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Characterizing the material properties of dutch unreinforced masonry

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Abstract

In the northern part of the Netherlands, the recent seismic activities have raised concerns about the behavior of unreinforced masonry structures which were not designed and constructed to resist seismic loading. The first step towards assessment of seismic behavior of masonry structures is to characterize the material properties. This characterization is the matter of importance, since the findings serve as input parameters for analytical and numerical models. To do so, destructive laboratory tests (standard and non-standard tests) have been carried out on samples extracted from existing masonry buildings. The compression, bending and shear properties of masonry were investigated in this research. The obtained properties were categorized with respect to masonry typologies and time periods.

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Keywords: URM; Experimental tests; Destructive tests; Material properties

1. Introduction

Due to the gas extraction, the number of seismic activities has recently been increasing in the northern part of the Netherlands. In this region the majority of building stocks are unreinforced masonry (URM) and they have not been designed and constructed to resist seismic loading. Consequently, the use of numerical models as well as analytical

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design methods is required to assess the behavior of the existing URM buildings. Therefore, there is a need to characterize the masonry at material level. To do so, an extensive experimental testing campaign was conducted with the collaboration of Delft University of Technology (TU Delft) and Eindhoven University of Technology (TU/e).

A large variety of typologies in terms of used materials and the year of the construction is typical features of the Dutch URM. Regarding the mechanical properties of URM, although some studies were conducted in other parts of the word [1], limited information was provided on the Dutch URM in terms of time periods and masonry typologies [2-4]. Therefore, an objective of the current research is to develop a guideline and provide a database, in order to characterize the behavior of the Dutch URM.

Accordingly, thirteen buildings from the northern part of the Netherlands were investigated and selected as testing objects. Different masonry typologies were identified, even from the inspection of each individual building. A series of masonry samples were extracted from the objects and delivered to the laboratories of TU Delft and TU/e. The specimens were characterized considering compression, bending and shear properties of masonry. In this paper, a summary of all the obtained results is presented. Furthermore, a comparison between the average values of the experimental results and corresponding values proposed in the design standards is addressed. Further details on the testing campaign presented here can be found in the related technical reports [5-6].

2. Materials and methods

Destructive tests were performed on samples extracted from existing masonry buildings and they were delivered to the laboratories of TU Delft and TU/e. All the delivered samples were sawn-cut in the field and separately packed according to ASTM C1532 [7]. The delivered samples were composed of masonry units including clay and calcium silicate brick and general purpose mortar with the joint thickness of 10 mm. The masonry objects belonged to the period between 1920 and 2010. Since the evolution of the construction process may affect the mechanical properties of masonry, the objects were also categorized according to the year of the construction. The clay brick masonry including solid, perforated and frogged unit was categorized as the pre-war period (until1945) and post-war period (after 1945) masonry. For calcium silicate brick masonry only the buildings constructed before 1985 were analyzed, when bricks and general purpose mortar were used. Compression, tension and shear tests were conducted to characterize the mechanical properties of masonry specimens. In addition, a displacement-controlled testing procedure was used to perform all the tests except the bond wrench test.

The compression properties of masonry were investigated by conducting tests in agreement with EN1052-1 [8]. The compression tests were performed in two orthogonal directions, perpendicular and parallel to the bed joints, with the aim of investigating the orthotropic behavior of masonry. Both cyclic and monotonic compression tests were performed. Following the agreements of the standard the test was modified for the case of cyclic loading and horizontal compression tests. For both vertical and horizontal configurations, the masonry specimens had the same dimensions and the same loading rate was applied.

The bending properties of the masonry were studied by performing four-point bending tests, both out-of-plane and in-plane, and bond wrench tests. Horizontal out-of-plane bending tests, where the plane of failure was perpendicular to the bed joints, were performed according to EN1052-2 [9] to characterize the flexural strength of masonry. It should be mentioned that the vertical out-of-plane bending tests were not performed in this research, since the extraction of intact samples based on the requirements defined in the standard [9] was not feasible. In addition, a four-point in-plane bending test was adopted where the moment vector was orthogonal to the plane of the specimen. Dimensions of the specimens and the test set-up adopted for both the in-plane and out-of-plane bending tests were identical and based on EN1052-2 [9]. The flexural bond strength of masonry was studied through carrying out bond wrench tests, in conformity with EN1052-5 [10], on stack bonded specimens, sawn-cut from the remaining parts of the specimens tested beforehand in the bending tests.

The shear properties of masonry were obtained by performing shear tests on triplets in accordance with EN1052-3 [11]. By adopting a displacement-controlled procedure, the initial shear parameters, including initial shear strength and coefficient of friction was studied and the residual strength properties, where a plateau was reached, was investigated. The initial and residual shear properties were found by applying the Coulomb friction criterion.