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Figure 1 (left). Villa on coastal dike in Wenduine, Belgium (Photo courtesy Koen Trouw).

Figure 2 (bottom right). Raised first floor for flood protection (Photo courtesy Koen Trouw).

Figure 3 (top right). Basement with flood protective window shutters (Photo courtesy Koen Trouw).

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CASE STUDY: WENDUINE, BELGIUM

VULNERABILITY OF BUILDINGS ON A COASTAL DIKE

On coastal dikes in Belgium, many residential buildings are found. Most of the old buildings are masonry structures with two to three floors (Figure 1). The ground floors are always elevated (Figure 2), and the entrances of the basements are closed by shutters (Figure 3). The most modern buildings are concrete reinforcement structures with concrete piles/columns as foundations. The walls are consisting of masonry or concrete. These buildings are 5 to 9 floors high. Some of the ground floors are elevated, and some are used as cafe, restaurant or store. The ground floors are equipped with large glass windows and doors.

A representative situation for Wenduine, a coastal town in Belgium, is used for the current case study. Figure 1 on page 30 shows the schematic sketch of a building placed on the top of the coastal dike in Wenduine. The beach level is set at 6.5 m above TAW (*Tweede Algemene Waterpassing*, which refers to Belgian standard datum level), which is chosen from the lowest toe position used in the study of Suzuki et al. (2016). The dike crest level is set at 8.5 m above TAW (and the distance between the building to the seaward slope of the dike (B) is chosen as 10 m in this case study.

In this research, two main simplified failure mechanisms of masonry buildings were considered. One is the collapse of the structural wall like an external load-bearing wall or stability wall, and the other one is localized damage of non-structural components like a non-load-bearing wall and glass windows. The vulnerability of the masonry walls and glass windows against overtopping wave impact was assessed under three scenarios, including two storm surges with return periods of 1000 (scenario S1) and 10,000 years (scenario S2) and one 10,000 years storm surge with a low beach level (scenario S3). The impact load was estimated by using the approach developed in this project (Chen 2016: 57-81). The overall results indicated that the chance of collapse of the masonry buildings on the dike is low under scenarios S1 and S2. But the non-structural external wall and glass windows are expected to break, which would lead to the inundation of the ground floor of the buildings. However, most of the key external structural walls are expected to fail when the buildings are located near the coast under scenario S3 (i.e. 10,000 year conditions with less shallow foreshores). Thus, we recommend increasing the strength of the external masonry wall on the ground, and reinforcing windows to avoid inundation.

Note: This assessment approach was developed specifically for the masonry buildings on a coastal dike with shallow water conditions. The existing masonry design code and empirical overtopping wave load were applied to set the limit state function of bending failure. Thus the applicable range of the hydraulic conditions of the empirical overtopping wave load formula needs to be checked for every other individual case.

This text is an adapted version of part of chapters 5 and 6 in the publication 'Impact of overtopping wave on buildings on a coastal dike' (Chen, 2016).

Figure 4. Belgian coast (Image courtesy Jesse Allen, Earth Observatory, NASA).