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Design to Thrive

Innovative Design and Technical Feasibility of a Low Operation and Maintenance Cost Dwelling Prototype for Immigrants in a Consolidated Urban Area in Santiago de Chile

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Abstract: The “Tendal” prototype exposed emerges from the participation of a team of undergraduate students and lecturers in the "Construye Solar" contest organized by the NGO Solar Route, the Ministry of Housing and Urbanism, and the Ministry of Environment of Chile. Its goal is the development of sustainable housing, orientated to vulnerable environment families. In the last decade, an intense flow of foreign immigrants has arrived in Chile. Currently, there is a disproportionate concentration of foreign population in central areas and precarious access to comfortable and good-quality housing. Public housing is located in the city periphery, which implies a high rate of emitted CO2 and airborne pollution caused by transportation needs. The question that arises is: What are the current needs of social housing in Chile, particularly for immigrants? This article aims to expose the urban, constructive, architectural and socio-technical feasibility of building blocks with low operation and maintenance costs. Universal accessibility, floor areas and cost regulations where given by the contest rules. An innovative solar clothes dryer to prevent indoor humidity is proposed. Environmental performance simulations where made. The prototype is under construction for being tested on May 2017 during the contest.

Keywords: mixed use, solar dryer, migrants housing, innovative prototype, low footprint.

Introduction

The “Construye Solar” competition is a challenge organized by the NGO Solar Route, the Ministry of Housing and Urbanism and the Ministry of Environment of Chile. It invites universities of Chile and world to develop a sustainable public family house prototype, in order to change and improve their environmental quality and construction technologies.

Full scale prototypes are built to be shown in an open public exhibition. They will also be evaluated on the basis of their energy efficiency, comfort and sustainability, among other aspects (http://www.construyesolar.com/el-proyecto/). Through its demands, the contest constitutes itself as an instrument that enhances sustainability inclusion in the academic and professional fields. This concept encompasses design, construction, operation and maintenance of dwellings.

The “Tendal” prototype exposed in this paper emerges from the participation of a team of undergraduate students and lecturers of the Central University of Chile in the "Construye Solar" contest. This article aims to expose the urban, constructive, architectural and socio-technical feasibility of building low rise blocks with low operation and maintenance costs. This residential building is aimed at the immigrant community and located in a consolidated urban area of Santiago Centro District. There are regulations given by the contest such as: universal accessibility, maximum floor areas and cost which were all taken into account. The team decided to design a multilevel building block complex. This was due to the fact that detached housing typology is not an adequate solution for achieving neither urban, nor environmental high standards, given their high area to volume ratio and low land use efficiency. Besides (PLEA, 2012; CIBWBC, 2013), up to date, few examples of sustainable residential buildings exist in Chile, the majority of them are detached single family dwellings. The prototype is under construction by students and volunteers for being tested next May 2017 during the contest.

Public and Private Housing’s current state: urban and building scale

Santiago´s urban structure and expansion model is based on single use zoning, consisting of purely residential large city areas with no associated infrastructure such as education, convenience stores and workplaces. This fact forces the residents to use motorized transport even for simple everyday tasks. Despite government initiatives intended to improve public transport, both buses and metros continue to be overcrowded and run with no fixed timetable (CIBWBC, 2013). At the same time the policies for achieving social housing targets has led to site selection based on low land value, almost always being located on the city limits. As a consequence, occupants have less on site or proximal work opportunities and incredibly high commuting times associated costs. (CIBWBC, 2013).

In Chile, residential developments and their related services carry on with no significant consideration of sustainability or energy efficiency (PLEA, 2012; CIBWBC, 2013). This results in low habitability standards (IC, 2006), such as low comfort levels in winter and summer, unacceptable indoor air RH and quality levels, all of them causing health difficulties and increasing operational and maintenance costs.

High rates of indoor RH existing in Chilean dwellings deserve special attention, having a major impact on thermal comfort and building pathologies. These rates are intensified in public housing, due to combination of indoor production sources and poor quality construction materials. Among all indoor sources, drying clothes and open flame heaters stand out. They derive and can be prevented through good architectural design practices that involve technical innovation and more restrictive associated regulations.

