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FLAT JACKS: EVOLUTION OF THE TEST TECHNIQUES

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SUMMARY

Tests undertaken with the flat-jacks on masonry, and carried out with the traditional system, show that final results may be strongly affected by a poor accuracy of the measurment and of the cut procedures.

Among the major sources of errors the following can be mentioned:

- the displacement of the measurement reference points due to vibration during the cut;

- the variation of the jack behaviour after repeated use of the device.

These difficulties emphasize the role of new test tecniques that allow an in-line control of the deformation induced by the cut and the role of a preliminary check of the jack coefficient, before every test.
With a strict metodology including those two perspectives, a satisfactory level of repeatability and reliability can be reached.
Some commentaries are proposed on advanced metodologies and some actual cases are described.

1. INTRODUCTION

The knowledge of the in-situ stress state at various points of a masonry wall is an important factor in determining the actual conditions of a building, and hence its safety.

This is the purpose of the flat jack test, which was first introduced in 1978 for the analysis of a monumental building (1) and which has undergone, since then, significant developments and improvements (2,3,4,5,6).

A brief summary of the principle of the flat jack-test technique for masonry follows:

a) the stress state of the masonry to be tested is first modified by making a horizontal cut perpendicularly to the surface of the wall;

b) the cut induces a release of the in-situ stress (σ_o) so that the edges of the cut tend to converge;

c) then, a flat jack is inserted in the inersion and the applied pressure (p), which forces the surrounding masonry to return to the same state of deformation as before the cutting is assumed to be approximately equal to the in situ stress;

d) the pressure value (p) is connected by a coefficient (Km), characteristic of the jack, and by the ratio of the area of the jack to the area of the cut (Kt).

Therefore the in-situ pressure is equal to:

$$\sigma_o = p \cdot Kt \cdot Km$$

where p = internal pressure of the jack by which the state of deformation prior to the cutting is restored;

Kt= area of the jack/area of the cut;

Km= contact area/area of the jack.

The increasingly widespread use of the test has added new experience in this field, demonstrating the potential but also the limitations and the possible sourses of errors of the test.
Here below are some observations regarding the test procedure and some of the technical aspects which improved the quality of the experimental results.

2. USUAL MEASURING PROCEDURE

In common practice measurement of deformations is made by means of a manual removable deformometer which uses reference points (data) applied to the wall (as in fig. 1a). Prior to the tests and during the subsequent phases the operator takes measurements by applying the deformometers from time to time between the data pairs placed across the cut.

In the test set-up generally adopted, 3 measurement bases are arranged, the length of which varies between 10 to 35 cm, according to the adopted instrument.

During these operations:

a) errors are possible due to handling when connecting the instrument to the reference points;
b) the obtained measurements are only relative displacements;
c) all intermediate information referring to the cutting phase is lost.

With regard to point (a), even if the deformeter is sufficiently accurate the repeated connection of the instrument to the datums may give rise to errors. Those are mostly due to manipulation by the operator to errors of parallax and to variation of the pressure exerted when positioning the instrument.

Regarding point (b) the obtained measurements consider only the relative displacement of two points which converge towards the incision. It is therefore possible to measure only the sum of the displacement of the two points and not the absolute displacement of each singular point thus loosing a valuable piece of information.

With regard to point (c) it is obvious that cutting operations imply the absence of obstacles. In usual practice therefore a first measurement is taken before cutting and another when cutting is completed. Any information relating to movements of the masonry blocks due to distubances to accidental slips or localized lack of homogenity in the surface is therefore lost.

3. USE OF NON REMOVABLE DISPLACEMENT SENSORS

In order to avoid manual monitoring and to enable measurements to be taken even during cutting operations some improvements have been introduced in the test methodology. These imply the use of displacement trasducers (derived from suitably adapted rock microfessure meters) arranged externally to the cut according to fig. 2.

Each microfessure meter consists of two ball and socket joints and a system of concentric rods integral with one of the two ball and socket joints: the relative movement of the anchorages is converted into movement between the two concentric rods measured by the displacement transducer.

The microfissure meter is anchored to the masonry by means of threaded head screw anchors, to which the ball and socket joints are screwed. The ball and socket joints are specially adapted so that they can easily be mounted and used in whatever uneven surface condition (see fig. 3).

For special requirements, as in the case of monumental building walls, the ball and socket joints may be glued to the masonry instead of being fixed using mechanical devices.

The displacement trasducers are connected in line with an analogue (or digital) acquisition unit, which enables the data to be plotted on a scale diagram.

The possibility of a detailed record of the displacements during all the various test phases (cutting, insertion of the jack, loading and unloading) has shown how easily situations which actually originate from other causes (such as for example local displacement of loose blocks of the wall) are confused with elastic deformations caused by release of stresses.

