- Barcelona
- Catalan Design
- Conceptual Circuit
- Critical Reinterpretation
- Crowdsourcing
- Ecoinnovation
- Ecoproduct
- Ethics of Function
- Historiographic Challenges
- Incorporated Energy
- Internet
- LCA Life Cycle Assessment
- Local Action
- Low Environmental Impact
- Material Environment
- New Designers
- New Materials
- Recycle
- Reduce
- Rehabilitation
- Research
- Reuse
- Sustainability
- Technological Transfer
- University
- Utility
- Utopia
- WWW
- Zero Emission

Industrialisation

Innovation

Modular Construction

Optimisation

Miguel Morte

"The term "optimisation" and all things related to it will be the key to the future transformation of construction."

Architect, Director of Development, Innovation and Projects for Compact Habit. First place winner of the 2007 Construmat Technological Innovation Award: Stackable and Integral Modular Construction System, First place winner in Construction Innovation of the 2010 Catalonia Construction Award.

Industrialisation and new construction design

Compact Habit is a company that through dynamic responsiveness and innovative work, has created a new paradigm based on industrialisation and new construction design. In order to design projects using methods that facilitate the industrialisation of construction, we need to rethink the way we work. Optimisation, and all things to which it relates, shall be the key to transformation, to “the industrialisation of construction”.

Current situation

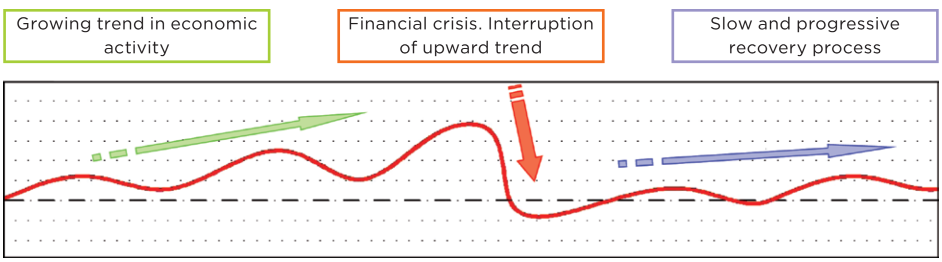
The current analysis of economic developments requires all professionals, whether or not from the construction sector, to reflect upon and rethink their profession in order to find new ways to approach it.

By observing the economy’s undulating behaviour over time, we can build a simile or “wave theory”. This theory tells us that low points are followed by periods of economic improvement, producing a rising wave of recovery until peak growth is achieved, followed by a crest that is later broken. From that point on, another similar period of gradual, slow growth begins.

If in day-to-day practice we do not find a dynamic response based on improvement and innovation, whether in the form of technical solutions or new businesses, we will not be able to speed up the recovery process. This tells us that with greater inventiveness (possibly acting in opposition to usual criteria and standards), we will be better able to understand the undulation of the wave, thereby triggering an increase in wave height or, in other words, in the magnitude of economic improvement.

We often hear that crises activate minds to produce new ideas, answers and solutions. But it is a pity that we need to get to this point. During strong economic periods, we fall prey to conformism and

▼ Wave theory. The rhythms of economy



the monotony of everything that surrounds us; we settle and we stop being competitive in our professional activities.

Is it not true that we normally find solutions to the usual problems we face on a day-to-day basis, both professionally and personally? We need to learn how not to conform during any economic phase; we need to find new solutions at every single moment in time. A new idea or solution might have greater success in a context of greater need, but properly addressing and developing an idea at a time of abundance allows us to keep one step ahead of the solutions available in the market and gives us the chance to calmly analyse and meditate on these new ideas or solutions, with time on our side. We could possibly even become more competitive.

Example: The Compact Habit Case

In 2004, the construction company Constructora d'Aro, with over 40 years of experience in the construction sector, started to address the construction sector's issues from the standpoint of quality and general improvement. It analysed the negative transformations that had been occurring in construction for years, mainly underscoring the following issues:

— Loss of quality in construction due to a lack of professional qualifications (positions were being filled by persons lacking sufficient professional experience).
— Stagnation in construction systems. A blatant lack of new ideas.
— Precarious construction methods, with safety in construction works and processes clearly involuting.
— Poor construction process controls as a result of deviations from financial planning and construction work project timelines.

