FLEXIBILITY OF ADHESIVE MORTARS: AN EXPERIMENTAL STUDY

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ABSTRACT

Flexibility of adhesive mortars is a very important property in all those situations where tiles are subjected to different and large movements, such as facades and large slabs. Evaluation of this property is not completely understood yet, even though there are methods that propose its determination. This report studies, through an experimental work, some adhesive mortars available in the Brazilian market. A methodology presented by UEAtc - Union Européenne pour L'agrément Technique dans la Construction is used. Initial results show the viability of the method proposed through a comparative analysis of the flexibility of the mortars tested.

1. AIMS OF THE PRESENT WORK

The present work aims to discuss the flexibility of adhesive mortars used in ceramic tile setting. Through laboratory tests, several kinds of mortars available at the Brazilian market were tested. An apparatus developed by the authors was used according to the method described in UEAtc - Union Européenne pour L'agrément Technique dans la Construction. Ten different mortars were analysed according to the same method. The test procedure also aims to allow a simple and reliable verification of adhesive mortar flexibility for contractor and construction companies. A new factor F is proposed in order to classify mortars.

2. TYPOLOGY OF ADHESIVE MORTARS

Adhesive mortars are mortars with a very specific destination: they should allow bonding between ceramic tile and different substrates. There are adhesives mortars with a large range of application and properties. The correct selection of adhesive mortars must consider the particular requirements of each situation under engineering and architectural points of view, including substrate and tile properties and application conditions.

The most common available adhesive mortars in the Brazilian market can be divided into the following categories:

- ordinary adhesive mortars;
- polymer modified adhesive mortars - one component;
- latex modified adhesive mortars - two components.

These mortars are cement based materials that usually have an addition of chemical admixtures in order to modify their properties. Ordinary mortars are often modified only with cellulose admixtures, while one component mortars are often modified with redispersible powders. Most of the time ethylene/vinyl polymers are used for this purpose. Sometimes acrylic powder is used too. When part of the admixture is latex based, adhesive mortars are named latex modified or two component adhesive mortars. In this case ethylene/vinyl, styrenes and acrylics polymers are used for manufactures.

The Brazilian draft standard on the specification of adhesive mortars classifies this material according to the adhesive bond, open time and sagging. Adhesive mortars are classified into three different types. Basic differences are based on open time and bond strength. Table 1 below shows this classification.

Property	Test Method Draft	Unit	Adhesive Mortar Type			
			1	2	3	3 E
Open time	18:406.04-003	min	> 15	> 20	> 20	> 30
Bond strength at 28 days:	18:406.04-004					
	air cure	N / mm^2	> 0,5	> 0,5	> 1,0	> 1,0
	underwater cure	N / mm^2	> 0,5	> 0,5	> 1,0	> 1,0
	hot house cure	N / mm^2	-	> 0,5	> 1,0	> 1,0
Sagging	18:406.04-005	mm	≤ 0,5	≤ 0,5	≤ 0,5	≤ 0,5

Table 1. *Mechanical requirements of adhesive mortars according to Brazilian draft standards (ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS, 1997).*

It is usual to find in Brazil adhesive mortars termed *flexible*. This classification is still confused because the concept of flexibility applied to adhesive mortar is still not clear. Only adequate standardisation based on research will solve this question

3. FLEXIBILITY OF ADHESIVE MORTARS

While hardening of Portland cement takes place, adhesive mortar gains bond and mechanical strength. On the other hand, layers of different material that make up the adhered ceramic tile system come to work together. Because of that, interfaces and materials are subjected to movements that create stresses that must not exceed material strength and bond between them.

Although influenced by different degree of restriction, ceramic tile facade panels defined by control joints need to dissipate stress to keep adequate performance and avoid problems. Bond, however, is not the only property that matters. Ceramic tile systems must absorb some degree of stress. Adhesive mortars, therefore, must be selected according to the situation they are going to be subjected to. Sunbaked large panels of ceramic tile demands more *flexibility* to avoid bond problems.

Cyclic load may also cause damage. Repeated movements of expansion and contraction can influence bond and cause failure because of fatigue. *Flexibility* also can avoid these problems.

