I-SUB
Gruppo Nazionale Italiano sulla Subsidenza
Italian National Group on Land Subsidence

LA SUBSIDENZA IN ITALIA: dal confronto tecnico-scientifico alla creazione di un gruppo di lavoro (iSUB-I)

17-18 febbraio 2026
Dipartimento di Ingegneria Civile, Edile e Ambientale
Universita' degli Studi di Padova

Integrazione di tecniche di monitoraggio multi-source multi temporale nella modellazione di sistemi geotecnici ricadenti in aree subsidenti e analisi delle conseguenze

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diciv Dipartimento di Ingegneria Civile

Case studies in The Netherlands

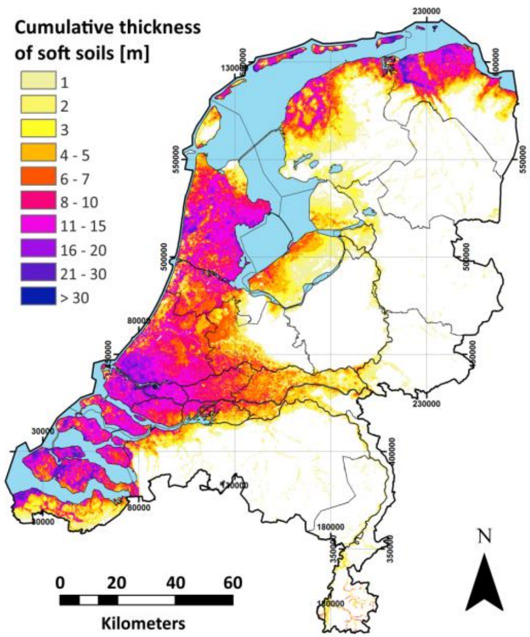
The lesson learnt from case studies in The Netherlands

The Problem: living on "soft soils"

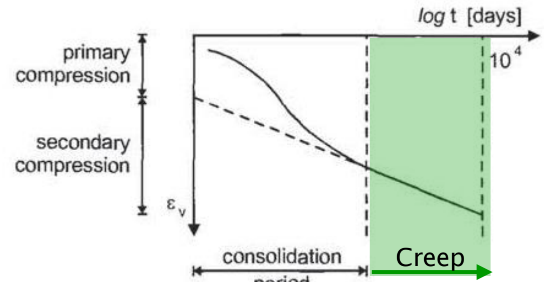
The subsoil of the western part of the Netherlands consists of layers of highly compressible fine-grained "soft soils" containing (organic) clays and peat whose thickness can reach a total of 20 m.

PREDISPOSING FACTORS

Cumulative thickness of soft soils in The Netherlands (courtesy of Deltares)



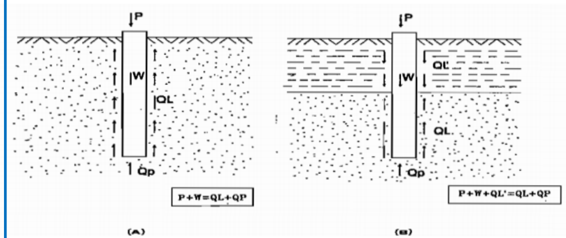
SUBSOIL MECHANICAL BEHAVIOUR



(from: Blommaart et al., 2000)

WIDELY ADOPTED DEEP FOUNDATIONS

EFFECTS ON FOUNDATIONS



Negative friction

Decay of pile due to soft rot (fungi)

Decay of pile due to bacteria

(from: Klaassen et al., 2015)

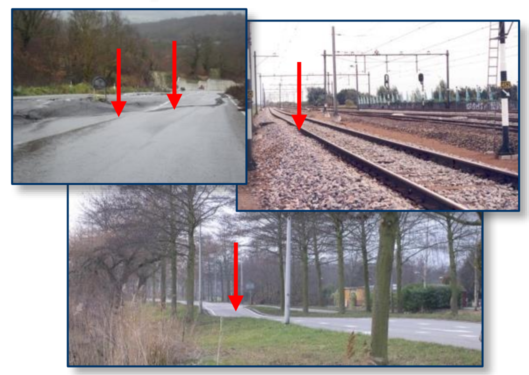
The analysis and prediction of the vulnerability of buildings resting with their foundation systems on "soft soils" are key issues for a proper management of settlement-affected urban areas.

What are the effects on the built-up environment?

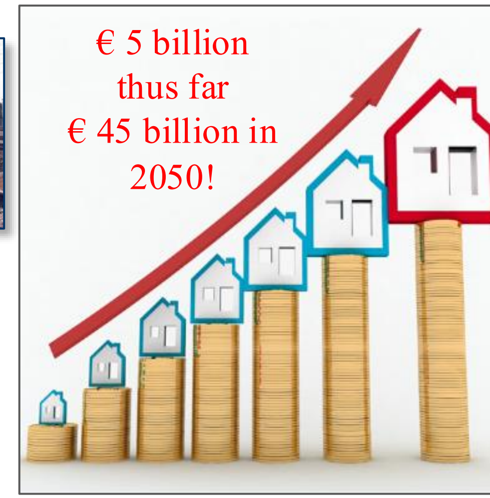
Structures and infrastructure networks located over subsidence-affected areas are exposed to settlement-induced damage and an increase of the flooding risk. In The Netherlands, efforts have been made *to predict the economic losses* induced by subsidence-related damage to buildings; these forecasts range from *5 to 45 billion euros by 2050* (*Bucx et al. 2015; Hoogvliet et al. 2012; Leusink 2018; van den Born et al. 2016*).

Damage to buildings

Damage to infrastructures



ECONOMIC LOSSES

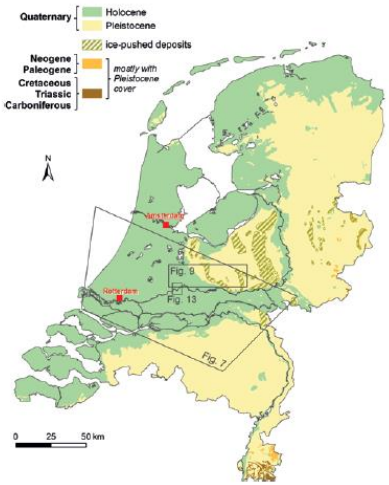


(from: Erkens et al., 2015)

Consequently, subsidence risk is a topic of particular concern for both the scientific and technical communities when the most suitable strategies for land-use planning and urban management need to be identified.

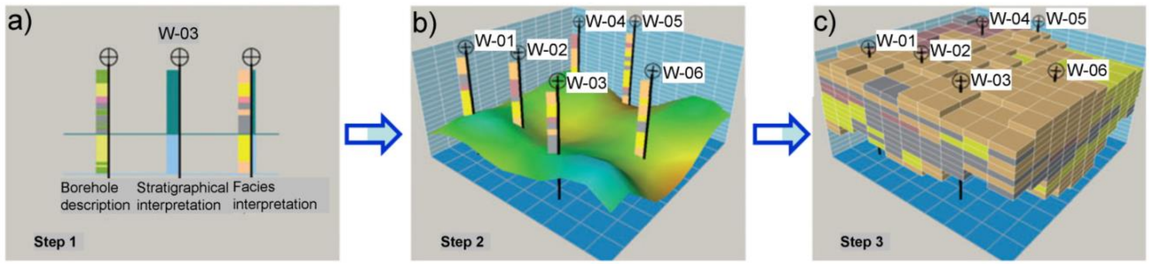
The Netherlands study area: geological context

GeoTOP Model



Source: Van der Meulen et al, 2013

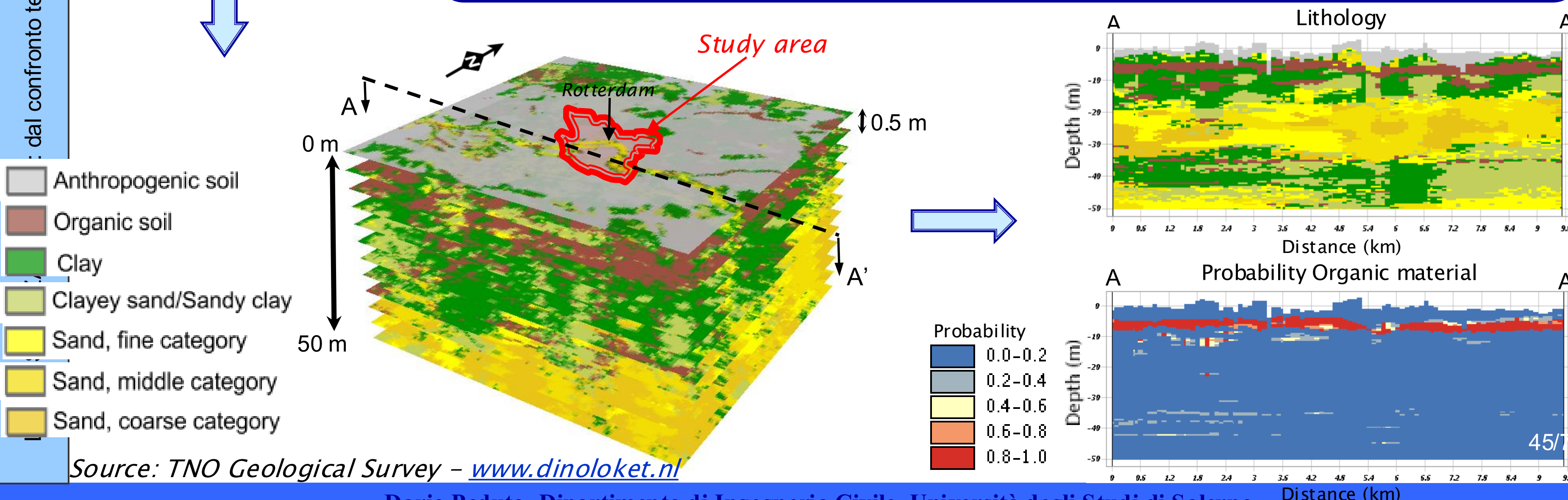
The GEOLOGICAL SURVEY OF THE NETHERLANDS (GSN) has built in the last few years a 3D geological 'GeoTOP' model extending to a depth of 50 m below the subsurface of the Netherlands. In Geotop, the surface is divided into millions of voxel of 100 x 100 meters in the horizontal direction and 0.5 meters in the vertical direction and for each of these are associated information as the lithostratigraphic unit and lithological class, characterized by different chemical and physical parameters. *(Van der Meulen et al, 2013)*



Borehole descriptions subdivided into lithostratigraphical, lithofacies and lithological units.

2D interpolation of the basal surface of each lithostratigraphical unit.

3D interpolation of lithofacies and lithology within each lithostratigraphical unit.



Source: TNO Geological Survey – www.dinoloket.nl

Case studies in The Netherlands: subsiding buildings

Four subsiding urban areas in The Netherlands with 706 masonry buildings resting on both shallow and piled foundations affected by widespread ground settlements mainly associated with the presence of highly compressible fine-grained "soft soils" and decay processes (due to fungal or bacteria attack) affecting wooden piles were analyzed.