In particular it was observed how detrimental for the accuracy of the results an inaccurate cutting procedure may be.

In line measurements also make it possible to perform several load cycles within a short time since the responses produced during progressive load increase can be quickly verified.

Thanks to the arrangement of the instruments and as a result of the distance between points or as a result of the distance between the points of anchorage the obtained displacements may be considered to be absolute for practical purposes. Reference points in fact, are approximativaly 65 cm away from the cut in an area only slightly effected by the variation in stress state caused by the test.

The diagram of fig. 4, obtained in a test on brick masonry, shows separately the displacements obtained above and below the cut.

As it can be seen, the movements in the lower zone, in fact, are smaller than those of the upper part.
In this zone in fact there is only decompression of the masonry whereas above there is a state of vertical tensile stess due to the weight of the masonry no longer supported by the base. This fact results in greater movements.

No reference in this paper will be made to the well known which uses two flat jacks positioned in pairsat a given distance to define the elastic modules of the included portion of masonry.

It is envisaged however that even with only one flat jack it is possible to investigate the approximate value of the elastic modules of the masonry. This may be performed using an arrangement of the sensors such as that described and the data obtained from the portion of wall below the cut, which always remains under compression.

4. CUTTING OPERATIONS

Experiments carried out with a in line acquisition system demonstrated the necessity of improving the quality of cutting operations.

It became necessary in fact to adopt an accurate and calibrated device capable of making a cut without causing disturbance to the masonry. With this aim, excellent results have been obtained in recent experiments using a special hydraulic saw with a 370 mm diameter diamond blade which produces an incision 4 mm thick.

The blade is ring shaped with an eccentric movement system which enables the blade to advance up to a depth of 265mm. A special jack with the same shape of the cut (1= 365 mm; D= 260mm; H= 3,5mm; is then inserted in the incision) (see fig 1.5)

In the above mentioned fig. 4 an example is shown of the displacement measured during the progression of the cutting. An accurate interpretation of these makes it possible to define whether the in situ stress has a constant pattern inside the wall or whether there is a tension gradient,due to combined compression and bending stress factors. The precision and quality of the cutting operations which are still now almost completely entrusted to the operator, have to be further improved.

Experiments have been carried out with a column type support with rack movement of the cutting device. This allowed an improvement in the value of Km, rising from a value of 0,9 to about 0,95 due to the fact that the shape of the cut and the shape of the jack correspond almost perfectly.

5. THE Km COEFFICIENT

Also called "edge coefficient", it defines the effective area of thrust of the flat-jack and depends on the deformability of the jack that is on its capacity to adapt to the surface of the cut, so applying constant pressure at all points. The coefficient is always lower than 1 and may vary from 0,80 to 0,95 according to different shapes of the jack. These values, seldom indicated by the manufacturers, were verified experimentally by the authors, simulating real in situ conditions in which between the contrast surfaces and the surfaces of the jack an initial gap was present.

Two fixed distances (d) between the contrast plates were adopted, namely 3,85 mm and 5,25 mm, which are respectively 10% and 50% greater than the thickness of the jack (3,5 mm). A load measuring device was used to record the face applied by the jack to the plates at a given internal pressure of 200 N/cm^2. It was thus possible to make a comparison between the face really applied by the jack to the contrast and the maximum theoretical value obtained by multiplying the internal pressure times the area of the jack.

A group of 8, new, semicircular flat-jacks of the same dimensions was tested. The following results were obtained showing a noticeable difference between the mean values of Km at different initial distance of the contrasts.

d(mm)	Km(mean)	Standard
3,85	0,91	0,03
5,25	0,83	0,03

table 1

The results show that coefficient Km is not a constant of the jack in fact if depends from the variation of its internal volume at different pressure. Significant gaps between the edges of the cut and the jack give rise to considerable variations in the results, which are unfortunately difficult to evaluate.

It can be concluded that it is advisable for the thickness of the cut to be as close as possible to the thickness of the jack, adopting an accurate cutting technology.

As a concluding remark, we have observed that also a repeated use of the same jack in the subsequent system test can modify the Km coefficient.

Fig. 5 illustrates the results obtained with the same jack that was mechanically flattened out at the end of various in situ tests and hence tested in laboratory conditions at the same pressure and with a 5/25 mm distance between the contrast plate.

After the first 5 tests the value of Km was practically constant. During the last in situ test a strong adaptation of the jack to relevant displacement between the masonry blocks caused a considerable drop in the Km value, putting it out of service.

Repeated checking of the jack after each in situ test is therefore a recommended practice which permits to identify any significant loss in its functional capacity.

