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USE OF MONITORING DATA FOR DIKE STRENGTHENING PROJECT KIJK

Introduction

The goal of the first study was to optimize the predicted land subsidence. The second study was to assess the condition of all buildings along 10 km of dike. The Krimpenerwaard is an area consisting of soft Holocene soil layers with ongoing subsidence mainly caused by changing groundwater levels and the associated drying out and oxidation of peat. The subsidence rate for the crest of the dike is different from that of the hinterland. In both studies INSAR and LiDAR monitoring data were used as primary input.

Monitoring

The INSAR measurements consist of settlement-data collected between 2013 and 2016 for different points located on the crest of the dike or buildings located near the dike. The used satellite data is generated and processed by SkyGeo. Also, the Current Dutch Elevation (Actueel Hoogtebestand Nederland, AHN) is used for determining the subsidence rate. The AHN3 map is a digital height map obtained by LiDAR measurement from airplanes or helicopters.

Determination of subsidence of the dike crest

The height of the dike is one of the key criteria in the primary dike safety assessment. Land subsidence is obviously an important factor when the future level of the dike crest is predicted.

Based on information of the Water authority "Hoogheemraadschap van Schieland en de Krimpenerwaard" (HHSK), the average rate of subsidence for the crest of the dike is about 11 mm/year. For the project this means that for the period 2025-2075, besides effects of sea level rise an additional 0,55 m of subsidence must be considered. Large parts of the dike also do not comply for macro stability which means that every additional load on top of the dike would increase the stability problem. By making a better assessment of the subsidence, the amount of soil needed to balance the subsidence is optimized.

A study was undertaken to determine the rate of subsidence based on monitoring data. The first step was to re-analyse the archive data from HHSK which is compared with average subsidence rate determined from the monitoring data, see figure 1. In general was concluded that the INSAR data and the HHSK data give almost the same average subsidence rate for the entire dike of about 7 mm/year. The average subsidence rate based on the LiDAR data is 8,9 mm/year. For further use in the project an average rate of subsidence for the crest of 8 mm/year is used. This means a reduction of 27% on the amount of soil needed to counteract for the subsidence.

Determination of settlement of the buildings along the dike

The buildings along the dike are sensitive to subsidence and ground deformation, both from natural origin (creep) as well as due to the effects of dike strengthening. The building administration (BAG) and the municipal archives provided valuable information like building year, type of construction and type, material and depth of the foundations. For 56% of all buildings information was available. The annual settlement rate of each building was derived from INSAR data. Combining the INSAR and archive data led to multiple relationships, for example a relation was found between building settlement and foundation type. Using these relationships the foundation and building properties can be assessed for all buildings where the archives are incomplete.
In the preliminary design phase of the project four different types of dike strengthening are designed and for all designs the risk of damage due to ground displacements is calculated using FEM and the limiting tensile strength method Netzel [3]. In these calculations the type and material of the foundation are the primary input parameters for this risk assessment.

