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Adaptación termo-energética de viviendas sociales evolutivas mediante una envolvente sostenible para zonas áridas.

Sustainable Thermo-energetic adaptation of evolutionary social housing through a sustainable envelope for arid areas.

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Resumen-- **El objetivo del trabajo considera, el desarrollo de una envolvente sostenible para la adaptación termo-energética de la Vivienda Social Evolutiva en Zonas Áridas. La metodología empleada considera estudios teóricos y prácticos a Escalas Urbana, de la Vivienda y Constructiva. Los que guiaron la investigación a estudios tecnológico-constructivos de la envolvente, del comportamiento térmico y la eficiencia energética (EE), con propuestas de mejoramientos a los prototipos base y ampliado considerando normas de Nivel Internacional y Nacional (ISO, CTE, IRAM). Mediante la utilización como herramienta para el análisis, de un software con antecedentes en distintos sistemas informáticos de computación, reconocidos a nivel internacional, y aplicados a la eficiencia energética edilicia. Para estos casos, los resultados cuali-cuantitativos demuestran alcanzar EE bajas, con clases H a F. Y para el Ampliado Optimizado Propuesto, con incorporación de capas complementarias termoaislantes sustentables exteriores, se obtiene una EE alta, clase B, transmitancia media ponderada K'_m=0,41W/m^2·K, con una variación térmica media ponderada τm=1,44°C. Se concluye, que cuando el mejoramiento termoaislante integra a toda la envolvente desde el diseño original, se alcanzan EE con cumplimiento a categorías de transmitancias térmicas recomendadas por Normativas.**

Palabras clave— Adaptación termo-energética; viviendas sociales progresivas; envolvente sostenible; zonas áridas.

Abstract— **The objective of the work considers the development of a sustainable envelope for the thermo-energetic adaptation of Evolutionary Social Housing in Arid Zones. The methodology used considers theoretical and practical studies at Urban, Housing and Construction Scales. Those who guided the research to technological-constructive studies of the envelope, thermal behaviour, and energy efficiency (EE), with proposals for improvements to the base and expanded prototypes considering International and National Level standards (ISO, CTE, IRAM). Through the use as a tool for analysis, software with a background in different computer systems, internationally recognized, and applied to building energy efficiency. For these cases, the qualitative-quantitative results show reaching low EE, with classes H to F. And for the Proposed Optimized Expanded, with the incorporation of complementary external sustainable thermal insulating layers, a high EE is obtained, class B, weighted average transmittance K' m=0.41W/m2°K, with a weighted mean thermal variation τm=1.44°C. It is concluded that when the thermal insulation improvement integrates the entire envelope.**

Index Terms— Thermo-energetic adaptation; progressive social housing; sustainable envelope; arid zones.

I. Introduction

In 2015, the UN approved the 2030 Agenda for Sustainable Development, an opportunity for countries and their societies to embark on a new path to improve the lives of all, leaving no one behind (United Nations O. 2015). Goal 12 of this Agenda: Ensure sustainable consumption and production patterns, considers that global consumption and production depend on

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the use of the natural environment and resources in a way that continues to have destructive effects on the planet. Sustainable consumption and production are about doing more and better with less. It is also about decoupling economic growth from environmental degradation, increasing resource efficiency and promoting sustainable lifestyles. Sustainable consumption and production can contribute substantially to the alleviation of energy poverty, and the transition to green, low-carbon economies (Calvo R. et al. 2021).

The government of Argentina, after the systematization of studies carried out at the national and international levels, is developing a project on the construction of a coherent, robust and monitorable indicator, based on the analysis of databases of 17.5% of households that are equivalent to 10 million people in a situation of energy poverty. It should be noted that it has the support of ECLAC and the Energy Poverty Network - RedPE, of the University of Chile (Argentina.gob.ar, 2019).

II. Description of the problem and state of the art

In federal states such as Argentina, common policies are resolved with a strong character of institutional interdependence. However, the situation observed in the VSE-IPV of San Juan is that they remain outside of it

process, and because they are not aligned, they counteract the partial achievements obtained in similar geographical areas.

For this reason, and with the aim of being able to provide answers to the limited existing urban planning, since the VSE present inadequate orientations to take advantage of natural energies (Fig. 1), and to the inefficient technology consequential to the use of natural energies, the VSE is not the same as the use of natural energies.

Fig 1. B°AMECOM 4 view with equal resolution in south and west orientation.

Fig. 2. VSE-IPV West Facades with or without Covered Carports and Active AC Equipment on Roofs

The *study problem* is aimed at trying to reverse the global situation of energy poverty, by reducing the demand for energy of the weakest, as well as needy inhabitants of Arid Zones, and avoid the "unnecessary" high consumption of energy to cover fundamental and basic needs in their deficient social housing.

This situation is demonstrated through the VSE-IPV built

in San Juan, to have a very limited knowledge of the reality described, in relation to Guarantee sustainable consumption and production patterns, such as adjusting the hygrothermal parameters inside the buildings. Therefore, to guarantee this modality, it must not be solved only through mechanical systems and "active" energy-consuming installations but also considering the conditions of the place and the potential of the climate (Fernández A., Garzón B. S., & Elsinger D., 2020).

