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RESEARCH FOR A CONSTRUCTION SYSTEM FABRICATED BY COMPUTER NUMERICAL CONTROL MACHINERY

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ABSTRACT

The main issue of this study is to create a Construction System, based on prefab pieces, made in a CNC machine. This system has to insist in the recyclability of all components. The system should allow for a bioclimatic performance of the whole building. The construction system will allow interior division flexibility. This means that the building user could easily move the partitions by himself or herself. In order to guaranty precision and security on the construction site and simplicity on the transportation system, there must be a complete coordination between the project and the building site. Adaptable to any geometry and measurement. Most of the prefabricated buildings, are not suitable for a non orthogonal site. Working with a CNC machine can avoid this.

Keywords: CNC, Recyclable, Bioclimatic, Adaptable, Flexible

APPROXIMATION TO A CONSTRUCTION SYSTEM

The following paragraphs and pictures show how the approximation of this Construction System has been.

The main goals of the construction system are the recyclability of all elements, energy saving, bioclimatic performance, economy, accuracy and safety in the building site and simple procedures to write the project documentation.

Far from creating new architectural forms and styles, we can say that creating new spaces for architecture is not the purpose of this research. The work is based in standard and normal spaces: it is not the main issue of this research, to create new scenarios.

Neither is the purpose of this research to create new installation facilities.

The first steps made, have tried to define an optimal building form. So the optimal building form means that the building, has to be as bioclimatic, as adaptable, as recyclable, as flexible and as precise as possible.

Nowadays, in order to make a building more flexible, it is necessary that all the installation could go by independently from the partition or structure. Guarantying an independence will make it easier to transform a kitchen space into a bedroom.

When designing a pipe pathway, it is appropriate that all tubes can be placed between the ceiling and the floor, for horizontal pieces. When it is a vertical section, it's better to place them without disturbing every-day spaces of the building. It's also appropriate that the tube could be registrable in all its length.

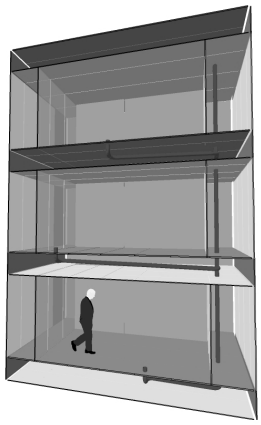

***FIGURE1**: finding the optimal form*

It is proved that a double facade system is the best choice to accomplish bioclimatic functioning of the building. In a nut shell, it's easier to get a comfortable acclimatization inside when we have double protection skin that includes a big air space in between.

We can say that we have a primary space, which people normally use, and a secondary space, that can be used for quotidian human use, but also a space which allows for pipes and installation flexibilities. And then a third horizontal space, exclusively for pipes and structure.

So if we see this form, then, we can easily embody the structure in this way, by using a Vierendeel or a Truss joist and a double support structure.

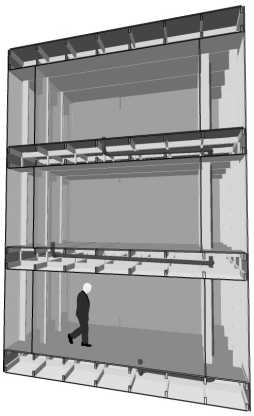

FIGURE2: *embodiment of the structure*

APPROXIMATION TO AN OPTIMAL STRUCTURE

It will not be pre-established, but in the previous works, the structure pieces have been approximately 5x18cm. The process to get a optimal structure scheme, has been contrasted by three different types, and finally we have chosen one. In the end, the structure scheme could be simplified in a diagram like the one shown below. The first calculation showed that a building of 4 floors could be built with this system. The structure, in case of need, could be reinforced with steel.

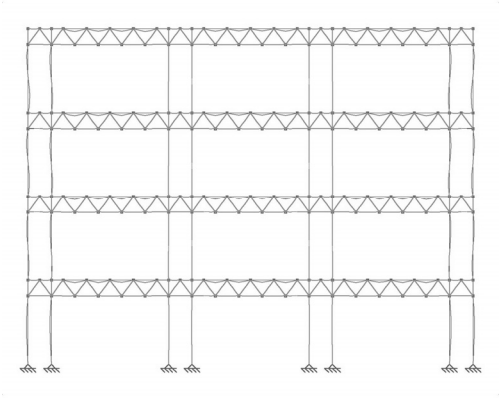

FIGURE 3: *diagram made from the structure calculation and the movements on it.*

The reinforcements will be considered as a part of the system, so in case it will be needed, each piece will be coordinated with the rest of the pieces, in the way that all reinforcement elements will have a hollowness already made for the pieces. All the solutions for the reinforcements will be predesigned, and it will be proper in the future, to have a catalogue of solutions for this purpose.

