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CERAMICS IN ARCHITECTURE

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Ceramics in Architecture
P. Vincenzini (Editor)

ARCHITECTURE AND RESEARCH WITH REINFORCED MASONRY

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By using a combination of prefabricated bed joint reinforcement with traditional masonry, a new type of composite material can be created which can provide the opportunity for Architects to achieve new levels of technical and design excellence.
This composite is obtained by placing a truss type bed joint reinforcement (Murfor wire) embeded in the horizontal masonry bed joints. The tensile strength of the masonry can be improved by the reinforcement either throughout the structure or just in localised areas dependant upon the size, quantity and positioning of this reinforcement.
Professor Adell is the first Architect in Spain to fully exploit the opportunities which this composite material can bring. The AutoSupporting Cavity Wall overcomes many of the problems normally associated with the connections between the two leaves of a cavity wall.
Professor Adell's work in Madrid is seen as breaking new ground in the use of reinforced masonry. Two Local Authority housing schemes provide two very different examples of the spectacular results this concept can bring using fair faced brickwork.

1. INTRODUCTION: REINFORCED MASONRY - A COMPOSITE MATERIAL.

Modern masonry products come in many different shapes, sizes and materials. Common forms include clay bricks, concrete and calcium silicate bricks and blocks, and aerated concrete blocks.

All of these materials have adequate compressive strength but suffer from a common problem in their lack of tensile strength. This shortcoming is usually seen when cracking appears in the masonry.

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To help overcome this problem, Murfor prefabricated wire reinforcement, with its unique shape and material properties, can be embedded into the masonry bed joints. The use of this reinforcement will control the tensile stresses within the masonry and so substantially reduce the risk of cracking.

This traditional view of the use of bed joint reinforcement can be extended further by considering the use of different widths and spacing of Murfor within masonry to create a new composited material for designer.

When using this material, structures can be subjected to both lateral and vertical loads at the same time if need be - whilst the spacing between movement joints can be extended.

By using these properties, the Architect can achieve new levels of design and technical excellence. (See figures 1) (A + B + C)

(A) Increased Spacing Between Movement Joints

If a wall of width 'a' and height of 'h' is reinforced with uniformly distributed Murfor throughout its height, the distance 'l' between the movement joints can be considerably increased without any cracking problems due to expansion and contraction in the masonry being encountered.

The minimum area of reinforcement used should not be less than 0.05% spread throughout the masonry.

The wall thickness will determine whether two or three layers of Murfor should be used per metre height.

(B) Reinforced Masonry Subject to a Vertical Deflection

When an area of wall is unsupported as in the case of a lintel or supported by a slab or beam which can deflect, cracking will occur unless it is reinforced.

A wall of width 'a' and height 'h' which is supported by two points at distance 'l' and subjected to a vertical load will deflect.

To prevent deflection and increase the effective height of the wall 'he', that is the distance between the reinforcement area and the top of the wall, the masonry reinforcement must be concentrated at the bottom of the wall.

To increase the concentration of reinforcement within a single bed joint it is possible to lay a number of small width strips of Murfor in the bed joint side by side. An example of this may be with a 200mm block to place two 50mm widths of reinforcement in the bed joint as opposed to the conventional one width of 150mm.

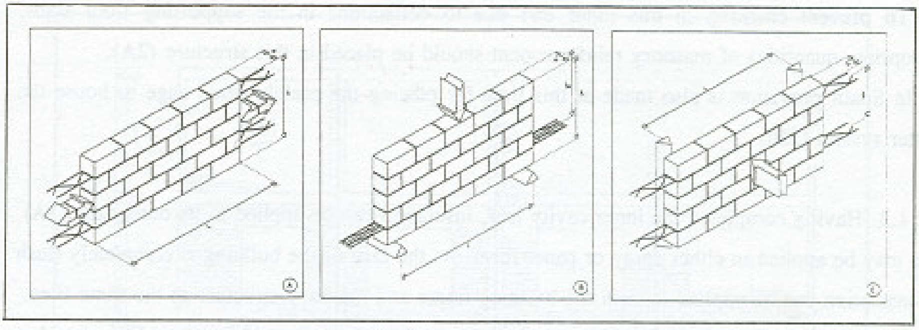
(C) Reinforced Masonry Subjected to lateral Deflection

Walls subject to lateral wind loads can be exposed to considerable stresses. Similar stresses are found in the retaining walls of cellars.

In the case of a wall of effective width 'd' subjected to a lateral load, it is possible to increase the distance between lateral restraints by the use of Murfor reinforcement uniformly distributed trhoughout the wall spaced at vertical distance 't'.

In all cases it must be remembered that the higher the compressive strength of the masonry material used, the more effective the use of masonry reinforcement will be.

By taking these properties of reinforced masonry as a composite material into account when designing structures, the Architect, through specifying prefabricated reinforcement in appropriate quantities and locations, is able to extend previous architectural boundaries.



2. AUTOSUPPORTING CAVITY WALL

The AutoSupporting Cavity Wall (ACW) is a means of construction designed to overcome many of the problems normally associated with the connection between two leaves of a cavity wall.

With the ACW system the two leaves of the cavity wall are constructed so that they are structurally independent and do not react with each other.

This structural independence between the two leaves is made possible by using the composite material features of reinforced masonry, that is: (A + B + C)

The ACW is built in four stages starting with the inner leaf construction.

The structural frame of the building may be constructed from either concrete or steel. The example we shall use to illustrate this method of construction was built in concrete in El Espinillo, Madrid.

2.1. The Construction Process of the Adell Cavity Wall (See figures 2 and 3)

2.1.1. At the first stage of construction particular attention must be paid to ensuring that the outer face of the building is completely flush (1A). Steel profiles to enable the later anchoring of the outer leaf wall to the frame should be fixed at this time (1B).

- Provision should also be made for supporting the base of the outer leaf of the wall (4A). Because of the vertical deflection properties of reinforced masonry previously described, this support need not be continuos.

2.1.2. The second stage of construction is to build the inner leaf of the cavity wall. Of major importance here is to ensure that the outer face of this wall is completely flush with the outer face of the building frame.

- To prevent cracking in this inner leaf due to deflections in the supporting floor slabs, appropriate quantities of masonry reinforcement should be placed in this structure (2A).

- In Spain provision is also made at this time for placing the prefabricated cage to house the shutter system (2B).

