquired after the execution of diverse promotions of this typology, including the participation in the research project about eco-efficient and sustainable detached house for Solar Decathlon Europe: Patio 2.12.

4.-Case study

A single-family house placed at the council area of Palomares del Río (Seville, Spain) is proposed as case study. It is developed in a unique floor. The living room has the double of the normal height and it has a small mezzanine. Its built area is of 135.74 m^2 and a useful total area of 117.23 m^2 (Table 1).

Useful area	**117,23 m^2**
Ground floor	**105,89 m^2**
Bedroom 1	8,79 m^2
Bedroom 2	8,82 m^2
Bedroom 3	8,54 m^2
Bedroom 4	15,34 m^2
Bathroom 1	4,09 m^2
Bathroom 2	4,12 m^2
Corridor	6,13 m^2
Hall	5,84 m^2
Kitchen	8,80 m^2
Living-dining room	35,42 m^2
Mezzanine	**11,34 m^2**
Studio	11,34 m^2

Table 1 “Useful area of the case study”

It has four bedrooms (two doubles and two singles), two bathrooms, a dressing room, a kitchen, a hall, a double-height living room, a studio and a dining room (fig. 1).

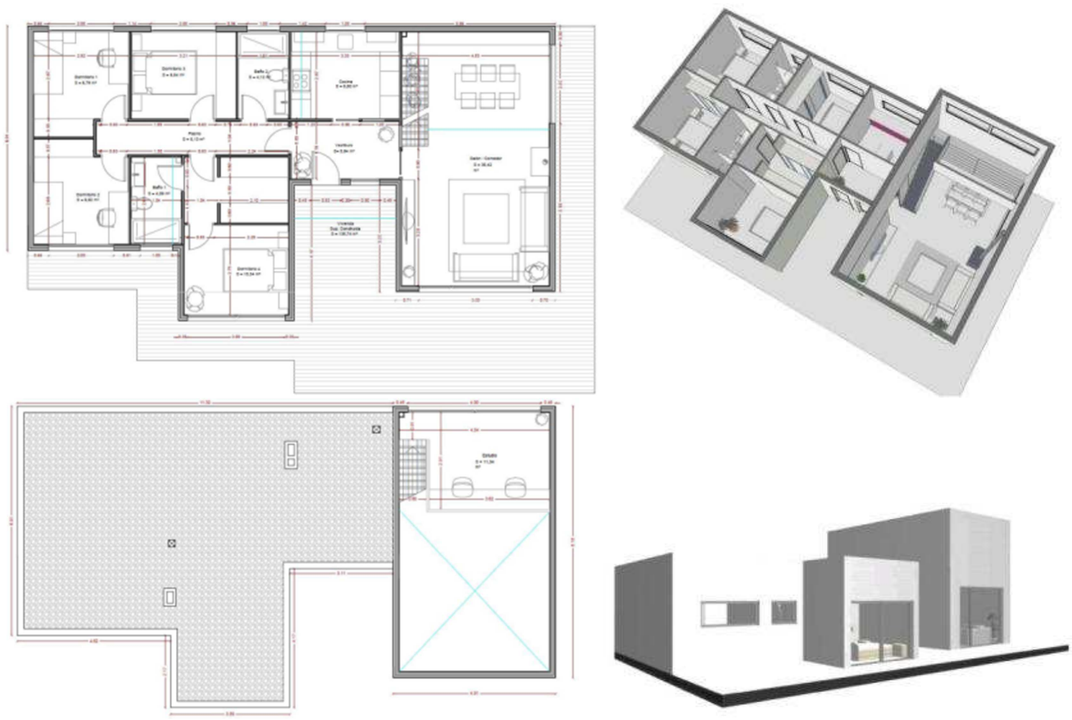

Fig. 1 “Case study: ground floor, mezzanine and two perspective views”. Source: estudio Heliopausa

It is placed not centred at the top of its 1100 m^2 piece of ground, opening two big windows facing southeast towards the freer area of the plot where the property will create a garden and build a swimming pool (fig. 2).