APPROXIMATION TO BUILDING PROCEDURE

How can all these pieces be produced in a proper or a synchronized manner? CNC technologies offer a solution. Nowadays, after making a precise 3D model, it's easy to produce each element of the building in a proper CNC machine. The furniture industry is already using this technology. This way, working on the building ground will be just assembling the pieces fabricated in the factory. For the development of the Construction System, it will be necessary to create a specific plug-in between the CAD that will be used for elaborating the building project and the CAM that the CNC

machines use. This plug-in or program, will offer a library of solutions, also the possibility to adapt to the geometry of the place and calculate different aspects of the building such as the structure and the thermal insulation.

And of course, if this construction system wants to work well in the market, its price has to be competitive. The uncommon parts compared with a ``normal´´ building are the structure and the partition. The first studies made in this field, show that the quantities of the budget referred to these uncommon elements are similar to those in a normal construction system. But this construction system works better for achieving energy savings. An edification built with this system saves at least 30 percent of the consumed energy compared to a similar construction made with common systems. It has to be said, that once the pieces have been fabricated, a none specialized person could easily assembly the building with a proper and computerized guide, using bar-codes for recognizing pieces and for placing them in the designed place.

To accurate the process of the construction system, it´s necessary to define some details. This definition will be proved by making prototypes and testing them in specialized laboratories. It is shown in the next pictures, how the construction system is during the building site. Anyway, it has to be said that, for now, the foundation system hasn't been redeveloped. This means that the foundation that are used in this system are normal or common.

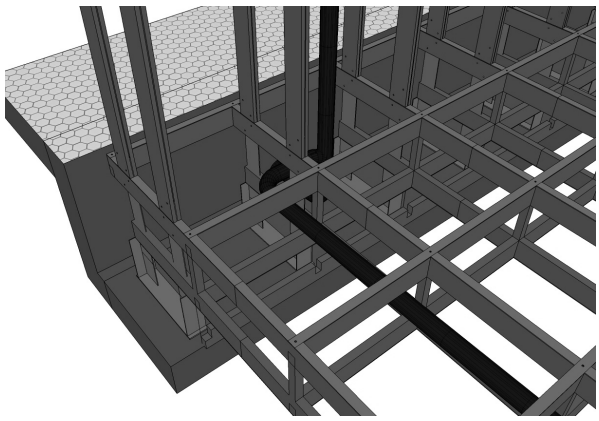

***FIGURE4**: the foundation system will require special attention as not to damage the soil ground of each place. The structure is based in the foundation. The reinforcement is already precut and available to put it in the hollowness of the structure the pipes have enough place to move along their spaces. These pipes can ``appear´´ whenever they are required, by cutting the floor, partition or ceiling panel when it is needed.*

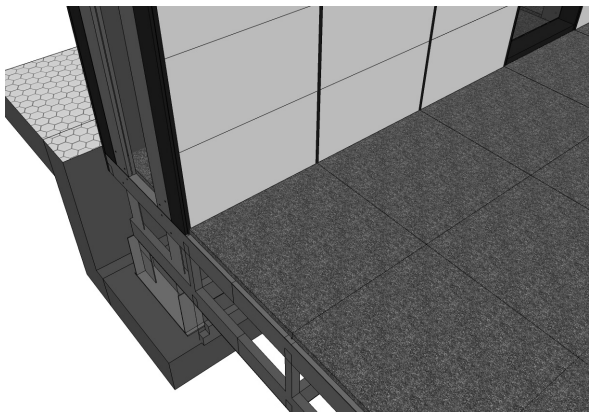

FIGURE 5: *the floor's and the ceiling´s panels, already precut in the CNC machine, are put on their place. the facade´s double skin is assembled. It's a design choice to make this secondary space habitable or just consider this place for a wardrobe, installation box or whatever else. Of course, it will depend on what length we leave for this secondary space, and then see if it's possible to make it usable.*

ADAPTABLE TO DIFFERENT USES

The system is both flexible in structure, in partition and in installations. The joists of the structure and partition could be opened or closed with a simple wrench. So the user, with the help or guidance of a architect (or similar), could move the partition, the installation or even the structure.

