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ALLWALL CLAY BRICK PLATE TEST

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ABSTRACT

Prior to the International Building Trade Fair in Barcelona CONSTRUMAT 97 it was decided to carry out a test on the ALLWALL System in order to present the same for the International CONSTRUMAT prize for "New Construction Techniques" The ALLWALL system was subsequently nominated as a "finalist" in CONSTRUMAT 97.
The test aimed to give experimental backing to the ASEMAS (The Architects' Mutual Insurance Association) report on facing walls (FFC001) titled "Exposed brick leaf enclosure walls" which indicated the design criteria for the Contemporary Façade and Self-bearing, Semi-supported and Curtain Walls. This report aimed to prevent cracking in traditional enclosure walls.
The said walls were developed in Spain under the commercial name of the ALLWALL INTEGRAL MASONRY SYSTEM and are based on the design criteria established by AIA Arquitectura s.XXI Technical Consultants.
The tests on this wall were carried out at the Material Laboratory at ETSAM (Madrid College of Architecture) using test instruments prepared for a Research Project into Horizontal Flexural Bending of Reinforced Masonry Walls.

Key words: *AllWall Masonry System; Universal Unit; Rib reinforcement; Bed joint Reinforcement.*

2. OBJECTIVES

As this was the first international test to be carried out on a bi-directional reinforced masonry wall, the test aimed to find the regularity of the wall's behaviour when working as a bi-directionally stresses plate and to establish whether the test results would exceed the design stresses.

The tested enclosure panel forms the basic component of the Alpha (Self-bearing) and Beta (Semi-supported) ALLWALL enclosure walls. The data obtained is also valid for the Gamma (Hanging) and Omega (curtain) walls.

The tests wished to observe the interactive behaviour of:

- The universal ALLWALL *Ladriflor* clay brick
- MARESA M-80 Mortar
- Murfor horizontal truss type reinforcement
- ALLWALL-Rib double wire vertical ribs
- The interrelation of brick/mortar/Murfor and brick/Mortar/ALLWALL Rib

3. TEST PLAN

Single testing was carried out using the instruments which had been manufactured specifically for the horizontal flexural tests on ACW and DCW walls at ETSAM.

A 3m long by 1.70m high single leaf wall was constructed using 11.5cm ALLWALL Ladriflor brick (240x115x70mm) which allowed the insertion of the ALLWALL rib (fig. 1) (Fig. 2). The Ladriflor bricks in question were the first batch to be manufactured by V.Bonet-Trenco.

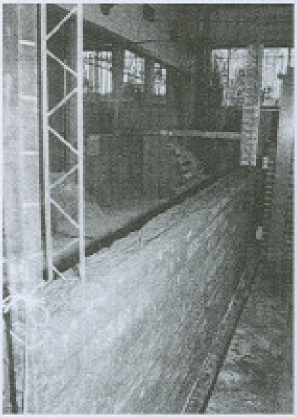
An M-80kg/cm^2 mortar pre-prepared by MARESA was employed in the approximately 1.5cm thick joints.

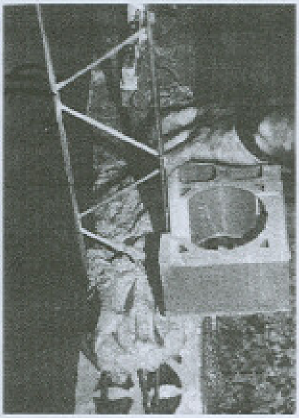
The horizontal reinforcement was formed by 5 Murfor RND 4/Z-80 truss-type bed joint reinforcement spaced every 40cm high (5 courses of 7+1=8cm), each one centred within the leaf (Fig. 3) (fig. 4), while the vertical reinforcement was formed by two ALLWALL ribs formed of pairs of 4mm diameter wires separated by 90mm, and placed vertically in the wall with a 2.70m horizontal spacing, at the points of the vertical reaction supports.

