ARCHITECTURAL PROTOTYPE FOR HIGH ENERGY EFFICIENCY URBAN HOUSING IN CENTER-SOUTH CHILE.

Flavio Celis, M.Arch PhD
Ernesto Echeverría, M.Arch PhD
Universidad de Alcalá (Spain)

Rodrigo García, M.Arch PhD
Maureen Trebilcock, M.Arch PhD
Universidad Nacional de Colombia (Colombia)

Olavo Escorcia, M.Arch PhD
Reinaldo Sanchez, M. Ing. PhD
Muriel Diaz, Arch.
Universidad del Bio-Bio (Chile)

BACKGROUND AND OBJECTIVES

Residential buildings in centre-south Chile have made consistent progress in the recent decades. Most of this growth is based on detached houses, executed in repetitive groups of a reduced size, of up to 60m², which subsequently increases spontaneously forming variable clusters with few facilities and a lack of urban cohesion. So far, the priority in Latin American’s urban development has been to face the demand for basic housing, relegateing, when not ignoring, the environmental problems, which has meant building inefficient homes with high energy demands, particularly significant in climates with a strong seasonal variability. In the Centre-South Chile there are specific studies that put these demands in a range between a minimum of about 110Kwh/m² for detached houses with two floors, and a maximum of 192Kwh/m² per year. In the simulations performed as part of the research project MEL CONICYT 81100003 (2011-2012) “Integrated Design for Energy Efficient Housing Reconstruction”, the average heating energy demand of a detached house in the study area has been calculated as 143kwh/m². This demand is fulfilled with burning combustion systems, especially in the lower class areas, combining poor fuel quality (non-certified wet wood) with low efficient equipments, resulting in poor indoor thermal conditions (with an inner average temperature of 16°C) and poor indoor air quality as a result of inadequate combustion. In the current context of strong growth of housing construction after the earthquake of 2010, and given the high price of conventional energy, reducing the energy demand has become a priority within the strategic objectives of the country’s development.

The project starts from the realization of the limitations of the previous experiences, and proposes a flexible system that enables the development of energy-efficient homes with multiple possibilities for grouping and growth under different climatic and socioeconomic levels for different areas. It is solved by a modular, replicable and high customizability construction system, that increase the quick construction after an earthquake, minimizes the costs and guarantees the constructive quality of an industrial process, inside the long tradition of this type of architecture (Prouvé, Koening, Lods, Ehrenkrantz). The development of the system is now in the penultimate stage of the project. The earlier stages consisted of analyzing the climate and constructive problems of the study area and its architectural background. At the current stage, the foundation for the design of CASA+ has been laid (the detailed implementation plan that defines the construction of a real-scale prototype is yet to be developed). The work methodology has been the Integrated Design Process, which combines multidisciplinary participation with different points of view with a working model that predetermines the goals to be achieved (qualitative and quantitative), developed in successive steps of complexity.

The specific goals have been defined in architectural aspects (minimal surfaces, grouping and integration ability), urban aspects (minimum density), economic aspects (cost range) and construction fields (modular systems and construction according to the local industry); as well as achievable goals for energy efficiency, as a minimum verifiable saving result was set to not less than 55% (category A in energy efficiency) with respect to a traditional house taken as reference.

The aim is to rethink the characteristics of traditional Chilean housing, consisting of a two floors house typology, with a length-width ratio of 2 to 1 and gabled roof, usually arranged isolated or paired, and with surfaces ranging from 36m² (low income housing) to 90m². In the middle or lower-middle class subsidized housing sector, the surface and number of bedrooms is very similar to the prototype of 60m². (Fig.1). Extensions in upper modules, with a third floor or living space under the roof, can raise the prototype’s surface up to 90m² with four habitable rooms. It is also possible to extend the modulation by the sides, increasing the surface area due to the modular nature of the proposal. The multiplicity of grouping possibilities from the same unit can generate many different neighborhoods and densities, along with material and surface characteristics of housing and the plot’s size without sacrificing the basic qualities of spatial quality and energy efficiency of basic housing (Fig.2).