6. CONCLUSIONS

The flat jack test technique has been found to be extremely useful and sometimes indispensable to obtain information useful for a correct structural diagnosis. As the obtained measures are always influenced at least by the heterogenity of the measuring and by the very particular conditions found in situ it is advisable to minimize all other form of inderterminacy.

For this purpose:

- the use of a special ring shaped saw and of a jack shaped to the cut tends to bring the Km value closer to 1;
- a reduced thickness of the jack and of the incision tends to bring the Km value closer to 1;
- the use of fixed sensors makes it possible to obtain undisturbed data in large number and enables the test to be repeated easily;
- an arrangement of the sensors outside the cut permits to take measurements also during the initial

cutting operations and to obtain information regarding the absolute displacement of the part above and of the part below the cut. This fact helps in identifying local disturbances and for imperfections in the masonry.

The importance of repeated checks of every jack, by laboratory control of the Km coefficient at the end of each in-situ test, should also be emphasized.

Finally attention should be drawn to the need for more in-depth research on the subject, both on the experimental and on the theoretical side, to succeed in making the test more rational and standardized.

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Photo 1 **Removable mechanical deformometer** used in common practice.

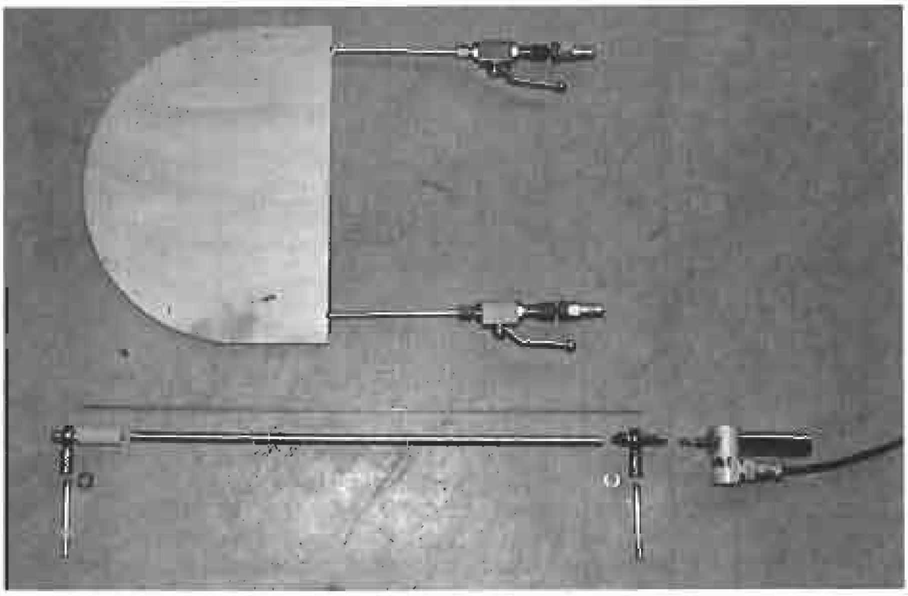

Photo 2 **Semicircular flat-jack and microfessure meter** components used in advanced test tractice.

Photo 3 Displacement sensor device: detail of an anchorage

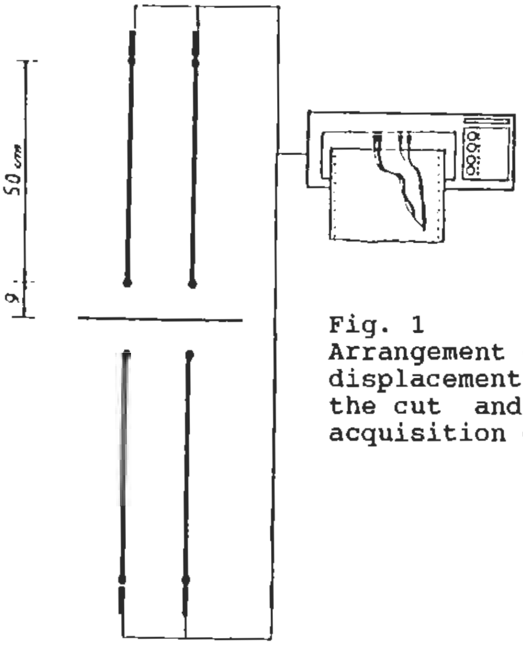

Fig. 1
Arrangement of 4 non removable displacement sensor external to the cut and connected with an acquisition data unit.