All this is supported by a flexible installation, partition and structure scheme. Almost everything is moveable, The only element that should be kept in place or fixed on every floor, it´s an installation shunt (even this could me movable but not recommended).

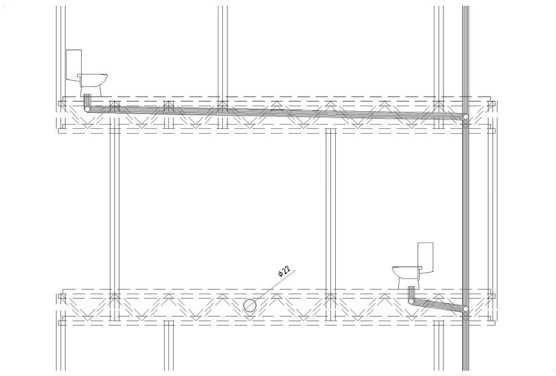

FIGURE 6: *as it is shown in the figure, the system's elements are moveable from one floor to the other .*

I will show an example of a hypothetical case. Let´s say we can make a 4 story building in a 900x600 cm plot and that we have 4 different types of use, which are:

a.-artist's atelier: a diaphanous space with a big terrace plus a toilet.

b.-couple apartment: living-room, kitchen, bedroom and a bathroom.

c.-bachelor apartment: a diaphanous space and a bathroom.

d.-office: a diaphanous space plus a toilet.

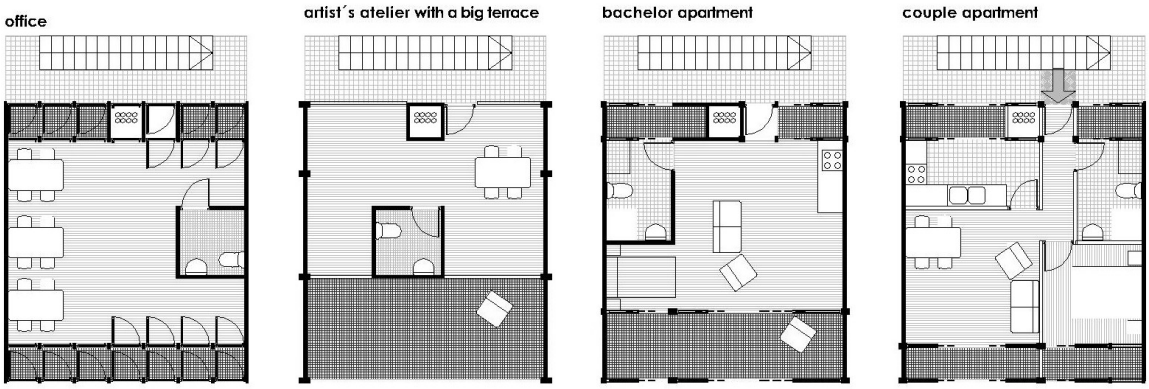

FIGURE 8: *All these types can be used and be combined in different stories. Just the installation shunt and the staircase is maintained in every floor.*

Buildings and places change from hand to hand . If we want to have this adaptability, there must be a maintenance, a parallel service has to be provided. This way, there will be a permanent link between the contractor and the user. This is not new, not even in construction world. The ideal situation would be that the building user could install or uninstall the partition walls or structure elements wherever he or she is interested. The client or the space user could request this parallel service to provide change of structure from place to place. If he would need a piece, he could buy or rent from the maintenance service. Of course, a technician should allow all these changes.

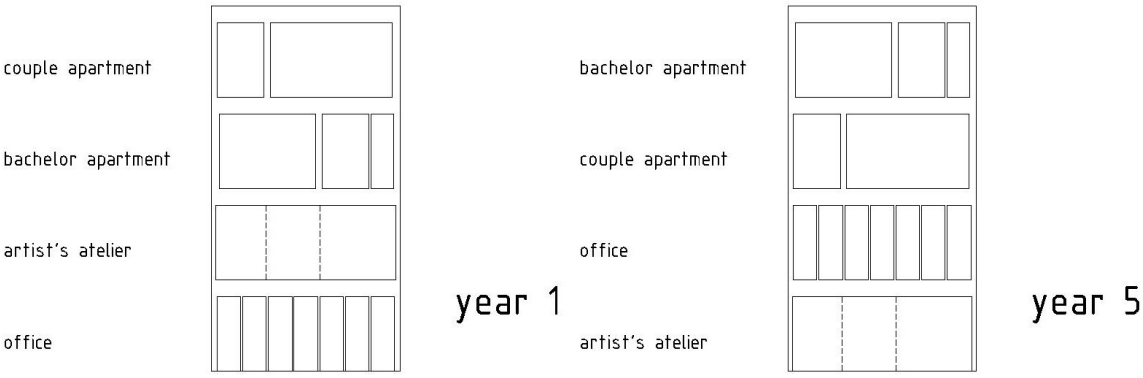

FIGURE 7: *as it is showed in the figure, the system elements are moveable from one floor to the other .*

ADAPTABLE TO DIFFERENT PLOT'S GEOMETRY.

