Engineering Surveying Standards

Karl-Hans KLEIN and Otto HEUNECKE, Germany

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SUMMARY

In contrast to Ordnance and Cadastral Surveys (Sovereign Surveys), organised by survey laws and administrative regulations, Engineering Surveys are of private law nature in Germany. To give a unified and commonly accepted framework within Geodesy and Engineering Surveys in particular, appropriate national standards were respectively will be worked out. These standards are open to everybody for application and shall establish accepted technical rules, as well. The paper describes the intentions and essential contents of the standards related to Geodesy and Engineering Surveys supervised by the commission ”Geodesy” at the German Institute for Standardization (DIN). These are in particular the standards DIN 18709 and DIN 18710.

ZUSAMMENFASSUNG

Im Gegensatz zur Landes- und Katastervermessung (Hoheitliches Vermessungswesen), die durch Vermessungsgesetze und Verwaltungsvorschriften geregelt sind, ist der Bereich der Ingenieurvermessung in Deutschland dem Privatrecht zugeordnet. Um hier einen einheitlichen und allgemein akzeptierten Rahmen zu haben, wurden auf nationaler Ebene entsprechende Standards ausgearbeitet, bzw. werden derzeit ausgearbeitet. Sie stehen jedermann zur Anwendung frei und sollen sich als anerkannte Regel der Technik einführen. Der nachstehende Beitrag beschreibt die Intentionen und wesentlichen Inhalte der Normen bezüglich Geodäsie und Ingenieurvermessung aus der Sicht des Arbeitsausschussses ”Geodäsie” im Deutschen Institut für Normung (DIN). Im Besonderen sind dies die Normenreihen DIN 18709 und DIN 18710.

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1. INTRODUCTION

Related to Surveying and Mapping / Geoinformation in Germany there is a clear dissociation between the Sovereign Surveys, especially Ordnance Surveys and Cadastral Surveys, and the so-called private regulated Surveys, in particular Engineering Surveys. Based on the concurrent legislation of the federal states within Germany the Sovereign Surveys are constituted. The fulfillment of the different tasks related to Ordnance and Cadastral Surveying (build up of a national geodata infrastructure, production of official topographical maps, real estate surveyings, etc.) are with some exceptions restricted to the national bodies, administration offices and agencies and their employees. Here, the term "standard" (norm) makes no sense (at least in Germany). On the other hand also Engineering Surveying, involved in so many activities in Civil and Construction Engineering economy, needs to have a common framework.

To disburden the legislature from the creation and maintenance of guidelines within the private economy in general the German Institute for Standardization (DIN), a national body of ISO, was established already in 1917. Standardization is a part of the self-administration of the national economy in Germany. Some general remarks on the aims and goals of the german standardization can be found in DIN 820-1 (1994). The standards in Germany are open to be applicated by everyone, but they are normally not mandatory for application. They try to reflect the well-accepted technical rules and should give a framework for contracts between customer and contractor. Anyhow, the partners involved – customer and contractor – have to agree upon a specific standard as a valid basement. Apparently more suitable agreements are always possible and in principle allowed for particular applications, but in cases of doubts usually the respective standards are cited, e.g. in court procedures.

All standardization efforts are done in standards committees (currently 76 committees, see: www.din.de) and their subsidiary working bodies where the interested parties (external experts from practice, administration and universities) are engaged unsalaried. Regarding this, DVW (and FIG) is deeply involved in (official, legal) standardization related to Surveying and Mapping in Germany.

Contract laws and mercantile determinations (e.g. remuneration) is not the subject of standards. A standard (norm) must be clear and consistent. If there are respective (e.g. surveying) laws, no standards can be created. There are different kinds of standards neccessary. Beside the norms with a technical content (requirements, defintion of formats and interfaces, etc.) there are norms with definitions and nomenclature only to give a common linguistic usage of established and accepted (!, standardization should not be a research area) terms and definitions.