Home heating is crucial for the definition of energy poverty and was one of the energy services that initiated the international discussion on this matter by problematizing the affordability of thermal comfort, mainly in European countries. In accordance with this, the WHO recommends maintaining indoor temperatures between 18ºC and 23ºC when the home is inhabited. Other research indicates that the risk of respiratory diseases increases below 16ºC and cardiovascular diseases increases below 12ºC (Calvo R. et al., 2019).

Therefore, the *hypothesis of this work* considers that with the sustainable thermo-energy adaptation of the VSE-IPV of San Juan – Argentina, through a sustainable thermal envelope

and efficient, complementary to the existing one, it is possible to obtain adequate interior thermal comfort, together with contributing to the reduction of energy demand over the increase in consumption of users, which impose active strategies.

Thus, the *general objective* considers the analysis of the responses to the climate and the conditions of the environment foreseen at the urban scale, existence of basic passive bioclimatic strategies from the project stage considered at the building scale, aimed at providing appropriate improvements to the integrated elements and components, at the constructive scale in this sense, after analysing the different scales, the following partial objectives are proposed for the construction envelope of the SST: to consider the climate together with the context in the design, to determine the thermo-energy capacity in the base and extended prototypes, to contribute to achieving the thermal comfort of users with limited resources in response to energy demand, to limit energy demand by applying a procedure for calculating heat transfers appropriate to their evolutionary process, Reduce the energy consumption associated with the pre-existing envelope.

And determine an "appropriate" construction system, which incorporates local materials together with the integration of the labour of the users, considering minimizing the environmental impact linked to the emissions produced and promote economic savings.

A. *Methodology, Strategies and Materials*

So far, 490 homes have been built. And 837 homes are under construction in different departments of San Juan. Both within the Warm Temperate IIIa and Warm IIa Bioclimatic Zones.

Fig. 3. Planimetry Central Area of the AMECOM Neighbourhood 4.

Fig. 4. Perspective of the Neighbourhood prototype with North access.

Considering the future growth of these VSEs, they will have a housing capacity for 2940 people with low resources.

In the case adopted as characteristic, and which is analysed in this work as representative of the VSE-IPV, with the same construction typology, the AMECOM 4 neighbourhood of Rawson has been selected. And for the purposes of the study, the central northern sector of this neighbourhood was chosen, because, in the north and south sectors, the Amecom 4 neighbourhood adjoins and integrates respectively neighbourhoods already built.

Considering the construction technology used in the envelope of the VSE and the requirements they present, in order to solve Energy Efficiency together with its "seed-type" constructive growth (Gelabert-Abreu D. and González-Couret D. 2013), with progressivity in quantitative extension and improvable in quality, a research process is used as a methodology that allows valid results to be achieved to alleviate Energy Poverty in different bioclimatic zones.

To this end, they were considered, starting from the decomposition of the study into parts or scales, to analyse them individually and then through a resulting synthesis to study them in a comprehensive way, using a quantitative method that considers Energy Efficiency (EE). To this end, the following sequential studies were applied:

1) Analysis of sectoral bioclimatic urban and architectural design

At the urban level, the orientation of the energy-architectural match of the 55 VSE-IPVs of this complex, do not follow a single location pattern in response to the climate. On the contrary, they are oriented and built in different opposite directions, without adequately considering the use of natural energy from the sun and the wind.

As can be seen indicated by the red line, through the planimetry (Fig. 3), 18 houses have been arranged that are accessed from the north, but that do not take advantage of the winter sunshine.

In addition, there are 8 VSEs that are entered from the West, and 10 that are accessed from the East, which do not take advantage of "passive" solutions such as refreshing wind in summer and adequate indoor sunlight in winter. And there are 19 homes, which are accessed from the south and which, if they could take advantage of both the wind and the sunlight to cool and heat, 50% of the living spaces of the prototype to be finished, due to the compact distribution of the floor.

In this sense, in only 1/3 of the VSE (and its associated impact) energy consumption could be reduced due to their implementation and location on the north-south axis. Therefore, the Urban Scale proves not to have a systemic design approach, to control the microclimate of open spaces, and favour access to sun or air breezes. In the perspective of the project of the

Fig. 5. Dark façade colours without block centres

Fig. 6. Dark Colores of Facades with Center Blocks.

expanded prototype studied (Fig. 4), it can be seen how the northern growth of the garages shades the bedroom openings, because it has an extensive covered area.

In general, the materiality of the original envelope used by the IPV, in the VSE of the entire neighbourhood complex, proves to be of low energy efficiency, as it is limited to placing only a scarce thermal insulation on the roof, which forces users with limited resources to depend on active energy-consuming systems.

2) Analysis of shape, location, growth and climate

The rectangular shape design is energy efficient. In warm temperate climates, it has been proven for single-storey buildings that to avoid energy consumption, the best building is rectangular in shape, but with the major axis in an east-west direction. Fig. 7 shows the distribution of spaces, habitable to the north and non-habitable to the south, considering a theoretical and interpretative proposal of the most energy-efficient party such as the one proposed by Fernández R. and Carella A, (1981). In the figure, the floor plan of this district and its functional areas have been schematized considering its future growth through the corridor, on a wider plot of land than that originally adopted in the neighbourhood.

