TASKS AND ACHIEVEMENTS OF THE FIG WORKING GROUP ON DEFORMATION MEASUREMENTS AND ANALYSIS

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Abstract: The FIG Working Group 6.1 (WG6.1), established in 1969, provides an international forum for the exchange of information on new developments in measurements and analysis of structural and ground deformation by organizing specialized international symposia and by creating international *ad hoc* committees (Task Forces) to solve special problems in the deformable world. Between 1975 and 2006, WG6.1 organized 12 symposia and two workshops. Between 1978 and 1986, an ad hoc committee (Task Force 6.1.1) on Deformation Analysis solved problems of the identification of unstable reference points and developed a Generalized Method for Geometrical Analysis of Deformation Measurements. In 2001, Task Force 6.1.2 presented a report on Terminology and Classification of Deformation Models. Currently, four additional Task Forces are working on various aspects of Interferometric Synthetic Aperture Radar (InSAR) applications in deformation determination, on the optimal use of laser scanners, on the analysis of cyclic deformations and vibrations, and on the geodetic engineering aspects of earth crust movements.

1. INTRODUCTION

The FIG Working Group 6.1 on Deformation Measurements and Analysis was established in 1969 at the initiative of the late Professor Tadeusz Lazzarini of the Warsaw Technical University. Between 1975 and 1986 the group was led by Aleksander Platek of Technical University of Mining and Metallurgy in Krakow, Poland. Since 1986, the group has been chaired by Adam Chrzanowski of the University of New Brunswick in Canada.

Since the very beginning, the Working Group 6.1 has played a very important role in providing an international forum for the exchange of information on new developments in deformation measurements by organizing technical sessions during the FIG Congresses and, more important, by organizing specialized international symposia and workshops. Since 1978, besides organizing the international symposia, WG6.1 stimulated international cooperation between various research centres by creating *ad hoc* committees (task forces) to solve special problems of the deformable world.

Initially, the main interest of the group was only in the field of deformation measurements using geodetic methods. Since 1986, the tasks have been extended into other monitoring techniques [1] and into interdisciplinary analysis and physical interpretation of deformations [2].

This presentation gives an update on the major events and achievements of the WG6.1.

2. INTERNATIONAL SYMPOSIA AND WORKSHOPS

Between 1975 and 2006, WG6.1 organized 12 symposia and co-sponsored two major workshops. They are listed below in a chronological order:

1975: 1st Symposium hosted by the Techn. University of Mining and Metallurgy, Krakow, POLAND, Sept. 22-24 (chaired by Prof. A. Platek);
1978: 2nd Symposium hosted by the University of Bonn, Bonn, GERMANY, Sept. 25-28 (chaired by: Prof. L. Hallermann);
1982: 3rd Symposium hosted by the Hungarian Geodetic and Cartographic Society, Budapest, HUNGARY, August 25-27 (chaired by Prof. A. Detreköi);
1985: 4th Symposium hosted by the Polish Society of Surveyors and Geodesists, Katowice, POLAND (chaired by Prof. W. Janusz);
1986: Deformation Measurements Workshop hosted by the Massachusetts Institute of Technology, Cambridge, MA, USA, 31 October - November 1 (chaired by Dr. Y. Bock)
1988: 5th Symposium hosted by the University of New Brunswick, Fredericton, N.B., CANADA, June 6-9 (chaired by Prof. A. Chrzanowski);
1992: 6th Int. Symposium hosted by the University of Hannover, Hannover, GERMANY, February 24-28 (chaired by Prof. H. Pelzer);
1993: 7th Int. Symposium on Deformation Measurements hosted by the University of Calgary, Banff, Alberta, CANADA, May 3-5 (chaired by Prof. W. Teskey);
1994: Perelmuter Workshop on Dynamic Deformation Models hosted by the Technion Israel Inst. of Technology, Haifa, ISRAEL, August 29 – September 1 (chaired by Prof. H. Papo);
1996: 8th Symposium hosted by the Hong Kong Polytechnic University, Kowloon, HONG KONG, June 25-28 (chaired by Prof. Y.Q. Chen);
1999: 9th Symposium hosted by the University of Warmia and Mazury, Olsztyn, POLAND, September 27-30 (chaired by Prof. A. Wasilewski);
2001: 10th Symposium hosted by the Metropolitan Water District of South California, Orange, California, USA, March 19-22 (chaired by C. Whitaker);
2003: 11th Symposium hosted by the Patras University, Santorini Island, GREECE, May 25-28 (chaired by Prof. S. Stiros).
2006: 12th Symposium hosted by the Technical University of Vienna, Baden, AUSTRIA, May 22-24 (co-directed by Prof. H. Kahmen of U. of Vienna and Prof. A. Chrzanowski of U. of New Brunswick)

The published proceedings of the above symposia and workshops provide an enormous wealth of information on the development of new techniques and new methods in monitoring and analysis of deformations.