At present, these issues would seem more than obvious to us, but identifying them during a period of economic plenitude when it would have been easier to settle for the day-to-day routine was not only progressive, but truly worth highlighting.

As a result of this analysis, the development of a new construction system was commissioned to solve these issues, prioritising objectives based on "how to build better". The conditions that the new solution had to meet were stated quite clearly as from the onset of the project.

How to come up with answers and solutions to the project. Methodology

When we are faced with having to provide a solution for a new project, whatever the subject to be developed may be, we can act in either of two clearly distinct ways:

Method 1

This method consists of searching the literature for related data that will give us new ideas we can apply to the project. We could say that this is the most obvious and easiest solution. In this case, we accept that others have already worked on providing solutions to the same problem, which solutions we will later screen, modify, adapt and reformulate.

Although it is perfectly valid approach, I dare say that is perhaps too conformist and easy.

A personal example follows. When I was studying architecture, we were asked to complete a single-family home project. I got a very good grade on this project, especially because my professor really liked the geometric shape I proposed. I had found the inspiration for this geometric shape from a sample of aluminium carpentry work that had fallen into my hands. Big mistake! I had developed a project from a shape, forcing it to comply with an attractive geometry. I was strongly influenced by the shape of the sample, but even though the result might apparently have been good, rather than solving a project by meeting the initial conditions, I had only solved it from a purely aesthetic point of view.

Indisputable and restrictive conditions have to be written out as from the onset and they must never be put aside until each and every one of them is resolved. We must not fall prey to convincing ourselves that we can modify initial conditions according to internal or external interests. We need to create personal justifications to validate the elimination or modification of initial assumptions.

I believe that a strong methodology begins by preparing an initial, thoroughly reasoned out list before starting out with the project. From that moment on, data may be added but not removed. This list of conditions must become the backbone of our project solution.

Method 2

Using the above-described list of conditions as an essential starting point, this method seeks to isolate, insofar as possible, the solutions that may relate to the project. That is, it avoids collecting purely informative data that may condition the development of an idea.

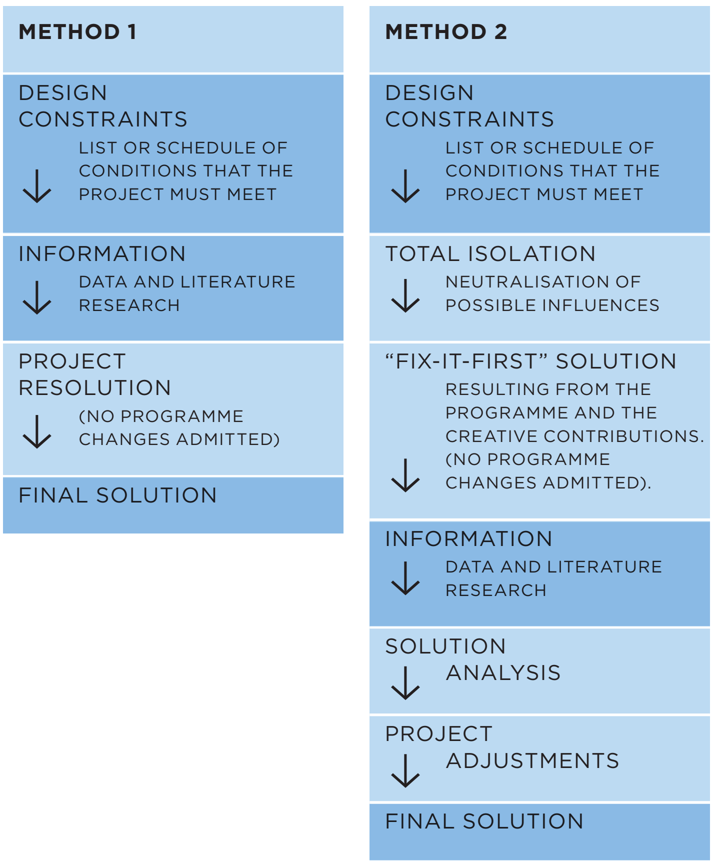
This situation will call for greater concentration and problem-solving work but will lead us toward a differentiated project solution with greater chances of producing a new idea that will help us make progress on approaches and solutions.

