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Structure and architectural project: two examples with masonry walls

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ABSTRACT: The paper presents two buildings solved with masonry walls: a family house in Betanzos and a multi-storey apartment building located at Lugo. The structure of the first one is solved by load-bearing walls of precast concrete blocks that arise from an elevated floor slab. The concrete block, though hidden, provides housing modulating, simplifying the tasks of construction, the wholeness of the building as well as guarantees other physical properties (fire resistance, thermal inertia, sound insulation). The second building is a residential building, which has four floors (the fourth one under the roof) built on a small site. There is a real 'tour de force' in this building project whose load-bearing walls of brickwork (perforated klinker) solve both structural requirement and thermal insulation of the façade with a reduced thickness. Through these examples, we offer an overview of various aspects relating to the materialization of the architecture

1 INTRODUCTION

The paper presents two buildings, both of certain architectural quality, solved with masonry walls. The first one is a family house in Betanzos, designed by the architect Mr. Rosales in collaboration with the architect also Mr. Crecente, which was rewarded in 2006 with the prize for architecture 'Juana de Vega'. The second is a multi-storey apartment building located at Lugo, work of the architects Crecente and Fuertes, top prize in a competition with jury. On both buildings the first author of these lines acted as a structural consultant.

2 SINGLE FAMILY HOUSE IN BETANZOS

2.1 *The building*

This is a home for a couple settled on a single floor -100 m^2 of housing and 50 m^2 covered porch, designed by the architects José Manuel Rosales Noves (Basic Project and Project of Execution) and Gonzalo Crecente Maseda (Project of Execution).

The building stands on a slope, in the upper part of the plot, next to the road. It was intended that the disturbance of the site was minimal, maintaining both natural ground slope of the terrain and the existing trees on the plot. The plot has a group of deciduous trees-oaks, chestnut and birch-integrated into a broader set. To allow for uninterrupted enjoyment of the whole, no fence was placed on the perimeter of the plot. This creates the need to delimit a space of housing, linked to it.

The residential area consists of the rooms in the home and the adjacent spaces. These spaces are used both as living area and as service one -garage and private outdoor area which is understood as an integral part of the house-. Integrated into enclosures are incorporated the necessary storage spaces as well as electricity and sanitation facilities. Housing areas and attached spaces form a parallelepiped volume organized around an open square courtyard -4x4 m^2 broad speaking-. Housing stays -except the bathrooms- open this entire yard, providing a counterpoint to outer space completing the program. The house is closed to the area by three of its four sides: it's open exclusively to the small park across the living-room and the porch. The roof of the building is constructed with warped concrete floor slabs, resulting two soft hyperbolic paraboloids carrying rain water to a single point on the north side, placed on the division between the bathroom and study. It was considered expose the underside of the surface thus generated, but eventually opted for a horizontal ceiling plane to facilitate the completion of the furniture.

