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THE INTEGRAL MASONRY SYSTEM

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Abstract

Preconceived ideas regarding materials and building techniques have frequently prevented the development of new techniques. In terms of brickwork, and as opposed to the developments seen with hollow concrete blocks, the tendency has been to maintain the tradition of a material which does not require reinforcement and which only works under compression in accordance with its thickness. However, the introduction of reinforcement in masonry provides an enormous qualitative leap forwards. In this contribution, J.Mª Adell, a practising architect and lecturer in construction at the Madrid Polytechnic University, describes the advantages of this technique and the results of his investigations in this area which have given rise to an innovative system of integral masonry, used with brick or block of clay or concrete.

Key Words

Brick, Block, Enclosure, Integral Masonry System.

1 Introduction

Over the last 30 years the brick walls built in Spain have mainly been enclosure walls to framed structures which have usually been built in reinforced concrete.
However, the fact remains that due to a "loose" interpretation of the MV-201 Code "Resisting brick walls" of 1972, and its subsequent adaptation in code NBE FL-90, it has been taken over all these years that because these enclosure walls were not loaded, it was not necessary to calculate the same as there were no standards demanding the same. Over these 31 years hundreds of buildings have been built with brick enclosure walls and throughout this time subtle but fundamental changes in building have been made which reveal the true resisting characteristics of Spanish enclosure walls.
The 5 fundamental changes which have led to the current situation are as follows:

I. The outer leaf of the enclosure walls has passed from one brick (24cm) thickness to that of half brick thickness (11,5cm).
II. The framed structure of 4 to 5m span has been changed to one of 5 to 7m span.
III. The edge beams of the structure have been replaced by flat beams.

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IV. The outer leaf is no longer supported in all its width. Overhangs 4cm of its 11,5cm.
V. The recommendation to fixing the walls to the frame to obtain better stability.

The effect of these larger spans, particularly in more slender brickwork, as is the case of public buildings, has sometimes led to the spalling of brickwork and an occasions to the collapse of complete panels of brickwork onto the street [1].

Every now and again Spanish society hears with some alarm of incidents which were completely predictable and avoidable and which may will entail irreparable damage.

On investigating the symptomatic problems of Spanish enclosure walls which had appeared in recent years, it was decided that a new building technology should be designed for these walls in order to confront these problems of cracking and collapse.

This circumstance gave rise to the employment of reinforced masonry [2] as the first step in the solution to the problem [3]. This was subsequently supplemented by the Integral Masonry System which allowed the vertical reinforcement of brick enclosure walls when necessary, in view of the need lo leave horizontal movement joints below the slabs of framed structures.

When applying the Integral Masonry System to the components which were recently designed for the same it is possible to construct buildings of reinforced or unreinforced masonry, by using universal units, bricks or blocks of any material, which may be vertically reinforced by rib reinforcement as and when necessary [4].

As such, the Integral Masonry System may solve any situation where it is necessary to place specific reinforcement and always respecting both the vertical modulation of the bed joints and the horizontal modulation of the masonry question [5].

The three-dimensional reinforcement of the Integral Masonry System makes it possible to build prefabricated walls on site or at the workshop. The said prefabricated walls may be built in a horizontal, vertical or sloping direction which substantially simplifies bricklaying technique and reduces labor costs.

The Integral Masonry System may be applied to all types of buildings [6].

2 The Integral Masonry System (AllWall)

An “enclosure wall” should be a wall which establishes the border between the interior and exterior of a building or property. It should offer the image of the desired façade and the durability demanded of its environment. When marking the exterior of an inhabited space it should be able to provide the environmental conditioning of the said against external conditions.

The enclosure wall, like the wall structure, is capable of withstanding specific, allocated loads and stresses on its own or by means of separate, main or secondary, lateral supports of reinforced concrete or steel which are employed to transfer certain loads such as wind loads.