Fig. 2 “Case study: Final location at the plot and some photographs during the execution”. Source: estudio Heliopausa

This case study has also been taken by Enrique Ramos Torres as an example to develop his Master Thesis titled 'alternative constructive systems: prefabrication and industrialization' within the master course Sustainable City and Architecture, official title of the University of Seville.

5.-Initial studies

There were several start point premises exposed by promoters that helped to convince them about the need to use industrialized and prefabricated constructive solutions [5] [6], introducing eco-efficient solutions that clearly improved their quality of life as well as the relationship between useful surface/built surface.

- The house had to be built within 4 months
- The improvement of the traditional habitability conditions resulted from an self-built house

At initial design stage, six different design were made (fig. 4) complemented with their corresponding study of surfaces and economic valuation compared with the traditional system and other alternative prefabricated systems (fig. 3). It has to be noticed in this moment that there were important economic differences between those offers received by construction companies specialized in traditional solutions and by those companies focused on any eco-efficient system, at this preliminary design stage, all of them made by real companies and under competitive specifications.

In this stage Balloon frame (26% cheaper than a traditional one), Steel frame (similar offer), Steel box (5% more expensive than a traditional one) and prefabricated concrete elements (38% more expensive than a traditional) companies were analysed.

After the first meeting with promoters another seven variations were decided to be done trying to adapt to the needs of them and to the constructive and technique requirements of the chosen prefabricated solution.

MODELO	SUPERFICIE UTIL	SUPERFICIE CONSTR.	DORMIT.	ESTUDIO	COCINA	DOBLE ALTURA
VIVIENDA 3D1	115,88	128,05	3	INTEGRADO	INTEGRADA	NO
VIVIENDA 3D2	120,12	128,05	3	AISLADO	AISLADA	NO
VIVIENDA 4D1	129,44	140,90	4	INTEGRADO	AISLADA	NO
VIVIENDA 4D2	129,75	145,24	4	AISLADO	AISLADA	NO
VIVIENDA 4D2´	129,75	145,24	4	AISLADO	AISLADA	SI

PRODUCCION:	*0,00*	*0,00 €*	*4 MESES*	*2 MESES*	*4 MESES*	*1 MES*
OBRA	*14 MESES*	*10 MESES*	*2 SEMANAS*	*3 MESES*	*2 MESES*	*5 MESES*
MODELO	**CONSTR. TRADICIONAL**	**CONSTR. TRADICIONAL**	**PREF. HORMIGON**	**BALLOM FRAME**	**METALICO**	**STEEL FRAME**
VIVIENDA 3D1	98.961,52 €	108.857,67 €	176.068,75 €	94.908,36 €	111.531,55 €	105.369,23 €
VIVIENDA 3D2	102.582,48 €	112.840,73 €	176.068,75 €	94.908,36 €	111.531,55 €	115.524,90 €
VIVIENDA 4D1	110.541,76 €	121.595,94 €	193.737,50 €	104.432,54 €	132.556,00 €	128.125,36 €
VIVIENDA 4D2	117.806,50 €	129.587,15 €	195.705,00 €	105.649,27 €	142.359,00 €	132.096,23 €
VIVIENDA 4D2´	131.806,50 €	144.987,15 €	199.705,00 €	107.649,27 €	152.653,00 €	147.325,80 €

Fig. 3 "Case study: estimated economic comparison". Source: estudio Heliopausa

Fig. 4 “Case study: initial proposals”. Source: estudio Heliopausa

The final solution was valued by 82 companies, 71 of them were national companies and 11 of them were foreign companies, specialized in 7 different prefabricated and industrialized solutions (fig. 5): projected concrete over expanded polystyrene (EPS), EPS panels shuttering, EPS blocks shuttering, prefabricated concrete panels, cross-fibres laminated wood panels, Balloon frame and Steel frame.

