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RILEM TC 177-MDT: 'Masonry durability and on-site testing'

RILEM Recommendation MDT. D.1 – Indirect determination of the surface strength of unweathered hydraulic cement mortar by the drill energy method

The texts presented hereunder are drafts for general consideration. Comments should be sent to the Chairperson Prof. Luigia Binda, Dipartmento di Ingegneria Strutturale, Politechnico di Milano, Piazza Leonardo da Vinci, 32, I-20133 Milano, Italy; Fax (+39) 02 23994220, Email: luigia.binda@polimi.it, by 28 February 2005.

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0. SUMMARY

There is an enduring interest in the durability of masonry acting as a composite material especially because a very large proportion of the world's heritage buildings and civil engineering structures are predominantly constructed from this material. There is a continuing need for information on the best way to maintain a state of good preservation of masonry and on sympathetic techniques for repair and reinstatement of deteriorated masonry.

In order to evaluate materials for use in both new and old structures, laboratory accelerated durability tests are necessary. Equally, a range of in-situ, non-destructive or semi-invasive tests are required to evaluate the status and condition of structures in the field and allow quality control of repair systems.

1. SCOPE

This recommendation specifies an in-situ method of testing or evaluating the performance of hydraulic cement mortars in masonry walls either 1) pointing mortar (where between 100% and 25% of the depth will be sampled depending on the thickness of the pointing layer or 2) full bed mortar (where only the surface layer (~5 mm depth) will be sampled). The method is indirect as what is measured is the energy consumption to cause the abrasion / attrition of a set depth of mortar by a rotating drill and this can be correlated with other properties such as cube strength by means of empirical calibration data.

The technique can give useful data on the following characteristics:

- Batch-to-batch variability of strength or general quality.
- Variation of quality in relation to a reference sample.
- Changes of properties with time, such as strength increases due to hardening and the effects of weather conditions and additives.
- Absolute values of mortar strength, provided a suitable calibration data-base is available.

It should be understood that the use of the test on weathered full-bed mortars may give only data about the weathered layer and hence a false indication of the overall condition of the full bed. For this reason, the test is not recommended for very old mortars. Tests on weathered pointing mortars can give reasonable data about the overall quality if a significant proportion of the full thickness is sampled. Thus on building sites the method has application both for quality control purposes and as a means for trouble shooting of recently placed mortar. In the laboratory it is useful for control of hardness development during curing and hardening, or as a monitoring/control parameter for other tests such as acid rain and freeze-thaw tests.

The method is viable over a wide range of mortar strengths from 1 to 20N/mm² but will lose accuracy at the ends of the range. The method is not suitable for mortar beds with a thickness less than around twice the diameter of the drill bit. Some independent calibration evaluation has been carried out.

2. PRINCIPLE

The basic principle is the measurement of the total energy consumed in drilling a set depth (5mm) into a mortar layer using a normal commercially available 4mm, diameter carborundum-tipped masonry bit. This varies with the hardness and strength of the mortar, the sharpness of the bit and probably other factors such as the moisture content, sand (aggregate) type and mortar formulation. This principle allows direct use for comparative tests between areas with differing mortar specification and for estimates of strength if relevant calibration data is available. The method will be unreliable for mortars containing large proportions of relatively coarse sand particles > 1mm diameter, especially if the sand particles are of a very hard material, (*e.g.* flint aggregate) because of aggregate interlock. The concept was probably first described by Chagneau and Levasseur [2] and trials of a similar system, also based on a standard battery operated drill connected to a total energy consumption integrator, were reported by de Vekey [3] and by others [4-6].

3. SPECIMENS

3.1 Selection of test area

Preferably, measurements are performed on mortar beds within areas or panels ranging from 1x1 m² up to 1x2 m², but smaller areas may be used where appropriate, for specific investigations. A clear depth of 5mm is required for the standard determination. The strength at different depths can be tested by drilling oversize access holes and then carrying out the standard procedure but this is likely to be impractical without specially adapted test devices.

3.2 Joint width

The standard apparatus uses 4mm diameter bits. These clearly need a minimum joint thickness in excess of the drill diameter. To avoid mechanical interaction between the drill and the masonry unit materials the hole should be centred in the joint and have a clearance of more than twice the maximum common particle size of the sand. Thus for a sand with a fair proportion of 1mm diameter particles, the joint width should be 8mm or greater. *(Note: 3mm diameter bits are now available and could be used in narrower joints but no calibration data is available to date).*

Fig. 1 - View of a commercially built test apparatus.

3.3 Specimen number

A minimum of ten replicate measurements, distributed randomly over the test area is recommended for each determination. If greater precision is required or the mortar is highly variable then greater numbers may be necessary.

3.4 Condition of test area

Ideally measurements shall be made on air dry masonry. For the purpose of field test this is defined as masonry which has not been wetted in the past 24 hours and which gives visually the impression of being dry (*i.e.* has some suction). Pore moisture or free water is likely to have a significant effect on the measurement and thus the moisture content should be measured in critical cases *e.g.* using the drilling technique RILEM MS-D.10 [1].

