Standardization of equipment and techniques in surveying engineering and deformation measurements

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Abstract

Although standards play a key role for planning and carrying out surveying measurements and tasks, most of them remain in a draft version for a long period of time. These standards are related to Geodesy, Engineering Surveying, Deformation Measurements and Geographical Information. The fundamental content of these international and national standards is in brief presented in this paper along with the most important standardization organizations.

1. Introduction

Surveying engineering has been subject to rapid technical evolution concerning both techniques and equipment. The latest developments in the field of survey instruments and survey methods are characterized by the introduction of new information technologies. Mainly GPS and RTK GPS, Terrestrial Positioning Systems (TPS, Total Stations), Electronic Levels, Laser Scanners and other new measuring devices represent these new technologies. The modern instruments have resulted into a revolution in positioning. Increased accuracy, speed and seemingly simple use are the characteristics of modern survey instrumentation and methods. But these advantages might lead to the degradation of surveying profession and could result in unnecessary increase of cost of positioning as well as to the underestimation of the operator's qualifications.

Standardization of survey equipment and techniques may help to overcome the above-mentioned problems. Standards can apply for every-day surveying work but it is critical to apply also in special applications such as deformation measurement of technical works and landslides.

In this text, the current situation of applying standards for surveying activities at the international, regional and national level will be presented and shortly discussed. These include standards for survey equipment, standards for laboratory testing and calibration and standards for positioning within the family of standards for geographic information and Geomatics, emphasis given on the existence of standards for deformation measurements.

2. Current standardization organizations and activities

There is a very significant amount of standardization activity underway internationally, regionally and at the national level. Large numbers of people and organizations are involved in these procedures.

2.1. The International Organization for Standardization (ISO)

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from 135 countries. ISO is a non-governmental organization established in 1947, essentially to provide recommendations to members aimed at harmonizing national standards. The mission of ISO is to promote the development of standardization and related activities in the world with a view to facilitating the international exchange of goods and services, and to developing cooperation in the spheres of intellectual, scientific, technological and economic activity. ISO's work results in international agreements, which are published as International Standards.

ISO began to function officially on 23 February 1947. The first ISO standard was published in 1951 with the title "Standard reference temperature for industrial length measurement". The acronym "ISO" is a word, derived from the Greek *ίσος*, meaning "equal", which is the root of the prefix "iso-" that occurs in a host of terms, such as "isometric" (of equal measure or dimensions), "isothermal" (of equal temperature) etc. From 'equal' to 'standard', the line of thinking is easy to follow. In addition, the name has the advantage of being valid in each of the organization's three official languages: English, French and Russian.

The adoption of ISO standards is voluntary, but users tend to have more confidence in products and services that conform to International Standards. Assurance of conformity can be provided by manufacturers' declarations, or by audits carried out by independent bodies.

Concerning the surveying profession and surveying engineering, the work of ISO started in the field of manufacturing. Today ISO is finalizing the updating and harmonization of earlier standards for older instruments for example EDM, Theodolites and Levels. Standards for new instruments as Digital Levels, Laserplanes, Total Stations, commonly used by the today surveyors have been started during the last years. In recent years, the **International Federation of Surveyors (FIG)** and particularly its Commission 5 (Positioning and Measurement) has worked with the relevant ISO technical committees to harmonize requirements, and a number of new standards.

A relatively recent area for ISO attention has been that of geographic information. A European Initiative in the early- to mid-1990s had resulted in some provisional standards in this area, but ISO is now in the process of publishing over 30 standards. They cover aspects from terminology to coordinate reference systems, including crucial areas such as interoperability. This is in line with an industry move to open systems standards, and the GIS manufacturers are key players in the ISO work.

The ISO objective for the standards is to specify *field procedures* to be followed each time the achievable precision or “accuracy” for a given surveying instrument used together with its ancillary equipment (tripod, staffs, etc) has to be determined. This will allow the surveyor to investigate that the precision given by the measuring equipment is appropriate to the intended-measuring task.