Sistema	Nº total de empresas consultadas	Nº empresas NACIONALES consultadas.	Nº presupuesto desglosado obtenidos empresas nacionales.	% de presupuestos desglosados entre empresas nacionales.
Proyectado de hormigón sobre EPS	9	7	1	14,29%
Encofrado de paneles de EPS	6	5	1	20,00%
Encofrado de bloques de EPS	9	6	2	33,33%
Paneles hormigón prefabricado	12	12	3	25,00%
Paneles madera contralaminada	8	6	4	66,67%
Estructura ligera de madera	20	17	3	17,65%
Estructura ligera de acero	18	18	3	16,67%
TOTAL	**82**	**71**	**17**	**23,94%**

Fig. 5 “Distribution of offers obtained by solution”. Source: Enrique Ramos Torres (Master Final Project)

Most of these companies sent a budget structured by chapters without details about their components. At the second requirement they reduced the budget. The costs of those chapters are compared below (fig. 6)

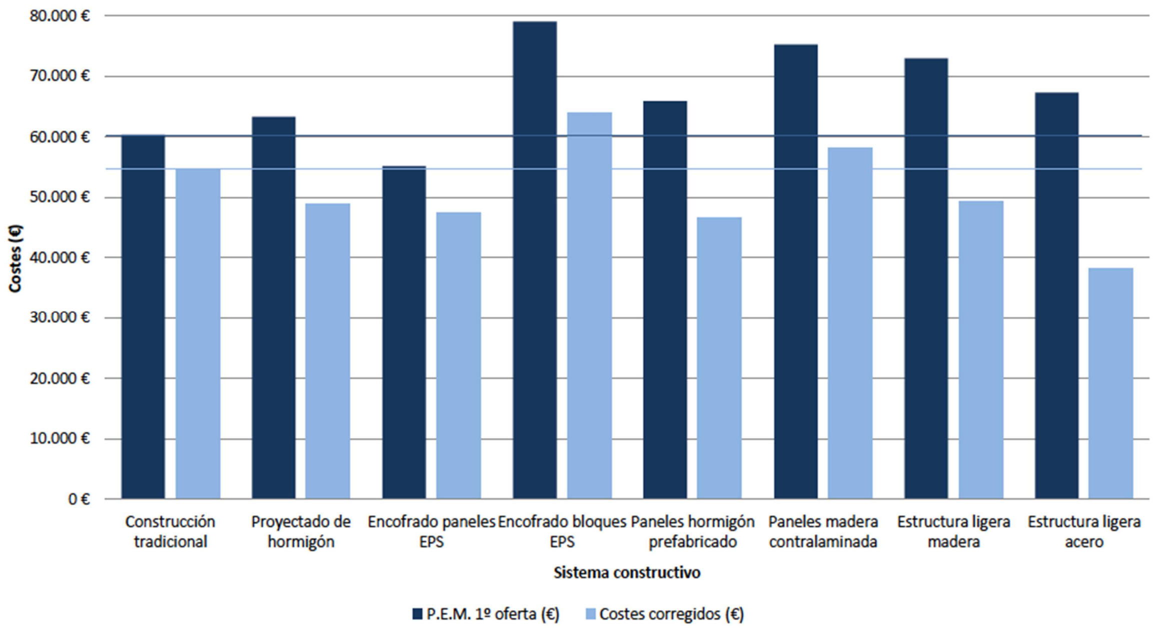

Fig. 6 “Comparison of the 1st and the 2nd economic offers received classified by constructive solutions”. Source: Enrique Ramos Torres (Master Final Project)

A comparison between U-values obtained with every system as ‘default option’ suggested by the company and those theoretical values based on the Catalogue of Construction Elements of the Spanish Building Code was also made (fig. 7), as well as a comparison between average execution times for the end of the building guaranteed by the company (fig. 8)