Under certain circumstances the enclosure wall may be considered as part of the wall structure of the building, and acting as a load bearing or stiffening wall of the said structure, though, at the same time, complying with the specific functions of the enclosure wall.

The Integral Masonry System consists of an assembly of *Walls, Lintels… (elements)*, made up by a specific number of *Brick or Block walls of 1 or more leaves (composites)* obtained from the combination of various *Units, Mortar, Bed-joint reinforcement. Thermal Insulation, Dampproof sheets, Anchors, Ribs, Fixings (components)* which are suitably *Interrelated* with the *Objective of constructing a suitable wall for the building* without/with structural function.

AIA Arquitectura XXI, is the consulting of the Integral Masonry System: IMS [7].

AllWall Systems is the company that develops the commercial aspects of the IMS [8].

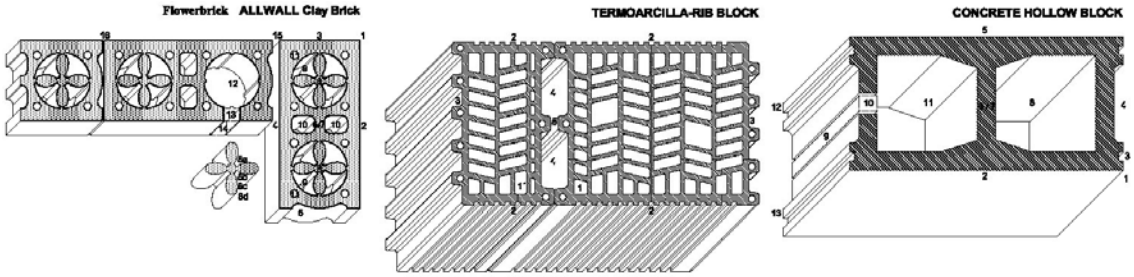
2.1 Masonry materials and components

2.1.1 Units

In essence the innovation of the Integral Masonry system lies in the design of masonry units, regardless of material, which contain small perforations which may be enlarged to create larger voids in the units which may house vertical reinforcement which is passed through a lateral access channel in the unit.

The reinforcing technique consists of passing the reinforcement through a lateral opening in the unit set on the unexposed face of the same (stretcher/header) without losing the inherent qualities of the masonry unit and, subsequently, without having large exposed voids. As such, the unit has to have a lateral channel which can be opened to allow access to the main void in the same and which will house the reinforcement.

In order to apply this system to all manner of materials be they clay, concrete, silica-calcareous, or cellular mortar or any other type imaginable, it is necessary to design the masonry units in such a way as to optimize the manufacture of the same but also, and more importantly, to broaden the field of application of the said units.



2.1.2 Mortar in joints with or without horizontal or vertical reinforcement

M-5 for concrete materials

No concrete it's used to fill the vertical holes: "Only mortar inside".

M-8 for clay materials

2.1.3 Bed joint reinforcement: The Reinforced Masonry

"Reinforced masonry" refers to the uniform steel reinforcement of brick or blockwork and substantially varies from the concept of strengthened masonry which purely entails localized reinforcement.

In the past, masonry walls were thick, uniform walls which served both structural and facing purposes. These walls had more than sufficient compressive strength and the broad width of the wall gave it stability without exhausting its strength capacity. Furthermore, it was also possible to consider the plastic behaviour of the wall when taking any cracking to be the result of readjustment in the light of tensile stress.

However, modern brick walls have reached their minimum possible thickness, equal to a brick's width, with evident disregard for its structural capacity and which gives rise to all manner of problems due to slenderness, the appearance of out-of-plane moments, etc. Furthermore, this departure from its original function has led to enclosure brickwork being set within steel or concrete frames. When the outer frame deforms, the comparatively stiffer masonry will subsequently crack and this is inadmissible in accordance with modern-day quality standards.

The solution then lies in the homogeneous reinforced masonry.

