AUTARCHIC STUDENT HOUSING BASED ON THE CANOPEA CONCEPT

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ABSTRACT

Our student accommodation project is based on the Canopea concept proposed by the Rhône-Alpes Team for the Solar Decathlon Europe Madrid in 2012. The initial prototype was an apartment designed for a couple and after the contest of September 2012, it has been rebuilt in Grenoble. In this paper, we propose to adapt this concept into share housing for six students. Our principal aim is to obtain an autarchic house with as little environmental impact as possible. Using local resources, reducing consumption, and adapting the design for efficient usage in our country, we can achieve the best balance and performance and reach our objective.

INTRODUCTION

The house is composed of 3 levels:

The first two levels are shared apartments for three students. The shared-rent system is compatible with a student’s low budget. In this house, the first two floors are exactly the same.

ENGINEERING AND CONSTRUCTION

Structure

The building is designed using the principle of CORE SKIN SHELL and it is designed for fast assembly. Most of the elements are prefabricated and so have to respect the dimensions for road transport.
The Core Skin Shell principle was invented to build towers at a low cost, but in the case of a 3 storey house, it can also be used with many advantages. We will explain what the Core, the Skin and the Shell are:

**CORE**: It is the compact prefabricated block containing all the technical equipment. It can be industrialised in order to limit assembly phase time on site and to simplify fluid and structure interfaces. It includes the technical room, the bathroom and the kitchen.

**SKIN**: The skin is a high performance thermal envelope. It defines the thermo regulated zones of the housing unit. It can be built with local materials and local companies prefabricate elements at affordable prices.

**SHELL**: This structural part supports solar panels and movable glass blades. It is a “carapace” that filters light and regulates solar gain, whilst capturing energy.

Once fixed to the building structure, the exo-structure increases stiffness and homogeneity of loading. It also serves to carry the roof solar panels, and to increase the seismic and wind resistance. Finally, maintenance of the facades is facilitated because they are accessible at any height.

One meter wide corridors, are made of steel beams supporting a wood floor. They enable free movement all around the house as there is a corridor for each floor except the communal floor.

The exo-structure is also very important for the Nanotower stability. Columns and external bracing systems prevent building distortions and torsions. The vertical columns, which gather together at the top, acting as hooping all around the Nanotower, prevent slender construction swaying. The columns and the exo-structure joints work in compression and tension, and are attached to anchorages on the floor, which are themselves attached to the foundations.

Diagonal bracing systems, in two opposed directions, form a net which stabilizes the building. This spatial triangulation which includes all the building, ensures it a high resistance. It also homogenises the stresses
that the construction has to support in the event of high winds or earthquakes.

**Figure 8 Torsion bracing**

The positive aspects of the Core Skin Shell concept are:

- Economy
- Energy efficiency
- Environmental impact
- Innovation

**Enclosure description**

The high performance enclosure is composed of steel and wood for the structural components, and of cellulose wadding and Vacuum Insulation Panels (VIP) for insulation materials. Wood was chosen for its thermal and environmentally friendly qualities, whereas steel was chosen for its strength and its resistance to hoisting. The interior earth plasters are made of 1/3 sand, 2/3 earth (clay), water and straw (to ensure good mechanical bending strength). Earth material is available in large quantities and is 100% recyclable or reusable. Except for its water consumption (about 2L of water for 1m² of earth coating), it is renewable and environmentally friendly. The earth used in the project is 100% local. Earth is also interesting for its thermal (inertia) and hygroscopic properties (moisture absorption and humidity regulation).

**Insulation**

The efficiency of the insulation materials is crucial. The thermal conductivity of these panels is excellent compared to the performance of regular insulators (0.0044 to 0.007 W/m.K). Despite its current price (40 to 60€/m²), this insulation should become more widespread in the years to come because it corresponds with the current economic requirements.

**External facing**

Outside cladding is made of three-ply fir wood panels from Savoy. As is the case for all the wood used in the prototype, the outside cladding is also produced from European sustainably managed forests. A green wood stain (acrylic based paint with water solvent) is applied to the panels. The peripheral passageways around the apartment create a buffer space between the outside and the dwelling. Exo-structure adaptive systems like motorized textile blinds or rotating glass louvers can control the passive solar contributions. Glass louvers enable the creation of a greenhouse effect in the winter garden whilst allowing panoramic views and summer over-ventilation as a cooling strategy. The micro-perforated sunscreens prevent the facade from over-heating.