2.1.3. Having completed the inner cavity leaf, insulation can be applied to its outer face (3A). This may be applied in either spray or panel form. As the face of the building is completely flush the insulation can be applied to both the building frame and masonry structure at the same time.

- To prevent the spread of fire within the building a fire protection barrier should be placed at each floor level (3B).

2.1.4. The final stage of construction is to build the outer cavity wall.

- A sufficient gap should be left between the outer leaf and the insulation to ensure the free flow of air within the cavity. Weep holes may also be left within the outer wall structure.

- The ACW makes full use of the properties of masonry reinforcement by increasing the spacing between movement joints. It is possible for example with reinforcement placed at 40cm centres throughout the height of the wall, to increase the movement joint spacing in clay bricks to every 30m (4F). Movement joints should still however be placed at every change of direction irrespective of spacing.

- In the example shown the base of this free standing outer wall (4A) is resting on concrete plinths. The area at the base of the wall between these plinths can be considered as a lintel. The vertical deflection likely at this 'lintel' is dependent upon the mass of masonry found directly above this point. As such the amount of masonry reinforcement required in this area will vary from the resultant loading.

- A damp proof course should be located in the appropiate position below all of the weep holes.

- When constructing masonry lintels for the windows (4B) the masonry reinforcement must extend 500mm beyond each side of the opening. Lintel hangers should be fixed into every other perpend joint in the bottom layer of masonry. As the bottom face of the masonry is exposed directly above the opening care should be taken to select appropriately solid masonry material for this area.

- With the outer leaf of the wall being reinforced throughout its structure it is not necessary to tie it to the inner leaf as a means of withstanding lateral deflection. Instead the properties of the composite material will adequately prevent deflection between the lateral supports (4C).

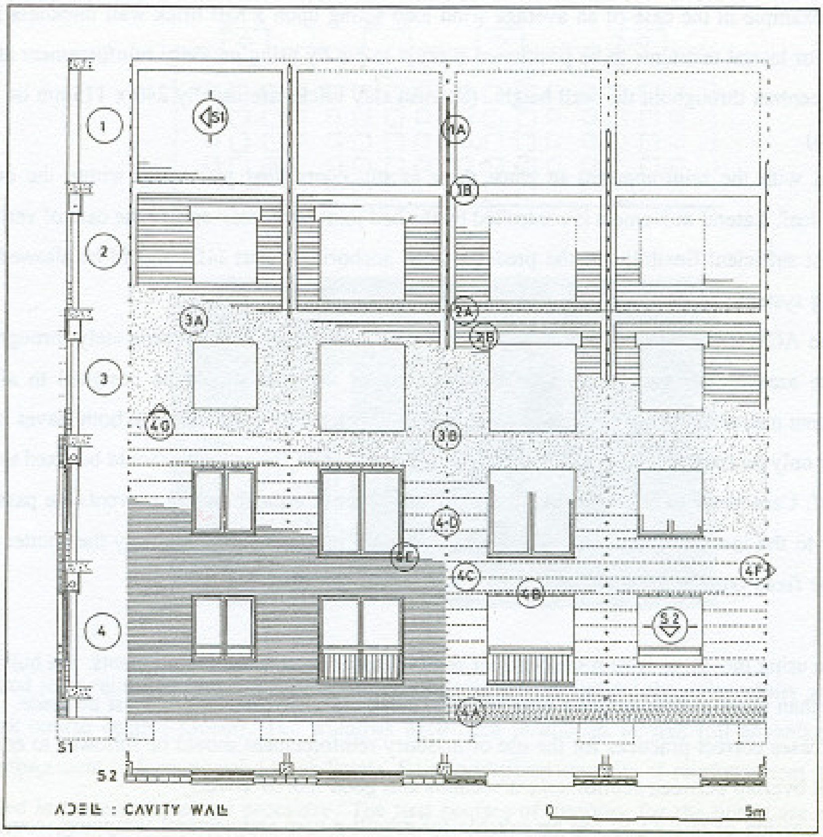


Figure 2: Construction process of the ACW, using an outer leaf of bed joint reinforced autosupporting masonry.

1. Structural Frame for the Building
   - 1A - Profile for the outer leaf anchoring system
   - 1B - All faces of the frame to be completely flush
2. Construction of the Inner Leaf of the Cavity Wall
   - 2A - Reinforcement in the inner leaf
   - 2B - Prefabricated cage for the shutter system
3. Fixing of Insulation
   - 3A - Continuously applied over building face
   - 3B - Fire prevention barrier at each floor
4. Construction of the Reinforced Masonry Outer Leaf
   - 4A - Base of the self standing wall
   - 4B - Masonry lintel reinforcement
   - 4C - Outer leaf reinforcement throughout its structure
   - 4D - Anchors for fixing the outer leaf to 1A profile
   - 4E - Connection for window frames, sill, shutter rail,
   - 4F - Increased spacing of movement joints
   - 4G - Cavity wall topping

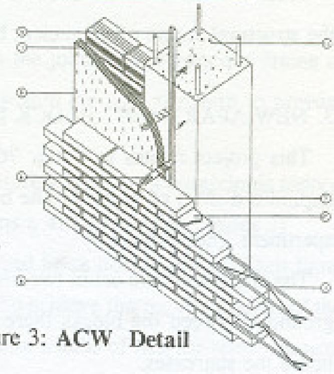


Figure 3: ACW Detail

1. Hollow clay brick in inner wall
2. Murfor reinforcem. RND5/E-80
5. Track outer leaf anchor. HMS 25/15-D
6. Halfeneisen lug ML 120/3 (6 cours. h.)
7. Palau fair-faced clay brick 240x115x50
8. Cavity wall outer leaf
9. Continuous applied insulation 40mm
21 Joint mortar 8 N/mm²

- For example in the case of an average wind load acting upon a half brick wall thickness it is possible for lateral restraints to be positioned every 4 to 6m by using masonry reinforcement at 40 to 50cm centres throughout the wall height. (Spanish clay bricks are usually 240 x 115mm or 290 x 140mm).

- Even with the reinforcement in place there is still controllled movement within the outer masonry leaf. Lateral movement is controlled by the bed joint reinforcement. In the case of vertical movement sufficient flexibility at the predetermined anchoring points (4D) should be allowed by the fixing system (1A).