The study of building moments that can interfere in the performance of ceramic tile is one of the most important features of the tiling design process. These movements have both internal and external origin and can be classified according to their main origin, as follows:

- movements due to permanent load;
- movements due to variable load;
- movements due to the action of temperature;
- movements due to the action of humidity;
- movements due to structural deformation;
- movements of foundations.

Depending on each particular case, one mechanism that generates movements becomes more important than another. Generally, however, the ceramic tile designer must pay careful attention to the possibility of thermal shock and hygroscopic movements. In the last few years structural deformation was usually critical, especially in high rise buildings. Drying shrinkage of masonry and stucco have to be always taken into consideration if cement based materials are used.

One of the most important problems about the performance of ceramic tile facades is to establish the magnitude of the movements that must be absorbed by the adhered tile system. In other words, the designer should be able to predict which is the *flexibility* necessary for the adhesive mortar and joint grout.

Adhesive mortars become *flexible* through the addition of polymers with elastomeric properties. Acrylics, styrenes and ethylene/vinyls are polymers used with that purpose. On the hand, polymers usually increase bond strength too. Is usual to find in Brazil adhesive mortars called ordinary or flexible. This classification is still confused because the flexibility concept of adhesive mortar is still not clear. Only adequate standardisation based on research will solve this question.

German standardisation DIN 53.265 (1980) also describes a method to evaluate the capability of deformation based upon the evaluation of shear strength of adhesive mortar. The test procedure considers the shear strength necessary to break the bond between two ceramic tiles, both set on concrete prisms. A minimum strength of 2,3 KN associated with a minimum deformation of 0,3 mm is required. The product of the strength multiplied by the deformation must be superior to 1 kN.mm. According to RIUNNO; MURELLI (1992) it is quite difficult to get a good reproducibility of specimens, specially when one has to set tiles on a 1.5 mm thick bed joint and moreover, keep the concrete prisms parallel to the ceramic tile during the preparation of specimens.

American standardisation ANSI A118.4 (1992) describes a method to evaluate the modulus of elasticity which can be consider an indirect way to measure the capability of deformation. Test procedures, however, do not fix numeric parameters to classify adhesive mortars deformability. For RIUNNO; MURELLI (1992), who studied this method, the determination of the modulus demands very accurate apparatus that increases error.

To be considered *flexible*, adhesive mortars must satisfy requirements of minimum load and strain during flexion tests. The UNION EUROPÉENNE POUR L'AGRÉMENT TECHNIQUE DANS LA CONSTRUCTION (1990) describes a procedure to evaluate flexibility of adhesive adhesives mortars. The flexion test described uses a specimen where a 3 mm thick layer of mortar is set on a board of expanded polystyrene foam. As an indication flexibility may be recognised if failure load is equal or exceeds 3 N while the corresponding deformation must be equal to or exceed 5 mm. The authors also reproduced this test procedure. They verified a strong influence of the polystyrene sheet where the mortars specimen is prepared. Nevertheless, these authors consider the UEAtc / CSTB procedure, the most adequate lab test to evaluate adhesive mortars flexibility.

4. LABORATORY WORK

In order to evaluate the flexibility of adhesive mortars a laboratory experimental study was carried out. Based on the work of RIUNNO; MURELLI (1992), the procedure recommended by UEAtc (1990) was used. First tests were run aimed to develop a cheap and easy-to-use apparatus that could reproduce conditions described by the method. After evaluating two different test mechanisms, an apparatus that controls deformation was chosen. Detailing of procedures is described bellow.

4.1. MATERIALS

A polystyrene sheet was used as a substrate for the application of mortar. The sheet was 5 mm thick and had a density of 16 kg/m^3. According to the directive density should be between 15 a 20 kg/m^3. It was cut into parts of 300 length and 80 mm width, as required.

In order to prepare adhesive mortars specimens on the sheet, a 300 mm long, 45 mm wide and 3 mm thick timber mask was prepared. All adhesive mortar specimens had these dimensions.

Ten different adhesive mortars were tested. These mortars were classified into different kinds, according to their composition. Table 1 shows this classification.

