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Master Thesis (Year 2013)

Planning and Realization of the GNSS/TPS-Monitoring for the Jürmela/Latvia Tower Project and Further-Development of the GOCA-System on GNSS Open-Source Software and Low-cost Hardware Technologies

Referee

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Key Words

Geo-monitoring, High-rise structures, structure deformation analysis, GOCA-System, TPS monitoring, GNSS monitoring, RTKLIB, frequency analysis

Summary

Fig.: Jūrmala Tower in Latvia

The main objective of this thesis is to test and evaluate the suitability out of the most commonly known and used geo-monitoring methods for high-rise structure movement and deformation detection by carrying out a practical geo-monitoring project of a sightseeing tower in Jūrmala, Latvia (fig. 1), as well as to test the suitability of the GOCA-System in high-rise structure geo-monitoring.

After literature studies carried out to support this thesis, three main sensor types were identified which are used for tower monitoring: geodetic, geotechnical and environmental. For the practical geo-monitoring realisation on Jūrmala Tower project only two of them were chosen:

- Geodetic Monitoring with application of TPS – total stations and thus the terrestrial surveying methods, and GNSS using professional and low-cost GNSS receivers and thus the satellite based positioning by using relative kinematic positioning mode.

- Geotechnical Monitoring using accelerometers (ACCLM)

Out of the above methods, GNSS monitoring has shown to be the most convenient one, whilst TPS was the most complex just based on the used setup. Concerning ACCLM monitoring, it requires close monitoring of the activity of people on the tower. Apart from that, based on common data analysis, it is advised that ACCLM monitoring be carried out simultaneously with GNSS monitoring. Each of the above mentioned monitoring designs dealt with different tasks:

- TPS monitoring – permanent and absolute displacement detection along with modeled tower mode shape detection;
- GNSS monitoring – fast movements, such as vibration and oscillation analysis;
- ACCLM monitoring – acceleration monitoring and thus fast movement analysis; together with GNSS data – frequency analysis.

The Geodetic Monitoring System GOCA (www.goca.info) was used as the main system and software for monitoring, and it was applied for TPS based monitoring.

In the frame of the thesis the further development of the GOCA system was carried out with respect to the use of the RTKLB software package, both online and for post-processing. In this way, the variety of GNSS receivers supported by GOCA-System has increased. Apart from GOCA, the open-source RTKLIB software package was used. With that, all GNSS data processing and analysis was carried out. For analysis and comparison needs, also the professional GNSS software Topcon Tools and numerical mathematics software MATLAB were used.

Based on the used TPS monitoring setup, no permanent or absolute displacement was detected. Also the modeled tower mode shapes could not be easily detected. Concepts for various mode shape detection were established, though only swaying and oscillation as elastic deformations could be assumed to be present.

The GNSS tests have proven that low-cost hardware and open-source software are suitable for monitoring purposes. Here, the u-blox GNSS receiver was used together with RTKLIB software. The achieved accuracy does not differ much from the one of professional GNSS technologies. A setup of two receivers was used as the GNSS monitoring design – one base station and one rover on top of the tower. In this way, only fast movements such as oscillations can be detected during the single monitoring epoch. In such a setup, the most important parameters to be considered are the position of sensors and the data-rate of the sensors. Receivers should be within 10 km distance from each other (also for L1 frequency receivers) with a clear sky view as that influences the solution most. Data rate is advised to be minimum 1 Hz for both receivers, though even better a higher data rate – around 5-10 Hz for objects such as sightseeing towers, as this enables better movement detection and also contributes to frequency analysis and accelerometer sensors if used

In the Jūrmala Tower project, based on GNSS monitoring, an oscillation frequency of around 0,75 Hz and a maximum amplitude of up to 2 centimetres could be detected. Apart from that, the occurring oscillation is not of a circular or elliptic shape but more or less random in short term.

Finally, ACCLM monitoring was used to complement the GNSS results. Besides that, frequency analysis was carried out, where two main frequencies of the Jūrmala Tower were found - 0,74 Hz and 1,13 Hz which could already be derived from GNSS data. Apart from this, the frequency analysis does not prove the hypothesis that people movement on the tower affect tower movement and stability. Furthermore, the presence of people movement on the tower can only be seen in the raw accelerometer data and not in any processed GNSS data. This shows that the possible inconvenience of people on tower due to apparent swaying etc. can not necessarily be connected to information on tower movements. Accelerations up to 0.2 m/s^2 on a tower are regarded as convenient for humans. So it seems that people are sensitive to lower accelerations that are present but not crucial for the safety and stability of tower structures.