Habidite, 48530 Ortuella, Vizcaya, Spain

Modular buildings of light, pre-stressed self-compacting concrete

Habidite is a construction system that was created to provide a response to one of the main concerns in the building industry: optimization of production processes through implementation of the most advanced technologies. The new system involves the manufacture of the components of a housing block in a controlled and stable environment by means of repetitive production. On completion, the components are transported to the destination site and the final assembly of the building takes place.

Valentín Gómez Jáuregui,
Oinatz Elorrieta Larruzea;
Habidite Projects, Vizcaya, Spain

Buildings developed in the Habidite system are the result of a combination of modules made of steel-reinforced concrete whose weight and scale allow for transport in conventional vehicles. The modules constitute habitable rooms, with all the facilities and finishes necessary for use. The possibilities for configuration are numerous. These might include educational buildings, health centres, hotels, residences, penitentiaries, etc. In the development of residential buildings, the modular combination allows for numerous and diverse combinations in accordance with the aim of achieving the highest degree of habitability and spatial quality possible in each case.

In housing, the system can generate everything from one-room apartments to single-family buildings, or housing units with as many rooms as one wishes, also allowing for selection of different kitchen configurations (kitchenette or independent) or inclusion or selection from among different additional rooms (bathroom, wardrobe, storeroom, study, etc), and through the joining of as many modules as necessary (**Fig. 1**).

Habitable modules are complemented by other modules for construction of a terrace, shafts for lifts, stairwells, distributors or roofs, thus forming the building as a

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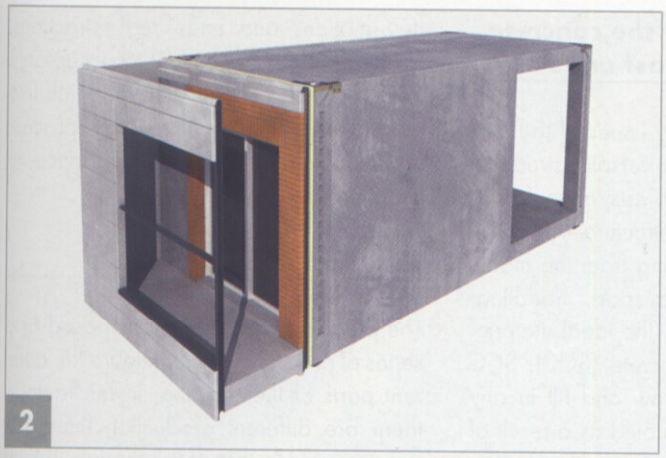
Habidite housing, made up of different modules (here: 3 modules joined as one unit, plus balcony module)



Typical housing unit

Valentín Gómez Jáuregui is a Civil Engineer from the University of Cantabria in Spain and the École de Génie Civil, Université de Liège, Belgium. He completed his academic training at the School of Architecture at Queen's University Belfast, UK, attaining a Master degree in Architecture. He has worked in the building industry, first as the Manager of the R + D Department, and presently as the Director of Production Technology of Habidite Projects.

v.gomez@grupoafer.com

Oinatz Elorrieta Larruzea is a Polymer Engineer from the University of Lea Artibai de Markina in Spain. He completed his academic training in the Laboratoire de Recherches et de Contrôle de Caoutchouc et des Plastiques, Vitry sur Seine, France, in the field of materials research. At present, he is working in the building industry as a Production Technology Development Engineer at Habidite Projects.

whole with all installations built-in at the factory, such as sanitation, electricity, heating, air-conditioning, etc.

Product details

The final product is the building fully constructed from the ground up, complete and ready to be delivered to the future tenants in a perfect state of use and habitability. The structure of the building down to the zero level (garages, ground floors, retail premises, foundations, etc.) is made on site. This is performed through use of traditional construction methods. For tall buildings, the first floor is supported on a mesh of prefabricated girders adapted to support the weight of the rest of the building. This set of pre-stressed beams made in the factory and taken to the worksite by conventional transport, is supported on structural columns which are either made on site or prefabricated. The modules, as large complete units may be of three types, primarily: housing modules, terrace modules and roof modules. The first two are for rooms to be used in housing units (**Fig. 2**), while the third refers to the slabs used to create a roof to the building.