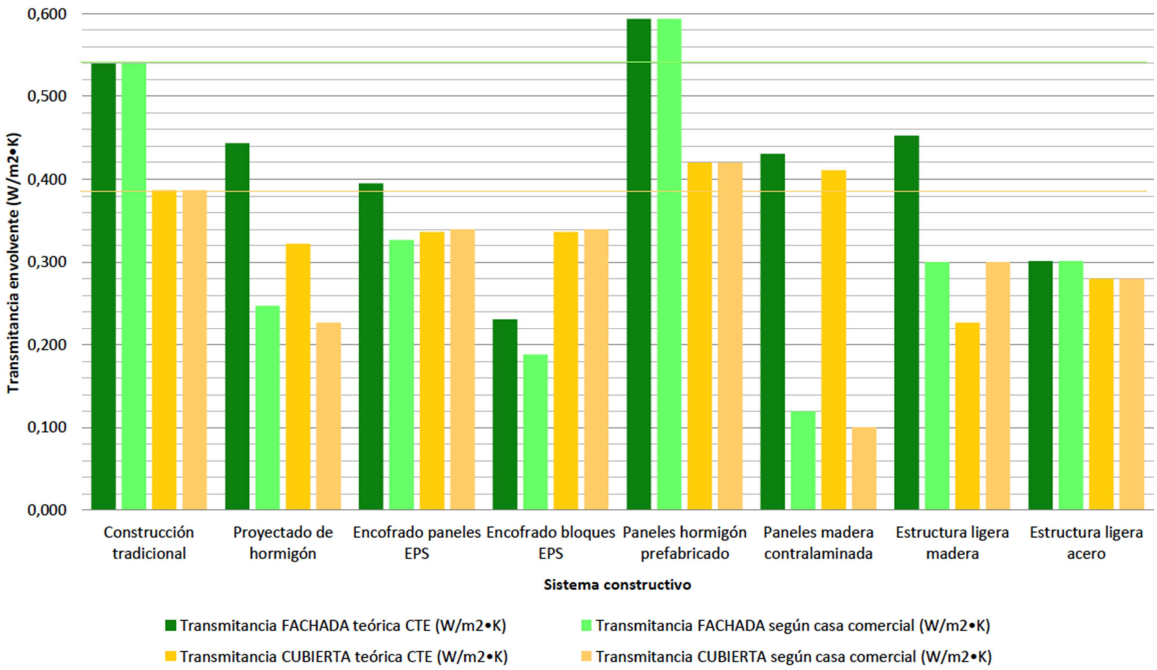

Fig. 7 “Case study: theoretical U-values vs provided U-values”. Source: Enrique Ramos Torres (Master Final Project)

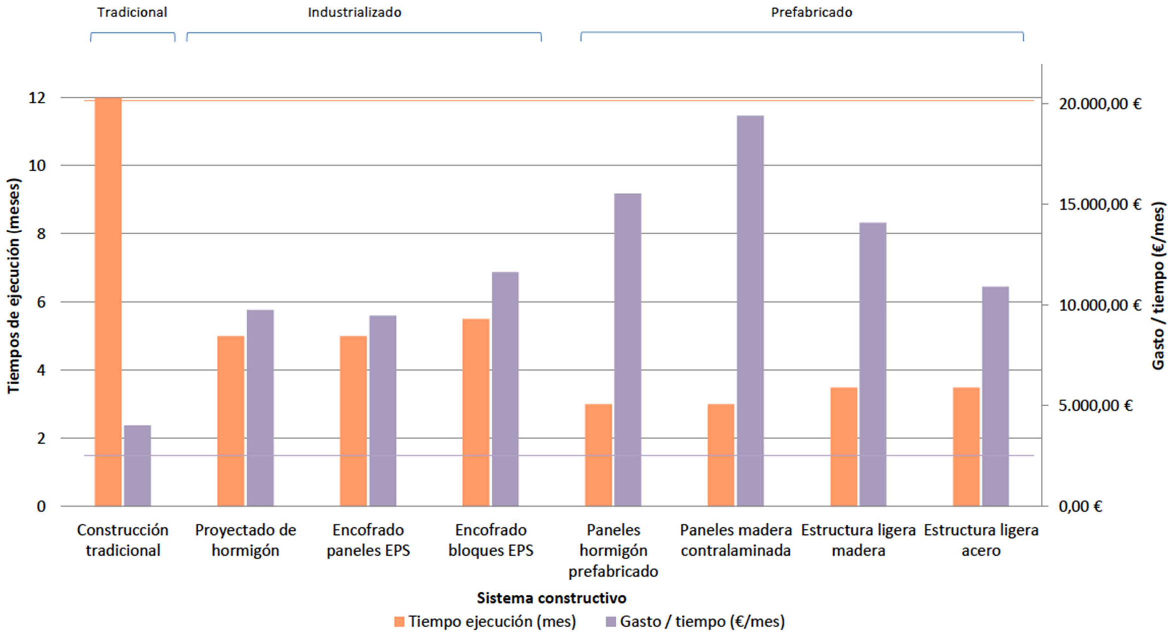

Fig. 8 “Case study: Constructive solutions, average guaranteed execution time and costs by month”. Source: Enrique Ramos Torres (Master Final Project)

Taking into consideration all of these aspects and the requirements of the promoters, Steel Frame structural system was chosen.
A summary of the constructive characteristics of every adopted solution is shown below.