This theory that I defend is evidently not perfect and no one is entirely immune to acquired influences, but by avoiding the search for data that is usually done before developing a project, such influences cease to exist, and we simply act with the knowledge we have, applying other extremely important elements, such as design logic, the logic of use, construction logic, financial logic etc. Above all, the most important thing is knowing how to provide solutions to the list of conditions, whether prepared conscientiously by us or given to us by the client.

Once the project proposal has been prepared with solutions to each of the items included therein, then it is certainly a good idea to compare it with other existing solutions and to search for bibliographical references. Any matches produced by this analysis will confirm that the process has been accurately completed and corroborated by others who have solved it before, giving us the strength to assert and consolidate a job well done. Any inconsistencies or formerly developed contributions will also be identified, evidently adding energy and sense to the project, as well as the desire to continue with the research part of the process.

Following the objectives of the work commissioned, we arrived at a solution consisting of an industrialised, modular construction system based on large-sized, ribbed modules made of reinforced concrete. We also developed a floating structural system based on acoustics. Going back to the previous point, upon comparison of these results, we found that ribbed solutions had already been used in the 1950s and that ribbed geometries seemed to be the easiest to optimise in terms of weight and structural resolution. Data on construction industrialisation factories that had been short-lasting–a major concern that was analysed in depth, although

▼ Process flow chart for both methods



a decision was nevertheless made to go ahead with the project–were also localised. Upon analysing industrialisation trends in other countries, they all tended to use lighter solutions (the advantages of concrete were also analysed). We found no floating structural solutions as the one we had developed, no structures based on acoustics and no transportable, three-dimensional concrete pieces of the proposed measurements (15.00 × 5.00 × 3.50 m).

All of these coincidences (or lack thereof) are the elements that establish the direction in which a project will be headed and that will ultimately lead it to a positive outcome. This subsequent analysis – mandated by matters related to intellectual and industrial property – is not only necessary, but also required in order to create new patents to protect new ideas.

Using the development of this construction improvement project as starting point, we arrived at a modular system where the transportable system was a structural concrete container that could be equipped with all possible services at the factory, so it could later be used as a building construction unit.

The final decision

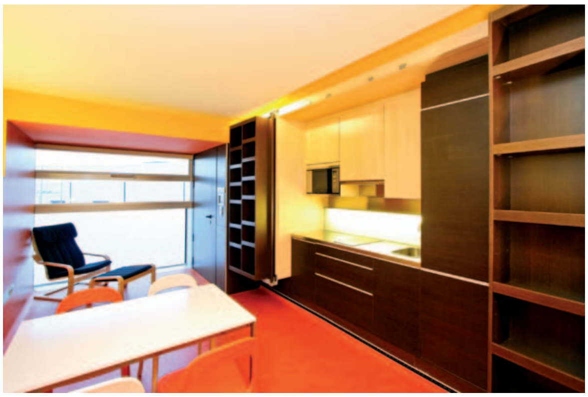
At that point, we could say that we were barely at the starting line on the path towards our goal, which is "to build better". The path had been found, but we still needed to develop an entire system that would allow for maximum construction industrialisation. Before going ahead with the investment, we decided to make a prototype of the home and submit it to Construmat 2007 to see if it would gain acceptance. The result was a huge success, as the "Modular and Stackable Construction System" submitted by Compact Habit won first prize in the category of Structural Products and Enclosures. This acceptance of the system helped provide support and validation, but it did not help us decide whether or not to go ahead with the industrialisation phase, which involved the construction of a factory. This decision had already been made based on the conviction of both the developer and the project team.