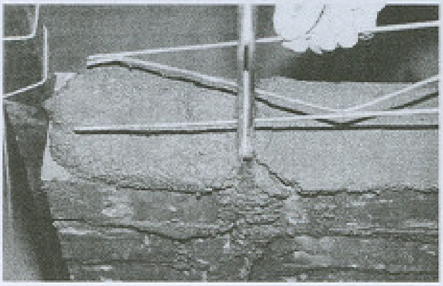
4. INSTRUMENTS

The test apparatus was formed by a triangular space frame structure which had been specially prepared for horizontal flexural testing at ETSAM, with specific variations for this test with reactions at only 4 points (see Fig. 9 and 10).

Figure 1. Construction of the Allwall Plate.
Figure 2. Placing of the Ladriflor brick on the rib.
Figure 3. Threading of Murfor reinforcement through Allwall Rib.
Figure 4. Completed Allwall plate.







The sub-project No. 2 of the Material R+D Programme had received the necessary funding to manufacture suitable apparatus for this type of testing. The said apparatus had to allow testing in any laboratory or place without a previously installed instrument infrastructure.

As such an independent and transportable test apparatus was designed which could be easily assembled and disassembled and transported, using a bolted assembly with relatively lightweight pieces (less than 50kg), which did not require a fixed loading or reaction infrastructure as is normally established in test laboratories and which require heavy slabs and/or thick reaction frames.

The said equipment may, therefore, be employed in any laboratory or place where it is necessary to test single or double leaf walls for horizontal flexural bending, or steel enclosure plates (sandwich type), or other elements for slabs, roofs, etc.

The originality of the test apparatus lies in its specially designed triangular space frame structure which include the supports or ribs for both the loading and reaction of the whole assembly, and which transfer the opposing stresses between each other *and, thereby, obtaining equilibrium without it being necessary to employ* *the external reaction components (slabs and/or frames) which are normally required in specialised structural test laboratories.*

The structure of the test apparatus basically consists of two steel HEB supports spaced 2.70m on which the wall is supported in reaction, and a double HEB central support which activates the response of the jack transmitting the load on the wall. The said supports are connected by flat triangular beams set over and below the instruments and which connect and transfer all the loading and reaction stresses (fig. 5)

The structure is dismountable for ease of transport and by virtue of the characteristics of the test walls (1 or 2 leaf) has a maximum free height of 2m, which may be increased by any additional free height for the testing of larger walls.

As a result of the triangular arrangement of the loading and reaction frame it is *possible to test on any horizontal* support base (without this needing to be reinforced) (Fig. 6)

The lower *triangle* arrangement is provided with wide thin metal flats which transfer the forces and, at the same time, allow the test wall to be set in position and the rubble to be removed on wheeled trolleys at floor level as the said plates are only 5mm thick (Fig. 7).

The *upper t*riangular arrangement of tubular profiles house the central guide which support the hanging bearing for the profiled load distribution structure, which is moved by the central jack in order to deform the wall during testing.

The *original design* of this apparatus may be scaled to suit the materials to be tested and allows economic testing both on site and in laboratories which are not usually fitted out for this type of test.

