



Notification: 'Localised subsidence: a potential source for building damage?' (KEM-44) a study within the Knowledge Programme on Effects of Mining

Organization: Ministry of Economic Affairs and Climate Policy (MEA)

Reference: KEM-44 / 202404115

Purpose of the notification

The purpose of this notification is to determine whether there are parties interested to perform the research as described below.

Background information

For decades, assessments have been made on when subsidence-induced strain may lead to building damage. However, the available guidelines by Boscardin and Cording (1989) are rather limited and have mostly been developed in the context of tunnel excavation, a relatively shallow source of subsidence. In Q2 2024 the TU Delft published results of research carried out for the Institute of mining damage Groningen (IMG) and the Commission on mining damage (CM) within the Gemma program. In this research TU Delft created finite element models and combined this with results of lab tests on masonry walls. The goal was to develop probabilistic fragility curves for representative masonry wall lay-outs under horizontal strain and curvature in combination with the factor Psi as an indicator of the extent of damage. With the results it becomes possible to refine the classification of damage according to Boscardin and Cording's criteria. Furthermore, the TU Delft has explored the transfer of strains from the shallow subsurface to buildings involving various soil and building models.

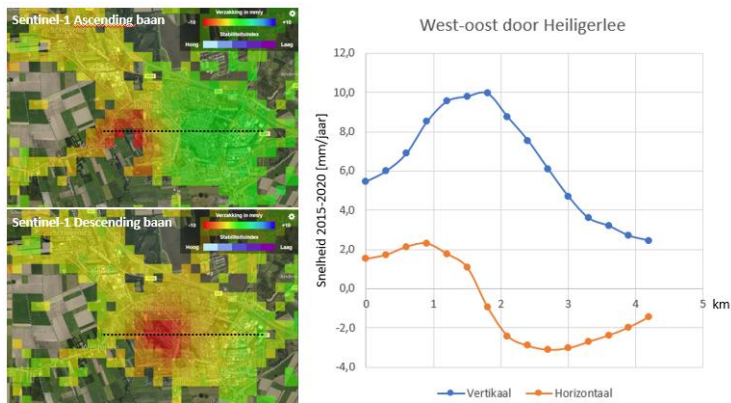
Objective

Guidelines: when and where is a risk of mining-induced building damage

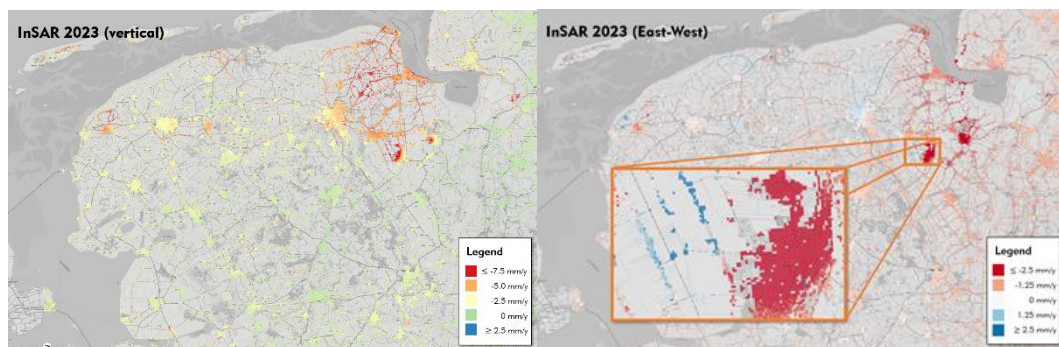
Clear guidelines on when and where effects due to mining-induced subsidence can be excluded (and when and where not) is the main objective of this research. This will help CM and IMG in advice and decisions on building damage resulting from subsidence. We see an important mechanism, described below, by which such subsidence might lead to damage of buildings. Indirect effects, through effects on water management, are not part of this research.

Direct strain on buildings

When mining-induced subsidence is strong and concentrated, such as is the case with salt solution or coal mining, there is a non-negligible horizontal component to the associated above-the-ground movement. With traditional levelling, this component was not measured, but with modern techniques such as PS-InSAR from space, we can observe and quantify its effect on buildings. An integral assessment of effects of subsidence on buildings is needed to justify risk assessment based on relatively simple subsidence modelling (observation I and II).



Observation I. An example of a single subsidence bowl, showing up slightly dislocated in the east-west direction in two different viewing geometries (left). By geometrically combining the two observations, a rough estimate of horizontal vs 'real' vertical deformation is constructed (right) along the 4 km long dashed line. Does this additional movement induce risks that may be neglected when only vertical movement is considered? And how is the total strain on buildings and associated damage risk to be assessed from large-scale subsidence modelling?



