SEBASTIAN GUBERNATIS / CLAUDIA IXCHEL

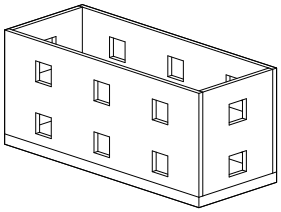
MASSIVE CONSTRUCTION

Abb.1 National Arts School Cuba

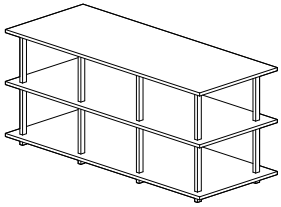
The following essay is an analysis about massive construction and prefabricated systems with the focus on Cuba during the first years of Revolution until now. Our main goal is to explain the variety of formal and structural alternatives found by architects and city planners as an answer to the challenge of constructing big projects with low resources. Besides we mean to talk about how these alternatives have changed through the years depending on the social, political and economical context, and their advantages and disadvantages among others.

What is massive construction?

Massive Construction is a form of supporting structure in which elements not only serve to close off the room, but also take on the static load-bearing function of a house in the form of walls and ceilings. It is therefore the opposite of filigree construction or lightweight construction, where the load-bearing elements are different from the space enclosing elements[1].



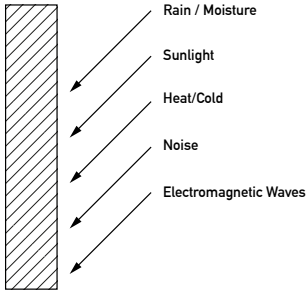
Massive Construction



Filigree Construction

Materiality

The definition of massive construction does not inheld a materiality of the construction, but because of materials conditions masonry,stone and concrete are the most used materials for this construction. In the course of time, different construction methods and building materials were developed, which should meet the changing demands on living comfort. Initially, this was stability, protection from moisture and the effects of the weather, and later



Qualities of a material

fire, noise and heat protection were added. Well-planned and carefully executed masonry will meet each of these requirements over a long period of time. A massive building envelope usually consists of medium to small-sized bricks that are glued with mortar, usually provided with additional thermal insulation and plastered outside and inside. A distinction is made between single-shell and double-shell construction. Interior walls are often created with large-format stones or drywall. Thanks to concrete construction, it is also possible in solid construction to either produce whole components on site or to prefabricate them in the factory.[3]

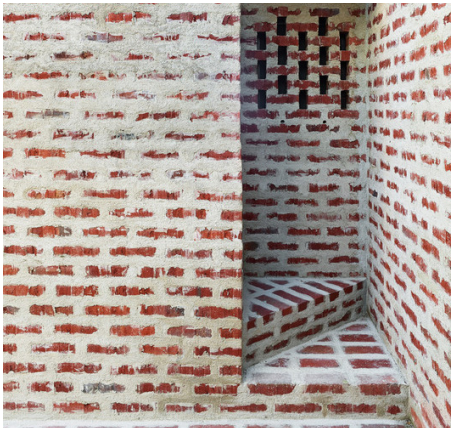


Abb. 2: brick with mortar

Abb. 3: sand-lime brick

Abb. 4: baked bricks

Abb. 5: prefabricated concrete Walls

Advantages

The interplay of masonry, plaster and, if necessary, thermal insulation is crucial for healthy building and living. Due to its moisture and warmth behavior, the building envelope can contribute to a healthy and comfortable living environment all year round. If mortar, stones and plaster are largely free of problematic ingredients, harmful emissions into the interior can be avoided. In addition to the good physical properties of a solid building envelope, it also protects against the influences of electromagnetic waves. The prerequisite for all of this is the use of building materials with the same properties and the careful execution of openings and connections.

Disadvantages

The main disadvantage of solid construction is that large amounts of water are required for the preparation of mortar, screed and plaster and the shell construction requires a longer drying time. The short construction times and quick occupancy can lead to considerable health problems due to an excessively humid indoor climate and mold.

Abb. 6: aerated concrete block

Abb. 7: natural stone

Abb. 8: brick with mortar

Abb. 9: concrete stone

Stone is one of the first materials chronologally when it comes to the method of massive construction. We distinguish between masonry stone and natural stone, where masonry stone is a ready made form for the building construction.

