

## Materic character of constructive dry systems for prefab-House. Research and didactics experience.

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**ABSTRACT:** The evolution of the housing models and the constructive process, recognizes in the light sustainable prefabrication, a sector in answer to the demands of energetic and materic reduction in the constructions sector.

Among the typologies of prefabricated systems, the research focuses the attention on the study of the catalogue houses, realized through "Kit" detachable, with dry technology, with a logic transferred by the industrial sector and particularly developed by the North-European Countries.

The study objective is a critical analysis of meaningful examples, to individualize some remarkable characters of it:

- The materic character: on materials mostly used and on their characteristics.
- The performance character: the common performances of residences, about energetic efficiency, and the yard's management.

The document makes reference to the research and, actually, didactics activities, developed by the authors inside the operational unity STOA of the DASTEC Department, to the Faculty of Architecture of Reggio Calabria, Italy.

### 1 LIGHT PREFABRICATION AND TEMPORARY LIVING

The cultural issues of sustainability, has shifted attention to the need to limit the consumption of material resources and energy, introducing the concept of useful life and recycling and reuse, modifying the processes of transformation, construction and traditional living patterns.

The temporary prefabricated housing units, the "machine for living" that embodies all the characteristics of contemporary living, is one of the themes explored since the advent of industrialization construction. The temporary housing is a major technological challenge for the future and a field of experimentation and innovation still largely to be explored.

The evolution of the housing models and the realized trials recognizes in the light prefabrication revolt to the sustainable, a sector in answer to the demands both of the housing contemporaneity, both to the application of energetic and materic reduction in the constructions sector.

The light prefabrication as a means of achieving a high level of industrialized production in construction, has always, historically, been a fascinating constructive technique from the theoretical point of view (consider the examples designed by Fuller, Prouvé, etc. ..) but very often associated with living models impractical and technological and environmental benefits of low quality.

The idea of prefab construction as insecure and emergency gives way to an evolution in form and content increasingly attentive to the needs of the consumer who is concerned with safety and sustainability. While there are many possibilities for building customized, they increase rapidly to motions serialized and standardized which adds to the already numerous advantages of mass production that come even closer to the world of prefab design, creating a system that

thought forms, environments, furniture and techniques that fall within an established chain. There is thus confronted with standard models and simultaneously studied for specific locations, often 'turnkey', complete with service elements and furnishings.

In recent years, in fact, the prefab building industry has developed enormously moving by leaps and bounds on comfort, environmental sustainability, and pollution, flexibility and technology, belying the stereotype prefabricated house, short-lived and lack performance. Prefabricated residence begins to represent as demonstrated by examples throughout the world, a model of architecture with character design methods and achieving precise, able to provide outputs high standard of quality, tailored solutions for the buyer, who hopes to have a unique residence, modern, sustainable, durable and, not least important, lower cost, both as regards the purchase maintenance. The different modes of implementation are represented by the house containers, the prefabricated house, modular or systems construction. The latter are particularly interest of this document, in close relation experience teaching and research, still in place, conducted by the authors at the University Mediterranea di Reggio Calabria, Faculty of Architecture.

## 2 NEW STANDARDS OF LIVING

The requirements of the system construction, environmental and technological, that express these characteristics are partly known and tested and are in part the consequence of recent developments in the overall requirements defined upstream. He highlighted the most significant ones related to the time component of the project and the architectural construction:

- Design flexibility: with it's to be understood both flexibility type (attitude of the building system to allow different configurations of size, shape, correlation and distribution of space in use phase) and the technological flexibility (ability of the system to allow construction functional and constructive integration between the technical elements, substitutability, adaptability and interchangeability of elements or components providing the functionality and performance appropriate use). Make changes in a prefabricated home, both with respect to the basic layout of the house, and after the installation of this, they become, therefore, possible operations through technological systems, characterized by areas for plant additions and demountable systems which facilitate the variability and maintainability.
- Adaptability: can be considered a re-configurability not instantaneous, immediate, but delayed in time. The independence of the location is based on the requirements for mobility and portability of the object that can provide organs for handling integration, or must rely on the means of transport. The movements can not be separated from the dimensional control of the shape of the unit load, which is used to compact systems (or expand during operation) or removed and replaced.
- Reversibility: as characteristic of a building system to be de-constructed so that the technological elements (materials, parts, components or systems), which is yet to be considered as real resources (and not residues, discards, refusals) from reintroduced in a subsequent manufacturing process or to reintegrate into the wild. The building system may have different degrees of reversibility depending on the performance level that products derived from its disposal compared to retain the original conditions of employment or in relation to new uses. Predicting the destination of the waste from the de-construction is related to the requirements of recyclability and reusability.
- Economic affordability: in the Italian property market, a prefabricated house costs definitely less of a traditional real estate.
- Ease and speed of installation: for structures equipped with facilities for automation technology, ranging from an average of four to six months of the yard.
- The efficiency of plan: Plans for the installation allows to quickly meet codes and regulations through the approval of building permits and provide the purchaser with a fully custom home.

