12TH INTERNATIONAL
BRICK/BLOCK
Masonry
CONFERENCE

Ade

CRACK CONTROL IN LONG CLAY WALLS WITH BED JOINT REINFORCEMENT

Josep Mª Adell[1], Concha del Rio[2]

[1]Professor, Dr. Architect. UPM. Universidad Politécnica Madrid. DCTA. Architectural Building and Technology Department. ETSAM. Escuela Técnica Superior de Arquitectura.

[2]Professor, Dr. Architect. UPM. Universidad Politécnica Madrid, DEE Department. Building Structures. ETSAM. Escuela Técnica Superior de Arquitectura.

ABSTRACT

Tests carried out under natural conditions in two Spanish cities: Pamplona and Toledo

This investigation was made possible as a result of the special collaboration of the R+D Department in 1996, by Concha Del Rio, Dr. Architect, Titular Professor of the Structures Department at ETSAM-UPM (Madrid Polytechnic – College of Architecture). This special collaboration was included in the Sub-project No. 1 of the coordinated National Plan of R+D Materials headed "Prevention of cracking between movement joints in long masonry walls", initially directed by Professor Juan Monjo Carrió of the Architectural Construction and Technology Department and Director of Investigation at AILAC, and which for unfortunate circumstances was not concluded.

The said investigation was coordinated in association with HISPALYT (The Spanish Association of Manufacturers of Clay Bricks and Tiles) in order to design walls which were more suited to the study of deformations and in order to adjust the investigation as far as possible to suit the interests of the said association. The test plan was monitored by Mr. P. Timperman of Bekaert.

Ongoing investigations had been carried out for many years by HISPALYT in order to establish the behaviour of ceramic units (bricks and tiles) under moisture expansion.

In Pamplona, the walls were constructed on an area of open ground at the University of Navarra College of Architecture and the tests were monitored at the CADIA building laboratory under the direction of Francisco Javier Bada Ruisánchez.
In Toledo the walls were built on an area of open ground at the Technological Centre for Fired Clay, and the test monitoring was carried out by Jorge Velasco and Javier Cerdeño.

Key words: *Clay Brick/block; Bed Joint Reinforcement; Thermal-Humidity Expansion.*

OBJECTIVES

The investigation attempted to ascertain the influence of bed joint reinforcement on the movement of very long masonry walls.

While movement is basically due to moisture expansion, thermal changes produce cyclical shrinkage and expansion which explain the oscillations observed in the graphs.

The investigation also wished to seek the advantages of bed joint reinforcement over traditional masonry walls in terms of cracking.

The research was carried out in two locations with different climatic conditions in order to evaluate the possible influence of the same.

In order to force the masonry to crack, 30 metre long walls were constructed which met at a right angled corner with a 1.5m wall, and where it was expected that the unreinforced wall would crack, and where it would be possible to compare the efficiency of the reinforced walls.

The investigation was programmed to last three years, this being the standard time required for the stabilisation of the clay expansion. Two years and three months have passed to date and so it is possible to anticipate the behavioural tendency of the said walls in accordance with their environmental conditions.

TEST PLAN

In order to obtain the expansion values for natural humidity and establish the desired correlations, four clay walls were built in two cities with very different weather conditions, and using the same type of clay and mortar at both locations.

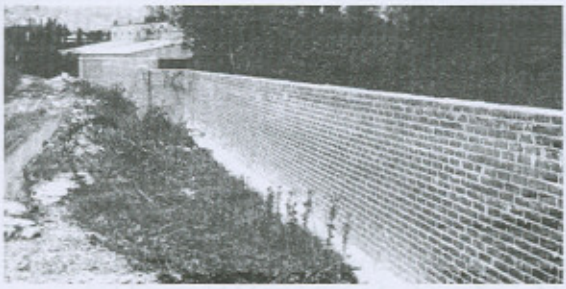
The selected cities were:
– Pamplona, with a mild and very humid climate (Fig. 1)
– Toledo, with an extreme climate (very cold/very hot) and dry (Fig. 2)

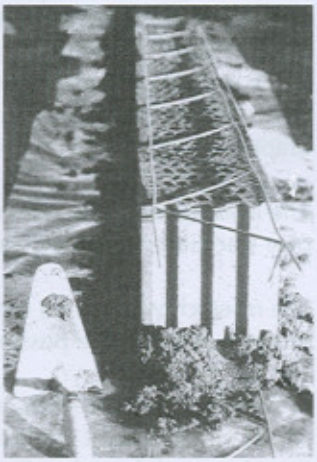
Four walls were built in each city, two of brick and two of lightweight clay block (Thermoarcilla) and one of each pair of walls was reinforced with Murfor type reinforcement while the other was left unreinforced.