2.2. Other international or regional standardization bodies

There are several other international or regional standardization bodies or organizations working in the field of standardization with interest (among others) in surveying or surveying-related tasks:

a. The **Comité Européen de Normalisation (CEN)** has become an important organization with the growth of pan-governmental activity at the European level - many of its standards are referenced by European Commission documents. The procedures of CEN are similar to those of ISO, with similar outputs. ISO and CEN have worked closely together for some considerable time, and the Vienna Agreement sets out arrangements for each to ratify the other's work. About 40% of all European standards are direct adoptions of ISO standards under these arrangements.

b. The **Federal Geographic Data Committee (FGDC)** is a 19 member interagency committee in the U.S.A. composed of representatives from the Executive Office of the President, Cabinet-level and independent agencies. The FGDC is developing the National Spatial Data Infrastructure (NSDI) in cooperation with organizations from State, local and tribal governments, the academic community, and the private sector. The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data.

c. The **Pacific Area Standards Congress (PASC)** is less developed than CEN, but in a similar way attempts to coordinate the development of standards in the countries around the Pacific.

d. The **International Valuation Standards Committee (IVSC)** consists of professional valuation associations from around the world, with almost 50 countries currently represented. Its objectives are to formulate and publish, in the public interest, valuation Standards for property valuation and to promote their world-wide acceptance; to harmonize Standards among the world's States; and to identify and make disclosure of differences in statements and/or applications of Standards as they occur.

e. The **European Group of Valuers' Associations (TEGoVA)** is currently working on the developments of valuation best practice documents at a European level. Its objectives are, among others, to write and promote valuation standards for application across Europe, to represent professionally qualified valuers of land, buildings and plant and machinery in Europe and present their views to the European Commission, European Parliament and other European organizations and to transmit views to the International Valuation Standards Committee (IVSC) on issues of common interest.

f. **The North Atlantic Treaty Organization (NATO)** issues STANAGs (standardization agreements), which have mandatory status for military authorities in the organizations' member countries. One of these, for instance, defines the Universal Transverse Mercator (UTM) coordinate reference system, which is widely used throughout the world. Another - number 7074, developed by the Digital Geographic Information Working Group (DGIWG) - sets the Digital Geographic Information Exchange Standard (DIGEST).

g. The **International Federation of Surveyors (FIG)** is one of the few bodies through which surveyors can formally be represented in international official standardization activities. FIG's aim in the field of standards is to assist in the process of developing workable and timely official and legal standards covering the activities of surveyors. In so doing, FIG is supporting its objective to collaborate with relevant agencies in the formulation and implementation of policies. FIG is also committed in its objectives to developing the skills of surveyors and encouraging the proper use of technology, activities which are becoming increasingly shaped by standards. FIG generally seeks to ensure that de facto standards become official standards as technology matures, or at the very least that all relevant official, legal and de facto standards are produced in full knowledge of all other related material.

h. The **International Maritime Organization (IMO)** is a United Nations specialized agency which issues conventions, ratified by countries, to regulate worldwide maritime safety. As part of this activity, it establishes reference standards for electronic chart display and information systems (ECDIS) used by regulated shipping.

i. The **International Hydrographic Organization (IHO)**, a scientific and technical organization which creates international minimum standards covering hydrography and nautical charting. IHO is an intergovernmental organization (IGO) not affiliated to the UN. The secretariat of IHO is called the International Hydrographic Bureau (IHB). The IHO publishes a Transfer Standard for Digital Hydrographic Data.

j. The **OpenGIS Consortium (OGC)**, a commercial body representing the manufacturers of GIS hardware and software and the providers of geographic data. The OGC is working towards the adoption of open standards, allowing the flow of data between different GI systems.

k. The **International Cost Engineering Council (ICEC)** which created an International Standards Working Group in 2000 'to promote and manage the development and promulgation of world-wide best practices and/or standards in cost management as represented by the fields [of] cost engineering, quantity surveying and project management'; and

l. The **International Association of Geodesy (IAG)** and the **International Cartographic Association (ICA)**, which have both in recent years increased their focus on standardization activities and adjusted their structures accordingly, and the **International Society for Photogrammetry and Remote Sensing (ISPRS).**

2.3. National standardization bodies

The members of ISO (national standardization bodies) are often government-run or supported in part, in recognition of their work in supporting free competition, trade and public order. Their key tasks are the production of national standards where this will support the national economy and/or protect citizens, and the promotion of the use of relevant international standards - with the growth of global trade, the latter role is increasingly important and fewer national official standards are being produced. They are generally encouraged to cover part of their costs (including the costs of participating in ISO activity and creating national standards) through selling materials, offering certification services, etc.

Moving to the field of legal standards, national governments, in their role as protectors of the right to hold land (on which so much economic development and stability depends), are an important source of regulations for cadastral surveyors. As with official standardization activities, such laws can lag significantly behind technical developments and, through setting input controls, can inhibit effective use of resources.