The main components of masonry stones are lime, sand, clay, loam and water. The raw materials are mainly mined in local regions and can often be processed without long transport routes. The heat storage capacity of the building materials also has a positive effect on the energy balance. The production of bricks differs depending on the type and composition. The following applies: the harder the stone, the more energy is required to burn the stones. The ecological cycle closes with the disposal or recycling of the building material. Masonry stone fragments can partially be reused during production; Dismantled material is used as a substructure in road and path construction.[3]

Abb. 10: Residence in Vrjovlje

For example the Residence in Vrhovlje built by dekleva gregoric architects for example is a handcrafted construction method with a hybrid structural systems of brick masonry, with a sloped roof erected in reinforced concrete. To give the building massing the monolithic impression of stone, the facade was executed with an outer layer of stone and concrete. Stone was placed in the slip-form, and then the mortar was added. The excess mortar that came to the surface through the joints was only partially removed.[2]

Abb. 11: Residence in Vrjovlje

Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens (cures) over time. In the past, lime based cement binders, such as lime putty, were often used but sometimes with other hydraulic cements, such as a calcium aluminate cement or with Portland cement to form Portland cement concrete (named for its visual resemblance to Portland stone).Many other non-cementitious types of concrete exist with other methods of binding aggregate together, including asphalt concrete with a bitumen binder, which is frequently used for road surfaces, and polymer concretes that use polymers as a binder.

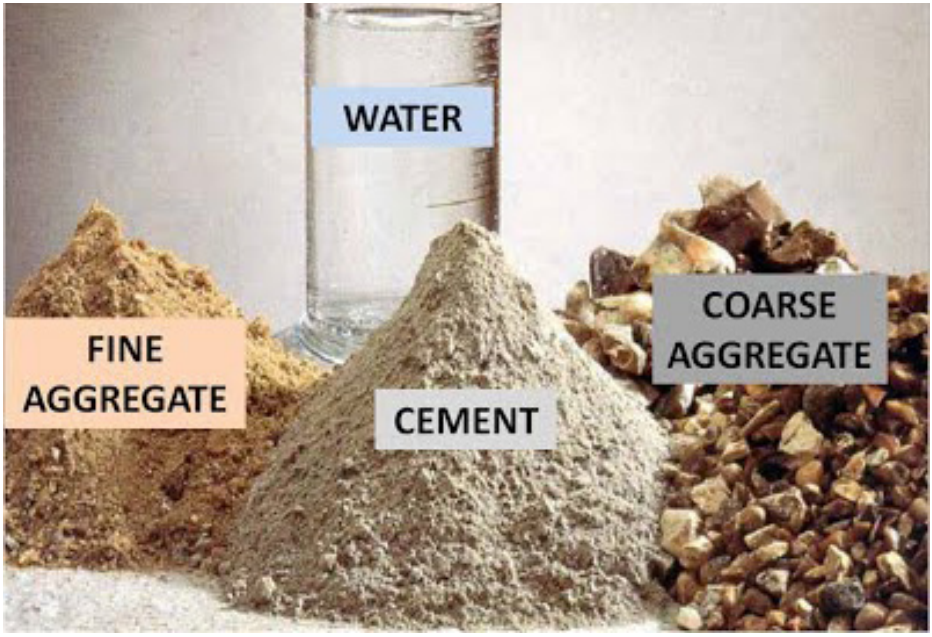


Abb. 12: Ingredients Concrete

Although wood is not a popular material considering massive construction, it can be used as shown in the following example;
- the holiday chalet in Maria Alm
- Aside from the reinforced concrete foundations and the walls in contact with the ground, it is a purely wooden structure. Thanks to the high degree of prefbrication, construction lasted just 16 weeks. The exterior walls exmploy glue laminated timber. The cantilever is made possible by story high cross wall elements. The floor decks and roof are also executed in glue laminated timber. Solid wood is the predominant material for interior surfaces and the furniture.[2]

Abb 13: holiday chalet in Maria Alm

Abb 14: holiday chalet in Maria Alm

MASSIVE CONSTRUCTION
FORTIFICATIONS

One of the earliest forms of massive construction are fortresses. Cubas interest in fortresses began around 1600 in response to defense and security amongst pirates and political attacks.

Compared to other countries in the region, Cuba has plenty defensive structures. Historically, Cuba was a sought-after land and defenses were needed to be built to protect it from intruders.

The fort was built of limestone quarried from the Havana shoreline and the fortification incorporated thick sloping walls, a moat, and a drawbridge.[4, 5]

Abb 15: Castillo de San Pedro del Morro

“Cuba will count as having the most beautiful academy of arts in the world." - Fidel Castro 1961.