▲ Industrial module assembly line. Specialised and organised work areas along the assembly line are fixed and the modules move at a steady pace

▲ Storage of a building, waiting to be assembled on site

▲ Transport and assembly of industrial modules

▲ Industrialised housing prototype with floating structural system, from company Compact-Habit. Presented at Construmat 2007. 40 m^2 dwelling for young people



▲ Inside the prototype's kitchen area

Then, industrialisation works started by designing a machine that could produce the concrete modules and a factory that would be capable of carrying out the entire production cycle, including full module finishing. In-factory operations consisted of building the concrete modules, conveying them across assembly lines or chains and equipping each module at different work stations to produce finished modules, ready for shipment to their final destination. A traditional concept in any manufacturing cycle, but adapted here to construction.

In 2009, despite the growing crisis, production was initiated at Compact Habit, turning our goals and all of the work done since 2004 into a reality, thanks to the original idea of improving and taking a step forward in construction. Admittedly, the idea behind this project and the hope it carried along with it, led from the beginning by Joseph Tarrant, president of Constructora d'Aro and current president of Compact Habit, was risky but innovative.

Taking the current situation into account, Compact Habit has produced 30,000 m^2 of construction. Because the entire technical part of the project was developed before the crisis, the company is currently providing one-of-a-kind technical solutions to the market, triggering technological advancement that implies having to bet constantly on innovation in order to maintain leadership.

The evolution and future of construction

Setting aside the case of Compact Habit as an example of how an industrialised system is developed and having lived this experience as from its very onset, I can draw certain conclusions on what I believe needs to evolve in the world of construction.

In order to realise where we are and where we want to go, we need to compare two opposite situations.

If we take the example of a residential building built with traditional construction methods, and compare it with an entirely different situation, such as the construction of vehicles for the automotive industry, there are a number of points we could highlight to create an intuitive comparison. This comparison does not follow any statistical analysis rules, but it might simply prove to be useful to give us a merely personal idea of where we are today. I recommend filling out this table with your own specific criteria. To make for easier reading, I included certain figures from a small statistical inquiry I conducted.

The significant difference found between these indicators is a reflection of the construction industry's present status, in turn due to how little construction systems have changed over time. Perhaps some people would say that we cannot compare the two columns shown above, but we could agree with this statement only if the future of construction remained unchanged, conforming to what the market is offering in terms of quality of housing. However, if we were to start asking ourselves how our homes should be, going beyond the limits of what our current systems are offering, we would surely demand a level of quality, materials and technological development in line with those currently showed by the automotive industry.

If we were to apply the second work method described herein (where we disconnect ourselves to the extent possible from the influences that surround us) and then compared the results of our proposal, I am sure that the level of our product or home would be much higher than that of current construction systems. For this reason, I believe it is essential to reformulate construction methods, based on maximum component industrialisation. It all boils down to achieving "minimum on-site work times" and maximum systematisation as an essential factor. It is clear that the more elements are worked in the industry, the better the quality of products, labour and safety.

Any attempt at industrialisation, however, is faced with the problem of smallerscale viability, as

	HOUSING CONSTRUCTION		
INDICATORS	TRADITIONAL CONSTRUCTION	INDUSTRIALISED CONSTRUCTION	AUTOMOBILE MANUFACTURE
QUALITY OF FINISHES	5	7	9
QUALITY OF HIDDEN PARTS	3	7	9
QUALITY OF STRUCTURE	6	9	10
QUALITY OF INSTALLATIONS	5	8	10
QUALITY OF MATERIALS	6	7	8
QUALITY OF AIR	5	5	8
TECHNICAL MEANS OF CONTROL	4	7	10
PRODUCT TRACEABILITY	2	8	10
THERMAL COMFORT	6	8	8
ACOUSTIC COMFORT	5	7	7
COMFORT GIVEN BY SHEATING MATERIALS	5	6	8
RESIDUE CONTROL	4	8	9
EMISSIONS CONTROL	4	7	8
ENVIRONMENTAL CONTROL OF MATERIALS	4	7	8
MAINTENANCE CONTROL	3	6	10
QUALITY OF WORK	3	8	9
SAFETY AT WORK	3	9	9
ENVIRONMENTAL IMPACT. IMMEDIATE SURROUNDINGS OF THE CONSTRUCTION/MANUFACTURING SITE. CONSTRUCTION WORK	2	8	8
CONSTRUCTION/PRODUCTION TIMES	3	10	10
TECHNOLOGICAL DEVELOPMENT	4	7	9
TOTAL	82	149	177

▲ Comparison of indicators between traditional construction, industrialised construction and automobile manufacturing product repetitiveness is required in order to use production techniques (moulds, tooling, process automation etc.). This is not possible with the existing construction and design systems, this being one of the most important triggers for change.