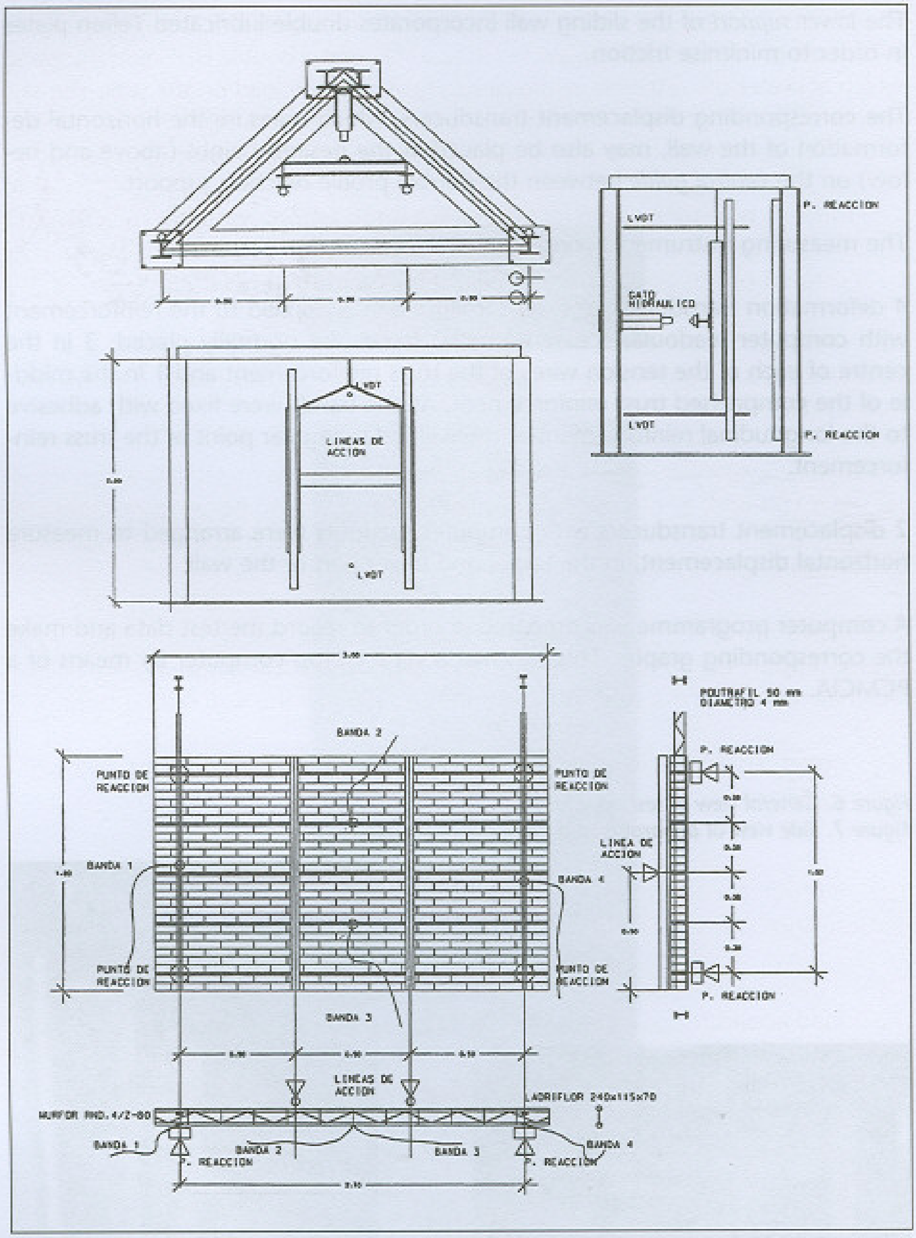
The *vertical* reaction supports are spaced 2.70m and the load is applied in two vertical strips spaced 90m and set at 1/3 span.

An electric pressure pump, set over the jack, has been designed to provide a regular load application suited to the test .

The *hydraulic jack* may be fixed at any level, in order to centre it at the mid-height of the wall, and runs along a guide rail between the double profile behind the reaction support. The pressure of the single central jack is computer controlled and transfers the loads of the pressure pump to the loan distribution structure over the wall.

The point and centred load of the jack is transferred to a *sliding hanging* load distribution structure by means of a ball and socket joint which equally distributes this to two vertical ribs which apply horizontal load on the wall at the thirds of its span. The said structure is *height adjustable* so that it may be centred on any type of wall requiring testing, regardless of the number of courses and up to 2m free height,

Figure 5. Design of for horizontal flexural bending test apparatus. Side, plan and front elevation.
Figure 8. Instrument arrangement for tests on Allwall Plate with reactions in 4 end points.



