Prefabrication

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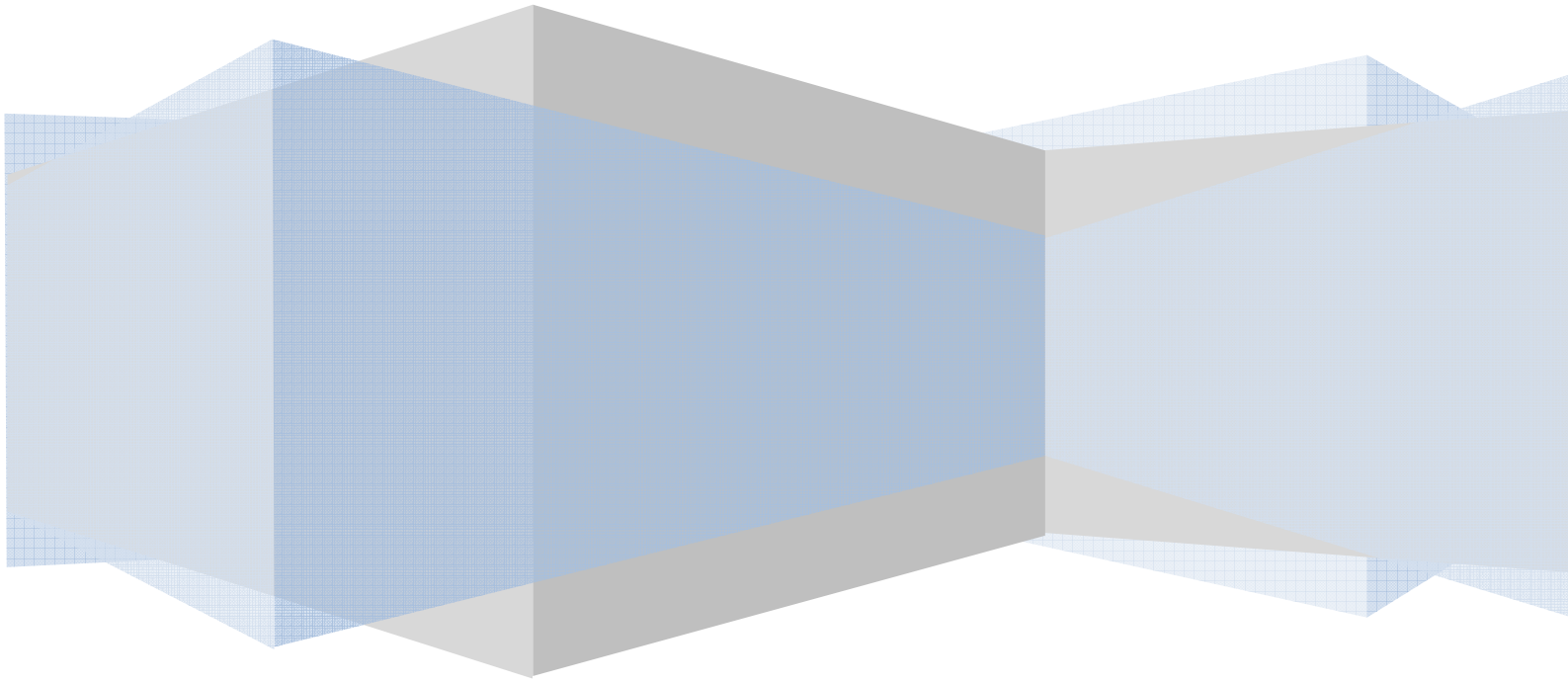

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INTRODUCTION

Aim to build as much of the building as possible under cover, out of the rain.
Anthony, 1945

This 'easy' sentence, adding other climatological factors, makes sense of the **prefabrication**. Probably, that's the initial reason to use prefabrication. But, as we'll see later, prefabrication also means less time, less cost, more productivity, more quality, among others.

But, What's actually mean prefabrication?
Probably, one of the best meaning is:
A manufacturing process, generally taking place at a specialised facility, in which various materials are joined to form a component part of the final installation.

Deepening on the broad term that is the prefabrication, we can find different topics like off-site fabrication, pre-assembly, modularisation…, which are all related even and are all 'made before construction'.

We will see in more detailed way the off-site fabrication, a fact that it's almost unkown in Spain, my home country, even there are also extremely climatological situations, like the 40-45°C we can reach in summer.