If clothing is dried within an enclosure (Rivera, 2012), about 10 kg of water vapour per day is released in each family laundry. Mould growth due to condensations in building envelope cause serious health problems. Besides, it implies high maintenance costs and shorter durability of dwelling. As the authors of the guide Welfare Housing: Sustainable

Design Guide for Residential Habitat (U. de Chile et al., 2004) states: "Cloth washing and drying activities should be done outside or in an intermediate private or common space".

Concerning open flame stoves, its use has extended due to the non-obligation of delivering dwellings with heating system, leaving the users the choice of portable heaters. On the other hand, fuel poverty exists for most of inhabitants of the country. These facts force the population to use open flame heaters and poor quality fuels, a polluting and inefficient heating solution. Cheap fuels used by occupants as Kerosene, LPG, and natural gas produce respectively (Rodriguez, 2009) 2.50, 1.60 and 2.25 kg of water vapour per kg of fuel. The production of indoor humidity increases as a result of the thermally inadequate built envelope because it is necessary to use more fuel to reach comfort temperature levels. Indoor air became very polluted as well.

Immigration's current state

In the last decade, an intense flow of foreign immigrants has arrived to the country increasing from 1.2% of total population in 2002 to 2.17% in 2012 (INE, 2002; INE, 2012). According to various sources in recent years migration has been characterized by being of Latin American origin, feminine, great ethnic heterogeneity and for being in an active age range (Poblete et al., 2014; INE, 2012; DEM, 2014).

The migratory phenomenon has a tendency to concentrate on certain territories, with a preference for certain cities and within these in particular residential areas (Segura et al., 2014; Poblete et al., 2014). This pattern of settlement, explains itself through the existence of attraction centers expressed through what Segura et al. (2014) calls objective variables for improvement of living conditions. These are the existence of employment sources, high connectivity with central urban areas which also allows jobs access and the existence of a possible housing market for rental or purchase combined with the presence of a primary social network in which the immigrant is inserted.

The Metropolitan Region of Santiago (DEM, 2005-2014) englobes 61.5% of foreign resident total population, the highest percentage of country regions. The capital district that concentrates the most immigrant population is Santiago Centro with 54.4%. This area (Segura et al. 2014) is composed by a system of mixed use neighborhoods with their own identity, where housing and trade coexist. The arrival and concentration of this new collective in the district affects the economic, social and urban morphology of this area. There has been an important neighborhood upgrading in certain areas of Santiago Centro (Segura et al., 2014; Poblete et al., 2014) given by the economic dynamism of immigrants who commonly open new stores and make more dynamic public spaces where they settle.

Within the conditions to foreigner status that must be complied to reside in Chile, housing stands out as the main demand and most vulnerable aspect. They must not only have enough money for renting but also fulfill the requirements to do so. These (Segura et al., 2014) constitute one of the main obstacles to get a house with minimum habitability conditions, and largely restrict their possibilities within the real estate market.

Social sustainability

Based on the studies carried out on the migration phenomenon, it was decided to locate the project in Santiago Centro District: Matta Sur neighbourhood, a working deteriorated area by the abandonment of sheds and warehouses.

The housing project enhances integration by providing immigrants a place of residence through government policies and mixing the migrant-national and foreign population in the same neighbourhood. Objective variables for the improvement of living conditions had to exist: location near city centre, reduced transfer times and distances, presence of services and trade and proximity to employment sources.

Mixed-use residential neighborhoods propose an urban model that emphasizes walkable distances. Motorized transportation is reduced as well as the associated carbon footprint. Strategies based on balancing population density and land-use means a request for urban intensity and active neighbourhoods. Considerations on social, economic and environmental sustainability in design, construction, operation and maintenance stages, helps to improve Nationals' Public Housing standards.

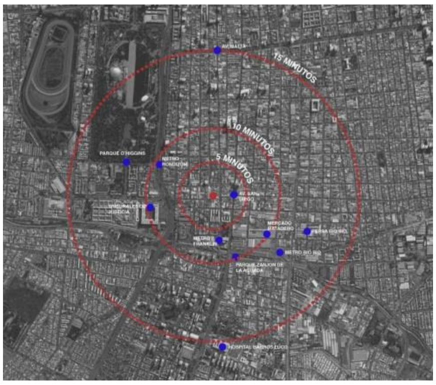


Figure 1. Map of walkable distances from the project site. Figure 2. Housing Complex Image

Locating public housing in a consolidated central urban area and having a mixture of public and private markets helps avoiding socio spatial segregation. Implementing an urban rooftop vegetable garden offers social relation spaces in residential housing, reinforces community strength and social cohesion between neighbors.