The *vertical supports* for both the load application profiles spaced at 90 cm and the reaction ribs set at 270cm, incorporate *steel rollers* and steel plates which are fixed to the wall by Epoxy mortar in order to minimise the concentrated stresses in the masonry.

The *neoprene adjusters* on the said rollers set on the masonry reduce the effects of inevitable tolerances incurred during the construction of the wall.

The *lower support* of the sliding wall incorporates double lubricated Teflon plates in order to minimise friction.

The corresponding displacement transducers, which measure the horizontal deformation of the wall, may also be placed at the desired height (above and below) on the *central guide* between the double profile reaction support.

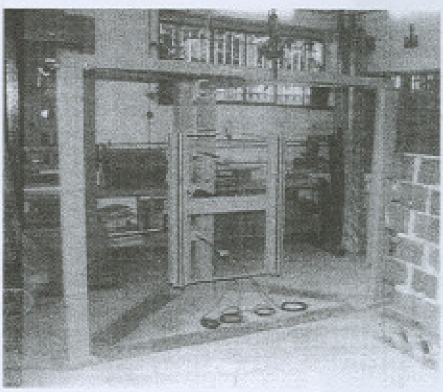
The measuring instruments consist of:

4 deformation transducers of extensometric bands applied to the reinforcement with computer readouts. 4 extensometric bands are normally placed, 3 in the centre of each of the tension wires of the truss reinforcement and 1 in the middle of the compressed truss reinforcement. All the bands were fixed with adhesive to the longitudinal reinforcement at the welded triangular point of the truss reinforcement.

2 displacement transducers with computer readouts were arranged to measure horizontal displacement, in the upper and lower part of the wall.

A computer programme was prepared in order to record the test data and make the corresponding graphs. This was made via a laptop computer by means of a PCMCIA.

Figure 6. General view of test apparatus.
Figure 7. Side view of apparatus and jack.



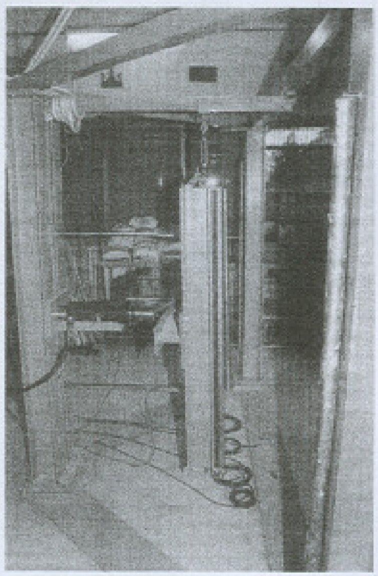
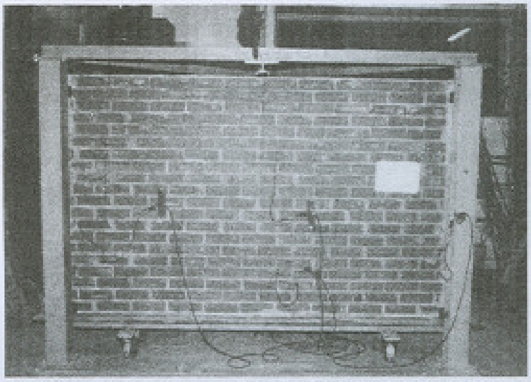
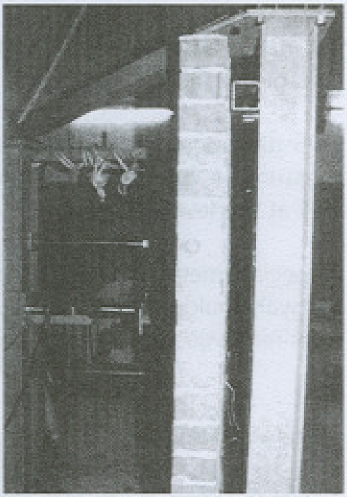


Figure 9. Side view of the Plate ready for testing with reaction points on the Allwall-Rib.
Figure 10. Front view of the instruments on the Plate and ready for testing.





