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Revising the French experimental standard for unfired earth blocks

The original French standard, often referred to as the "Mayotte" standard, was first published in October 2001. Mayotte is a French island in the Indian Ocean, close to Madagascar, and conventional building products are said to be 35% more expensive on the island [1]. A local solution made of compressed earth blocks (CEB) was therefore very advantageous. Mayotte has a significant heritage of compressed earth block construction with more than 18,000 recent buildings. Their widespread adoption gave rise to the French standard on compressed earth blocks and more recently in 2018 to a technical validation procedure, elaborated in France by the CSTB (Centre Scientifique et Technique du Bâtiment), for earth blocks used as a structural material for R+1 (two-storey) buildings only and up to R+4 (five storeys) if the blocks are non-structural [2].

The French standard gives no indication of the type of building in which the earth blocks can be used. It homogenises the testing procedures for brick manufacturers so that they may label their products in terms of performance as defined by a set of standard tests. This in turn guarantees the quality of the product to the consumers and building control inspectorate. This is the context and scope of the old and the new version of the standard. The materials it concerns are unfired earthen blocks or bricks (both terms are used synonymously) used for internal and external masonry walls. Any additional products used (additives or hydraulic binders) that are not naturally present in the earth must be declared. It details test procedures for full blocks with perforations of no more than 25% with an apparent dry volumetric mass greater than 1050 kg/m^3. The characteristics of the blocks that need to be tested and verified according to the standard are described below.

Application classes

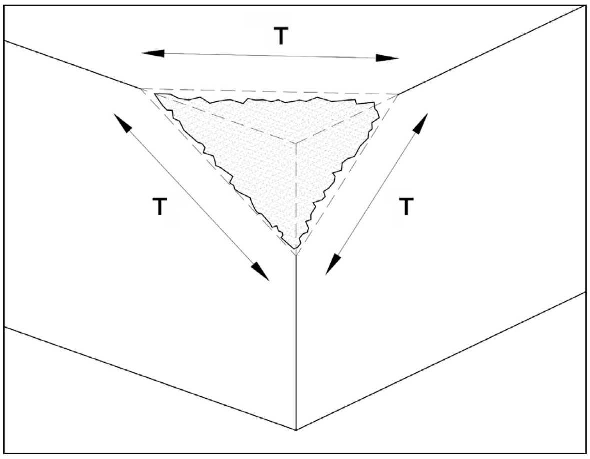
In the new version, the results of the tests define the type of application for which the blocks may be used. The tests relate to the resistance of the blocks to water degradation. Four application classes are defined according to the climatic conditions to which the brick wall will be exposed and follow the same pattern as those given in the German DIN 18945. The classes are described in Table 1.

Form, size and shape

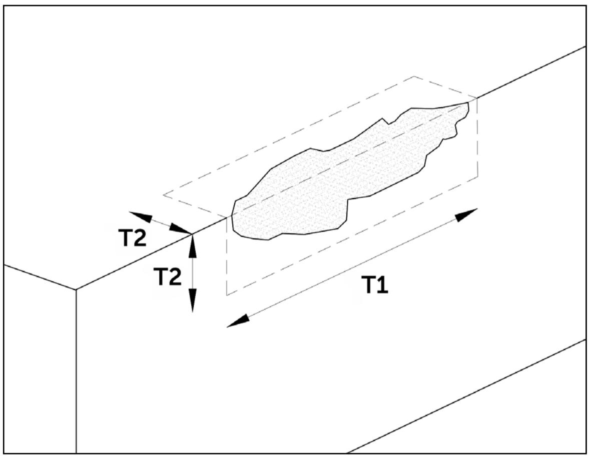
The are no restrictions on size, the blocks should be in the shape of a parallelepiped and sufficiently homogeneous with a dimensional variation of less than +/- 3 mm for CEB and extruded earth blocks and +/- 6 mm for unstabilised blocks. The blocks should not exhibit any significant cracks (e.g. that span the full length of a block). Figure 1 and Figure 2 show the maximum permissible extent of defects to the integrity of the blocks and should not exceed the length described in Table 2.