The constructed walls are 30m long by 2m high and all end at a right angle where they meet a smaller wall of 1.5 m long by 2 metres high. The angled joint is bonded.

All the walls were built on a strip foundation and fitted with damp proof coursing (Fig. 3) which enabled them to move towards the built corner as their movement was restricted at the other end by means of a reinforced column set on foundations.

Figure 1. The 4 long parallel walls in Toledo.
Figure 2. The 4 long aligned walls in Pamplona.
Figure 3. Base of the 1st course of Blockwork with Murfor.





In order to withstand wind action, steel uprights (IPE 120) were placed every 5m to allow the transfer of the said action from the walls. Anchors were subsequently placed to allow the movement of the masonry wall in a longitudinal direction without limiting the free expansion and contraction of the wall (fig. 4).

The bricks were clay perforated bricks of 24x11.5x7cm, while the lightweight clay blocks were 30x19x19, both brick and block being manufactured with the same type of clay.

The reinforced walls, were reinforced every 40cm vertical height (5 courses of 7+1=8cm) in the brickwork and every 2 courses of 20 cm (19+1) in the lightweight clay block walls. The reinforcement employed in the brick walls was Murfor RND 4/E-50mm truss type reinforcement, while that in the block walls employed Murfor RND 4/E-150mm.

Murfor was placed in the corners in three different forms in order to assess its performance.

- In the corner of the reinforced brick wall in Toledo, the truss reinforcement was only overlapped by 10cm in order to allow the right angled meeting of the wall without bending the reinforcement.
- In the corner of the reinforced brick wall in Pamplona, 50mm wide truss reinforcement was angled so that it was off centre and on the inner dihedral angle of the corner.
- At the corners of the reinforced clay block walls in Toledo and Pamplona the reinforcement was angled.

The proportion of steel in each wall is equivalent to 0.054% of the brick wall and 0.003% of the lightweight clay block wall.

The mortar employed in both cases was provided by Carlos Cabal and prepared by MARESA, MEGAMIX, with a strength of M-80Kg/cm^2

The walls were orientated in the same direction in both cities, with the longest dimension facing south. Due to the restricted area in Toledo, the walls were constructed parallel to each other, though with sufficient spacing to prevent the action of shade, while in Pamplona the walls were arranged in a row with suitable spacings between each wall.

The walls have been measured every 15 days at their longer ends, with a reading being taken at the top and the bottom of each end. This has provided a graph of each wall which shows the increases in length of the masonry over the time and including the figures for moisture expansion together with those of thermal expansion or contraction (fig. 5).

The air moisture content and temperature has been constantly recorded in order to build up graphs showing variations in local humidity and temperature.

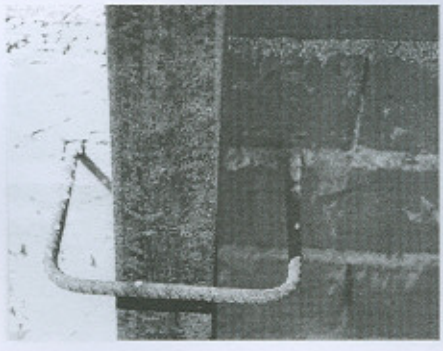
Reference points, in the form of fixed plates, were attached to the walls in order to ensure constant measurements.

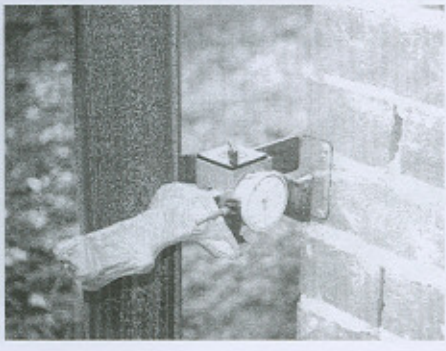
The walls were built simultaneously in both cities in January 1997, employing the same clay material and after having allowed two months to pass prior to building in order to prevent excessively high initial expansion.

INSTRUMENTS

Fixed structures, set free of possible deformations of the wall, were constructed at a slight distance from each long end in order to allow the periodical measurement of the lengths of the walls and any ensuing deformation at specific reference points.