ROTTERDAM

SCHIEDAM

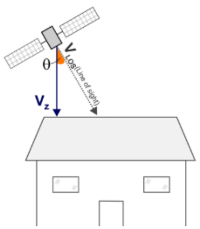
DORDRECHT

ZAANSTAD

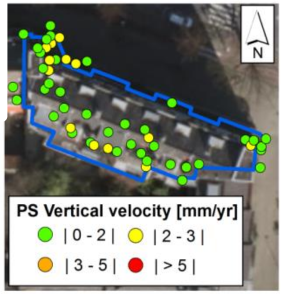
Peduto D., Korff M., Nicodemo G., Marchese A., Ferlisi S. (2019). Empirical fragility curves for settlement-affected buildings: analysis of different intensity parameters for seven hundred masonry buildings in The Netherlands. **Soils and Foundations**, 59: 380–397, https://doi.org/10.1016/j.sandf.2018.12.009

Subsiding buildings: assessment of the intensity parameters

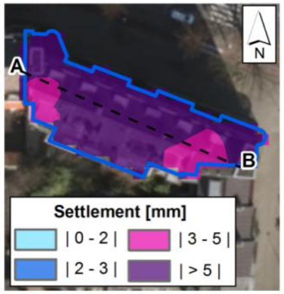
For each building (identified using the built-up map and DInSAR velocity map), the PS-settlement profile is retrieved and the intensity of different subsidence-related intensity (SRI) parameters of foundation movements affecting a sample of 706 buildings in similar geo-lithological settings (i.e., presence of soft soil strata) is estimated.



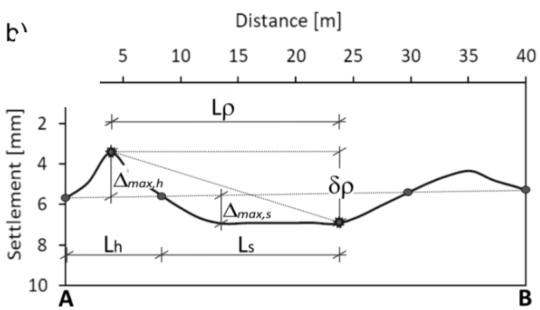
PS vertical velocity



Cumulative settlements



PS-settlement profile



706 SINGLE BUILDINGS
(Sample of buildings)

Surveyed buildings		
Case study	Foundation type	
	Shallow	Piled
Zaanstad	0	81
Rotterdam	0	183
Schiedam	104	206
Dordrecht	76	56
Total	**180**	**526**

– differential settlement (δρ): computed along the profile as the difference between the maximum and the minimum values of the recorded settlements;

– rotation (θ), or slope: assumed as θ = δρ/Lρ, where Lρ indicates the distance at the foundation level between the two points where δρ was computed;

– deflection ratio: obtained as Δ/L according to the definitions provided by Burland and Wroth (1974), where Δ is the displacement of a point relative to the line connecting two reference points and L is the distance between these two points.

Peduto D., Korff M., Nicodemo G., Marchese A., Ferlisi S. (2019). Empirical fragility curves for settlement-affected buildings: analysis of different intensity parameters for seven hundred masonry buildings in The Netherlands. **Soils and Foundations**, 59: 380–397, https://doi.org/10.1016/j.sandf.2018.12.009

Phase I: building fact-sheets

BUILDING FACT-SHEETS - (Building I1) DATE: 12/05/2015

SECTION 1: Location area and building information

Municipality	Schiedam (NL) – West neighborhood
Address	Rembrandtlaan, 12 - 36
Cordinates	51°54'44.74"N – 4°23'02.71"E
Occupancy type	Private houses
Floors number	3
Construction age	1929
Structural typology	Masonry
Foundation type	Piles

SECTION 2: Background data

Geological contex — PSI Data

Cumulative thickness of soft soil (organic material and clay)

GeoTop Model – TNO Geological survey

TSX data (2009-2014) asc. and dsc. Orbit at street level

TSX data (2009-2014) asc. and dsc. Orbit on top of building

SECTION 3: Damage survey

Field survey photos

Classification of visible damage (Burland, 1977)

Category	Severity level	Brief description	
D0	Negligible	Hairline cracks less than about 0.1 mm.	☐
D1	Very Slight	Fine cracks that are easily treated during normal decoration. Some cracks in external brickwork or masonry.	☐
D2	Slight	Cracks easily filled. Redecoration probably required. Recurrent cracks can be masked by suitable linings.	☐
D3	Moderate	The cracks requires some opening up and can be patched by a mason. Repainting of external brickwork and possibly a small amount of brickwork to be replaced. Service pipes may fracture.	☐
D4	Severe	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes disrupted.	☐
D5	Very Severe	This requires a major repair job involving partial or complete rebuilding. Beams lose bearing, walls lean badly and require shoring. Danger of instability.	☐

SECTION 4: Settlement parameters and building deformation

TSX data on ascending and descending orbit in the period (2009-2014) on top of building

Cumulative settlements derived from TSX data

Settlements gradient derived from TSX data

Peduto, D., Nicodemo, G., Maccabiani, J., Ferlisi, S. (2017). *Multi-scale analysis of settlement-induced building damage using damage surveys and DInSAR data: a case study in The Netherlands.* **Engineering Geology**, 218:117-133, doi: 10.1016/j.enggeo.2016.12.018.

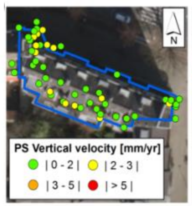
Subsiding buildings: probabilistic cause-effect relationships

Cause-effect relationships between the magnitude of the selected SRI parameter "differential settlement ($\delta\rho$), and damage severity levels as well as empirical fragility curves (generated adopting a cumulative log-normal distribution function, *Zhang and Ng, 2005; Negulescu et al., 2010; Peduto et al., 2017; among others*), were derived for the sample of analyzed masonry buildings resting on (180) shallow and (526) wooden pile foundations.

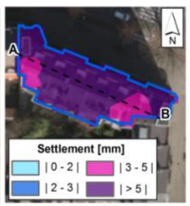
Category of damage and degree of severity	Description of typical damage
D0 (Negligible)	Hairline cracks less about 0.1 mm.
D1 (Very Slight)	Fine cracks and rarely visible which are easily trated using normal decoration. Typical crack widths up to 1 mm.
D2 (Slight)	Cracks visible that can be masked by suitable linings or easily filled. Doors and windows may stick slightly and require easing and adjusting. Typycal crack widths up to 5 mm.
D3 (Moderate)	Cracks much visible with possible expulsion of material which require some maintenance works. Typical crack widths are 5 to 15 mm.
D4 (Severe)	Widespread cracks and extensive damage which riquires breaking-out and replacing sections of walls, especially over doors and windows. Settlement may cause slight tilt to walls and fractures to structural members. Typical crack widths are 15 to 25 mm but also depends on number of cracks.
D5 (Very Severe)	Extensive cracking with structural damage which requires a major repair job that can involving partial or complete rebuilding. Settlement may cause tilt or rotation of the walls. Danger of instability which can require the evacuation and abondonment of the building.

Damage Classification (modified from Burland, 1977)

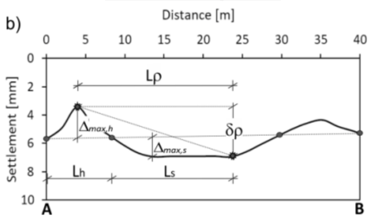
1a) DInSAR velocity



1b) Settlement



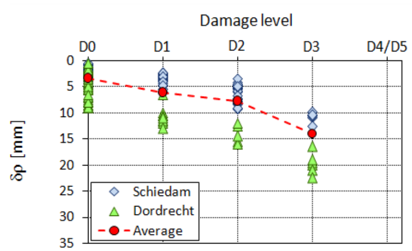
2) SRI parameters along the settlement profile



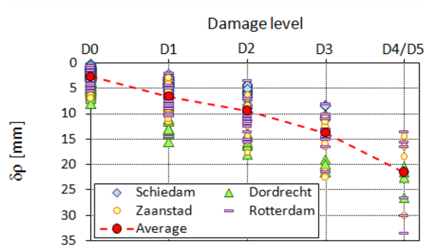
3) Damage severity level

Cause-effect relationships

SHALLOW



PILED



Probabilistic model

Cumulative log-normal distribution function

$$P(Damage \geq Di|SRI) = \Phi\left[\frac{1}{\beta_i}\ln\left(\frac{SRI}{\overline{SRI}_i}\right)\right]$$

Φ = standard normal cumulative distribution function;

SRI **= subsidence-related intensity parameters;**

$\overline{SRI}_i$ **= median value of** ***SRI***

β **= standard deviation**

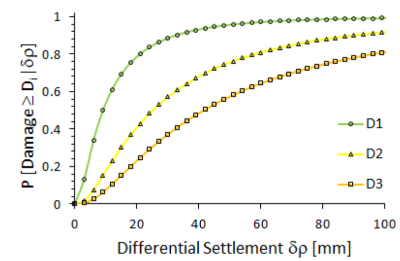
Fragility parameters

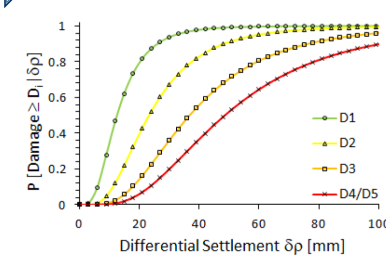
The maximum likelihood method was used to estimate the fragility parameters (Shinozuka et al., 2003).

$$L\left(\overline{SRI}_i, \beta\right) = \prod_{j=1}^{N}\prod_{i=0}^{k} P_i\left(SRI_j; D_i\right)^{y_{ji}}$$

$$\frac{\partial \ln L\left(\overline{SRI}_i, \beta\right)}{\partial \overline{SRI}_i} = \frac{\partial \ln L\left(\overline{SRI}_i, \beta\right)}{\partial \beta} = 0$$

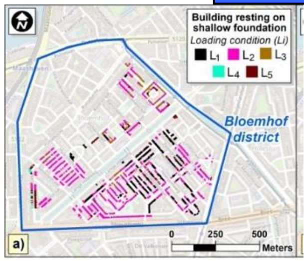
Fragility curves





Peduto D., Korff M., Nicodemo G., Marchese A., Ferlisi S. (2019). Empirical fragility curves for settlement-affected buildings: analysis of different intensity parameters for seven hundred masonry buildings in The Netherlands. **Soils and Foundations**, 59: 380–397, https://doi.org/10.1016/j.sandf.2018.12.009

Subsiding buildings: combination of numerical and empirical approaches

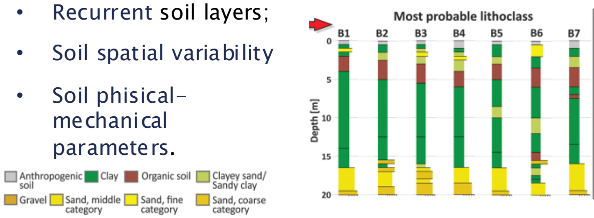


Setup of Hydro-Geomechanical-Loading ($H_iG_iL_i$) scenarios for numerical simulations

Typified Hydro-Geomechanical-Loading ($H_iG_iL_i$) scenarios

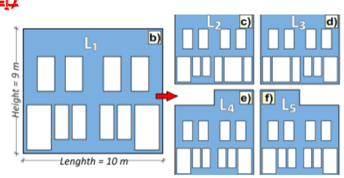
5 geostratigraphic conditions (G_i)

- Recurrent soil layers;
- Soil spatial variability
- Soil phisical-mechanical parameters.