Table 1: Application classes

Application domain	Application class
Exterior masonry with no rendering exposed to weather	CL1
Exterior masonry with rendering exposed to weather	CL2
Exterior and interior masonry sheltered from weather	CL3
Interior dry masonry (no mortar used)	CL4



01 Extent of defects at block corners



02 Extent of defects along block edges

Table 2: Defect dimensions tolerance

Default location	T	T1	T2
Maximum length allowed (mm)	20	30	5

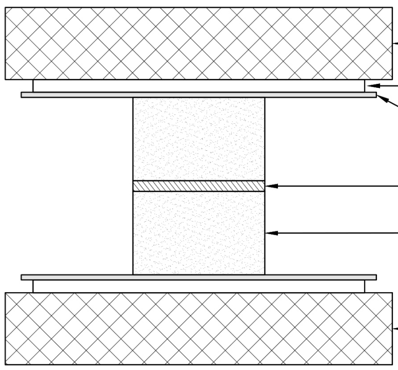
Compressive strength

In the new version of the standard, only the dry compressive strength is considered. The mechanical resistance of a block varies greatly depending on its moisture content [3]. The standard specifies that the blocks should never be saturated with water. Consequently, specific construction designs must be employed to ensure that earth blocks cannot be saturated by water. Such precautions are a matter for the building designers or builders and are not part of the scope of the present standard. The decision to specify only the dry compressive strength was motivated by the following reasons:

– The normal conditions correspond to the dry compressive strength.
– If both values were provided, the risk is that the wet compressive strength would be employed systematically for structural design. This would effectively completely rule out the use of unfired clay blocks, or at least excessively favour the use of stabilisation methods. For centuries, intelligent design solutions using unfired earth blocks have not led to any problems of durability.

Test procedure

The compressive strength test differs considerably from the German standard and is, therefore, discussed here in greater detail. The French standard tries to minimise the effect of excessive dissipation of energy at the edges so that it better approximates the real compressive strength of a wall bond. To reduce energy dissipation, friction at the edges needs to be avoided with an elastic material that allows lateral displacement. The aspect ratio was also considered, and the test assembly therefore employs two half blocks with a normalised mortar (regardless of the size of the brick). This increases the aspect ratio which reduces the effect of energy dissipation at the edges and provides an indication of the compressive strength of assembled blocks. A description of the procedure is given in Figure 3. The results, expressed in MPa, correspond to the maximum force on the cross-sectional surface of the specimen, and is classified in different categories as shown in Table 3.



03 Compressive strength test

Table 3: Categories of compressive strength

Compressive strength category	RC 0	RC 1	RC 2	RC 3	RC 4	RC 5	RC 6
Minimal compressive strength (N/mm^2)	<1	1	2	3	4	5	≥ 6

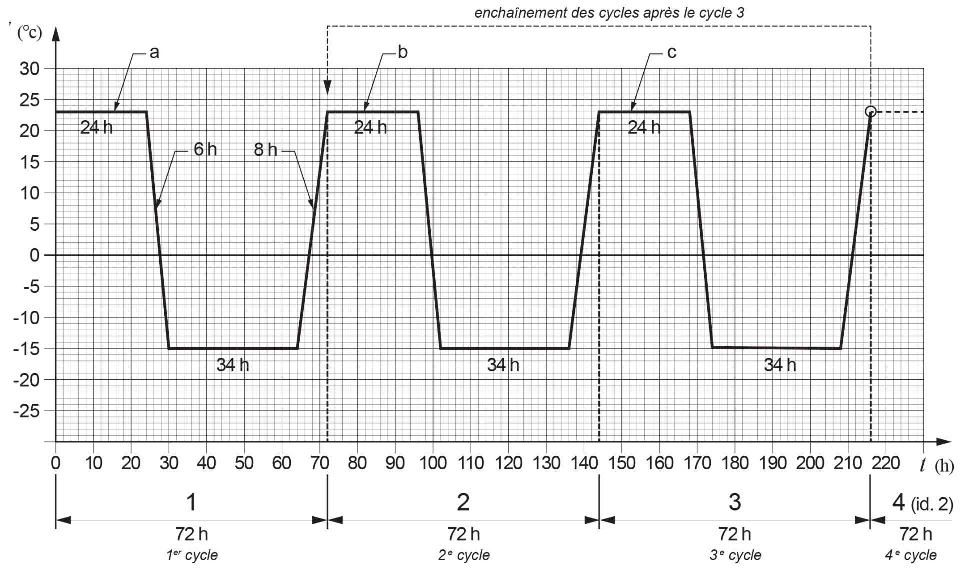
Durability with respect to exposure to water and freezing

The previous version only considered liquid absorption by capillarity and dimensional variations under extreme conditions. In the new version, based on the German DIN 18945, several tests are considered to estimate the impact of water on the durability of the brick, which determines the application class. Table 4 presents the tests considered and for which application classes they are required. The capillarity test is no longer included as the consensus is that it provides no valuable indication of durability.

