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Monitoring of natural deformation behaviour of buildings in Amsterdam – On line Monitoring for the North-South Metroline-

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ABSTRACT: About 3.8 km of the new North/South Metroline in Amsterdam will be constructed through the old historic centre of the city. The route under the inner city will be constructed with two bored tunnels of 7 m diameter, varying in depth between 20 and 31 m below ground level and three underground stations to be constructed using a strutted excavation with the cut and cover method. The tunnelling and the construction of the deep underground stations could cause soil deformation in the surrounding ground, which consequently induce damage risks on the adjacent building depending on the magnitude of the differential settlements. The observational method concept will be applied for both construction methods to combine design and work on site with the aim to achieve the best performance regarding the minimalisation of settlement induced damage. On line monitoring and control of the effect of soil deformation in the surrounding area such as on buildings, bridges and services has therefore been an essential part in the design of the North/South Metroline. This paper presents the results of the first 4 months of the base monitoring period (one year before start construction) with the fully automized building monitoring system. Temperature influences on the deformation behaviour ("breathing") of the buildings in Amsterdam are described. The basis results deliver important information about movements which occur without any excavation activities in the nearby surrounding.

1 OBJECTIVES AND CONTRACTUAL ARRANGEMENTS FOR MONITORING IN AMSTERDAM

Monitoring of the impact of the underground construction due to the North-South Metroline on the urban surrounding in Amsterdam has the following objectives:

- To check the contractor's performance against the contractual deformation limits.
- As part of the IBCS (Interactive Boor Control System), to use the on line monitoring data from the surroundings to guide the Tunnel Boring Machine (TBM) (Kaalberg & Hentschel 1999).
- As legal evidence of deformation with regard to damage in relation to the construction work on the North/South metroline in Amsterdam; in assessing damage claims.

In the North/South metroline project, monitoring activities are to be contracted separately from the contracts for the main construction works. The monitoring contract comprises detail design, installation and maintenance of a remote on line monitoring system for buildings and soil, supplemented by traditional manual precise levelling as backup (Netzel & Kaalberg 1999). The performance of the monitoring contractor comprises the provision of monitoring data in digital format at the frequencies and accuracies as stated in the contract. The monitoring contract has been awarded to the French-Dutch consortium SOLDATA/GRONTMIJ JV.

2 ON LINE MONITORING SYSTEM FOR BUILDINGS

Structures within the predicted area of influence will be monitored on line by the automatic monitoring system. Some 1500 buildings in Amsterdam are in the area of influence. The on line monitoring system comprises about 75 fully automated total stations, computer-controlled theodolites, which monitor some 5500 prisms in a continuous operation. The prisms and the total stations are installed on the front and side facade walls of the buildings in the area of influence (Fig. 1). The locations have been selected along the entire route so that each prism can be monitored by at least one total station. The prisms are measured within a visible range of 75 m to the required degree of accuracy. For the North/South Metroline, between 50 and 100 prisms are monitored by one total station. They are linked to a datalogger that collects the data and transfers it via radio link to the head office of the monitoring contractor. The on line monitoring system determines the x,y,z deformations of the prisms. The monitoring frequency depends of the construction activities.

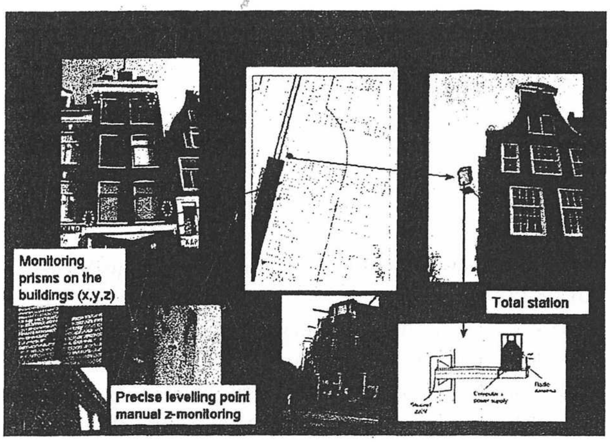

Figure 1: On line building monitoring system

Three monitoring frequencies are defined for buildings along the route of the North-South Metroline:

- Base monitoring

For information about the natural deformation behaviour of buildings without the effect of the North/South Metroline: Low frequency.

- Process monitoring

Active monitoring during the construction work: High frequency (hourly readings for TBM-tunnelling).

- Close out-monitoring

Monitoring of long-term effects planned at present stage for one year after construction works: Low frequency.

