Damage to masonry buildings induced by Subsidence

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Introduction

Figure 1. Examples of cracking damage to buildings due to settlements.

Assessing and predicting damage to buildings caused by subsidence is a complex challenge that involves correlating the vulnerability of affected structures with the severity of the subsidence hazard.

Damage assessment analyses require detailed information of the about the characteristics of the buildings (such as construction materials, geometry, and foundation types) and of the subsurface system on which they are resting. This process introduces inherent uncertainties, especially when dealing with a large number of buildings.

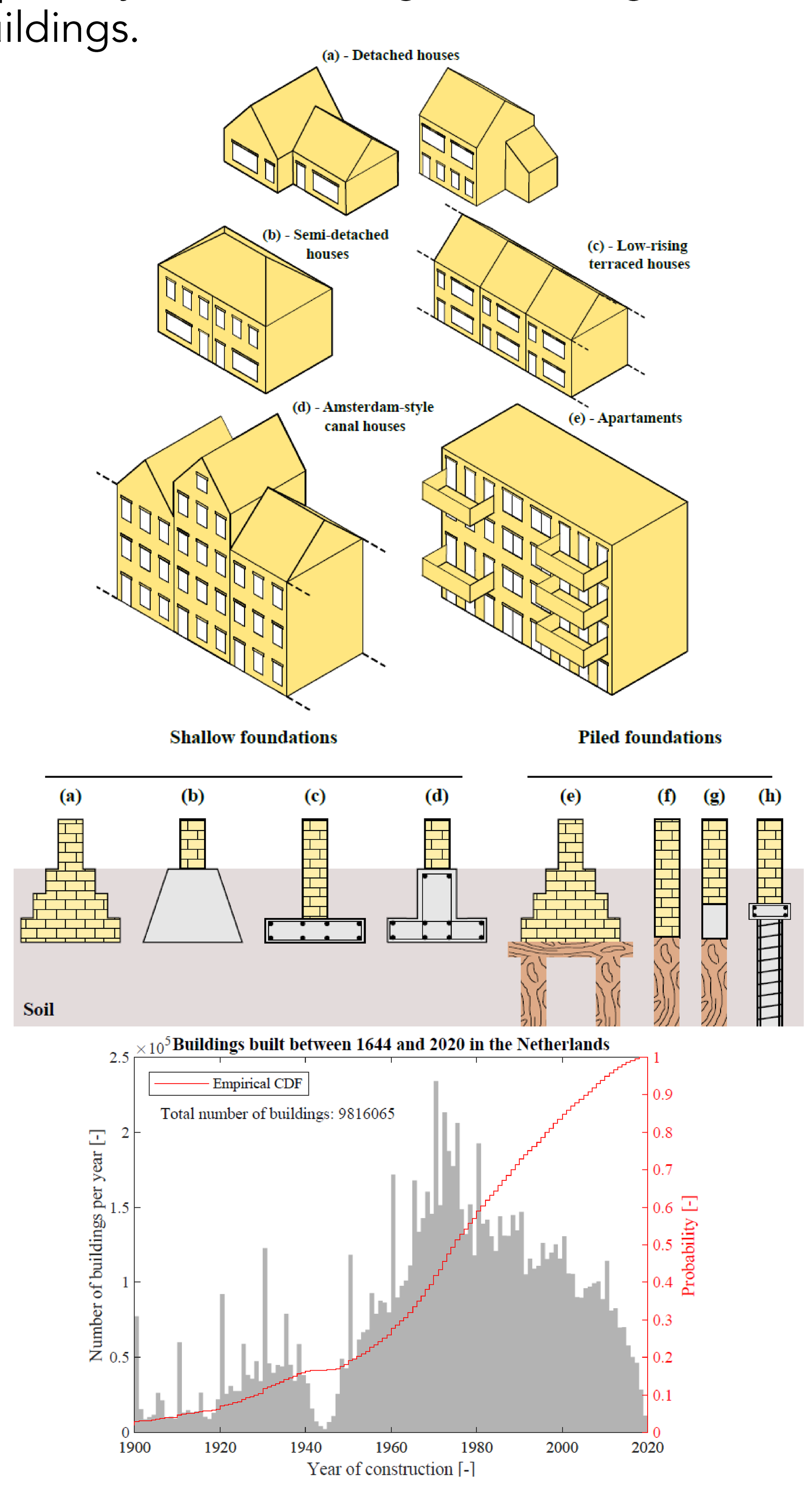


Figure 2. Schematic illustration of the different housing typologies in the Netherlands and common foundation systems and histogram of the year of construction for existing buildings in the Netherlands. Data available in the BAG3D (https://3d.bk.tudelft.nl/) database.

Numerical analyses for buildings exposed to subsidence

Numerical models can be employed to assess damage in structures subjected to settlement. These models simulate the structure experiencing settlement, accounting for the material's non-linear behaviour.

As the settlement is gradually applied, cracks begin to form in response.

Different simulations provide insights into how different building geometries, materials, foundation systems, and settlement patterns influence the results.