The Escuelas Nacionales de Arte (ENA) was constructed between 1961 and 1965. It has been designed by the cuban architect Ricardo Porro and his Italian partners Vittoria Garatti and Roberto Gottardi.

The three major concepts of the design were; first to integrate the school into the wild character of the landscape, which was a private golf course in the western suburb of today called Marianao; second to only use locally produced bricks and terra cotta tiles, which were cheaper than imported materials like steel and cement because of the US Embargo on Cuba; and thirdly to use the Vault as a gemoetric symbol that stands in bold contradiction against the International Style of the Western capitalistic architecture. The complex includes

Abb 16: Escuelas Nacionales de Arte

rooms for contemporary dance, music, drama, plastic arts and ballet practice

The enthusiastic support of the National Art Schools in the early 1960s was sinking by the end of the decade, and compositions of the complex were left unfinished. More than 50 years later, much of the concrete is flaking and the brick and mortar has been eroded. Therefore some of the buildings remain in use today where others lie abandoned.

Because of its architectural importance, it was decided in 2018 that the National Art School should be conservated and supplemented professionally. The Fondazione Politecnico di Milano will act as the lead organizer of this project.[6,7]

Abb 17: Escuelas Nacionales de Arte

Dom-Ino System Le Corbusier

The Dom-ino system was created by Le Corbusier in 1914 during the first postwar period as an answer to those demands, and its comprehension is indispensable in order to understand the first Revolution projects.

The Dom-ino system is a prototype for the massive production of houses. This model proposes an open floor plan composed by concrete slabs over the smallest possible number of concrete columns reinforced by the edges, with access stairs in every level, located on one side of the floor plan. The structure must be totally independent from the floor planes, which gives the possibility of designing freely the interior configuration. This model removed the load-bearing walls and support beams for the ceiling.

MASSIVE CONSTRUCTION
PREFABRICATION

Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub-assemblies to the construction site where the structure is supposed to be located.

Panel assembly process

The triumph of Revolution on January 1, 1959 meant not only the independence from United States but also a significant social, economic and politic transformation. The Revolution inherited big differences between the capital and the rest of the country, a quarter of the population resided in the capital, so as a half of the urban population. Besides almost all the institutions and public services were located in the capital as well. That´s why the first government goals were to eliminate these differences by urbanizing the rest of the country and paying more attention to the peripheral areas inside the city.

The consequential changes due to the triumph of Revolution caused the exodus of a big part of the population to other countries, especially United States, which included big Architecture studios and their corresponding professionals. That´s why the responsibility of carrying out the constructive work, in a context of low resources availability and economic crisis because of USA blockade during this period, felt over the shoulders of a few professionals and the architects in formation.

Among other alternatives, the Sandino Prefabricated System was used in the "Plan Cordón de la Habana". This project involved the nowadays territories of Boyeros, Marianao, 10 de Octubre and Guanabacoa, and its main goal was to relocate the country people in the area. The construction of 120 one level houses in 44 days was possible by using The Sandino Prefabricated System.

This low technology system was created by José M Novoa during the 50´s, and it is commonly used all over Latin-America at the construction of one- and two-level houses.

_ The system consists of a light elements constructive solution based on walls made up of precast elements (panels and columns), whose weight is around 65 kg.
_ The modulation is around 10.40 m between column axes and the space between them is filled by five precast panels or windows

Composition:
_ slabs
_ foundation beams
_ columns: the section is 0.11 x 0.11 m, 2.45 meters height and its weigh is around 67-70 kg.
_ panels
_ windows frames
_ doors frames

Mounting:
_ Collocation of corner columns
_ Collocation of alignments cords
_Alternate placement of the first panel, sticking it by wooden cribs.
_ Pouring concrete between the foundation and the joint.

Advantages:
_ As a system can, be used easily depending on the constructive necessities by different technology productions and prefabrication ways.
_ It doesn´t require high-qualified operators.
_ It can be made by manual technologies.
_ Offers advantages of low-cost manufacturing, speed of execution and design flexibility.

Disadvantages:
_ The appropriate thermal conditions in the interior spaces are not guaranteed and its exterior shapes generates serious conflicts about the evacuation of rainwater and humidity.