**Flooring**

Inside the housing, there is "100% made-in-France" solid oak flooring (CBM® specialized company, "Massif Central" forest : PEFC and FSC labels) and for the peripheral walkways, the south terrace and the communal upper floor there is French thermo-heated ash produced by the Ducerf® company (Burgundy forest, PEFC and FSC labels). The glulam beams used for the top communal floor roofing come from French forests ("Massif Central" forest and "Massif du Morvan" forest) and are produced in a French sawmill located in "Sougy- sur-Loire".

**Glazing**

In order to obtain free solar gain it is more efficient to have double or single glazing in the south windows and triple glazing for the other orientations. However in this case due to acoustic reasons, it is preferable to use triple glazing all round. The shell of the house (outdoor perimeter) is basically composed of two different elements: the louvers system and the blinds. Louvers are glass blades moving around a central longitudinal axis. They are used for ventilation purposes. Around the housing unit, louvers enclose a winter garden. During summer, to avoid the greenhouse effect they can be slid back and hidden behind the blinds.
• Thin envelope: good ratio of net floor areas/gross floor area.
• Bioclimatic openings repartition: natural lighting from four directions.
• Various solar protections: mobile or fixed, enable the regulation of external gain and comfort.
• Orientation on four sides: natural cross-ventilation
• Multiple buffer spaces (top floor, south winter garden…) reducing the indoor/outdoor temperature difference.
• Low inertia for a quick thermal solution.

These components have a low carbon footprint and they are easy and fast to assemble so they enable the balance between economic and ecological aspects.

HEATING, VENTILATION AND AIR-CONDITIONING (HVAC)

In this section we will present the thermal aspect of our project. In order to save energy, the thermal equipment must consume the minimum possible.

Ventilation

In this apartment the air flows are controlled to minimize heat losses. This flow system is controlled primarily through the heat pump. Airflow can move freely from one room to another through the wall vent ducts.

Outside the automatic opening will also help to create or stop drafts depending on the period of the year.

Phase Shifter

The Phase Shifter is our major innovation. It is a dynamic system that shifts the external air temperature variation curve by 12 hours. Hence, the air leaves this system with the temperature it had 12 hours previously. Lowering heating and cooling needs by approximately 30% is thus possible.

Thermal Storage Tank

A 250 litre thermal storage tank enables the connection of radiant panels to a water-water heat pump. The heat pump is connected to the radiant panels and also to low temperature district heating. In fact it is possible to do some power capping on the thermal storage tank. This tank contains PCM (phase change material) which enables the storage of more than would have been possible if only water had been used.

Heating / air conditioning

The heating system of the two apartments is supplied by an air to air turbofan heat pump.

The heat pump recovers the cold outside air (fresh air) (7) which is slightly heated by the hot air coming out (old air) (8) without mixing the two flows. The heat pump will then complete the heating of fresh air to the desired temperature with an air compression system (see image below) for heating and expansion for cooling the temperature.

The hot air produced is then directed into the ventilation system to heat different parts of the apartment.
Domestic hot water production

The hot water is produced by some of the solar panels which are dedicated exclusively to the water heating. Water is stored in a tank and heated by an air to air heat pump. Water is then redistributed to feed the everyday hot water.

Outline 2 - the benefits of using this technology are that it is efficient and autonomous thanks to solar panel energy consumption. Heating economies are partly achieved as a result of the large glazed surfaces available to the apartment which allow heating of the environment thanks to air movement.

The control of airflow provides optimum comfort not only for heating in winter periods but also for cooling the apartment in the summer and this with low power consumption.

ELECTRICAL SYSTEM

In France, and more generally in Europe, the demand for electricity at peak periods tends to increase every year. In a prospective approach to finding solutions to energy constraints in the coming years, we want to provide a strategy to optimize energy needs and reduce consumption levels.

Today, in economical and ecological accommodation, the integration of photovoltaic technologies is of the utmost importance. With this project, our goal is to go further in this direction.

Regarding lighting, the design combines both aesthetics and energy efficiency. Thus, functional lighting and ambiance are arranged to provide the lighting power requirements according to each space (500 lux above desks and 100 lux in corridors for example) whilst proposing specific atmospheres in each room.

All the accommodation is equipped with home automation, innovative technology that reduces consumption.

PV

Tenesol has developed its BIPV (Building Integrated Photovoltaics) crystalline SI modules technology. These BIPV laminated glass modules consist of photovoltaic cells inserted between two layers of screen printed or coloured extra-clear tempered glass and they can be fully customized.