The immersion test entails immersing the brick in 10 cm of water for 10 minutes. The mass loss is weighed and provides an indication of the resistance of the brick to immersion. This test makes it possible to rapidly eliminate blocks that may be very sensitive to the contact with water. The contact test involves placing moist cellulose textile in direct contact with the surface of the brick. The test involves observing the occurrence of any resulting cracks and defects. All classes of brick that will be exposed to wet mortar need to undergo this test. The freeze/thaw cycle test is required only for class CL1 and CL2, that is to blocks exposed to external weather conditions. The cycles used are illustrated in Figure 4 where (a) corresponds to a period of humidification (0.5 g/cm^2) with the moist cellulose textile, (b) a period where the sample is placed in a sealed box or a climatic chamber without the moist cellulose textile, (c) a second cycle of humidification (0.25 g/cm^2). Here too the occurrence of cracks and defects that form during the test are observed.

Table 4: Durability tests and application classes

Class	**Immersion Test** (Mass loss in %)	**Contact test**	**Freeze/thaw cycles** (# of cycles)
CL1	≤ 5	No cracks, or defect due to swelling observed	≥ 15
CL2	≤ 5	No cracks, or defect due to swelling observed	≥ 5
CL3	≤ 20	No cracks, or defect due to swelling observed	Not required
CL4	Not required	Not required	Not required



04 Temperature curve in the freeze/thaw cycle testing

Abrasion resistance

This test was already part of the previous French standard and entails using a metal brush of a given mass to brush the brick evenly for a specific period of time. The mass variation is recorded, and the result is expressed as the abrasion coefficient (g/cm^2) given by the following formula:

$$Ca = \frac{M_0 - M_1}{S}$$

where M_0 and M_1 are respectively the dry mass recorded before and after the test, S is the surface brushed during the test. The abrasion test is not mandatory for certification of the blocks.

Designation of the blocks

Blocks that are certified by the standard will carry a designation that denotes the type of manufacturing process, the application class, categories describing the range of its compressive strength and density, the dimensions, the stabiliser content and the reference to the present standard, for example: BTE – CL2 – RC 4 – 2.0 – 5 × 11 × 22 – 0% – XP P13-901.

For the method of production, the abbreviation BT is earth brick "Brique de Terre" in French and the following letter is either Compressed, Extruded or Moulded (Adobe).

Additional testing procedures

Further characterisation, including the vapour resistance factor and thermal conductivity, can also be undertaken but is not mandatory. These tests refer directly to existing European standards, respectively the NF EN ISO 12572 and one of the following NF EN 12664, NF EN 12667 or NF EN 1745. Fire resistance testing is not considered necessary if there is less than 1% per dry mass of organic matter in the brick.

Conclusion

This paper presents an overview of the new version of the French experimental standard XP P13-901. The full testing procedures are described in the standard. It certifies unfired earth blocks, provides a unified testing procedure for brick producers to declare the performance of their products. The revision of this standard responds to increasing activity in the field of earth construction in France. At present, standards and regulations that can bring earth a step closer to becoming a more accepted and used construction material are still lacking in France. Meanwhile, we are seeing a surge in interest from the general public and authorities looking to develop the use of this material. In 2020, a national project on earth construction is being initiated to encourage scientists and professionals to work together on overcoming aspects that still represent an obstacle to development in the sector.

Method of production	Class	Mech. strength category	Density category	Dimensions (cm)	Stabilisation (% of dry mass)	Normative reference
BTC	CL1	RC 0	1.2	h x b x l	0 %	XP P13-901
BTE	CL2	RC 1	1.4		< 5 %	
BTM	CL3	RC 2	1.6		5 – 10 %	
	CL4	RC 3	1.8		> 10 %	
		RC 4	2.0			
		RC 5	2.2			
		RC 6				

Example: BTE – CL2 – RC 4 – 2.0 – 5 x 11 x 22 – 0% – XP P13-901

05 Designation scheme for the labelling of unfired earth blocks

Reference literature

[1] *Le Bloc de terre comprimée de Mayotte reçoit une ATEx du CSTB, Batiweb, https://www.batiweb.com/actualites/vie-des-societes/le-bloc-de-terre-comprimee-de-mayotte-recoit-une-atex-du-cstb-2018-11-05-33591*

[2] *Ouvrages en maçonnerie de BTC, parois et murs,* ATEx n°2588, ART.TERRE Mayotte

[3] Champiré, F., Fabbri, A., Morel, J.-C., Wong, H., McGregor, F. *Impact of relative humidity on the mechanical behavior of compacted earth as a building material* (2016) Construction and Building Materials, 110, pp. 70-78.