ORDINARY ADHESIVE MORTARS	POLYMER MODIFIED ADHESIVE MORTARS	LATEX MODIFIED ADHESIVE MORTARS
OM 1	PMM 1	LMM 1
OM 2	PMM 2	LMM 2
-	PMM 3	LMM 3
-	PMM 4	LMM 4

Table 2. *Different kinds of adhesive mortars that were tested.*

4.2. TESTING APPARATUS

In order to prepare mortar a digital scale was used. Dosage of admixtures and water were in weight. A laboratory mixer was used to mix mortar's components.

A steel trowel was used to spread mortar on the surface of the polyethylene sheets. Timber masks were used to guarantee the geometric the shape of the specimens.

In order to test specimens under flexural load according to the UEAtc (1990) recommendation a new apparatus was developed. An analogic extensometer was used to control specimen deformation with an accuracy of 0,01 mm. The digital scale was also used to measure applied load. A chronometer controlled speed test. A view of the test apparatus is shown in Figure 1.

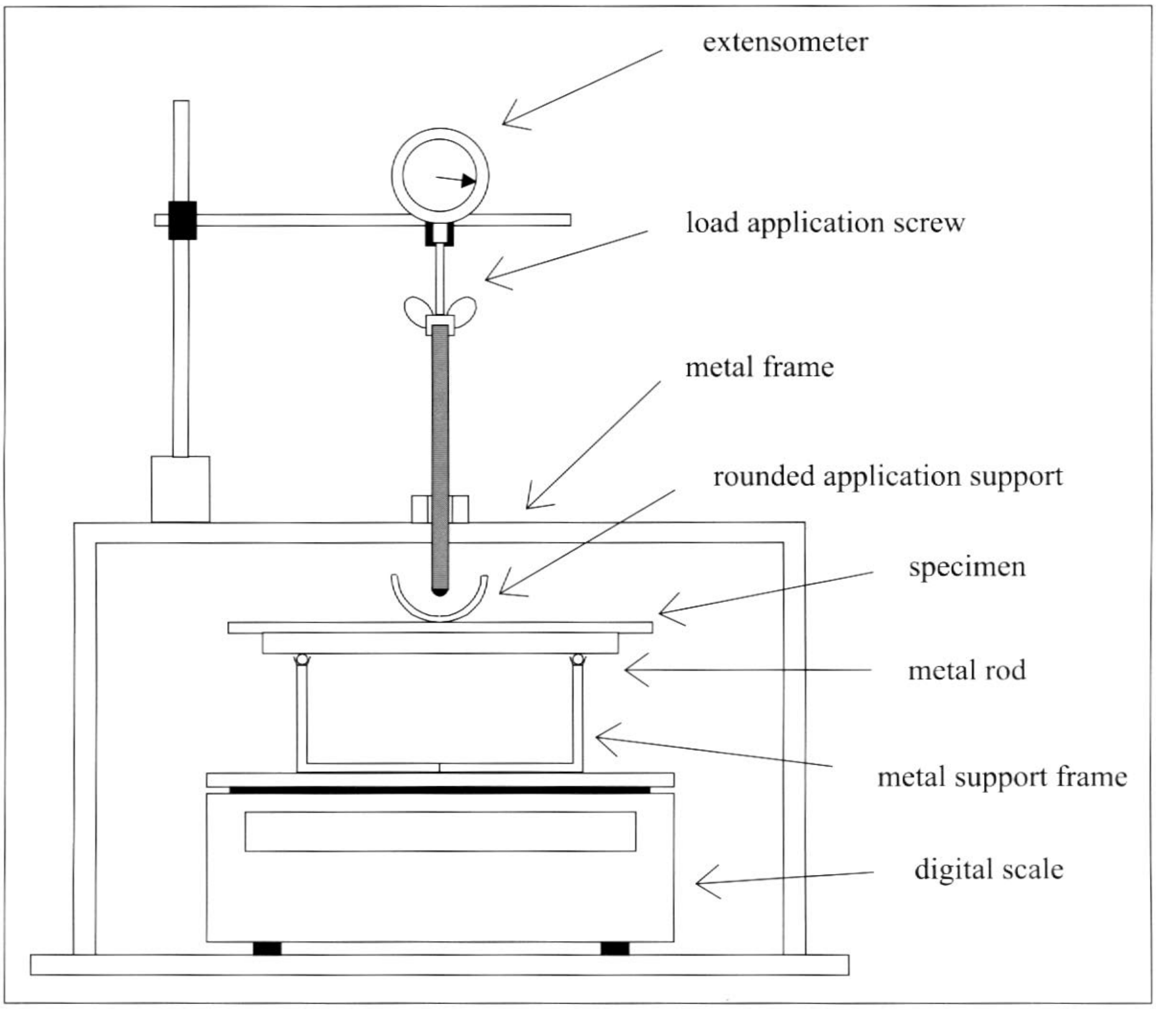

Figure 1. *Apparatus used to control deformation and measure load under flexural test of adhesive mortars.*

4.3. TESTING METHOD

Mixing procedures

Adhesive mortars were prepared according to the manufacturer's specifications, taking into consideration the recommended amount of water and admixture dosage. A planetary mixer was used to mix materials for at least 2 min. Fresh mortars remained *resting* for about 10 min. After that, mortars were mixed once more for 1 min.

Testing procedure