DESIGN STRATEGIES

CASA+ should be understood as a system design, a set of architectural and constructive elements that with different possibilities for clustering on each scale result in diverse architectural and urban solutions having in common a significant improvement in energy efficiency with respect to a conventional home of the same size. It combines a number of solutions adapted to different architectural scales, considering different environmental stresses taken from the detailed climatic analysis carried out during the development of the MEL research.
In the geographical scope of the study, the analyses show needs for energy input (heating) in winter, sun protection and natural ventilation in summer (no need for cooling) and a need for reducing humidity throughout the year. The bioclimatic diagrams for Concepción’s area shows that there are long periods of the year (winter, spring and fall) where the passive solar contribution would be sufficient to reach the comfort zone, requiring only some heating input at some specific periods (Fig.3).

Diagrams for Concepción’s area shows that there are long periods of the year (winter, spring and fall) where the passive solar contribution would be sufficient to reach the comfort zone, requiring only some heating input at some specific periods (Fig.3).

The following design strategies to consider in the prototype depending on the environmental requirements defined in the climate diagram of reference:

1. The strategies to reduce the thermal losses, as the decrease of the envelope area by compact units with a small form factor and by aggregations of more units (detached homes, attached or block). To do this, CASA + adopts a structure based on cubic forms, thus reducing significantly the form factor, with a relationship surface/volume of 0.75 (the area by reference is the sphere, 0.60). When compared to a traditional house with the same area, usually prismatic, CASA+ reduces the exposed surface by 20%. The prefabricated panel system with inner insulation, implying a U factor of 2.41 W/m²K and the improvement by 20%. The prefabricated panel system with inner insulation, implying a U factor of 2.41 W/m²K and the improvement by 20%.

2. The strategies to reduce the solar insulation in summer (although extreme heat conditions are not climatically significant in the study area) in highly exposed north facades during the summer (even more with the high amount of window's surface), are the use of setbacks on facades to generate shadow.

ARCHITECTURAL DESIGN AND CONSTRUCTION SYSTEM

The building systems used in the traditional construction are variable, but the most common consists of a first story made of masonry, a concrete structure and a second story with a gabled roof made of timber framework with enclosures made of wood panels. The thermal behavior of traditional housing is a consequence of the construction system, which follows the established legal rules. The location and placement of the housing plots follows an economic criterion (filling all the available space) rather than a rational study of local climatic factors (orientation, sunlight, obstruction).

The prototype attends, however, to a global concept of sustainability, which involves not only the improvement of the comfort conditions (compared to traditional housing) through improved building systems, but also through a correct formalization and orientation of the dwellings in the urban context. The improvement of the form factor intervene in this point, as it implies a better relationship between volume and surface area, and is complemented with a modular construction system, based on a sandwich panel SIP, with a modulation of 2.45 m x 1.225 m, which can be placed either vertically or horizontally. They conform cubic units to the addition of a structural framework, establish the basic unit in modules of 2.67m x 2.67m. The plan of CASA+ is arranged with the junction of 4 units, generating a square of 5.34 m side and 28.5 m² of floor area. The basic house, with two levels, is then defined by an area of 57m², to which the staircase module is added. This element is conformed as one piece attached to the cubic structure in the opaque facade, generating a total area of 60m² and 53.5 m² of floor area.

As a result of the contact with companies of the construction sector in the study region, it has been decided to use a mixed construction system that combines elements that may either be manufactured in a workshop or industrialized (such as cladding panels and decks), with uncomplicated assembly work (Fig.4). The materiality of the finishes, enclosure systems and decks can be easily exchanged, leading to multiple aesthetic choices. The constructive system consists of a structural system, an enclosure and a facilities system. The facades are solved by a wood sandwich SIP panel with EPS insulation 100mm thick. These elements may or may not be coated on their inner sides, while the outer face comprises a waterproof treatment and may be coated with a waterproof and breathable membrane. The finish is a ventilated facade system of lightweight concrete 10mm thick. The outer panels are directly fixed to the structure, formed by a framework of beams and pillars that define a cubic cage, which can be done in steel, solid or laminated wood, and can come directly manufactured or prepared to be assembled on site using screws and pins. Diagonal bracing ensure vertical stability, while the horizontal stability is stiffened by the slabs. The foundation can be done on site with ditches, or come prefabricated as concrete blocks. The slabs, in the basic proposal, are made of concrete with steel decking 0.75mm thick that can be performed on site or come prefabricated from the workshop. However, since in some climatic regions studied, the difference day-night temperature is not very significant, they could be replaced by lighter elements such as the same SIP sandwich panels used in the facades but with a higher thickness (150mm ). The roof is defined by the same deck, incorporating a landscape deck. The staircase is considered as a prefabricated separate element.