3 DATA MANAGEMENT WITH GIS

For efficient use of the data collected before, during and after passage of the TBM and construction works, it is essential to have rapid access to a large quantity of data and on line graphical visualisation options of the data, to be interpreted rapidly. For these reasons, the client has developed a GIS system for the storage, rapid interpretation and visualisation of measurement data before, during and after construction activities (Fig. 2). An estimation of the amount of data during the 6 years construction work of the North/South Line indicates that approximately three times as much data as for the JLE Extension will come available. The GIS system is linked with a database specially designed for the monitoring requirements. The structure of the GIS system and the database use unique codes to identify each monitoring sensor, which is registered digitally in the GIS system. GIS is the important intermediary for settlement risk management with the IBCS-concept, the observational method for TBM-tunnelling (Netzel & Kaalberg, 1999).

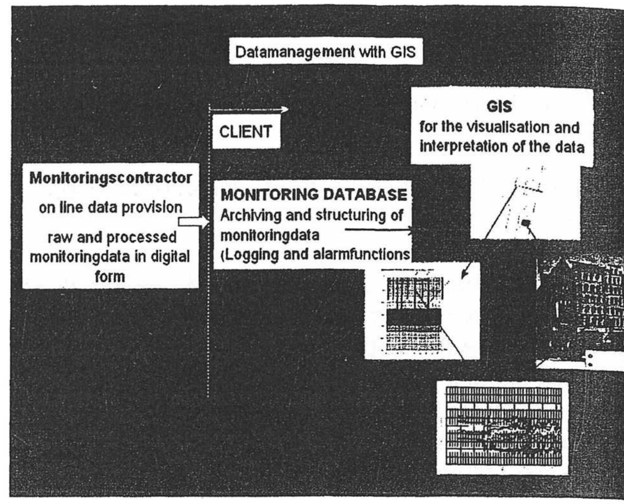

Figure 2: Datamangement

4 RECOMMENDATIONS FOR INSTALLATION WORK OF THE ON LINE MONITORING BUILDING SYSTEM

4.1 *General*

The installation of ca. 5000 prisms on the adjacent buildings, being namely properties of private owners resp. companies, required a long preparation time where communication and information already started two years before. The owners of the adjacent buildings had to be convinced that the installation of prisms on their buildings and the collection of monitoring data is necessary for controlling the construction activities, with the aim to protect their buildings from negative influences of the excavation works. During the installation some practical problems had to be solved which are typical for the use of an optic measurement equipment in urban surrounding.

4.2 *Sight Line obstructions*

The definitive design of the monitoring system had to take into account all possible obstructions (trees, signboards etc.) which could block the direct sight lines of the total stations to the prism's. As demolishing the trees is a highly unpopular and impossible measure in urban surrounding, it has been decided to regularly maintain (over app. 7 years monitoring period !) the sight lines through the trees by cutting selected parts of the branches. To avoid sight lines through trees, an unacceptable amount of extra total stations should have been added.

4.3 *Power supply of the total stations*

Each total station needs a power connection. For the North-Southline in Amsterdam it is decided to obtain the power not by the houses of private owners, where the total stations are fixed on, but to get the power from the municipality power net. The requirements for regular maintenance and rapid access in case of problems with the automated system were the reasons for choosing not the power supply from private houses. Branches of the adjacent subsurface power services were made and a cable connection was installed.

4.4 *Required permissions of different municipality divisions in urban surrounding*

The need for permissions for installation works (for example the blockage of streets due to the cranes for installing the prisma's on height, see Fig. 3) needs a meticulous approach for getting all the necessary permissions on time. It is recommended to appoint an environmental manager to deal with all these aspects, because it can significantly cause delays in the planning of the installation work.

Figure 3: Installation of prism's and total stations on building façades in Amsterdam

5 ON LINE MONITORING SYSTEM AROUND THE METRO STATION CEINTUURBAAN

The building monitoring system around the planned deep excavation pit for the Metro station Ceintuurbaan is installed in juli 2001. The situation of the planned station area with respect to the adjacent buildings and the locations of the 8 total stations is shown in the map in figure 4. The computerized theodolites (total stations) form a geodetic network and monitor ca. 600 prisms, fixed on the adjacent buildings inside the influence area. Deep datums are installed as reference points outside the influence area.