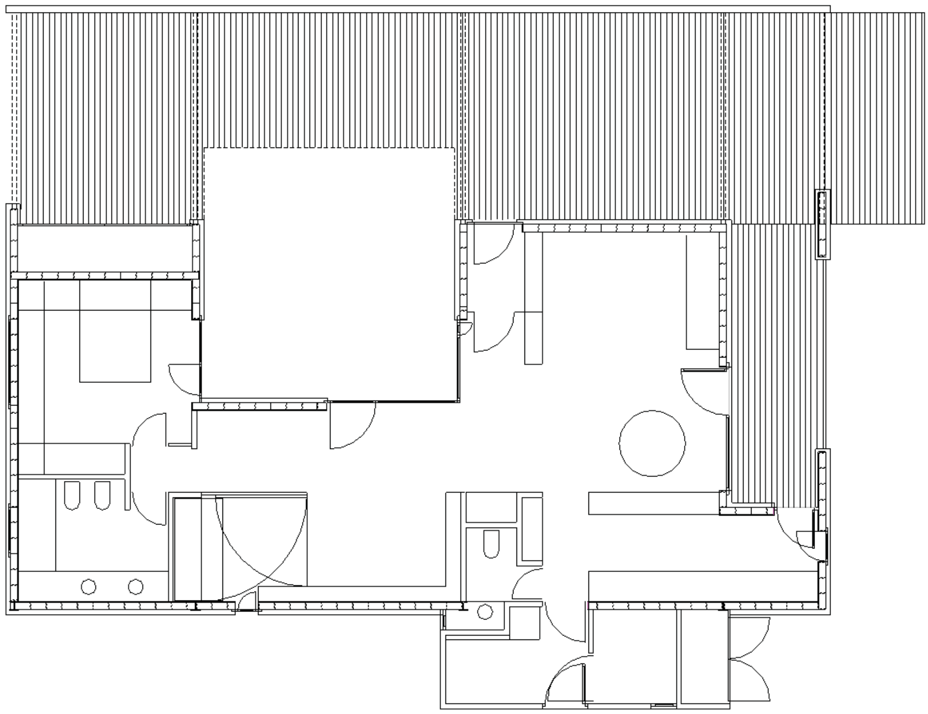

Figure 1. Single Family House in Betanzos. Floor plan.

From a structural point of view, two very different concepts are combined: massiveness -bearing walls and slabs- and lightness -steel profiles- to adjoining outdoor space. Because of the slope, the building touches the ground only at two sides, creating a buoyancy effect in the other two. As it was advanced, the structure is solved by load-bearing walls of precast concrete blocks that carry the warped concrete slabs of the roof. These walls arise from the plane defined for the ground floor slab which is supported on concrete walls running in the area in contact with the ground and steel stanchions where it floats over the ground. The set becomes complete with a structure of metal beams and stanchions that define the enclosure of outdoor spaces attached to housing. This main structure is completely hidden behind claddings: the two structural systems that compose receive a common exterior finish based on wood panels. Both the massiveness of the load-bearing walls as the lightness of the steel grid disappear under the skin of wood panelling surrounding the building.

This coating is composed of phenolic plywoods with okume finish at the outside and with birch one inside. The plywoods are mounted on a double battens system: on the vertical structural elements is placed a first set of horizontal battens to which is fixed a second group of vertical battens responsible for supporting the wooden board that forms the coating. The battens of the first set are formed both by aluminum battens on the walls and by galvanized sheet folded omegas on metal profiles, while the second group are made of treated pine in the all cases.

Finally from the wall structure is hung a built drawer with metal elements that contains spaces ancillary facilities. Its complementarity is expressed with a different cladding, consisting on some corrugated metal plates fixed on the metal framework of the drawer. The structural solution develops the metaphor about this little space for the facilities (the backpack housing): its own steel structure, independent, forming a rigid cage, which is manufactured in a workshop and is hung from the load-bearing walls of the main structure which has been previously built.

Figure 2. The building under construction.

2.2 *Description of the structure*

Keep in mind the structural-construction system since the beginning of a project is a personal choice in the way of understanding the practice of architecture. In this case we chose a load-bearing wall structure for the values it brings to the project, among which stand out:

The rigor metric and constructive associated with the masonry walls provides reasonable and understandable limits to facilitate the resolution of conflict between the idea and its realization.

The monolithic construction associated with load-bearing walls let solve the enclosure, isolation and structure – sometimes also the partitioning- with a single construction element: the structure.

The precast concrete block, if hidden, provides the house its modulation and streamlining of the work force as well as its permanent character.

The thermal inertia of the masonry walls gives uniformity to the inner temperature values, decreasing energy intakes required for thermal conditioning of the building under a continued use.

The load-bearing walls restrict thoughtless changes in the house: the respect that the owners have to structural elements provides immutability guarantees to housing, since, by elementary prudence requires that any modification be consulted beforehand.

2.2.1 *The 'dematerialization' of the structural material*

The structural concrete block sets not only the height of the housing but also its modulation in plant. Besides defining the size of the housing area, horizontal modulation extends to the adjacent open area and fixes the location of the metal structure that closes it. Only the facilities area, the backpack of the house, escapes the discipline imposed by the concrete block module. Thus, although the structural material (precast concrete block) remains hidden, the grid defined by its modulation supports all areas of housing: the block is lost as a physical component but is remained its geometric imprint.