The need also to ensure versatility in any condition of employment, meaning flexibility in performance of the components, is being pursued with the technique of "dry stratification", according to which the required performance is achieved with the juxtaposition and integration of layers or specific items. In this sense, the technological choice of "dry stratification", becomes

synonymous with hybrid technology where the performance expectations are achieved through various construction techniques and materials, but more appropriate to the specific use.

### 3 STATE OF THE ART: RESIDENCES AND FACTORY

The increasing interest toward the development of highly prefabricated evolved, sustainable, implementable, light and to dry, prefab-system is bringing, through a technological transfer from the industrial sector, to the development of projects of Kit catalogue houses. A matter, for the time being, particularly developed by the North-European Countries, both in industrial circle and scientific. To show it, are different companies that are investing the proper Know how for realize cutting and detachable Kit, through the use of low environmental impact materials and dry technologies, as:



Figure 1. IKEAS' Boklok house installation.

- Ikea that, in collaboration with the Swedish building colossus Skanska, has realized the wood prefab-system, Boklok. The project borns in 1997, in answer to the necessity to purchase a residence in Sweden, to more economic prices, emerged through a study realized from the founder IKEA in 1996. The BoKlok houses, based on the strengths client's needs, are smart residences, of high quality, with a flexible plan type open-space, ample lengths and ample openings, guaranteeing visual and bright comfort. The construction/assemblage is realized by specialized workers in less than a month. The residences, follow plain of industrial workmanship entirely similar to those of an integrated chain. A constructive wood framed system, with wood insulated panels sandwich, developed by the Peace Timber Systems of Milton Keynes, to climb on the yard, to reduce the times of construction maintaining the quality allowed by an industrial production. The system, allows the maximum flexibility in the addition of housing unity, in the choice of different typologies of coverings and in the fittings integrations for the energetic saving as solar panels or other.
- Toyota: employed from over 20 years in the building sector, using the same technologies used in the construction of motorcars but, suiting theme for the realization of modern prefab-buildings resistant to the earthquakes. The new ecological necessity compared to the auto market with the design of hybrid motorcars allows the Toyota to invest in ideas that allow a mutual exchange of energy between the residence and the motorcar; Toyota interacts with the electric system allowing the motorcar to enter to the panel of recharge but, at the same time, to act in generating of energy. Of the steel framed houses, exist 12 versions. The steel frames in the houses are painted with anticorrosive paint using methods adopted from its car production. The windows of the houses are made from the same shatter-resistant glass that Toyota uses in his cars to deter burglars.

Toyota engineers are also experimenting with using solar panels as house siding and powering homes with fuel cells, which combine hydrogen and air to produce electricity.

