SAFETY OF BRICK MASONRY FINISHINGS ANCHORED IN REINFORCED CONCRETE STRUCTURES UNDER DIFFERENTIAL MOVEMENTS

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ABSTRACT This paper describes experiments to obtain necessary data regarding safety of brick masonry facings installed by metal devices into concrete structures subject to differential movements between bricks and concrete. One method of brick masonry finishings was examined against two types of movements as follows:

(1) Horizontal thermal and moisture movement in a long term.

(2) Flexural and shearing deformation in plane.

One 20 m long wall specimen with brick masonry finishings on both sides was prepared in order to measure differential movements between the two materials for the first type of movements. Another wall specimen with a brick masonry finishing was loaded horizontally in the same plane of the wall for the second type of movements.

As a result, various types of differential movements were measured. The fracture processes and the permissible deformation are discussed on the basis of these experiments in order to improve the safety performance of this type of brick masonry.

1. INTRODUCTION

In Japan brick masonry finishing constructions are very popular in high class buildings which are supported by reinforced concrete walls with metal ties and mortar. When we try to apply it in seismic countries, we must take account of the structural safety against movements between brick masonry and structural walls, which is caused by daily heat and moisture and occasional earthquakes. At the same time we must offer details of this construction. Experiments whose results were reported here were carried out to apply special large sized bricks to a govermental botanic building which was called Okinawa Tropical Dream Center.

2. EXPERIMENTAL PROGRAM

2.1 Materials

Tested bricks are large sized and have a pitched surface and holes for metal wall ties. The physical properties of bricks are shown in Table 1. In this case water absorption and expansion due to absorption were measured after 24 hours in water.

Joint and castinig mortar was normal cement mortar. Various types of stainless steel were used for anchoring brick masonry to

reinforced concrete walls.

2.2 Specimens

These types of specimens were prepared as shown in Figures 1, 2 and 3. The first type of specimens was to examine directly the bond and installing strength between masonry and concrete.

The second type was a wall specimen to test flexibility between these two components under lateral cyclic loading in plane.

The last type was a long wall to examine long term behaviours under moisture and thermal movements. In this case, two types of bricks, pre-wetted brick and no pre-wetted one, were adopted on the both sides of the wall respectively.

2.3 Experimental Methods

2.3.1 Direct Tension and Shear Test. This type of specimens is a rectangular parallelopipedon with two brick masonry components on the both sides anchored by four wall ties each other. In the case of tensile specimen two special metal plates were bonded on the surface of masonry components, and then pulled by a loading device directly.

Direct shear specimens were loaded in plane in compression. The slip deformation between two components was measured.

2.3.2 Lateral Loading Wall. In this experiment a horizontal force was applied to a structural reinforced concrete wall at the top by a 100-ton jack. Displacements at various positions of the specimen were measured to be able to seperate the bending, shear and slip deformations of the concrete wall and the brick masonry.

The ultrasonic velocity at five points of the wall was also measured to detect occurrence of bond fracture between the two components. Finally the length of crackings of both concrete and masonry was measured after a set of cycle loading of the same maximum displacement at the top.

2.3.3 Moisture and Thermal Movement. The slip deformation between the two components was measured at five points as shown in figure 3. The points from 1 to 4 were set on the side of the southern surface and the other was on the edge of the northern surface. This measurement was continued through the term from a mid summer to a mid winter. Recording slip deformation was carried out by an analog recorder.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3.1 Direct Tension and Shear

The experimental results of direct tensile and shear tests are shown in Table 4 and Figure 4. The bond strength of this type of face materials is so small that the weight of the finishing cannot be supported only by the bond strength even in usual states without earthquakes. Therefore the mechanical properties of metal devices are very important to keep this type of

buildings in safety. The experimental results showed great ductility and sufficient strength more than required value.

3.2 Lateral Loading of Wall

The relationship between horizontal load and displacement of the wall structure is shown in Figure 5. The relationship between the horizontal load and the relative displacement of the brick masonry finishing to the structural concrete wall is also presented in Figure 6.

The story drift angle at maximum load was +1/200 and -1/400. The yielding of bending reinforcements and horizontal reinforcements occurred respectively in the 2nd cycle and the 9th cycle. After the 9th cycle, the yield of the shear reinforcements caused the reduction in strength of the wall.

On the other hand the relative displacement of the brick masonry to the structural wall was almost zero in the early cycles. However this displacement occurred during the 5th cycle when the story drift angle was about 1/600. The complete exfoliation between the two components seems to have occurred at that time. The experimental results of ultrasonic velocity also offered the evidence of exfoliation as shown in Figure 7.

The fracture patterns of both concrete and brick masonry in the specimen are shown in Figure 8. Figure 9 can offer the experimental relationship between the density of cracks and story drift angle quantitatively. According to these figures, the thickness of brick masonry finishings seems to have a great effect in concealing structural crackings. This effect is important to improve the various performances of buildings.