The house was originally designed to be erected with a structure made of precast thermo-clay blocks, but its construction coincided in time with the establishment of the decennial insurance requirement of the sponsor and the emergence of organizations of technical control, the OCT. At that time, these agencies put many obstacles to using thermo-clay blocks by considering them as a non-traditional or experimental material. Therefore, in order to assure the house with no problems, it was decided to use masonry walls made of precast concrete block (200 mm cellular, tongued and grooved blocks). This decision forced to readjust the size of the home because of the different formats of the concrete blocks and the thermo-clay ones. As the modulation of the house derives from the dimensions of the structural material, it is a paradox the impact of compliance with a regulatory obligation arising from seemingly unrelated legislation on the outcome of the dwelling.

Figure 3. Single Family House in Betanzos. Final State.

2.2.2 *Exploring the limits of the structural materials*

Obviously, in a dwelling of a size so small, the boundary aforesaid limits are not resistant materials, but their mechanical limitations, shaped work.

This exploration becomes visible firstly in the concrete warped slab. As mentioned above, the roof is made up with a conventional one-way slab, placed in a non-conventional way, generating a slightly warped ruled surface that slopes oriented towards a single point of drainage. This leads to the completion of a chained border nerve high enough to absorb the height differences arising from the construction of the roof slope. However, this exploratory attitude of the material, which leads to break their limits, it is more evident in the work on the masonry structure, which highlights two situations:

One of the structural singularities of this work is that the most of the load-bearing walls do not reach the ground, arise from an elevated horizontal concrete floor slab partially supported on steel columns. The desire for placing a horizontal box on a sloping terrain made it necessary to combine the two options of foundation on footings: continuous footings under load-bearing walls and isolated footings under steel supports. These are steel stanchions with a hollow small section in order to allow the ground floor to float above field. This floatation made necessary an extra rigid unidirectional slab to prevent the walls from fissuring, due to these are load-bearing walls.

To reinforce this floatation effect, is projected a cantilevered corner with a span bigger than usual. This cantilever is solved by working together the two unidirectional slabs of the building: joint work is achieved by placing some tie rods embedded into the block masonry of the load-bearing walls that fill the frame formed in that way. A kind of mixed wall-beams are set in which concrete blocks masonry acts as a shear stiffening element while the edge beams of the floors bear the axial forces caused by the cantilever bending (the ground and roof slabs forming the beam flanges and the concrete block masonry making the web). Different calculation models were used to confirm the validity of these structural items, ranging from the rod method implemented on a matrix calculation program (prudently developing the proposals of the current regulations for concrete) up to a finite element model on a commercial program.

This type of project decisions forced the development of several models of computation for validation, as well as continued attention during the construction works.

The use of these solutions and methods of calculation was made only after being assured that the direction staff would carry out adequate supervision of construction task, since (although the rules say never) the most important option in structural design is to adjust the projected solutions the capabilities of the performers. Exemplary in this respect was the architect rigor impressed with the implementation of the work and that included not only the structure but all throughout.

3 HOUSING IN RUA FALCON, LUGO.

3.1 *Introduction*

The second building is a residential building, which has 4 floors (the fourth one is under the roof) built on a small site located within the walls of the city of Lugo.

Lugo is an old city of Roman foundation. Sheltered by its Roman walls (now declared World Heritage Site) hides the second historical downtown (by extension) from Galicia. The decline of this historic downtown due to well-known reasons led the Administration to intervene and seek recovery of this area. Rua Falcon is an alley located within the city walls, near the Plaza del Campo square. The area is socially degraded by being adjacent to the area in which prostitution takes place. This social degradation has entailed a special degradation of the built heritage. There was a small vacant plot on this street (an unusual situation in a historical downtown) ending a row of houses. About this site was launched a competition for a residential building (the only use that planning allows), which was won by the architects Javier González Fuertes and G.onzalo Crecente Maseda (Fuertes&Crecente architects) with a scheme of only a house per plant with a final duplex that attaches to housing the space under the roof, creating situations of double space. From the urban point of view, the building creates the facade of the entire housing stock.

