PASSIVE PROGRESSIVE?

What happened when a design team decided to build a Passivhaus from timber and straw bales in the foothills of the Pyrenees? **Oliver Style** explains

PROJECT TEAM

- **Client:** Jordi Vinadé, Itziar Pagès
- **Architecture:** Nacho Martí, Maria Molins, Oriol Martí
- **Passivhaus design, building physics, PHPP, M&E:** Oliver Style, Vicenç Fulcarà – ProGETIC SCP
- **Contractor:** Albert Fargas – Farhaus
- **Structural Engineering:** Manuel García Barbero – Klimark
- **Architectural Consultant:** Valentina Maini

Despite more than 100 years of cumulative knowledge, research and development, it seems we are largely failing to deliver comfortable buildings with good air quality, sufficient natural light and low energy demands. According to the RIBA CIBSE CarbonBuzz platform (**www.carbonbuzz.org**): 'On average, buildings consume between 1.5 and 2.5 times predicted values.' We are creating environments in which Europeans spend up to 90% of their time, but what we build generally doesn't do what it says on the tin. Why?

Monitored energy and indoor climate data shows that the deviation between predicted and real-life energy consumption is smaller in Passivhaus buildings than in conventional new-build projects[1,2] – despite the unpredictable user behaviour and technical fallibility described in these pages by Chris Butters of Gaia Architects[3]. The question of whether all future building should follow the Passivhaus model is an important one, and the points raised in Butters' article add to a lively and relevant debate on how we can close the performance gap.

This article intends to contribute to the debate, documenting the work behind the design and construction of the Larixhaus in Collsuspina near Barcelona, a family home that represents the first prefabricated timber and straw bale Passivhaus on the Iberian peninsula. It is currently in the process of being certified.

Integrated design with a 'fabric-first' approach

The brief was to design and build a small home with a specific construction cost of no more than £1,008/m² in less than eight months, bringing together natural,

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Windows are triple glazed with two low-emissivity coatings and argon gas filling

renewable materials with a high level of energy efficiency and indoor comfort. The integration of the design team helped to bring the project in on time and on budget, with close collaboration between the client-developer, architect, engineer and contractor. Such multidisciplinary integrated teams are key to designing low-energy buildings that perform as predicted.

Passivhaus Planning Package (PHPP) energy modelling was used throughout the Larixhaus project to test design strategies and meet the stringent requirements of the Passivhaus standard. A proprietary location-specific climate file was generated for the modelling and compared with the last 10 years of data from a weather station located 6km from the site, showing close alignment. A simple, and relatively compact, building form was chosen, with 339m^2 of thermal envelope enclosing a gross exterior volume of 437m^3 over two floors, for a form factor of 0.78. The longest dimension of the building was aligned east-west, enabling a perfectly southern orientation for the most highly glazed façade and providing maximum daylighting to reduce artificial lighting loads. The building aspect ratio is 1:1.3.

The goal was to minimise heat loss in the building fabric and reduce active heating needs in the winter, while avoiding overheating during the summer. The construction system was a proprietary prefabricated timber system with straw bale insulation. The moisture content of the bales was measured in the field – and again in the workshop before assembly – to make sure relative humidity content was no more than 15%. The bales had an average density of 104kg/m^3, and were positioned vertically in the wall structure to provide a 400mm insulation layer, with minimal air gaps around the bales to reduce convection currents within the assembly.

On the outside of the external walls, the straw was enclosed with wood-fibre breather board, followed by a ventilated gap and larch cladding. This was designed to reduce transmission heat gains in the summer and provide an exit for water vapour year-round, releasing any interstitial moisture build-up in the straw insulation layer. On the inside, the bales were enclosed by 22mm formaldehyde-free oriented strand board (OSB), which acts as the airtight layer, with Fermacell gypsum fibre board over a service void for a dry-lined finish. The structural timber that bridges the envelope was thermally broken with cork insulation. The wall's thermal transmittance was calculated to be 0.127W/m^{2}K.

Two straw bale cassettes were used for the roof, with the bales positioned in the same direction as the walls, and finished with clay roof tiles over a ventilated air gap. The roof's thermal transmittance was 0.122W/m^{2}K. For the floor slab, 130mm of rigid polystyrene was positioned under the slab, with 60mm of insulation around the edge of the slab, providing a thermal transmittance of 0.165W/m^{2}K.