Figure 4, IPN Rib and wind anchoring.
Figure 5. Comparator with 0.1mm precision in Pamplona.





These fixed reference points were set in the upper and lower parts of each long end of the wall.

Comparators with an accuracy of within 0.1mm were employed to register the slight movement variations.

A weather station was also installed in the area to measure and register the daily and hourly humidity and temperature in order to evaluate the influence of the same in the length variations of the masonry.

ANALYSIS OF RESULTS

The tests for moisture expansion carried out in accordance with the Spanish Code UNE-67036-99 have revealed the following results:

	Brick	Block
Pamplona	0.53 mm/m	0.62 mm/m
Toledo	0.64 mm/m	1.14 mm/m

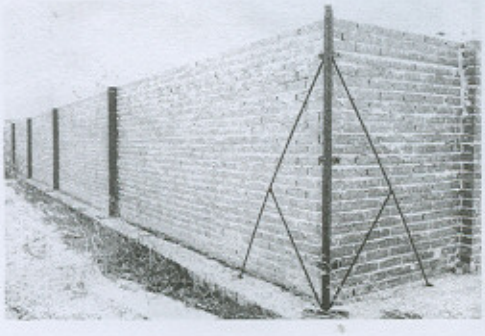
The graphs obtained reflect the typical seasonal variations, showing proportional increases and decreases in the graphs of all the walls. This allows us to compare the relative values (as this included temperature) and absolute values of natural expansion. However, the said comparative relative values give absolute ratios when comparing walls set in the same environment.

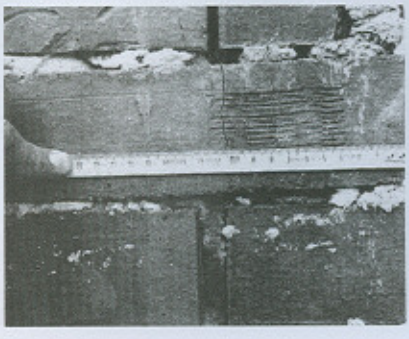
At 800 days the graphs and corresponding data allow the following deductions to be made:

Pamplona

The data obtained at Pamplona has provided more regular and uniform results as is reflected in the figures and graphs.

Figure 6. Long reinforced brick wall in Pamplona
Figure 7. Same wall with cracking at corner





The brick walls have expanded 0.335mm/m while the reinforced brick walls have increased 0.235mm/m.

From this it can be taken that the reinforcement has reduced the expansion of the brick wall by 30%.

The lightweight clay block walls have expanded 0.260mm/m while the reinforced block walls have increased 0.175mm/m.

It can be, therefore, taken that the reinforcement has reduced the expansion of the block wall by 33%.

The unreinforced brick wall showed fissures and/or cracking at regular distances every 3 or 4m, which proportionally increased towards the corner of the wall. The corner reveals a broad crack several millimetres thick, which runs from the top to the bottom of the wall. It is possible to observe a displacement between the smaller and longer sides of several millimetres.

No cracks or fissures have been observed in the face of the reinforced brick wall. However, at the corner where the reinforcement has been angled there is a slight crack running from the outside to the inside of the brick and stopping at the reinforcement. This crack occurs at the lower part of the long face of wall, 6" from the corner, and does not stretch to the upper part of the wall. (Fig. 6) (Fig. 7).

The crack which appears at the corner is no more than two tenths of a millimetre wide.

No cracks were observed in either the reinforced or unreinforced block walls and the corner of both walls also showed no signs of cracking.

Toledo

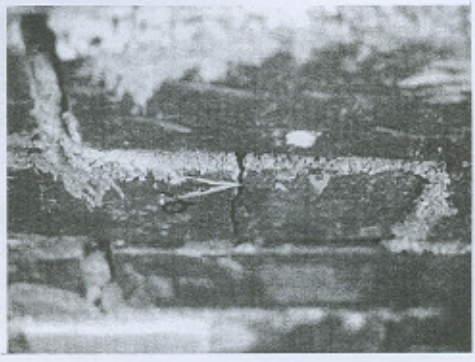
The data obtained from Toledo has been equally regular but reveals less variables than in Pamplona.

The brick walls have expanded 0.66mm/m while the reinforced brick walls have increased 0.58mm/m.
From this it can be taken that (with the necessary corrections) the reinforcement has reduced the expansion of the brick wall by 19%.