This provision coincides with what is explicit in the description of the problem and state of the art when considering the need to adjust the hygrothermal parameters, inside the buildings taking advantage of the conditions of the place and the potential of the climate, to avoid leaving the conditioning of the interior climate, only to the mechanical systems and "active" installations that consume energy.

On the other hand, this situation is in line with what was stated by the Valencian Building Institute of Spain (2014), in relation to the fact that, due to current technological advances, construction practices based on passive design have been abandoned.

In addition, it is highlighted that a large part of the energy needed to heat or cool a home can be saved, if it is based on a good architectural design based on bioclimatic strategies, which bring interior conditions closer to those of human comfort.

The design of the shape of the base SST shows an implantation from the middle of the batch and ends towards the front (Fig. 8). This resultant, which corresponds to the "seed" type modality, maintains from the beginning a coherence in the urban language. And it shows that the starting point considered in the design of growth agrees with and close to the thought of Sullivan L. H. (1922), who expressed that "*form always follows function*". This thought is further confirmed by the arrangement of the openings, which are always arranged perpendicular to the growth edges of the social and private areas.

Fig. 9 shows more clearly how the Special Growth of the VSE towards the interior of the lot, which is destined to occupy the other half of the land, and does so through the private or social zones, was programmed from the Project. With respect to envelope I and II, it is visualized, as it doubles III and IV respectively, but so will its exposure to thermal impacts.

In this case, the expansion of the IPV prototype in its basic growth demonstrates a spatial relationship of juxtaposition. Because the plant can grow since the new construction touches the previous one. In the social area the living room is created and in the private area the private bathroom is created next to the master bedroom. This spatial extension facilitates the functional intersection of the dining room with the living room and the secondary bedrooms with the main one.

However, there is obviously a great difference with respect to what L. Sullivan proposed, in relation to the design methodology adopted by the IPV and the analysis that V. Olgyay (1963) proposes, in terms of design and its form, together with the resulting building growth. In which climatic parameters and contextual conditioning variables must be considered, "*from the outside in*".

These results show that when the VSE are improperly implemented, the amount of insulation will increase to the extent that their orientations favour the increase of thermal impacts on the envelope.

3) Analysis of the climate of the place, Proposal of Passive Strategies according to Bioclimatic Zones and technological response of the envelope.

In general, in this arid-dry zone and within the Warm Temperate Suburban Subzone IIIa it has a Water Deficit of 781mm/year, annual average rainfall of 96 mm, thermal amplitudes greater than 14°C, average seasonal Global Solar radiation varies from 335W/m^2 to 621W/m^2 between winter and summer respectively. Summers are relatively hot with average temperatures ranging from 14.7°C to 24.8°C, and with average maximums exceeding 33.1°C, only on the E-W extension belt.

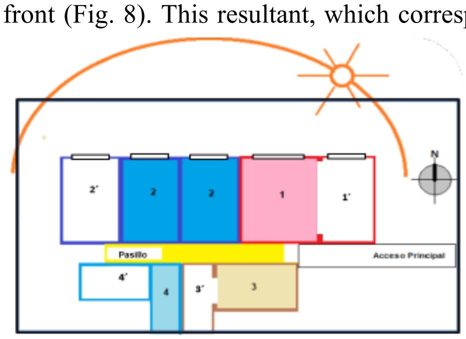

Fig. 7. Graphic interpretation of the proposed efficient party. References: 1- Living room, 1´- Dining room extension, 2- Children's bedrooms, 2´- Bedroom extension 3- Kitchen, 3´- Future laundry room, 4- Bathroom, 4´- 2nd bathroom.

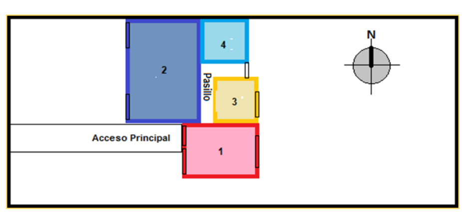

Fig. 8. Base Prototype Schematic Floor Plan. References: 1- Living room, 2- Children's bedrooms, 3- Kitchen, 4- Bathroom.

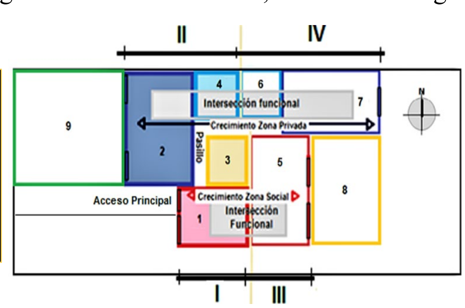

Fig. 9. Schematic Floor Plan of the Extended Prototype. References: 1- Living room, 2- Children's bedrooms, 3- Kitchen, 4- Bathroom, 5- Eat, 6- Private bathroom, 7- Bedroom floor, 8- Gallery, 9- Covered garage.

It has low relative humidity, reaching 47% in January and 65% in June. Winter is not very cold and has average temperatures between 8°C and 12°C, and minimum values that are rarely less than 0°C. The annual partial pressures of water vapor are low, with average summer maximum values of 1870Pa (14 mm Hg). The predominant cool winds and somewhat loaded with humidity measured at 2 m. altitude, are those coming from the southeast quadrant in 43.20% per year and south in 15.31% per year. Among the occasional winds is the zonda, which is a strong, warm and very dry wind.