The proposed apartment layout is a 59 sq. m. open floor plan with a central core of services and a multiuse walk around arrangement than can create private spaces through sliding doors for different activities. Modular convertible furniture provides a flexible, non hierarquical space. This allows high adaptability to specific needs of immigrant families.

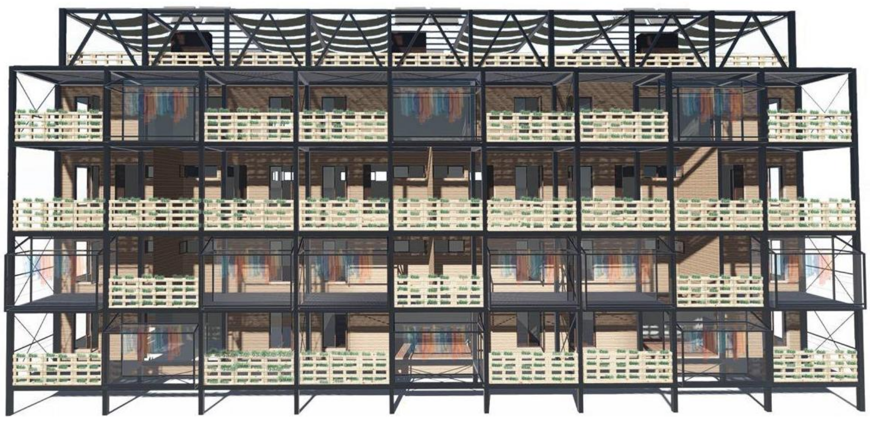


Figure 3. Housing block North façade image

Economical sustainability

Regarding house operation and maintenance, when implementing new technologies would be desirable to have trained tenants to improve certain use habits and to re-enforce their environmental awareness. A manual of active and passive facilities has been made.

When considering economic strategies, the objective is to subsidize the housing complex and the associated equipment with government programmes. A study of the available subsidies has been made, considering among them, one for housing improvement. The house complex will include different values and floor plan apartment typology.

Although renewable energies' implementation is an expensive investment it would reduce operational costs, reflecting these benefits both at personal and public level. The apartment cost, considering construction materials, renewable energy devices, transportation, specialized services and all other costs coming from construction stage reaches $21.000.000 which is the budget allowed for this contest. (aprox. € 30.000)

Environmental sustainability

The project presented is intended for the city of Santiago de Chile. The conceptual design method was Carl Mahoney's, originally orientated to humid tropical climatic zones adapted (Armijo, G. 1974) to be used in other climates such as those existing in Chile.

The climate of Santiago (33º 30´S) has a short and cold winter and a long hot and dry summer, with a mild 15º Celsius annual average. Temperature day and night swings are of 10º to 20º Celsius. This important and differential characteristic leads to design envelope with thermal mass capable to achieve interior moderated peak temperatures. The wind is almost non-existent and rain is about 350 mm per year and only at wintertime.

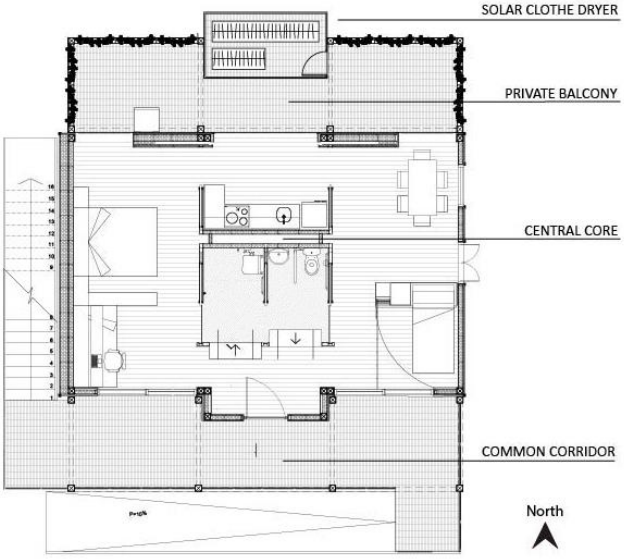


Figure 4. Floor plan"Tendal" housing prototype.