The lightweight clay block walls have expanded 0.275mm/m while the reinforced block walls have increased 0.21mm/m.

It can be, therefore, taken that (with the necessary corrections) the reinforcement has reduced the expansion of the block wall by 29%.

Figure 8. Corner of Long Brick Wall in Toledo.
Figure 9. Crack at the corner of the same wall.



The unreinforced brick wall reveals fissures and/or cracking at regular distances every 2 or 3m, which proportionally increase towards the corner of the wall. The corner reveals a broad crack several millimetres thick, which runs from the top to the bottom of the wall. It is possible to observe a displacement between the smaller and longer sides of several millimetres. (fig. 8) (Fig. 9).

No cracks or fissures have been observed in the face of the reinforced brick wall. However, at the corner where the reinforcement overlaps by only 10cm, there is a visible crack which is alternately staggered up both faces of the joint at 6" from the corner.

The crack at the corner is as much as 2mm thick.

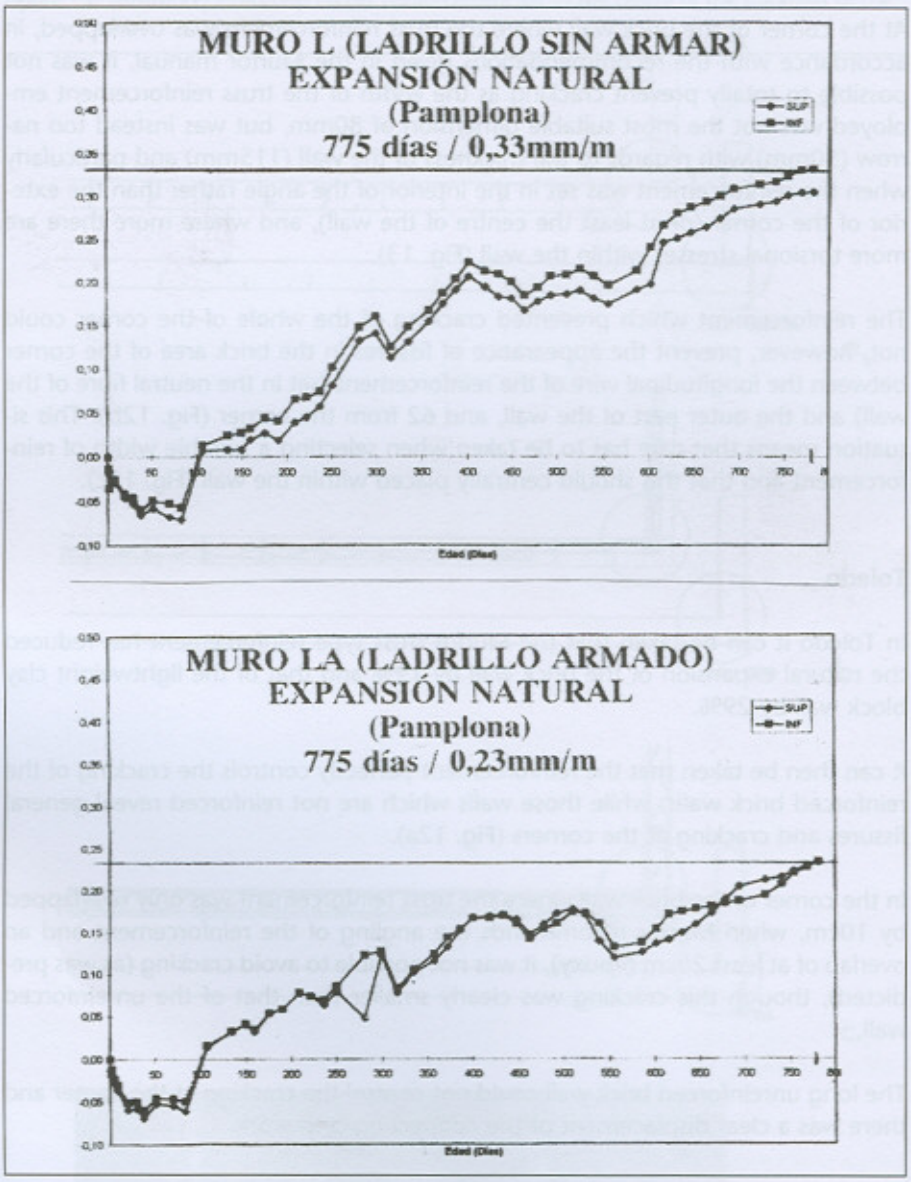
No cracks were observed in either the reinforced or unreinforced block walls and the corner of both walls also showed no signs of cracking.