Observation II. An example of the measured vertical (left) vs. the horizontal (right) deformation velocity derived from publicly available InSAR measurements (EGMS, 2023). The inset picture on the right shows an area west of Veendam where a relatively large difference in horizontal movement is detected: blue is moving towards the East and red is moving towards the West. This movement must be related to salt mining.

We inquire at KEM for advice on scientific approaches that may validate the applicability of these fragility curves. The topics that require investigation include the horizontal strain and angular distortion on buildings caused by both vertical and horizontal movements that can be measured at the surface.

In many cases, only extension strain derived from the differential *vertical* deformation is considered. The gradient in *horizontal* deformation may add to this strain. The above rough analysis in Observation I shows (for this particular case) the latter effect to exceed the strain due to vertical movement alone by 50%, and to occur in other parts of the subsidence bowl as well. Here, we aim to gain insight in the full picture of strains in the shallow subsurface, and how these are transmitted to buildings.

It is expected that the horizontal strain also develops and changes in time. Based on measurements from the past and subsidence models as a function of time, we aim to get insight in the changes in horizontal strain over time and whether this can have an increased impact on the damage (the Psi) over a time averaged strain over a longer period than is usually assumed in the analysis.

Research questions

The research questions to be addressed are:

- (I) to quantify more systematically the observed horizontal deformation for appropriate cases in the Netherlands;
- (II) to quantify the development of horizontal deformation as a function of time for those cases identified in (I).
- (III) to review the existing literature on the effects of (differential) ground movement, also related to shallow effects: where in (or near) a subsidence bowl may stresses occur, and how do directions of movement interact?
- (IV) to validate, sharpen, or define a simple set of rules by which the total strain on buildings due to ground deformations can be assessed from predicted vertical motions alone (possibly combined with background knowledge on underground characteristics of the location); and
- (V) to define, based on the above calculated total strain, in combination with fragility curves from the TU Delft, a classification system by which probability of different building damage categories due to direct deformation of the underground can be evaluated. Damage (the Psi) over a time averaged strain over a longer period than is usually assumed in the analysis.

Deliverables expected

1. Report on literature study results and on the observed cases.
2. Report on building effect assessment rules, with advice on how to interpret causes of building damage.
3. Presentation of the project and results at completion to KEM-Panel and at the KEM-DeepNL Colloquium.

References

Boscardin and Cording (1989) Building Response to Excavation-Induced Settlement. Journal of Geotechnical Engineering

Volume 115, Issue 1. [https://doi.org/10.1061/\(ASCE\)0733-9410\(1989\)115:1\(1\)](https://doi.org/10.1061/(ASCE)0733-9410(1989)115:1(1))

Deltares (2018), Invloed van bodemdaling door zoutwinning Nedmag op bebouwing en infrastructuur, kenmerk 11203195-000-GEO-0002, <https://www.nedmag.nl/sites/default/files/2019-07/WP%202018%20referentie%2020%20Deltares%20invloed%20bodemdaling%20op%20bebouwing%20en%20infrastructuur.pdf>

EGMS (2023), European Ground Motion Services, website: <https://egms.land.copernicus.eu/>

Kontogianni, V., Pytharouli, S., & Stiros, S. (2007). Ground subsidence, Quaternary faults and vulnerability of utilities and transportation networks in Thessaly, Greece. Environmental Geology. 52. <https://doi.org/10.1007/s00254-006-0548-y>.

Samieie-Esfahany, S., R. Hanssen, K. van Thienen-Visser, & A. Muntendam-Bos, (2009). On the effect of horizontal deformation on insar subsidence estimates, Proc. 'Fringe 2009 Workshop', Frascati, Italy, 30 November – 4 December 2009 (ESA SP-677, March 2010)

Van Staaldin, P.C., K.C. Terwel, & J.G. Rots, (2018). Onderzoek naar de oorzaken van bouwkundige schade in Groningen, TU Delft rapport nr. CM-2018-01. <https://www.nationaalcoordinatorgroningen.nl/documenten/rapporten/2018/juli/11/rapport-onderzoek-oorzaken-schade>

Timeline

Intended start of project September 2024 with a duration of 1 year.
Intermediate reporting on the first deliverable.

Budget

The maximum budget for this research is **€ 100.000,-** (one hundred thousand euros) excluding VAT.

Required skills / experience / capacity

InSar/Geodetics, Geomechanics, Structural mechanics, Building Codes.

Application

Interested companies / consultants are invited to respond to the Procurement Office of the Ministry of Economic Affairs and Climate Policy, to the attention of Mrs. J.C. van Domburg by e-mail IUC.accountEZK@rvo.nl.

You do not have to send documents, only an e-mail if you are interested.

Interested parties will receive the request for the tender by e-mail as soon as possible after the deadline for responding to this notification.

The deadline for responding to this notification is set at the **21th of May 2024, 10.00 am CEST**.