

Potential damage of land subsidence to the built heritage

Living On Soft Soils – Work Package 3.2

LOSS Symposium

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Type of damage caused by land subsidence

Damage can be defined as a physical harm that **alters** the **functionality**, the **usefulness** and the **economical values** of a structure, from its initial state.

Damage associated with land subsidence can be divided into **direct** and **indirect damages**:

Direct damage:

Damage to buildings, including residential, industrial and public.

Damage to infrastructure (roads, railway, sewers, water supply networks, communication systems, etc.).

Damage to public and private green spaces.

Indirect damage:

Increased flood risk.

Loss of land (near water bodies).

Lower agricultural productivity.

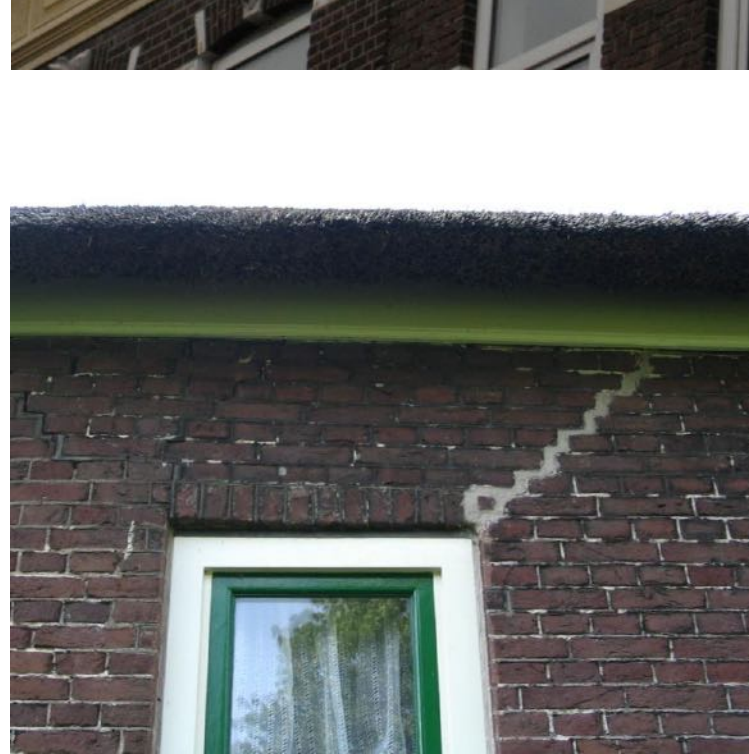
Social unease.

...

Aesthetic damage

Aesthetic damage involves fine cracks that can easily be treated during the regular maintenance works.

The cracks are visible on inspections and may also involve finishing and decorative features.



Functional damage

Functional damage is defined by any harm to the functionality of the building or parts of it.

Examples includes the jamming of windows and doors, accessibility problems and damages to the underground services.



Structural damage

Structural damage affects the strength of the building or of part(s) of it. Extensive repair work is required and, in some cases, the complete rebuilding.



Damage to infrastructure

Subsidence results in damage to **roads, pavements, sewers, water supply networks** and **gas pipelines**, that require maintenance and management strategies.