3. TASK FORCES

In the late 1970s and early 1980s, WG 6.1 concentrated their efforts on geometrical analysis of geodetic deformation surveys. It was reflected in the content of the papers presented at the FIG symposia in Krakow in 1975 and in Bonn in 1978. At that time, the main problem of the deformation analysis was the identification of unstable reference points in geodetic

monitoring networks. Several approaches were proposed by different authors. As a result, an *ad hoc* Committee on Deformation Analysis (Task Force 6.1.1), led by A. Chrzanowski, was established at the symposium in Bonn with a task of comparing different approaches and developing a unified theory for the geometrical analysis of deformation surveys. Initially, six research centres (University of New Brunswick in Canada, Universities of Karlsruhe, Hannover, Stuttgart, and Munich in Germany, and Delft in the Netherlands) joined the work of the committee. Eleven other centres joined the committee work after the 3-rd symposium in Budapest in 1982. The work of the Committee was summarized in three published progress reports ([3], [4], [5]) and several internal reports with a final report [6] presented at the 13-th International Congress of FIG in Toronto in 1986 (the report is available at: http://ccge.unb.ca) . The work of the *ad hoc* committee resulted, among others, in solving the problem of the identification of unstable reference points by using either:

- the method based on the congruency test of the quadratic forms of residuals of displacements obtained from least squares adjustment of single epochs of repeated observations vs. combined two-epoch adjustment ([7], [8], [9]).
- the method based on the Iterative Similarity Weighted Transformation (IWST) of displacements until the sum of absolute displacement components of the reference points becomes minimum ([10], [11]).

An important outcome of the study by the *ad hoc* committee was the development of the *generalised method of geometrical deformation analysis* ([10], [12]) , [13]) that allows for using any type of deformation measurements (geodetic techniques and geotechnical/structural instrumentation), even if scattered in space and time, in a simultaneous geometrical analysis of deformation measurements and modelling of displacement and strain fields. The IWST is a part of the generalised method in analysing the deformation trend.

During the 5th symposium held in Canada in 1988, a general agreement was reached that all basic problems of the geometrical analysis had been solved and no further international cooperation in that area was needed. At the same time, a recommendation was made that WG6.1 should become more active in an interdisciplinary approach to the physical interpretation of deformation measurements, particularly in the aspects of an optimal combination of the geometrical analysis with deterministic modelling of the load-deformation relationship for the purpose of a better understanding of the mechanism of deformations (see, e.g. [14], [15]). The 5th symposium was the first in the series of the FIG symposia that besides geodetic engineers the symposium was attended by many top specialists in other fields of engineering and geosciences.

The growing interest among geodetic engineers in the interdisciplinary approach to the integrated analysis and physical interpretation of deformations brought a confusion into the terminology used in deformation modeling. In 1992, at the 6th Symposium in Hanover, some authors became confused with the use of the terms such as dynamic or kinematic models of deformation, deterministic vs. statistical, or parametric vs. non-parametric modelling etc. The main confusion arose from the fact that some authors did not distinguish a difference between modelling the load-deformation relationship and geometrical analysis of the observed deformation. As a result, another *ad hoc* committee (Task Force 6.1.2) was created to look into the terminology and classification of deformation models. The Task Force based their work on the terminology used in the *system theory* and presented their final report [16] at the 10th Symposium in California.

Recent developments in a full automation of monitoring surveys and in new technologies such as Interferometric Synthetic Aperture Radar (InSAR), pseudolites, laser scanners, create new applications in the deformable world and need for further studies. At the FIG Congress in Washington, D.C., in 2002, two new task forces were established:

- Task Force 6.1.3 on the Optimal Use of InSAR led by Xiaoli Ding of the Hong Kong Polytechnic University (e-mail: lsxlding@polyu.edu.hk) and
- Task Force 6.1.4 on Monitoring and Analysis of Cyclic Deformations and Structural Vibrations, led by Gethin Roberts of the Nottingham University (e-mail: gethin.roberts@nottingham.ac.uk)

Two more task forces were established at the 11th Symposium in Santorini in 2003:

- Task Force 6.1.5 on the Optimal Use of Laser Scanners, led by Maria Tsakiri of the Technical University of Athens (e-mail: mtsakiri@central.ntua.gr) and
- Task Force 6.1.6 on Geodetic Engineering Aspects of Earth Crust Movement, led by S. Stiros of Patras University (e-mail: stiros@panafonet.gr)

Reports on the work progress of the above Task Forces will be presented at the next FIG Congress, which will be held in Munich, Germany, on 8-13 October 2006. During the 12th Symposium in Baden, Austria, a proposal has been submitted [17] to create a new committee (Task Force 6.1.7) on the use of continuum mechanics as a basis for establishing a common interdisciplinary language between geodetic engineers and other engineers and scientists in deformation analysis. Thus the work of the Task Force 6.1.7 will be a follow up of the Task Force 6.1.2.

