

Semi-probabilistic model to assess the design of anchors in masonry under seismic loading

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ABSTRACT Fastenings to set up technical equipment, façade, and secondary structural components, are widely used in building construction. Their static design, which depends on the type of support systems and anchors, is clearly defined in standard codes. However, a lack of standard design rules under seismic loadings in masonry support is noticed. The main difficulty is the wide variability of type of masonry supports and anchors. Nowadays, the only strict design method is to carry out standard seismic tests for each anchor/masonry support couple. From practical and financial aspects, in particular in existing masonries, this solution is toughly doable. The aim of these researches is to define a method to calculate the seismic design resistance from standard pullout in-situ static tests. A statistical analyze was conducted on laboratory static and cyclic tests on 9 couples anchor/masonry support. Finally, a methodology is given with a 1.75 seismic safety factors to apply to the static strength for both hollow and solid masonries.

KEY WORDS Fastening, Anchor, Seismic design, Pullout test, Cyclic test, Masonry.

I. INTRODUCTION













Masonry walls are one of the most used systems in building construction. These walls can be active structural components of a building (load bearing walls) or can be used to form a separation inside a building, or regarded as partially structural elements when they are subjected to off-plane loading [Bui 2014]. In the last 25 years, engineers have reinstated brickwork as an economical and high-performance structural material for buildings [Sutherland 2015]. Anchors to set up technical equipment, cladding, and secondary structural components, are widely used in this kind of structure. Their static design, which depends on the type of support systems and anchors, is clearly defined in standard codes. However, a lack of standard design rules under seismic loadings in masonry support is noticed. The main difficulty is the wide variability of type of masonry supports

and anchors [Hofmann et al. 2017]. Nowadays, the only strict design method is to carry out standard seismic tests for each anchor/masonry support couple. From practical and financial aspects, in particular in existing masonries, this solution is toughly doable. In order to address this issue, fastener industrials, masonry industrials, brackets industrials, technical centers are gathered in order to propound a seismic design method of anchor in masonry. In this paper, a design method was defined, which uses the static pull-out strength obtained with in-situ tests and a seismic safety factor.

II. BIBLIOGRAPHY

There are different ways to realize a cladding support according the building construction material: concrete walls, masonry walls and light material walls. The type of anchors used depends on the supports masonry and the load to bear. Table 1 gives an overview of the main mechanical (metal-plastic) and chemical anchors, and masonry supports [Boussa et al. 2014].

TABLE 1. Types of masonry and fasteners.

Masonry							
Picture							
Masonry	Solid brick	Vertical perforated brick	Horizontal perforated brick	Hollow masonry	Cellular concrete masonry		
Fasteners							
Picture							
Fastener	Hilti HRD10	Spit B-long	Etanco FM 10X8	Fischer 8-XR	Wurth-10	Fis HT	Simpson AT-HP
Type	Mechanical					Chemical	

The failure modes of an anchor can affect either the anchorage system, or the block [Meyer et al. 2001]. Under tension loads, the most frequent failure mode is by pullout of the drilled hole with or without the mortar. In perforated blocks, the mortar plugs in the cavities of the unit can also be sheared off. A shear failure of masonry mortar can also occur by splitting, breakout or pulling out of the block. Under shear loading [Welz 2008], the most common failure mechanism in the anchorage itself is the steel failure of the anchor rod. The block can also be split, fail by local cracking (in front of the anchor or at the back), pullout of the bond at the edge of the masonry. In France, the anchor group of the French association of construction products and equipment (CISMA) recommended a methodology (Figure 1) to calculate the characteristic resistance value $R_{k,static}$ under static loads from in-situ tests [CISMA 2013].

III. EXPERIMENTAL DATA BASE

Among the numerous experimental studies (Eligehausen et al. 2006; Fushs et al., 1995, Delhomme et al, 2018), static and cyclic tests were carried out by the CSTB on 9 pairs of fastener/masonry support [Boussa et al. 2014]. These 9 pairs are composed of 5 different supports and 7 different fasteners (2 chemical and 5 mechanical anchors). For each pair, 20 tests were performed: 5 static tension tests, 5 cyclic tension tests, 5 static shear tests and 5 cyclic shear tests. The resistance was defined as the maximum load measured. The mean static tension and shear resistances, respectively N_{Static} and V_{Static} , and the relative variations (standard deviation divided by

the mean) were calculated from 5 identical tests. In the shear and tension cycling tests, the cyclic loading was followed by a static residual loading until the failure. The tests were conducted in displacement control. The tension experimental setup consisted of a hydraulic actuator (50 kN capacity and 100 mm stroke). Concerning the shear tests, the hydraulic actuator (400 kN capacity and 100 mm stroke) was connected to a steel frame to transmit the loads to the anchor [Boussa et al. 2014].