It is important to note that today the integration of photovoltaic systems in new buildings is required under French regulation. Ultimately, this new form of photovoltaic panel permanently alters the function of a photovoltaic installation in the home. That which was designed to produce electricity at the origin, becomes a means of making use of solar energy and plays a key role in the aesthetics of the roof that is covered. The photovoltaic system becomes roofing and is completely integrated with the structure of the frame.

From the study of standard configurations and associated production simulations, we defined the type of geometry (plane, sheds, double-orientation, etc...), and the orientation and pitch of the panels. Our goal was to find the optimal solution that takes into account: adaptability to the site, the aesthetics and energy production.
Compared to an optimal configuration of sheds inclined at 30°, the solution of sheds at 5° will provide the necessary power and capture solar radiation optimally with a seasonal logic by limiting shadow effects. This is particularly interesting in a city like Grenoble, where shadows cast by the mountains have a strong influence. Thus, the sheds at 5° configuration on a surface of 84 m² is an optimal solution for the home.

Energy storage
PV production can therefore be used directly for household needs, or stored in batteries located in the communal area when there is a surplus. Storage for an apartment has been sized to 5 kW for a clipping level of 1 kW. Once the needs of the household exceed 1 kW, the stored battery energy can be used. Technically, an inverter / charger role will establish the connection between the batteries, the inverters and the consumer to distribute electricity in different directions as needed.

Lighting prototype
Communal areas and levels of housing are differentiated by the use of colour: the private areas of the housing use uniform sources and neutral colours (Warm White: 2700 to 3000K), whilst the first floor and the corridors are punctuated with coloured spots.

Spots surrounding the last level illuminate the space with a colour variation programme reminiscent of leaves changing colours with the seasons. This also indicates the friendly nature of the last level distinguishing it from the other floors.

Light fittings were chosen for their low power consumption: only LED (light emitting diodes) and compact fluorescent sources are used because they combine quality light, low consumption and long life.

Energy Management & Automation
The accommodation is equipped with a touch pad. It is the interface between the occupiers and all the simple and complex systems of the housing (heating and cooling, lighting, blinds and shutters, switch plugs, music...). This home automation system not only simplifies the management of various functions of the home through a single control tool, it also optimizes the energy consumption. To facilitate the use of this innovative system, energy management software advises users via the touch pad.

Outline 3 - various electrical devices used for this building, assure optimal comfort (using automation) in an energy-efficient home (using photovoltaic modules and environmentally friendly renewable energy).
litres each. These light and 100% recyclable tables are easy to use and perfect for gardening on a balcony or terrace.

![Figure 19 Vegetable garden table](image1)

To complete the gardening space, we use a worm compost to reduce waste and provide fertilizer for the garden, in addition this is an odorless way of composting.

1 - Household waste is poured into the first floor of the worm compost.
2 - The worm composters work day and night on the first 3 floors.
3 - Every 3 months, about 10 kg of solid compost is harvested on the third floor.
4 - Every day they harvest up to 10 ounces of concentrated liquid fertilizer.

- Transportation and water networks: As the Canopea concept is based on localisation in an urban area, this leads (1) to reduced transportation consumption and (2) to rainwater harvesting. In this case, rain water is collected and stocked locally in order to irrigate the garden in the balcony located around the skin and the eventual vegetable garden on the third floor. As it is situated in a city we are not preoccupied by the autonomy of the grey water recycling and link it to the network. This has a minimal impact on the balance sheet of the implantation. A Waste Water treatment system needs a big area to be constructed, but this does not have as high a performance as we desire.

Way of life: The people's way of life is a crucial factor to obtaining the best performance. Our objectives on a large scale are to reduce the whole carbon footprint and be more adapted to the environment. People have to adopt a green way of living by for example: eating local products, adapting to the weather and using the equipment in the apartment in the best way.

**CONCLUSION**

This paper shows the adaptation of the Canopea concept for housing for six students. Finally we summarize the different aspects:

- Structure: The livable stories are easily adaptable for a new use. With a minimum of modifications it could become a family apartment
- HVAC: The building requires as little energy as possible and a single 2kW heat pump will be enough to satisfy its heating and cooling needs
- Electrical Supply: Even if the photovoltaic panel surface was over-dimensional for a standard accommodation design, in our case this same surface allows it to be completely electricity independent.

During our visits to the prototype built in Grenoble, we realised tangibly the comfort obtained from an acoustic, thermal and practical point of view, these factors were also really appreciated during the contest in Madrid.

**REFERENCES**