At the end of the 1960s, the generation born at the beginning of the revolution finished their primary studies and there were not enough secondary schools where they could continue their training. Faced with this growing demand, the plan for Basic Secondary Schools in the Countryside (ESBEC) was conceived, located in rural areas in which students combined their teaching activities with agricultural activities. As a variation of these, the Pre-University Vocational Institutes of Exact Sciences (IPVCE) emerged, in which in addition to carrying out agricultural activities, the study and practical teaching activities concentrated on the basic sciences, with the aim that graduates of the center will join careers of these branches.

The Vladimir Illich Lenin School of Exact Sciences is located in the Arroyo Naranjo municipality, Havana, Cuba, in a land limited to the south by the Globo ring road. The School with its sports fields occupies an extensive area of 80 hectares and is separated from the roads that surround it by an extensive strip of gardens. The project began in 1972, under the direction of the architect Andrés Garrudo Marañón. This contemplated a wide architectural program, due to the great variety of dynamics and activities that it interwoven: internal life, study at different times of the day, combined with various practical agricultural, scientific and recreational activities for thousands of students and teachers. This type of school arose as a result of the political, economic and social context of the moment, explained at the beginning of this section, which redefined the idea of basic secondary school. The necessary profitability and speed of execution of this type of projects demanded a practical construction system that used local resources, as an answer emerged the Girón Prefabricated System, which constituted the main structural solution for educational buildings at this time.

The Girón Construction System is essentially made up of a reinforced concrete skeleton structure with floors formed by reinforced or prestressed slabs of double T section. The exterior walls are also made of reinforced concrete, some of them contribute to the resistance of horizontal forces, acting as shear walls or tympanums when the skeleton is insufficient for it, with the peculiarity that these tympanums do not have to coincide in the same vertical plane or continue to the foundation, which facilitates the composition of each floor for architects.

Main features:
The structure can withstand operating loads or overloads of 300 and 600 kg / m2, wind pressures of 175 kg / m2 and earthquakes up to grade 7, according to the M.S.K. scale.
The system allows a modular silver network of 6m x 6m or 6m x 7.50m or any combination of these.
Up to 5-story buildings can be built with 3.30 meters of floor-to-floor prop.
In buildings of one to two levels, you can strut of 4.20 meters on the ground floor.

Components:
Foundation plate, concreted in place.
Prefabricated vessel to receive columns
Lower fraction of the column, embedded directly in the vessel. When its cross section is greater than 0.30 x 0.40 m, it is called a pedestal.
Beams that go from one column to another, including the corresponding cantilevers; Only the lower zone is prefabricated, achieving a final resistance after concreting the beam joint with the double T slabs.
Intermediate or upper section of the column: it goes from the upper level of a beam on one floor to the lower level of the beams on the next floor that they serve as support; each column fraction of this type is called a column.

Connections between the parts of the skeleton:
Plate-glass connection: it is made by hardening the concrete of the plate, which surrounds the legs of the precast glass.
Vessel-pedestal or vessel column connection: it is carried out by embedding the vertical element in the vessel and by hardening the concrete that is poured between the two elements.
Beam-slab joint
Pedestal-beam-slab or column-beam-column joint
Connections between skeletons and panels:
It is carried out mainly by welding the metal inserts anchored to the surfaces of the prefabricated elements.
The prefabricated components of the System according to their function can be classified in the groups mentioned below:

Group 1: Glasses
Group 2. Pedestals
Group 3: Beams
Group 4: Slabs
Group 5: Alero beam
Group 6: Columns
Group 7: Panels
Group 8: Stairs

Advantages related to the use of the Girón Prefabricated System:
It uses production techniques with a high degree of industrialization, experienced in the country and with relatively little need for investment.
It uses highly mechanized construction techniques, but without requiring a high level of qualification in the generality of the workers.
Open construction system that allows its use in a greater number of projects.
As a system, it has demonstrated its flexibility for design, to the point that its use has been extended to areas such as hospitals, hotels and offices.
The skeletal structure characteristic of the Girón System allowed a large opening of openings and therefore panels running along the teaching blocks, whose orientation to the north not only satisfies the necessary

levels of lighting and ventilation, but also the minimum or almost no sunlight of the facades during the day. The bedrooms were oriented to the east so that, although the sun shines on the façade during the morning, users are not affected since the programs in these premises cease at that time due to teaching activities. In the same way, the mostly free ground floor configuration of the building allows the uninterrupted flow of air throughout the entire school area, which added to the different patios and wooded training squares that are interspersed with the blocks of classrooms and premises contribute to a fresh and pleasant interior environment of the center.