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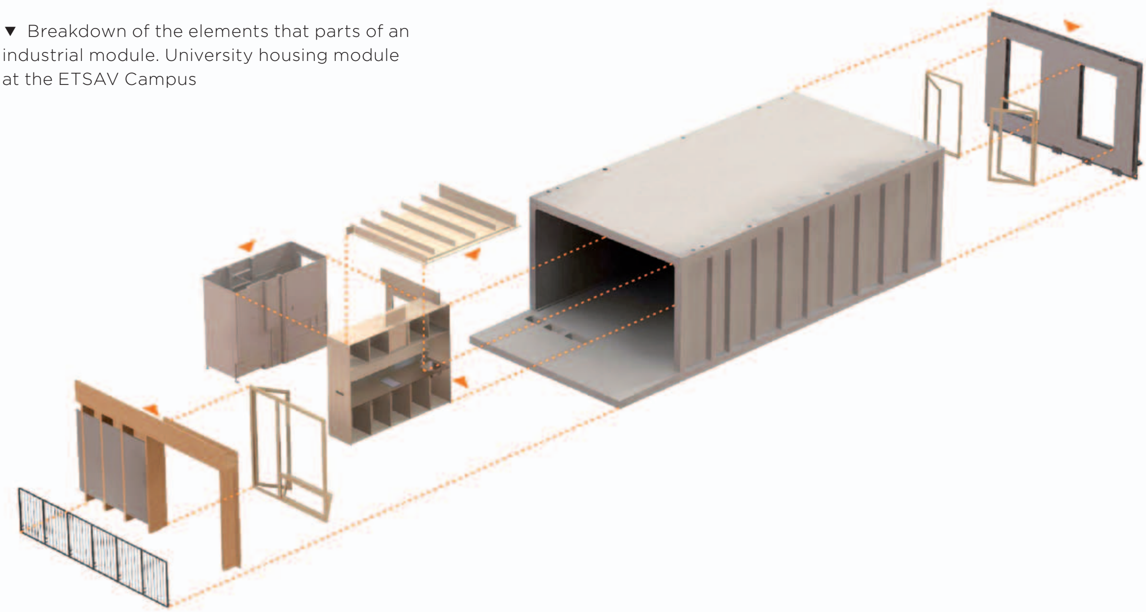
▲ Installation of a prefab building. University housing module at the ETSAV Campus in Sant Cugat del Vallès. Architect: H Architects, S.L. and Data A.E., S.L.

New design methods

So far, architectural design has been based on solving distribution issues, giving a certain aesthetic look to the building and completing it with all the technical equipment required. Projects are developed with a conformist construction system methodology that only incorporates new regulations developed and progresses slowly in new construction solutions. Important actions such as the introduction of environmental criteria require years and years of raising awareness. As little as five years ago, talking about the environment was odd and less than widely accepted. But through social and scientific pressures, a small step forward was taken in terms of social acceptance.

We are just beginning to enter a process of change where the environment is treated with the strictness it deserves and for such purpose, implementing policies and aids to facilitate the transformation is of the essence. It is clear to see that the entire process of social acceptance of environmental issues has been slow but has progressed gradually. This tells us that any change, and specifically in this case, changes in the construction sector, will follow the same process, going through the process of social accepting the new ways to design and build.

▼ Breakdown of the elements that parts of an industrial module. University housing module at the ETSAV Campus



All of this will be triggered as a result of the needs that society itself generates, including economic and productive factors.