For the ACW system to operate at its best, the two leaves must function separately throughout the entire area of the wall. Covers fixed to the top of the wall should be designed to allow independent movement of the two leaves (4G). Any other elements which relate to both leaves must similarly only be fixed to one of the leaves. The window frames for example should be fixed to the inner leaf. Care needs to be taken around the still area to ensure the throating prevents the passage of water to the inner cavity whilst maintaining structural independence. Similarly the shutter rail should be fixed only to the inner wall (4E).

Before using the ACW system the designer needs to asses his specific requirements. If a building of more than three or four storey's is to be constructed, specific calculations must be made.

In all cases correct practices for the use of masonry reinforcement should be followed to ensure sufficient overlap between reinforcement sections and good mortar cover.

Other version of this ACW can be suitable for rebuilt a new architectural wrapping, covering the structural frame of an ancient building.

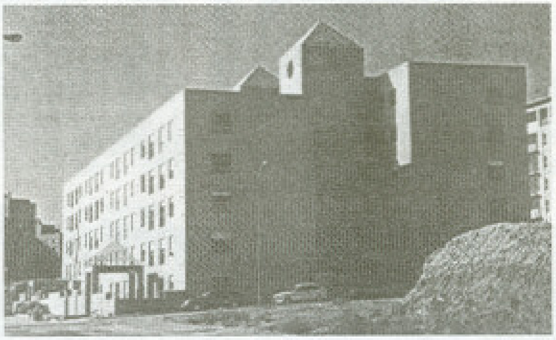
3. NEW APARTMENT BLOCK IN EL ESPINILLO WITH TWO TETRAPILONIS

This project relates to a new 76 dwelling apartment block built on a greenfield site in the El Espinillo district of Madrid. The building is five storey's high and has only four basic designs of apartment. (See figures 4)

The apartments are set in two blocks, one behind and slightly above the other due to the sloping ground. Between the blocks there are areas of open courtyard and four brick built towers wich house the staircases.

The frontage of the building is dominated by the square windows which are used throughout. The large 2m diameter windows are for the dining rooms, the smaller 1.5m windows for the bedrooms.

The building is based on a concrete structural frame which is finished using a brick cavity wall. Fair faced bricks are used on the outside, hollow bricks on the inside. The design of the building is based on the composite material properties of reinforced masonry.



Figures 4:

Bed joint reinforcement has been uniformly distributed throughout the outer cavity wall at six brick course centres (36cm). The windows have been positioned to take full advantage of this reinforcement in forming solid brick lintels. Small additional amounts of reinforcement have been added in these areas where necessary. The first courses of masonry for the lintels are supported using lintel hangers in the perpend joints.

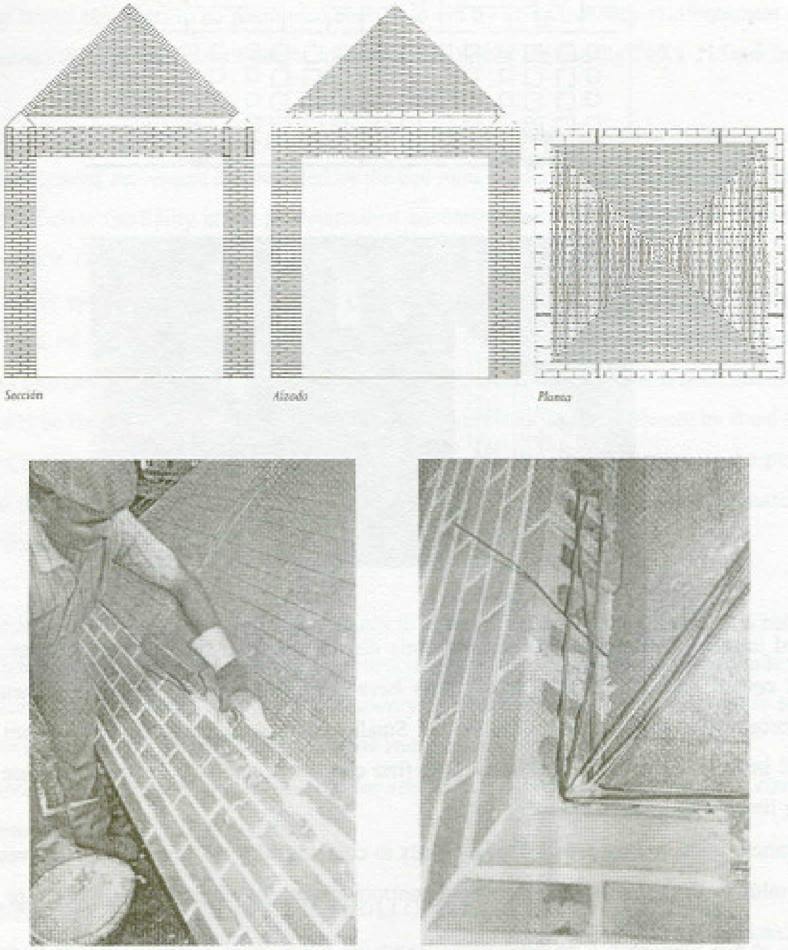
Movement joints are spaced at 33m intervals to coincide with the joints in the concrete frame of the building. The masonry reinforcement controls movement within the wall structure to prevent any cracking.

The two main entrances to the blocks in El Espinillo each feature a brick built tetrapilonis topped with a four sided reinforced brick cover. The tetrapilonis forms a 4m cube. (See figures 5)

The cover for the tetrapilonis is supported upon four reinforced brick double lintels. Each lintel has a 3m span and has a section 500mm high x 115mm wide. To achieve the required depth of the lintel, that is the same width as the tetrapilonis pillars, two 30mm widths of Murfor reinforcement were used in the bottom bed joint followed by a further 50mm width in the second.

Each double lintel needed to withstand a load of 5 KN/m which would be exerted by the roof cover. In tests the lintel sections were seen to withstand loads of 35 KN/m without any sign of cracking.