Also the modularisation will be analysed, a construction way that sometimes seem to be a bit 'vulgar' and provisional, because his 'plug and play' way, but also can be a great manner to get buildings on a real fast way, and not so 'simple', as we will see.

HISTORICAL DEVELOPMENT OF PREFABRICATION

Several instances in history can be viewed as early forms of prework. A few significant instances stand out. Documented examples of prefabrication can be found as far back as the 1600's. As early as 1624, the English brought with them to Cape Ann a panelized house of wood for use by the fishing fleet (Peterson 1948). This house was subsequently disassembled, moved, and reassembled several times.

There are numerous other examples of what could be considered very early uses of prefabrication or modularization, such as Stonehenge. Encyclopedia Britannica dates the modern form of prefabrication back to 1905.

The post-World War I years brought a strong stimulus to prefabrication, but mainly in Europe. The U.S. continued to experiment with prefabrication, while Europe built with it. In Europe, is promoted and advanced prefabrication as an industrial development during this time.

Modularization, prefabrication, and preassembly have not had a steady increase in use over time. Instead, use has fluctuated over time due to economic changes, population surges, wars, and other social and political factors. In addition to these factors, technological advances may also have an impact in the near future.
Fluctuations also vary by construction sector, with the housing industry experiencing the greatest impact.

Prefabrication became a recognised movement in the early thirties.
Interest in the idea spread beyond the initial groups of inventors and small companies first involved. The spread of the prefabrication concept can be attributed to a variety of economic, social, and technical factors. The underlying cause, however, was the Great Depression. However, by 1940, there still were less than 30 companies that were manufacturing and selling prefabricated houses on a steady basis .The vast majority of home production involved comparatively little in the way of new materials or prefabrication. All in all, excluding precut houses, only 10,000 prefabricated units were produced between 1935 and 1940. This constituted less than 1% of all single-family homes built in non-farm areas during that period.

Housing demand during times of war also caused increases in prefabricated housing. Prefabricated dwelling units for war workers during the early 1940's were aresult of Federal housing agencies and their purchasing. The U.S. government has, at times, been prefabrication's best customer. One sign of the industry's growth during the Second World War was the formation of the Prefabricated Home Manufacturers' Association in 1942. It was set up to disseminate information, establish industry standards, study distribution problems, improve manufacturing methods, make cost and accounting studies, and serve as amedium for the exchange of ideas.

The housing industry number for prefabrication production during World War II was approximately 200,000 units. This relatively large number still represented a small part of the total war housing units, numbering 1.6 million. Even though the prefabrication method was on the incline, it did not become the preferred method.
The housing sector of construction, as described above, has been a key driver of prework. In times of drastic housing needs such as after wars and during economic booms, prework was used extensively as a quick solution. Even recently, fluctuations continue in the prefabricated housing market.

The 1970's saw a separate resurgence in prework of sorts, evidenced by the short lived, but important, Industrialization Forum. This publication ran from 1969 through 1977 and provided a wide variety of information. The early 1970's did see a slight upswing in prefabrication. This did not last long, however, as the end of the decade saw a fall once again and the journal ceased publication.

A new alternative to manufactured housing is the factory-built home industry
These homes are built on factory floors and then transported to the building site for final assembly. They can be customized for individual tastes, yet take advantage of production facilities and their quality is often better than can be found for site-built houses. The various forms of factory-built houses are modular homes, panelized building systems, post-and-beam construction, and log houses.

OFF-SITE FABRICATION

This branch of prefabrication involves the design and manufacture of 'modules' from a whole construction, but made away from the work site.
The mean objective is to remove as much work as possible from each 'module' to be done on-site.

The most of building projects can be subdivided in these 'modules':
-Substructure: Foundations and works below ground
-Frame: The structure of the building
-Envelope: The external walls and roof that form the perimeter of the building
-Services: The mechanical and electrical building services distribution
-Internal works: The internal walls, raised floors, suspended ceilings and applied
-Facilities: The major parts that are provided by the developer for the use of the end-user, like kitchens, lifts, toilets, etc.

Let's see which of them can be made with off-site fabrication with an example for a commercial building:

Substructure:
-Foundations: Both piled and pad foundations are available as precast concrete elements.
-Basements: Precast concrete wall elements may be included. Also items of mechanical and electrical plant in basements are often prefabricated.
-Drainage and underground services: Other than use of large section (or even continuous) pipe lengths, off-site fabrication is not often used.