In order to design using methods that facilitate the industrialisation of our buildings, we need to change the way we work, giving priority to the reduction of on-site work times and the use of components and materials that companies will need to develop to achieve this goal. Obviously, there are two clearly differentiated ways to build. When the building's design allows for the industrialisation of a large part of it and a construction system developed by an industrial company (currently, systems such as Compact Habit, Modultec, Yorkon etc.) is used, design and construction operations are streamlined, but this is not always possible. For buildings that are not so systematised, we need to resort to finished and semi-finished components developed by companies, for example, quick assembly structures, complete bathroom cabins or panel bathrooms or kitchens with built-in installations, interconnecting modular installations, installation kits, fluid pavements, enclosure walls made with technical panels, finished facades formed by large panels and anything else that can reduce construction times.

▼ University housing module at the ETSAV Campus. Industrialised polyester and fibreglass shower cabin. Monoblock system with integrated installations, plumbing fittings and accessories

If we become accustomed to preparing projects with produced elements or to designing these elements for companies, we achieve the clear objective of introducing construction into the industry, causing the creation of production series. As a result of the systematisation and processes that industrial work requires, this will cause us to rethink which materials we should use and we will come to realise that the materials commonly used for construction will no longer be appropriate to work with under these new approaches. We cannot compare the handwork that traditional construction requires with the possibilities offered by the industry, mainly based on productive efficiency criteria. This will lead to the development of materials and to coming closer to the previous comparison that used the automotive industry as a benchmark of quality and industrialisation.

The companies that are currently working on the industrialisation of construction are at the beginning of the process of change. Steps have been taken in terms of doing construction work at factories through transportable, stackable three-dimensional systems, but their industrialisation is limited to optimising processes with the industrial methodology but using architectural projects made under traditional approaches and with materials that have the same problems. To better understand the transformation of materials, let me use the example of gypsum plasterboards.

When red brickwork construction was most commonly used and the gypsum plasterboard solution started being introduced, we thought it was a huge step forward in construction, as it provided us with a cleaner and quicker construction method. The system has been evolving and improving, so much so, that it has become the most common and preferred material in use today. But if we turn to the world of industrialised construction, we find that we are using it the same way we use it at construction sites. This is clearly not a step forward, as industries require much more agile processes. The manual procedures used for its installation are unacceptable for the industry; therefore, we need to find a new

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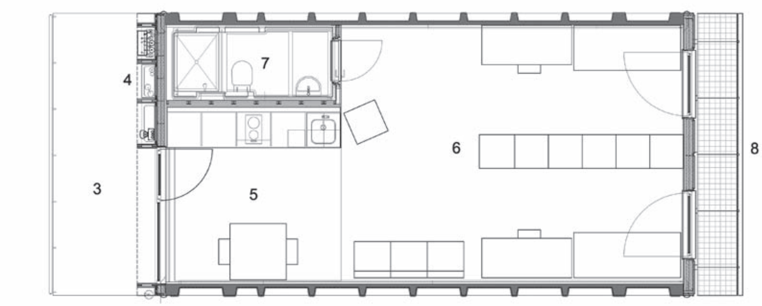
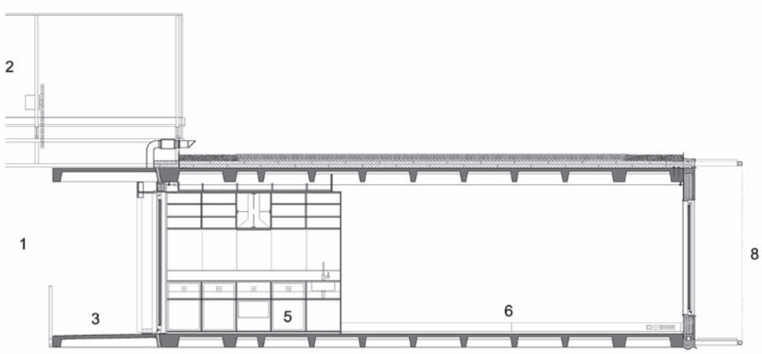
▲ Built-up area of the inner courtyard of the university housing module at the ETSAV Campus in Sant Cugat del Vallès. Architect: H Architects, S.L. and Data A.E., S.L. Commissioned by: Polytechnic University of Catalonia. Builder: Constructora d'Aro