Source: Deltares



Source: omroepflevoland.nl



Source: sensar.nl

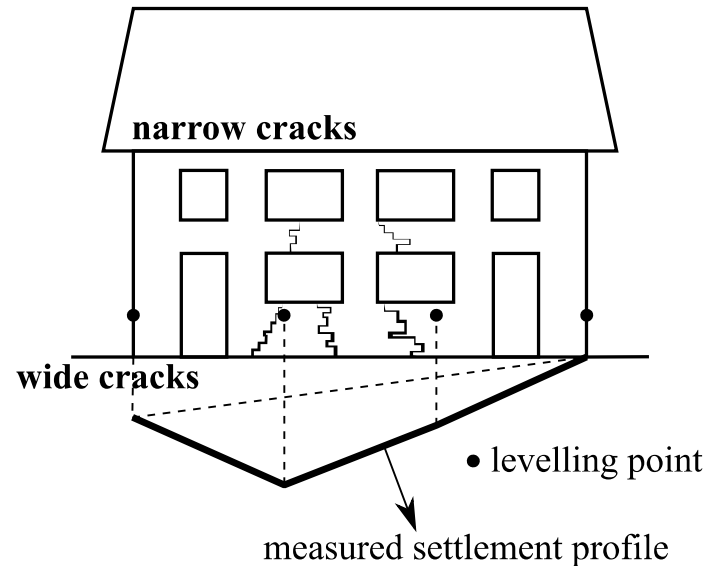


Source: h2owaternetwerk.nl

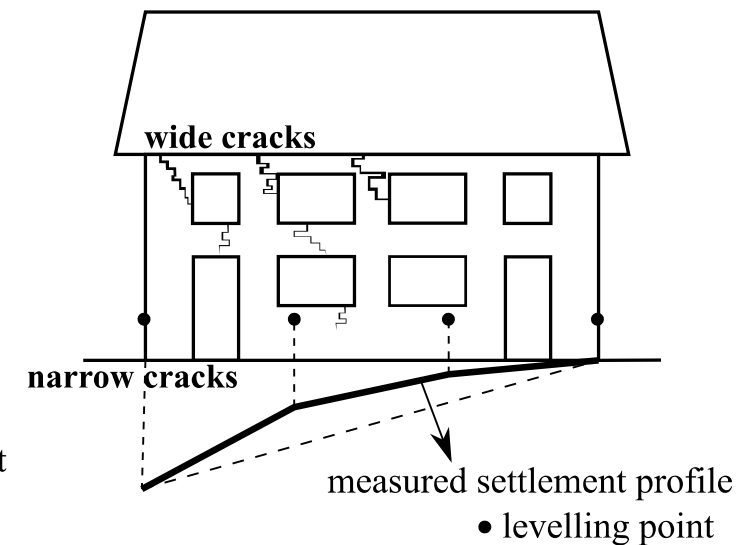
Damage to masonry buildings

On the scale of the single building, the damage induced by subsidence does not only depend on the magnitude of the induced settlements but also on their rates (over time), as well as on the shape of the settlement profiles which result from the interaction between the structure and the subsoil.