If we don´t want to artificialize virgin land, we have to re-build in the actual non used plots of our cities. The main problem with Prefab systems is that these are quite difficult to adequate to existing plots and geometries in the city centers. They normally need a flat orthogonal ground and a certain modulation or measurement. In the actual urban context, a plot may be 13 meters 39 centimeters long. Could a normal prefab building adequate to these sizes and local laws? I guess it´s quite complicated. A CAD-CAM coordinated system can avoid this. Why? Because the material is cut in the exact measure we want and in infinite number of angles. So, the geometry of the joists are flexible enough to be adopted into a city center plot and facade laws.

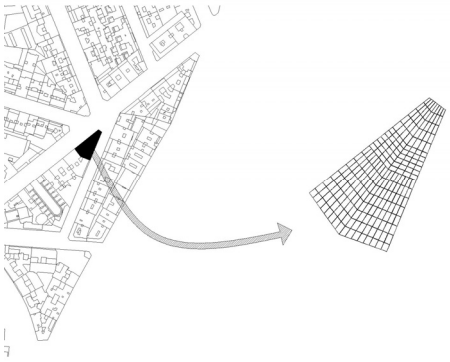

FIGURE 8

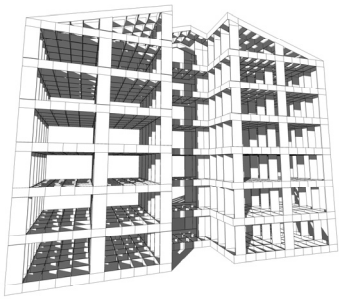

FIGURE 9: *3D cross-section*

FIGURES 8-9: *the construction system is adaptable to any geometry. If we take one of the most ``complicated´´ plots in the Bilbao city center, we can easily adequate the system to the geometry.*

This structure is easily adaptable to non-orthogonal geometries and measures. In the CNC machine, the joists can be made in infinite angles and the cutting of a piece can be produced in any length we want, so we can say that the system is free from modulation. So, even if creating new forms was not the main purpose, this construction system is adaptable to a variety of forms and spaces. This can be really useful when adapting a project to specific ground geometries and urban rules.

REFURBISHMENT: THE SYSTEM APPLIED TO OLD BUILDINGS

Another strategy to avoid consuming new land is to refurbish actual buildings. I will explain the experiences of refurbishment in the old city quarter of Bilbao, and how could this system be a choice for these cases. Nowadays, there are more than fifteen thousand apartments with no use or not occupied in the municipality of Bilbao (a municipality of 350.000 inhabitants).

It has to be said that historic center´s buildings have crooked geometries. The typology of the buildings are the same as in the Middle Age Bilbao, meaning that typology between two parallel walls and two facades is kept. The main rooms are in the front facade facing the street. During the first industrial era, in the historic city center buildings, the insertion of plumbing system in a wooden structure building has not been always successful. Even more, because of the humidity created by those pipes, the wooden structure near these plumbing infrastructure, is almost always rotten or damaged. The structures are so damaged, that the municipal urban office asks for an architect to certify the structure whenever a refurbishment is made.

The structure is considered a common part of the building, but at least in Spain, each apartment normally has its owner. And normally he the owner lives in that apartment. It is rare when there is just one owner of the whole building. Plus, in old city centers, they don´t have too much money. In this situation, total refurbishments are quite difficult. So only partial refurbishment are made when a particular apartment owner decides to renew his apartment. The most problematic sides of this partial refurbishments are the wet rooms, that is the kitchens and the toilets.

So let's say, as a general view, that we have a problem of damaged structure in wet rooms, an old plumbing system and an insufficient insulation of the back facades. And the owners of the apartments have economic limits to make a complete refurbishment.