It can be said that the Lenin achieved a high level of functionality and design, while alternatives were used that broke with the typical monotony of the Girón System, such as the murals and hand sculptures of important Cuban artists, among which there is one of the emblematic roosters of Mariano Rodríguez.

´´ The Girón system was a very appropriate solution for what it was designed for. The regrettable use that it was subsequently put to other functions beyond its purpose has led to some negative judgments that it does not deserve. In the schools built with the Girón system, aesthetic achievements and adequate solutions from the functional point of view were achieved. ´´ (María Victoria Zardoya, The Architecture of the Cuban Revolution)

Other relevant projects carried out with this construction technique:

- Palace of the pioneers Che Guevara (1978) designed by Néstor Garmendía
- Volodia educational center (1978) designed by
- Heriberto Duverger
- Hotel Mar Azul (Combination of Girón system with Sliding Molds and Light Prefabricated System, 1974) designed by Mario Girona
- Hotel Tritón designed by Vicente Lanz
- Las Ruinas Restaurant designed by Joaquín Galván

Unlike the rest of the country, in Havana it was not necessary to build large health facilities at the beginning of the Revolution, since there were enough private hospitals and clinics that after their nationalization became part of the assistance network of the National Health System free of Cuba. During the 70's, the services of this branch were enlarged, through the construction of new polyclinics, such as the one in Centro Habana (an exponent of the Girón System explained above), but by the 80's the growth and modernization of many of these hospitals became necessary.

The order prefabrication system in this period was the SAE: Open Skeleton System. This was used in the Cardiovascular Surgery Center of the William Soler Pediatric Hospital, the School of Nurses, three hospitalization blocks of the Calixto García Clinical Surgical Hospital, the Julito Díaz Rehabilitation Hospital, the Superior Institute of Medical Sciences annexed to the Piti Fajardo Hospital, and in the construction of the Pediatric Hospital of Marianao Juan Manuel Márquez.

Similarly, during this decade new centers related to the field of medical and biotechnological research were erected in the capital to respond to another line of the Cuban economy that was taking off, the development of scientific research. In this way, the Center for Genetic Engineering and Biotechnology emerged, designed by Rafael Moro and inaugurated in 1986, and in which the SMAC prefabrication system was used.

Prefabricated system of skeleton structure for buildings from one to 18 floors.
It has a rigid beam-column joint, a portico system that eliminates the use of eardrums.
Modules of 6 and 7.20 meters are used for beam spans and 6, 7.20, 8.40, 9.60 meters for slab spans (when double T can reach up to 21.80 span meters). The struts are 3.60, 4.20 and 4.80 meters.
The foundation consists of prefabricated cups, plates and closing beams cast in situ.
The columns are a single section of 0.30 x 0.60 m.
The beams are formed by two longitudinal ribs joined by vertical diaphragms transversely and connected in their upper part by a horizontal sheet.
The slabs can be Spiroll or Double T prestressed with single section and curtain walls.
Control of planimetric and altimetric errors is vital in the assembly of this system.
A use load of 200 to 1,500 kg / m2 has been considered.
This system has two variants:
LC solution: Wall panels with drawer or Spiroll slab and covered with any of the same elements or Siporex.
AC solution: Walls and roofs of corrugated cement-based tiles.
The skeleton of the structure consists of solid rectangular reinforced columns and post-tensioned beams or trusses for the roofs.
It admits the use of 5, 10- and 20-ton bridge-cranes and subhook transport of up to 3 tones.
The foundation is isolated and consists of a monolithic reinforced concrete plate and vessel.
Mezzanines with loads of use of 500 and 800 kg / m2 have been developed for this system, for props of 3.60 and 5.40 meters.
There are 20 plants, with a potential capacity of one million 062 thousand m2 of warehouses in this system, distributed throughout all the provinces except Villa Clara and Holguín.

