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THE INFLUENCE OF MURFOR DIAGONAL REINFORCEMENT IN THE BUCKLING OF DCW WALLS TESTED IN SPAIN

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ABSTRACT

This work is a continuation of the horizontal flexural tests carried out on reinforced masonry walls at the Architectural Construction and Technology Department (DCTA) at Madrid Polytechnic (UPM). This work could not have been carried out without the kind collaboration of CEDEX (Centre of Research and Experiment) who made these tests possible.

This work is one of the advancements of the future doctoral thesis of Carlos Gonzalez Bravo, who signs this work together with his tutors, Josep Mª Adell Argilés and Concepción del Rio.

On the analysis of the said tests it was possible to verify one of the unknowns which still remained pending after finalising the horizontal flexural tests on Duplex Cavity Walls (DCW). This unknown being mentioned in the title of this work and basically consists of the buckling of the diagonal reinforcement in two leaf cavity walls.

Key words: *DCW - Duplex Cavity Wall; Bed joint reinforcement; Wireslenderness.*

1. OBJECTIVES

This work aimed to establish the behaviour of the diagonal reinforcement set close to the supports (wall reactions) when subject to horizontal bending. While the problem of shear stress in beam type structures is fairly well known, when breaking tests have been carried out on concrete beams for shear stress it has frequently be seen that the beam has failed due to flexural stress rather than shear stress. The new methods regarding shear in concrete structures have shed some light on the problem[4] by establishing and marking the types of loads in the points considered as discontinuous areas of the structure[5].

Furthermore, when a structure is analysed by the strut and tie method, the arrangement of the compression and tension lines is not always apparent.

However, in the case of bed joint reinforced masonry, which implies the use of two materials which until recently were considered to be incompatible, that of brick and steel, the struts and ties method is incredibly simple (See Fig. 1). Perhaps this is because the said struts and ties are literally drawn within the structure and leave no doubt as to their working.

This type of construction method allows a simplicity of form and structural possibilities which could well lead to the resurgence of masonry in competition with all other high tech construction methods.

The struts and ties are simply responsible for transferring the shear at the interface in the structure from the compression cord to the tension cord and vice versa. In the case in hand, the cords of the structure are formed by the two leaves of masonry and while it is well known that masonry works fairly well under compression but poorly under tension, the structural reinforcement of the small diameter steel bars together with the truss like arrangement of the reinforcement (See Fig. 2) provides the masonry with very considerable inertia[6] as opposed to unreinforced masonry (against bending stresses) or that which is simply connected by cavity wall ties.

On of the factors which determines and establishes this new system is the use of murfor truss type reinforcement.

Figure 1. Example of cavity wall reinforced with Murfor truss type reinforcement.

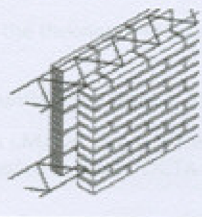


Figure 2. DCW wall tied with Murfor bed joint reinforcement.

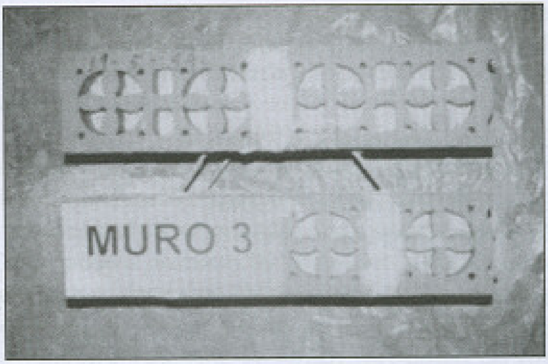
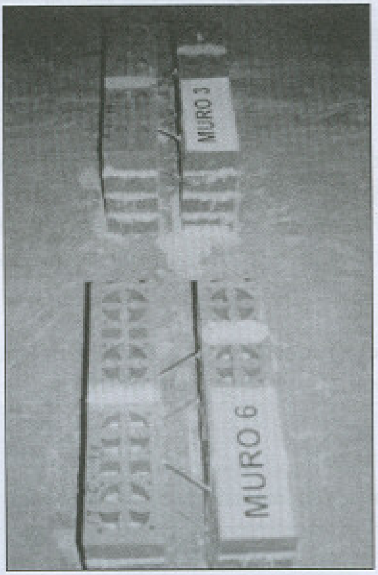


Figure 3. Two specimens prior to testing.