3.3 Moisture and Thermal Movement

The slip deformation occurred in plane and the direction was the same to brick masonry expansion or reinforced concrete shrinkage. As shown in Figure 10 the slip deformation increased very gradually in the early stage before the 15th day and this deformation suddenly increased on the 15th, 16th and 24th day. The detailed change in the deformation is shown in Figure 11. The values of the southern edges changed very suddenly at about 2 pm on the 15th, 16th and 24th day which were very sunny days after wet days. This means that temperature takes an important role in breaking the bond between masonry and concrete due to swelling of clay bricks.

Figure 12 shows the distribution of the slip deformation through the whole specimen. The deformation at the edges was bigger than at the center point. In the early stage before 25th day, the distribution was not linear, which mean that the inner concrete wall restrained the masonry finishings with high rigidity. After the 25th day the distribution was almost linear because the rigidity of anchoring devices is much smaller than the rigidity of a brick masonry wall itself.

As another important information, the slip deformation of pre-wetted brick masonry located on the northern side of the specimen was very smaller than the other part which was installed without

pre-wetting. This result suggested that pre-wetting before installing was very effective in preventing damages due to swelling.

4. CONCLUSIONS

Based on the experimental results mentioned previously, the author's conclusion could be summarized as follows:

1) The bond strength between brick masonry and concrete was not enough to support brick masonry finishings.

2) Metal ties which anchor brick masonry finishings to the structural concrete had the ultimate shear strength of 8040N which also had sufficient ductility in this experiment.

3) This type of brick masonry finishings had flexibility to follow usual movements in plane and had strength to stand usual dynamic forces out of plane under earthquakes.

4) The interface between the two components in the case of the lateral loading wall was completely broken when the story drift angle was 1/600.

5) The brick masonry finishing was effective in concealing structural cracks. In the case of the moisture and thermal movements specimen, pre-wetting is very effective in minimizing moisture movements.

6) The interface between the two components in the long wall was broken in bond when the swelling strain of the brick masonry was 25μ.

7) The relationship between the slip deformation and the distance from the center of the wall was not linear before bond fracture and was almost linear after bond fracture.

Table 1 Properties of Bricks

Compressive Strength(MPa)	Flexural Strength(MPa)	Water Absorption (°/wt)	Swelling Strain* ($x10^{-6}$)
91.5	79.3	7.1	136

* From absolute dry to water saturated under 20°C

Table 2 Mix Proportion of Mortar

Kind of Mortar	Volumetric Ratio		Compressive Strength(MPa)
	Cement	Sand	
Cement Mortar	1	3	23.9

Table 3 Installing Method of Brick Masonry

Kind of Anchor	Kind of Wall Tie	Spacing of Wall Ties (cm)	
		Horizontal	Vertical
Stainless Steel M10	Stainless Steel ϕ4	80	64

Table 4 Mechanichal Properties of Installing Devices

Shear Load at Bond Fracture* (10^2 N)	Shear Bond Strength (MPa)	Maximum Shear Load per a Tie (10^2 N)	Shear Deformation at Ultimate (cm)	Shear Rigidity per a Tie (10^2N/cm)	Maximum Tensile Load per a Tie* (10^2 N)
298	0.056	80.4	1.29	617	54.9