5 loading conditions (L_i)

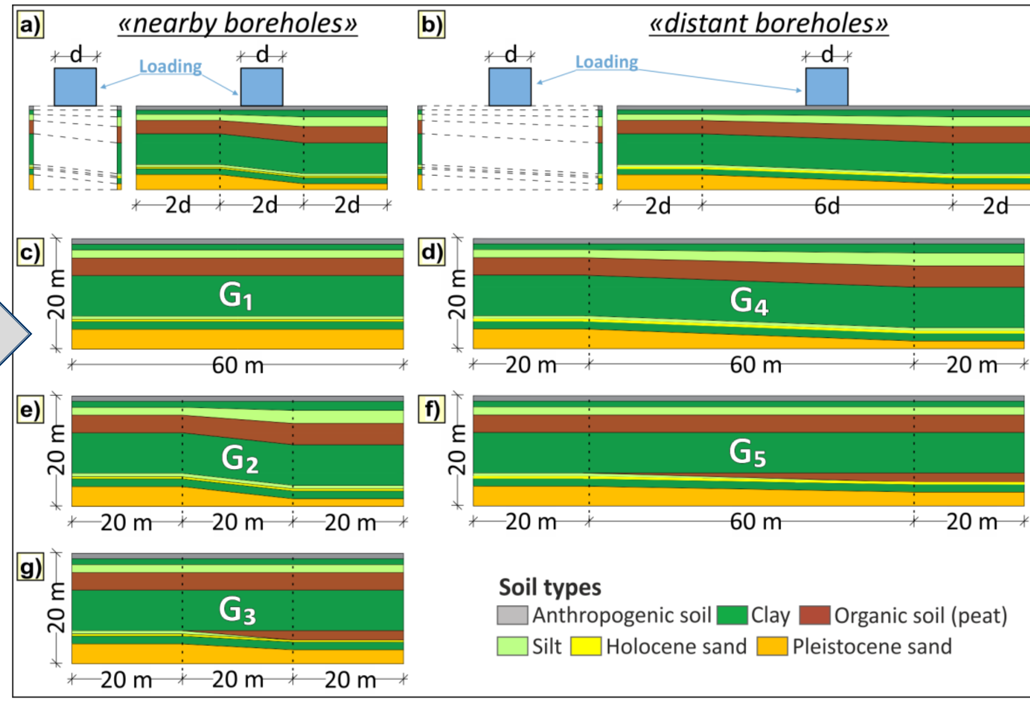
- L_1: symmetrical case;
- L_2 and L_3: asymmetry in openings;
- L_4 and L_5: asymmetry in height.



9 drawdown functions (H_i)

Water level variation (head level) (m)	Water table level (from ground surface) (m)	H_i conditions: Linear drawdown	H_i conditions: Immediate drawdown
0.00	−1.50	H_1	H_1
−0.25	−1.75	H_2	H_6
−0.50	−2.00	H_3	H_7
−0.75	−2.25	H_4	H_8
−1.00	−2.50	H_5	H_9

The typical loading (L_i), combined with the geostratigraphic (G_i) and water table (H_i) conditions, allowed to identify 225 "typified" $H_iG_iL_i$ scenarios.



Peduto D., Prosperi A., Nicodemo G., Korff (2022) District-scale numerical analysis of settlements related to ground water lowering in variable soil conditions. **Canadian Geotechnical Journal**, 59(6): 978–993, DOI: 10.1139/cgj-2021-0041

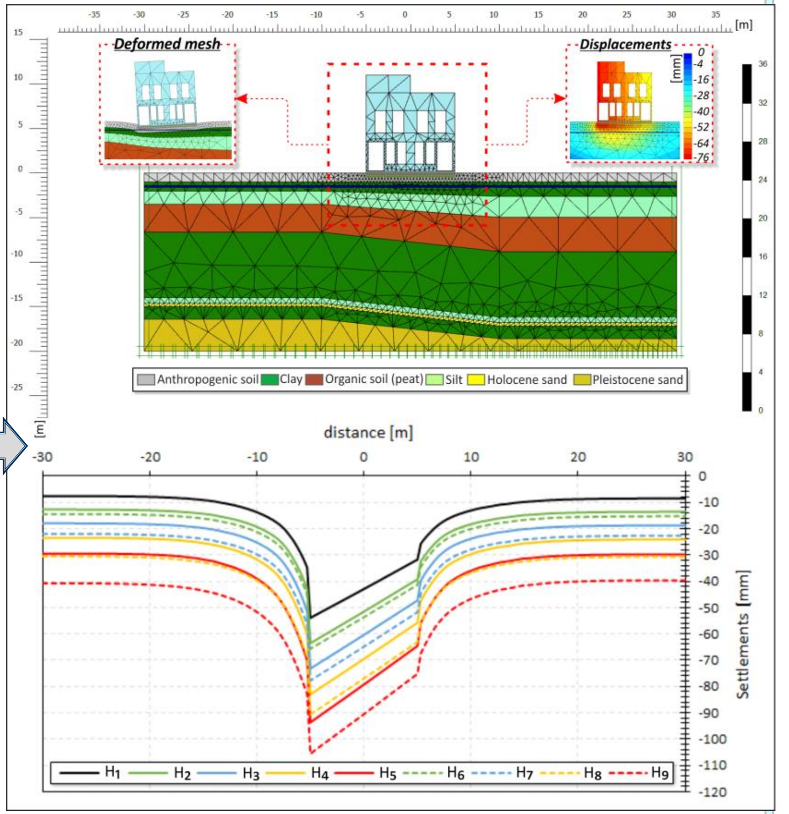
Subsiding buildings: combination of numerical and empirical approaches

Numerical simulation of different Hydro-Geomechanical-Loading ($H_iG_iL_i$) scenarios

Numerical simulations

225 finite element analyses (conducted using Plaxis2D software) were carried out for each defined HGL scenario considering:

- the lowering of the water table as the triggering factor for settlement occurrence;
- the time-dependent water drawdowns using the flow function in Plaxis2D;
- a time interval of 30 years (10.950 days);
- a fully coupled flow-deformation analyses (soft soil creep model – SSC was assigned to peat, clay, and silt soils and a Mohr–Coulomb – MC criterion was assigned to the sand);
- the soil – (shallow) foundation interaction (modelled as interface elements set at the base of the building with a virtual zero thickness and properties related to the soil parameters of the surrounding soil layer);
- a mesh with plain strain 15-node triangular elements (a good compromise for time-consuming calculations);
- a deformation boundary conditions “normally fixed” at left and right sides of the modelled soil volume (i.e., horizontal displacements are fixed);
- the masonry building resulting in a mean load equal to 25.5 kN/m²;
- the maximum differential settlement as the difference in the vertical settlement between the side points of the building’s footprint.



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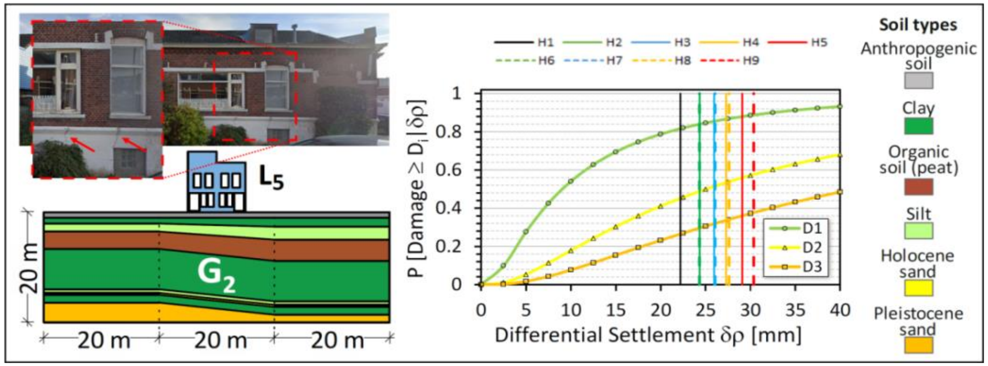
Subsiding buildings: combination of numerical and empirical approaches

Forecasting building damage over the time at the district scale

SUMMARY OF THE RESULTS ACHIEVED

The damage severity level that the buildings undergoing the computed differential settlements may experience was assessed using available empirical fragility curves for masonry buildings on shallow foundations.
An example for the L_5 loading condition resting on G_2 soil scenarios (inclined layer with rapid thickness variation), which the previous results identified as inducing the highest differential settlements, leading to higher probability of more severe damage.



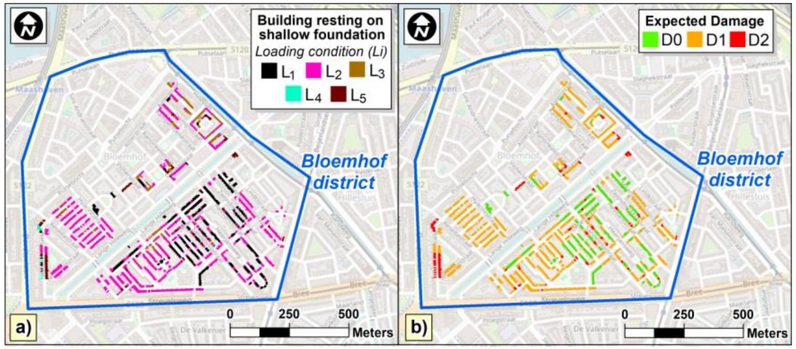
HOW THE RESULT ACHIEVED COULD BE USED?

The outcomes obtained can help to predict the expected damage (ED) to the built heritage (buildings on shallow foundations) over the time considered for the numerical simulation in different H_i, Gi and L_i conditions.

$$\mathrm{ED(SRI)} = \sum_{i=0}^{1} p_i d_i$$

p_i: damage probability associated with the occurrence of the i-th expected Di, which can be retrieved from the fragility curves (computed value of the SRI parameter)

d_i: numerical index whose value changes according to the considered expected Di (e.g., assumed equal to 0.20, 0.40, 0.60, 0.80, and 1.0 for, respectively, D1, D2, D3, D4, and D5 of Burland et al.'s 1977 classification)



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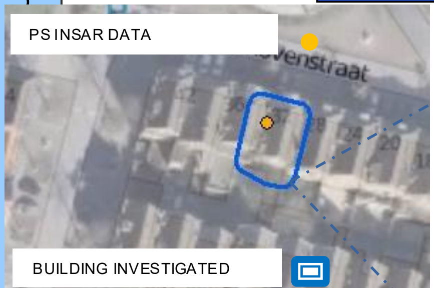
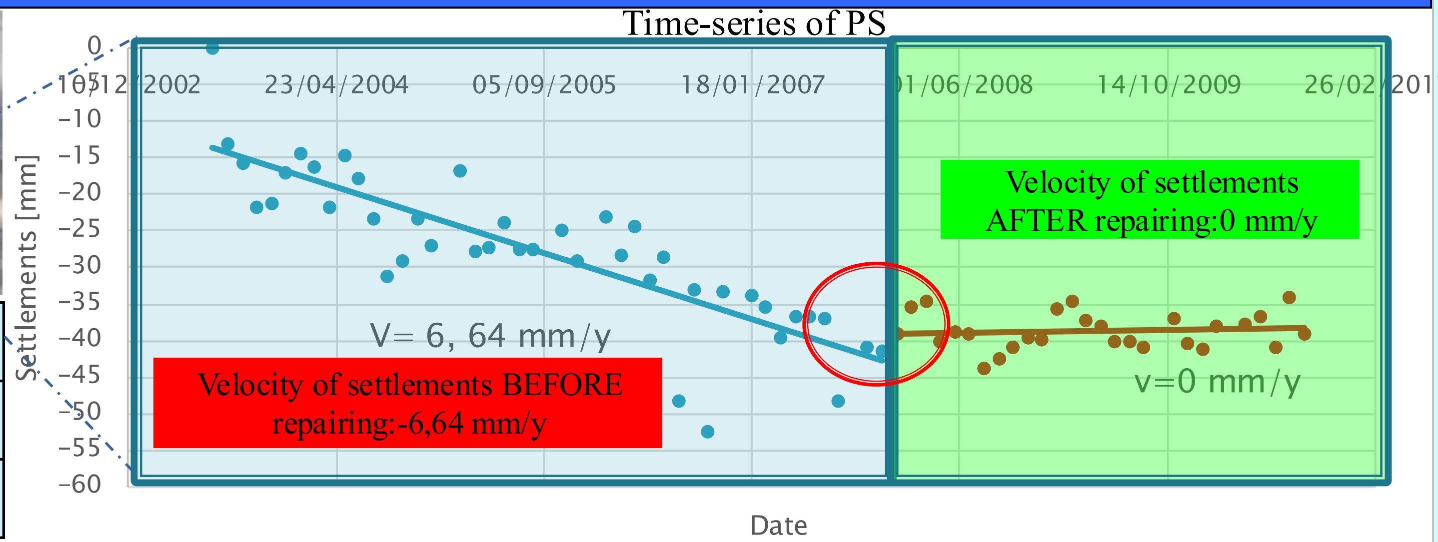
DInSAR data for checking the effectiveness of building foundation repair: examples in The Netherlands