Figure 5:

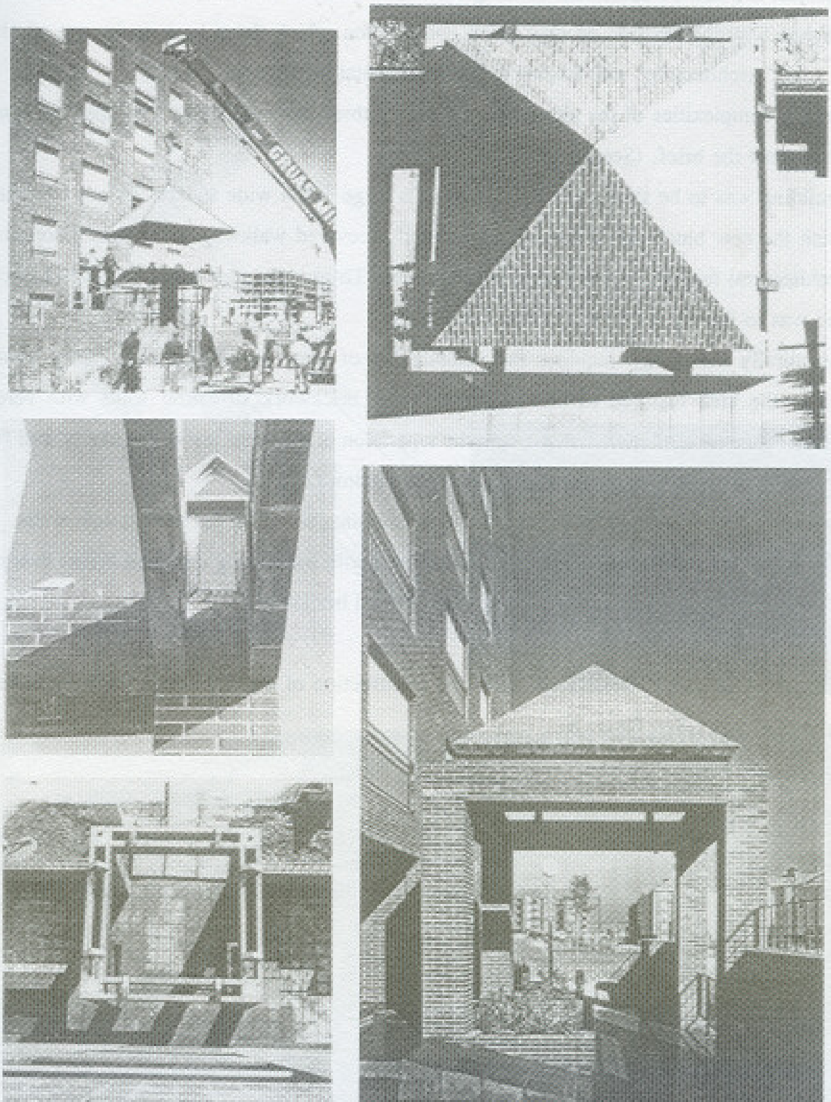


The cover for the tetrapilonis involved the novel use of reinforced masonry. It is a half brick thick with fair faced sides being visible from top and bottom.

Both covers were prefabricated in an off-site factory. Each cover was constructed in a different way to present a different personality for each door whilst also allowing further experimentation to take place into the potential for reinforced masonry.

On one cover the bricks have been laid horizontally, on the other, vertically. For the horizontal brick cover the bed joint reinforcement was laid in the normal way. For the vertical bricks the reinforcement was placed horizontally through the holes in the Palau bricks. In both cases reinforcement is provided at the edges of the cover.

Figure 6:



After fabrication the covers were transported to site where they were set to rest on top of triangular metal supports which lay on top of the masonry lintels. This method of support gives the illusion of the cover resting on air. (See figures 6)

4. NEW APARTMENT BLOCK IN PLAZA DE LA REMONTA

This project is a new 57 apartment building situated in the residential district of Tetuan, Madrid. The area has a strong traction of clay brick construction which dates back to its use of '19th Century Brick Architecture' well known for its ornamental brickwork.

Due to the complexities of the site a total of twenty three different designs of apartment were required to meet the brief. (See figure 7)

The building was to be situated in the corner of a large 100m wide square. Existing buildings onto which the new block was to be joined featured a covered walkway which was amongst the many architectural features which had to be continued. To give the new block its own character, its corner was to feature a cylindrical tower at the top.

Architecturally the design required the combination of two opposite criteria. Many existing buildings in the area featured traditional header bond brickwork structural walls with vertical windows. Modern construction methods with the separation of the outer leaf of the cavity wall from the structural frame called for the use of horizontal windows.

The outside of the building was designed with a combination of curved and straight walls. The curved walls are constructed in header bond brickwork with contrasting coloured bricks every six courses. The straight walls are built using stretcher bond brickwork.

4.1. Reinforced masonry has been used in the construction of the two wings flank the tower at the buildings corner. (See figure 8)

The masonry reinforcement was used to:

4.1.1. Support the vertical load of the masonry resulting from the construction of the lintel.

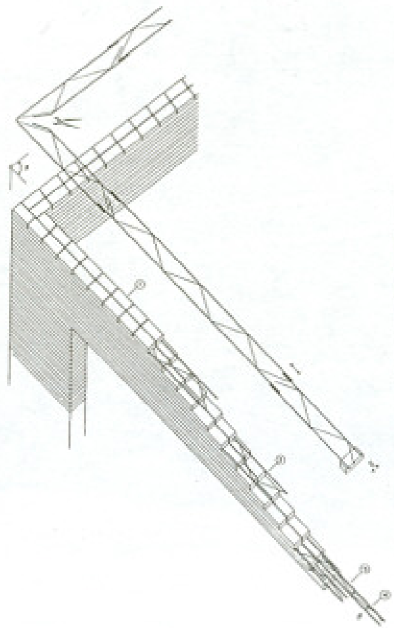
4.1.2. Overcome cracking problems in the masonry lintel which could be caused through expansion and contraction.

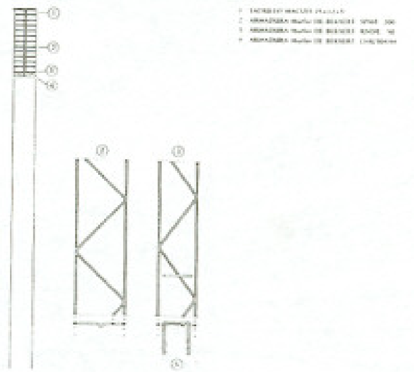
4.1.3. Tie together acute angle corners.

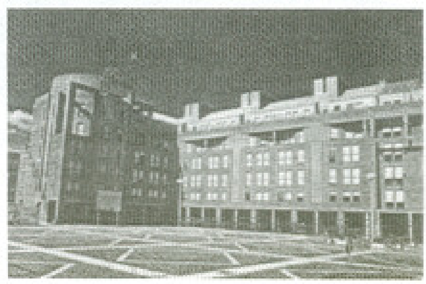
4.1.4. Tie together the two brick leaves of the wall so presenting a fair faced exterior on each side.

