APPLYING NON-STANDARD INSTRUMENTAL SOLUTIONS TO EXAMINE VERTICAL DISPLACEMENTS IN ENGINEERING CONSTRUCTIONS AS EXAMPLIFIED BY THE MONITORED SUPPORTING STRUCTURE OF A REACTOR

Marek Woźniak, Sławomir Jastrzębski

Institute of Applied Geodesy
Warsaw University of Technology

1. ABSTRACT

In measurements of vertical displacements of constructions, when direct access to checkpoints is very difficult or life threatening, one should apply the measuring technology which would fulfill accuracy requirements and yet avoid all the dangers. The technology in question could involve special code levelling staffs instead of classical solutions.
The paper presents tests involving the above method in measuring deformations of the supporting structure of a chemical reactor right after a building disaster or in the trial load of a rebuilt structure. Examples of other positive applications of such a solution are also shown.

2. NEGLIGENCE-CAUSED CONSTRUCTION FAILURES AND DISASTERS

For a long time we have observed, especially in big towns, a rapid growth of high-rise building development. Quite frequently, it concerns supplementing the existing buildings. The erected structures can even have several floors underground and be situated next to other buildings. When the foundation trench is deepened, the geotechnical conditions of the ground are upset, which may drastically worsen the stability of the adjacent buildings.

The main causes of construction failures and disasters are:

- **neglecting the principle of the so-called "safe building",**
- **unverified designs of the supporting structure of a building,**
- **no objective control of the building's reaction to changeable working conditions.**

The above has been confirmed by recent building disasters in Poland and elsewhere.

Fig. 1. Effects of control negligence and lack of proper reaction to undergoing changes.

The control of how a building object behaves should be carried out by geodesic monitoring of the preventive character. It is supposed to provide objective information about geometric changes in the object's behavior, represented by characteristic structural points. The routine control measurements include precise levelling.

3. AUTOMATIC (CODE) LEVELLING

Recent years have witnessed a dynamic development of measuring technology, levelling techniques included. "Code" levelling is affecting not only measuring equipment: an instrument with an appropriate staff but also the way the measurement is carried out. The new situation allows advanced automation of the monitoring process concerning the displacements by means of digitalized reading and data recording systems.

Fig. 2. A measuring set for precise levelling.

The system of code levelling, besides its obvious merits, has some disadvantages such as sensitivity to diverse lighting conditions, limited visibility of "graduation" and sensitivity to substrate vibrations and air vibrations in the target area.
There are situations when it is impossible to make measurements by classical methods – difficult access to checkpoints, pliancy of a tested structure, safety conditions in the tested area.

4. CONTEMPORARY SYSTEM SOLUTIONS IN LEVELLING

Standard measurements – with the use of invar coded staves and auxiliary accessories. The measurements are made between horizontally or vertically stabilized benchmarks on a structure.
Non-standard measuring solutions – mainly involving permanently fixed staffs or their fragments (engineering graduation) fixed directly to tested objects. This solution works very well in situations when access to the tested object is hampered or virtually impossible, when the structure reacts under the weight of a surveyor or there is a danger of death or serious accident.
Automatic measurements – with the use of a levelling instrument controlled by servomotors. This solution considerably speeds up repeated measurements but has certain drawbacks which mainly come to the mounting of all checkpoints at the same height. Such instruments have not been mass produced yet. They are individually made.

5. THE APPLICATION OF NON-STANDARD INSTRUMENTAL SOLUTIONS IN THE MONITORING PROCESS OF VERTICAL DISPLACEMENTS UNDER THE CONDITIONS OF A BUILDING DISASTER

As a result of a building disaster of the supporting structure of a chemical reactor, the situation required monitoring the displacements of a building under very special conditions. Also right after it happened, recording how the supporting structure behaved while the reactor was test filled required a special measuring technology. The optimal solution seemed to be using "code engineering staffs". It provided "full measuring access" to points in the high risk area.

Fig. 3. Control measurement conditions of supporting posts.

The measurement performed according to this technology was very fast to make, exceptionally well automated, giving objective measurement results. In addition, it was performed away from the zone of direct risk.
During control measurements five measuring cycles were carried out for the following loads: 0, 200, 230, 250, 270 tons, respectively.

The determined vertical displacement values of checkpoints throughout load changes came close to -13.58 mm, with the mean measurement error estimate of ± 0.1 mm.
Such a small value of error resulted from short sight lines to individual checkpoints on the analyzed structure.
The accepted procedure of the intervening monitoring mode enabled to obtain a very high level of accuracy, ensuring performance safety and "optionally" frequent measurements of the intermediate states for the structure checkpoints.

6. OTHER MEASUREMENTS CARRIED OUT IN NON-STANDARD TECHNOLOGY

Preventive monitoring carried out in the so-called scheduled mode involved the studies of deforming changes in the truss structure of the roof over the Main Hall of the Warsaw University of Technology Building. (Fig.4.).
The method of performing the task was unique among those formerly used by being devoid of structural deformations caused the weight of a surveyor. The value of this deformation was of the – 0.8 mm range, depending on where in the structure the surveyor stood.

Fig. 4. View of the roof structure over the Main Hall.

Intervening monitoring – safety risk to an apartment building posed by a deep foundation trench for an adjacent building (Fig.5.).
The lack of structural safeguards and room control resulted in considerable damage of the building.

Fig. 5. Trench area - the view of a protective structure.

The situations mentioned above are by no means exceptional, constituting an area of atypical applications of levelling methods in safe and effective deformation monitoring.

7. CONCLUSIONS

- **Non-standard instrumental solutions can be successfully applied both in preventive and intervening monitoring. They enable to start or continue the studies of vertical displacements in places, to which access is very limited or involves great safety risk.**

- **Levelling staffs and code divisions, despite their lower quality of division marking than in the case of precise invar staffs, enable to obtain the required precision of vertical displacement measurements if properly applied.**

- **The measurements made on selected objects amply confirmed the suitability of such a solution in measuring engineering constructions.**