The Ministry of Housing (2019) of Argentina has created Minimum Quality Standards for Social Interest Housing (EMC-VIS). This entity works to promote comprehensive, affordable and sustainable housing solutions based on Social Approach Stages. Shaping quality projects that incorporate components of efficiency, effectiveness, sustainability, urban integration and secure tenure. And it is proposed to place the beneficiary of the housing solution at the centre of housing policy, encouraging the execution of quality solutions that ensure durability and promote economic savings in homes. In its 2019 Review, it proposes as an objective the optimization of comfort conditions in homes and outdoor spaces, consequently, the reduction in energy demand through the incorporation of specific guidelines and strategies.

In winter, the sun could penetrate through the openings to the east and west, if there are no obstructions such as the roofs programmed for the gallery and covered garage. Since for it to reach the bottom of the premises, its depth should not be greater than 2 to 2 and 1/2 times the height of the window measured from the floor. On the contrary, when the elongated shape is not in the north-south direction and the openings are in the east-west direction with the depth is greater than 2 and 1/2 times the height of the window, solar radiation will not reach the bottom of the living space.

In addition, in hot summer climates, it is advisable to lengthen the dwellings and allow a wide sweep of ventilation through the windows, a situation that is limited since in the rooms the facades are also reduced to half that they could be if they were arranged according to the E-W axis. The elongated east-west shape will allow good lighting, for which the windows must be related to the size of the room and the width of the land. Its depth may be shorter so that the surface of the same is maintained.

At the same time, within the EMC-VIS, in the Growth section, the need for the user to have a Home Extension Manual is highlighted. And about Energy Efficiency (EE), it specifies the minimum conditions that must be met by the exterior enclosures of homes to reduce temperature loss and guarantee an acceptable level of thermal comfort, IRAM 11601 (2012). And he clarifies that the concept of EE consists of the Rational Use of Energy. It is the difference between the amount of energy used in an activity and the amount planned for its performance. The more efficient energy the home, the greater the savings in energy consumption.

4) Studies of thermal behaviour and EE of the VSE-IPV enclosure. Proposals for improvement.

Evaluating the energy efficiency of a home based on a survey of it and obtaining the corresponding Label in accordance with the procedures established at the national level, is not an easy task, if you do not have the necessary acquired knowledge. To this end, the Qalcular online computer tool has been considered, which allows both professionals and users to provide recommendations or make efficient improvements.

In this, priority is given to evaluating the energy demand of new housing projects or those in use, from the point of view of the energy efficiency of their envelope and generating a label. This is carried out based on the weighted average thermal transmittance of the outer envelope (K´m). On the other hand, each energy efficiency class is linked to the condition of the weighted average variation (τm). The τm, or temperature difference between the interior surface of the enclosure and the interior design surface in the centre of the premises, is determined at 20 °C.

The selection of the tool created by the Institute of Energy and Sustainable Development - IEDS (2017), is linked to being able to facilitate to consumer users the possibility of managing variations to the base project, including passive strategies aimed at reducing energy demand in all stages of the VSE and in the different elements of the envelope based on the two variables mentioned τm and K´m. By choosing sustainable construction systems, achievable with opaque materials (masonry, plaster and thermal insulation, etc.), non-opaque (air, openings with DVH, etc.) and according to the weather stations considered by the computer tool.

1- τ_m = **Diferencia** de la Temp. entre la **superficie interior** de la envolvente (componentes) y la temp. interior de diseño que se da en el centro del local, la cual está determinada en **20 °C.**

$$\tau_m = \frac{\sum_1^{n\,comp}(\tau_i . S_i)}{\sum_1^{n\,comp} S_i}$$

- $\tau_i = 0{,}13 \frac{m^2.k}{W} . K_i . \Delta t$
- $0{,}13 \frac{m^2.k}{W}$ - la resistencia térmica superficial interior, en °C,
- K - la transmitancia térmica (m^2°K), $\frac{1}{Rt} = \frac{1}{Rsi + \Sigma Rn + Rse}$ (Catidad de calor que atraviesa un componente)
- Rt - resistencia térmica superficial total (m^2°K/W), $= \frac{e}{\lambda}$ espesor del material / conductividad térmica (cap. de conducir el calor)
- Ki - la transmitancia térmica de cada una de los componentes de la envolvente (Wm^2°K),
- Δt - la diferencia de temperatura de diseño interior y exterior (°C), y
- Si - la superficie de cada una de las componentes de la envolvente (m^2)

2- *K´m* = Transmitancia Térmica Media Ponderada de la **envolvente exterior** del local, para brindar respuestas a la **demanda de energía** de viviendas en proceso y/o construidas.

$$\tau_m = \frac{\sum_1^{n\,comp}(\tau_i . S_i)}{\sum_1^{n\,comp} S_i} \quad \therefore \; \tau_i = R_{Si}.K_i.(t_{int} - t_{ext}) \quad K_i = \tau_i / R_{Si}.(t_{int} - t_{ext})$$