4.1.5. Resist lateral wind loads.

Figures 7 and 8







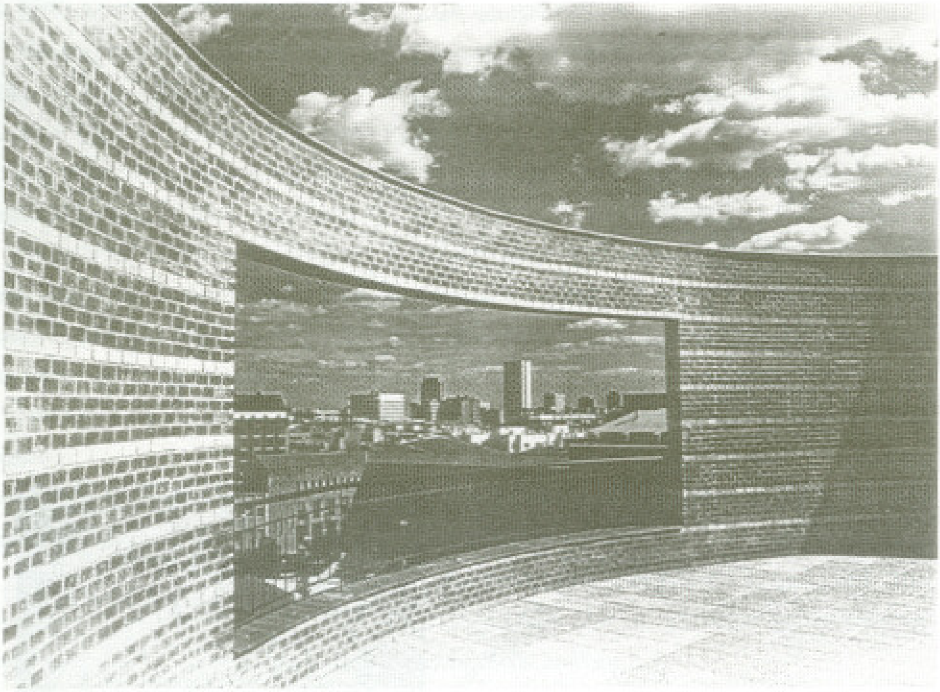


Figure 9:

All of this has been achieved by the use of different combinations of prefabricated reinforcement in masonry which provides a new composite material for creative architecture.

In the final analysis, masonry reinforcement can greatly assist the Architect but as with all things it is his imagination and creative use of space which will be remembered as with this window which frames the sky of Madrid. (See figure 9)

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XIX^th CENTURY BRICKS ARCHITECTURE: RATIONALITY AND MODERNITY

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The analysis of clay brick architectural works in Europe between the middle of the XIX^th century and the beginning of the XX^th century shows that they already exploited the material's technical and formal possibilities, and they followed the constructive rationality tendence prevailing in the beginnings of the industrial era.
These works reveal enough connections among themselves, so as to be able to assemble them under the common name of "XIX^th Century Bricks Architecture", a name beyond nuances of style characteristic of each region or country.
This paper analyzes the most significant values of the Bricks Architecture which allow it to be understood as a step towards modernity.

1. INTRODUCTION

During the last decades of the XIX^th century, it was developed in Europe an interesting architecture whose common characteristic was the clay brick.

In Spain, historians named it with the generical label of "neo-mudéjar"[1] architecture, associating it with ancient architectures where it was possible to show the exposed brickworks. With this label, it seemed that the theoretical concepts related with style, form, and even date, were immediately solved.

But if we analyze this architecture with more rigour, taking into account also the technological, constructive and compositive aspects, we shall notice almost inmediately it encloses much wider concepts. The label appears to be too limited as to encompass all of them, because it refers only to a formal characteristic of some of the significative works, from the bullfighting Plaza of Rodriguez Ayuso & Alvarez Capra (1874), already demolished, till the bullfighting Plaza Monumental de las Ventas (1932) (See Fig. 1).

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1. "Mudéjar" is the architecture carried out by christians in the moorish regions of Middle Age Spain. "Neo-mudéjar" is the modern architecture that recreates the ancient "mudéjar" themes (e.g. facing brickwork, horse-shoe arches, etc.).

Figure 1
Monumental Bullfighting Plaza, Madrid

Figure 2
XIXth century Bricks Architecture: technique and form, by J.M. Adell

If we renounce to the partial view that divides architecture according to styles, we shall be able to see clearly the identity wich characterizes a way of building, that from now onwards we can simply call XIXth CENTURY BRICKS ARCHITECTURE.

2. THE BRICK: A MODULAR ELEMENT

Let us analyze the implications of the word "bricks" in order to be able to enter in depth in this Architecture, which is self-defined by the name of the material it is built with.

The brick has been used all along history, but in the XIXth century it begins to have an importance of its own, because it resumes in itself a whole industrialization process that is characteristic of these years.

The use of these ceramical parallelepiped units, during the XIXth century, has the connotation of a series of technical and formal breakthroughs, that will have even a symbolic progress value in their mode of use.

During this century, the great technological breakthroughs of the Brick Industry are accomplished. The ancient burning operation is substituted by circular or straight continuous industrial kilns. The roller mills, pug mills, etc., which use extruding or pressing technoligies, will improve productivity enormously. The result will be a prefabricated element with defined and controlled physical characteristics.

Even if not all bricks will have exactly the same measures, a modulation process begins. Due to it, the ancient proportions -more or less square- will be slowly abandoned. An standardization of forms and dimensions begins, till it will be established the proportion of "the length twice the width".

Moreover, new types of elements appear, as a direct result of the industrialized manufacturing systems: hollow bricks, perforated bricks, pressed bricks. Towards the end of the century, even the conglomerated prefabricated materials begin to rise as an alternative, as they don't need to undergo a burning process.

On the other hand, it is necessary to remember that during this period, the traditional measuring systems will be subject to an standardization process. The ancient mesuring units ("sogas" -cords-, "varas" -yards-, "pies" -feet- and "palmos" -palms-...) of each region, will be substituted by the Metric System, as a new, unique and universal measuring system.

The result of all this transformation was that "the brick" came to be considered as a "new material" with the characteristic of being a "modular unit", that began to be understood as the "basic element" of a whole "conceptual structure" that allowed to "rationalize the architecture composition" according to "constructive principles". The architecture of this period was built with this new understanding of the brick, using widely varying styles, everytime architects wanted to bet for a "modernity option" with the use of a "traditional material", "transformed by the industrial revolution".