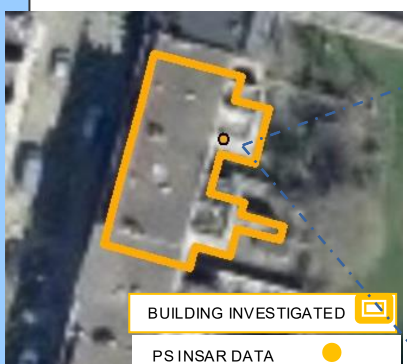
Peduto D., Nicodemo G., Maccabiani J., Ferlisi S., D'Angelo R., Marchese A. (2016). *Investigating the behaviour of buildings with different foundation types on soft soils: two case studies in The Netherlands.* In: Gottardi G., Tonni L. (Eds.), VI Italian Conference of Researchers in Geotechnical Engineering, CNRIG2016 - Geotechnical Engineering in Multidisciplinary Research: from Microscale to Regional Scale, 22-23 September 2016, Bologna (Italy). Procedia Engineering, Volume 158, 2016, Pages 529–534, http://dx.doi.org/10.1016/j.proeng.2016.08.484

Check of the effectiveness of building foundation repair

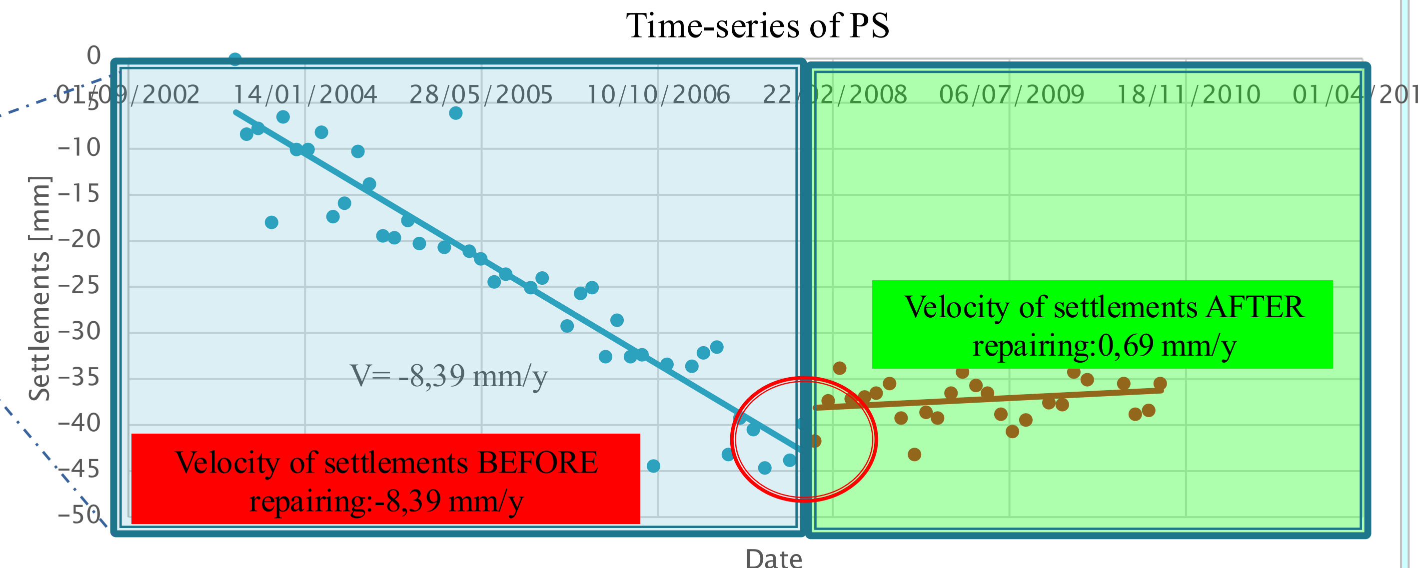


Street	Oudenhovenstraat 32
Repairing Date	Nov. 2007
Repairing cost	€ 97.000





Street	Koninginnestraat 8-20
Repairing Date	Mar. 2008
Repairing cost	€ 23.000



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Application to bridges in urban area: the case study of the bridges in Amsterdam city

Peduto D., Elia F., Montuori R. (2018). Probabilistic analysis of settlement-induced damage to bridges in the city of Amsterdam (The Netherlands), **Transportation Geotechnics**, 14: 169–182, https://doi.org/10.1016/j.trgeo.2018.01.002

DInSAR application to bridges: the case study of Amsterdam

With its network of more than 100km of canals, it's no surprising that Amsterdam has become renowned as the "**City of Bridges**".

Indeed, according to the local tourist board, Amsterdam has about 2000 bridges crossing the city's many roads, canals and waterways.

Differential settlements induce bending moments and shear in the bridge superstructure. These moments and shears can potentially cause structural damage.

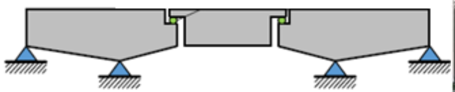
DInSAR application to bridges: the case study of Amsterdam

Type of Amsterdam bridges (according to the degree of redundancy)

Statically determinate bridges

- simply supported beam

- Gerber beam



- simply supported beam for movable bridge

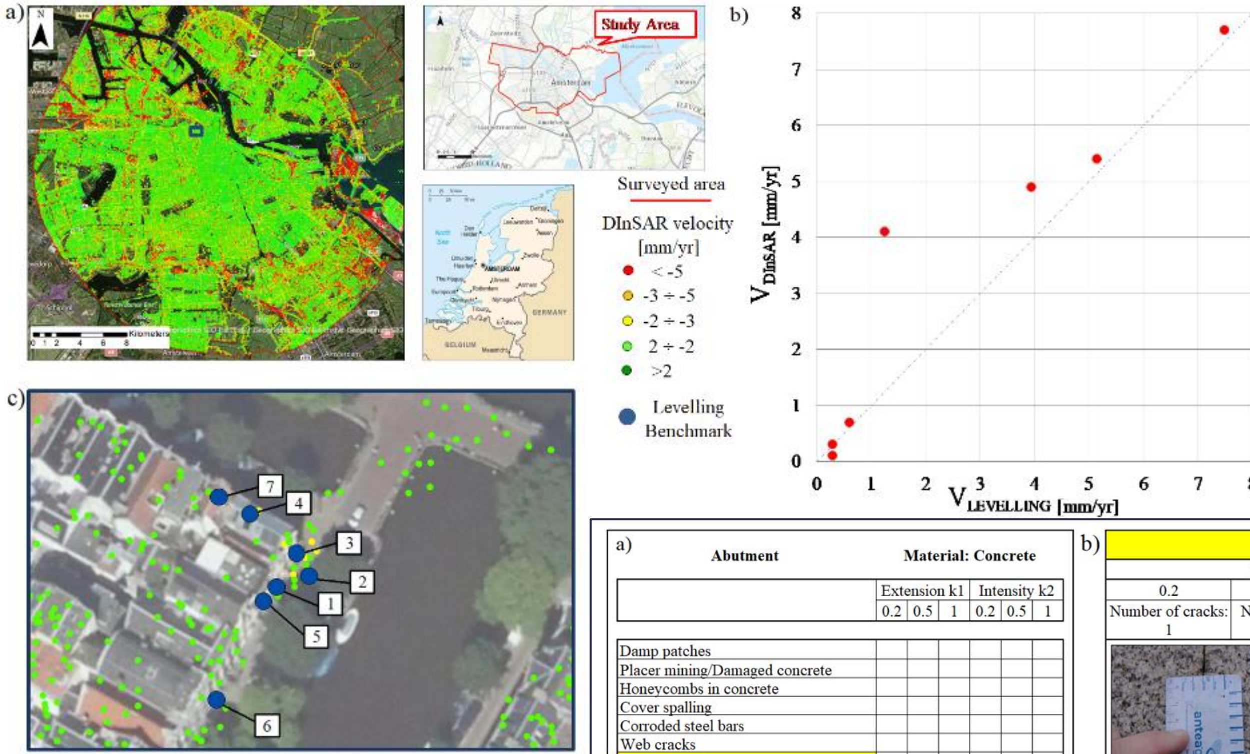
Statically indeterminate bridges

- fixed bridge

- continuous beam

- fixed arch

DInSAR application to bridges: the case study of Amsterdam



DInSAR data validation

The bridge damage fact-sheet

a)

Abutment	Material: Concrete					
	Extension k1			Intensity k2		
	0.2	0.5	1	0.2	0.5	1
Damp patches						
Placer mining/Damaged concrete						
Honeycombs in concrete						
Cover spalling						
Corroded steel bars						
Web cracks						
Vertical cracks						
Horizontal cracks						
Diagonal cracks						
Deteriorated rebend						
Impact damages						
Damages caused by structural bearings						
Out of plumb line (vertical line)						
Embankment instability						
Erosion at the feet of the bridge						
Embankment placer mining						
Neoprene bearings failings						
Penduluum failings						
Rockers (rollers) failings						
Composite bearings failings						

b)

VERTICAL CRACK					
Extension k1			Intensity k2		
0.2	0.5	1	0.2	0.5	1
Number of cracks: 1	Number of cracks: 1÷3	Number of cracks: >3	Hairline	1÷2 mm	>2 mm

c)

Damage level	K1+K2	Extension and intensity
D1	≤ 0.4	1 hairline crack
D2	$0.4 < k1+k2 \leq 0.9$	1 crack of 1÷2 mm thick 2÷3 hairline cracks 2÷3 cracks:both hairline and 1÷2 mm thick
D3	$0.9 < k1+k2 \leq 1.4$	2÷3 cracks of 1÷2 mm thick 1 crack thicker than 2 mm >3 hairline cracks >3 cracks: both hairline and 1÷2 mm thick
D4	$k1+k2 \leq 1.9$	2÷3 cracks thicker than 2 mm >3 cracks thicker than 2 mm > 3 cracks: both 1÷2 mm thick and thicker than 2 mm >3 cracks thicker than 2 mm

Peduto D., Elia F., Montuori R. (2018). Probabilistic analysis of settlement-induced damage to bridges in the city of Amsterdam (The Netherlands), **Transportation Geotechnics**, 14: 169–182, https://doi.org/10.1016/j.trgeo.2018.01.002

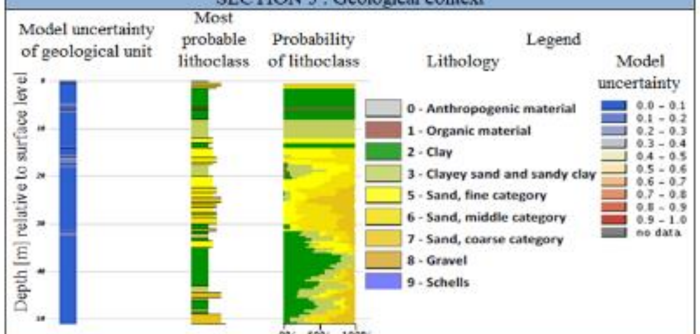
DInSAR application to bridges: the case study of Amsterdam