And where the results are exposed on a label that has a scale of letters A to H, (Fig. 10). The letter A is assigned to the most efficient envelopes, and with the H to the least efficient envelopes, associated with ranges of K´m values of the exterior envelope of the premises or building. On the other hand, each

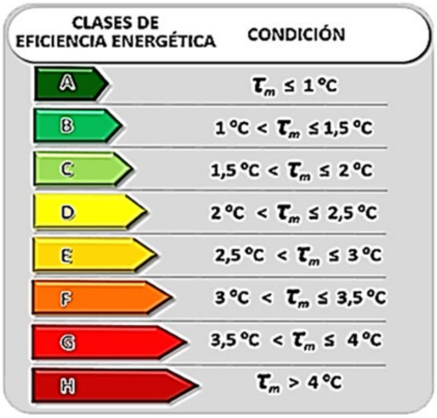

Fig. 10. Energy efficiency classes and weighted average variation of the internal temperature τm.

energy efficiency class is linked to the condition of the weighted average variation of the interior temperature of the envelope τm.

In this sense, it was analyzed *how and when is the time to begin a process of sustainable improvement* of evolutionary social interest housing, in which the growth of housing with the minimum possible demolition must be foreseen.

Users must be able to add anti-seismic spaces, which allow responding to a high level of energy efficiency, through the analysis of the following alternatives:

5) Base housing built and delivered by the IPV to users

It is worth mentioning that they have an earthquake-resistant structure of Reinforced Concrete (H° A°), brick masonry, interior plaster with lime plaster, latex paint after the placement of plaster, exterior plaster with rustic finish and latex paint, ceramic brick slabs or H° A° with applied plaster ceiling, roof covering next to a slope of lightened concrete with thermal insulation with EPS beads and asphalt membrane coating on leveling folder.

The partial results obtained with the Qalcular software (Fig. 15) show that, for the house without growth with an enveloping area of 158.84m^2, a K´m of 1.91W/m^2°K and a τm of 6.59°C are obtained. Therefore, it corresponds to the H class of EE or the one with the lowest efficiency, because the τm exceeds the thermal condition of 4°C by 2.59°C.

6) Base housing expanded and improved by users with sustainable criteria

Low-cost improvements have been introduced to housing with growth, considering finishes that users with limited resources are used to or can make during and during the expansion, under the perspective of the Rational Use of Energy (ERU). Such as thermal quality improvements over existing openings that include overlapping windows, identified as double windows. Double windows allow the original single windows to be reused, without chipping the surrounding structures or walls and including a thermal breaker between them. In addition, to improve privacy and luminosity along with thermal transmittance, interior curtains have been placed.

On the other hand, bio-degradable vinyl tiles have been considered as floors in the expanded area of 46m^2 on folders containing perlite as a thermal insulating material of natural volcanic origin, under two different presentations, as part of a complex next to cement and as loose fill.

Also in order to unify finishes on the existing base area of 57m^2, the same plastic tiles adopted for the growth zone have been placed as floors, because these finishes can be easily adhered to the pre-existing worn floors, whether concrete or low-quality ceramic.

In addition, and to improve the thermal and water-repellent insulation of the VSE on the new area, loose perlite in a thickness of 15cm was adopted as a fill in order to improve the slope of the roof covering, which was finished by a folder with 2cm perlite. And finally covered by a composite roof
By 5mm asphalt felt, painted with 1.5mm white acrylic resin.

The partial results obtained under these conditions (Fig. 15) and for an enveloping area of 270.90m^2, show an improvement in the K´m of 1.24W/m^2°K, and therefore in the variation of τm in which a value of 4.29°C is obtained. But because τm exceeds the thermal condition by only 0.29°C, it also corresponds to the US class H.

7) Expanded Housing, after being improved by the users, includes flexible, appropriate and appropriable technologies with sustainable criteria.

Subsequently, and in continuity with a perspective with URE or conservationist thermal, which considers preserving the improvements of the user described above, the inclusion of a new "complementary thermal insulating skin" has been proposed, on top of the existing opaque envelope.

Fig. 11. Views of the pomeca, mold on vibrating table and plate of the precast ceiling mounted on the roof.

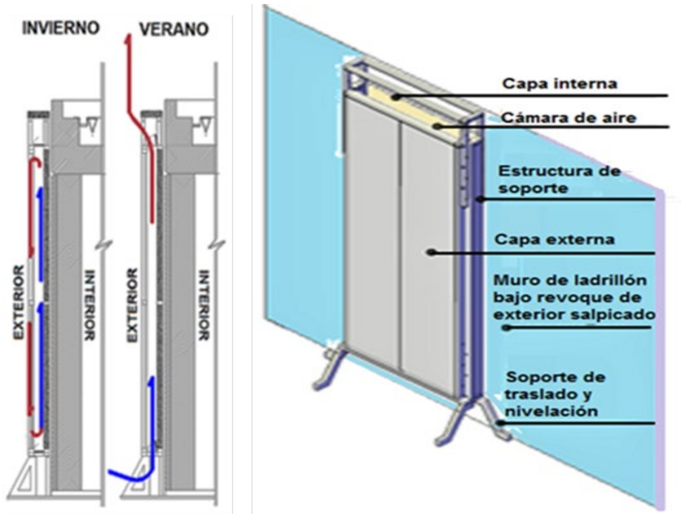

Fig. 12. Detailed cutting of seasonal operation and views with thermo-insulating system specifications.