New technical qualities of Murfor:

(A) Imposed Strain: dilatation, contraction, expansion, shrinkage.

(B) Vertical Bending: lintels, partitions, facing walls.

(C) Horizontal Bending: wind action, earth/water load, earthqueake

New applications of Murfor:

(1) Crack control: As = 0,03% Wall section (every 40 or 60 cm. height)
(2) Increase in Technical Possibilities: Murfor hanging hooks LHK
(3) Savings and increased architectural possibilities: Murfor the constructive idea.

2.1.4 Anchors between masonry and frame: two sliding movements anchors (AllWall-ANC)

New technical qualities of AllWall anchors:

(A') Anchors with horizontal movements: dilation, contraction, expansion, shrinkage
(B') Anchors with vertical movements: dilatation, contration, shrink, seat, deflexion.
(C') Anchors transversal actions not allowed: wind, earth, water load, earthquake.

New applications of AllWal anchors:

(1') Anchors of supports and slabs in the same front: 2 sliding movements and reinforcement.
(2') Anchors for supports at different recesses: double sliding movement.
(3') Anchors for continuous/not continuous walls (1&2 movements): wall ties for cavity walls.

2.1.5 Vertical rib reinforcement with its own fixing system (AllWall-RIB+FIX):

New Technical and qualities of AllWall ribs and fixings:

(A'') Vertical cantilever wall: AW-Rib with 2, Fixings in base.
(B'') Vertical bending wall: AW-Rib with 1 Fix in base and 1 Fix in top.
(C'') Hanging Walls (build in situ or prefabricated): AW-Rib with load and retention fixings.

New applications of AllWall ribs and fixings:

(1'') Industrial buildings: external walls, enclosure walls, internal walls, partitions.
(2'') All masonry in buildings: enclosure walls, facing walls, load bearing walls.
(3'') The best masonry for solid walls or cavity walls: AllWall always the best option.

2.1.6 Wall types

Enclosures could be one homogenous leaf wall or two leaves of the same or different material, with/without central cavity or thermal insulation: solid walls/cavity walls.

2.2 The Integral Masonry System: ACW/DCW

The Integral Masonry System can be used in enclosure walls of different materials:
Components of the Integral Masonry System (AllWall) [9]:

Murfor Truss-type. Reinforced Masonry: Crack control.
AllWall Anchors. Wall stability with double freedom of movement.
AllWall Ribs and Fixings. Resistance to the wind and against overturning.

Clay units: Flowerbrick AllWall, TabiDuplex, Termoarcilla-Rib Block.
Concrete units: Ferrater-Torho Unit; Concrete Hollow Block; BLOC+ blocplus.
The new line of development, more in keeping with current techniques, responds to the following criteria: the presence of vertical and horizontal movement joints, the use of anchors to allow freedom of movement between the frame and the enclosure wall, and cracking control.
It is necessary to underline the importance of keeping the movements of the enclosure wall and the frame independent of each other. This then requires a radical change of the concept which currently prevails in Spain regarding the functioning of enclosure walls. In Europe, the construction of masonry walls of up to four storeys in height employs a load bearing inner leaf which is stable against wind action together with an outer leaf which gains it stability by passing the wind pressure through to the inner leaf by means of wall ties.
However, in Spain, external walls are set within a framed structure and are, subsequently, compressed and do not require wall ties. Due to the fact that horizontal joints are placed below the slabs to prevent this from loading on the wall and working independently, the external wall has to be either anchored to the structural supports

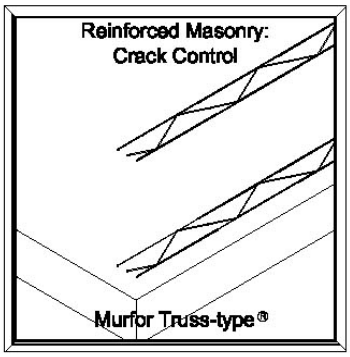
(when these are present in the façade and when they are suitably close together) or be strengthened by vertical ribs in order to ensure stability.
In order to allow differential movements between the structure and the masonry and to eliminate the need for a huge quantity of wall ties, two solutions have been developed based on the cavity wall making full use of the bed joint reinforcement possibilities.