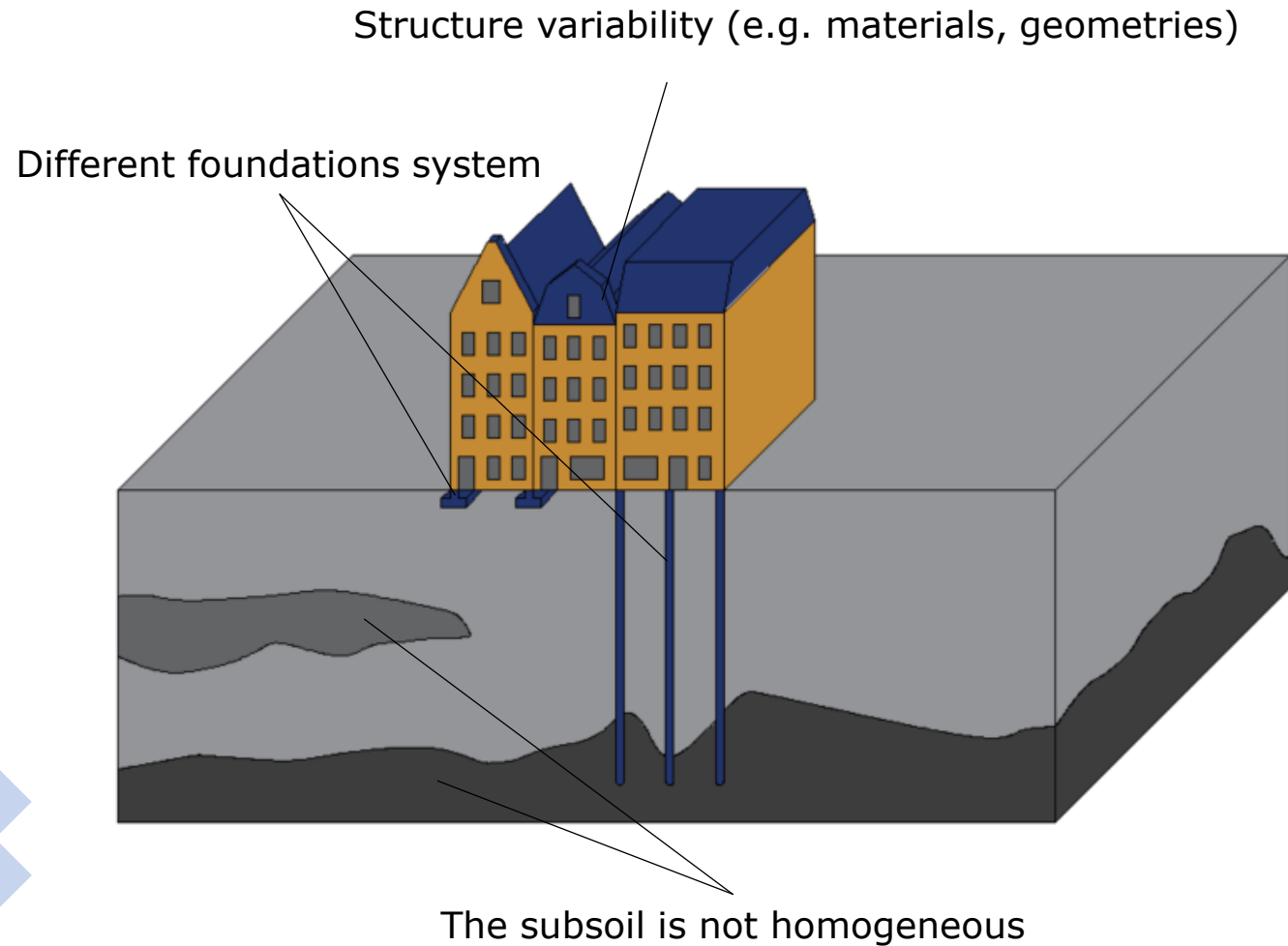
Sagging settlement profile



Hogging settlement profile



Damage to masonry buildings



The **uncertainties and large variability related to the structural and soil features** need to be considered.

Probabilistic analyses provide a promising perspective to deal with the uncertainties in the damage assessment of a large number of buildings.

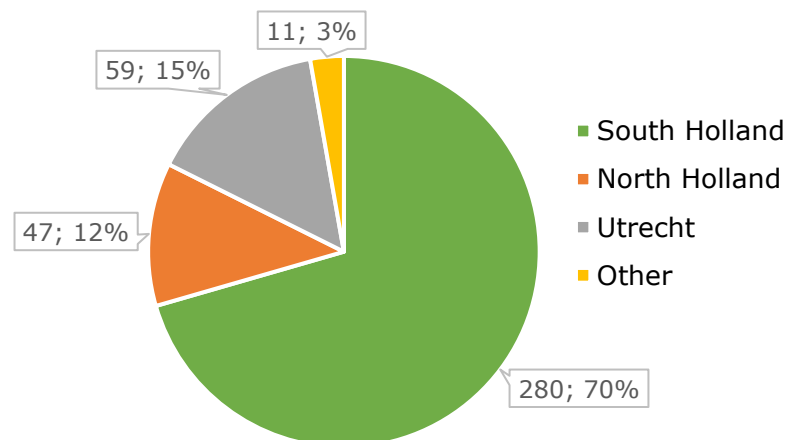
Overview of the progress

We collected the information of **387 field surveys** over different Dutch provinces into a **digital database**.

The collected documental information include:

- measurements of bed-joint levelling along the building façades (*lintvoegwaterpassing*);
- photos and descriptions of the recorded crack patterns;
- the recorded foundation system.