Advantage:
The system enables the design of warehouses with one or more spans of 12, 18 or 24 m, with 6 m spans, expansion joints every 72 m and free props of 3.60, 4.80, 6.0, 7.20, 8.40, 9.0 and 10.80 meters.
It has great flexibility, which enables a wide range of design solutions
Its ability to reach several levels allows to cover large programs

The Open Skeleton System is designed to be applied in a large number of mass-use programs.
Supports up to 17 plants.
It uses 6.0- and 7.20-meter beam spans and 6.0, 7.20, 8.40- and 9.60-meter slab spans.
The beams can have cantilevers of 0.90, 2.10 or 2.70 meters.
The props can be 3.30, 3.60, 3.90, 4.20 and 4.80 meters, between levels of finished floors.
The foundation consists of precast reinforced concrete cups embedded in cast-in-situ plates. When there are eardrums, their foundations are concreted in situ.
The columns are one, two or three sections in length.
The pedestals are 4 different lengths.
The beams are made up of an inverted channel section, made up of two precast beams and an in-situ concreted upper band.
The slabs are hollow Spiroll technology 20 and 30 cm thick.
It also has closing beams, tympanums, stair beams and vertical, horizontal and corner closing panels.
It supports a load of use of up to 1500 kg / m2, depending on the lights and the number of floors.

The fall of the Russian socialist camp meant a significant crisis for Cuba in all spheres, affecting food and the satisfaction of basic needs, with prolonged interruptions of electricity service. This crisis modified the plans related to construction. The tourism sector acquired a greater boom, and the main construction efforts were destined to this branch.
The prefabricated systems already explained were once again widely used in this construction task, being used in the following works:
_ Hotel Melía Habana
_ Hotel Neptuno
Other architectural themes:
_ La Puntilla Shopping Center

General advantages about prefabricated systems:

Lower Costs
The industrialization of processes results in a reduction in labor costs (associated with both a lower number of hours and a lower cost per hour). the greater planning of the works and the lesser probability of unforeseen events (for example inclement weather) results in a shorter execution period, generating an economic optimization of the work.

Optimal quality
The prefabricated industrialized manufacturing achieves high quality finishes both in geometry and in surface quality.

Monolithic structure and high resistance
The structural functioning of all vertical walls as deep beams together with the plate effect of the slabs, as well as the joining system between panels, gives the resulting structure great strength against vertical loads, as well as excellent performance against horizontal stresses (earthquakes)

Reduction of occupational risks
The activities carried out in the industrial installation can be planned and controlled better than those carried out on site, resulting in an improvement in

the working conditions for the operator.

General disadvantages about prefabricated systems:

_The elements suffer states of transitory load in their transport, positioning, lifting and adjustment, which can affect the structural resistance of the piece

_The collection, handling and form of transportation can affect the pieces if these operations are not carried out by trained personnel.

_These require a very important initial investment to start up the production system, but it is justified in large works with reduced execution times.

_You must have heavy equipment for the assembly of structural elements and have enough space to maneuver with this machinery.

_Coordination of tasks for facilities is essential to avoid downstream work. An error in the resolution of these conflicts can lead to the failure of the work (joints, times, costs, structural resistance).

At present, after the boom and bust periods of this technique, prefabrication is resumed in Cuba. Its many advantages are taken advantage of and the aspects that previous years contributed to its detriment are also taken into account.

Although Cuba is still working with massive construction, current projects are not characterized by the same typical repetitive module in the same territory. The Great Panel VI can be cited as an example of the above, a system that underwent a first modification, from which the GP-VI-M arose, which now responds to the Flexible Prefabricated (PREFLEX). In the province of Holguín, specifically, modifications were made to the Grand Panel VI, from which the Grand Panel Holguín (GPH) emerged. Small-format prefabricated building systems have also been implemented, such as the Block-Panel (B-P) and the residential building system (SER), both as alternatives to achieve a diversity of housing solutions.

Likewise, progress has been made towards made-to-order prefabrication, which is understood as the use of prefabrication when it is only economical to do so. In this, the use of industrialized materials and components is combined with other traditional construction techniques. This solution has succeeded in favoring the economy, safety and aesthetics of the buildings and all of them.

Although it is considered a trend of change of thought compared to traditional prefabrication, in Cuba, until today, this has only covered social buildings. This trend sees the light from these ideas and is imposed day by day, since it responds to the need to pre-fabricate, but taking into account the priorities and characteristics of the context. The prefabrication to order arises as an alternative solution to break with the problems of urban monotony, at the same time that it takes advantage of the great advantages of the prefabrication construction technique.

Teaching blocks of units 3 and 4

Teaching blocks of the old units 5 and 6

Training places

Pool and Nailing Tank

One of the roosters from the Mario Rodriguez series

Lenin`s mural located in unit 6, current unit 1

Genetic Engineering and Biotechnology Center built with SMAC Prefabricated System

Julito Díaz Rehabilitation Hospital built with SAE Prefabricated System

Juan Manuel Márquez Pediatric Hospital built with Prefabricated SAE System

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