SECTION 1: Location area and bridge information

Municipality	Amsterdam
ID	437
Position	in de Johan van Hasseltweg over het Mosplein
Material	Concrete
Structural typology	Fixed bridge

SECTION 2 : Geographic position

SECTION 3 : Geological context

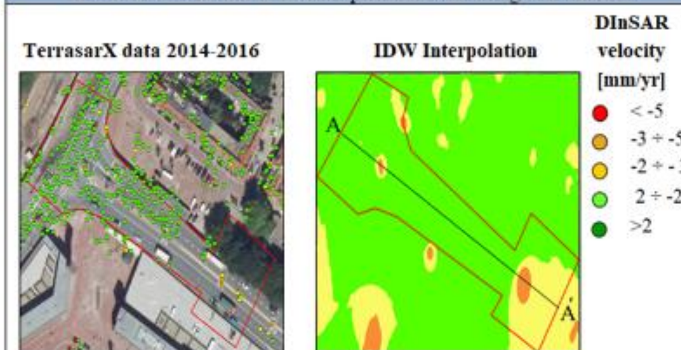


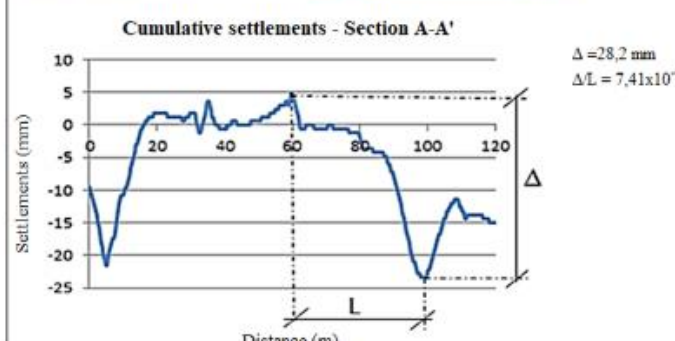
SECTION 4 : Damage survey

Damage level	*Description*	
D1	1 hairline crack	☐
D2	1 crack of 1÷2 mm thick	☐
	2÷3 hairline cracks	
	2÷3 cracks:both hairline and 1÷2 mm thick	
D3	2÷3 cracks of 1÷2 mm thick	☐
	1 crack thicker than 2 mm	
	>3 hairline cracks	
	>3 cracks: both hairline and 1÷2 mm thick	
D4	2÷3 cracks ticker than 2 mm	☒
	>3 cracks ticker than 2 mm	
	> 3 cracks: both 1÷2 mm thick and ticker than 2 mm	
	>3 cracks ticker than 2 mm	

SECTION 5 : Field survey photos

SECTION 6: DInSAR settlements parameters and bridge deformation

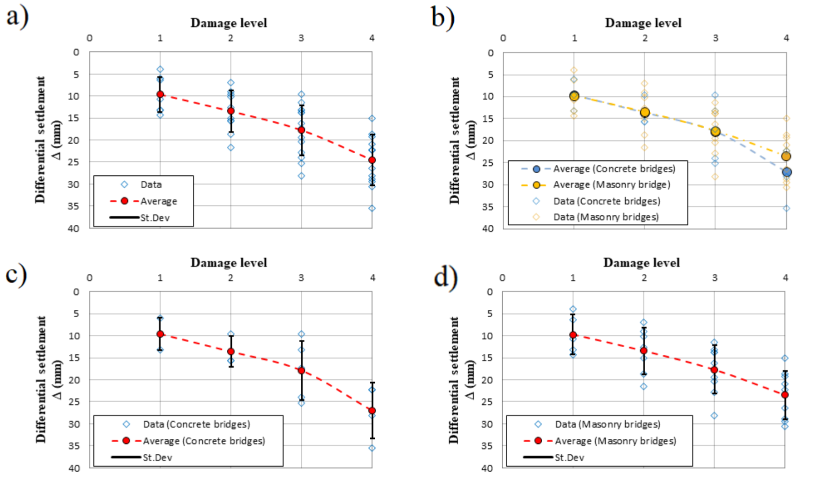




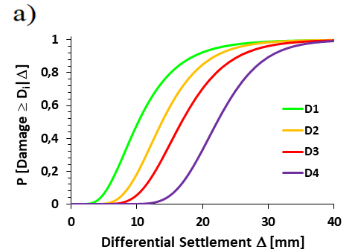
Peduto D., Elia F., Montuori R. (2018). Probabilistic analysis of settlement-induced damage to bridges in the city of Amsterdam (The Netherlands), **Transportation Geotechnics**, 14: 169–182, https://doi.org/10.1016/j.trgeo.2018.01.002

DInSAR application to bridges: the case study of Amsterdam

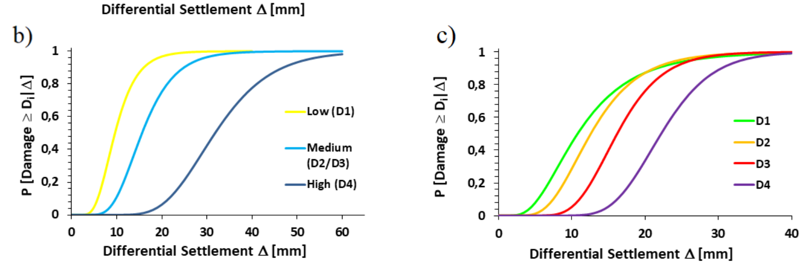
Differential settlement vs. damage



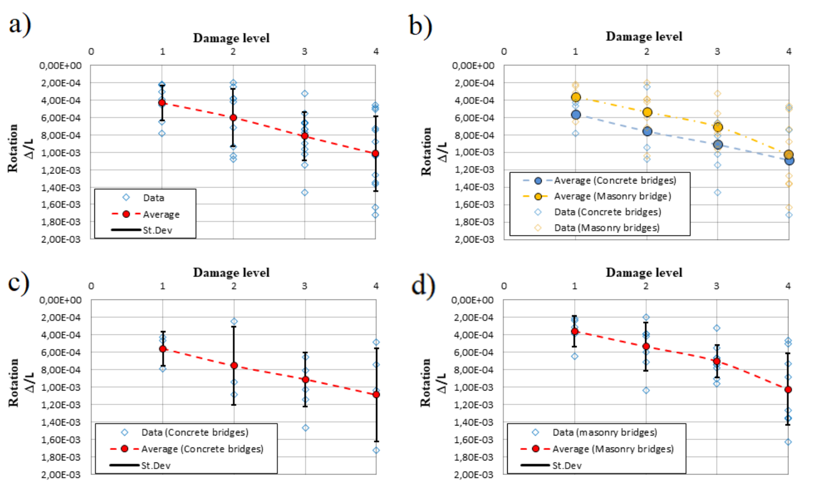
Fragility curves



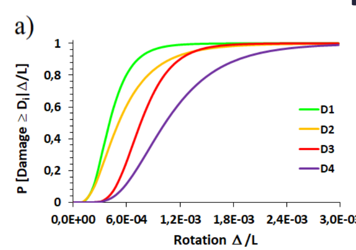
Damage severity level	Selected bridges (45)		Concrete bridges (15)		Masonry bridges (30)	
	Median [mm]	St.Dev. [mm]	Median [mm]	St.Dev. [mm]	Median [mm]	St.Dev. [mm]
D1	10,2	0,47	9,60	0,40	10,80	0,54
D2	13,8	0,36	15,60	0,36	12,60	0,41
D3	16,8	0,32			16,20	0,30
D4	22,2	0,24	31,80	0,30	22,20	0,25



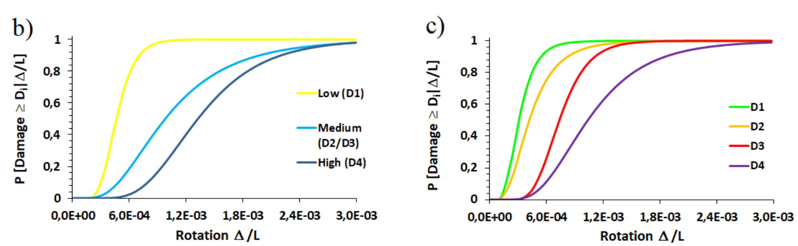
Rotation vs. damage



Fragility curves

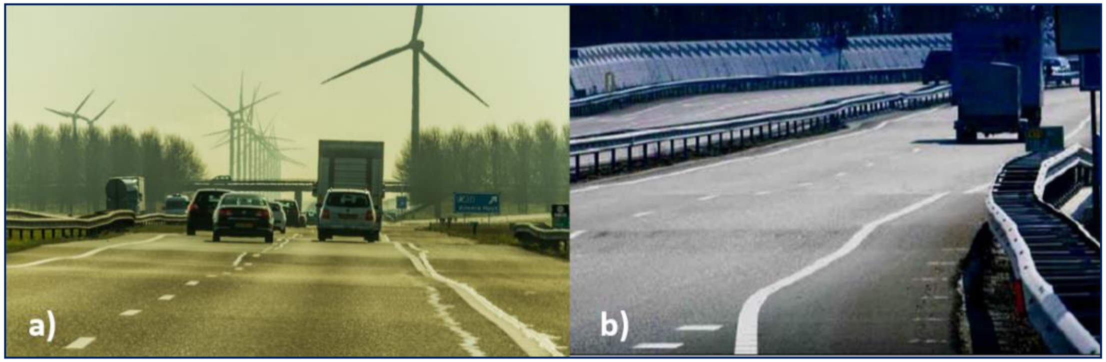


Damage severity level	Selected bridges (45)		Concrete bridges (15)		Masonry bridges (30)	
	Median	St.Dev.	Median	St.Dev.	Median	St.Dev.
D1	4,06E-04	0,45	4,62E-04	0,33	3,08E-04	0,44
D2	5,09E-04	0,60	9,80E-04	0,55	4,17E-04	0,53
D3	7,58E-04	0,36			7,36E-04	0,32
D4	1,03E-03	0,46	1,33E-03	0,40	1,04E-03	0,45



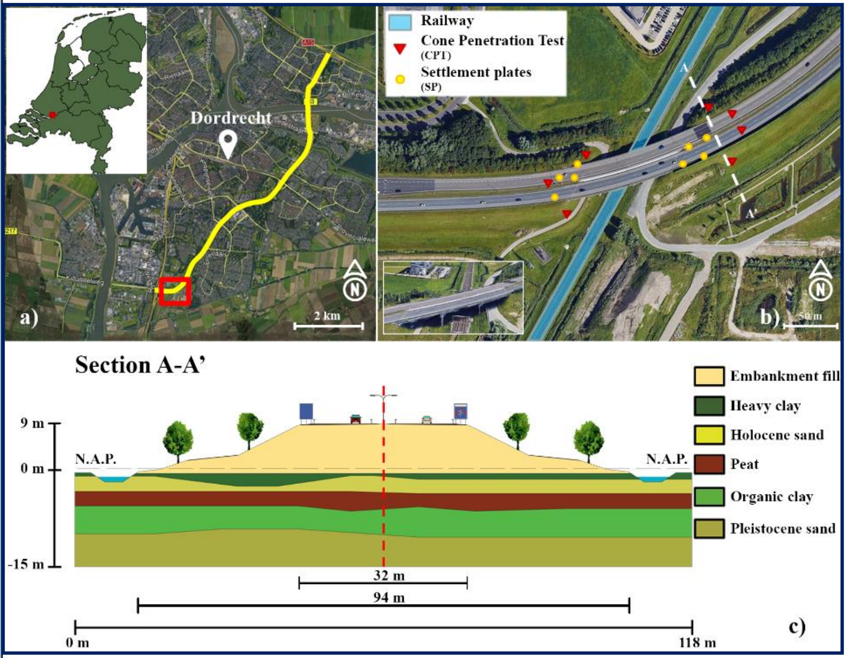
Peduto D., Elia F., Montuori R. (2018). Probabilistic analysis of settlement-induced damage to bridges in the city of Amsterdam (The Netherlands), **Transportation Geotechnics**, 14: 169–182, https://doi.org/10.1016/j.trgeo.2018.01.002