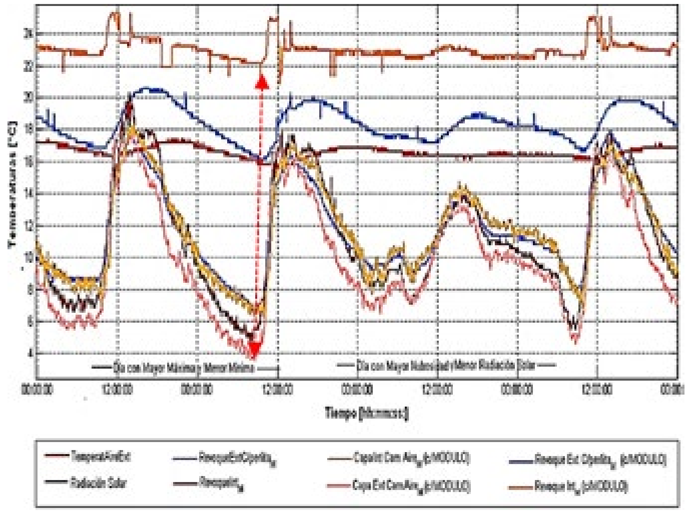
Fig. 13. External-interior thermal behaviour in the winter stage of the wall with the insulating prefabricated module.

This skin considers on the walls the inclusion of a light modular envelope composed of loose perlite in layers of 5cm with an intermediate air chamber of 17cm. And on the roof, it considers the inclusion of a precast ceiling of cement-pomec complex on a 4cm air chamber. To this end, this "complementary skin" has been extended both on the walls and ceilings of the base house and in the extended area.

The partial results obtained under these conditions and for an enveloping surface of 270.90m^2, demonstrate a more convenient K´m of 0.91W/m^2°K, in which a variation of τm equal to 3.07°C is obtained. Because the τm exceeds the thermal condition by only 0.07°C, it corresponds to the F class of EE (Fig. 15).

8) Extended Housing that ceases to be understood as an object, to be understood as a process that includes the user and begins from the original design called: Proposal for energy optimization integrated into the envelope, considered for a sustainable design.

As a component of an exterior horizontal complementary envelope system, the pozzolanic properties of PP in its natural condition were exploited. Studies of structural behaviors were developed jointly by the IMA-FI-UNSJ Institute, of Argentina, and the Institute of Concrete Science and Technology, Polytechnic University of Valencia, Spain (ICITECH-UPV), (García Figueruelo B. et al., 2017). For its application both in prefabricated elements, as well as in mortars for plasters and folders.

This form of use allows a partial substitution of Portland Cement, under a sustainable technical vision. Thus, the proposed optimization improvement, for the house with growth of 103m^2, considers the incorporation of a roof overhead, with a new insulating contribution on the existing roof that introduces a horizontal air chamber.

This air chamber is generated by precast compounds composed of a 1:10 pozzolanic cement-pomec complex, executed on a vibrating table (Fig. 11). It is worth mentioning that the figures of the table and the vertical plate were published in Buigues Nollens A. (2013). Both the sustainable construction technique and the experimental results of the thermal behavior were obtained in the IMA-FI-UNSJ laboratory (Buigues Nollens A. 2013).

These improvements in EE and thermal quality were complemented by the incorporation of a vertical ventilated prefabricated thermo-insulating system in the façade walls, depending on the station.

As can be seen in Fig. 12, the vertical system is made up of a modular support structure whose movable, disassembleable, and reusable components include loose, granulated, shaken pozzolanic pomec as a regional fireproof thermal-insulating material of volcanic origin, both in the outer and inner layers, both with a thickness of 5 cm. These layers include an intermediate air chamber, which remains closed in winter to improve thermal insulation and open in summer to promote natural air thermocirculation.

he integrated design of these new complementary layers, both horizontally and vertically, make up an opaque envelope, which has been developed under a non-destructive perspective, whose components are executable in a prefabricated form and applicable through a simple execution practice "in situ" that allow their subsequent reuse.

The interior exterior winter thermal behavior of the experimental wall in the laboratory, with the complementary thermal insulation module shows us in red (Fig. 13), that while the outer layer reaches 4.12°C, the inner layer of the plaster reached 22.15°C. Reaching a thermal amplitude of 18°C. It is worth mentioning that Fig. 12 and 13 have already been published by the author in Buigues Nollens A. (2021).

Therefore, from the point of view of energy efficiency and in order to achieve the minimum category of comfort B suggested and the EE class recommended by the IRAM 11900 Regulation (2010), the improvements studied only for the extended area of 46m2, have been extended to the entire 103m2 plant, by means of an Energy Optimization Proposal integrated to the entire envelope. both opaque and transparent, and considered from the initial project stage for a sustainable design of the SST.

The partial results obtained under these conditions and for an enveloping area of 270.90m^2, demonstrated a suitable K´m in the order of 0.41W/m^2°K, and a τm of 1.44°C is obtained. Because τm is between 1°C and 1.5°C, it corresponds to EE class B (Fig. 15).

