# Prefabrication and Automated Processes in Residential Construction

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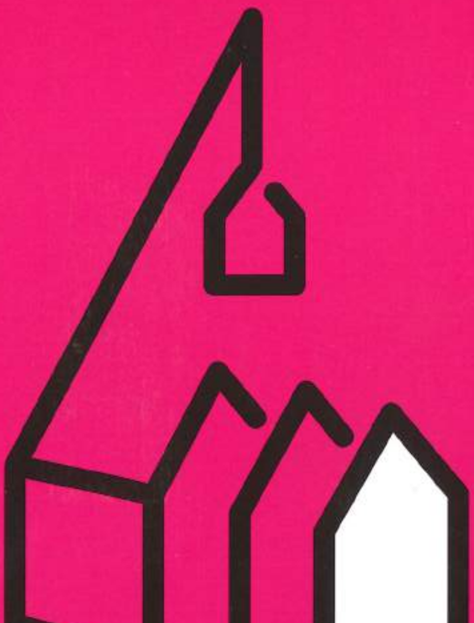

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## Student Housing Sant Cugat

Architect
DATAE & H Arquitectes
Location
Barcelona (ES)
Building type
Multi-storey housing
Year of construction
2008–2009
Building dimensions (w*l*h)
28 x 65 x 6.5 m
No. levels
(L00, L01)
On-site construction
9/2011–7/2012, 8 months
Off-site fabrication
04–05/2009, 6 weeks
On-site assembly
10 days
GFA (gross floor area)
3,101 m²
GBV (gross building volume)
2,480 m³
No. apartment units
62
Costs of prefabrication
€1,872,752
Total costs
€2,784,739
Annual operating energy
82 kWh/m²
Primary Energy Consumption
88 kWh/m²

Organised within two opposite building blocks, the 57 student residences are located in Sant Cugat del Vallées, a town in the suburban area of Barcelona. The low-rise, two-storey apartment buildings are arranged around an open courtyard. The precast concrete modules cover 3,013.50 m² of the total 3,101 m² GFA. These 62 prefabricated units, including a few cells for common space, are completely manufactured off-site. The final on-site assembly and delivery of the room modules from the plant to the construction site required special freight services.

The table on the left gives an overview of the construction cycles and building data that is relevant for the comparison of system design approaches. On-site processes are distinguished between conventional works including site preparation and building completion – for example, the construction of the roof, installation of MEP supplies, and so on – and on-site assembly that comprises the installation of prefabricated parts. Furthermore, general information regarding the building dimensions, areas, mass, and construction costs are shown. In this case, energy performance values are based on Swiss Minergie standards and refer to the building's total GFA.

The 57 apartments, consisting of reinforced concrete modules, each measuring 11.20 m × 5.00 m × 3.18 m and offering 39.95 m² of floor area, include a bathroom pod and balcony space. They were fabricated within six weeks using an indoor assembly line (Compact Habit, 2014). Standardised dimensions – fixed widths and heights (but alternating lengths) – enabled resource- and time-saving production sequences. Off-site manufacturing contributed to process control and improvement of the construction's energy management. Furthermore, the reuse of formwork provided significant economical advantages. Figure 5.3.22 shows the set-up of fabrication equipment in Barcelona.

Left 5.3.21
Elevation of inner courtyard and access balconies of apartments
Photo: © Compact Habit, 2014.

5.3.22
Off-site facility accommodating assembly line, fabrication, and installation equipment
Source: © Compact Habit, 2014.

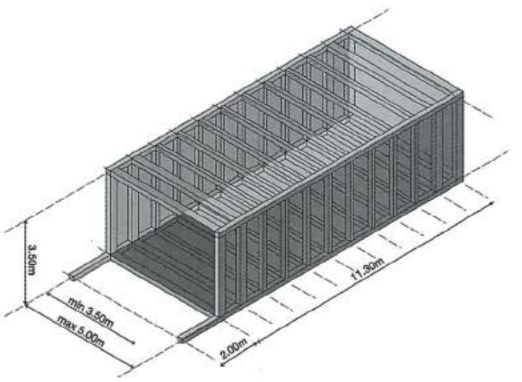
### Structural Concept and Assembly Strategy

The structural framework of each module is based on a planning grid spaced at 0.90 m intervals. Concrete ribs transfer vertical and horizontal loads. The tubular structure enables easy stacking of units without further support. The decoupling through flexible elements, which are located at the bearings between the cells, impedes direct sound transmissions (Compact Habit, 2014).

Figure 5.3.23 (a) shows the structural framework of a concrete cell, highlighting its maximum span dimensions. Stacking the units leads to double build-up of wall and floor slabs, requiring the placement of flexible sound barriers at bearings. Due to its structural stability, no additional bracing of the building block is required. Figure 5.3.23 (b) shows the lifting of an apartment module during assembly. For on-site works, heavy-duty equipment is required to manoeuvre the 45 tonne units.

Mechanical and technical supply systems are preinstalled on defined routes and connected to the main installations on-site. The construction method enables rapid on-site assembly, enhanced cost and time management, the reduction of risk and noise, and controlled waste management. Furthermore, disassembly of the modules does not require demolition. The system permits building relocations with minimal effort and guarantees easy modernisation or modifications of cells. However, the weight of the container-shaped units varies between 25 and 45 tonnes depending on the dimensions (Concrete Products, 2014). Constraints due to transportation and logistics need to be considered.