Frame:
-Structural steel:
Structural steel frames, by their nature, incorporate off-site fabrication. Many steel-framed buildings will use prestressed precast concrete floor units.
-Reinforced concrete: Precast concrete frames are naturally prefabricated off-site

Services:
-Distribution network: The distribution network for mechanical and electrical services can be pre-assembled off-site
-Plant rooms: Off-site fabricated plant rooms have been used effectively on many projects, especially where they can be located on the roof of the building.

Internal works:
-Ceilings and floors: Most commercial buildings incorporate off-site fabricated systems for suspended ceilings and raised access floors.
-Partitions: Various off-site fabricated partition systems are possible, like gypsum board walling system, or with posts and panels, which are used where relocatability is desirable.

Facilities:
-Washrooms and lifts: Most of the facilities provided by commercial developers can be assembled off-site. Office washrooms and lift shaft are typical.
There are usually areas of high value and complex construction and therefore can gain greatest benefit from off-site fabrication.

ADVANTAGES

Why is the off-site fabrication a better way for construction?

There is a basic triangle in the building process, which is composed by the aspects **time-quality-cost**.
These three, among many others, are benefiting from the use of the off-site fabrication.
Let's see why each aspect is benefiting:

TIME

The principal benefit of the off-site fabrication is the possible reduction in the on-site programme duration. This is achieved by the overlapping of off- and on-site activities which would be done in sequence using traditional methods. Using off-site fabrication the pre-assembly of the units is done off-site at the same time that the foundations and main structure are being constructed on-site. Then, there is a general saving in programme time. The actual human resource hours may also be reduced by the increased productivity achieved in a factory environment. However, the main time reduction is achieved by completing activities in parallel.
The reduction in project duration will almost always be a benefit to the project team members. The client will obtain the facility at an earlier date, which will usually mean an earlier start to production, or an earlier letting of a commercial development, both of which will lead to earlier income generation. Some clients, especially retail clients, will hold this as a very great advantage, in many cases affecting the viability of the project as a whole.
Also a reduction in the time mean a money saving. The reason is because many projects require external funding through loans from banks. Then, the sooner the loans are repaid, the lower the overall cost.
A big advantage is got also for the refurbishment, because a shorter on-site production allows to less disruption to the existing building users and a quicker return if relocation is needed.
Reducing on-site time also means an earlier release of fees for the designers and others consultants.

QUALITY

The principal thing that increases the quality of off-site fabrication is that always facilities will be better.
Manufacturing facilities usually have a stable workforce who can be trained properly and can produce high quality work. In the case of on-site fabrication, sometimes the workers are recruited locally for each project. That means they need a specific training and need time to get their best (Learning curve).
Manufacturing facilities also can be designed to assist the workers in the best way possible, a fact that it's not usually possible in on-site fabrication.
Also the quality control and assurance procedures are easier to apply in the factories, and allows to do it before the delivery.
Furthermore, even if it is not an usual fact, the sabotage or occasional vandalism is easy to avoid in off-site fabrication, opposite that in on-site.

COST

As mentioned before, the reduction in time programme should mean a reduction in the general cost to the client. This is normally achieved by providing income generation at an earlier date than would be possible with a conventional construction approach.
Nevertheless, due to the reduced on-site time there should also be a reduction in the preliminary costs associated with the site set-up costs, as elements of these are expressed as costs per week. Providing the off-site fabrication strategy is agreed at an early stage, these savings could be passed on to the client.
In addition to the benefits from shorter site duration, there will be savings due to effective use of off-site fabrication by reducing the extent of site activities. This will require less site-based human resource with its attendant costs. Shared welfare facilities such as canteens, drying rooms, changing facilities and even living accommodation can be minimised, leading to further cost reduction. Also from the rented items, like the crane. There will also be some cost benefit due to increased productivity in the manufacturer's works.

There are also savings from safety. The better working condition in the factory means a reduction in the risk of damage. The risk from off-site working is from transportation damage, and it is easier to manage than the many risks that have the on-site works.

Also if off-site fabrication would be more used, its price will decrease. That's because is accepted between the people that off-site fabrication is expensive, so the price has an unreal level.

Other issues:

PREDICTABILITY AND RELIABILITY

The fact of off-site fabrication allows the client to have more control of the work execution. In other words, the clients can be sure that their project will satisfy their needs, be delivered to the specified quality, within the cost plan and to the agreed timetable.
Also, the standardisation in construction permits to increase predictability in a project, because the used items have been tried. It permits also to know the time that it would take, and how they are made early, an unexpected correction would be possible.