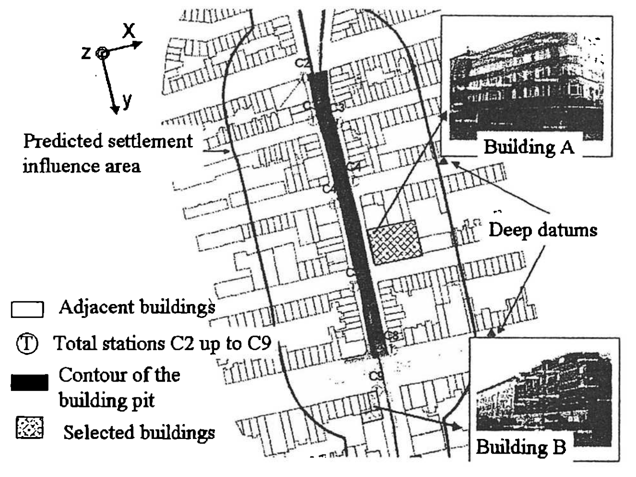

Figure 4: Map of the situation around metro station Ceintuurbaan

6 RESULTS BASE MONITORING

The results of the first 4 months basic monitoring period of the selected buildings A and B will be presented in detail in the next chapters. The location of the two buildings is shown in figure 4. Structure A consists of a concrete frame construction on the ground floor level and a masonry construction on the upper three storeys. Structure B is a typical 4 storey Amsterdam masonry construction. Both buildings are founded on wooden driven piles in the first sand layer being the pile toe bearing layer of most of the buildings in Amsterdam. The monitoring frequency in the base period is 6 times a day (every 4 hours). The data is collected with the specific developed GIS-system and on line available and accessible at the Design Office North-South Line. The basic monitoring period for both buildings started in juli 2001. The presented deformation values are relative values with respect to an average of the first week of the basic monitoring period. The temperature is measured at a central point in Amsterdam without any shadow influences. The prisms fixed on the façade walls however experience shadow effects, which explain the sometimes delayed relations of the cycles between temperature and deformation. Figure 4 shows the monitoring results of the vertical deformation of the indicated prism for building A in

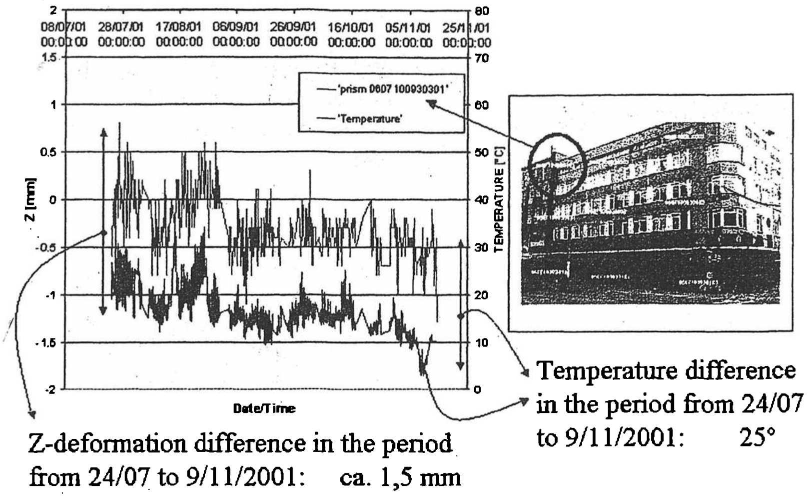

Figure 5: Vertical deformation in relation with the temperature for the first 4 months basic monitoring

combination with the temperature for the first 4 months of the basic monitoring period.

The distributions show the proportionality of the deformation and the temperature. It also shows a general vertical movement of the prism at the cold end of the 4 month period compared to the warm beginning of the monitoring period. This can have two causes, which can occur in a combined mode:

- Overal temperature decrease from 30°C to 5°C over the 4 month period leads to temperature induced vertical movement, which would periodically occur and disappear when the warm period starts again.
- A general natural settlement of buildings on piled foundations due to proceeding soil consolidation effects in the Amsterdam subsoil. The general experience for the Amsterdam buildings throughout the last decades shows average settlements of ca. 1mm/year.

The information about the development of the deformations in the next 8 months basic monitoring will clarify the contribution of both effects.
A detailed consideration of the relation between temperature and the vertical deformation z shows the daily day and night cycle for a warm and a cold day Figure 6: Daily cycle for the vertical z-deformation on a warm day (Fig. 6 and 7). Figure 6 shows the heaving of the point with increasing temperature during the warm day. Figure 7 shows the deformation cycle of a cold day. The smaller difference in deformations on the cold day (0.5mm) is also related to the clearly smaller temperature differences on the cold day (4°C), compared to the warm day (1mm due to a difference of 12°C).