B. Strategies applied

On the other hand, the Qalcular software was applied as a quantitative research strategy. This tool establishes a simplified methodology of value for projects scientific-technological within the framework of a defined environmental policy, aimed at calculating the level of efficiency of the envelope in buildings with human habitation, susceptible to heating, due to their proven acceptance and public utility (Battaglini F. and Vaucheret V. 2020).

This program presents as a background the analysis of different computer systems, recognized as

international level applied to building energy efficiency, such as: Lider Calener, Archisun, MIT Design Advisor, Energy Plus and HOT2000. They were downloaded and tested in their most usual aspects (Battaglini F., 2016). At the same time, this analysis highlights some comparative advantages of the program developed at the IEDS, such as the use of climate data from the different bioclimatic zones of the country.

C. Technological characteristics and materials of the proposed envelope.

As part of the sustainable technology characterized by being "appropriate" for the region and at the same time "appropriate" by VSE-IPV users, the application of Pozzolanic Pomeca (PP) was planned in a comprehensive way.

In the Area of Renewable Energies and Environment (AERyA-IMA-FI-UNSJ) the thermal properties of PP have been studied, because it is a sustainable material with volcanic mineral origin, existing in the central-western region of Argentina, which as a result of its closed and empty microcells, demonstrates a thermal resistance with a bulk density between 30 -130 kg/m3, it reaches a value of 0.054 W/m°k, (according to IRAM this value is similar to expanded perlite). These improvements were executed, tested and verified at an experimental level in the IMA-FI-UNSJ laboratory (Fig. 14), (Buigues Nollens A. 2021).

Fig. 14. Views of the Laboratory next to the prefabricated thermo-insulating envelope system integrated in the sensor installation stage.

III. RESULTS

The results obtained at the urban level of the Amecom IV neighbourhood, in relation to the SSVs located in Zone III: Warm temperate, do not show that they are designed by means of a compact grouping. And their envelopes do not show that they have been planned either, to reduce the impact of the thermal amplitude that occurs in the region. Since the density of walls is medium, since it is executed with solid bricks of 1800kg/m3, in ceilings the ceramic blocks are of low density in the order of 730kg/m3 and the openings do not have hermetic double glazing (DVH), they have a thermal transmittance K between 4.14 to 6.31W/m^2.

At the same time, on a building scale, the orientation of the houses and the sizing of the outdoor spaces obstruct and do not optimize sunlight in winter. Since the extension of dense and not very transparent roofs, intended for double garages or pergolas next to the grill, located in front and back respectively, of the houses arranged to the NW, N, NE, E block the winter sunlight. And they prevent heating the room by the arrival of an approximate [direct + diffuse] radiation of 58.14W/m^2 (50 Kcal/m^{2}h) through the window.

In addition, in only 2 (two) exposed windows of the main façade of the base VSEs, exterior metal lattices have been included, without considering orientations such as the South, from where no solar radiation arrives. This shows that the work is not designed to control direct and diffuse radiation or avoid thermal losses at night depending on the time of year.

And neither in the constructive growth of the VSE, it has been planned to minimize surfaces to the East and West. On the other hand, the Aspect Ratio of the basic prototype (0.89:1) with respect to the extended prototype (1.84:1) doubles, i.e. its exposure to thermal impacts increases.

This exposure is corroborated by the lack of adoption of light colours in the exterior envelope, where the α absorptivity coefficient that considers the fraction of the solar radiation incident to an area absorbed by it is low. Because 2/3 of the exterior walls of the enlarged prototype have an absorptivity α to solar radiation in the order of 0.55 to 0.65 and 1/3 has an absorptivity α to solar radiation in the order of 0.7 to 0.75.

Therefore, from the analysis that demonstrates the lack of responses to the climate and the environmental conditions foreseen on an urban scale, together with the lack of application of basic passive bioclimatic strategies in the project stage that is verified in the stage of execution of work at the building scale of these SSTs, the opportunity for improvement is restricted to obtaining Hygrothermal Quality through the development of a system of integrated components and elements intended for thermal insulation and the use of passive strategies.

This system was aimed at providing appropriate improvements to the elements together with the components integrated into the SST, on a constructive scale in order to solve the problem of Energy Efficiency that the base prototypes have and expanded through a proposal for energy optimization integrated to the entire envelope, both opaque and transparent, and considered from the initial project stage aimed at obtaining a sustainable design of the SST. Only in this way is it feasible to achieve an adequate and lower K´m, with a class B τm of EE (Fig. 15).

IV. Discussion

The proposed optimized construction system (SCOP) demonstrates that the variations of the variables under study are linked and tend to decrease. They do this by means of a moderate exponential decrease in the exterior of the Km, which produces interior thermal variations with a rapid exponential decrease in τm, verifying that from class F to C or B the EE increases (Fig. 16). It is discussed whether both the constructive and energetic suitability of the SCOP are possible to execute and achieve in isolation, by its low-income users.