4. APPARATUS

The most sophisticated form of the concept developed at the University of Pisa [4, 5], has been commercially manufactured in Italy and is illustrated in Fig. 1. This is based on a standard 9.6 volt battery-operated electric drill modified to give an alarm when a set depth has been reached. A 4mm diameter drill is used. It has a convenient digital energy consumption integrator which can screen out the idling (free running) energy consumption of the drill. Further papers, relevant to the commercial system, are listed in the bibliography [6, 7].

5. PROCEDURE

Select an area of the wall of the order of 1-2 m². This may be roughly square or could be a long rectangle enclosing one, two or more bed joints which are likely to be built from the same mortar batch.

Switch the drill system on and check that the battery is sufficiently charged. Select the first drilling position. Try to use as flat an area as possible and avoid obvious surface inclusions of large aggregate particles and any other obviously unrepresentative sub-areas for the hole-position.

Set the drill running and allow the system to stabilise and balance out the free-running power consumption. The system emits a tone when ready. Apply steady pressure and drill at the chosen point until a second tone indicates that the 5mm depth has been achieved. Record the result. Repeat this process on randomly selected but approximately evenly distributed points over the chosen area and record all the data. Normally a minimum of ten replicate measurements will be taken. However, on a variable substrate, as many as 50 may be taken to optimise the precision of the method.

If the wall is pointed to a minimum depth of 5mm with a different mortar to the bedding mortar, this procedure will give data on the pointing. To test the bedding mortar, small areas of pointing have to be removed in advance of the test operation.

Check the drill bit regularly by visual inspection and replace it when it starts showing obvious signs of wear.

To achieve a very consistent (repeatable) result calibration reference material may be employed to give a more objective indication of drill wear. Two materials have been suggested – a soft brick manufactured in Italy and a soft chalk rock found in the UK. Neither have been fully evaluated as yet. If such a reference is used then a reference drilling would have to be carried out after a set number of test drillings; e.g. *after every set of 10 sample drillings. This would allow a wear correction to be applied to the test result.*

6. TEST RESULTS

Where the data is used to indicate/monitor quality variation, to follow changes due to hardening or cyclic actions in durability testing, it is sufficient to calculate the mean of the ten (or more) measurements.

If absolute indications of equivalent strength properties such as cube strength, flexural strength or tensile strength are required the data must be transformed using a suitable calibration curve. Previous calibration trials indicate that the relationship between drilling energy and strength properties is not linear and therefore each individual measurement must be transformed before the mean is calculated. A calibration for cube strength is supplied with the commercial system but other parameters would require further data.

Examples of calibration data for cube strength are given in the References / Bibliography.

7. STANDARD CALIBRATION PROCEDURE

The following procedure is typical for calibration of the technique to indicate the cube strength of un-weathered hydraulic cement mortars.

1. A set of mortar mixes with a varying content of the main hydraulic cement are defined.
2. For each defined mortar mix of the set, a mix is made up using carefully measured quantities of binders, aggregates and water. The type and grading of the aggregate should be reported.
3. Normally, standard quality control tests such as air content, density, flow and consistence are measured.
4. Standard cubes (100mm, 70.7mm or 50mm side) or prisms (40x40x140mm) are cast complying with BS EN 1015 or an equivalent national standard and the specimens are cured as specified.
5. Simultaneously, unit / mortar stack prisms are built using the same batch of mortar and are cured in accordance with BS EN 1052-1, RILEM LUM B3 or B4 or an equivalent national standard.
6. At the end of the curing period the cube strength is measured in accordance with BS EN 1015-11, or an equivalent national standard and at a similar time the drill energy test is carried out on the stack-bonded specimens.
7. A calibration curve is plotted relating the drill energy data with the cube strength data.

In principle the same procedure could be carried out with other mortar types and other parameters such as flexural strength or hardness.

8. TEST REPORT

1) A reference to this method.
2) A description of the masonry including
   - the size of the area(s) or the panel(s) tested
   - the type and size of the masonry unit;
   - the height and width of the mortar joints;
   - the date of erection of the masonry;
   - the nominal specification of the mortar (if known)
   - other relevant data, *e.g.* curing conditions.
3) The moisture content of masonry being measured, where critical.
4) All individual measurements with an indication of their location.
5) The mean of individual measurements or the mean of equivalent strength values as required.

9. REFERENCES AND BIBLIOGRAPHY

[1] RILEM MS-D.10, 'Measurement of moisture content by drilling', *Mater. Struct.* **30** (1997) 323-328.

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[3] de Vekey, R.C., 'In-situ tests for masonry', Proc. 9th Intl. Brick and Block Masonry Conf. Vol. 1 (1991) 621-627.

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[7] PNT-G Instructions manual.