* Charged area per a tie supposed 80x64cm

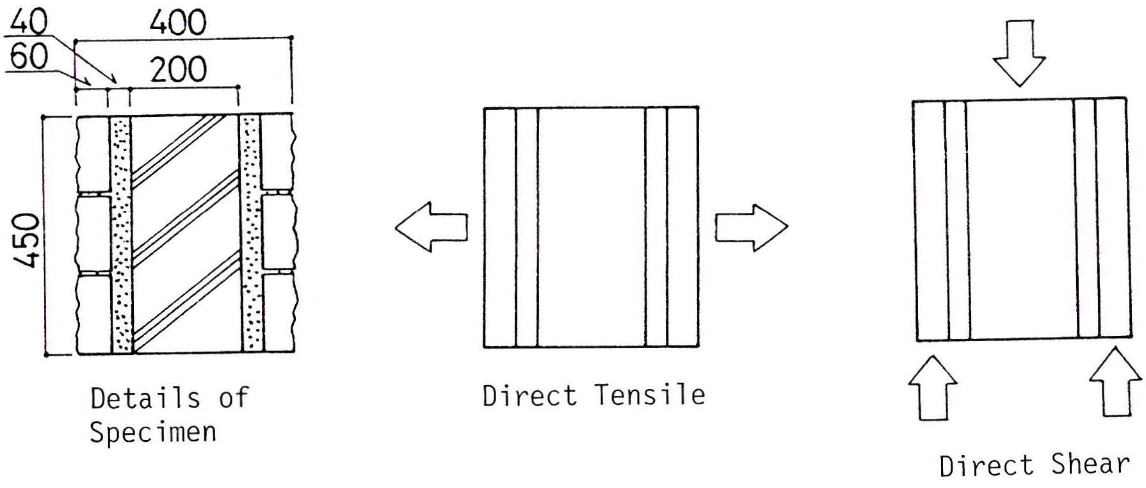


Figure 1 Direct Tensile and Shear Specimens