Application to road-bridges transition zones

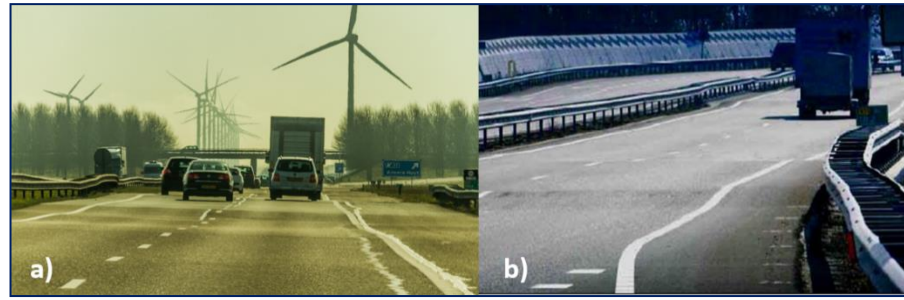


Peduto D., Giangreco C., Venmans A.A.M. (2020) *Differential settlements affecting transition zones between bridges and road embankments on soft soils: Numerical analysis of maintenance scenarios by multi-source monitoring data assimilation*. **Transportation Geotechnics,** 24 (2020) 100369, 10.1016/j.trgeo.2020.100369

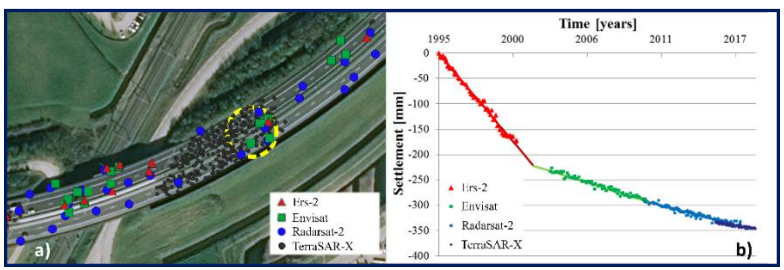
The bridge-embankment transition zone on a highway in the Netherlands



Subsoil model

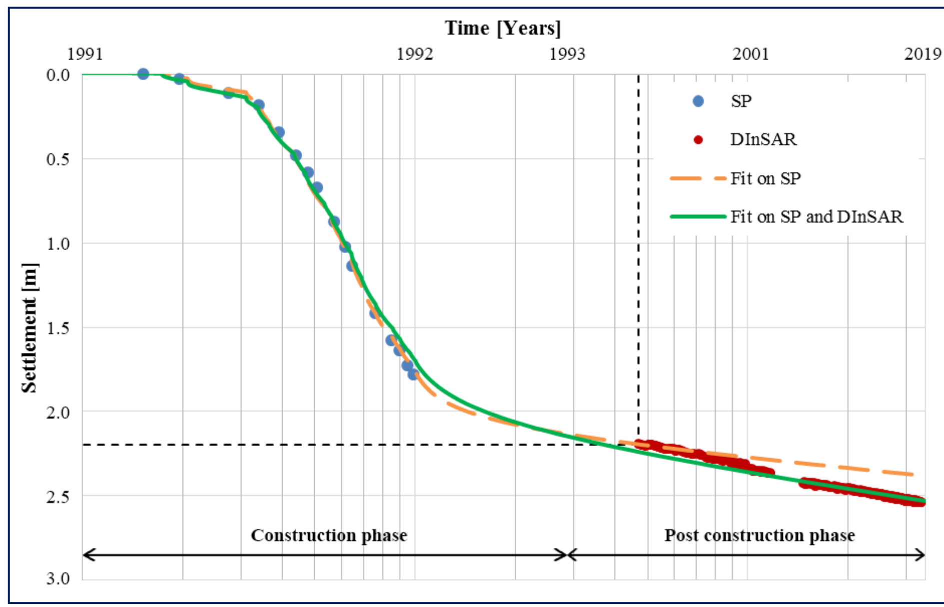


Bumps on highways embankments



Measured settlements

Fitting of measured and modeled settlements for the geotechnical model calibration



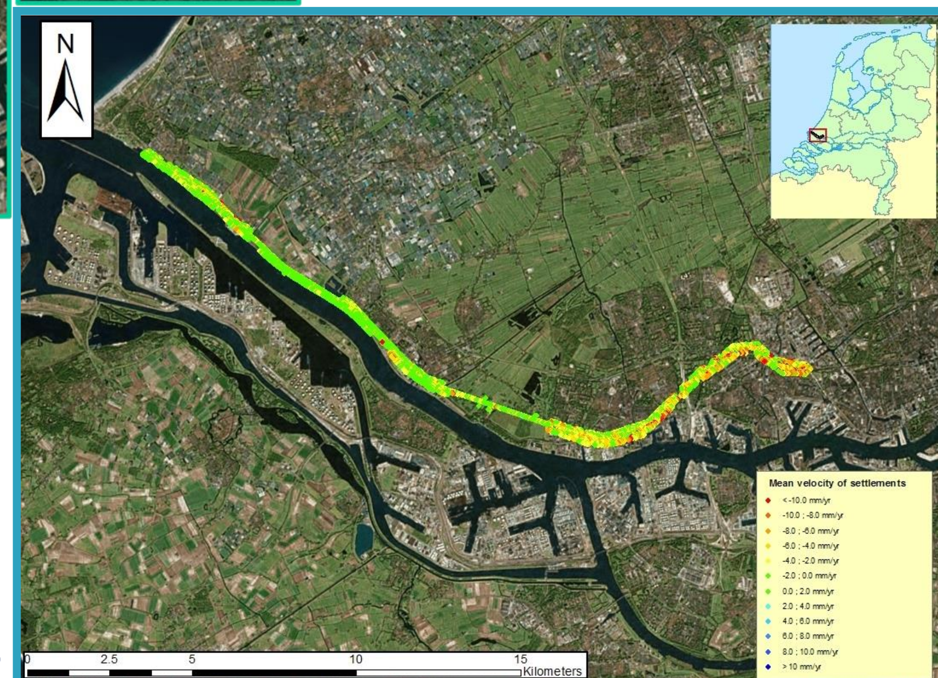
Peduto D., Giangreco C., Venmans A.A.M. (2020) *Differential settlements affecting transition zones between bridges and road embankments on soft soils: Numerical analysis of maintenance scenarios by multi-source monitoring data assimilation.* **Transportation Geotechnics**, 24 (2020) 100369

Application to railway embankments

Peduto D., Huber M., Speranza G., van Ruijven J., Cascini L. (2017). DInSAR data assimilation for settlement prediction: case study of a railway embankment in The Netherlands. **Canadian Geotechnical Journal**, Vol. 54, No. 4 : pp. 502-517,.

The railway from Schiedam to Hoek van Holland

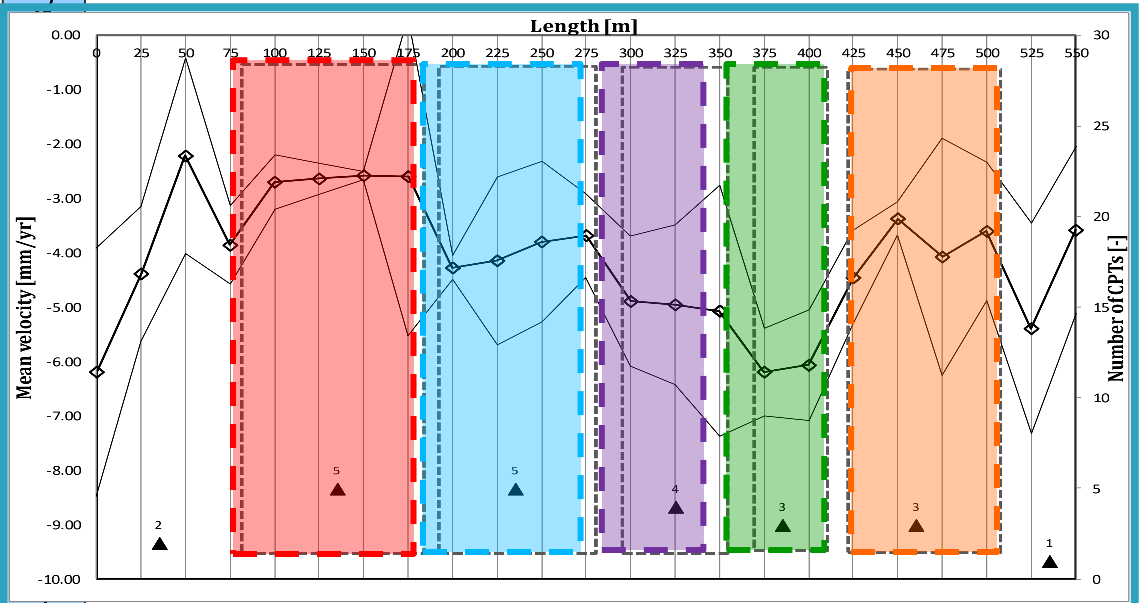
Track of the railway embankment



Along track DInSAR-derived settlement rate map

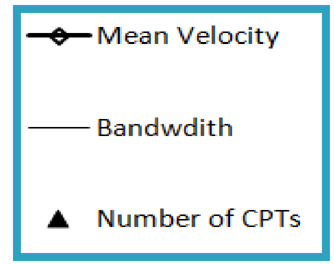
Peduto D., Huber M., Speranza G., van Ruijven J., Cascini L. (2017). DInSAR data assimilation for settlement prediction: case study of a railway embankment in The Netherlands. **Canadian Geotechnical Journal**, Vol. 54, No. 4 : pp. 502-517,.