The connection and transmission of data from the jack, extensometric bands and displacement transducers, are collected on a capture display.

Wheeled trolleys of the same length as the wall were used to transport the constructed walls to their precise point within the test apparatus.

The laboratory assistants and bricklayers who built the walls collaborated with the technicians in the moving of the walls and in centring the same between the supports.

In order to visualise the cracks in the wall under horizontal flexural bending, each crack was marked with chalk and numbered in order of appearance.

The testing of the Allwall plate employed the same computer program that had been created for the R+D Project "Horizontal Flexural Tests", and was simply carried out by setting gauges on the horizontal truss reinforcement and on the vertical ribs (Fig.8). The computer program was applied in real time by the architectural scholarship holder C. Gonzalo Bravo.

The continuous vertical reaction supports of the wall spaced 2.70m are transformed into 4 point supports at the top and bottom of the said verticals. The reaction is, therefore, only obtained at the four extreme points of the plate (Fig. 9) (Fig. 10).

The total length of the wall is supported on sliding Teflon plates.

The measuring apparatus consisted of four deformation transducers of extensometric bands two of which being applied to the Murfor reinforcement and the other two to the Allwall ribs, and in both cases set in the central area of the stretched reinforcement.

The two bands on the Murfor horizontal reinforcement were set on the stretched area of the second and fourth truss reinforcement.

Two displacement transducers with computer readouts were also employed to measure the horizontal deformations and set in the upper and lower parts of the wall at the level of the second and fourth Murfor reinforcement.

A special "method" was employed to clear up the tested material so that the tested wall could be demolished in-situ and in the same testing area and the rubble then removed to a skip by wheelbarrow.

5. ANALYSIS OF RESULTS

The monitoring of the test revealed the deformation of the plate in a bi-directional manner, there being clear deformation in both vertical and horizontal directions prior to failure.

Five 4mm diameter wires, distributed regularly in the bed joints, were stretched in a horizontal direction and four wires grouped in twos were stretched in the vertical, these being set in the void of the Ladriflor brick, spaced 2.70m and uniformly distributed in the courses every 40cm (Fig. 11).

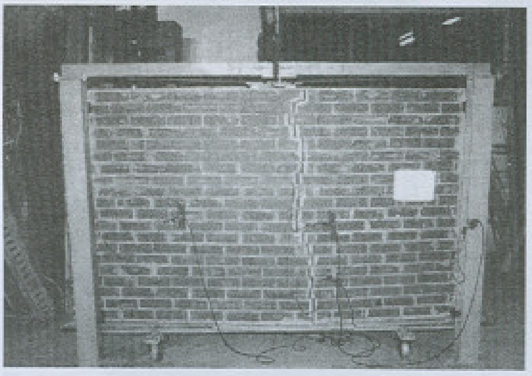
While there was similar quantities of steel in both vertical and horizontal directions, as the wires were more concentrated in the vertical than the horizontal, and as the wall was of double length over height, it was logical that there would be greater deformation and eventual yielding in the horizontal reinforcement over that seen in the vertical reinforcement, given the concentration and shorter length of the latter.

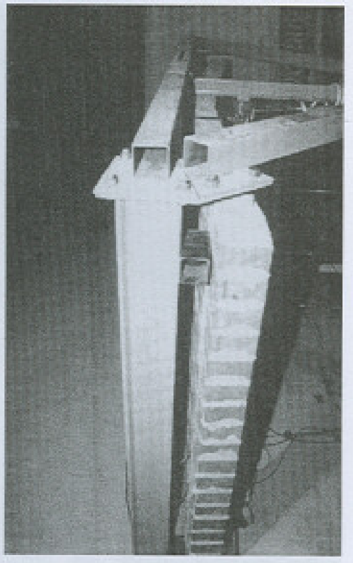
The test, therefore, concluded with a yield over and above the yield stress of the Murfor horizontal reinforcement and without reaching the said stress in the Allwall vertical ribs, the smaller deformation of this latter reinforcement not causing cracking in the brickwork which returned to its original state (without deformation) once the test had concluded (Fig. 12).