▶ Floor plan and cross-section of the module for university housing at the ETSAV Campus. Total module area: 56 m² constructed area. Module dimensions: 11.20 x 5.00 x 3.18 m

Description: Each module is a 40 m² housing unit for one or two students. It is organized around core services (bathroom and kitchen), leaving the rest of the surface as open space to be distributed to the occupants' taste

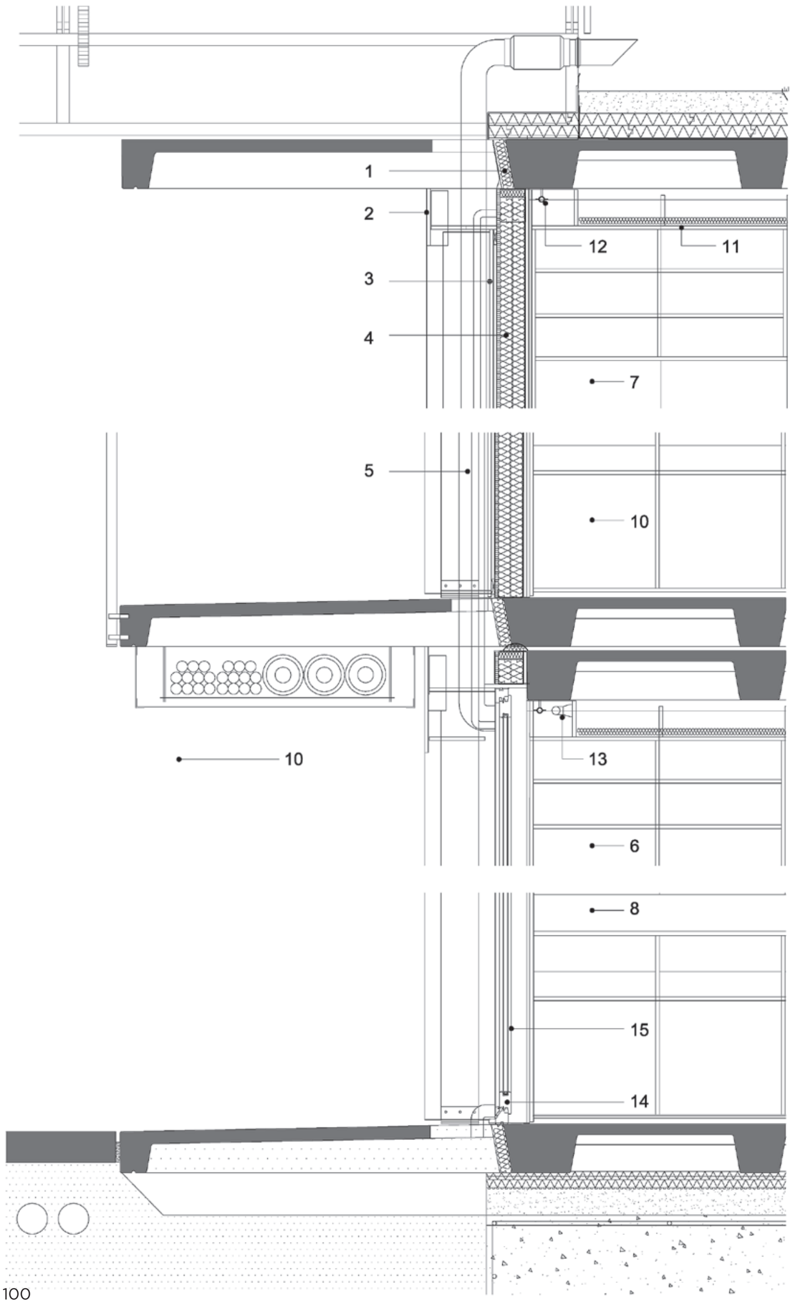
1 Covered inner courtyard with sunlight and ventilation control
2 Courtyard cover
3 Access walkways
4 Outdoor facilities
5 Kitchen and dining area
6 Hall-study-bedroom
7 Bath
8 North/south facade





▼ Built-up area of the inner courtyard of the university housing module at the ETSAV Campus in Sant Cugat del Vallès. Architect: H Architects, S.L. and Data A.E., S.L.