Within DIN the commission NA005 - (Building and Civil Engineering Standards Committee) - 03 (Surveying and Mapping / Geoinformation) - 01 (Geodesy), current chairman Prof. Dr.-Ing. K.-H. Klein, is responsible for creating and maintaining the standards DIN 18709 and DIN 18710 related to Geodesy and Engineering Surveying in particular. In the following the content of these standards is performed and discussed.

Not discussed are other standards related to Surveying and Mapping / Geoinformation (see Knoop, 1997), e.g. DIN 18723 "Field Procedures for Accuracy Tests of Survey Instruments" with its 8 parts (see: www.din.de). Furthermore, the involment of the respective standards to the wide field of other guidelines and technical bulletins available in Germany is not elaborated here, neither the interrelations with VOB (guidelines for the submission and letting, see: www.din-bauportal.de) and HOAI (guidelines for the honorarium calculation, especially part XIII; see: www.hoai.de). Some more information concerning this matter can be gained from the website www.cces.de.

These mentioned other guidelines and technical bulletins ("de facto standards" - see Greenway, 2002 - obliged to the parties involved) are appointed to particular tasks, demands and needs by the responsible authorities and companies, e.g. the recording and documentation of the buildings at the properties of the German State by the German Ministry of Defense and the German Ministry of Transport, Building Structure and Urban Development. This is to be seen beyond the required Cadastral Surveys. Aim is the set up of an information system of the entire infrastructure (LISA, more details see: www.bfrvermessung.de). In such assignations, completely different from (official) standards, often specific instruments, procedures, data structures and data flows are prescribed bindingly. Therefore, however, these kind of guidelines are normally not suitable to become (official) "standards".

2. DIN 18709 CONCEPTS, ABBRIVIATIONS AND SYMBOLS IN GEODESY

DIN 18709 – 1: Concepts, abbreviations and symbols in Surveying and Mapping, General

DIN 18709 – 2: Concepts, abbreviations and symbols in Geodesy, Engineering Geodesy

DIN 18709 – 3: Concepts, abbreviations and symbols in Geodesy, Hydrographic Surveying

DIN 18709 – 4: Concepts, abbreviations and symbols in Geodesy, Adjustment of observations and statistics

DIN 18709 – 5: Concepts, abbreviations and symbols in Geodesy, Evaluation of continuous series of observations

Fig. 1: Parts of DIN 18709 "Concepts, abbreviations and symbols in Geodesy"

The DIN 18709, titled as concepts, abbreviations and symbols in Geodesy, is a purely nomenclature standard and consists of five individual parts, see Fig. 1. A character of all parts of DIN 18709 is that there are no hints for applications and circumstances the given terms are used for. The standard is – with the exception of part 1 - currently under construction (see Klein, 2006).

2.1 General Remarks on the new Standard DIN 18709

The development of a new or revised standard demands to publish a preliminary issue at first. After given the opportunity for caveats and their discussion within the concerned commission of DIN the final state is reached. However, a quite complex procedure. Parts 4 and 5 of DIN 18709 are preliminary at present. Completely revised issues for the older issues of parts 2 and 3 will be available soon. Part 1 “General” of DIN 18709 (amount 87 pages and an additional appendix) is still dated from 1995. Here, especially terms and definitions of Geodesy, including astro-geodetic and gravimetric measurements e.g., can be found, often explained by small sketches (e.g. to be seen in Fig. 2).