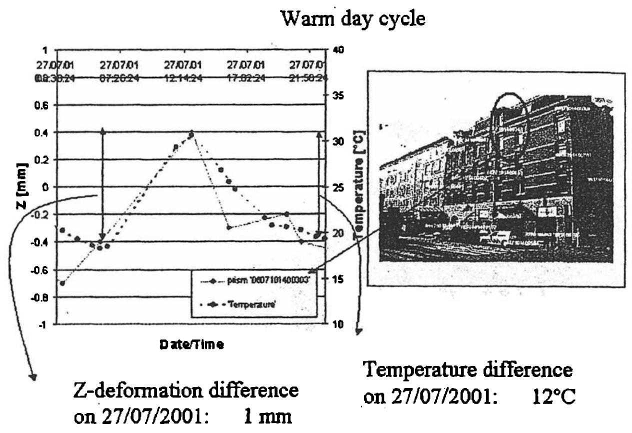

Figure 6: Daily cycle for the vertical z-deformation on a warm day

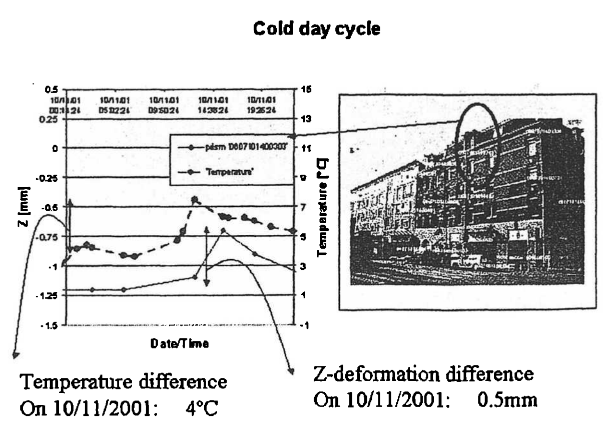

Figure 7: Daily cycle for the vertical z-deformation on a cold day

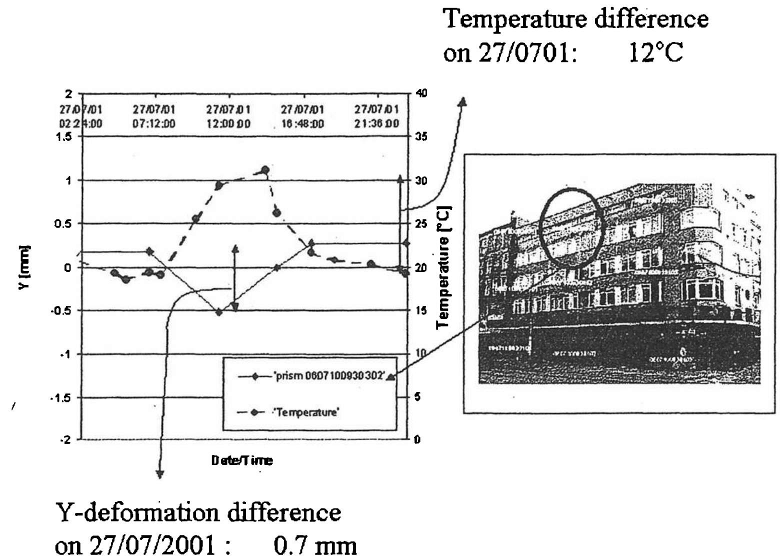

Figure 8: Daily cycle for the horizontal y-deformation (in the plane of the façade wall) on a warm day

It should be noted that there could also be some background influences due to the traffic vibrations (trams and cars), which should occur periodically with almost the same magnitude. Regarding the frequency of measurements with respect to the nature of deformation effects due to traffic vibrations, it can be concluded that these effects are not registrable with this monitoring system. It should be emphasised, that it is not the purpose of this monitoring system to monitor clearly vibration effects, because other specific instrumentation would be necessary to monitor these effects in terms of vibration frequency and vibration speed.

7 CONCLUSIONS

An automatized on line monitoring system is installed to monitor the deformations of 1500 adjacent buildings before, during and after the construction work for the North-South Metroline in Amsterdam. The first 4 months of in total 12 months basic monitoring show valid information about the natural deformation behaviour of the buildings due to temperature differences. Daily fluctuations up to 1mm are monitored in relation with the daily temperature distribution. The knowledge about the deformations in the base period is important for the settlement performance control during the excavation works and will be compensated in the contractual arrangements.

REFERENCES

Netzel, H., Kaalberg F.J., Settlement Risk Management with GIS for the Amsterdam North/South Metroline, Proceedings of the world tunnel congress 1999, Norway

Netzel. H., Kaalberg F.J., Settlement risk assessment for the North-South Metroline in Amsterdam, CIRIA Conference The response of buildings to excavation induced ground movement, London 2001

Netzel H., Kaalberg F.J., Monitoring of the North/South Metroline in Amsterdam, CIRIA Conference The response of buildings to excavation induced ground movement, London 2001

Kaalberg, F.J., Hentschel, V., Tunnelling in soft soil with high waterlevel and pile foundations: Towards the development of settlement orientated and settlement minimizing TBM control, Proceedings of the world tunnel congress 1999, Norway