This type of reinforcement, which is widely known in Europe, has been manufactured for many years now. This type of reinforcement is used to reinforce the bed joint of the masonry and is very economical. The trusses are manufactured in different widths (varying between 50 and 280mm depending on the section used for the longitudinal reinforcement[7]) using a reel and when placing a diagonal, which is welded to the longitudinal reinforcement, this may be considered to have an eccentricity e_o which we have referred to as the pre-eccentricity of the Murfor type diagonals. This pre-eccentricity is no more than the deflection incurred by the reinforcement on manufacture, and in 1994 O. Pfeffermann established that this would take a sinusoidal form[8].

TEST PLAN

The test wallettes[9] consisted of four course high cavity walls and Murfor reinforcement RND 5/E-250, with varying sections of diagonal reinforcement and different cavity widths,

W-1 and W-2, Ca = 5cm, Diagonal = 3.75mm
W-3 and W-4, Ca = 5cm, Diagonal = 5mm
W-5 and W-6, Ca = 7cm, Diagonal = 3.75mm
W-7 and W-8, Ca = 7cm, Diagonal = 5mm

It should be indicated that the values taken for e_o have been measured on the reinforcement, the values of which varying in accordance with the 5 or 7cm wide cavity.

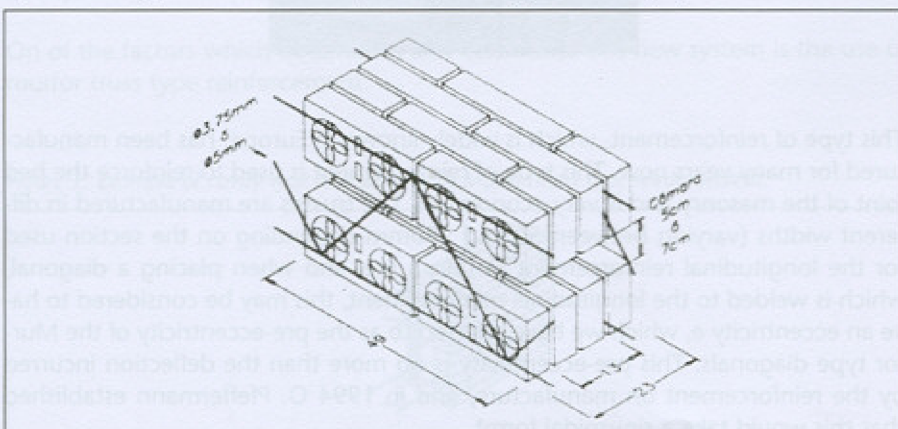
In the theoretical calculations the buckling length was taken as the length of the bar set within the cavity. This hypothesis is based on previous wall tests[10] in which no loss of bonding was observed between the reinforcement and the mortar nor any deflection of the bed joint[11].

The values for e_o are as follows:

Using 3.75mm reinforcement the value was 0.4mm with a 5cm cavity, and 0.8mm for a 7cm cavity. With 5mm reinforcement the value was 0.1mm with a 5cm cavity, and 0.2mm for a 7cm cavity. It is, therefore, clear that the stiffest reinforcement offers more resistance to the sinusoid formed as a result of the reeling of the reinforcement.

The e_o will be the subject of more detailed study for cavity spacing within the doctoral thesis mentioned at the beginning of this article.

Figure 4. Arrangement of the tested specimen, showing the brick employed in the test12.



The professionals at CEDEX played a very important role in the testing and test arrangement, and this work could not have been carried out without their assistance.

When testing the wallettes it was necessary to secure the two leaves so that they would not deflect from one another.

It should be borne in mind that the specimen only contained four diagonals which crossed the two leaves. This was designed as such in order to assure the buckling failure of the reinforcement. As in previous studies[13] the very slender reinforcement could pose a problem for the extensometric bands. However, in this case none of the gauges came loose in any of the tested specimens.