The solution adapts to the narrowness of the lot (with average dimensions of 4.50 x 15. 50 m2, it has a ratio less than 1:3) adopting a linear arrangement, based on the length of the resulting facade (although it has two facades, defines a double corner). The corner nearest the Plaza del Campo square provides access to the building, point from which you access the common staircase giving access to the accommodation offered. The service spaces, like stairs, kitchens and toilets, are arranged attached to the dividing wall, placing the living and sleeping spaces adjacent to the front, so that it generates a flow parallel to the main façade. The roofing is projected from a single water scheme, with the ridgepole disposed on the dividing wall. This solution is customized to fit the irregular geometry of the site and the presence of the side facade.

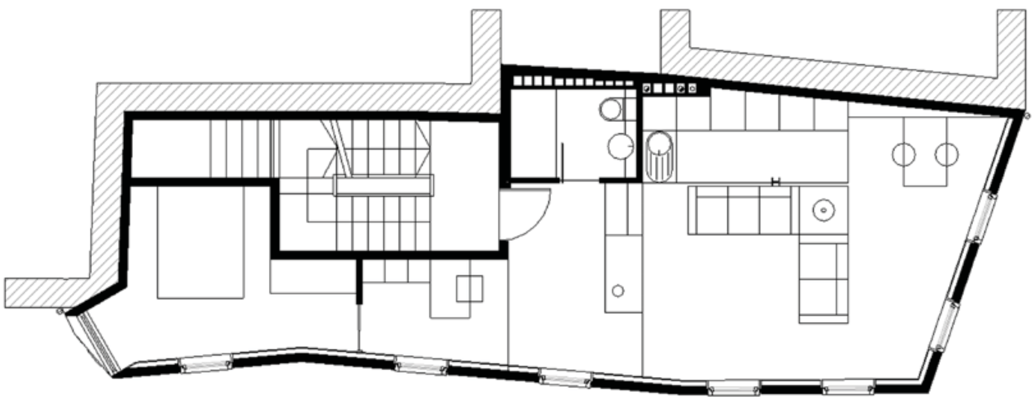

Figure 4. Housing in Rúa Falcón. Typical floor plan.

3.2 *Setting the constructive solution.*

The small depth of the lot was the first difficulty of the project. This was enhanced by having to reduce the already limited available width to ensure that the alley was accessible to fire fighting services. Falcon Street is the only possible access for emergency services to part of the urban fabric. It runs along the main facade of the building, the longer one, so that the widening of this road required by the Fire Service, led to the loss of a very valuable plot area. To compensate this decrease in area, it was decided to reduce the thickness of the external envelope. This led to a solution based on an outer leaf of perforated brick externally plastered which was internally folded with a cladding of insulated plasterboard. This solution ensured a sufficient thermal and acoustic insulation. Watertightness (suction of brick) and mechanic (strength) reasons led to choose a type of perforated brick called clinker by manufacturers.

The pressure to minimize the space occupied by construction elements led to add the structural requirement to those ones that the building envelope should satisfy. Fortunately, the stability of the façade to horizontal actions was enhanced as a result of the breakdown caused by the redrawing of the access street due to the reasons outlined above. This same pressure led to use steel columns in the interior, given that their occupation is the smallest. As a result of this process, brick masonry overcomes the partition condition which has been relegated for a long time and recovers its structural competition which is present at its origin. It is closed what appears to be a process of return, a process during which the thickness of masonry has been reduced considerably. Limited access to the building site due to the existing narrow street led to put in place metal floor decking because it was very difficult as the introduction of prefabricated elements of a certain size as the supply of concrete, forcing pumping horizontally more than 30 m to achieve the lot from the point the mixers could access. Nevertheless, durability and maintenance reasons lead to build the ground floor slab and the walls that hold it in concrete, forming a sort of rigid concrete base which serves as start point of the described structural solution. This rigid base, which helps to resolve the slight slope of the street, was formalized as a plinth clad in stone.