3. RATIONALITY: FROM LINKING TO BONDING

In order to understand the evolution happening in the masonry constructive organization, going from "trabazón" (linking) to "aparejo" (bonding), let's study the following real case:

In the Madrid 1857 Building Ordnances, quoted by Fornés & Gurrea in their "Art of Building" (2), which were also applied in Valencia and Seville, it was established that the bricks to be used in any construction works should be a foot long, a quarter wide, and two inches thick. These measures depended on the "vara" (yard) submultipla -a third of a yard equaled a foot, a fourth of a yard equaled a "quarter"-, and they conditioned the proportions of the unit bed face, where the length was not twice the width. In Castille, the metric value of the yard was 864 mm.

This type of unit imposed by the Ordnances rendered impossible, due to the 3:4 proportion of its bed face, to alternate the disposition of the brick "length-wise" (stretchers) and "width-wise" (headers) in the brickworks. For a good execution of the wall it was enough to contemplate the "trabazón" (linking), both in the wall front surface and in its thickness, that is to say, to avoid the joints vertical continuity through a regular placement of the bricks.

It astonishes us that in the book "Art of Bricklaying" by Juan de Villanueva, published in Madrid in 1827 (based on the book "Art and Uses in Architecture" by Fray Lorenzo de San Nicolás, in 1667) it was not found the term "aparejo" (bond) but only the term "trabazón" (link). The diagrams of this book confirm the use of the brick whose proportions were established by the Ordnance, with the impossible alternance of stretchers and headers within the same brickwork.

During the restoration of ancient buildings, bricks one foot long and quarter wide have been found, as a confirmation of these facts.

The impossibility of alternating units "length-wise" and "width-wise" will cause that, when bricks will be standardised, and the new proportion will be "the length twice the width", the "aparejo" used in Madrid will be th "aparejo a tizón" (headers bond), going on with the same traditional way of linking (See Fig. 2).

Knowing the Architecture of the preceding period, it can be verified how in Madrid there was no tradition of leaving any facing brickworks.

The Architecture of preceding periods has used the brick as a cumulative material, that would conform the wall through a linking process. Then, where is the difference? Why, in the XIXth century, priority is given to the material, as a defining feature of an architecture? Simply because in this case brick is used with such rationality that gives a special conceptual structure to this architecture, both from a technical and a formal viewpoint.

During all the XIXth century, just because the brick acquires fixed proportions, the constructive process of linking leaves way everywhere to the bonding process.

Bonding is a combinatory technique, that substitutes the addtion process by a series of logical laws which give to the walls built according to them formal characteristics of its own, so as specifical load bearing characteristics.

It is towards the end of the XIXth century when it is gained consciousness that the generical name of bonding in brickwork, meaning "adequate disposition of the brickwork units", also acquires in each particular case a "specifical value", determined by each one of the different possible ways of regularly placing the units in the brickwork, also assuring the linking.

Due to this fact, books appear all over Europe, establishing some of these combinatory laws; in the beginning, these laws are defined simply with numbers, as in the case of the frech book "La brique ordinaire au point de vue decoratif" (3) where the bond patterns named 1, 2, ..., 6 are depicted.

The fact of verifying that in specifical places -countries or regions- it is common to build brickworks assembling the bricks always in the same way, leads to associating the name of the "bond pattern" with the "name of the place". Thus we know the english, french, flemish, belgian, dutch, american, ..., bonds.

In Madrid, as the research published in the book "XIX[th] CENTURY BRICKS ARCHITECTURE: TECHNIQUE AND FORM" (4) proves, every building constructed during this period had the brick placed "a tizón" (headers) in the brickworks (due to the reasons already discussed). Such a circunstance, together with nationalistic reasons, led to establish a synonim between "aparejo a tizón" (headers bond) and "aparejo a la española" (spanish bond).

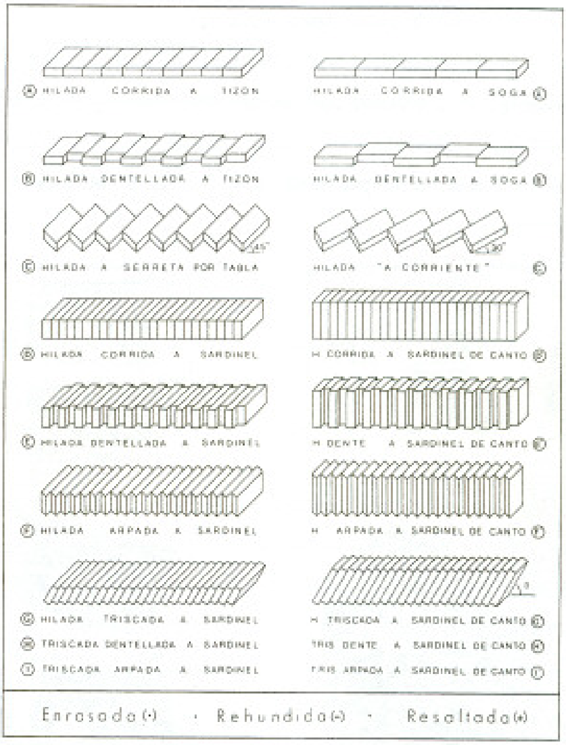

Figure 3 - Types of brick courses

The Madrid Bricks Architecture, that exposes outwardly the brick "headers" and thus the maximum number of joints, shows a surface with a maximum subdivision according with the unit modulation.

The headers bond allows more ornamental possibilities than the bond pattern obtained combining stretchers and headers. This technical fact makes the Bricks Architecture "a la española" outstanding form the viewpoint of its formal richness, comparing it with the other Bricks Architectures of this period, which used other bond patterns.

If we analyze the combinatory process rendered possible by the prismatic unit, from a geometric and constructive viewpoint, we can see that it becomes almost infinite, following simple rules of brick assembling (see Fig. 3). Besides the usual ways of placing the brick in the masonry, horizontally and vertically, combining its width and its length, which give place to the denominations of "a tizón" (headers bond), "a soga" (stretchers bond), "a sardinel" (rowlock bond), or "sardinel de canto" (soldiers bond), it also exits the possibility of placing it in a slant way called "triscada".

In all those cases, besides, the brick courses can be "corridas" (continuous run course), "dentellada" (tooth course) or "arpada" (seesaw course).