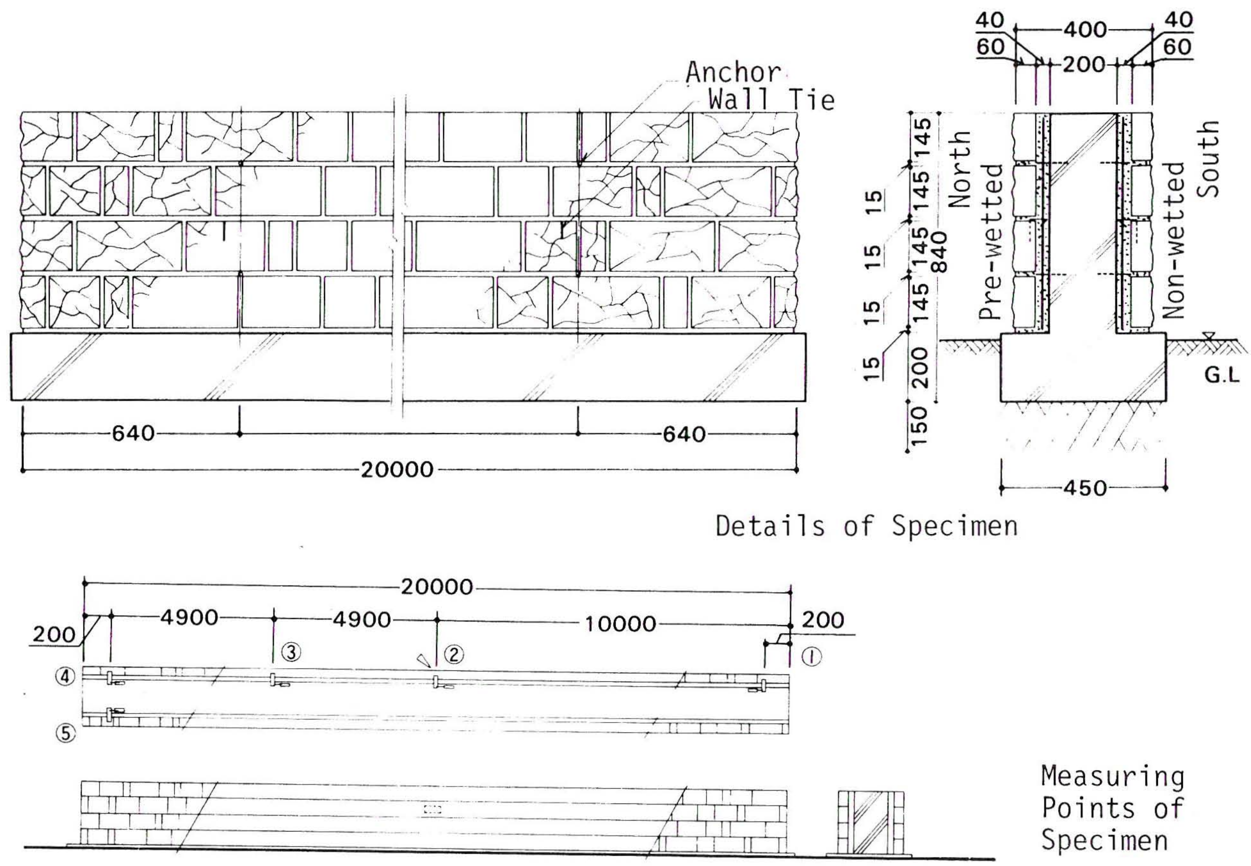
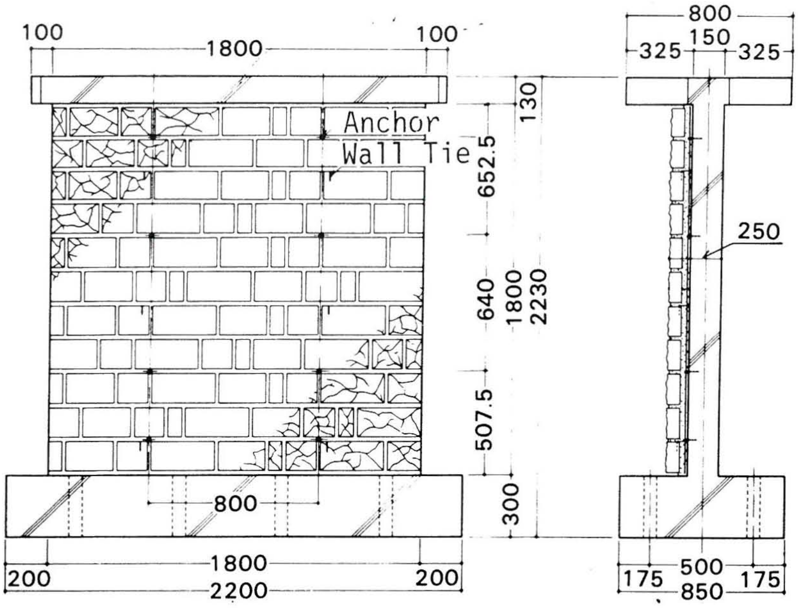
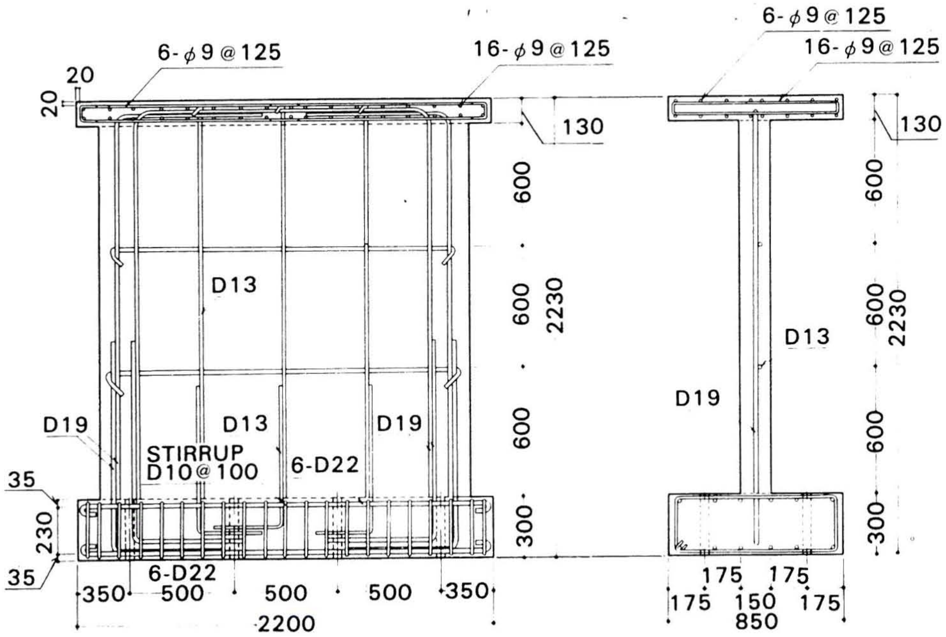