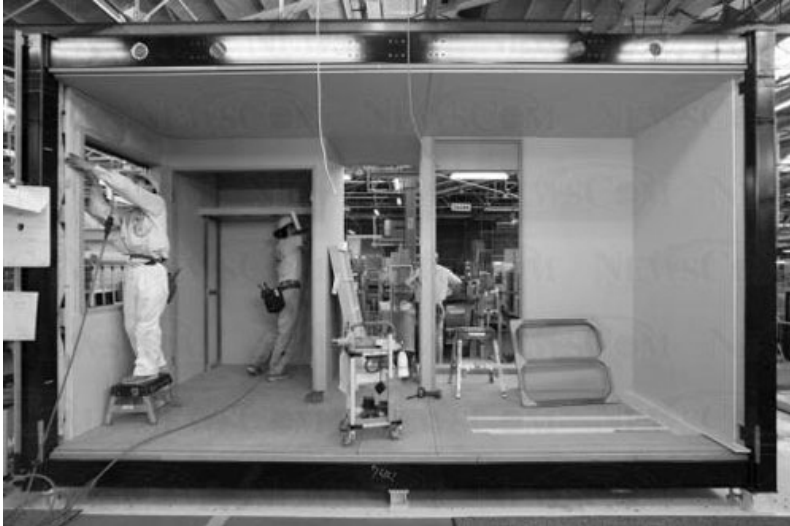


Figure 2. Japanese housing production (Toyota). Font: Getty Images

- Bosch: the system of profiles in aluminum league 6060 - T5, born for different uses in comparison to that architectural, it has been more times experimented for the realization of "Kit" residences, in which the system acts from carrying structure. The screw connections among the profiles, allow a laying fast work and simplified, also furnishing a good quality of resistance for the big loads. Among the principal examples of realized residences:
- Loblolly House, designed and realized by the KTA study (Kieran-Timberlake Associate). It's a construction prefabricated on component, in which a "Kit" of parts can be dismantled and reconstructed with different configurations for different places or residences. Besides the framed aluminum structure, the principal parts are: attics and prefabricated ceilings with integrated wiring and cartridges, pre-assembled bath and kitchen modules and infill panels in wood of cedar. Not having been designed for architectural use, the Bosch system has been integrated by architects from a group of five necessary connectors to satisfy the structural requisite of a building with three floors.
- The TK iT House, planned by the Californian study Taalmankoch, it's a prefabricated residence, already realized in different versions in USA, in which the Kit of assemblage is constituted, besides the framework in Bosch's aluminum profile, from a steel coverage in steel and photovoltaic roof, from a glass façade and screen panels in vinyl material, from a radiant floor, furnishes and equipments to be chosen to catalogue.
- Lignotrend: system of modular prefabrication constituted by a heart in wood, with high characteristics of seismic resistance and thermal- hygrometric performances that respects the European legislations in subject of statics, antiseismic, thermal-acoustic insulation, prevention fireproof and energetic saving. The panels are glued with glue of polyurethane deprived of formaldehyde and certified in class of issue E0, that doesn't exude polluting substances. The wood glued layers guarantee the stability in the form, the absorptive capacity and the regularization of the damp. The system Lignotrend allows a rapid assemblage so that to reduce the times of yard of around 70%. The elements are multifunction and it's possible to integrate electric cables and installation tubes. Differently of the constructions in masonry a profit is around the 10% of habitable surface in more, thanks to the reduced thickness of the panels. The ecological cycle is respected by the choice of the materials up to the disposal.
- LOQ kit: it's a system of Kit prefabricated components, interchangeable for residences, easy to assemble and customizable. LOQ kit it's based on a technical revolution in house-building, proposing a model of circular progress, in which the actors of the trial are tied up from an only common objective: that to start an orchestrated plan, for realize more houses through sustainable technologies, to accessible prices.



Figure 3. LoqKit different configurations. Font: [www.loq-kit.com](http://www.loq-kit.com)

When a client purchase a house LOQ Kit, their house will be included in a maintenance program of the life cycle. The life cycle of the reusable components is submitted to careful controls of the Loq-kit society, guaranteeing the reliability of it.

In the moment in which it lowers the performance level of the same, the society withdraws the components and divide them in single parts, profits to be recycled in new components. It deals with a sustainable economic program of reuse, that assures that the components don't finish in the dumps, contributing to the reduction of the C&D wastes. The components, of different dimensions and the connections, are geometrically coordinated. The connections are characterized by the system "snap-lock", that allows to the single parts to be removed, substituted or even to be used in another residence. The Kit of assemblage is formed from three types of components: modular frame structure (in recycled steel), modular infill and modular covering "snap".

Among the principal manufacturing of prefabricated residences, are underlined:

- Envision Prefab: it realizes a sustainable prefabricated to zero impact , using container with systems of energetic provisioning and resources that combine solar and photovoltaic panels and LED illumination .
- Echo-Steel Homes: it's based on a rationalized design, using the 76% of recycled steel coming from autocars, industrial equipments and metal wrecks. Their models in fact don't use wood making them resistant to mold and bugs and insulating them in effective way.
- International Homes of Cedar: it's in contrast with the modern innovative design of the most greater part of prefabricated, proposing a rustic style, through the use of cedar coming from checked forests. The material offers a good durability, resistance to the parasites and thermal resistance.
- Modern Shed: it directs the design on the modularity, creating working spaces directly connected to the residence allowing the integration of a module for the garage. The Modern Shed aims to the design and to a sustainable architecture that makes to choose to own clients thermal insulation in recycled denim, cork floors and other sustainable finishes.
- New System House: it proposes a bioclimatic prefabricated residence, to low energetic consume, that has the tendency to reduce to the minimum the environmental impact exploiting the renewable energetic sources. The residence has an elevated energetic performance that is attested with a thermal requirement (heating) equal to 20 KWh/m<sup>2</sup> per year; it has a compact volume with the purpose to have the minimum dispersant surface, with ample and bright inside spaces, rationally distributed. On the north side , a volume is risen to use garage, with function of filter, necessary to mitigate the thermal dispersions (colder façade). On the south side it is foreseed that it's possible to close in the winter months with flowing glass door, creating in this way a solar greenhouse of heat's accumulation. The inside vol-

- ume is articulated so that to create a natural ventilation, guaranteeing a correct microclimate and a good air quality both during the winter and during the summer.
- Rubner House: The Rubner houses is realized with material ecologically appreciated, among which the wood, but also with plasterboard and cellulose panels and the insulating hemp and cork.

#### 4 OPEN PROBLEMS ABOUT MATERIAL EFFICIENCY

The prefabricated residence begins to represent, as shown by examples in all the world, a model of architecture with characters, design methods and realization well precise, in degree to furnish realizations from the elevated qualitative standard, custom solutions for the client, that hopes to have an unique, modern, sustainable, durable in the time residence and, aspect not less important, from the most contained costs, both as it regards the purchase that the maintenance.

Despite the elevated resonance of the sustainable prefabrication's sector, few of them actually, reach elevated levels of energetic certification and make an efficient use of materials during the productive processes.

The technological managers of the temporariness privilege, as the preceding examples show, the constructive systems in recycled metal, aluminum, certified wood and plastic material .

Besides the material choice, the off-site design is based on advanced modular systems, on new design, models and innovative products, with the objective to minimize C&D wastes and discards to really maximize an energetic efficiency and a possible ecodesign.

The environmental comfort is mainly guaranteed from the housing system through the envelope. This has to furnish the necessary performance levels to answer to the requisites about thermal aspects, hygrometric, acoustic, visual, bright, of a normal residential activity, through a design that conjugates the design and technological aspects to those environmental.

The material choice of a prefabricated residence engraves, naturally, on the performance levels in different way:

- for wood constructive systems: the choice of the woody essences to be employed for the construction is remarkable, appraising the material's availability in site, with least energetic consumptions for lumber's transport and privileging the conifers in comparison to the broadleaf, for the most greater natural protection given by the resins. The constructive trial foresees a reduced requirement of energy in comparison to that of the traditional buildings, thanks to the easy material's workability. Problems are hardly set related to the thermal bridges, thanks to an energetic behaviour of the structure almost always homogeneous.
- for aluminum constructive systems: the league's choice is fundamental, because it must be water and corrosion resistant, for a long service life, and must guarantee a good mechanical resistance of the elements and a good workability to get profiles fit to use. The aluminum has a volume density equal to 2,7, that is around 1/3 of that of the steel. It's mechanical resistance can be modified in relationship to the application's type which is destined through the employment of appropriate binding. The design flexibility allowed by the aluminum structural profiles and the elevated resistance-hung ratio, are somehow the reasons for which in the last years this system has become object of architectural experimentations in the extraeuropean panorama. The good thermal conductivity in some cases can constitute a disadvantage which, however, it easily makes up for through particular profile's design and using thermal cuts with insulating material.

#### 5 THE PROPOSAL

With the purpose to make operational the research, it is currently in progress a convention among Department DASTEC (Art, Science and Technique of Construction) of the Mediterranean University of Reggio Calabria and a firm in the field of the efficient fittings, named Termocasa, headquartered in Reggio Calabria.

The Convention has the purpose to effect an action of research having the following object: *"experimentation of housing (named Tecnemi) to improve the energetic efficiency and to increase energy's quota consumed coming from renewable sources, promoting the opportunities"*

of local development", in locality Lazzaro of Motta San Giovanni commune (R.C.) The scientific responsible of the project are the Prof. A. Nesi and A. De Capua. The design part is taken care by the PhD M. Aversa.