Currently the building has an "A" energy rating as per the CTE. The air intake for indoors is on this facade, via a micro ventilation system built into the woodwork. The energy design criteria used for the building are far more demanding than those defined in the CTE. Efforts have been made to achieve Minergie (Switzerland) energy rating standards. This certification will be achieved when the courtyard is shortly covered with a system that will control sunlight and ventilation. With this solution, the courtyard acts as a general heat exchanger for the building, managing to reduce energy losses that occur upon outside air intake into the housing units (renewal)



1 40 mm extruded polystyrene built into module structure. Lining with 0.8 mm EPDM coating.
2 18 mm plywood with phenolic finish on both sides. Removable panel for inserting equipment into the module interior.
3 18 mm plywood with phenolic finish on both sides. Screwed on a support frame of the same material.
4 Multi-layered facade comprising a perimeter frame with U150 x 50 x 4 profile and 1 mm galvanised sheet secondary profiles. Enclosure with double-layer 12.5 + 12.5 exterior and 18 mm interior plasterboard. Space between panels filled with 120 mm insulation with mineral wool. External protection with an 0.8 mm EPDM panel for waterproofing. Between profiling and interior plasterboard, a polyethylene vapour barrier acts as thermal bridge break for the metal profiles.
5 Galvanized iron pipes Ø125 for extraction/ventilation of kitchen and bathroom (and living room).
6 Kitchen cabinets with 18 mm plywood with phenolic finish.
7 Wall covering with 9 mm plywood and phenolic finish. Removable panels.
8 Countertop and edges with 1.5 mm vibrated finish stainless steel (quality 316).
9 No cupboard backboard to ensure access to installation.
10 Backboard featuring 9 mm plywood with phenolic finish, removable for accessing the installation panel.
11 False ceiling made of 18mm plywood with phenolic finish and superstructure of the same material. Application of 40 mm mineral fibre blanket over the board.
12 Curtain rod made of ¾" galvanized conduit, fastened with 30 mm spacers and galvanised brackets.
13 Fluorescent 35W / 2700 °K (827) colour temperature.
14 Laminated pine finish carpentry with clear Lasure varnish. Built-in microventilation system.
15 Laminated glass inside (6) + 14 + (3+3).

▲ University Housing at the Manresa Campus - FUB / EPSEM / UOC. Location: Manresa University Avenue #12. Manresa (Barcelona). Commissioned by: City of Manresa. Builder: Constructora d'Aro. Architect: Xavier Tragant. Number modules: 75 units. Total constructed area: 4,110 m². Total module constructed surface: 56 m². Module dimensions: 11.20 x 5.00 x 3.18 m

solution to install gypsum plasterboards, modify mounting methods or switch to another material. This example also applies to most of the materials we normally use.

This is one of the problems encountered by those of us who work in the world of industrialised construction. We have taken a step forward, but we still have a long way to go. We need to transmit all these new possibilities and push toward a real change in construction. This new approach, which directly involves how technicians design their projects can represent, from a traditional viewpoint, a limitation on projectual creativity. Generally, when we are faced with the systematisation and rationalisation of the design, we always look at it from a negative point of view. On the contrary, a good design was basically valued for its creative and aesthetic capacity. This has to change radically. Design teams can no longer be formed by a single person; instead, they must be formed by a conglomerate of specialists developing a co-ordinated project. Its valuation will depend on how well the team has responded to all the conditioning factors of design, one of them being global optimisation (functional, spatial, technical, and environmental optimisation, life cycle, capacity for industrialisation, execution times, financial value). The crisis and the evolution of the society are making us head toward maximum utilisation of resources, which is the highest value that should be given to any project.

The term "optimisation" and all things related to it will be the key to the future transformation of construction. It could be said that the greatest value that an architectural project may have will eventually be its ability to consume less material and human resources and to respect the environment. This major change in valuation parameters shall represent a new of thinking, both socially and professionally.