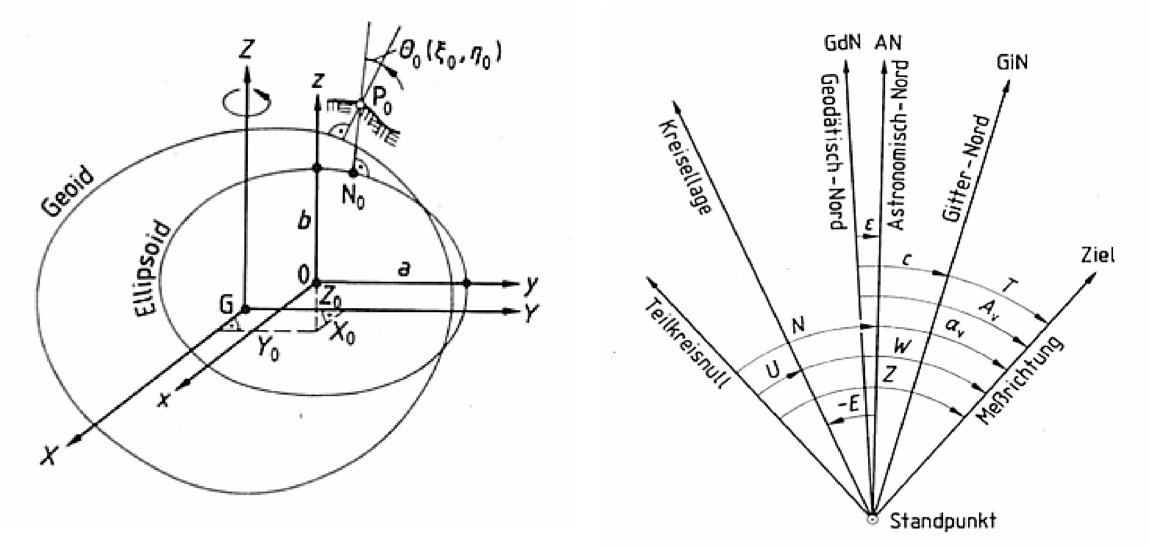

Fig. 2: Geodetic datum and measurement of directions with a gyro (see: DIN 18709-1, 1995)

The revised parts 2 on Engineering Geodesy and 3 on Hydrographic Surveying will be more or less a collection of relevant terms and definitions. Hydrographic Surveying is relevant for a standard because in the meantime often projects are submitted on a contract base.

2.2 DIN 18709 – 4: Adjustment of Observations and Statistics

In comparison with the older issue of the DIN 18709-4 (dated 1984) the revised version comprises some new aspects (amount now over 50 pages with 2 brief annexes). Contents of this standard are the basic terms and definitions (including formulae) of random variables *x* and random vectors ***x*** as they are available in Geodesy (statistical inference, normal distribution, etc.). The law of error propagation (“variances and covariances of functions of a random vector”) as well as the algorithms of the general case of adjustment (Gauß-Helmert-Model) and the parametric adjustment (Gauß-Markov-Model) are presented. Furthermore, regression and transformation models (see Fig. 3) are outlined. Some basic characteristics of reliability (e.g. redundancy criteria) in adjustment models are given.

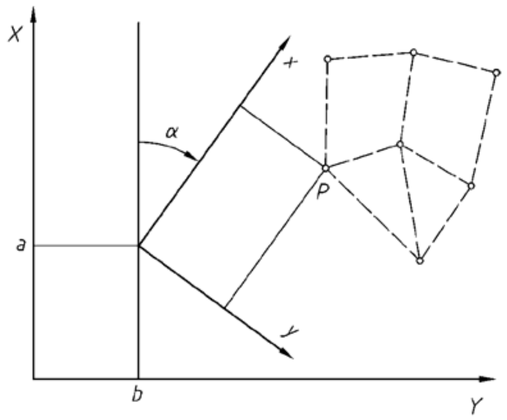

Fig. 3: Graphical explanation of a 2D similarity transformation (see: DIN 18709-4, 2005)

One aspect in the revision was to get an adaptation to the language use of the “Guide to the Expression of Uncertainty in Measurements” (see: DIN V ENV 13005, 1999), which is very popular in most of the measuring disciplinces today. Important is furthermore the separation between qualitative and quantitative terms of accuracy, which has to be adopted to Geodesy, too.