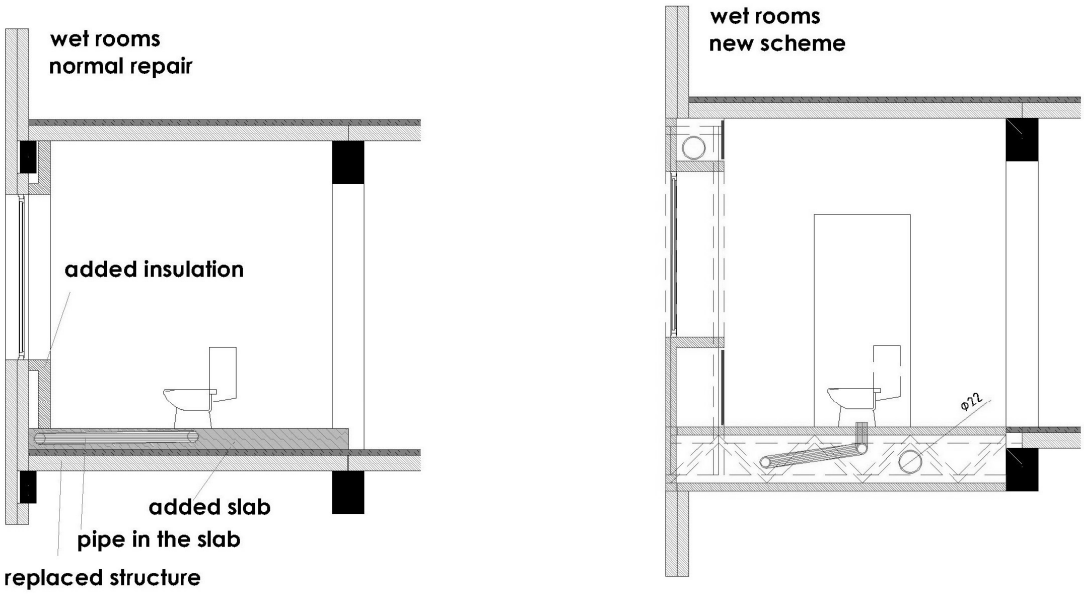

FIGURE 9: *comparative of the two kind of refurbishment.*

How are these reparations done? Normally the wooden structure is replaced or reinforced by steel beams. This situation is quite difficult for the user who lives in the floor below, because normally, part of their ceiling gets tore down. So during the reparation the two apartments are unfortunately communicated. To bother the neighbor below is unavoidable in the actual property system, and the neighbor can´t be placed in another apartment.

Normally, the wet rooms are close to the plumbing main pipe, to avoid pipe long distances. But when the renewal of the house is done, the client may not want the same distribution as it was before. So the fecal pipe needs more length. And that's why the whole wet rooms usually have their floor 20 cm higher than the rest of the apartment. So what would happen if the user of the apartment required a change, again, on his wet rooms? He would have to tear down the 20 cm step and then change the pipes.

The construction system described in this paper may offer a solution to this problem. As we can see figure 9, a normal wooden structure's framework is almost 60 cm high. So this new system can be placed and it's compatible with the old structure. With this system, as it is said before, the user could change the installation from one place to the other whenever it is required. An there would be enough space to put more installation, such as And of course, no other neighbor would be disturbed using this system.

Finally, there is another choice to implement the system in concrete structure buildings. Unfortunately it is quite difficult to replace the structure. But we can improve the facade conditions. This is was the aim when doing the renewal of the entrance hall of the Architects Chamber in Bilbao. Here, a refurbishment of the facade was needed in order to let natural light in, fit a new air conditioning systems, place a book-shelf and design a shop window.

FIGURES 10,11,12: *previous situation, process and final result in the Basque and Navarre Architect's Chamber, Bilbao. Project by Metak Arkitektura Tailerra .*

CONCLUSION

For now, the design of the construction system is in the middle of its process. The precise 3D models are already made and have been proved with calculation programs. The next step to be made is the production of prototypes and to prove them. Once the prototypes are tested, a tool to make this construction system more efficient will be needed. That is the plug-in program. And after this, all the procedures to put this system in the market will be needed, such as patents, special codes and classes for getting specialized in designing, creating and fabricating with the system.

This Construction system offers the possibility of the maintenance of the building. In a way, if the tenant of the building requires a change in it, he or she should ask for a supplier to get the necessary pieces to make the change possible. This maintenance concept is developed in further fields, such us transport (renting services). So it can be interesting to have an offer of this kind, specially for social dwelling, hotels, office building and etc.

This construction system has to be compatible with other systems. Of course, like any other construction system, it probably cannot solve all the details or problems that occur in the construction. It´s almost impossible. That´s why it has to be amicable with the other systems.

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