5.1-Structural system
5.1.1-Foundation
According to the geotechnical study ordered to CEMOSA, a foundation was executed based on a reinforced concrete slab of 40 cm height (HA 25-B-30-IIa, normal control, B-400-S) placed at 1 m depth respect to ground surface. This slab was on a 10 cm of

poured concrete (HL-150/B/20). It has some embedded *Jimten* sinks as part of the sewage system.

5.1.2-Supporting structure

The supporting structure is a Steel Frame structural system composed by 2 mm thick S250GDZ275 galvanized steel profiles, disposed at vertically (C-form, 175.5x50 mm) and horizontally (U-form, 200x75 mm) linked between them and with foundation by means of hexagonal head self-screw bolts of 6.3x25 mm.

5.2-Construction elements

5.2.1-Vertical external wall

External thermal Isolation system composed by: starting screwed steel profile, treatment of the *viroc* panels supports with RHONA A-2000 devices to bridge the gap, tapping of rigid expanded polystyrene panels (according to UNE-EN 13499 with mortar RHONA T-700) and fixing cleats spread covering 6 unit/m^2, reinforce devices at every corner by means of corner brackets; superficial panel protection based on two mortar layers reinforced with alkali-resistant fibre glass mesh RHONAMESH T-150 of 145 gr/m^2; first coat layer done with REVIQUARZ; final coating made with white acrylic mortar REVIQUARZ. Interior finishing made with plaster board panels of 15 mm thickness anchored to omega-form steel profiles. The air gap of this structural system has been filled with 10 cm of rock wool of 100 kg/m^3.

5.2.2-Roof

The roof is composed by a non-woven double geotextile layer *danofelty* PY300 with short polyester fibres of 300 gr/m^2. Waterproof layer of grey coloured plasticised polyvinyl chloride (PVC) *Rhenofol* CG 1,2reinforced with non-woven glass fibre synthetic felt with a durability of 40 years, exposed even at the DIT400/R-09 in accordance with CTE. Flat roof system is finished by means of porous *filtrón* slab and extruded polystyrene, DANALOSA brand of 50x50 cm and 75 mm thickness.
Rainwater system is made by 'pluvia de Geberit' system connected to sewage system.

5.2.3-Openings

PVC frame windows of different sizes and dimensions. Security glazing 4+4 with 6 mm of butyl, air gap of 10 mm, and 4+4 with 6 mm of butyl. *Kimberling* premiline PVC frame system with thermal break and neoprene air tightness joints. Slide, close and security features.

5.2.4-Partitions

Made by means of plaster board partition 46/600 composed by two plaster board layers of 15 mm thickness each screwed at each side of a galvanized steel structure of horizontal and vertical profiles of 46 mm with a separation of 600 mm between axis. Between the two double plaster board layers the partition incorporate a rock wool panel of 40 mm thickness.

5.2.5-Building services

Conventional building services are implemented. The house is completely equipped with plumbing, sewage, electricity, telecommunications, cooling and heating active systems (a fireplace included), solar collectors and hybrid ventilation services.
It has to be highlighted the Geberit system installed at the roof to execute it without slope, as well as those *Jimten* sinks embedded in the reinforced concrete slab.

Solar domestic hot water is helped with heat pumps belonging to air conditioning systems. It was also proposed a domestic hot water system by means of a heat transfer from the heat air at the air gap, but it was discarded due to the space needed to allocate the accumulating tank inside the house.

6.-Problems found at the moment to introduce each eco-efficient alternative

The most important problems found during the design and building process in the case study are shown below. It is important to highlight that those complications never disappear once a stage is past but they are added to those appeared at new stages.