The project uses a system of vertical window openings hollows from floor to ceiling as a compositional element. It contrasts the rhythm of the vertical windows to the horizontal expression of metal floors, which is achieved by the effect is achieved by delaying the plane of the wall at each floor level. This mechanism gives the load-bearing walls the appearance of non-structural elements; this is a formal treatment of non-bearing walls. The use of window openings from floor to ceiling has a great significance from the structural point, due to the fact that on the one hand this language breaks the wall in separate elements eliminating its stability introduced by the folds and on the other hand it interrupts the loading plane of the wall. Retrieving the wall as a whole and resolving the vertical transmission of the loads despite the interruption of the plane of the wall were points of emphasis in structural design. Thus the first concern in structural design was to restore some continuity of the wall based on the stiffness of the element of chains (HEB-180). To get (obtain) this it is essential to ensure the anchorage (connection) of the brick load-bearing walls to (with) the horizontal metal elements acting as chains. This was achieved using perforated bricks and metal rods acting as wall ties: a lot of rods were welded to the metal elements acting as chains and were passed through the holes of the perforated bricks. Lately the holes were stuffed with mortar in order to anchor the rods.

At the upper end of the front wall is placed a mixed beam that follows the perimeter of the facade and that continues on the dividing walls at the same level, closing the perimeter of the building and generating a horizontal ring. Since there is no floor slab linking both long sides of the building, the ring was tied in between in order to give it greater rigidity. Above this level, the roofing is constructed from a single water scheme, with the ridgepole disposed at the rear of the building, on the dividing wall. The lightness of the roof, consisting of a copper strip on sandwich panels of wood panelling supported on metal straps, forced to solve it with details that permit its operation in conditions of pressure and suction. Also because of this lightness is performed chained mixed beam, made of steel and a considerable volume of concrete, in order both to provide rigidity to the upper part of the wall as having a weight that compensates for any suction that can be given, and ensuring a minimum compression in the upper courses of the wall, always the most affected by these horizontal forces. This beam acts both as beam filler and as wall plate.

Figure 5. Housing in Rúa Falcón upon completion.

The second structural effect caused by the recesses created in the facade at each floor level is the interruption of loading of the wall. This contingency was resolved by giving certain rigidity to the flanges of the beams and, to solve the problems of torque that may appear, by placing several stiffeners attached to transverse metal beams supplemented by tie rods welded to the flanges of the chains. In this respect the correlation between structural solution and the calculation model was an aspect of special attention. To ensure cross bracing three rigid steel frames were built. Interestingly, the larger beams used in the work are required for these frames, as a result of the horizontal forces acted on the building.

To close this section, is provided a reflection on the legislation on structures. The project of this building coincides in time with the enactment Technical Construction Code in Spain. Its content in the world of masonry structures (the DB-SE-F document) is a transposition with nuances of Eurocode EC-6. Unfortunately both standards are closely linked to a very specific method of calculating (replacement frames) and to very specific constructive solutions, making them very difficult to apply to cases like this. Therefore, the definition of the calculation model was complex, since it had to transpose the regulatory requirements not covered by the computer program to what we had to add its own limitations. Obviously, all these aspects were reflected in a document detailing the various solutions used in a consistent manner with the hypothesis of calculation prescribed.

3.3 *About the construction system*

Earlier it has been commented that, from the point of external appearance, the project gives the load-bearing walls formal treatment of supported elements. In this case it is clearly a building in which the structure is absent in its final appearance, even being denied because it is treated as a non load-bearing element, but whose construction is a real tour de force.

It came as a surprise to see that the constructive method proposed by the construction company, but due to factors completely unrelated, was consistent with this picture: instead of running load-bearing walls firstly and then the horizontal elements, the building was built by placing the metal pillars and horizontal elements firstly; resting on temporary uprights the beams of chain. Then the masonry walls were made and finally was placed the steel floor.

Figure 6. Housing in Rúa Falcón under construction.

4 CONCLUSIONS

Perhaps the most comforting idea is that a construction system that is present at the birth of architecture is still valid today and is able to address both in an isolated situation like a urban context. It is gratifying that a constructive system that evolved from the thick wall and lean against the wall was reduced to a compartment wall is again seen as value-resistant wall. It is gratifying that a constructive system which has evolved from wide wall to slender wall to be finally reduced a mere partitioning element, becomes to be taken into account for its resistance value nowadays.

True, this fact is by no means exclusive of the examples presented, it is also fair to note that, unlike most cases in which masonry elements are reintroduced is not for aesthetic reasons: in both cases the factory is not seen, considering their contribution to the building construction in other terms, either as a means of ensuring the rationality and modulation either in response to a problem specific constructive

Finally note that, even on small scales as before us, the desire to go beyond seems innate to the art or science? of building.