Proper capture of solar energy at block's design is fundamental. After simulations in the equinoxes, solstices at different hours of the day were performed, distance between buildings, shape and dimension of blocks were defined. Good orientation is combined with solar control devices. The single corridor block has its long axis with an east west orientation. The largest façade is facing north - south. In consequence, living spaces are North orientated; access is located South and the facilities in the centre. These facts facilitate cross natural ventilation at summer nights and two-way direction for better daylighting. Central core services are in the most efficient position for facilities and technical services. Balcony floor of galvanized steel grating has double function: outdoor space and semi-transparent solar control device, without blocking air convection. Fully insulated pre-fabricated modules supported by independent steel framed structure with double-glazing and siding with copper impregnated wood, all reduce thermal bridges. The result is a highly efficient dwelling for Chilean standards. The structural system gives the possibility of making light walls with locally certified 120mm sheep wool insulation.

The use of materials with the least possible carbon footprint is considered. Local supplies such as wool and pinewood are chosen. The structural material used is steel, which has a much lower impact than reinforced concrete. Steel can be recycled indefinitely and allows easy assembly and disassembly, turning it into a suitable material for prototype production. Healthy materials are also used, as cooper treated wood frames and exterior façade.

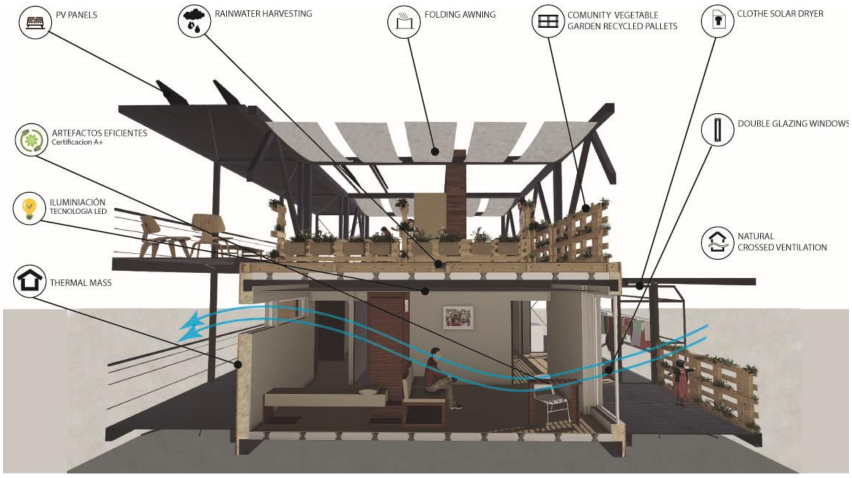
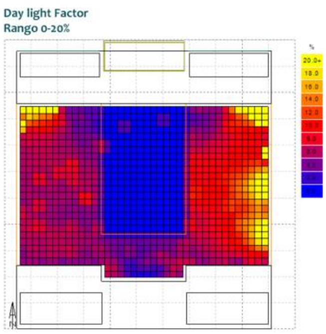
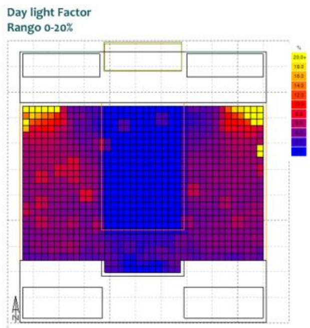


Figure 5. “Tendal” Prototype and community rooftop section.

Apartment’s analysis of daylight availability, sun path simulation and Daylight Factor analysis were carried out. Size and location of windows in all four different orientations were defined. Also shape, dimension, layout and solar protections where settled. Design principle of daylighting was light capture coming from north and south. This is associated with summer overheating protection with balconies. Windows principal target it to seek good light distribution, considering the interior furniture space variations.

It is possible to conclude through simulations that the strategies proposed to generate better natural lighting and thermal gain through the radiation improve substantially by incorporating steel grating as the material of corridors and balconies. This allows solar radiation during winter. On the contrary in summer a mobile solar protection is devised in the north balconies.