2.4. Private sector – De facto standards

De facto standards are being developed when a certain procedure is followed by many practitioners without being adopted or proposed by a standardization body. De facto standards in form of national laws, codes and regulations are found in almost all countries to organise the work of surveying and registration of cadastral data. Commercial firms are becoming increasingly important in the development of de facto standards. Microsoft (MS) is a classic example - other software manufacturers need to ensure that their programs interface successfully with Windows and other MS products if they are to be successful. AutoCad and the DXF file format for exchanging drawing files among CAD programs is another example. There are many more other organizations and companies setting, wittingly or not, de facto standards.

3. Standards for Survey Equipment

Existing ISO activities concerning survey instruments are concentrated in several Technical Commissions (TC59/SC4 and TC172/SC6). Unfortunately the existing standards are taking into account either the construction or manufacture points of view only. Since 1997, the Technical Commissions TC59/SC4 and TC172/SC6 dealing with the same subjects have been integrated into TC172/SC6 (Geodetic and surveying instruments), this in order to eliminate the duplication of standards for the same instrument used for different applications and to propose a new set of standards for "Field Procedures for Determining the Accuracy of Surveying Instruments". The scope of the TC172/SC6 is stated as “standardization of terminology, requirements and test methods for geodetic and surveying instruments, their components and accessories”. The approved standards are:

ISO 17123-1:2002 Optics and optical instruments – Field procedures for testing geodetic and surveying instruments – Part 1: Theory

ISO 17123-2:2001 Optics and optical instruments – Field procedures for testing geodetic and surveying instruments – Part 2: Levels

ISO 17123-3:2001 Optics and optical instruments – Field procedures for testing geodetic and surveying instruments – Part 3: Theodolites

ISO 17123-4:2001 Optics and optical instruments – Field procedures for testing geodetic and surveying instruments – Part 4: Electro-optical distance meters (EDM instruments)

ISO 17123-6:2003 Optics and optical instruments – Field procedures for testing geodetic and surveying instruments – Part 6: Rotating lasers

ISO 12858-1, Publication date: 1999-04 – Optics and optical instruments - Auxiliary devices for geodetic instruments – Part 1: Invar leveling staffs.

Other standards for survey equipment can be found in the German National Body of Standardization (the well-known DIN standards):

DIN 18718, Publication date: 1986-01 – Types and elements of geodetic instruments; terms

DIN 18719, Publication date: 1975-12 – Surveying instruments; centering, stub and socket

DIN 18720, Publication date: 1995-07 – Instrument and tripod connectors on surveying instruments

DIN 18721, Publication date: 1977-11 – Circle graduation with visual reading for surveying instruments

DIN 18722, Publication date: 1983-02 – Tubular level for surveying instruments; terms and requirements

DIN 18723-1, Publication date: 1990-07 – Field procedure for precision testing of surveying instruments; general information

DIN 18723-2, Publication date: 1990-07 – Field procedure for precision testing of surveying instruments; levels

DIN 18723-3, Publication date: 1990-07 – Field procedure for precision testing of surveying instruments; Theodolites

DIN 18723-4, Publication date: 1990-07 – Field procedure for precision testing of surveying instruments; optical distance measuring instruments

DIN 18723-5, Publication date: 1990-07 – Field procedure for precision testing of surveying instruments; plumbing instruments

DIN 18723-6, Publication date: 1990-07 – Field procedure for precision testing of surveying instruments; electro-optical distance measuring instruments for short ranges

DIN 18723-7, Publication date: 1990-07 – Field procedure for precision testing of surveying instruments; gyroscopes

(Draft standard) DIN 18723-8, Publication date:1998-08 – Field procedure for precision testing of surveying instruments - Part 8: Rotating laser levels

DIN 18724, Publication date: 1990-06 – Geodetic instruments; precision of levels and Theodolites from technical data

DIN 18725, Publication date: 1971-03 – Surveying instruments; reticules

DIN 18726, Publication date: 1996-07 – Tripods for surveying instruments.

4. Standards for Laboratory Calibration and Testing

Unfortunately not all the Standards allow checking, testing and calibration to be carried out uniquely in the field. In many instances engagement of metrological procedures is required. The application of metrological procedures is justified also by new aspects of Quality Management as required by Standards ISO 9001:2000 and also by increasing complexity of measuring systems, which are reflected in completely new methods of calibration.

