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Challenges in Characterizing Interface Properties in Historic Masonry Infrastructure

Uday Jain, Rita Esposito

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Background

During the Dutch Golden Age in the 17th and 18th centuries, the city of Amsterdam underwent rapid urban expansion, driven by trade and migration. This led to the construction of numerous earth-retaining walls and bridges, forming part of the Canal District (Grachtengordel). This historic infrastructure serves both functional and a monumental role as part of Amsterdam's UNESCO World Heritage Site [1]. The oldest constructions in the city centre are predominantly composed of thick, multi-wythe clay brick masonry supported on timber pile foundations. The timber piles forming the foundations of these retaining walls and bridges have exhibited deterioration in recent years. However, the masonry superstructure has shown a capacity to redistribute stresses. Accordingly, mechanical characterisation of these structures is essential to evaluate its current condition and to design appropriate interventions. The multi-wythe walls of these structures are typically 600-1400 mm thick, fully-bonded and constructed using clay brick masonry with a lime-trass based mortar. Despite their critical role in the city's transport infrastructure, the mechanical properties of this historic masonry remain poorly documented. In particular, interface shear and bond properties, which can be critical in out-of-plane failure of the masonry superstructure, are lacking. To this end, this extended abstract describes the challenges encountered so far in the characterisation of interface properties and a possible strategy together with preliminary results for a quay wall structure in the city of Amsterdam.

From splitting test to direct tensile test

Horizontally extracted cores are often the most feasible approach for in-situ characterisation of multi-wythe masonry infrastructure, as it limits damage while allowing extraction of representative material. Furthermore, such method is often employed by asset owners to evaluate the thickness and composition of the wall in case proper historical documentation is missing, and can be reused for mechanical characterisation. Tests performed on cylindrical masonry cores with a single bed joint have shown potential for characterise the shear properties brick-mortar interface initial shear strength, coefficient of friction) through splitting tests [2], [3], [4]. However, previous investigations have been performed on samples extracted from buildings

A preliminary investigation adopting splitting tests on cores extracted from a bridge pillar has revealed several challenges in the use of such method to evaluate shear properties at brick-mortar interface [5]. Due to the multi-wythe nature of pillar and walls in urban infrastructure, the extraction of I-shaped cores with only a bed joint across the thickness of the structure is difficult. Additionally, a previous study by Li & Esposito [5] showed that instead of achieving a sliding failure at the brick-mortar interface, pure tensile splitting failure of the brick occurred (Figure 1). This could be due to the higher bond strength of the masonry extracted from infrastructure compared to the masonry extracted from buildings.

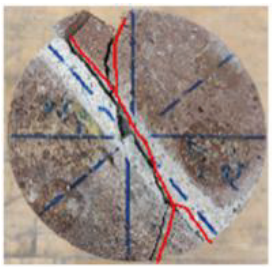

Figure 1: Tensile failure of brick in splitting test on masonry core [Li & Esposito [7]]

To investigate the brick-mortar interface for masonry infrastructure, an alternative testing approach was adopted, shifting the focus from splitting to tensile tests. Smaller prismatic specimens containing a single bed joint were extracted from masonry cores and tested in direct tension to determine tensile bond strength. This procedure involves several experimental challenges, including specimen preparation, selection of appropriate boundary conditions to promote failure at the brick-mortar interface rather than within the adhesive-plate or the brick-adhesive interface. Accordingly, careful attention was paid to surface preparation and bonding of the specimen to the loading pates to minimise undesired failure modes. Figure 2 shows an example of force-displacement curves for specimens from the same infrastructure showing a desirable failure at brick-mortar interface and an undesirable failure close to the loading plates.

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Concluding remarks

The adopted experimental approach offers a practical means of determining interface properties from small-diameter cores extracted in situ from masonry infrastructure, while minimising damage to heritage structures. Direct tensile tests together with compression tests on masonry cores (e.g. Jain & Esposito [6]) are currently being used to characterise several quay walls in the city of Amsterdam to create a mechanical property database. The resulting properties constitute essential input for numerical models used in structural assessment, supporting informed intervention, strengthening, and preservation of historic masonry infrastructure. Additionally, previous studies have shown that spatial variations in environmental exposure within masonry infrastructure are associated with variability in mechanical properties [5], [6]. This motivates further investigation through testing of samples extracted from sections of the structure with differing exposure conditions.

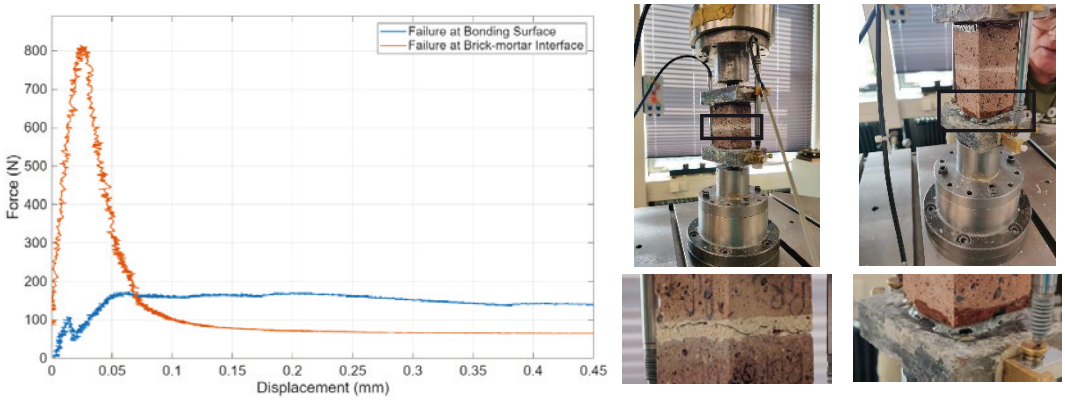

Figure 2: (a) Force-displacement curves for (b) desirable failure at brick-mortar interface, and (c) undesirable failure near loading plates

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