Figures 6, Daylight factor analysis: favourable apartment case, north, south and east windows.
Figure 7.Daylight factor analysis: unfavourable apartment case, north and south windows.

The solar clothes dryer is a small polycarbonate room attached to the steel frame at north balcony. It has openings at the floor and at the upper front creating natural convective flow. In addition it has a small movable PV to energize a small fan to improve airflow at cold season. It substantially diminishes indoor humidity production, improving hydrothermal comfort and gives an appropriate technical solution.

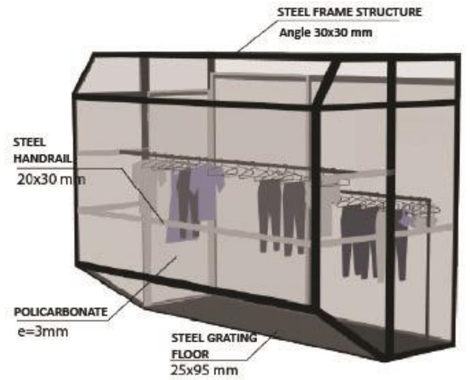


Figure 8. Solar clothes dryer design. Figure 9. Team photo: solar clothes dryer integrated in the prototypes terrace.

Cross ventilation strategy combined with a controlled ventilation system with heat recovery contributes to a good indoor air quality. Natural ventilation should be used in summer mainly at night, periods in which the outside temperature is within the range of comfort (18 to 24 ° C). During winter at cold hours, there is a need of renewing air without opening windows. A heat recovery air to air exchanger will be implemented to reduce the CO_2 concentration inside, associated with a CO_2 sensor.

Strategies for efficient water use are as follows: economical and efficient faucets and artefacts use and establishing housing energy saving behaviours for occupants at user´s manual. For the housing block wastewater treatment (grey and black waters) the "Tohá System ®" is proposed to be installed. Is a Chilean technology created by Dr. J. Tohá in the University of Chile's Laboratory. The system is also named as Dynamic Aerobic Biofilter.

For hot water supply an electric water heater with integrated heat pump is installed, storing 270 litres at 45°C with COP 4.3. For optimal efficiency, a programme establishing a timetable for its use is settled. The appliance should be working during the day, so the energy comes from the PV panels. During night time water is kept hot with no need for electricity with a minimal loss.

Heating peak demand occurs in August 1st at 6:00 hours, when 2098 watts are needed to keep 19°C. The interior temperature is within comfort parameters range (18 -25 °C) through the entire analysis. A 2 kW convective radiator produces enough energy to cover the demand corresponding to the most unfavourable moment of the year.

The PV panels are located in the rooftop´s steel structure. The on-grid system feeds electrical apartments demand, but energy taken by the grid is valuated only 60% of the regular tariff. As a consequence electrical appliances should be used in daytime so the electricity is provided by the panels. The heat-pump consumes 0.6 Kw and for a 150 liter daily demand 4.8 operation hours are needed. This situation is satisfied between September and April and partially between May and August. Between October and March there would be a surplus for consumption.

Conclusions

Supportive, inclusive mixed and dense house prototype is achieved. As the project is founded in the migration phenomena a sensible design of 4 levels blocks with moderate density is proposed. It is a mixed-use, modular, collective block. It is situated within the deteriorated city centre connecting houses to urban centres, services and jobs. Open plan apartments are flexible for housing different family groups. Vegetable gardens are located at a portion of shaded rooftop for community work and in private balconies for families.

Environmental strategies for Santiago are adopted with design decisions for design for Mediterranean climate. These are: single corridor block with main facade and private balcony facing north; Solar clothes dryer and space for gardening; translucent corridor so light can pass through and envelope U values 21 % of standard Chilean Regulations.

Clothes solar dryer substantially diminishes indoor humidity production, improving hydrothermal comfort and gives an appropriate technical solution.

The construction of this residential building prototype is technically feasible with the current local resources, technologies, knowledge and construction related professionals, with no air pollution emission and with much lower environmental footprint.

At the contest, Tendal prototype won the first prizes in Sustainability, House Comfort Performance (monitoring) and Water Usage; Second prize in Architecture and Urban Design; third prize in Innovation and Interior Functionality.

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