The computer programme (see Fig. 5), which was based on the same arrangement employed in the DCW testing, that is to say, with transducers interpreting electrical current as microdeformation of the reinforcement, allowed the introduction of the time factor with regards to the data obtained for the stresses in the reinforcement.

CONCLUSION

The significance of the pre-eccentricity e_o while affecting the results did not prove to be a handicap to the correct performance of the wall. In the tests it may be seen that the buckling of the diagonals did not follow a regular pattern (See Fig. 6 and 7).

Figure 5. Instruments employed in the tests. CEDEX Laboratory.

Figure 6. Tested specimen in which it is possible to observe the buckling of the diagonal reinforcement..

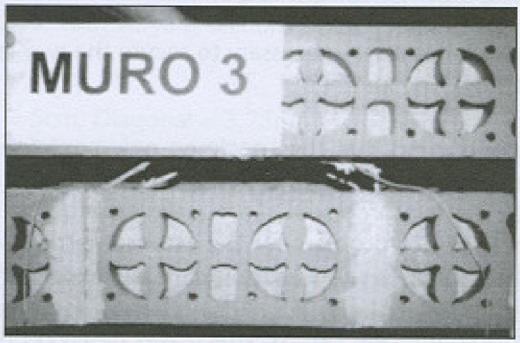
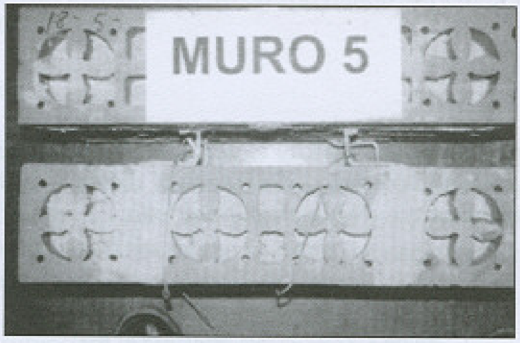


Figure 7. Tested specimen in which it is possible to observe the buckling of the diagonal reinforcement..



The fact that buckling occurred in different directions makes it possible to assume that the stresses on the faces of the wall were not produced in a uniform manner. This could be the case if we consider that there are normally irregularities in the construction of the walls and that it is impossible to transfer equal thrust load to the four diagonals.

Once again[14] it was seen that there was no bond failure between the reinforcement and the mortar, which then supports the previously mentioned hypothesis regarding the buckling length of the diagonal reinforcement concentrated in the cavity.

Therefore, the test results reveal an aspect which was already inferred by numerical calculus, in that the pre-eccentricity affects the buckling behaviour of the wall in spite of the fact that this does not occur in a uniform manner in all the reinforcement.

The results also revealed local failures (See Fig. 8) in some specimens which deflected the results, though this is fairly common in this type of tests where opposing results arise due to the differing cavity widths.

Figure 8. Load graph of a tested specimen.

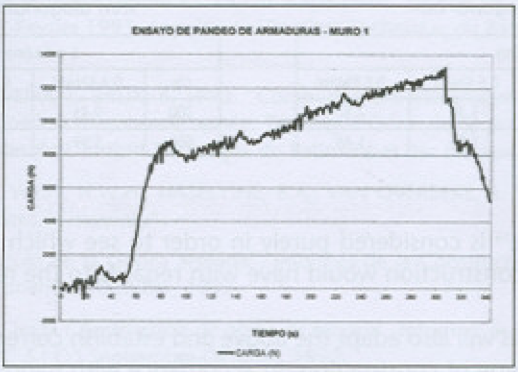


Figure 9. Wallette prior to testing.

The measurement of the eccentricities is worthy of more exhaustive study and the values of these may well bring the test results much closer to the results of numerical calculus.

Furthermore, other possible work hypotheses may be presumed, such as the mathematical-empirical approximation of the limit of eccentricity based on different suppositions of the pre-curvature of the reinforcement on manufacture, or by the tabulation by degree of cavity width and reinforcement diameter.

These and other factors will be considered in the aforementioned doctoral thesis.