CONCLUSIONS

The results of the moisture expansion tests reveal very different results between Pamplona and Toledo which become more intensified with regards to the clay blockwork.

Figure 10. Graph showing natural expansion of long brick walls in Pamplona. Unreinforced brickwork.

Figure 11. Graph showing natural expansion of long brick walls in Pamplona. Reinforced brickwork.



Pamplona

In Pamplona it can be taken that the Murfor truss type reinforcement has reduced the natural expansion of the brick wall by 30% (Fig. 10) (Fig. 11) and that of the lightweight clay block wall by 33%.

It can then be taken that the reinforcement perfectly controls the cracking of the reinforced brick walls, while those walls which are not reinforced reveal general fissures and cracking at the corners (Fig. 12a).

At the corner of the brick wall where the truss reinforcement was overlapped, in accordance with the recommendations given in the Murfor manual, it was not possible to totally prevent cracking as the width of the truss reinforcement employed was not the most suitable dimension of 80mm, but was instead too narrow (50mm) with regards to the thickness of the wall (115mm) and particularly when the reinforcement was set in the interior of the angle rather than the exterior of the corner (or at least the centre of the wall), and where more there are more torsional stresses within the wall (Fig. 13).

The reinforcement which prevented cracking of the whole of the corner could not, however, prevent the appearance of fissures in the brick area of the corner between the longitudinal wire of the reinforcement (set in the neutral fibre of the wall) and the outer part of the wall, and 62 from the corner (Fig. 12b). This situation means that care has to be taken when selecting a suitable width of reinforcement and that this should centrally placed within the wall (Fig. 12c).

Toledo

In Toledo it can be taken that the Murfor truss type reinforcement has reduced the natural expansion of the brick wall by 19% and that of the lightweight clay block wall by 29%.

It can then be taken that the reinforcement perfectly controls the cracking of the reinforced brick walls, while those walls which are not reinforced reveal general fissures and cracking at the corners (Fig. 12a).

In the corner of the brick wall where the truss reinforcement was only overlapped by 10cm, when Murfor recommends the angling of the reinforcement and an overlap of at least 25cm (epoxy), it was not possible to avoid cracking (as was predicted), though this cracking was clearly smaller than that of the unreinforced wall.