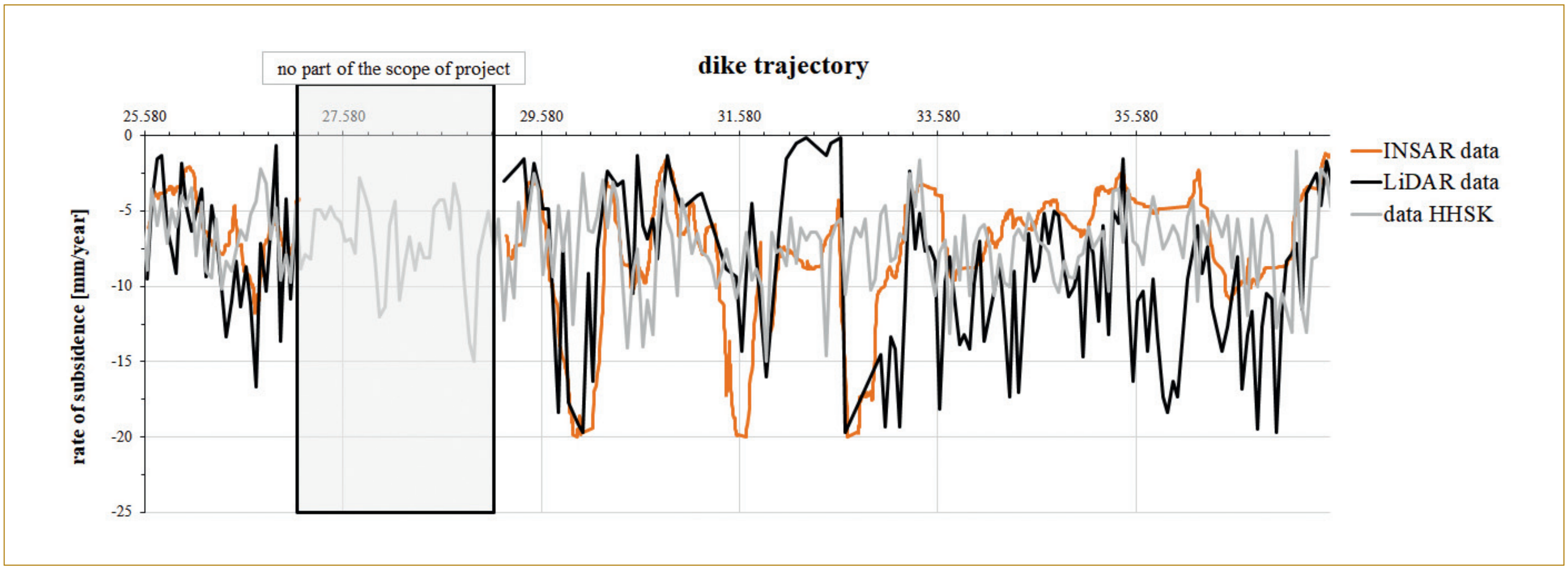


Figure 1 – Comparison of subsidence rate determined with different measurement methods and HHSK archive data.

SUMMARY

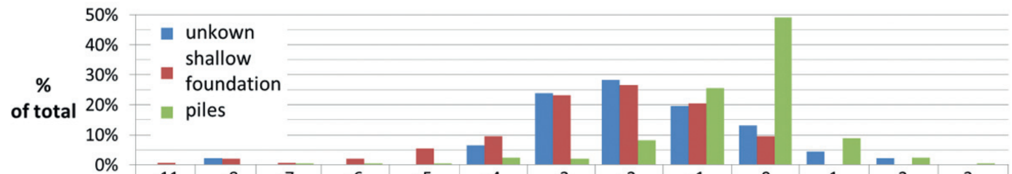
For the dike strengthening project Krachtige IJsseldijken Krimpenerwaard (KIJK) in The Netherlands two studies have been undertaken for which monitoring data played an important role. The data is used to determine the amount of soil needed to balance the subsidence and to quantify the building settlement due to natural subsidence.

Conclusion

Using INSAR and LiDAR monitoring data it is possible to optimize the subsidence rate for the dike crest from an average of 11 mm/year to an average of 8 mm/year. This means a reduction of 27% on the amount of soil needed to balance for the subsidence. Also, using INSAR data it is possible to determine the settlement rate for almost all buildings of the KIJK project. Combining the building settlement with other data sources it is possible to estimate the foundation type of a building. Although this is not 100% accurate, in combination with safe assumptions it gives a good indication in the preliminary design phase of the project.

Acknowledgements

The work presented in this paper is part of the KIJK dike strengthening project in the Netherlands. The authors would like to thank their partners from IB-KIJK, BWZ Ingenieurs, Greenrivers and Infram.



	-11	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3
unkown	0%	2%	0%	0%	0%	7%	24%	28%	20%	13%	4%	2%	0%
shallow	1%	2%	1%	2%	5%	10%	23%	27%	20%	10%	0%	0%	0%
pile	0%	0%	0%	0%	0%	2%	2%	8%	26%	49%	9%	2%	0%

building settlement in mm/year

Figure 2 – Distribution per foundation type versus settlement rate in mm/year.

Reference

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[3] Limiting tensile strength method, H. Netzel, 2009.