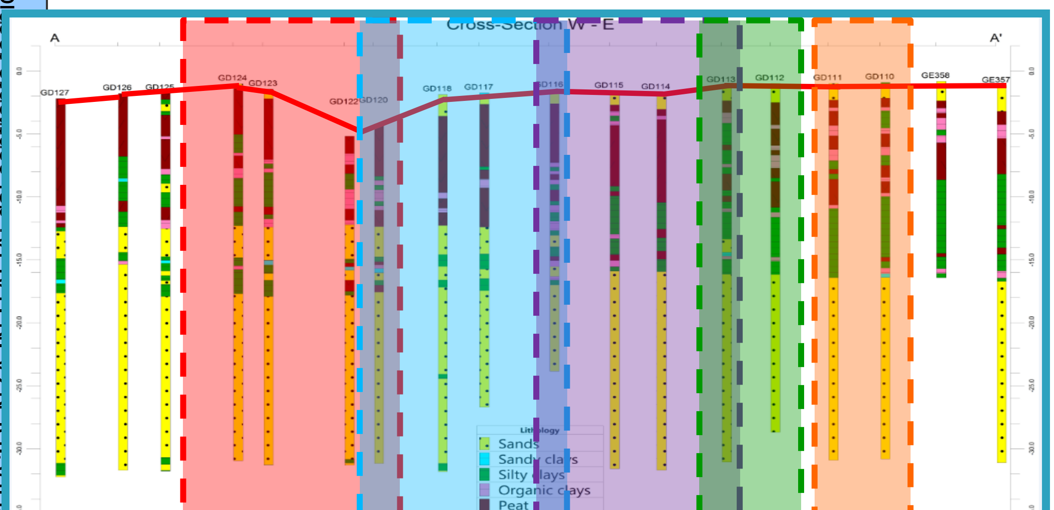
The railway from Schiedam to Hoek van Holland

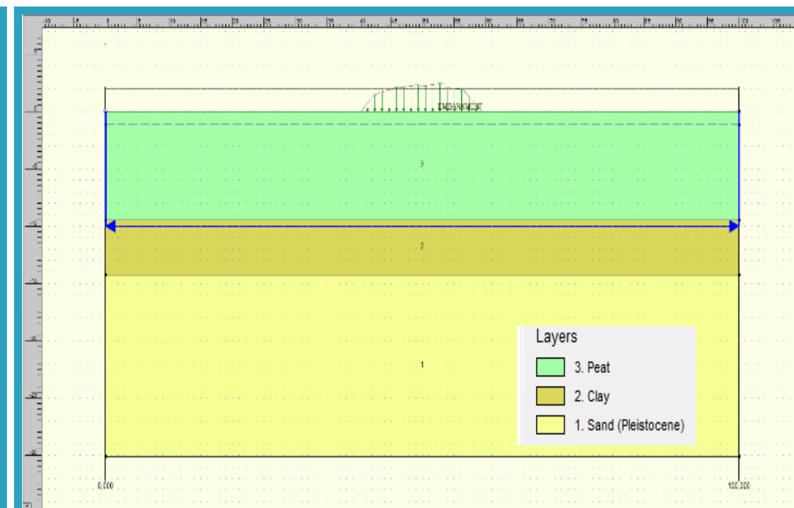


25 m

For each homogeneous sub-area, using CPT data, it is possible to define the mean and the standard deviation of cumulative thickness of layers.



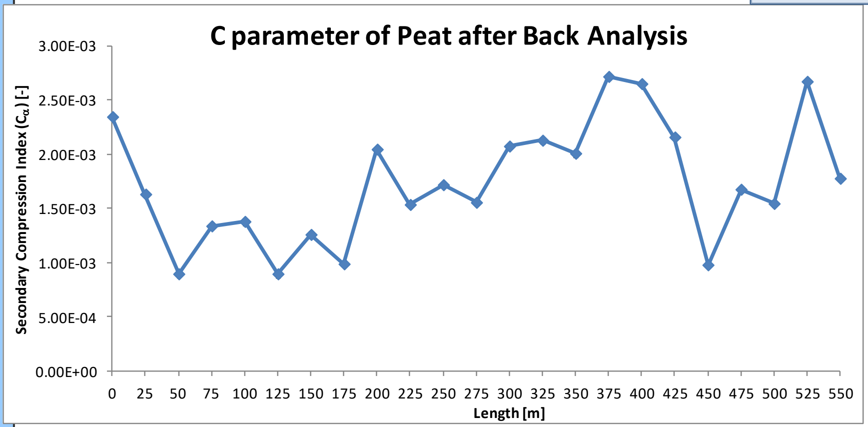


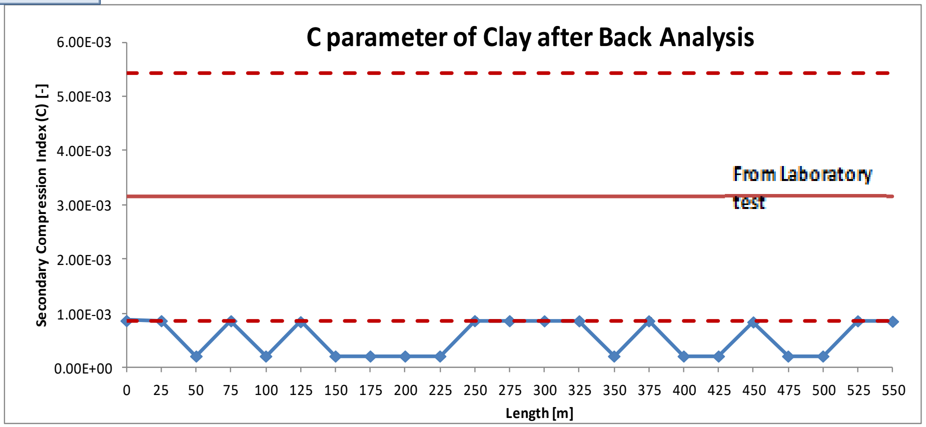


Peduto D., Huber M., Speranza G., van Ruijven J., Cascini L. (2017). DInSAR data assimilation for settlement prediction: case study of a railway embankment in The Netherlands. **Canadian Geotechnical Journal**, Vol. 54, No. 4 : pp. 502-517,.

The railway from Schiedam to Hoek van Holland

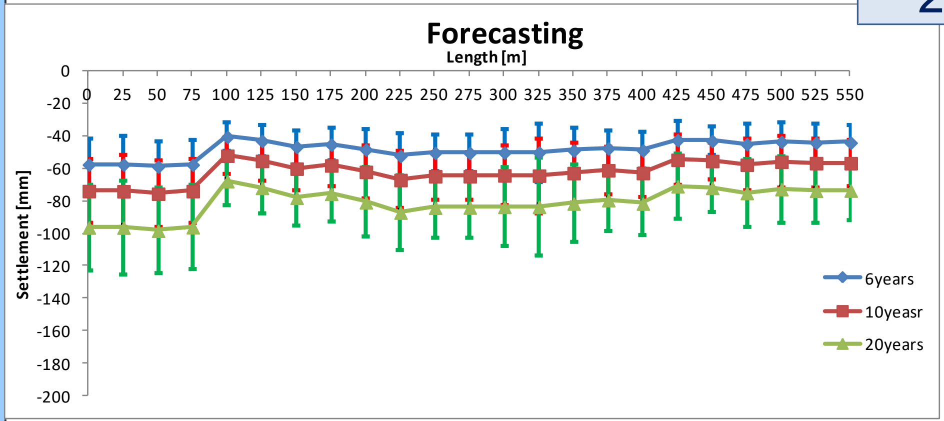
25 m

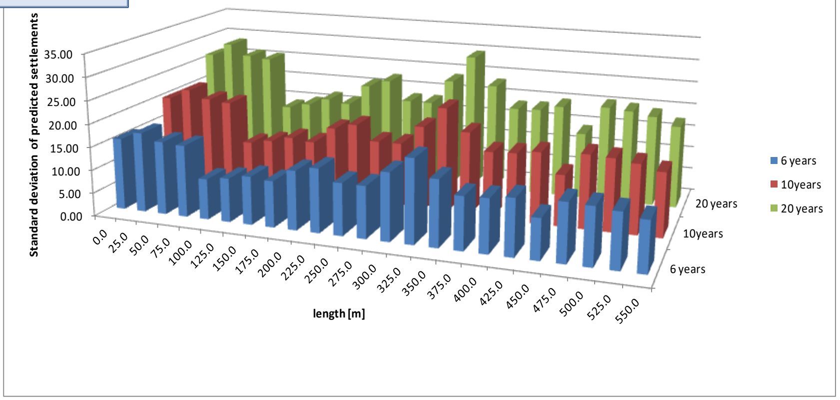




As output we have the C parameters for both layers. For clay we have Laboratory test and it is possible to compare result with them. The results are close to laboratory test, in particular, to lower boundary of st.dev. for both 25m and 50m. For peat it is available only one test and it makes no sense to do it.

25 m





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Analysis of damage of urban quay walls via in-situ surveys and topographic and DInSAR displacement monitoring: The canals of Amsterdam City (The Netherlands)

QW in Amsterdam city

Which is the problem?

Luongo D., Nicodemo G., Venmans A., Korff M., Sartorelli L., Maljaars H., Peduto D., (2025). The Quay Walls of Amsterdam, Netherlands: An Approach for Collapse Risk Mitigation at the Municipal Scale Based on Multisource Monitoring and Surveying Data.. **Journal of Geotechnical and Geoenvironmental Engineering, 151(2), 05024014. https://doi.org/10.1061/JGGEFK.GTENG-12981**

QW in Amsterdam city

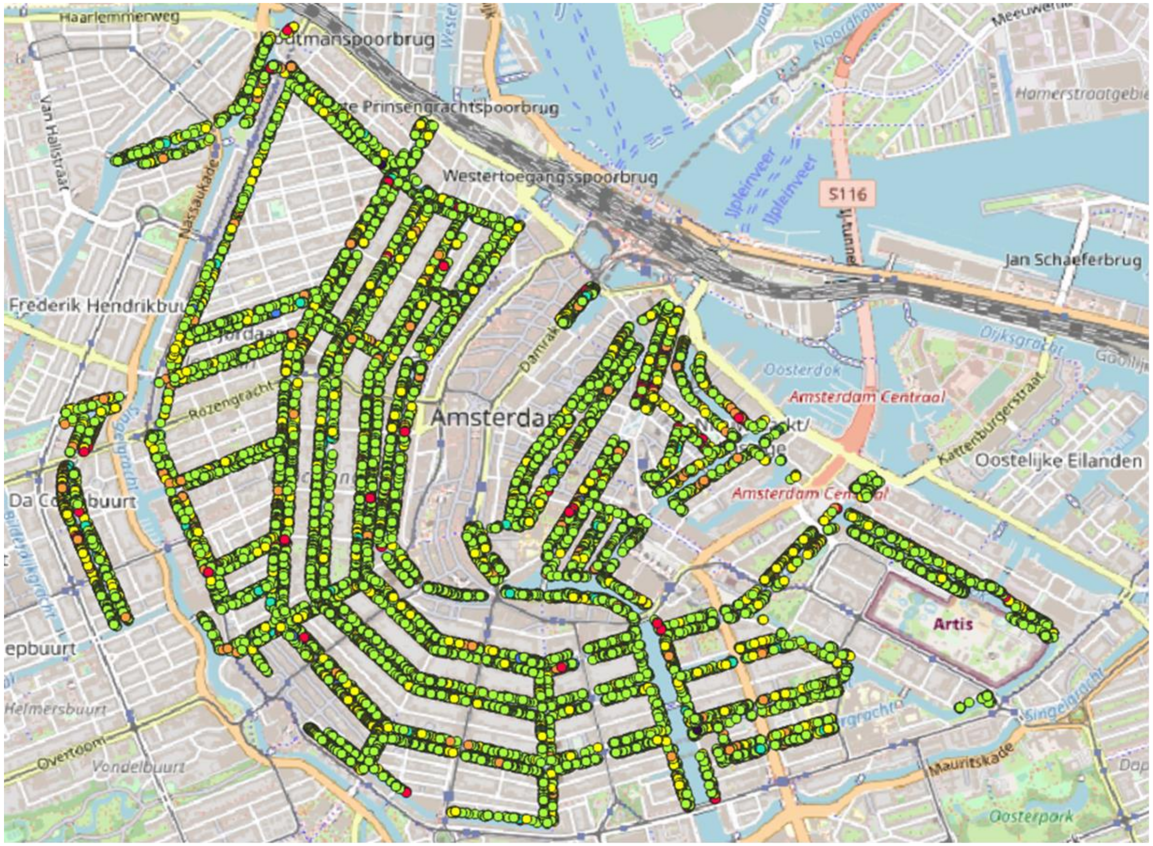
Which are the causes?