The test concluded with the cracking of brickwork and the failure of the horizontal reinforcement, revealing a vertical crack centres in the middle third of the tension brickwork.

The tension borne by the reinforcement (two horizontal and two vertical) and indicated in the stress-strain tables, show the regularity and uniformity of the test, while revealing greater deformation in the upper area than in the lower area of the brickwork, which was probably due to the influence of the continuous lower support.

Figure 11. Front view of the Plate after testing with vertical crack in the middle third of the wall.
Figure 12. Side view of the Plate after testing with breakage suffered by vertical failure





The microdeformation of the reinforcement shown in the corresponding table, also indicate that mentioned above.

6. CONCLUSIONS

The wall has behaved under testing in the manner of a bi-directionally reinforced slab or plate. Given its greater length than height the failure has occurred, as was predicted, in the centre of the longest tension reinforcement.

The results of the test show clearly different results between the ultimate stress in the two Murfor reinforcements, the lower being at the limit of the ultimate strength of steel and the upper 1/3 being below the ultimate strength of the said material.

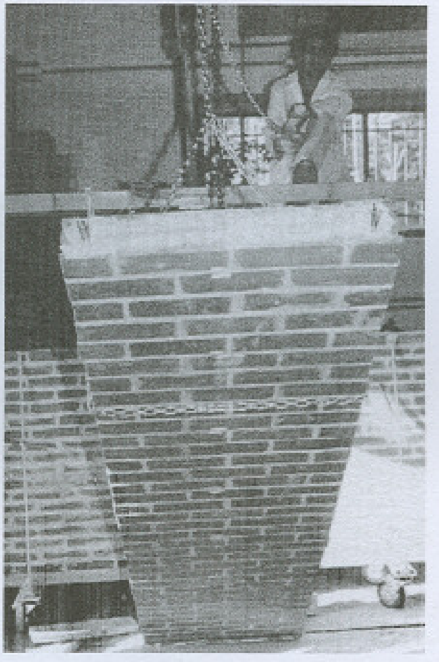
As such, it may be taken that, for reasons which we are unaware of, the recordings of the values in the upper strip are 1/3 below the estimated values.

In any case, this technical variation in the interpretation of the results by no means affects the good behaviour of the wall seen during testing.

7. OTHER TESTS TO BE CARRIED OUT

When testing the above plate for the CONSTRUMAT '97 Trade Fair, another wall was built with contrasting proportions to that of the tested ALLWALL plate.

Figure 13. Vertically elongated Allwall Plate built to verify the resistance of the two Allwall ribs.
Figure 14. Horizontal manipulation of the Allwall plate showing the stiffness of a slab.



The first ALLWALL test was made on a wall of greater length over height, which predictably failed as a result of the breaking of the Murfor reinforcements.

However, the other wall was built with a shorter length in proportion to its height, being 0.75 m long by 3m high and _ brick thick. The wall was reinforced with two ALLWALL ribs at the ends and with regularly spaced Murfor truss type bed joint reinforcement.

The object of this other test was to break the wall by the failure of the ALLWALL rib, which were duly equipped with the corresponding extensometric gauges.

While awaiting the necessary funds to carry out this latter test, the wall was transferred from its original vertical position to a horizontal position by means of the laboratory pulley and set on one end of a trolley to the side of the test lab.

The photographs show that the plate performs with the stiffness of a slab which, in turn, opens up more applications of the Integral Masonry System. As the plate when set in a horizontal position may serve to build an entire masonry building, in terms of load bearing walls and supports as well as floor slabs and roofing.

8. BIBLIOGRAPHY

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