The bathroom and kitchen facilities can be performed either in a traditional way or come prefabricated from the workshop. The lower floor’s wet unit, where kitchen and toilet are grouped, and where an air conditioning indoor unit could be placed, can be done industrially, including furnishings and appliances, and then be assembled in the working place. The climate control...
system is designed to support a unit of biomass considered carbon neutral, located at the center of the house. Given the need for ventilation due to the humid climate (1 ach), the climate control system is supported by a system of heat recovery located in the forced renewal unit. Natural cross ventilation is established between the lower floors and the skylight located over the stairway.

Supports for solar or photovoltaic energy are installed on the flat roof.

RESULTS AND CONCLUSIONS

About the architectural proposal for the CASA+ housing model previously described (2 floors and 60m2); simulations were performed with specific software. All simulations were performed with a north orientation of the main facade. In all the studied cases, sharp declines in energy demand were obtained when comparing data between materiality referred to the Thermal Regulation and the proposals. Several starting decisions for the architectural design, and the choice of materials, have been predicted from previous investigations, such as increased insulation of the envelope to suitable U values, the use of inner thermal inertia, or the dimensioning of the windows in approximately 20% of the floor surface (Fig.5). From the results obtained in the simulations, the following conclusions can be drawn:

- The CASA+ prototype, simply by being architecturally designed according to the climatic conditions, obtains, using an envelope according to the Thermal Regulation for a comfort range between 18°C and 27°C, an energy demand of 115-100kWh/m2. lower than homes built today in Chile in the area on the research, which ratio ranges from 190kWh/m2 to 143Wh/m2, according to data provided from previous research.

- The CASA+ prototype developed with an improved thermal envelope in relation to Thermal Regulations, shows a decrease in energy demand of 70-75%, and fits into the category A of energy efficiency as it shows savings exceeding 55% over the reference building according to TR. This improvement increases up to 75-80% in the case of semi-detached houses, with a common dividing wall, and 80-85% in the case of terraced houses matched by two sides. Improving energy efficiency in detached and semi-detached houses is between 20-22% in the case of semi-detached houses and between 30-32% for terraced housing. The values in the lower ranges, between 47 and 16 kWh/m2 are values already adjusted to acceptable quality standards in developed countries.

- Another quality of the prototype is to achieve these standards with a sufficiently tight economic investment in cost-benefit ratio. The budget studies show that the construction of CASA+, considering the plot, represents an impact of 57USD/m2, which fits into the average cost, that is at the 65USD/m2. Major savings could be achieved by improving the execution times at the workplace, increasing prefabrication, which could lead to improvements in finished or incremental of the floor area.

- The first CASA+ prototype is currently in the pre-project implementation phase. The interest of the property market on the proposal, leaves the door open to a new phase in which, if it is possible to combine synergies and attract the adequate funding, the completion of a construction project. Its development would be made in UBB to assess the complexity of construction, cost and assay, and above all, to make the energy monitoring over a prolonged period of time, so that the feasibility of the proposed scale can be demonstrated. The research methodology allows to be extended to other climates of the region and other Latin American socio-economic realities, with a previous study of local peculiarities, both in terms of climate and the constructive development. The system, currently limited to detached or grouped house, could be developed using the same methodology for high-rise housing. The private sector participation in the development of the system is considered crucial by being involved in the technological development and financial feasibility, as well as the legislature, by facilitating the exchange of improving energy efficiency by equivalent improvement in the construction and architectural quality of the middle and lower class’s homes.

REFERENCES