2.3 DIN 18709 – 5: Evaluation of Continuous Series of Observations

The new DIN 18709-5 (amount 36 pages including 10 brief annexes) makes allowance for the situation that time series (stochastic processes, see Fig. 4) are becoming more and more important in Geodesy and Engineering Surveying: “This standard is made for the handling, evaluation and interpretation of stochastic processes as they are available in Geodesy by continuous time series. Intention is to adapt the habitual language use of Geodesy and other disciplines. … Typical applications of this standard are the analysis of continuous deformation measurements (e.g. at buildings) and the modelling of processes with a time component (e.g. trajectories of vehicles). Beyond this these methods are also suitable for the description and evaluation of measurement procedure which produces time series (e.g. measurements with the Global Positioning System).” It seemed not to be advisable to integrate these items of signal analysis in a revised issue of the DIN 18709-4.

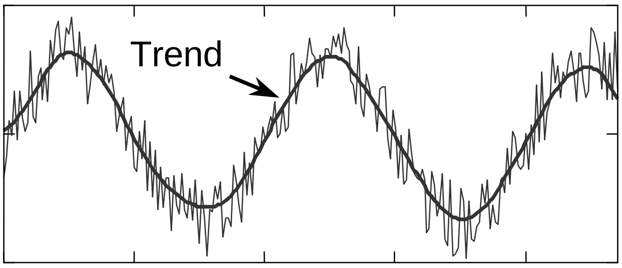

Fig. 4: Typical time series with a trend (sinus function) and its variations (see: DIN 18709-5, 2006)

The content of this standard are the terms and definitions (mostly including formulae) concerning:

- one-dimensional stochastic processes (trend, auto covariance function, auto correlation function, stationarity, ergodicity, Fourier transform, power spectrum, sampling rate, sampling frequency, autoregressive process, white noise / red noise process);
- relations between one-dimensional random processes (e.g. cross covariance function, cross correlation function, cross spectrum, phase lag, coherence);
- multi-dimensional random processes (e.g. random field, multi-dimensional auto covariance function, multi-dimensional cross covariance function);
- one-dimensional filters (e.g. convolution, weight and transfer functions, moving average, low- and highpass filter, amplitude response, noise amplification);
- filtering and prediction methods (e.g. collocation and Kalman filtering).

3. DIN 18710 ENGINEERING SURVEYS

Engineering Surveys according to DIN 18710-1 (1998) are dealing with site surveying, setting out, and deformation measurements (see Fig. 5) at buildings and other objects, e.g. constructions and machines. Part 1 is named "General Requirements" and can be seen as the underlying basis of the other three parts. An overview of the content of DIN 18710 is given in Klein / Heunecke (2000) already. All given statements in this standard are requirements respectively recommendations on a very general level and are not to be seen as a substitute for a text book or a compendium. Expertise of the user is requested, however.

It is still expected that DIN 18710 will develop to an important technical basis for contract letting, execution and evaluation of Engineering Surveys in the whole field of Civil and Construction Engineering. A proven (market) need is undoubted, because Engineering Surveys have to give their economic contribution even if the immediate resulting effects ("quality management") often will not be seen as a direct benefit (e.g. Klein / Wolff, 1996).
One of the main intentions of DIN 18710 is to achieve a better communication between the different partners involved in Engineering Surveys, to create a legal protection and a mutual confidence of these partners. It is to accentuate that this standard is made to cover the whole spectrum of Engineering Surveys. By defining some general requirements the contract letting will be made easier, the execution of a survey is well-structured and also some rules for evaluation and documentation are given.

In a standard like DIN 18710 only very general and mature requirements and recommendations can be made, but no specific techniques or instruments e.g. can be suggested. There are also no recommendations on how to execute a specific survey in detail. Here every user proceeds on his own responsibility and the choice of suitable instruments and techniques is devoted to the user of the standard, too. However, it is stated that everything has to be documented to make a survey comprehensible (for the contractor).