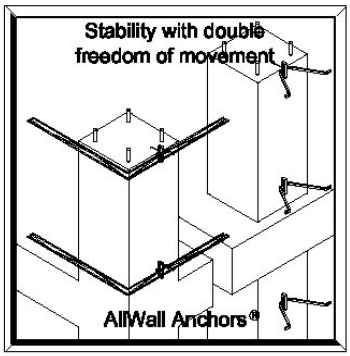
I M S

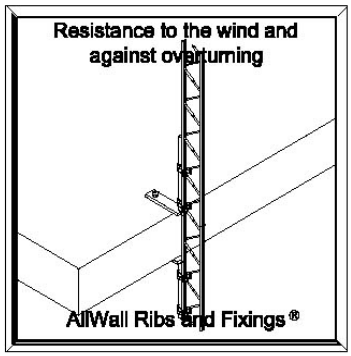
THE INTEGRAL MASONRY SYSTEM ®

ALLWALL: Allways the best option

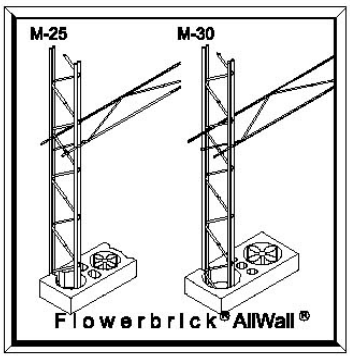
COMPONENTS OF THE INTEGRAL MASONRY SYSTEM

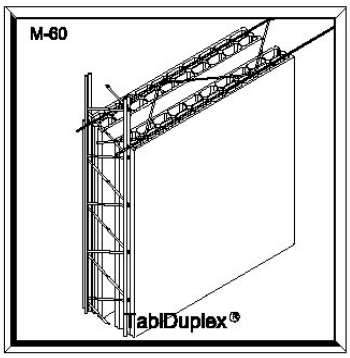


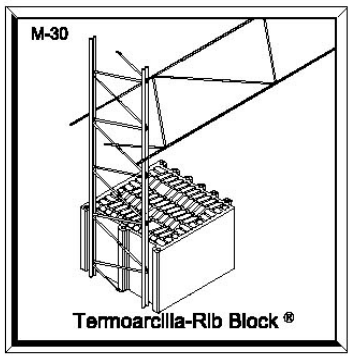




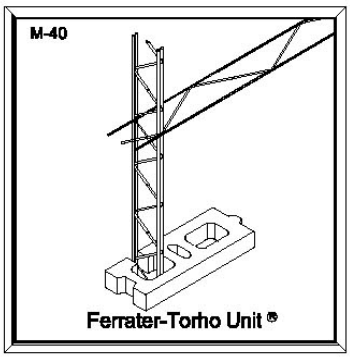
CLAY UNITS OF THE INTEGRAL MASONRY SYSTEM