6.1-Preliminary draft stage

6.1.1-Modular and prefabricated systems are unknown

In general, university education lightly approaches to show most of these alternative constructive systems. This causes a great technical ignorance about their possibilities obstructing their adoption by building designers. Anyone who want to venture to introduce any of them starts with a burdensome ignorance that push the architect to walk a tightrope at technical level, without knowing, at first stage, their real advantages and inconveniences, their possible future pathologic problems due to a bad execution, and the current costs. Not to mention in many cases there is also an implicit difficulty on structure calculation and building code justification.

6.1.2-Systems incompatibility

Beside every commercial personnel guarantee that any design can be perfectly adapted to the chosen constructive system, the reality is that looking forward cost optimising and taking advantage of the real economy of these prefabricated systems, building design has to be modulated in accordance with industrial specifications.

The problem is that at early stages when nothing is really clear at all, especially if a system is more appropriate than other, even a certain product from different manufacturers, optimal dimensions for each one usually are different and that implies a huge increase of working office hours.

6.1.3-Small-print initial offers

Initial offers were rather economical (90% of the companies offered a budget 40% cheaper than the initial building), but they were full of small-print and ‘invisible’ terms trying to hide indirect costs and non-included ones that multiply the initial cost. At this stage, the architect turns out in a truly negotiator, running the risk of transferring promoters some economic expectations that can end up in a double-price (59% of the companies).

6.1.4-Difficulty to persuade promoter to move to non-traditional alternatives

Self-promoting in council areas are usually carried on by a type of promoters who want what they are accustomed to see at their immediate environment and are afraid of introducing anything new. This situation force the architect to be well-documented about advantages and inconveniences of those constructive systems to be able to take down every prejudice, during a debate, and achieve the promoter to rely on a constructive system which seems ‘rare’ for him and non-conventional.

6.1.5-Large secrecy from the companies

All contacted companies for every different studied system have shown a great resistance to send technical information that makes difficult to take a decision as well as to optimize the costs of the chosen system.

6.1.6-Delivery time dependent on third parties

When an architect considers using a non-conventional system has to establish a working time planning dependent on third persons, running the risk of breaking his own contract.

6.2-Base project stage

6.2.1-Constructive variability between systems complicates the base project wording and highly slows it

Each commercial brand has its own dimensions that, although not much, they vary all designed spaces (and their planimetric representation). Even more if we doubt between each other eco-efficient systems. This makes that even at base project stage, the designer ought to carry out constructive definitions as if it were at execution project in an stage with a heavy lack of information: at this phase results from the geotechnical study are not usually yet known but choosing a certain construction solution depended largely on the type of foundation to be executed as building costs highly varied. Several hypotheses have to be taken in consideration simultaneously to guarantee delivery times.

6.2.2-The project is redrawn in multiple occasions

Another problem derived of these initial phases where the system is not clear yet is that any change, by own decision or by a greater cause (more frequent than desirable in these types of constructive solutions), implies a complete redrawing of the project. In our case, once the final design was selected, the base project had to be redrawn up to six times adjusting it to different solutions to get real optimized offers. All this made within a delivery time that is not usually longer than a month.

6.3-Execution project stage

6.3.1-Difficulty to choose a eco-efficient system: 'pathological' indecision

A professional studio has little time to develop a project. This makes it difficult to have enough hours to be able to credibly and reliably choose a new system, among a set of variables, unless the team is well experienced in that.

One of the main inconveniences is that they are relatively new constructive systems not being executed enough time ago to know if they will produce any kind of constructive pathology in future or not. As all designers well know, commercial personnel will always try to sell their product and as much as they were asked about their future reliability, they will firmly answer that their product is magnificent and they haven't ever received any complaint. But it is almost impossible for them to show you a building executed with their eco-efficient product which has more than ten years. That's why 'general constructive culture' and a certain 'risk factor' come into play.

6.3.2-Construction lack of definition, imminent risk

50% of consulted companies make important lacks of information: although they send typological sections for façade and roof, these sections haven't got data enough to be able to value if this solution would cause any kind of pathology. And what it's worst: the companies didn't provide information about how mechanical fixes had to be made (to foundation, between profiles, etc)

6.3.3-Don't sign anything you don't know

Our experience tells us that companies tend to bind to sign a contract although there is a high lack of constructive definition not provided by them. Adjusted delivery times pressure and market dynamics contribute to high risk for agreeing to sign something to get some information lately found not to be enough or is not adjusted to building codes.