RELOCATABILITY AND REUSABILITY

Off-site fabricated modules can be designed to be relocated or reused.
Then, changes could be made within a building, or even moving the whole building like an answer to varying market needs, or for example, for temporal events.

APPLICATIONS

The classification depending the size (from smallest to biggest) of the prefabricated 'item' is:

-Non-volumetric application
-Volumetric application
-Modular building

Non-volumetric

This category involves the lowest items on the construction, like would be panel systems for cladding, internal partitions, steel frames or prefabricated riser pipework.
We can say that they are not a module on their own.

Volumetric

In this case, they are a module on their own.
Different exemples would be non-loadbearings units that are ready for installation into independent frames, plant rooms or toilet modules.

Modular building

This category will be analysed on the Modularisation part.

PRE-ASSEMBLY

A common definition for preassembly is "*a process by which various materials, prefabricated components, and/or equipment are joined together at a remote location for subsequent installation as a unit*" Tatum, 1987.

The preassembly may be completed at the site work in another location than the place of final installation. The preassembly process can involve adapting sequential activities into ones that are parallel.
A preassembly often contains only portions of systems, and work from a variety of crafts is typically necessary.

Preassembly is generally considered to be a combination of prefabrication and modularization. It may use fabricated components made offsite and then assembled near the site. These units can then be installed at the site, similar to modules.

MODULARISATION

The fact of the modularisation started with the creation of a measure unit.
The 'module' allows repeating it and controlling the sizes.
We are so use to it that we don't realise of it, but actually our basic module (1 meter) is just a once decided size.

If we transfer this concept to the building field, having a standard module like can be one dwelling; we can repeat and get a whole building.

So, the modular building is like 'the maximum possible' from prefabrication.
In this case, we are not talking about different 'items' within a dwelling or building, but it's a 'complete' one on its own.

TYPES AND USES

We can find various types of modular buildings:

I. PREFABRICATED CLASSROOMS

Though the years, we can still find prefabricated classrooms. These are used for different reasons: an increased demand for education requires a speedy construction, such as classroom assistants while conducting reforms, etc.

Despite having the minimum requirements, it use is not accepted by the majority of the population.

II. WORKS

They are used in any work. These modules allow us to have more comfort in the works. It is usually installed several modules: a dressing room, so that workers can be changed before and after work.

This dressing room will have toilets, sinks and showers required according to the number of workers.

Another module in the works is the dining room, so that workers can eat in a healthy condition and rested to work more comfortable. For workers, who control the construction, there are one module designed to be an office, which will be meetings, schedule changes, etc

All these modules are provided with drinking water, electricity, air conditioning even heating.

III. DWELLINGS

Actually these modules tend to be more common. This type of construction is cause to the requirement of building a home in the shortest time possible. Another reason, why every day is used more these modules, is by design and by the desire to innovate, we can even reduce the cost of the work.
That should be the way to continuing the development of modular buildings to get away from 'temporal' houses and convert them into a 'real' and 'definitive' houses.
The modular building is also a great idea for refurbishment.
Obviously, It depends on each case, but may be a solution, for example, for a new penthouses on the top of the buildings [*That's the idea for the project or my group]*

IV. INDUSTRIAL USE

Like a stored module, it is common to find modules in sites for the location in these places of several companies.

V. REAL- ESTATE PROMOTION MODULES

Another use of these modules in construction is the establishment of an office promoter in the work place to sell these houses. This offers the advantage of proximity to housing in order to teach it to buyers. Thanks to its mobility, can be used in several real estate developments

VI. CAFES, RESTAURANTS, ETC ...

The fast-food restaurants and franchises uses this system constructive to introduce a new restaurant in a city. This allows quick installation and makes it easy to change the look of the restaurant soon.

DESIGNS

BAG HOUSE

Is an idea of Stefan Eberstadt, because after his experience living in a little apartment with a small window to the outside. He decided it was a good idea to put living space in front of a window.

With the shape of a cube, suspended by steel cables anchored to the deck and facade of the building.

Has a folding furniture.

Module´s electricity comes from the building that is anchored.

EVOLUTIVE RESIDENCE

Is a future option. Consists of a prefabricated modules comprising an ecocomunity.

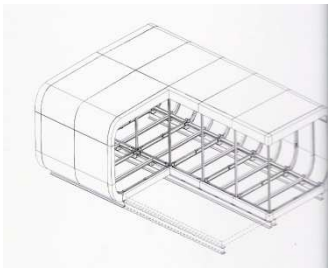
The lining of these modules is chestnut.