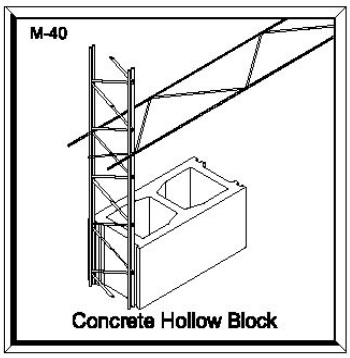


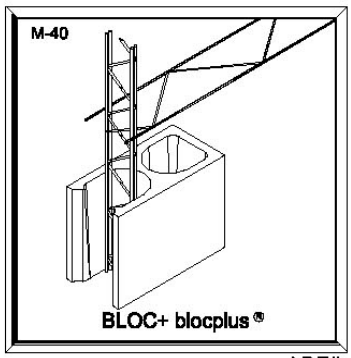




CONCRETE UNITS OF THE INTEGRAL MASONRY SYSTEM







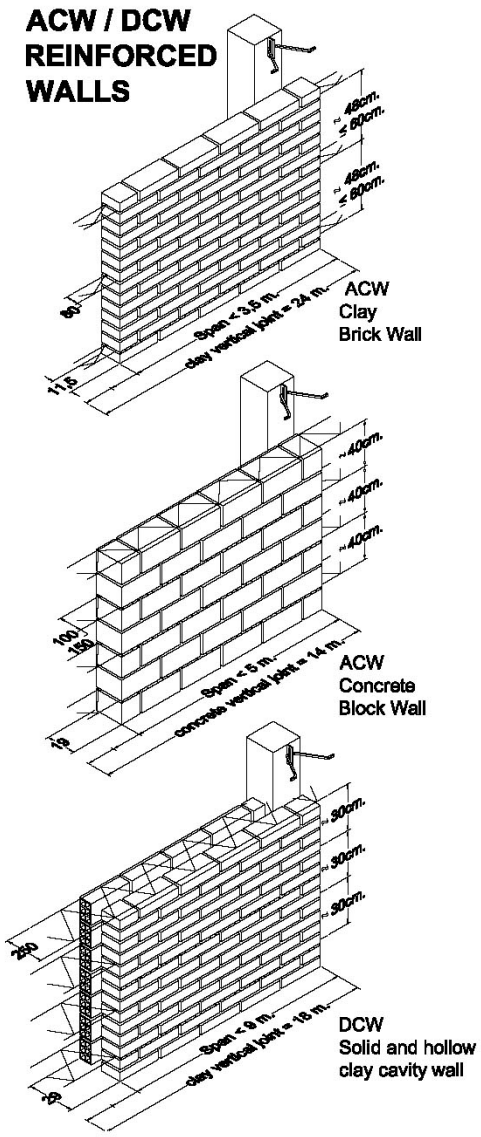
2.2.1 Autosupporting Cavity Wall

External half-brick thick, load-bearing enclosure wall with only vertical connection to supports or bracing walls, as a result of the reinforced wall's capacity to work under horizontal bending. This only compromises the outer leaf in terms of its ability to absorb wind action as it works independently of the inner leaf. The main drawbacks with this system lie in the fact that the structural supports have to be set within the façade and that the anchor points cannot be spaced in excess of 3,5m with brick or 5m with block.