Figure 5.3.24 (a) shows completion procedures of off-site works, including slab extensions of roofs and ceilings, and preparation for transport. In Figures 5.3.24 (a) and (b) the application of weather-proofing layer, in this case sheet metal, and on-site connection of MEP supplies are shown.




a

b

5.3.23
(a) Structural variants of concrete modules;
(b) On-site assembly of modules using heavy-duty equipment
Source: (a) Albus, 2014, based on Compact Habit; (b) © Compact Habit, 2014.

a

5.3.24
(a) Off-site completion of concrete modules;
(b) Installation of MEP supplies
Source: © Compact Habit, 2014.

b

### Summary and Results

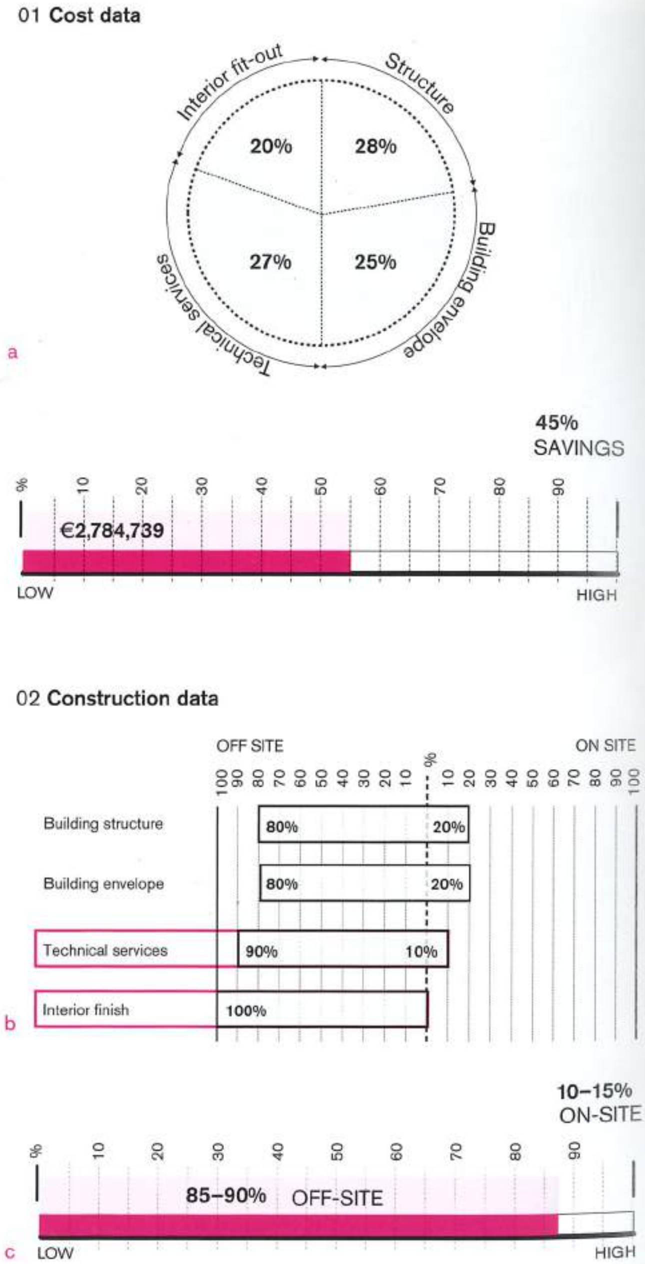
The planning approach represents an alternative solution for a low-cost student-housing complex. The cost-effectiveness of construction significantly influenced the planning and realisation of the project. The development of a modular structure, consisting of highly preinstalled units, contributed to short construction cycles. Prefabrication enhanced thermal performance properties of the façade, significantly contributing to the building's extraordinary ecological performance. Furthermore, the integration of the ensemble within the landscaped environment, the arrangement around a central courtyard, and external circulation corridors in front of the apartments contributed to the socio-cultural appreciation of the design.

Thanks to the double built-up of wall and floor components, the modular concrete system provides excellent insulation values, allowing for an energy certification 'A' for buildings. Depending on the choice of materials and built-up, an acoustical insulation of 55 dB for walls and 56 to 57 dB for floors and ceilings can be achieved. Furthermore, U-values for thermal transmittance of the building envelope are at 0.30 W/m²K and range between 0.22 W/m²K and 0.30 W/m²K for roofs, depending on the configuration and material use.

Contributing to its life cycle balance, the construction process and building operation enable energy savings and a reduction of carbon emissions. Compared to conventional building approaches, savings of up to 60 per cent are expected (Hauser et al., 2013, p. 1399).

Figure 5.3.25 indicates the economic aspects of the construction, such as the cost distribution and process durations. The distribution of costs is approximate, based on a general contracting agreement with a single operator.

However, for a comprehensive life cycle analysis, logistical dependencies and transport distances between off-site manufacture and building site play a major role and need to be considered.




5.3.25
(a) Distribution of costs (b) Construction processes according to off- and on-site processes (c) Duration of process cycles
Source: Albus, 2015.