The building's heat capacity was calculated to be 84Wh/K per m^2 of treated floor area (compared with approximately 200Wh/K per m^2 for a thermally massive construction). In the absence of a detailed dynamic simulation (unviable for projects of this size and budget), the PHPP tool was used to find a balance between the building's limited thermal mass and the size of openings, external shading devices and natural night ventilation. Given the site's altitude at 888m, peak summer temperatures are lower than coastal Mediterranean regions, averaging 20°C with an 8.8K daily temperature swing – useful for free night cooling. It was assumed that users would open four tilted windows for 60% of the day and night, with a 1K indoor-outdoor temperature difference and no wind, providing an estimated average ventilation rate of 0.35 air changes per hour

(ACH), or 136m³/h. The model showed that with no active cooling, summer overheating frequency (when the indoor air temperature exceeds 25°C) could be kept below 3%.

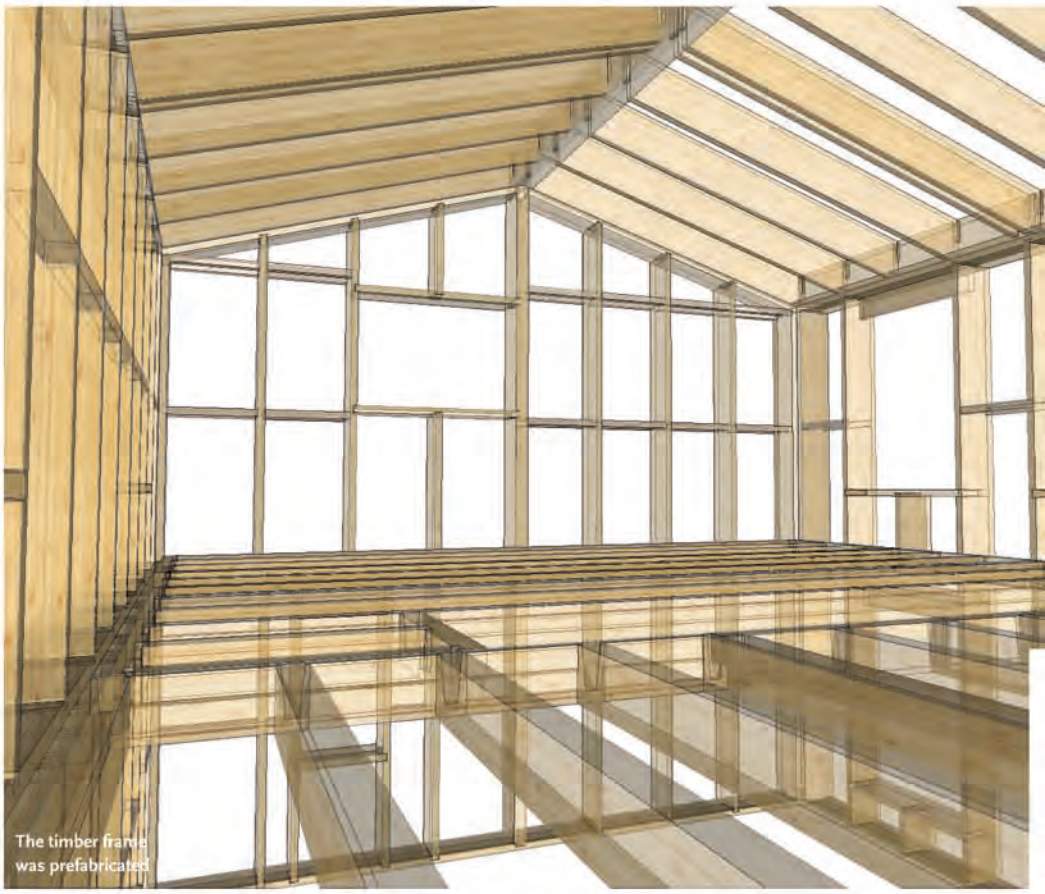
Low energy solar buildings are naturally very sensitive to solar gains. The model was used to find the correct winter-summer balance of heat gains and losses through windows, assisting in the glazing and frames specification: triple glazing with two low-emissivity coatings, argon gas filling and TGI-spacers (for a centre-pane U-value of 0.65W/m²K and solar factor of 47%), together with softwood frames with a U-value of 1.00W/m²K, and incorporating cork insulation to reduce thermal bridges. The average installed window U-value is 1.06W/m²K – not enough for central Europe but sufficient to meet the Passivhaus comfort and hygiene requirements in the Collsuspina climate.