4. CONCLUSIONS

Frequent symposia organized by WG6.1 provide a venue for the interdisciplinary exchange of information on new developments in deformation measurements and analysis. The WG6.1 stimulates the international cooperation in solving problems in deformation studies by establishing *ad hoc* committees (Task Forces). The Working Group 6.1 has become a truly interdisciplinary study group. Through the interdisciplinary approach to deformation studies, the FIG Working Group 6.1 links surveying and geodetic specialists with specialists in structural, mining, geomechanical, and geophysical disciplines.

REFERENCES

[1] Chrzanowski, A. (1986). "Geotechnical and other non-geodetic methods in deformation measurements. Deformation Measurements Workshop, Modern Methodology in Precise Engineering and Deformation Surveys - II, MIT, Massachusetts pp. 112-153

[2] Chen, Y.Q. and A. Chrzanowski: An Overview of the Physical Interpretation of Deformation Measurements. Deformation Measurements Workshop, Modern Methodology in Precise Engineering and Deformation Surveys - II, MIT, Massachusetts, pp. 207-220, 1986.

[3] Chrzanowski, A. with contributions by Members of the FIG ad hoc Committee: A comparison of different approaches into the analysis of deformation measurements, Proceedings, FIG-XVI Congress, Paper No. 602.3, Montreux, August 9-18, 1981.

[4] Heck, B., J.J.Kok, W. Welsch, R. Baumer, A. Chrzanowski, Y.Q. Chen, J.M. Secord:

Report of the FIG Working Group on the Analysis of deformation Measurements in*: Deformation Measurements*, Ed. I.Joó and A. Detreköi, 337-415, Akademiai Kiadó, Budapest, 1982.

[5] Chrzanowski, A. and J. Secord: Report of the Ad Hoc Committee on the Analysis of Deformation Surveys, *Proceedings, FIG-XVII Congress* Sofia, Bulgaria, June 19-28,. Paper No. 605.2, 1983.

[6] Chrzanowski, A., and Y.Q. Chen: Report of the ad hoc Committee on the Analysis of Deformation Surveys, *XVIIIth Intern. Congress FIG*, Toronto, 1-11 June. Proceedings, Paper No. 608.1. 1986.

[7] Pelzer, H. : Neuere Ergebnisse bei der statistischen Analyse von Deformationsmessungen. *Proceedings of the FIG XIV International Congress*, Washington, paper No. 608.3, 1974.

[8] Niemeier, W.: Statistical tests for detecting movements in repeatedly measured geodetic networks. *Tectonophysics*, 71, pp. 335-351, 1981.

[9] Gründig, L., M.Neureither and J. Bahndorf (1985), detection and location of geometrical movements, *the Journal of Surveying Engineering, vol. III, No.2, pp.118-132.*

[10] Chen, Y.Q.: Analysis of Deformation Surveys - a Generalised Method. (Ph.D. Dissertation)Technical report No. 94, Dept. of Surveying Eng., University of New Brunswick, 262 p. 1983.

[11] Chen, Y.Q., A. Chrzanowski, and J.M.Secord (1990). " A strategy for the analysis of the stability of reference points in deformation surveys". *CISM Journal*,Vol.44, No.2,Summer, pp.39-46.

[12] Chrzanowski, A., Y.Q. Chen and J. Secord: On the strain analysis of tectonic movements using fault crossing geodetic surveys. *Tectonophysics*, Vol. 97, pp. 297-315, 1983.

[13] Chrzanowski, A., Y.Q. Chen, and J.M. Secord: Geometrical analysis of deformation surveys. *Proceedings of a Workshop on Deformation Measurements*, Massachusetts Institute of Technology, Cambridge, Mass., October, pp. 170-206. 1986.

[14] Chrzanowski A., Y. Q. Chen, A. Szostak-Chrzanowski and J. M. Secord (1990): Combination of Geometrical Analysis with Physical Interpretation for the Enhancement of Deformation Modeling", *Proceedings of the XIX-th International Congress FIG, Helsinki*, Finland, 10-19 June, Vol.6, pp. 326-341.

[15] Chrzanowski A. and A. Szostak-Chrzanowski: Enhancement of Deformation Modelling in Engineering and Geosciences by Combining Deterministic and Generalized Geometrical Analysis". *Proceedings of the Annual Conference of the Can.Soc.for Civil Eng.,* Fredericton, June 8-11. Vol.IV, pp.479-488. 1993.

[16] Welsch, W. and O. Heunecke: *Models and Terminology for the Analysis of geodetic Monitoring Observations*, International Federation of Surveyors, Publication No.25, 22 p. 2001.

[17] Szostak-Chrzanowski, A., W. Proszynski, and W. Gambin: Continuum Mechanics as a Support for Deformation Monitoring and Analysis, submitted to the 12th FIG Symposium on Deformation Measurements, Baden, Austria, May 22-24, 2006.