The intervention areas of the program, regarding the production of renewable source energy and the promotion of the energetic efficiency, are:

- The planning and the construction of integrated models of intervention, both in relationship to the energy production from renewable sources both in relationship to the energetic saving, particularly in areas to strong environmental vocation;
- The consolidation, the growth and the diffusion of information and know-how that can allow aware decisions from the administrations and of the population.

The research activity lent by the university consists of producing:

- A methodology of theoretical-practice approach on whose base to program, to plan, to realize and to appraise building interventions with the purpose to guarantee the energetic efficiency of the buildings.
- Criteria and description of technical solutions and relative specific capitularies.
- This is finalized to the realization of a building prototype on which to experiment the proposed solutions.

The constructive model (structure, building wrap, fittings) currently in phase of design elaboration to the DASTEC, has the objective to experiment a strong integration of the principals factors (architecture, constructive techniques, fittings), through dry technologies, to the purpose to reach to an elevated environmental comfort, and to a meaningful energetic saving. Such abilities can be express according to some fundamental points:

- The reduction of the energetic requirement improving the efficiency of the envelope through the meaningful exploitation of the renewable energetic sources.
- The exploitation of the natural elements to get conditions of inside comfort, integrated from solar profit and of the other local climatic factors, through an approach defined by the literature "climate sensitive building". The assignment of the fittings is not therefore, as it happens in the most greater part of the cases, compensate to the performance lacks of the building, but of integration and support to the envelope's spontaneous tendency to maintain comforting inside conditions.

To forehead of an absolute integration of the fittings systems in the elements of envelope and partition, both in the nets of distribution and in the systems of provisioning, it's chosen to insert in integrated way the technological systems of acquisition and exploitation of the renewable energetic resources (solar thermal, photovoltaic, geothermal etc.).

For the technical and constructive definition of the housing form "Tecnema", coherently with the more actual technological trend of temporary constructions, it's chosen to adopt dry constructive systems.

This technology (Trockenbau in Germany, Structure-Enveloppe in France), it's characterized for the tall design grade of the technical solutions is characterized for the dosage of materials, and therefore of the performances (thermal, acoustics, fireproof, etc.), without reverting in the errors of the prefabrication.

The system essentially it's based on a constructive paradigm released in separate entity, with precise functions and performances, that are:

- external envelope
- structure
- nets and fittings endowments
- inside envelope

The structural component is conformed by a framework steel, the envelope inside and outside are constituted by panels composed by insulating layers and "skins" of finish external-inside, the dividing walls are composed from a double plasterboard plating.

## 6 CONCLUSIONS

Prefabrication and sustainability are now two complementary aspects of a new trend of building systems in off-site, made with materials and environmentally friendly technologies and energy

efficiency, a possible scenario for development, primarily to respond to a social demand for residential.

The trend in the world of sustainable prefabricated is fairly clear and aimed at a reduction in the size and specialization of functional envelope layers to achieve higher energy efficiency. The new challenge for companies that make ready-made is, in fact, a balance between the economy of an innovative design and sustainable construction a reality and costs of raw materials.

The aim has shifted towards achieving energy-efficient structures, capable of reducing the consumption of raw materials, to select healthy and sustainable materials, to choose sites and methods of installation that can minimize the impact of climate (in particular exposure), in which the fundamental role it plays always the designer, not the constructive method. Prefabricated houses still depend on external agents that can block the installation as is the case for the connection of gas, electricity and water at less than a prefab sustainable energy to generate electricity independently, eliminating connections to electricity and gas.

The research, therefore, will offer support, test and evaluate, possible project proposals, currently in preparation, teaching experience of the authors of the document. Will be proposed design solutions that combine energy and environmental performance of materials with off-site construction systems analyzed in relation to issues affecting the location in the Mediterranean environment.

The dry construction stratified, represents in the technical panorama the more advanced example of rationalization of the constructive processes attainable through elevated industrialization grades.

In comparison to the experimentation in action, it has been verified that the "energetic" advantage of the dry construction stratified resides especially in the diversification of the layers.

From the point of view of the architectural language, the separation between structural parts and envelope system facilitates the amplification of the expressive and organizational possibilities of the external curtains, conditioned by the presence of structure elements to vertical development. From the technological point of view, the system allows to satisfy more and more ranges of punctual performances: demands of environmental character, fittings applications type, solutions to stimulate the passive use of the resources, employment of fit materials to answer to the legislations of containment of the energetic consumptions etc.

Everybody choices that certainly conduct to the attainment of a superior environmental comfort to that present in a traditional construction.

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