After positioning the specimen in the apparatus, the extensometer and digital scale were set up. The operator began controlling 2 mm/min displacement at the centre of the specimen through a screw as seen in Figure 1. The scale was used for load measurement. The operator assistant took note of load when failure occurred. One has to pay careful attention to the load shown by the scale. When the first crack happens, the load usually is relieved. This observation is particularly important when adhesive mortar is considerably deformable. A mirror in the correct position can also show when the first crack happens, but a spot light is necessary.

4.4. TESTS RESULTS

Test results are presented in Table 3. Load and deformation at rupture is shown according to the UEAtc (1990) procedures. Values of load represent the average of six to ten determinations for each kind of mortar. Coefficient of variation remains around 15 %. Factor F is the product of deformation in mm by the load in g, divided by 1000. This number can be used to simplify understanding and comparison of deformability considering load together.

ORDINARY MORTARS	deformation - mm	load - g	F factor
OM 1	**0.85**	**160**	**0.1**
OM 2	**0.91**	**149**	**0.1**

POLYMER MODIFIED MORTARS	deformation - mm	load - g	F factor
PMM 1	**4.13**	**370**	**1.5**
PMM 2	**1.84**	**304**	**0.6**
PMM 3	**2.53**	**436**	**1.1**
PMM 4	**4.15**	**374**	**1.6**

LATEX MODIFIED MORTARS	deformation - mm	load - g	F factor
LMM 1	**4.40**	**612**	**2.7**
LMM 2	**10.31**	**277**	**2.9**
LMM 3	**5.53**	**334**	**1.9**
LMM 4	**11.00**	**218**	**2.4**

MINIMAL REQUIREMENTS ACCORDING TO UEAtc (1990)	**5.00**	**300**	**1.5**

Table 3. *Deformation and load of flexural test of adhesive mortars hardened film. F factor is a suggested parameter.*