The door blower test result was n50 = 0.32 ACH (q50 = 0.26 m³/h.m²) – approximately 15 times more airtight than new buildings in Spain, which average n50 = 5 ACH. Cold bridges throughout the building structure were eliminated or reduced with 2D finite elements modelling and optimisation in the design phase. Prefabrication of the structural and thermal envelope of the building took six weeks to complete and site assembly two days. Most of the airtight layer was pre-installed, together with window frames, thereby providing high-quality detailing and avoiding the on-site complications that can arise from damage to the airtight layer. The minimal on-site construction times resolved many of the technical and budgetary challenges of the project.

Indoor air quality and efficient ventilation

The first step to achieving good indoor air quality was to minimise or eliminate materials with high VOC emissions. Following this, a whole-house mechanical heat recovery system was chosen for full fresh-air ventilation with minimal heat losses in the winter. Careful planning made sure the duct lengths were kept to a minimum, with silencers on the indoor supply and return ducts, and adequate sizing to control air velocities and eliminate noise. The ventilation unit was fixed on acoustically insulated mounts and located in the service cupboard by the entrance on the ground floor. The ventilation system has a maximum measured sound pressure level of 33dB(A) in living spaces.

A Passivhaus-certified Zehnder Comfoair 350 ventilation unit was specified, with an estimated seasonal COP of 9. Efficient DC fan motors with a specific fan power consumption of 0.29Wh/m³, used for an estimated 4,700 hours in the year at an average ventilation rate of 95m³/h, mean that the unit is predicted to consume 129kWh/a – approximately £35 of Spanish electricity yearly.



The timber frame was prefabricated

> For successive days with no sun, radiators are turned on for half an hour at night and in the morning, to maintain comfort

Monitoring: beyond PHPP

A monitoring system will be installed in the coming months, providing quantitative data over a two-year period, monitoring outdoor and indoor temperature, humidity and CO_2 levels, and energy consumption for space heating, ventilation, hot tap water, lighting and equipment. It will be particularly interesting to see the building's in-use summer performance, and it will help all of those involved in the project to analyse strengths, weaknesses and areas that require improvement.

Currently, feedback from the client shows that with outdoor night-time temperatures reaching -1°C, indoor temperatures have remained above 20°C with no active heating, as long as there is sun during the day. For successive days with no sun, radiators are turned on for half an hour at night and in the morning, to maintain comfort.

Bales have an average density of 104 kg/m³ and provide 400 mm of insulation

A door-blower test found the house to be 15 times more airtight than a typical house in Spain

The specific construction cost of the build has come in at £1,010/m², an estimated 14% more costly than building to current regulations in Spain. This gives a simple payback time of just under nine years, for a building with an expected useful life of 80 years. Will the Larixhaus close the gap? Watch this space. **CJ**

References

1 Ridley I, Clarke A, Bere J, Altamirano H, Lewis S, Durdev M, Farr A, 2013: *The monitored performance of the first new London dwelling certified to the Passive House standard. Energy and Buildings*, Volume 63, August 2013, Pages 67-78, Elsevier.

2 Schnieders J, Hermelink A, 2006: *CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building.* Energy Policy, 34 (2006), pp. 151-171 (Elsevier)

3 Butter C, 2013: Designing reality. *CIBSE Journal*, April 2013, Pages 18-19. Cambridge, UK.

4 Brister A, 2012: All for one. *CIBSE Journal*, July 2012, Pages 22-23. Cambridge, UK.

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PROJECT BASICS

- **Building type:** Detached, single-family house
- **Energy standard:** Passivhaus new-build
- **Location:** Collsuspina, Barcelona, Spain
- **Treated floor area (PHPP):** 92m²
- **Construction type:** Timber construction
- **Completion date:** December 2013
- **Completion time:** Seven months
- **Space heating demand (PHPP):** 15kWh/(m²a)
- **Space cooling demand (PHPP):** 3.2kWh/(m²a)
- **Heating load (PHPP):** 11W/m²
- **Cooling load (PHPP):** 3.9W/m²
- **Primary energy requirement (PHPP):** 96kWh/(m²a)
- **Construction costs (gross):** €1,010/m²
- **Airtightness (n50):** 0.32 ACH

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