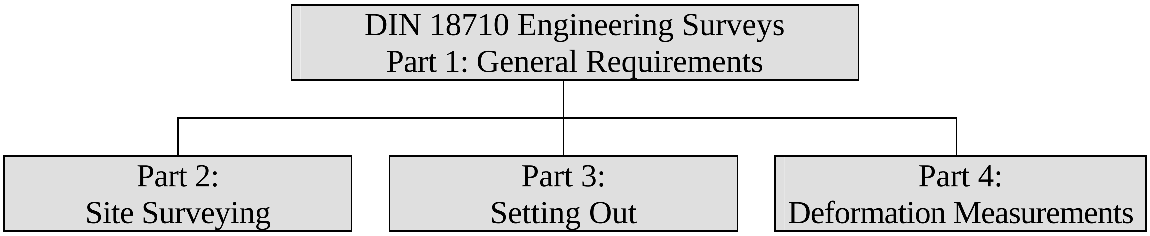

Fig. 5: Design of DIN 18710 “Engineering Surveys” (see Klein / Heunecke, 2000)

3.1 DIN 18710-1: General Requirements

The main intention of the DIN 18710 is concluded by the scope of part 1: “This standard defines general principles concerning surveys for buildings, their elements (e.g. industrial plants, traffic plants, machinery plants) and other objects. The requirements and proofs of this standard shall contribute to set up agreements about surveys. This standard shall also contribute to the regularisation of quality and records of Engineering Surveys and shall ensure that results can be interpreted unambiguously.” The essential content of part 1 is the summary of the most important terms and definitions (e.g. establishment of an external and an internal reference frame), and the enumeration of global requirements for Engineering Surveys.

The given requirements in part 1 are dealing with the organisation of a survey, the personnel, the instruments and techniques to apply, the accuracy aspects, the evaluation and the documentation in particular. They are covering all aspects of a specific survey. Most of these given requirements are obvious and, however, at least partly more or less elementary. For instance, if the naming of responsible persons for the survey is requested to ensure an impeccable execution. A review on the most important terms of sizes and tolerances is given in an annex, because requirements of the geometric quality are usually defined by tolerances. Statistics say, that about 90% of all quality requirements are of geometric nature, thus, quality assurance can be done mainly by determination and evaluation of geometric quantities. Deficiencies in the static behaviour, the operation of construction elements or the building as a whole and – last but not least – in the aesthetics of the construction are very often consequences of shortcomings in the geometric quality.

Therefore, in many Engineering Surveys the achievement of a well-balanced relationship between tolerances and the required accuracy of a measurement procedure is of practical importance. Such relationships are to be set up for particular normal sizes with respect to their actual measures under well-defined conditions, e.g. a specific reference temperature. Here the DIN 18710 recommends to obtain a ratio V of

$$10\% \leq V \leq 20\%, \qquad V = \frac{\sigma_x}{T} \tag{1}$$

between tolerance T and standard deviation (in the sense of measurement uncertainty) σ_x . In DIN 18710-1 it is furthermore stated: “The measuring techniques are to perform in that way, that the accuracy and reliability of the survey according to the requirements will be ensured and that the aims of the surveys will not be affected by systematic errors”. To fulfill the reliability criteria a survey is very often carried out by a doubled occupation of the points. For such a typical situation the accuracy of the result will increase by (uncorrelated, uniform kind of observations presumed)

$$\sigma_{\hat{x}} = \frac{1}{\sqrt{2}} \sigma_x \tag{2}$$

and the respective partial redundancy r (defined in DIN 18709-4, 2005) as the main reliability criterion is to be obtained by

$$r = 1 - \frac{\sigma_{\hat{x}}^2}{\sigma_x^2} = 0.5 \,. \tag{3}$$

Such a scenario is admissible according to DIN 18710-1, where $r > 0.3$ is recommended. Both, a measured value x together with a respective standard deviation σ_x makes the result of a survey ”complete”.