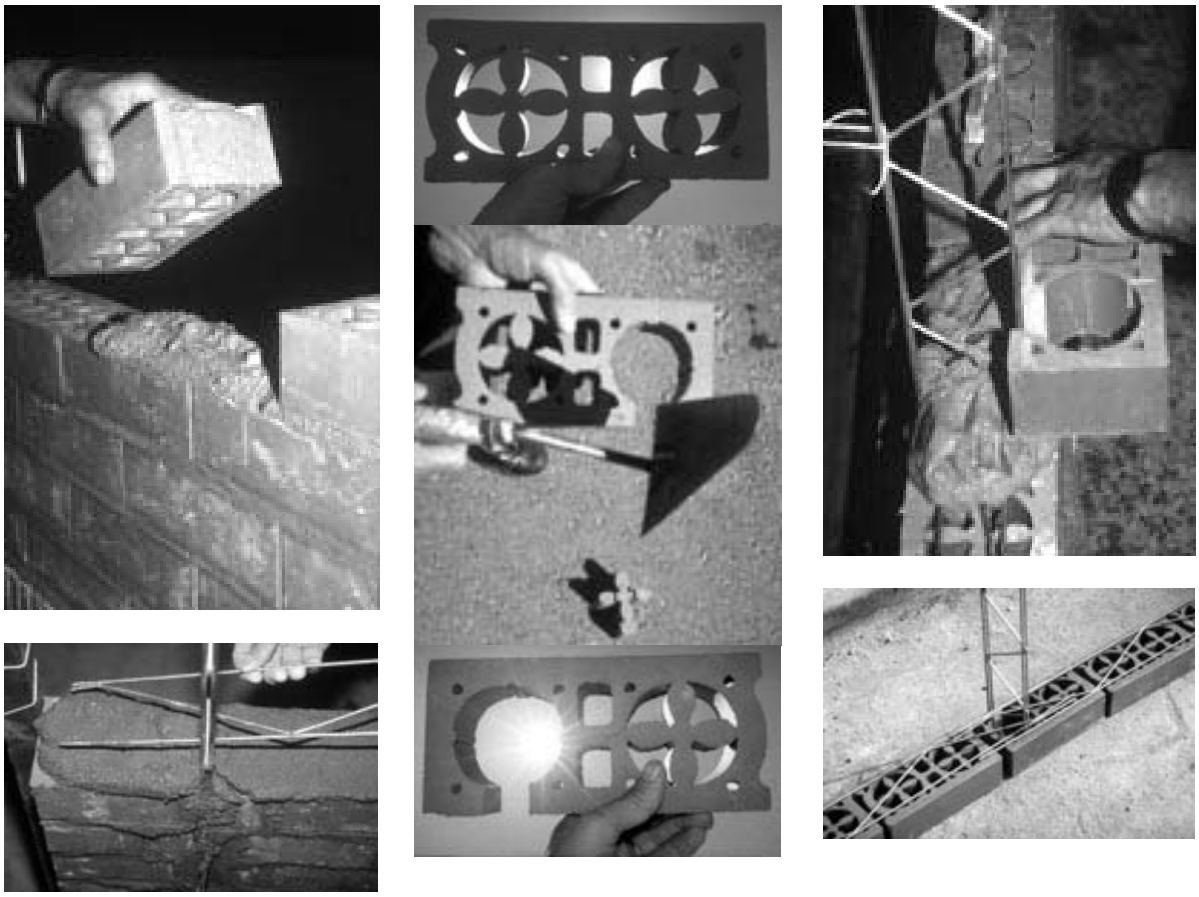
2.2.2 Duplex Cavity Wall

The two leaves of the enclosure wall work in conjunction to absorb wind action. The bed joint reinforcement controls cracking and works as a wall tie. In a cavity wall formed of two half-brick thick cavity leaves connected by bed-joint truss reinforcement in withes every 30 centimetres, the anchorage at the supports may be spaced up to 9m and it is possible to obtain vertical continuity up to three or four storeys. Both leaves may be totally continuous or just the outer leaf and in which case this would be totally self standing.

***ACW** Autosupporting Cavity Wall laying*



***DCW** Duplex Cavity Wall laying*



AllWall Flowerbrick: Opening , positioning with mortar and vertical rib reinforcin

2.3 The Contemporary Façade with Integral Masonry System

The horizontal arrangement of bed-joint reinforcement cannot overcome all possible structural circumstances. On some occasions it is necessary to reinforce the masonry vertically, even though this may be in just a localized position. The solution then has to consider the interrelation of the horizontal and vertical reinforcement in order to obtain structural plates.

We shall now outline a method of reinforcing masonry while maintaining its bond and exposed face and describe the step-by-step construction of the same.

Intense research over recent years has brought about three technical advances which have enabled significant progress to be made in the search for an integral masonry system: the universal masonry unit, rib reinforcement and anchors.

2.3.1 Supported enclosure walls: Alpha (a) and Beta (b)

- Self-bearing (Alpha enclosure). Autostanding

External leaf of self-bearing reinforced masonry (truss type reinforcement set every 40-60 cm in height) enclosing the structure and without connections to the inner leaf or horizontal joints at the slabs. The leaf is built with vertical continuity and is supported on the foundations or an edge beam. The system includes a ventilated cavity with continuous cavity thermal insulation.