In spite of this, it is necessary to make some comment on the values calculated by O. Pfeffermann (15) for the buckling of reinforcement in cavity walls, in the light of the Spanish code which stipulates the verification of the range of variations incurred at distances between supports in the wall with the values of pre-eccentricity measured in tests.

Table 1. Tabulated in accordance with 3.75mm diagonal bar.

L máx (m)			
t/p	0.4 KN/m²	0.6 KN/m²	0.8 KN/m²
300	4.75	3.30	2.57
600	2.57	1.85	1.48

Table 2. Tabulated in accordance with 5 mm diagonal bar.

L máx (m)			
t/p	0.4 KN/m²	0.6 KN/m²	0.8 KN/m²
300	9.45	7.72	5.99
600	5.99	4.13	3.20

The Spanish code[16] is considered purely in order to see which scope of application this type of construction would have with regards to the regulations.

The doctoral thesis will also adapt the above and establish correct methods of calculation for this type of construction, in accordance with national standards and related Eurocodes, such as those of loading, masonry and steel structures.

In order to calculate the maximum span between the supports of the wall under horizontal bending, Pfeffermann worked on the basis of a two leaf clay masonry wall with a 7cm cavity. In this way it was possible to ascertain the values for the said span for the two diameters used in the tests (3.75mm and 5mm).

Where *t* is the vertical distance between reinforcement and *p* the dynamic wind pressure.

With regards to the values of the NBE-EA-95 and those of the eccentricities indicated earlier for the test specimens, there is a variation of around a150% increase in span. It should be noted that Pfeffermann employed an eccentricity of 2.5mm (that is to say considering the whole bar as subject to buckling) as opposed to the 0.875mm employed here to establish the comparison (as a result of only considering the cavity area as that of buckling).

In spite of this, the values of the maximum spans will always be established by the verification of the wall under bending, that is to say, the resistance of the longitudinal bars.

By way of conclusion it may be indicated that these small advances in the field of reinforced masonry reveal the great technological potential of the same, though it is still necessary to consider the final conclusions provided in the doctoral thesis.

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NOTES

[4] See Calavera Ruiz, J.A. A new Development in the Spanish Code EHE: The Strut and Tie Method. Intemac Quarterly No. 34-2 Quarter 1999).

[5] These areas are those which suffer disturbances in their isostatic arrangement and which normally occurs at supports or on the loading of the structure. See. op. cited in note 4.

[6] See Adell J.M/Gonzalez-Bravo. C/Laheras F. Horizontal flexural tests on bed joint reinforced duplex cavity walls (DCW), tested at the DCTA-UPM- 12th IBMAC Madrid. 2000.

[7] See Murfor Manuel. Bekaert.

[8] See Adell J.M. La fábrica armada. Annexe 1b. Calculation of horizontal bending by O. Pfeffermann (DCW) Ed. Munilla- ieria. Madrid 2000.

[9] These tests correspond to the sub-project 3 "Comparative Study of increased characteristics of reinforced masonry as opposed to unreinforced masonry" within the programme "Investigation into the physical and mechanical behaviour of bed joint reinforced clay masonry, in order to control cracking and increase technical and architectural possibilities of masonry", carried out

at CEDEX (Centre of Research and Experiment) and which will be presented at the 12th IBMAC. Madrid 2000.

[10] See Adell J.M/Gonzalez-Bravo. C/Laheras F. Horizontal flexural tests on bed joint reinforced duplex cavity walls (DCW), tested at the DCTA-UPM- 12th IBMAC Madrid. 2000.

[11] See Adell J.M & Laheras. F. (II) Bond tests. ETSAM. 1st National Conference of Architectural Technology, Madrid 1994.

[12] See Adell J.M. La fábrica armada. Ed. Munilla- ieria. Madrid 2000.

[13] Op. cit. note 7.

[14] See Adell J.M & Laheras. F. (II) Bond tests. ETSAM. 1st National Conference of Architectural Technology, Madrid 1994.

[15] We refer to the calculation made by O. Pfeffermann and published in La Fabrica Armada by José María Adell Argilés. See Adell J.M. La fábrica armada. Ed. Munilla- ieria. Madrid 2000.

[16] NBE-EA-95. Building Standards. Steel Structures.