Building data for each province:



Example of damage pictures:



Documental information:

beknopte bouwkundige omschrijving:

- vrijstaande semi-bungalow met aangebouwde garage en serre
- hoofdpand heeft begane grond en eerste verdieping
- garage heeft begane grond en zolder
- opbouw baksteen, spouwmuur
- pannendak
- begane grondvloer steenachtig
- kelder aanwezig

pand is constructief in goede conditie, geen scheurvorming waargenomen

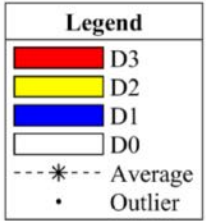
lintvoegwaterpassing: Fugro 4006-0468-000 d.d. 01-08-2008

(huidige situatie)	verschilzett.	rotatie	richting	rel. hoekverdr.
	dz	hoek	mm/meter	δ/L
woning linkerzijgevel	1 mm	1:455	2,2	< 1:3000
voorgevel	9 mm	1:756	1,3	< 1:3000
rechterzijgevel	18 mm	1:455	2,2	< 1:3000
garage linkerzijgevel	10 mm	1:235	4,3	1:460
voorgevel	14 mm	1:255	3,9	1:280

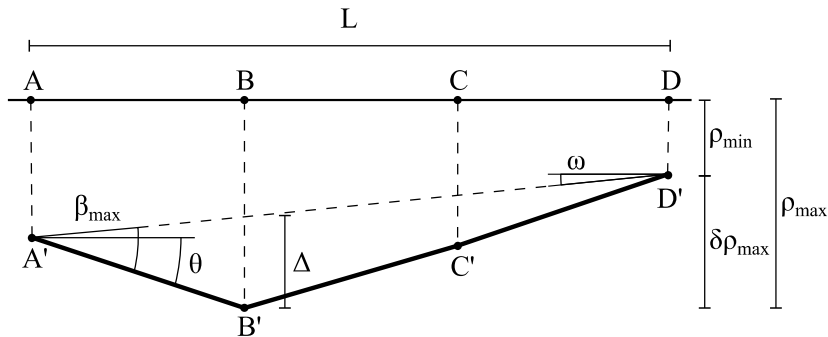
Hoofdpand staat niet geheel waterpas, helt flauw voorover richting kade en naar rechts.
Garage staat niet geheel waterpas, helt flauw naar links en mogelijk iets richting kade.
In relatie tot de meetnauwkeurigheid (± 5 mm) zijn de gemeten zettingsverschillen beperkt.
Relatieve hoekverdraaiing in huidige situatie plaatselijk iets groter dan 1:300 (architectonische schade).

ZAKING IN MM T.O.V. HOOGSTE PUNT
0 = HOOGSTE PUNT

Overview of the progress



Digitalized settlement profile:

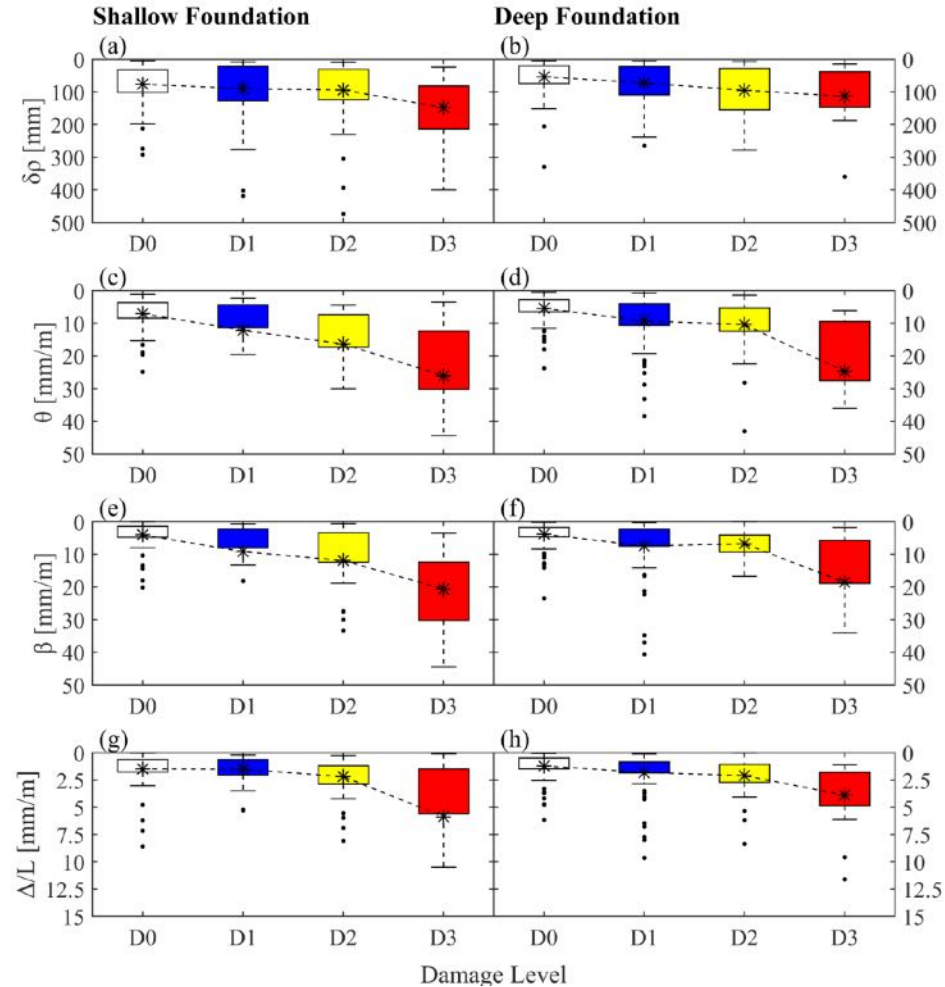


Four parameters were computed for each building and they were related to the severity of the observed damage:

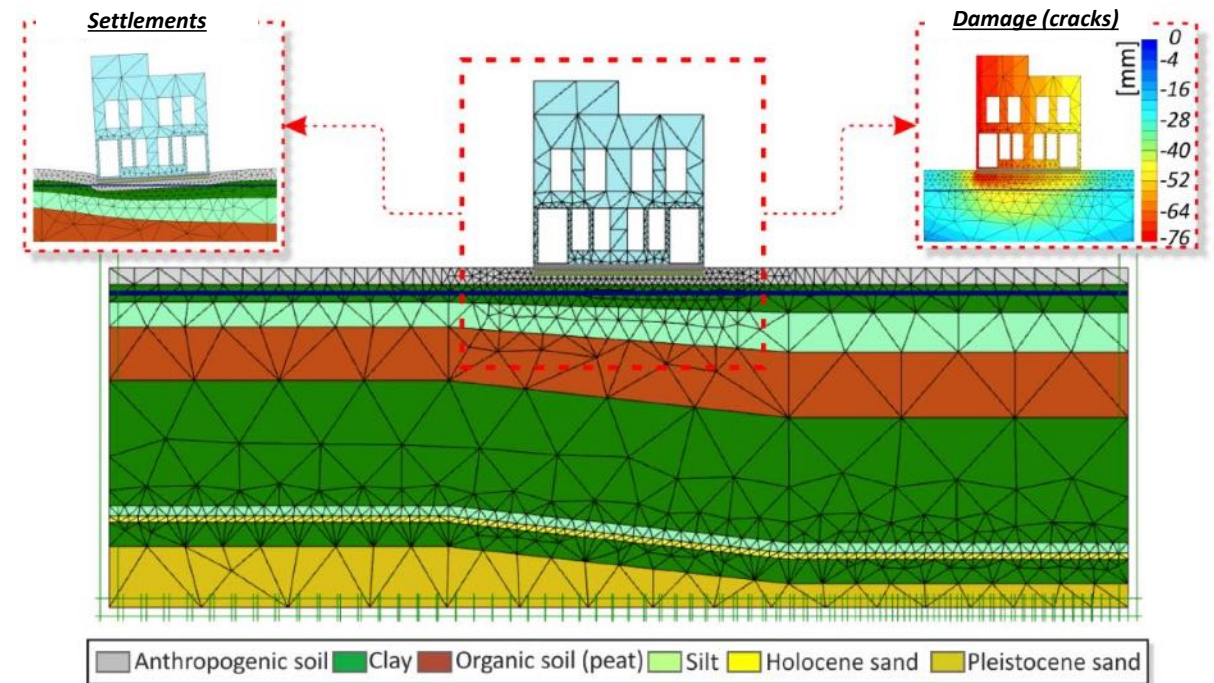
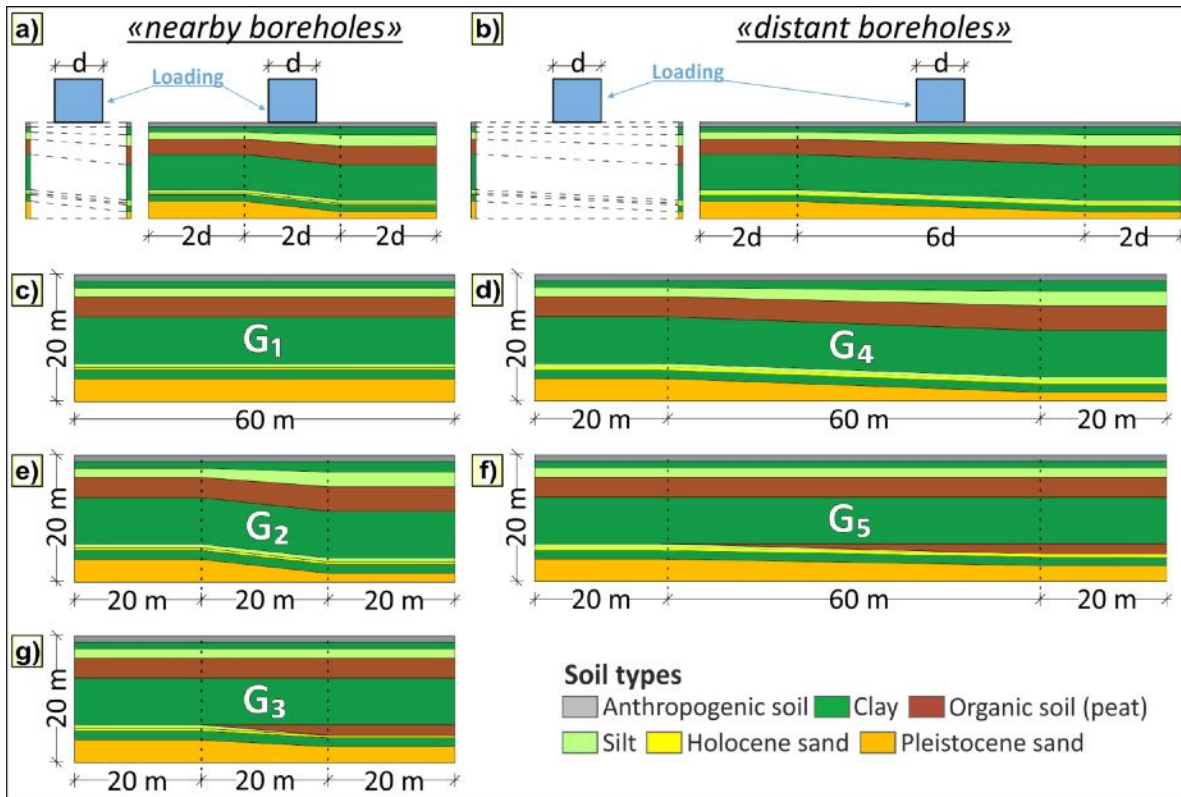
- **Differential settlement** $\delta\rho$;
- The **rotation** θ ;
- The **relative rotation** β ;
- The **deflection ratio** Δ/L .

Considered damage class:

Burland and Wroth (1974)		Approximate crack width (mm)	Damage Level
Category of damage	Damage class		
Aesthetic damage	No Damage	up to 0.1 mm	0
	Very slight	Up to 1 mm	1
	Slight	Up to 5 mm	2
Functional damage, affecting Serviceability	Moderate	5 to 15 mm	3



Future developments



Final remarks

The result of the analyses, once further validated against additional building data and computational simulations, could represent a useful tool for risk analyses associated with land subsidence.

Hardcopies and **archives** of the surveyed buildings and infrastructure **may contain very useful documental information** waiting to be retrieved and collected.

Any suggestion, comment or question is welcome and encouraged.




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**Thank you for
your attention**

**Dank u voor uw
aandacht**