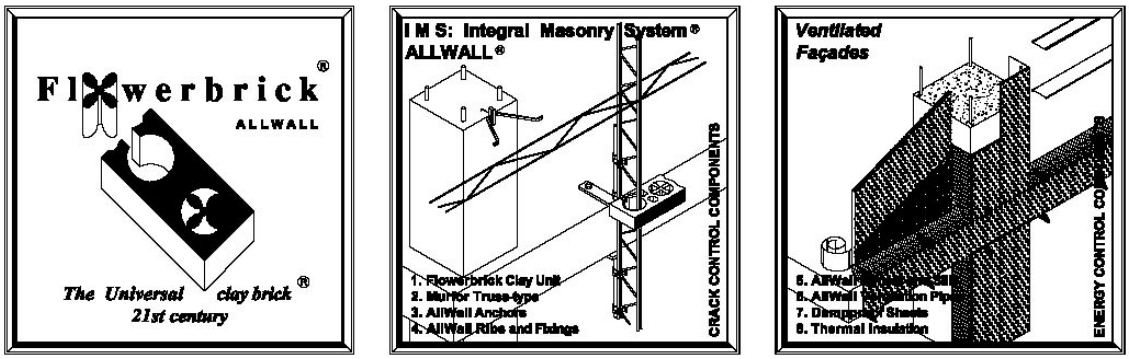
- Half-resting (Beta enclosure).

In housing buildings it´s very common the use of the half-resting (Beta) enclosure walls, due to the new type of construction in Spain with the Integral Masonry system.