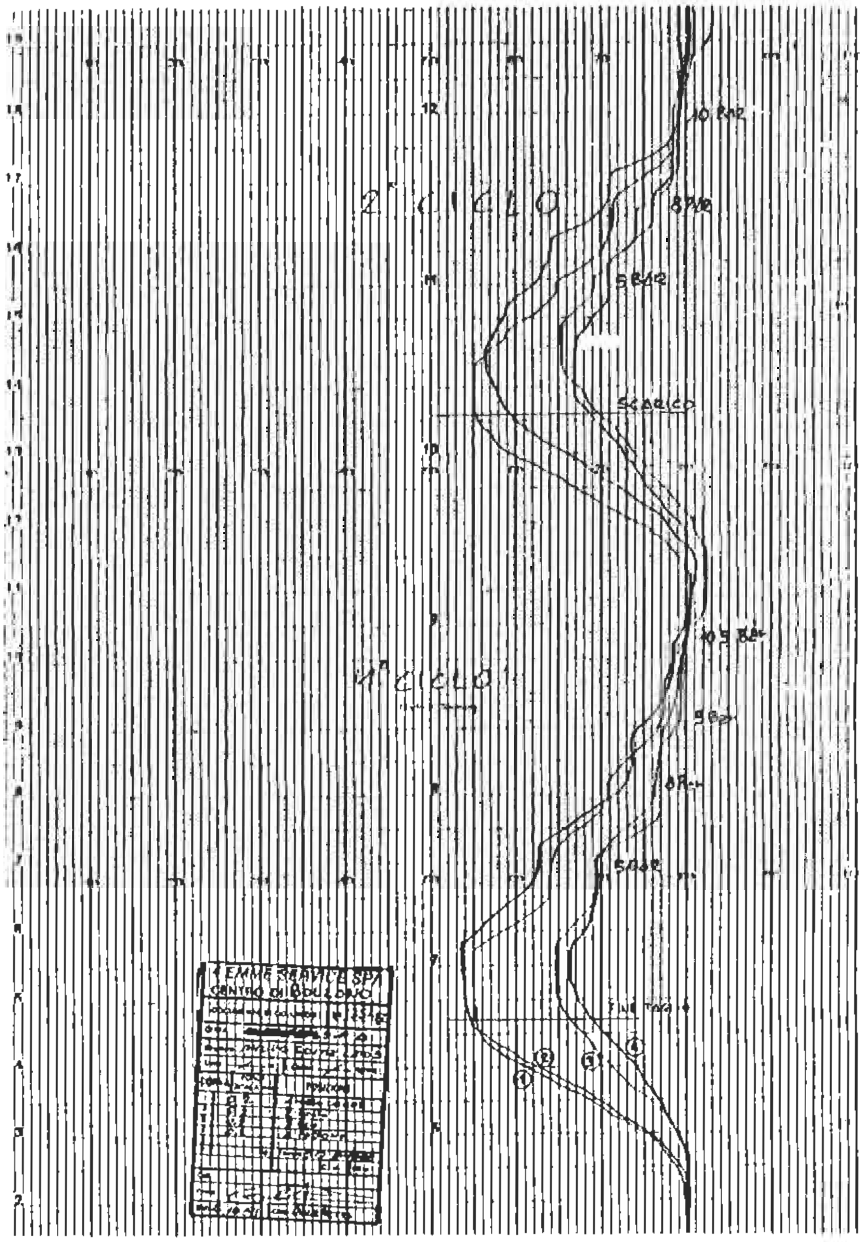

Fig.2 Record of the displacement at various cycles. Sensors (1) and (2) above the cut, show displacement greater than sensors (3) and (4), below the cut.

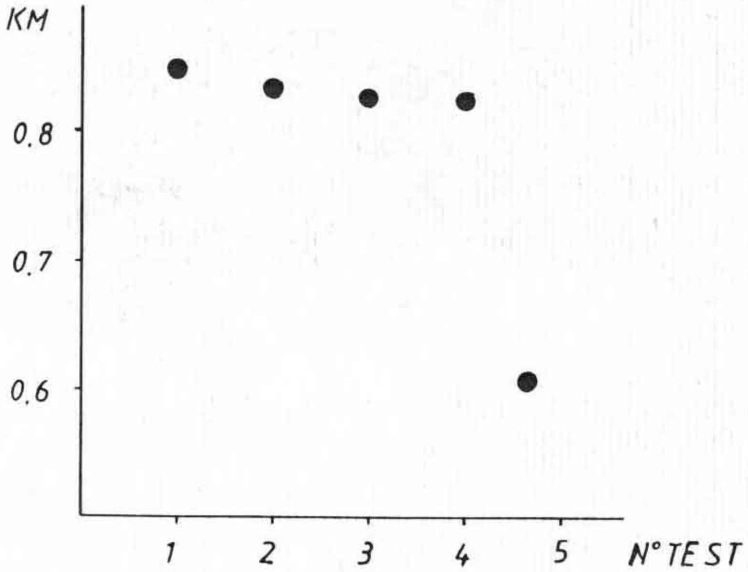

Fig. 3 Case history of the variation of KM for a flat-jack after various in situ tests.