The results help identify the relationship between the magnitude of the settlement and the extent of the damage.

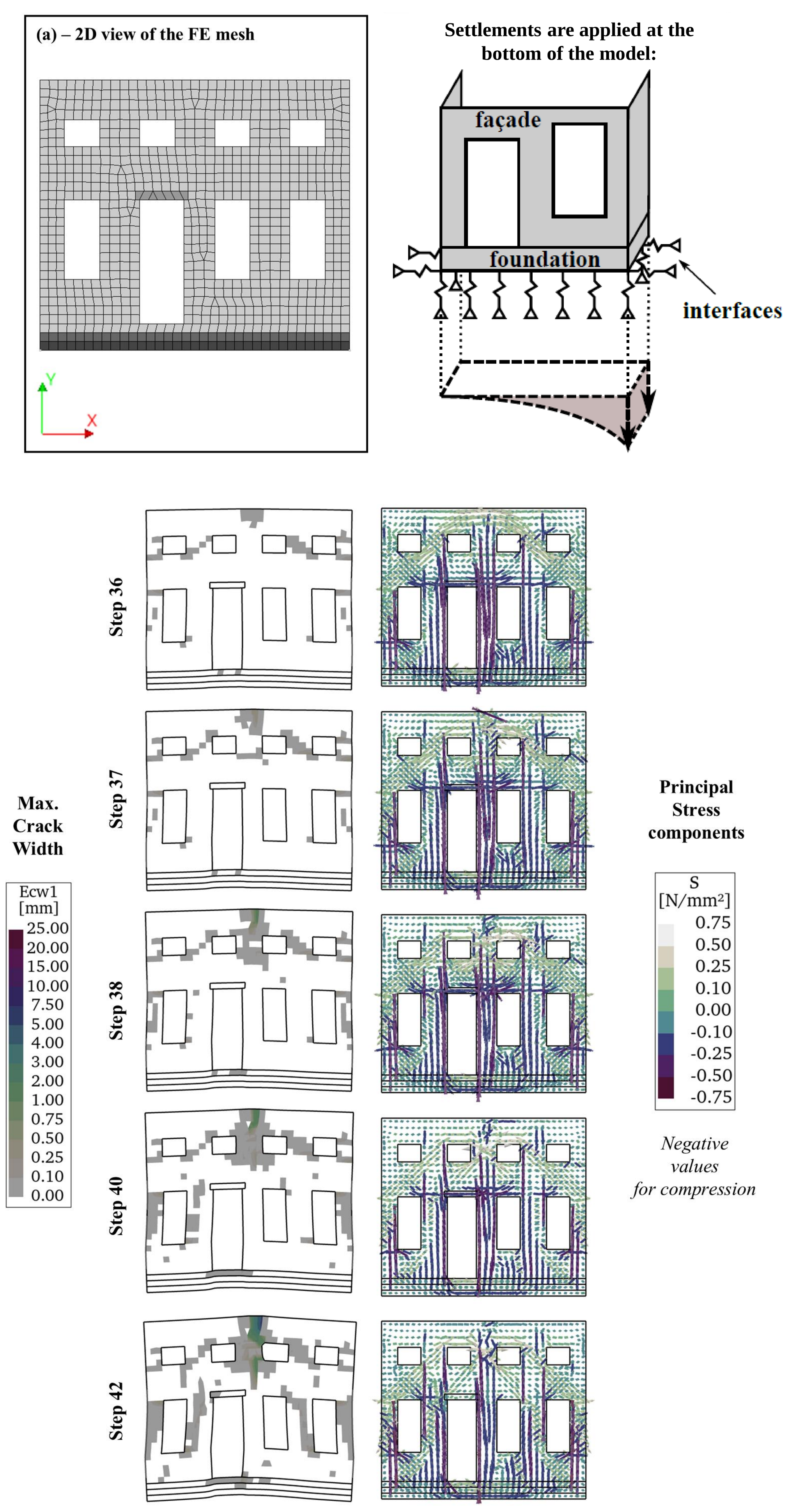
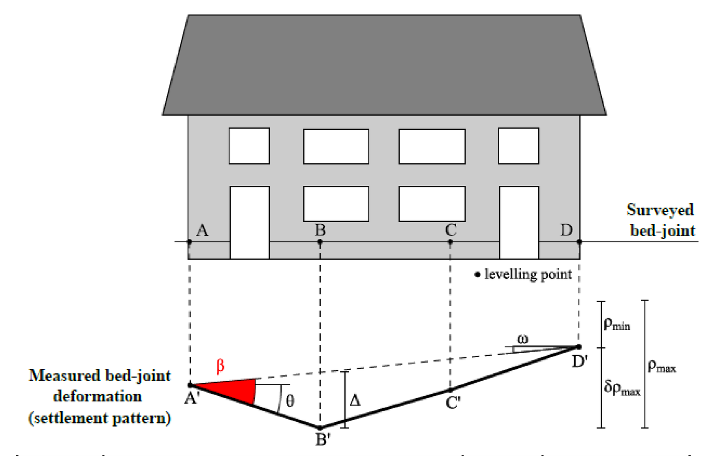


Figure 3. An example of a Finite Element analysis of a masonry façade built on an unreinforced masonry foundation subjected to settlement. The model simulates the damage to the façade caused by differential settlements occurring at both ends of the building, while the central portion remains stationary (creating a hogging settlement shape).