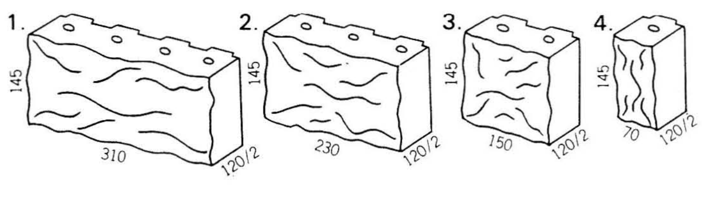
Figure 3 Moisture and Thermal Movement Specimen



Details of Specimen



Method of Reinforcing



Bricks Used in Experiments

Figure 2 Lateral Loading Specimen

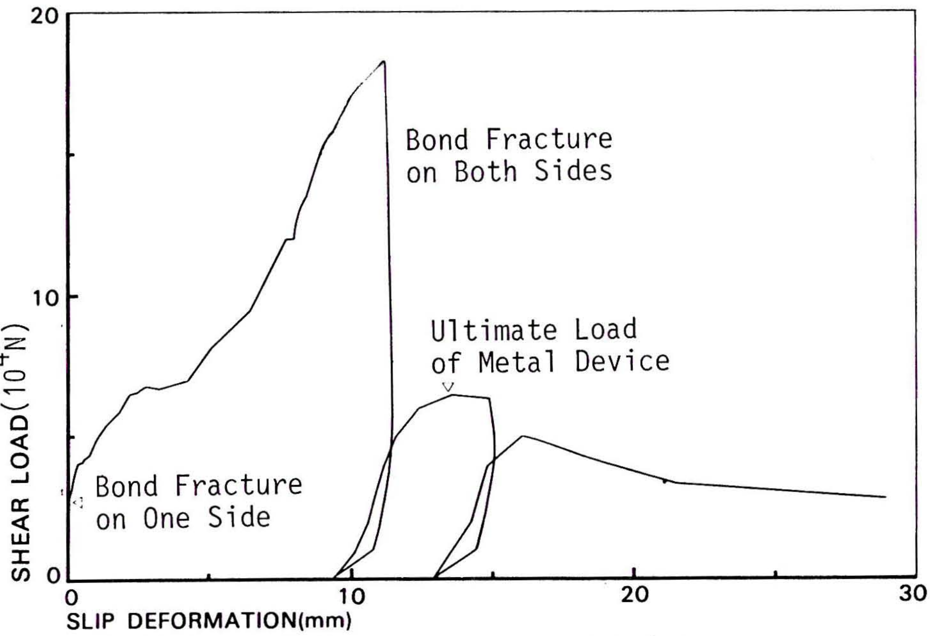


Figure 4 Experimental Results of Direct Shear

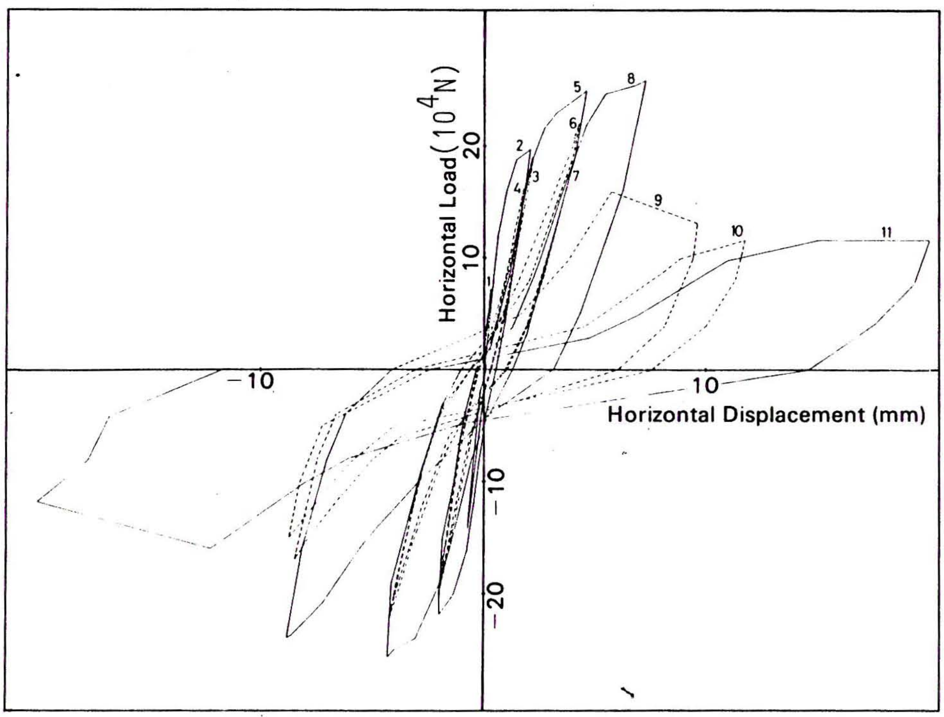


Figure 5 Experimental Relationship between Horizontal Load and Displacement of Wall Specimen

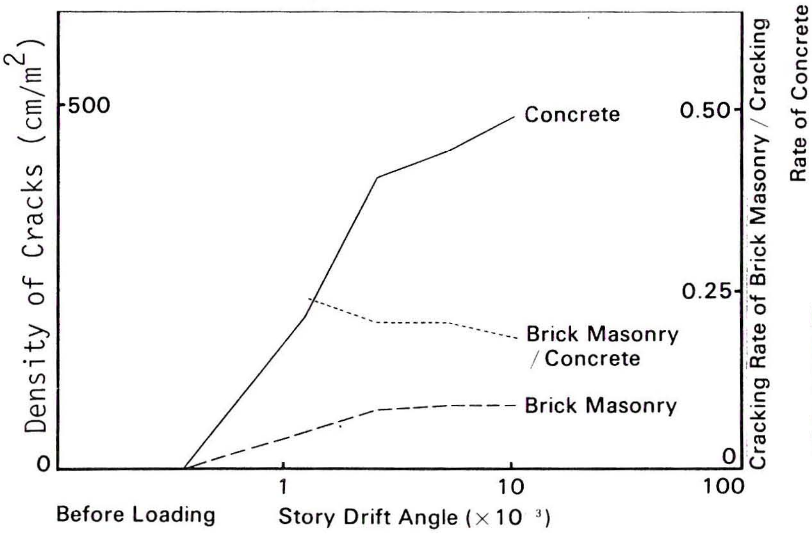


Figure 7 Experimental Relationship between Density of Cracks and Story Drift Angle of Wall Specimen