The plastic feature of the brickworks wall surface can be also enriched using the possibilities of "sinking in", "flattening" or "projecting out" the courses, relatively to the wall surface, thus adding attractive nuances of light and shade.

The cromatic feature can be emphasyzed using bricks of different "colours" in the afore mentioned dispositions.

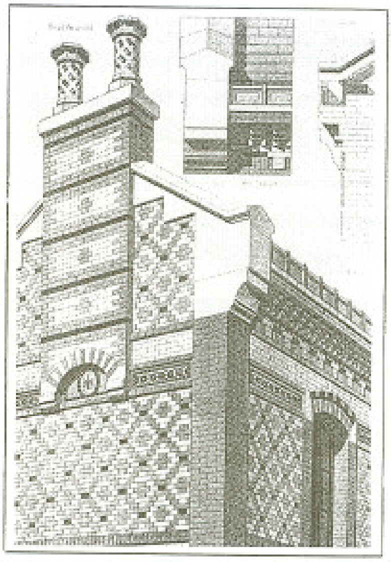

Figure 4
La Brique et la Terre Cuite, 1880 and 1889, Paris
P. Chabat. Gardener House

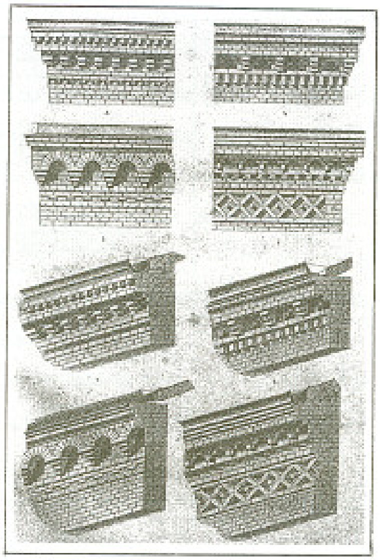

Figure 5
Bricks Architecture, 1875, Barcelona
Fleischinger/Becker. Cornices.

4. EUROPEAN BRICKS ARCHITECTURE: A WAY TOWARDS MODERNITY

The formal result of this combinations of an abstract kind leads will serve for constructing in Europe the so-named XIXth century Bricks Architecture. It will include buildings so different between themselves as the Madrid Bullfighting Plaza, the Berlin School of Architecture by Schinkel, or the model of a gardener's house published by Chabat in "La brique et la terre cuite" - Paris 1880-89-, in order to enable any builder to construct it. (See Figure 4).

There were important ideological differences between these buildings: some of them chose gothic as a figurative model, other ones romanic or moorish, that is to say neo-middle age models.

But all of them are the result of intellectual currents that were born during th XIXth century as an answer to the questions about modernity asked during the XVIIIth century and, which is more important, they are a direct way for understanding the Architecture that will be made during the XXth century.

Really, this XIXth century Bricks Architecture can be considered as a popular response to the classicist cult architecture. In it, the master craftsmen and bricklayers express their freedom, respecting the simple laws of the bond, and they conceive "their architecture", enriching it with moral and local values.

Someone speaks about their constructive sincerity: "Leave your walls flat and bare, do not plaster them with lies"... -John Ruskin writes- (6).

It is associated in a literary way even with socialist theories (William Morris), and it reflects the authoctone traditions of every place of Europe, in a moment when nationalisms are becoming so strong.

An architecture made with facing brickworks will be found, with the same rationality in the building process, in such different places as London or Milano, Berlin or Madrid. Even if we think about the american Architecture, we shall see how this influence also got across the Atlantic, and became an architecture of popular character, as it is reflected by some buildings of Memphis, of Chicago, or by the Bullfighting Plaza of Bogotá.

The graphic publications carried out in this epoch were a very important vehicle for the difussion of this way of understanding architecture. Among the most significative works we have the book by Fleischinger, published in Berlín in 1864, and again, later in 1875, in Barcelona, with the title "Brick Architecture" (see Figure 5).

This kind of books were mainly a collection of plates where it was expressed the grammar of the brick language, ordered according to its elements. They described in a simple way the constructive technique of each one of them, and as an ending to these combinations, they offered models that the builder could directly reinterpretate.

The plates of these works, most of them printed in colour, enriched the imagination of the craftsman-bricklayer, because he found in them the rules that would allow him to ideate his own creation.

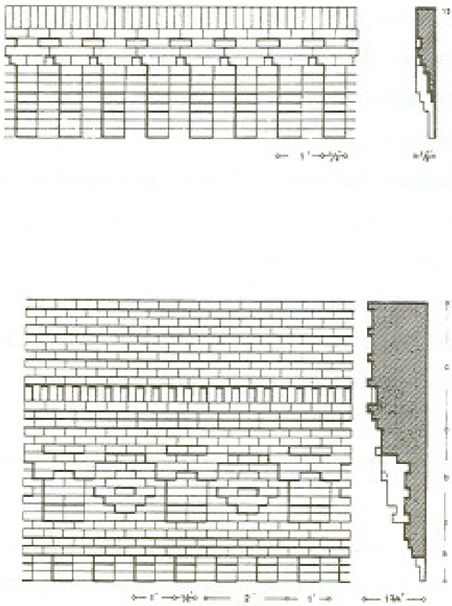

Figure 6
a) Brackets cornice
b) Three-part overhanging cornice with 33 courses

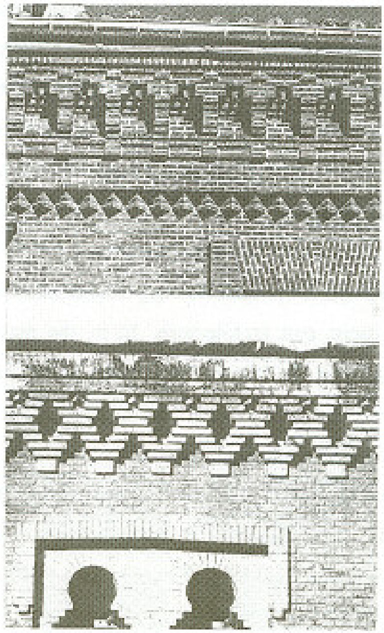

Figure 7
Cornice with tooth courses

5. THE LOAD-BEARING WALL AND THE BRICK ARCH

Respecting this rational play of unit articulation, together with the bricklayer's freedom for expressing his own feelings against the classicism's academical rigidity, we must take into account other conditionants that cause an architecture with such different styles to have, however, some common characteristics, both from a technical and from a formal viewpoint.