Numerical-based fragility functions

The results of the numerical analyses can be used to generate fragility curves, which link the intensity of the settlement affecting a structure to the probability of experiencing a specific level of damage.



Category of damage	Damage class	Approximate crack width	Description of typical damage (and ease of repair)	Damage group:	Damage Level	Parameter of damage
	Damage classification system:					
Aesthetic damage	No Damage	Imperceptible cracks	-	No Damage	DL0	$\Psi < 1$
	Negligible	up to 0.1 mm	Hairline cracks of less then about 0.1 mm are classed as negligible		DL1	$1 \leq \Psi < 1.5$
	Very slight	up to 1 mm	Fine cracks which can easily be treated during normal decoration.	Light Damage	DL2	$1.5 \leq \Psi < 2.5$
	Slight	up to 5 mm	Cracks easily filled. Re-decoration probably required. Some re-pointing may be required.		DL3	$2.5 \leq \Psi < 3.5$
Functional damage, affecting serviceability	Moderate	5 to 15 mm	The cracks require some opening up and can be patched by a mason. Re-current cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced.	Moderate to severe damage	DL4 and above	$\Psi \geq 3.5$
	Severe	15 to 25 mm	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows.			
Structural damage, affecting stability	Very Severe	Higher than 25 mm	This requires a major repair job involving partial or complete re-building.			

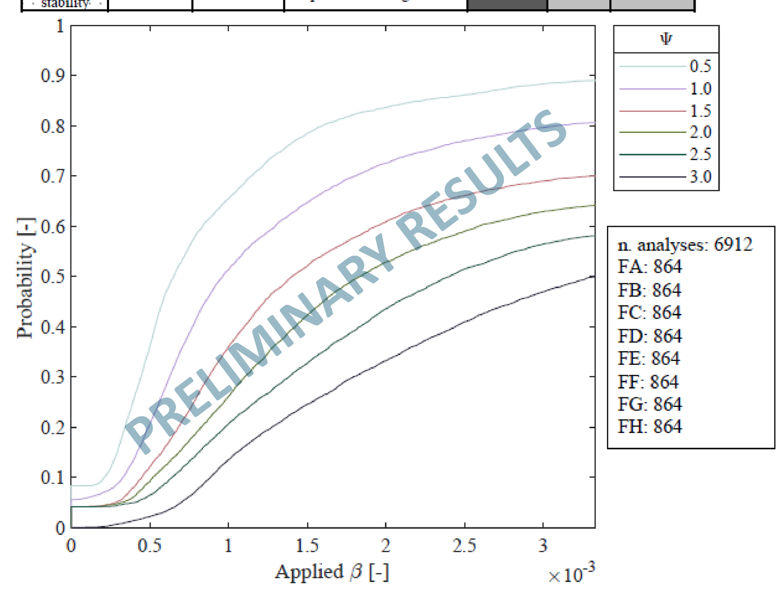


Figure 4. Fragility functions (work in progress) for building exposed to subsidence

Recent publications

Journal articles:

- Prosperi, A., Korswagen, P. A., Korff, M., Schipper, R., & Rots, J. G. (2023a). Empirical fragility and ROC curves for masonry buildings subjected to settlements. Journal of Building Engineering, 106094.
- Prosperi, A., Longo, M., Korswagen, P. A., Korff, M., & Rots, J. G. (2023b). Sensitivity modelling with objective damage assessment of unreinforced masonry façades undergoing different subsidence settlement patterns. Engineering Structures, 286, 116113.
- Prosperi, A., Longo, M., Korswagen, P. A., Korff, M., & Rots, J. G. (2024a). 2D and 3D Modelling Strategies to Reproduce the Response of Historical Masonry Buildings Subjected to Settlements. International Journal of Architectural Heritage, 1-17.

Conference contributions:

- Prosperi, A., Longo, M., Korswagen, P. A., Korff, M., & Rots, J. G. (2023c). Shape matters: Influence of varying settlement profiles due to multicausal subsidence when modelling damage in a masonry façade. In Tenth International Symposium on Land Subsidence 2023.
- Prosperi, A., Longo, M., Korswagen, P. A., Korff, M., & Rots, J. G. (2023d). Accurate and Efficient 2D Modelling of Historical Masonry Buildings Subjected to Settlements in Comparison to 3D Approaches. In International Conference on Structural Analysis of Historical Constructions (pp. 232-244). Cham: Springer Nature Switzerland.
- Prosperi, A., Longo, M., Korswagen, P. A., Korff, M., & Rots, J. G., (2024b) Comparative analysis of coupled and uncoupled 3D Finite Elements models for masonry structures subjected to settlements. 18th International Brick and Block Masonry Conference.

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