- Changes in design conditions between the past and today
- Aging of the foundations
- Deterioration of the wooden piles (fungi and bacteria) (Klaassen 2008; Bettiol 2016)

Gemeente Amsterdam

https://www.structuremag.org/?p=1235

QW in Amsterdam city



ASC LOS velocity [mm/yr]	
-18,21 - -5	mm/yr
-5 - -3	mm/yr
-3 - -1,5	mm/yr
-1,5 - 1,5	mm/yr
1,5 - 3	mm/yr
3 - 5	mm/yr
5 - 16,79	mm/yr

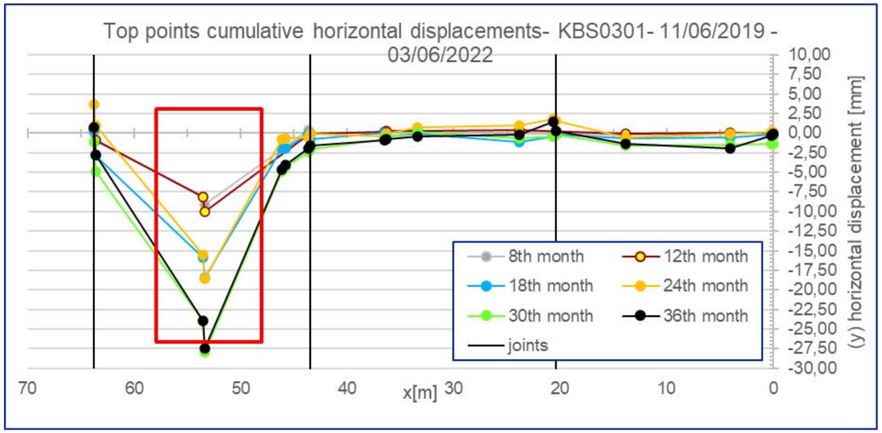
DSC LOS velocity [mm/yr]	
-18,21 - -5	mm/yr
-5 - -3	mm/yr
-3 - -1,5	mm/yr
-1,5 - 1,5	mm/yr
1,5 - 3	mm/yr
3 - 5	mm/yr
5 - 16,79	mm/yr

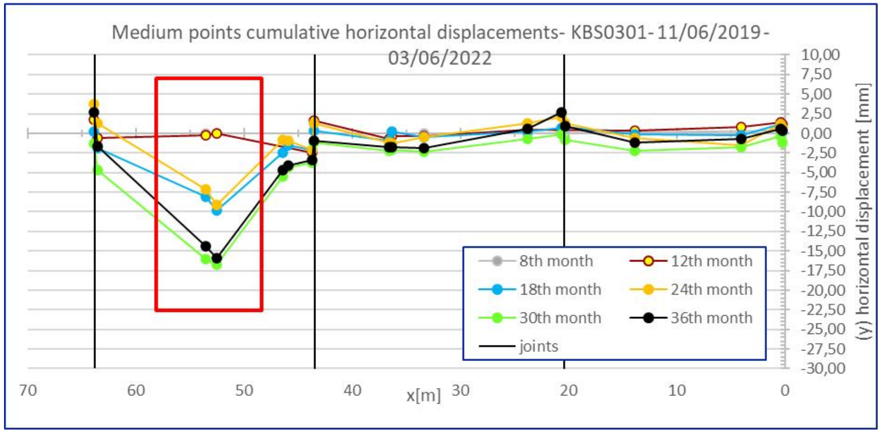
The considered polygon is composed by :

- Quay wall + Road

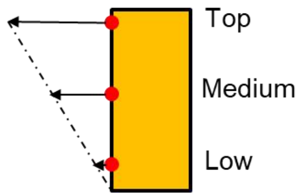
Luongo D., Nicodemo G., Venmans A., Korff M., Sartorelli L., Maljaars H., Peduto D., (2025). The Quay Walls of Amsterdam, Netherlands: An Approach for Collapse Risk Mitigation at the Municipal Scale Based on Multisource Monitoring and Surveying Data.. **Journal of Geotechnical and Geoenvironmental Engineering, 151(2), 05024014. https://doi.org/10.1061/JGGEFK.GTENG-12981**

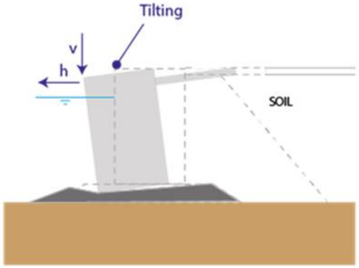
QW in Amsterdam city

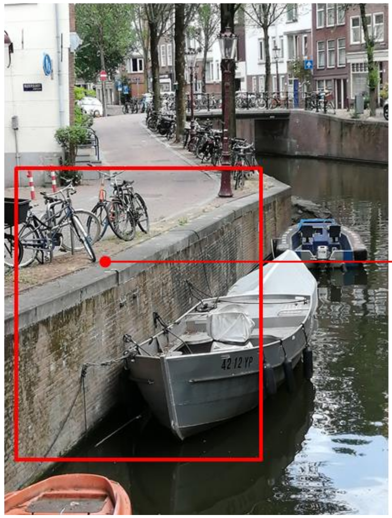




Three levels of terrestrial measurements







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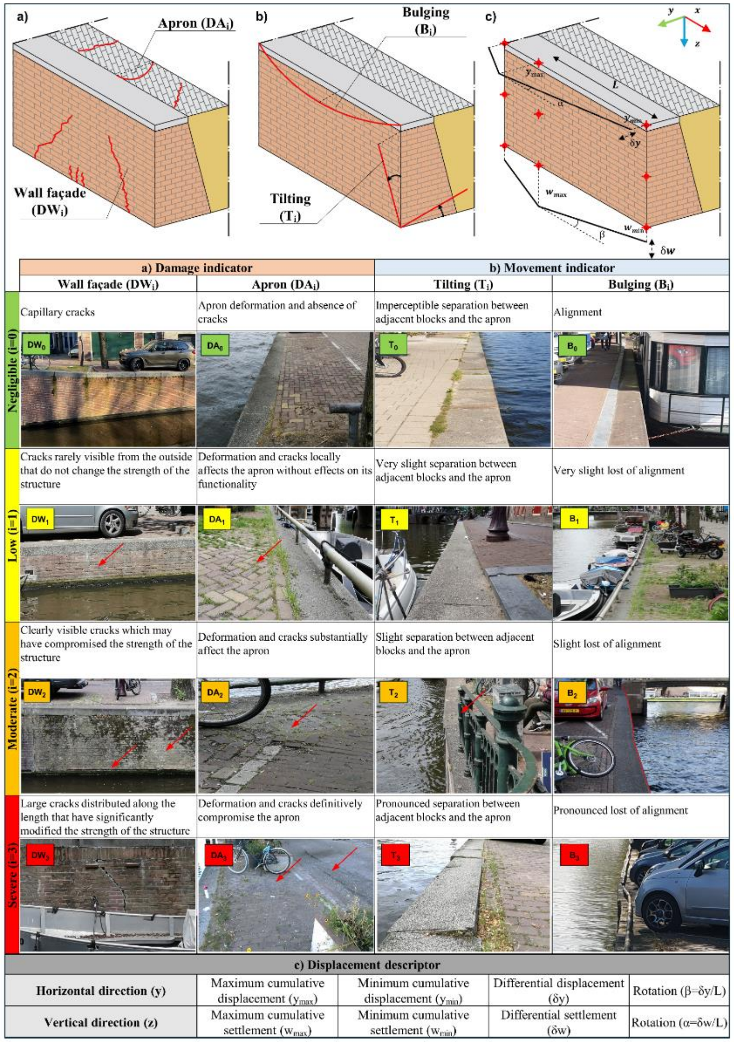
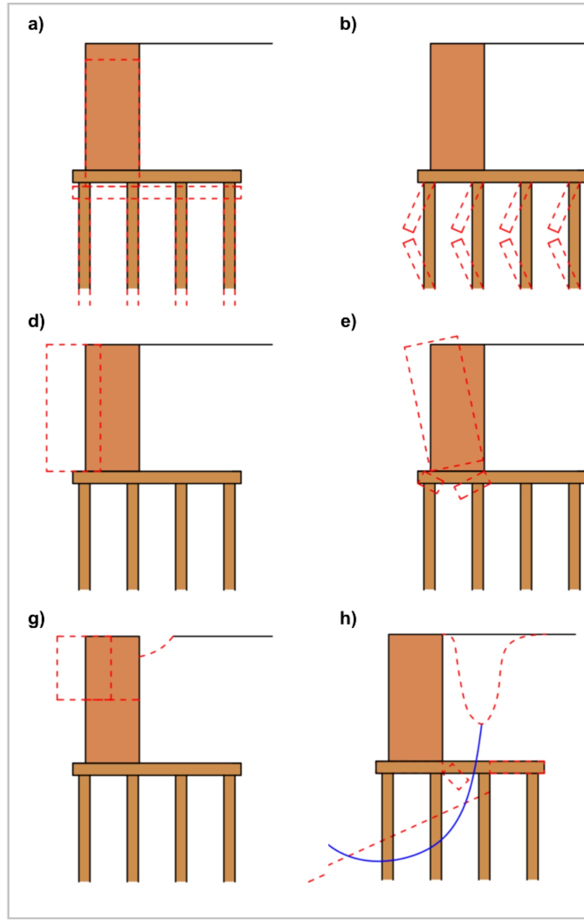
QW in Amsterdam city

Damage, movement and displacement descriptors of quay walls



Typical collapse mechanisms of quay walls



Mechanism	Horizontal traslation	Vertical settlement	Rotation
a)	no	yes	no
b)	yes	yes	yes
c)	no	no	yes
d)	yes	no	no
e)	no	no	yes
f)	yes	no	no
g)	yes	no	no
h)	yes	yes	yes

Luongo D., Nicodemo G., Venmans A., Korff M., Sartorelli L., Maljaars H., Peduto D., (2025). The Quay Walls of Amsterdam, Netherlands: An Approach for Collapse Risk Mitigation at the Municipal Scale Based on Multisource Monitoring and Surveying Data.. **Journal of Geotechnical and Geoenvironmental Engineering, 151(2), 05024014. https://doi.org/10.1061/JGGEFK.GTENG-12981**

Remarks

- ✓ Geotechnical studies concerning subsidence risk in urban areas can valuably benefit from the combination of innovative (*DInSAR)* and conventional (e.g. GPS, topographic levelling) monitoring techniques.

- ✓ The *DInSAR data,* thanks to their improved ground resolution and accuracy, can be *used to calibrate key parameters of subsoil model.*

- ✓ The *DInSAR data* currently offer a huge dataset of *displacement data* that, integrated with structural damage assessment and geotechnical criteria, can be used to derive the representative spatially-distributed intensity parameters for *vulnerability analysis at different scales*.

- ✓ The *empirical procedures* proposed for the analysis of vulnerability in areas affected by subsidence phenomena allow retrieving *relationships between the damage severity and the selected DInSAR-derived intensity parameters* (i.e. differential settlements).

- ✓ The use of ad hoc fragility curves with the numerically computed differential settlements would allow predicting – considering the different HGL conditions – the expected damage level (Di) for all buildings resting on shallow foundations in a pre-fixed time interval.

In the context of subsidence risk management affecting large urban areas, the presented procedure could represent an efficient way for both professionals, researchers and territorial agencies to address proper mitigation strategies by efficiently prioritizing those areas affected by subsidence-related problems.

I-SUB
Gruppo Nazionale Italiano sulla Subsidenza
Italian National Group on Land Subsidence

Integrazione di tecniche di monitoraggio multi-source multi-temporale nella modellazione di sistemi geotecnici ricadenti in aree subsidenti e analisi delle conseguenze

Thank you for your kind attention!

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