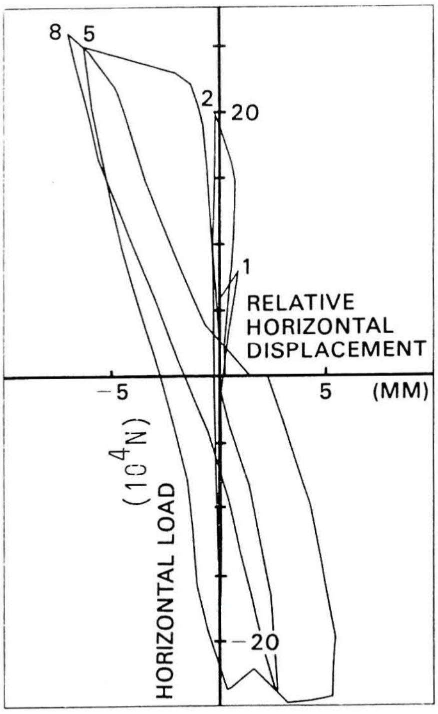
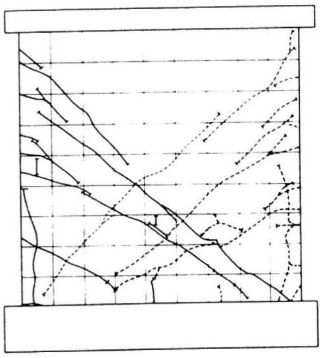
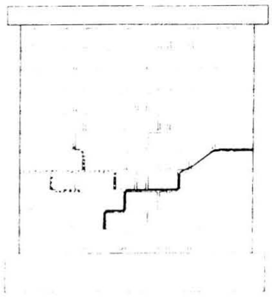


Figure 6 Experimental Result of Relative Displacement of Brick Masonry

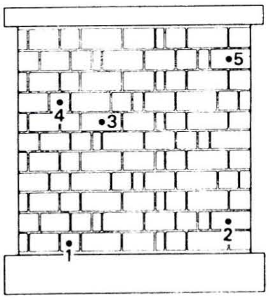


Concrete Wall



Brick Masonry Finishing

Figure 8 Fracture Patterns of Wall Specimen



Measuring Points of Ultrasonic Velocity

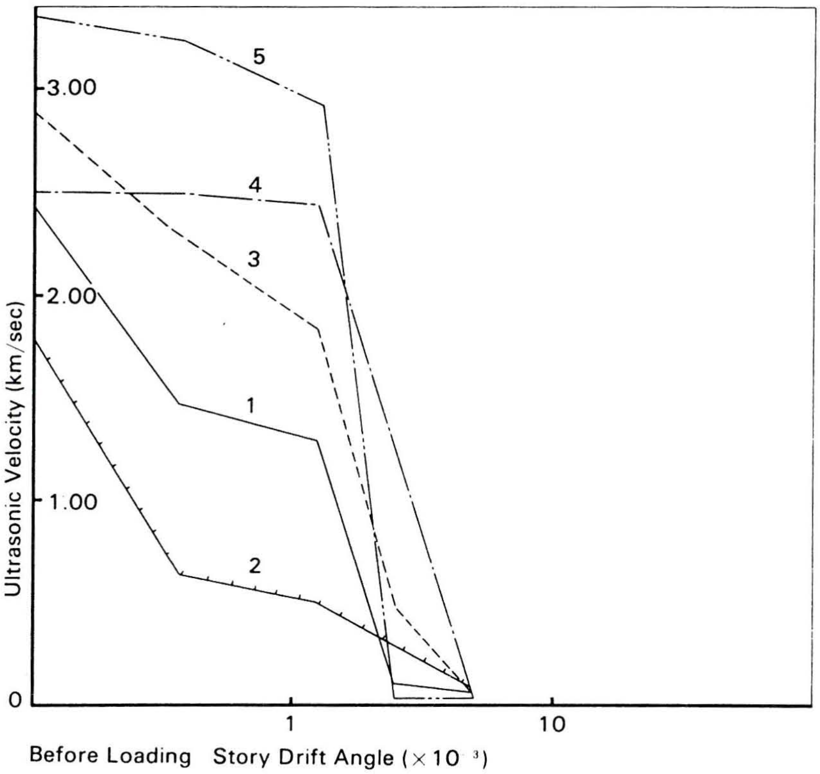


Figure 9 Experimental Relationship between Ultrasonic Velocity and Story Drift Angle of Wall Specimen