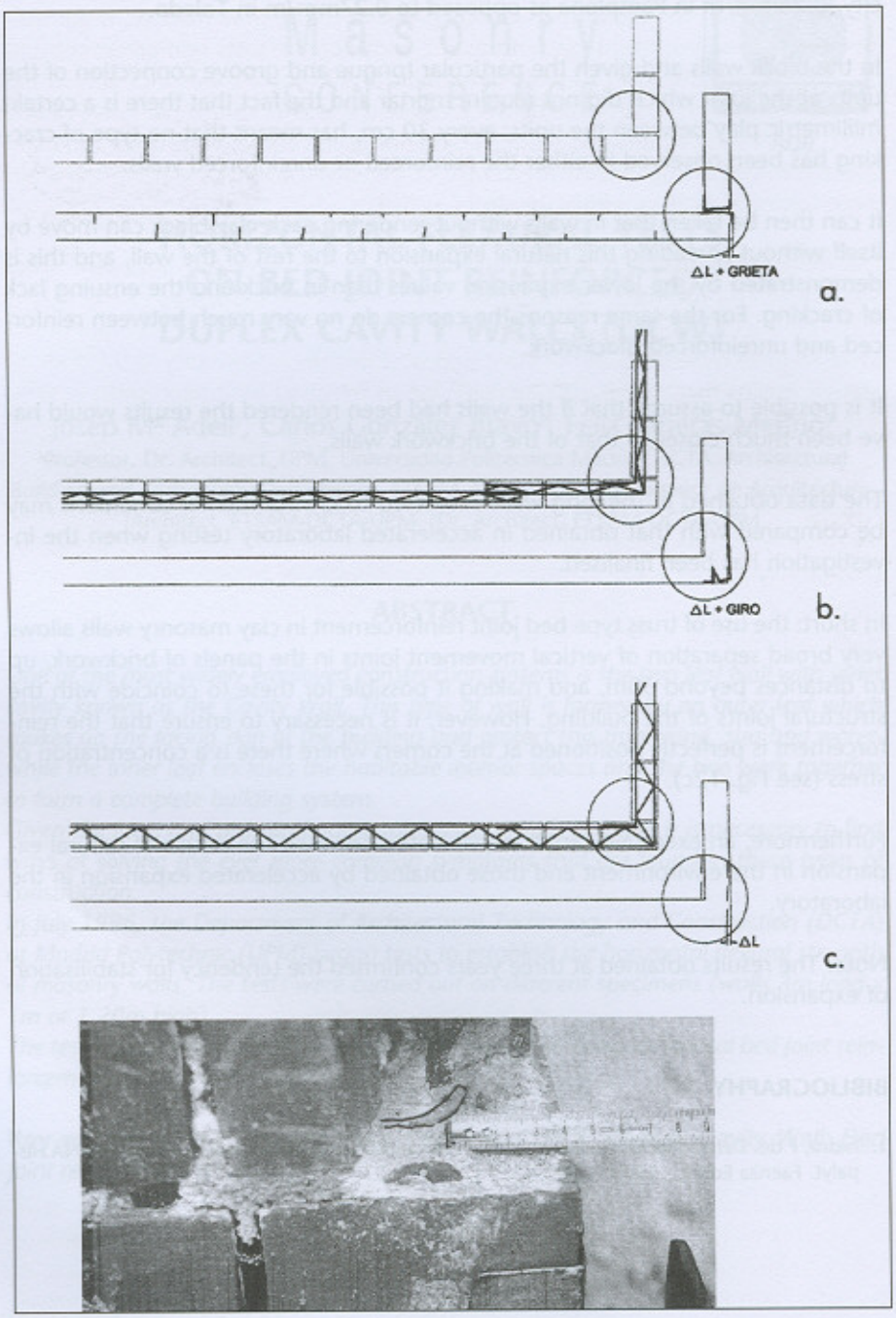
The long unreinforced brick wall could not control the cracking at the corner and there was a clear displacement of the connecting brickwork.

Comparisons between Pamplona and Toledo

In absolute values it can be taken that in spite of the fact that the walls were built with the same materials in both locations, the climate of each place has had a sizeable influence as the unreinforced walls in Pamplona showed a natural expansion of 0.33mm/m (See Figs. 10 and 11) under a humid and mild climate, while

Figure 12. Graphic illustration of the behaviour of Long Brick Walls.
a. Unreinforced wall: cracking in corner by displacement and generalised cracking.
b. Wall with incorrectly placed corner reinforcement. Cracking at corner by turning.
c. Correctly reinforced wall without cracking.

Figure 13. Illustration indicating corner reinforcement set in the centre of the thickness of the wall.



those in Toledo incurred double the amount (0.66mm/m) in a dry an extreme climate.

Curiously, in the case of the unreinforced lightweight clay block walls there was hardly any difference between the natural expansion values of the walls in each city, 0.26mm/m in Pamplona as opposed to 0.27mm/m in Toledo.

In the block walls and given the particular tongue and groove connection of the units at the joint which did not require mortar and the fact that there is a certain millimetric play between the units, every 30 cm, has meant that no type of cracking has been observed in either the reinforced or unreinforced walls.

It can then be taken that in walls without rendering each clay block can move by itself without spreading this natural expansion to the rest of the wall, and this is demonstrated by the lower expansion values than in brick and the ensuing lack of cracking. For the same reasons the corners do no vary much between reinforced and unreinforced blockwork.

It is possible to assume that if the walls had been rendered the results would have been much closer to that of the brickwork walls.

The data obtained in the long walls subjected to environmental conditions may be compared with that obtained in accelerated laboratory testing when the investigation has been finalised.

In short: the use of truss type bed joint reinforcement in clay masonry walls allows very broad separation of vertical movement joints in the panels of brickwork, up to distances beyond 30m, and making it possible for these to coincide with the structural joints of the building. However, it is necessary to ensure that the reinforcement is perfectly positioned at the corners where there is a concentration of stress (see Fig. 12c).

Furthermore, an excessive variation was noted between the results of natural expansion in the environment and those obtained by accelerated expansion in the laboratory.

Note: The results obtained at three years confirmed the tendency for stabilisation of expansion.

BIBLIOGRAPHY

1. Isidro, F de. *Determinación de la humedad en los productos cerámicos españoles.* Revista NA Hispalyt. Faenza Editrice Ibérica 1997.