Housing modules

Housing modules are of octagonal parallel geometry, i.e. rectangular prisms of large dimensions (6.60 x 3.30 x 3.00 m) modulated so as to allow for configuration of diverse typological combinations. Its main load-bearing structure is anchored in a pre-stressed horizontal slab, four vertical pillars in the corners, four upper perimeter beams and a slab resting on these as a ceiling. The structure is completed by perimeter and internal walls, which configure the layout of the housing unit. Each pillar has an embedded Pillar-Multipurpose Part (PPP), resulting in four PPP for each module, the functions of which will be described below.

Terrace modules

Terrace modules are self-supporting, with dimensions that are smaller than those of the housing unit and are distinguished from them as follows: rather than resting on each other, they are cantilevered and anchored to the sides of the adjacent housing modules. Even though its structure has characteristics similar to those of a housing unit, they need not be closed, and can even be constructed without a covering roof. The terrace modules can also be fully made in the factory and are anchored to the housing module prior to being transported to the work site.

Roof modules

The roof modules, which serve for the collection of rainwater, are components with factory dimensions that coincide exactly with those of the housing module so that they in fact rest on the last habitable floor of the building. The functioning of the roof allows

for collection of rainwater falling on the roof. The water is then channelled to the central roof plates, consisting of orifices that lead to the rainwater downspouts.

Façade and utilities

To achieve full thermal, acoustic and water insulation of the façade and corner modules, these are placed on an exterior panel of steel-reinforced concrete which is fully independent and versatile, with an exterior coating which is adaptable to any type of material, thus yielding an effective ventilated façade.

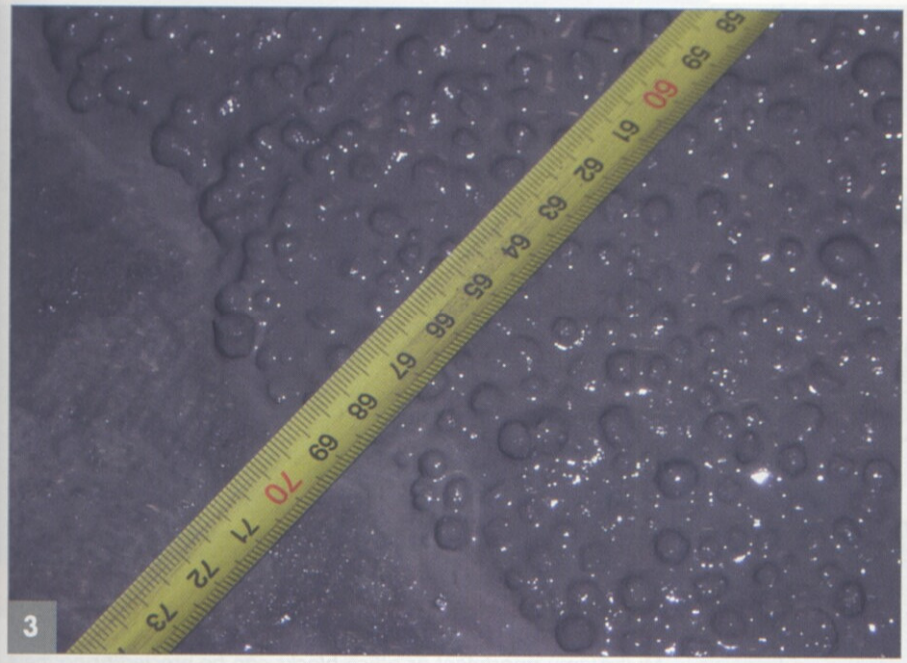
As for utilities, the solution adopted here seeks optimal exploitation of natural resources as well as a design that minimizes the consumption of water and energy. All utilities were designed such that consumption of resources during the process of design, execution, use and end of lifetime will comply with the requirements for sustainability. They are included in the factory design of modules, and in addition to standard ones such as electricity, gas, plumbing and heating (through a radiant floor), they provide solar energy installation, photovoltaic power, climate control, recovery of rainwater and grey water, fire protection, and others, including the necessary control units, energy saving and power supply facilities, sensors, activators, remote control, etc.