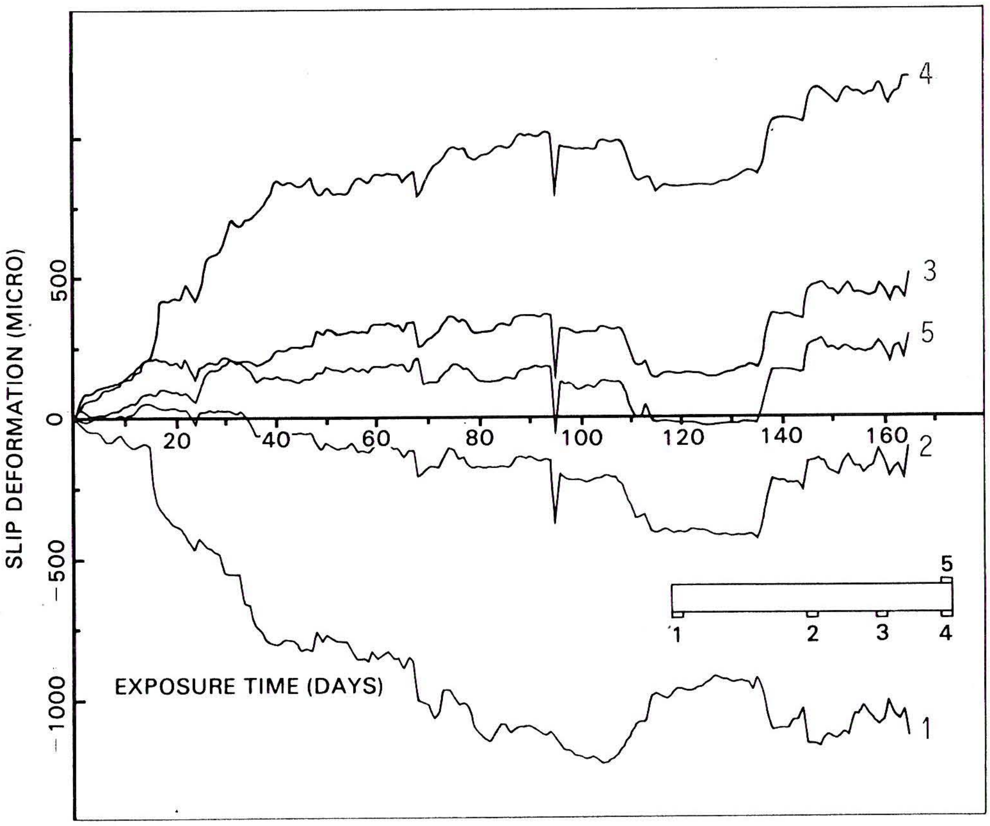


Figure 10 Experimental Results of Long Term Moisture and Thermal Movement of Long Wall Specimen