6.3.4-You won't find specific bibliography and if it exists it leaves much to be desired

Provided generalized ignorance about these systems the best thing is to learn by means of bibliography and contrasted technical documentation. It is suppose they will provide you more coherent and solid answer to your problem. But there is not so much specific bibliography and those documents aren't currently useful and don't treat the issue depply.

6.3.5-Guile as market value

It is common to discard some specialized companies during the execution project (in this case study it happened with eight different companies specialized in Steel Frame). Some business guiles were detected which caused the rupture of any professional relationship.

Some examples to bring to light this situation are: playing with small-prints in the budget and with the constructive solution, trying to force us to pay for a technical project if we wanted to get some technical information which usually is very poor, importing their materials and profiles from foreign countries or distorting delivery times and final prices.

In this case study each of those eight contacted companies refused at first time to give technical information about their steel profiles, even dimensional information, far from giving thickness and nothing at all about galvanization type. The current situation is that although all those companies are focused on building a single-family isolated house made with a Steel frame system and adjusted to CTE requirements each company provides different types of steel profiles, different thickness and different galvanization protection.

Few days to hand the execution project we knew there are no Steel frame industries in Spain. Here in Spain these companies usually have galvanized steel coils (in most cases imported from China) and other equipment to finally ending up hand making *in situ* every special piece for fixtures and finishes.

6.3.6-Working with eco-efficient solution usually means large displacements

Eco-efficient solutions usually have a wide distribution net but factories are placed in certain nodes, at Northern Spain in general (fig. 9). This implies that if a certain system or manufacturer is wanted to be deeply known the architect should have to travel to those factories to know the product at first-hand and to be able to ask *in situ* every doubt he could have, increasing the embodied energy of a project supposed to be efficient.

Displacement factor, thus, acquire high importance at the moment of budget calculation as the product has to be brought to building site from places enough away and also these solutions have to be executed by specialized people who have to be displaced and accommodated for a certain period of time.