3.2 DIN 18710-2: Site Surveying

A site (or topographic) survey deals with the recording of geometrical quantities of the state of objects and their documentation, for instance in a GIS (e.g. a building information system). The typical structure of a site survey is characterized and the importance of the data organisation is specially emphasised; some hints for the documentation are given. Completeness and correctness of a survey is of special interest. Examples of objects to record for different purposes with their accuracy requirements are listed in tabular form. All given requirements are made with respect to the content of DIN 18710-1. It is mentioned in particular that often a site surveying can use data from the curatorial geodata infrastructure.
Part 2 of DIN 18710 is in preparation at the moment.

3.3 DIN 18710-3: Setting Out

Setting out is the realisation of geometric quantities (in form of points) in the field based on a respective planning. In DIN 18709-3 some typical examples for setting out objects and their important points to stake out are listed in tabular form in a similar manner than in DIN 18710-2.

Consistent documents for the setting out are of special interest whilst the documentation has to be performed graphically (“plan”) and numerically (“data”). A representative checklist for a survey is included and an example is given by an annex.

3.4 DIN 18710-4: Deformation Measurements

Content of DIN 18710-4 (2002) are surveys for the determination of movements and distortions of an object. This includes all necessary efforts of planning, execution and evaluation of such kind of surveys. It is mentioned that the result of a deformation survey is the quantification of the geometric behaviour of an object with respect to time but the task can be seen in the explanation of the changing geometric behaviour as a result of causative factors, too.

The evaluation has to distinguish between the measurement uncertainties and the significant movements and distortions of the monitored object, usually this is made by statistic tests. Known as a rule of thumb the displacements are significant if the ratio to the standard deviation is bigger than 3. This part of DIN 18710 is discussed in detail by Heunecke (2002).
Of special interest in this standard is the so-called Monitoring Program. In this program, to be developed by the partners, the aims and intentions of the surveying should be explained and the measuring techniques should be defined. Additionally, some basic requirements about the survey points, the survey instruments and the necessary accuracy of the measurements are laid out.

4. CONCLUSION

The essential content of the DIN 18709 and DIN 18710 is briefly presented above. These standards are related to Geodesy and Engineering Surveying in particular. Whilst DIN 18709 is a purely nomenclature standard, DIN 18710 is made for the planning and execution of Engineering surveys. Most of the standards are preliminary at the moment – a state that holds on for quite a while right know. One reason is that sometimes compromises are hard to achieve for the final release of a standard.
Albeit, at the moment one has to think about the creation of adequate standards like DIN 18709 und DIN 18710 on an international level. This is due to the globalisation and internationality in Civil and Construction Engineering, which are expected to increase in the future with a growing european and international market.

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BIOGRAPHICAL NOTES

Karl-Hans Klein, born 1941, is Professor for Geodesy and Engineering Surveying at the Bergische Universität Wuppertal, since 1992. Since 1993 he is the chairman of the commission "Geodesy" at the DIN standardisation committee "Building and Civil Engineering" (NA005). His main activities are concentrated on the impact of quality management in Engineering Surveying and the quality control in building industry.

Otto Heunecke, born 1960 in Hildesheim, is Professor at the University of the Bundeswehr Munich, Institute of Geodesy, since 2002. He is member of the commission "Geodesy" of DIN since 1996. His main interests are related to deformation measurements, geo sensor networks, terrestrial laser scanning and geodetic methodology.

CONTACTS

Prof. Dr.-Ing. Karl-Hans Klein
Department of Surveying
University of Wuppertal
Pauluskirchstraße 7
42285 Wuppertal
GERMANY
Tel. + 49 202 439 4071
Fax + 49 202 439 4076
khklein@uni-wuppertal.de
www.bauing.uni-wuppertal.de/vermess/

Prof. Dr.-Ing. Otto Heunecke
Institute of Geodesy
University of the Bundeswehr Munich
Werner-Heisenberg-Weg 39
85577 Neubiberg
GERMANY
Tel. + 49 89 6004 4666
Fax + 49 89 6004 3907
otto.heunecke@unibw.de
www.unibw.de/IfG/