IV. STATISTICAL ANALYSIS

Starting from the CSTB tests, a statistical analysis was performed in order to calculate the standard deviation and the characteristic value of each couple anchor/masonry support. For each resistance a characteristic value was calculated with a 5 % probability of non-exceedance and a confidence of 90 %. The results show that a normal distribution provides some negative characteristic resistances due to the scattering of the results inducing a high standard deviation. To reduce the standard deviation, the closest maximum loads obtained with only 4 tests, and then 3 tests, were kept. Some characteristic resistances obtained were still negative. Consequently, a log normal distribution according to [EC0 2003] was used to avoid this issue and enforce positive characteristic resistances.

V. SEISMIC SAFETY FACTOR AND SEISMIC DESIGN RESISTANCE

In this part of study, a methodology of calculation of anchors under seismic load will be defined by an analogy with the static methodology. The design value is defined as:

The seismic design resistance (Eq. 1) is calculated from the static characteristic resistance:

$$R_{d, sis} = \frac{R_{k, static}}{\gamma_m \gamma_{sis}} \quad (1)$$

where $R_{k, static}$ is the characteristic static resistance, γ_{sis} is a partial safety factor for seismic design and γ_m is a partial safety factor for the material defined in ATE. Generally, for use in masonry $\gamma_m=2.5$ [ETAG 020 2012] [ETAG 029 2013].

The partial safety factor for seismic design γ_{sis} is given in Eq. 2:

$$\gamma_{sis} = \frac{\min(R_{k, in-situ}, R_{k, 5\% static})}{R_{k, 5\% cyclic}} \quad (2)$$

where $R_{k, 5\% static}$ and $R_{k, 5\% cyclic}$ are the static and cyclic characteristic strengths with a fractile of 5%, respectively.

The envelope seismic safety factor γ_{sis} for hollow and solid masonries from tension and shear tests are 1.75 and 0.8, respectively. To simplify, γ_{sis} equals to 1.75 is considered for all masonry supports.

Finally, the methodology to calculate the anchors under seismic loads is given in Figure 1.

VI. CONCLUSION

In this research, CSTB tests database was the base of a statistical analysis in order to calculate the characteristic resistances. Two approaches were considered, the first one with a normal distribution, but negative values were obtained due to the high dispersion obtained in the experiments. The use of a log normal distribution was an efficient method to reduce the dispersion and avoid negative characteristics resistances. Finally, a methodology is defined, with a 1.75

masonry seismic safety factor to apply to the static in-situ strength. In this regard, the uncertainties associated to the uncontrolled characteristics of the masonry and the fasteners are properly accounted in the seismic design resistance.

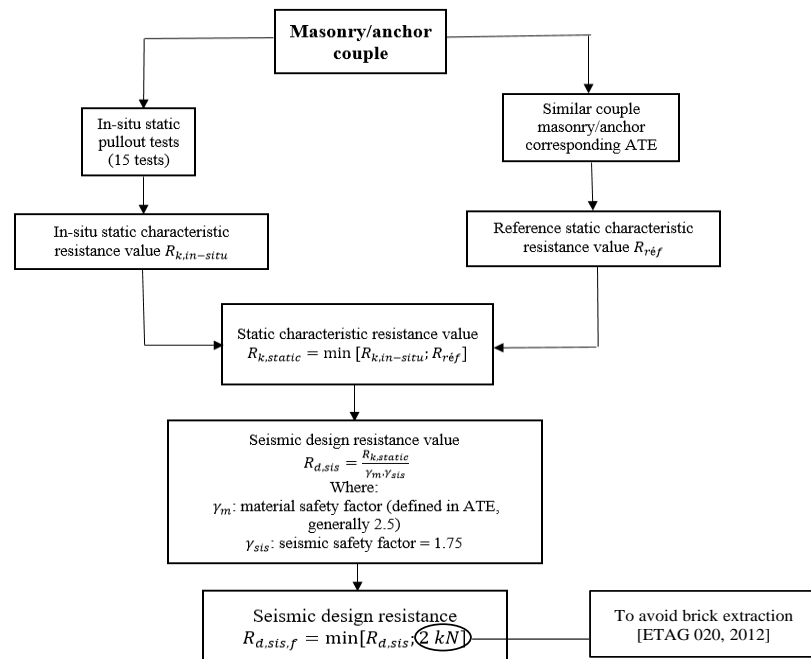


FIGURE 1. Calculation methodology of seismic design resistance

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