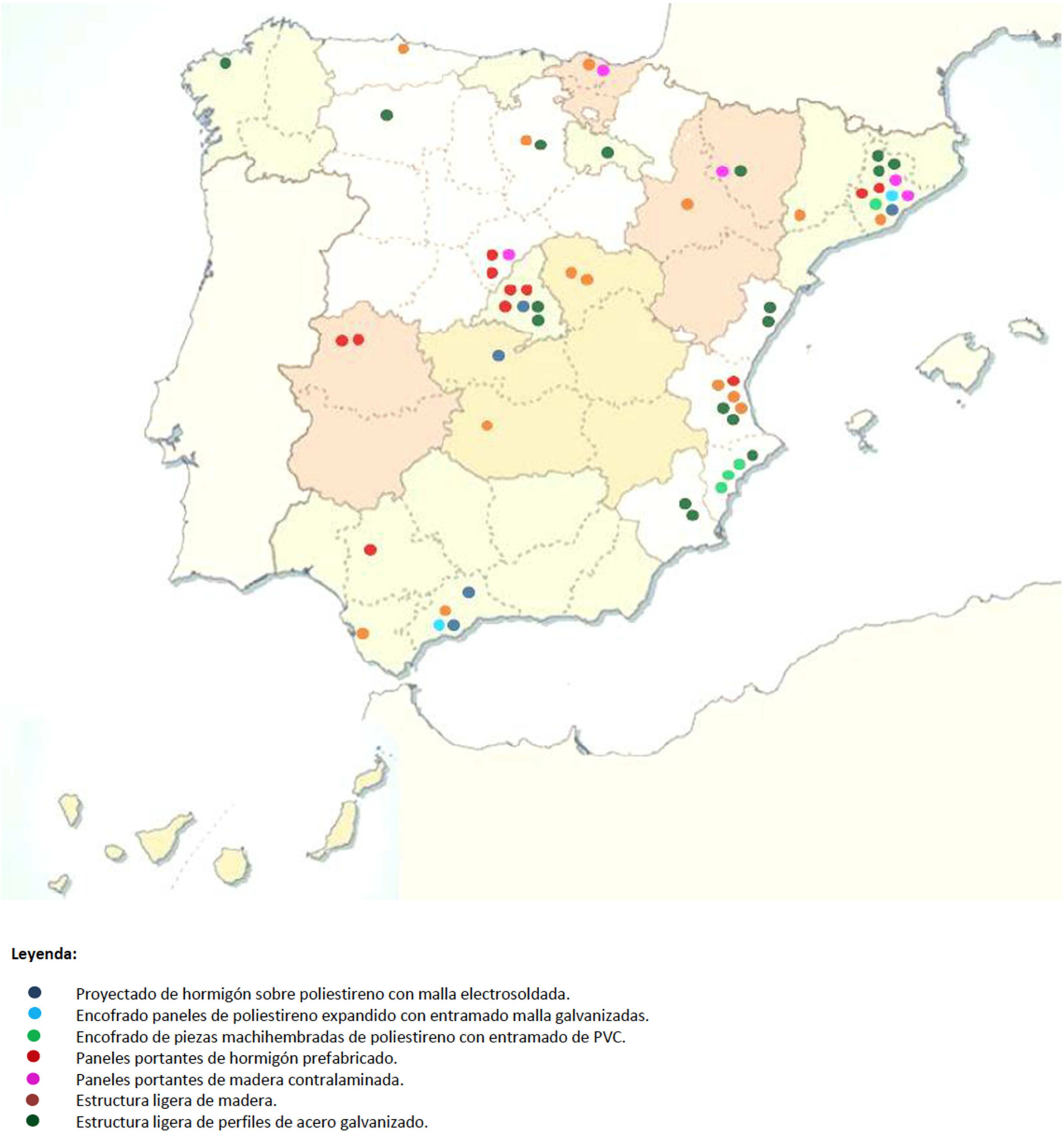

Fig. 9 “Case study: Localization of contacted companies”. Source: Enrique Ramos Torres (Master Final Project)

6.4-Built-in supervision stage

6.4.1-Eco-efficient solutions require an intense and exhaustive supervision

These solutions that are able to generate a large built-in volume in short time require weekly intense dedication by the architect to sure appropriate execution. At least they require two or three visits a week.

6.4.2-Distance between building site and headquarters usually generate problems with final revision

Distance between building site and the headquarters of the company which is executing the chosen eco-efficient alternative system makes that once they have finished its work if a problem is detected it is very hard to convince this company to solve it in person due to economical costs. Any complaint is solved virtually on line.

6.4.3-Tolerances are minimized, stress is increased

Prefabricated systems fit together as ‘kits’. They have pretty low tolerances. Any mistakes putting land references or working with concrete, which has intrinsic tolerances (like a bad-executed slab foundation) causes serious economical problems and important delays. That’s why the architect has to have an exhaustive control that is usually transformed in repetitive orders, high technical persistence and annoyance generating conflicting stress.

6.4.4-Non-payment to third parties is emphasize

Usually this type of solutions requires auxiliary equipment and some non-specialized workforce who is recruited locally due to it is cheaper. The distance between the headquarters of the main company and those third parties increases the possibilities of non-payment as it seriously obstructs any complaint resolution.

7.-Conclusions

Implementing eco-efficient solutions in architecture is an absolute and undisputed necessity under our point of view. Their slowly widespread has been focus of multiple debates. Nevertheless, derived from our experience (exposed in this case study but more numerous) it is demonstrated that professional curriculum can act as a double-edged sword at the moment to face with application of these alternative constructive systems.

If they try to assimilate them starting from traditional lessons learnt about traditional constructive solutions performance and execution they will continuously fall in some mistakes.

Knowing the risks taken is fundamental in this project organization but also new problems it will have to face with if it wants to design more sustainable, ecological and efficient architectural reality.

The fact is that despite all efforts, in our case study, and being within an economical crisis, this house has been revaluated 50%.

ACKNOWLEDGMENTS

Authors want to thank complete team from Estudio Heliopausa S.L. for their energy and implication on developing and executing this project.

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