Characteristics of the concrete used for the precast units

Perhaps one of the key issues of the project is the utilization of a versatile structural material that allows an easy manufacturing process and high structural versatility. Due to the needs arising from the manufacturing process, transport, handling, workplace safety, etc., the ideal material is self-compacting concrete (SCC). SCC has the capacity to flow and fill in any part or corner of the mould as a result of the action of its own weight with no other method of external compacting needed and with no segregation or blockage of aggregates. These characteristics are combined with the lightness provided by the inclusion of lightweight aggregate and/or lightweight sand (expanded clay) as well as the necessary additives (superplasticisers and viscosity agents) to keep the materials in suspension and to maintain the required fluidity (**Fig. 3**). The result is a self-compacting lightweight concrete (SCLC), which is ideal for prefabrication. Nevertheless, there are other requirements such as a high production pace and a certain frequency in the concrete cycles. This results in the need for sufficient early age concrete strength to allow a reliable demoulding process. The use of special admixtures such as accelerators is inevitable, as well as cement with specific proportions and characteristics. It is unquestionable that this type of concrete may be susceptible to significant deferred deformations and undesired retractions. However, these are limited to acceptable levels owing to proper control of all factors involved in the production process and, which is of no lesser importance, in the curing process.

The production process

The production process is composed of a series of processes that configure the different parts of the building. In the factory, there are different production lines, the main one being that of the module, which is fabricated in a continuous, conveyor supported operation. There are also other, auxiliary lines, where additional components are produced, such as stairs, balconies, ceilings, roofs and foundation beams. The production line of a module is composed of three zones: the first of these carries out the pre-stressing of the slab and creates the load-bearing pillar (PPP). In the second zone, the utilities and steel reinforcement are installed and the concrete is cast for the entire module structure, including interior walls. In this production step, also all other processes are performed in order to achieve a fully complete and packaged module for transport to the destination building. In the last zone, processes such as placement of additional utilities, auxiliary elements (façade panels, balconies, stairwells, etc) are performed, as well as provision of insulation, installation of the roof, and inclusion of furniture, home appliances



Self-compacting, light-weight concrete offers the ideal solution for the production of the precast units

and finishes. Final cleaning, quality control and packaging are incorporated in the last production step as well.

Transport and assembly on site

The transport of modules is a critical phase, since it may give rise to some of the most substantial demands to which they will be subjected (accelerations, vibrations, wind action, etc). Nevertheless, any type of standard transport can be used, such as truck, train, ship, etc. Care is to be taken to ensure that each part is perfectly packaged, labelled and catalogued in order to protect them from dirt, breakage, loss, etc. Prior to and after transport, each of the parts must be handled with the greatest speed, precision and safety. Lifting is generally done with cranes by means of levelling beams that will ensure the horizontality of the modules at all times. These beams are metal frames that include connection points for the concrete modules. Their corners are lashed with a special lifting tool that fits into each of the PPP.

On the work site, after the goods have been unpacked, module assembly follows a predefined process for lifting, placement, embedding, levelling, mechanical anchoring between modules (and façades or balconies) and installation of horizontal and vertical connections. Then, connection of the utilities continues and the placement of interior and exterior joint covers completes the building (**Fig. 4**).

Summary and conclusions

The Habidite construction system for modular industrial buildings provides a series of benefits that include the following:

- Modularity: Possibility of achieving limitless building types with just a few module types.
- Versatility: Finishes open to change, façades for different aesthetic criteria, different types of materials, colours, textures, etc.
- Quality: Use of the most advanced technologies in utilities, finishes, comfort and so on.
- Cleanliness: Finished, clean product from production to on-site delivery.
- Optimization: Of all the resources involved - materials, time, money, energy - owing to the industrialization of a practically artisan product like housing.
- Energy savings: Use of solar energy,

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Multi-storey apartment or office blocks can be erected using the Habidite precast system

use of photovoltaic solar energy, optimization of energy consumption for heating and hot water, thermal insulation and water tightness.

- Water savings: Exploitation of rainwater for toilet cisterns, recycling of grey water – showers, sinks, etc – for cisterns, and incorporation of the latest technology in sanitation to save water.
- Materials savings: Optimization of quality of materials used in each component, drastic reduction in rubble and leftovers, reuse of waste materials.
- Regulation: Consistent with all regulations, with substantial improvements in some (e.g. CTE in Spain).
- Environment: Garden-covered roofs, reduction in use of fossil fuels, use of materials which are not harmful to the environment.
- Industry: Creation of a new type of industry and generation of jobs in good working conditions with a drastic reduction in workplace safety hazards.
- Yield: Improvement in material quantity, execution times, delivery deadlines, financing conditions, etc.
- Independent of climate: 95% workshop labour, thus reducing stoppage times owing to adverse weather and improved working conditions for employees.

Further information:

habidite® technologies

Habidite
Barrio Bañales, 14
48530 Ortuella, Vizcaya, SPAIN
T +34 946 354 841 · F +34 946 354 837
info@habidite.com · www.habidite.com