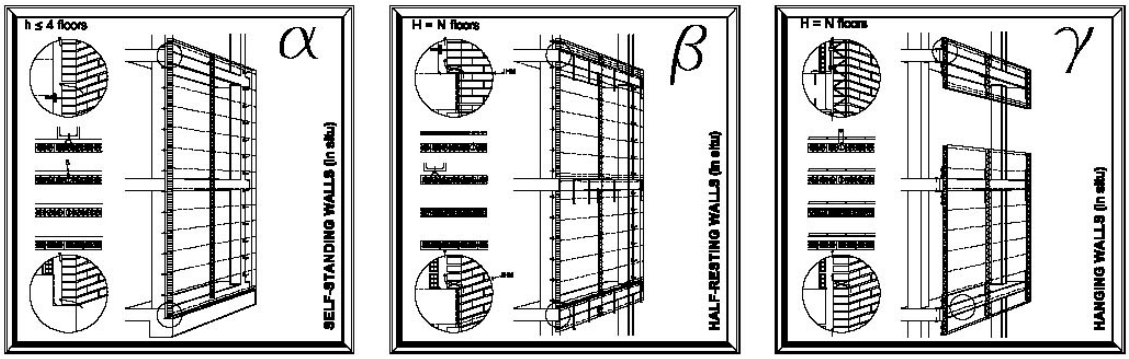
The Contemporary Façade

Architecture with Crack Control and Energy Control

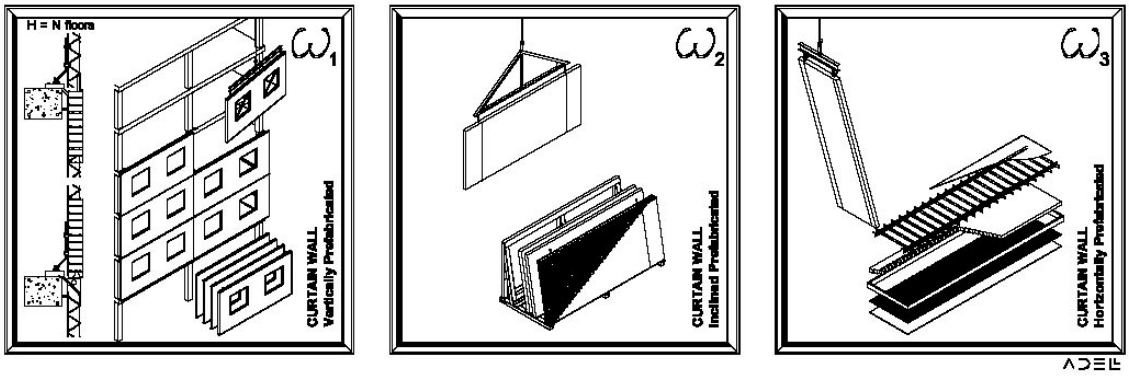
COMPONENTS OF THE CLAY BRICK CONTEMPORARY FAÇADE



TYPES OF ENCLOSURE WALLS BUILD IN SITU



TYPES OF ENCLOSURE WALLS´ PREFABRICATION



2.3.2 Hanging walls: Gamma (g) and Omega (w)

- Hanging wall built “in situ” (Gamma enclosure)

External leaf of hanging reinforced masonry (truss-type reinforcement every 40 cm in height). The horizontal joints are set at the level of each slab and the leaf is fixed at each storey by anchors set on the upper leading face of the floor slab. The system includes a ventilated cavity with continuous cavity thermal insulation. This solution, built “in situ”, is suitable for tall buildings. Vertical ribs are spaced every 2.75 metres when there are no columns on the façade.

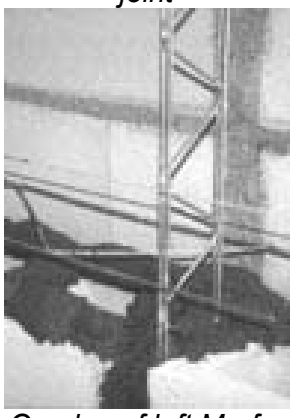
- Prefabricated systems (Omega enclosure)

External, ventilated enclosure wall without connection to inner leaf and with totally continuous cavity insulation. The wall may be prefabricated on site or in industrial.
Wall panels may be prefabricated in a vertical position - occupying less space but requiring skilled bricklayers and the use of plumb lines, spirit levels and string lines-, in a horizontal position – far quicker and without the need for skilled labour. At least two vertical ribs and their fixings with X,Y,Z tolerances must be placed towards the ends of each panel in order to allow raising and anchoring the same to the frame.
The use of reinforcement in clay masonry and the recent advances seen in the area, particularly with regards to three-dimensional reinforcement, all open up a wide range of possibilities. In addition to the more patent advantages such as increased safety against cracking, higher strength properties and the improvements made to many building solutions… it is also necessary to add the possibility of prefabrication.

Rib housing in perpent joint

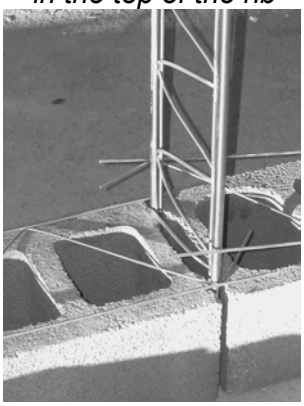
Overlap of right Murfor into AllWall rib

AllWall Telescopic fixing in the top of the rib



Overlap of left Murfor into AllWall rib

AllWall rib in perpent joint every 2,80m span



Concrete hollow block + Murfor + AllWall Ribs

Murfor and AllWall rib only with mortar

Easy manipulation of AllWall ribs h=8m

AllWall Rib and it´s fixing before adjustin

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2. Horizontal flexural text. Bed joint reinforced duplex cavity walls (DCW) 73-84
3. The influence of murfor diagonal in the blucking of DCW test. 85-94.
4. The universal masonry unit and rib reinforcement. 95-106.
5. The integral masonry system and the contemporary façade. 107-119.
6. AllWall clay brick plate test. 121-130.
7. New concepts to be includen in standard enclosure walls. 131-142.
8. Millenium House. 143-154.
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