Provides greater privacy at the top, and the master bedroom and the room is oriented towards de south to enhance the brightness.

NOMADHOME

Is the union of modules of 11 m^2 with commercial or residential use that modules can be interchangeable, expandable or collapsible anytime.

The basic housing has 50 $m^{2,}$ but thanks to unused partition walls, seems to have 70 m^2
Has a bathroom, a sink, a kitchen, a dining room and a bedroom.
This type of housing also offers solutions for commercial spaces.



U+A HOUSE

Its design is intended for three different climates, has a square of 26 m^2 with rounded corners.

The maximum height of the prototype is 9, 14 meters.

The external finishes are made according to patterns of paint selected by the customer.

ZERO HOUSE

Formed by two rectangular bodies as a container like an horizontal and vertical overlap.

This prototype generates its own electricity, storing rainwater and treats its own waste.

Areas of night and day are perfectly separated.

They are suspended on a 4-point anchor that does not require earthworks, making it suitable for places where the foundations are not allowed.

CUBE / BOX [Idea for the penthouse of our project]

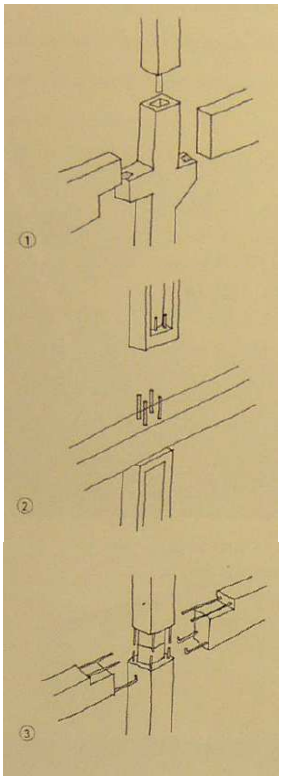
APPLICATION ON MATERIALS: PREFABRICATED CONCRETE

After the first development of reinforced concrete related to on-site fabrication, there was a possibility to transport small pieces with prefabricated concrete.
To understand that concrete could be transported once set, allowed many possibilities and at the same time, a new vision of this material

After that, The climatological conditions didn't condition its on-site setting, the humidity and temperature just affected to execution process, and they could be totally managed since they were done on protected places.
Also the formworks could be placed on their best way to make easier the concrete discharge.
Furthermore, vibration and stripping could be controlled better.
There's no doubt that means such a big increase on concrete quality.

These improved producing conditions meant also a reduction on time execution, further a reduction on costs.

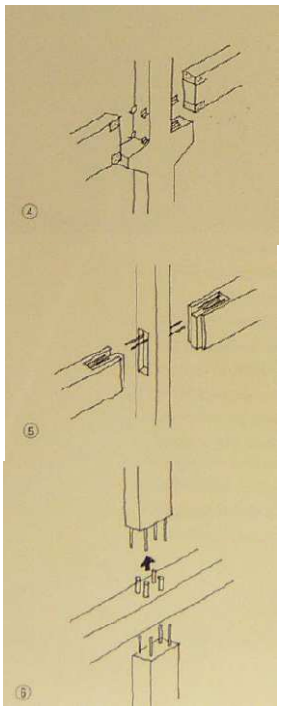
Since prefabrication meant less cost and better quality, its attempt was immediately. Initially, the system was to use load-bearing walls of prefabricated concrete, since concrete is a good material for 'heavy' constructions and with inertia, and was no problem with unions. However, that was a 'back in time' system, losing the advantages that skeleton system had given.
Then, the problem with the prefabricated lineal pieces (pillars, beams and slabs) was the union.
Finally, the prefabricated concrete reached to a new ways of how to use the steel bars. From initial reinforced concrete, thanks to prefabricated concrete, now prestressed and post-tensioned concrete gives a new field of possibilities. Then, some ways are developed:



The easy unions are just supported on brackets.
The pillars are linked with metallic elements for centering.
Sitting is regularised with metallic plates.

With screws and bolts, unions can be improved and get some degree of fixity

To make the union resistance to bending moments, a solution is concreting the knot, solving the continuity of steel bars with sleeves or welding. The connection between beams and pillars is not necessary to be done in the same knot.



Unions may also be resistant to bending moments between caps by welding

The union can get to sneak all binding mechanisms, hewning the support areas and overlapping steel bars.

In post-tensioned unions, the only binding mechanism is the system of introduced forces, resulting in compression and friction between parts. The unions between bars, made after each tightening operation, are resolved with sleeves.

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