On the contrary, these improvements with which thermal comfort is obtained from the VSEs, respond to climatic, cultural and constructive particularities, given the design together with the system adopted. They will be feasible, as safe to carry out, if they are contained considering a broader management role of the IPV, in an IPV Improvement Program as part of a Line of Action of the Undersecretariat of Urban Development and Housing (National Housing Plan, 2017).

Based on an Integrated Management Project, which includes the "appropriation" of the users, as part of the evolutionary process of design and self-construction with technical assistance during the life cycle of the VSE. In which it is feasible to include the complementary thermal envelope system in walls and ceilings, as well as the provision of thermally specialized carpentry.

V. CONCLUSIONS

The VSE-IPV complexes built in the arid zone of San Juan lack a systematic application of passive bioclimatic strategies in each of the phases of the project and work. This situation was verified at different scales; through the lack of introduction of design procedures, which demonstrate control of the microclimate of open spaces, and favour access to sun or air breezes on an Urban Scale. And that do not demonstrate that they have been considered through the integration of knowledge, techniques and design tools to resolve the appropriate orientation of evolutionary social housing at the Building Scale, for a convenient habitability of users with limited resources.

Escalas	Condición[1]	Clases	Prot.Base	Prototipo Ampliado		
			1	2	3	4
A	$\tau_m \leq 1°C$	Situación Sistema Constructivo Optimizado Propuesto con Usuarios				
B	$1°C<\tau_m<1{,}5°C$					1,44°C
C	$1{,}5°C<\tau_m<2°C$					
D	$2°C<\tau_m<2{,}5°C$					
E	$2{,}5°C<\tau_m<3°C$	Situación Mejorada considerando al Usuario				
F	$3°C<\tau_m<3{,}5°$				3,07°C	
G	$3{,}5°C<\tau_m\leq 4°C$	Situación Original y Mejorada por el Usuario				
H	$\tau_m>4°C$		6,59°C	4,29°C		
	[1] τ_m = es la variación media ponderada de la temperatura entre la superficie interior de la envolvente y la temperatura interior de diseño determinada en 20°C.					

Fig. 15. Comparative results of the weighted average variation with respect to the temperature τm, between the original and improved prototypes according to Energy Efficiency classes.

For this reason, the intervention is limited to the improvement and adaptation of the envelope of the VSE-IPV, on a constructive scale, not as a subsidiary of the appropriate architectural urban design, but as the only option, to adapt the interior environments to the needs of the users considering the climate of the place. Where the constructive design for the improvement, considers a light technological proposal, integrated by a modular structural support system, whose mobile, disassembleable, and reusable components, together with a fireproof thermal insulating regional material with volcanic origin, such as the loose pozzolanic pomec, granulated shaken, prove to be projected to massively solve the thermal comfort of the houses during the evolutionary or growth process and/or as a completed construction, according to the tests carried out at IMA-FI-UNSJ Laboratories in Argentina, and ICITECH-UPV in Spain.

Through improvements in the Construction Elements that make up the entire expanded plant, it was demonstrated which are advisable to execute, to produce an exponential decrease in the average temperature and transmittance. They allow us to achieve adequate indoor thermal comfort, reduce energy demand with responsible energy consumption with respect to the free increase in consumption, which is imposed by active strategies.

In this sense, it stands out in the changes included in the project and introduced in the construction elements, through the new resulting "complementary layers", which show that they produce improvements of high energy efficiency when they are integrated. That is, when construction adjustments are made simultaneously throughout the envelope, which allow classes C or B to be reached. On the contrary, improvements introduced

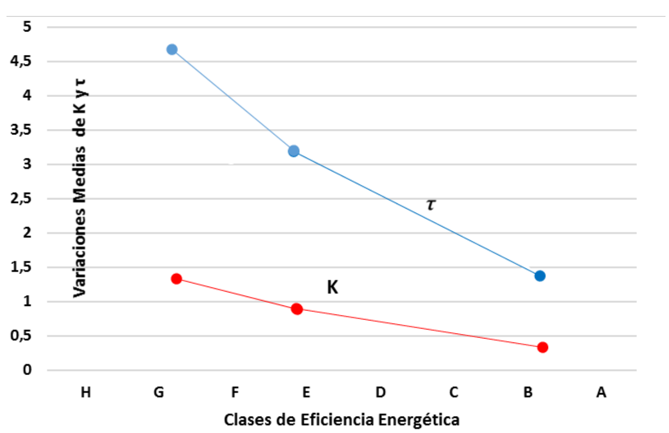

Fig. 16. Evolution of the resulting EE through the inclusion of sustainable breeding technologies in the envelope of the expanded prototype.

in isolation such as those that can be introduced by the user, reveal results with low class of EE such as H, or if this improvement is produced in isolation they result in middle class.

On the other hand, this situation verifies the need to introduce, from the project stage, an innovative comprehensive planning with respect to the isolated institutional construction intervention that is currently being carried out. That facilitates an execution of work in an effective manner, integrated improvements of rehabilitation with high EE together with the spatial expansion. And it adapts to the development of "traditional" construction solutions, because they are the most used by "users integrated into an efficient SST construction process", with their own means. It should be noted that the methodology used can be replicated in other bioclimatic zones, both locally and internationally, facilitating their real access to sustainability, and in which there is a need to overcome the risks of energy poverty.

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