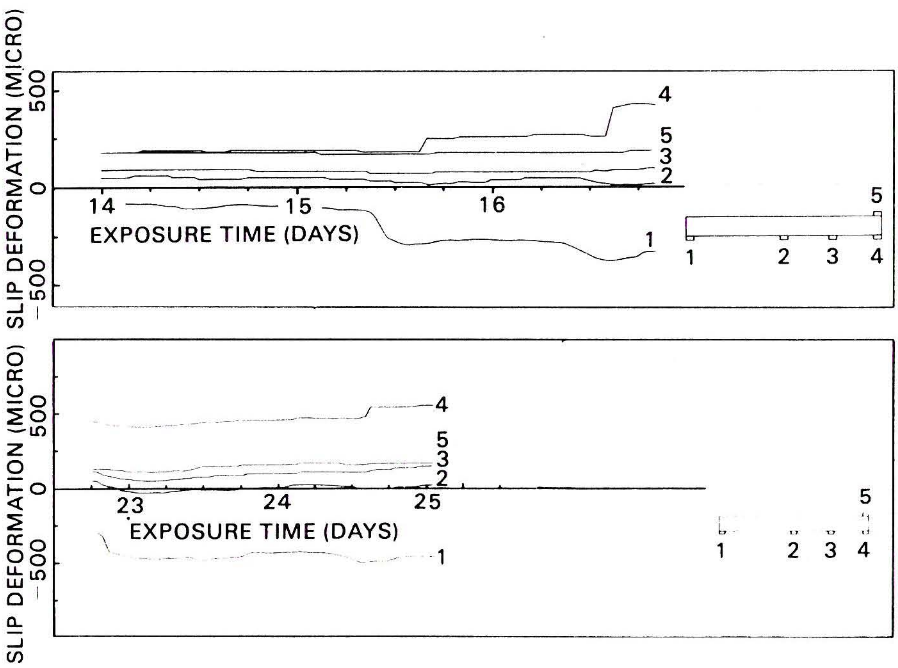
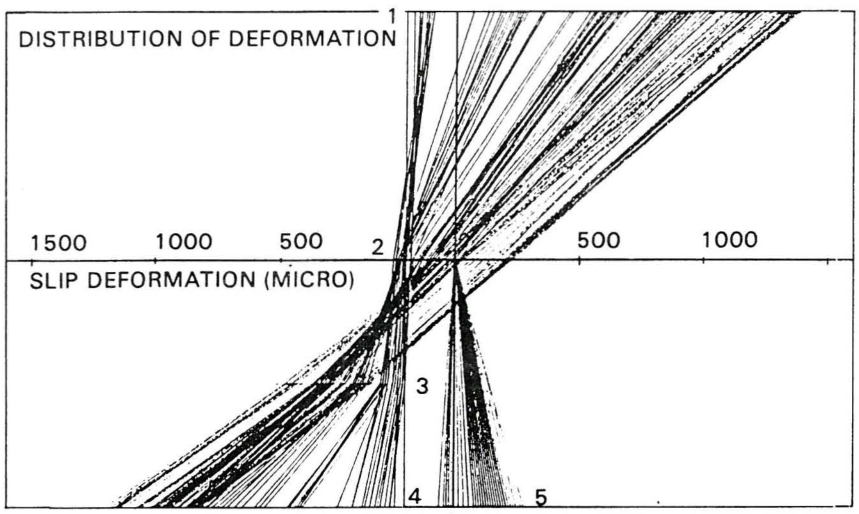
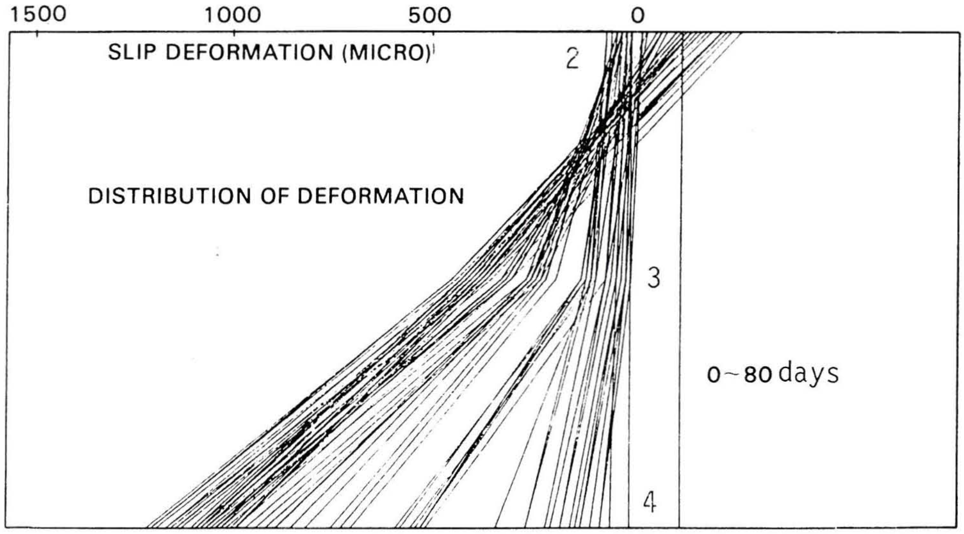


Figure 11 Experimental Results of Moisture and Thermal Movement at Breaking Days in Bond



Whole Specimen



Part of Specimen

Figure 12 Experimental Results of Moisture and Thermal Movement Distribution of Long Wall Specimen

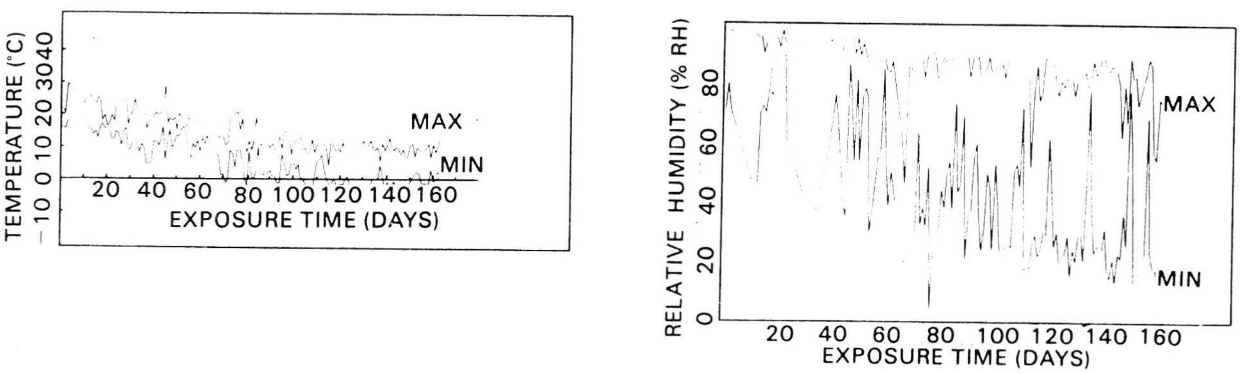


Figure 13 Records of Temperature and Relative Humidity of Exposure Site