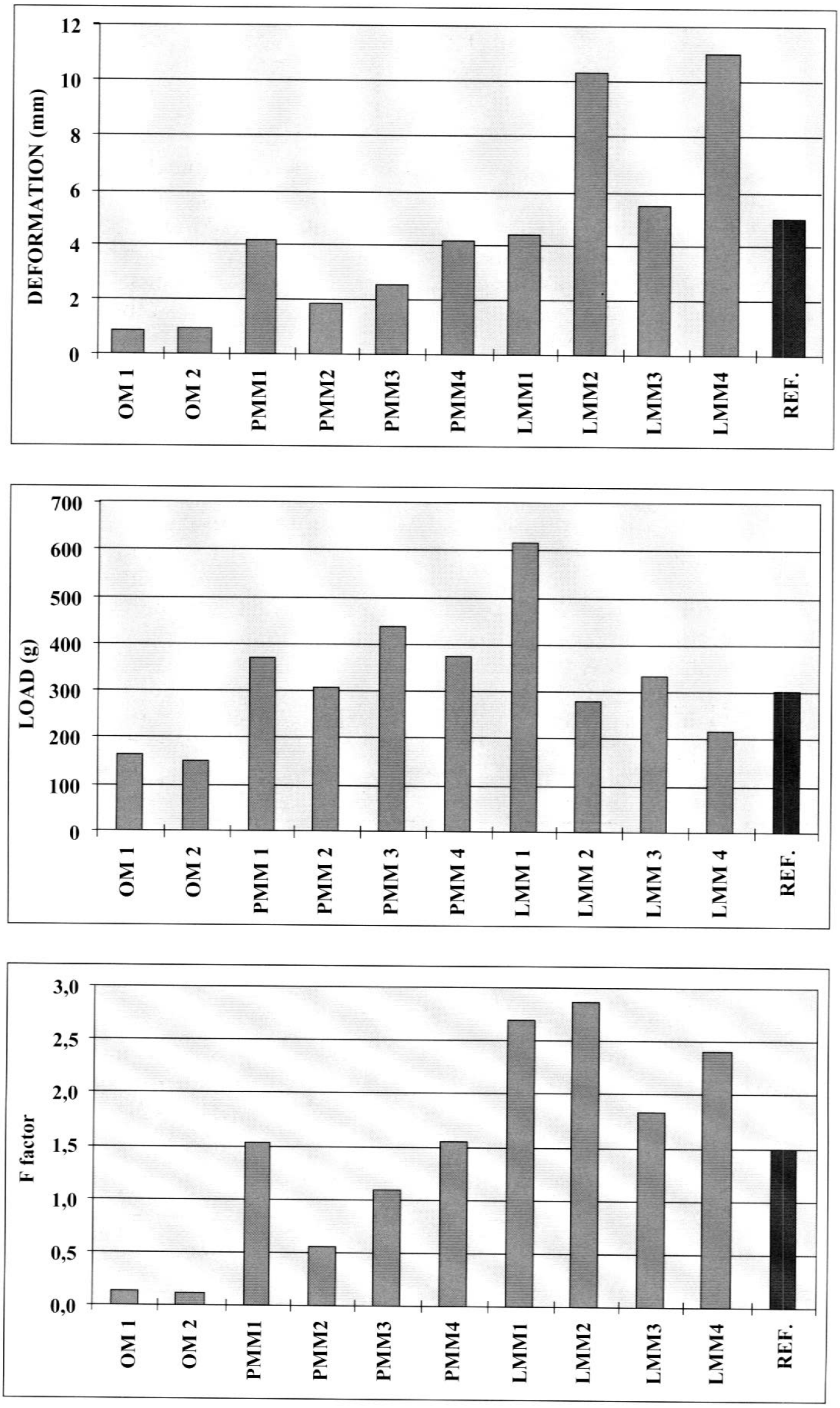

Figure 2. *Deformation and load of flexural test of adhesive mortars hardened film. F factor is a suggested parameter.*

5. CONCLUSIONS

Based on test results it is possible to conclude, in general terms, that the flexibility of the adhesive mortars referenced OM, PMM, LMM grows in this order due to the amount of polymer added. Chemical and physical properties of polymers also interfere in the results.

Test procedures and apparatus, in spite of their simplicity, show good results for evaluating flexibility, specially when flexibility is not very *low* or *high*. Tests of mortars with very high or very low flexibility are more difficult to conduct and to measure load and deformation at rupture. Low flexible mortars crack very suddenly and highly by flexible seem to never crack - only very small cracks can be seen. In these situations more accurate equipment should be used.

In the near future the authors intend to improve the apparatus and compare its results to an INSTRON machine recently purchased by the laboratory. A larger number of results may be used to allow a classification of adhesive mortars according to flexibility and categories of utilisation.

Results allow identifying a strong tendency of high flexibility in latex modified mortars. This particular feature could also be observed by RIUNNO; MURELLI (1992) through a similar comparative work.

It is recommended that researchers keep on studying flexibility to verify if the UEAtc (1990) directives are enough to consider the flexibility of adhesive mortars. It is suggested setting up an international laboratory program to evaluate the properties of mortar in order to reach definitive parameters to elaboration of adequate ceramic tile facade design. One should also remember that flexibility is only one requirement of adhesive mortars. Many others have to be considered. Designers must take into account that for each particular situation other requirements may arise, such as: tensile bond strength, shear strength, open time, durability and applicability.

6. REFERENCES

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