One of them refers to the load-bearing characteristics of the brickwork masonry; the other one, to the way of making openings in this material.

Bricks Architecture is normally conceived with load-bearing wall structures, for any kind of buildings, from a church or a museum, till the most humble house.

XIXth century Bricks Architecture proposes a masonry homogeneization, with a progressive decrease of its thickness, thanks to the regularisation of its units and joints. This allows to obtain the maximum wall compressive strength.

During the last decades of the XIXth century, cast-iron structures are combined with load-bearing

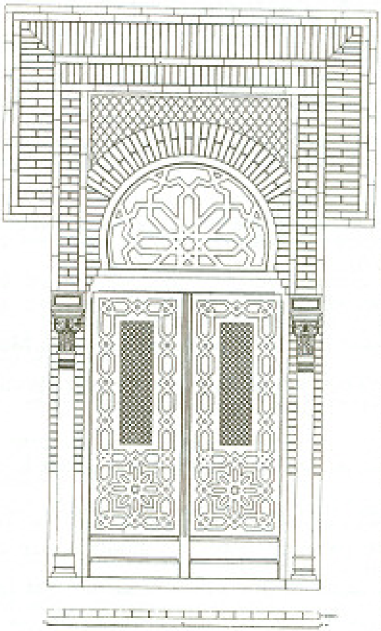

Figure 8
Moorish arch with alfiz

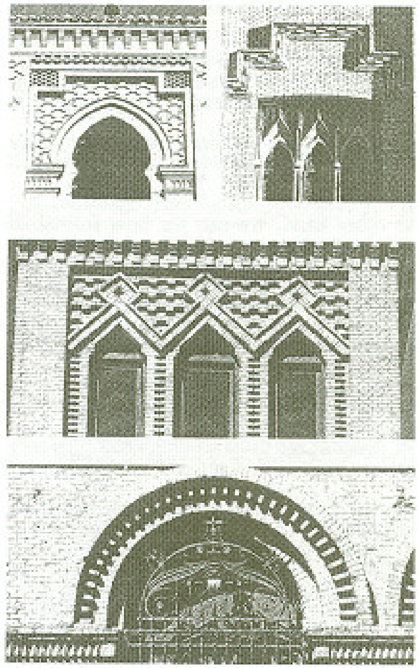

Figure 9
a) Moorish arch b) Ring-leaves arch
c) Straight 45° arches
d) Bonded arch with projecting and sunken arch rings

masonry. Both of them will become progressively independent, specially in industrial buildings. The structural character of the XIX[th] century load bearing wall will influentiate the building general design. It will have a difect influence on the façades composition.

The wall thickness, the solid/void rhythm, the formal signaling of the floor-dividing lines as lines where the slabs are supported, and of the cornices as a protection of the façade from the overhanging roof, will become important ornamental themes, thus confirming again the rationality and freedom of this architecture. (See Figures 6 and 7).

The cornices construction tests the ceramic bending strength, as the brickworks units overhang more and more, without using any steel elements. This fact limits the masonry total outward projection to barely two feet, with a maximum height of 35 courses of growing projection.

It is significative that it is described in detail how to make openings in the brickworks, as one of the most characteristic themes of this architecture.

In Bricks Architecture, the building process is used for profiting from the material expressivity, developing a technical-formal discourse based on the brickworks execution technique.

The bricklayer experiments with this creative freedom, combinating one after another "modillones" (bracket courses), "dentellados" (tooth courses) and "arpados" (seesaw courses) of different extension and rhythm, giving singularity, originality and personality to each construction work.

On the other hand, we can see how formal reasons, rather than technical ones, become more important for defining the arches form (See Figure 8).

The structural solution used for closing the wall above an opening is usually the same: an arch, which forces the brickworks above the opening to work only under compression stress. Moreover, it allows the builder, when establishing its form, to put into it any of the different historical or regional stylistic particularities.

The arch is built with a refined bricklaying technique, and its construction becomes in itself an ornamentation process, where each element "roscas" (rings), "dovelas" (voussoirs), "salmeres" (starting voussoirs), "claves" (key bricks), ... are the most important motifs of the building construction and composition. According to the technical and formal trade-off that has been accepted we shall find different arch forms: "straight", "circular", "curved" and "mixed" (curved plus straight lines). Within these forms, we can also find different constructive organizations: "de roscas" (ring arches), "aparejados" (bonded arches), and "de hojas" (ring-leaved arches). All this together with ornamental brick mouldings.

The expressive richness of the technical-formal discourse of the arch acquires greater extent because it is possible to use the brick grammar in several planes, that go form the arch's "guardapolvos volados" (projecting arch rings), till the "arquivoltas" (sunken arch rings) which give to the opening a horn-like depth, going through the own arch'a "front" on the wall surface.

In all arches, the starting unit deserves special attention, together with the "buttresses" and the "key closing", either with "single-unit voussoirs" or formed by several bricks, "fishbone-like", "indented", "purse-like", etc. (See Figure 9).

The voussoirs are made with great care, observing the arch geometric characteristics, controlling either the distribution of the varying width of the joints, or the different shape of the voussoirs.

It is common to create a frame around the arch, called "alfiz", enriching it with some ornamental brickwork.

Due to the evolution experimented by these two themes (the load-bearing wall, and the arch), the later architecture will abandone these constructive techniques, and this formal repertoire. New techniques and materials will be used, leaving aisde the evolution possibilities of the brickwork masonry.

This first one, because it becomes a closing wall, made usually of two leaves, lighter and lighter, the resistant frame being separated from the masonry.

The second one, due to the appearance of lintels, which substitute the arch, thanks to their bending strength capability.

Already in the XX[th] century, steel becomes decidedly part of architecture; laminated steel and reinforced concrete frames revolution the way of building. The tensile strength of these new building materials make it possible to change the rational vertical composition of the façade imposed by the solid/void rhythm, arches and buttresses, substituting it by an horizontal composition for the treatment of the masonry openings, whose construction had been freed from structural strength.

Only now, almost entering the XXI[st] century, there is again an appreciation of the masonry values, combinating steel with masonry materials wisely, enriching its qualities through the use of "reinforced masonry".

However, these changes don't make us to forget our admiration, with some homesickness, of the work carried out by so many Architects and Master Craftsmen who devoted their history and time to a work often anonymous and little valued, searching the maximum expressivity with brickworks, following the schemes of a modular element. This paper renders due hommage to them.

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