There are many excellent geodetic laboratories for testing and calibration of survey instruments, but not all of them comply with the metrological confirmation system as defined by ISO 10012/1. The traditional methods for checking, testing and calibration of the major part of geodetic instruments are partly or totally outdated. New instruments have to be tested as complete systems consisting of interconnected sensors, firmware, application software, data acquisition, data transfer and user interface. The ISO/IEC 17025 – *General requirements for the competence of testing and calibration laboratories* describes in detail the requirements and specifications for the operation of a testing and calibration laboratory.

5. Standards for positioning geographic information

Activities on Standards related to positioning of Geographic Information are being treated mainly by ISO/TC211 and by CEN/TC 287. The scope of the TC211 is stated as "*standardisation in the field of digital geographic information*" with the aim of "*establishing a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the earth*". The stated objectives of the TC211 are to increase the understanding and usage of geographic information, to increase the availability, access, integration and sharing of geographic information, to promote the efficient, effective and economic use of digital geographic information and associated hardware and software systems, and to contribute to a unified approach to addressing global ecological and humanitarian problems.

Most of the pre-standards are now completed or short before completion. If we consider that according to GIS specialist over 80 % of all activities on global, national and regional level have spatial or geographic aspect it is no surprise that the initiative for standardisation in this field came from the GIS experts and not from surveyors. The most important documents are:

- ISO 19111-2003 Geographic Information/Geomatics – Spatial Referencing by Co-ordinates
- (pre-standard) ENV 12762:1998: Geographic Information – Referencing Direct Position.

Other standards about geographic information are:

- ISO 19101 Geographic information - Reference model
- ISO 19103 Geographic information - Conceptual schema language
- ISO 19105 Geographic information - Conformance and testing
- ISO 19107 Geographic information - Spatial schema
- ISO 19108 Geographic information - Temporal schema
- ISO 19109 Geographic information - Rules for application schema
- ISO 19110 Geographic information - Feature cataloguing methodology
- ISO 19113 Geographic information - Quality principles
- ISO 19115 Geographic information - Metadata
- ISO 19118 Geographic information - Encoding.

The increasing adoption of modern survey instruments and namely GPS for positioning and navigation makes it necessary for surveying profession to ensure national and international standards for geo-referencing and spatial co-ordinate positioning. Standards related to GPS techniques are:

- DIN EN 61108-1:2002-11 (Draft standard) – Global navigation satellite systems (GNSS) - Part 1: Global positioning system (GPS); Receiver equipment; Performance standards, methods of testing and required test results (IEC 80/344/CDV:2002)
- DIN EN 61108-2: 1999-05 – Maritime navigation and radio-communication equipment and systems - Global navigation satellite systems (GNSS) - Part 2: Global navigation satellite system (GLONASS); receiver equipment; performance standards, methods of testing and required test results (IEC 61108-2:1998); German version EN 61108-2:1998.

Some other standards include guidelines about surveying procedures and positioning during the construction of buildings:

- ISO 8322-5:1991 – Building construction – Measuring instruments – Procedures for determining accuracy in use – Part 5: Optical plumbing instruments
- ISO 8322-6:1991 – Building construction – Measuring instruments – Procedures for determining accuracy in use – Part 6: Laser instruments
- ISO 4463-1:1989 – Measurement methods for building – Setting-out and measurement – Part 1: Planning and organization, measuring procedures, acceptance criteria
- ISO 4463-2:1995 – Measurement methods for building – Setting-out and measurement – Part 2: Measuring stations and targets
- ISO 4463-3:1995 – Measurement methods for building – Setting-out and measurement – Part 3: Check-lists for the procurement of surveys and measurement services
- ISO 7078:1985-12 – Building construction; Procedures for setting out, measurement and surveying; Vocabulary and guidance notes
- FGDC-STD-007.4-2002 – Geospatial Positioning Accuracy Standard, Part 4: Architecture, Engineering Construction and Facilities Management.

Some other standards include guidelines about surveying procedures and positioning for developing the digital maps required in GIS applications:

- FGDC-STD-007.1-1998 – Geospatial Positioning Accuracy Standard, Part 1, Reporting Methodology,
- FGDC-STD-007.2-1998 – Geospatial Positioning Accuracy Standard, Part 2, Geodetic Control Networks

- FGDC-STD-007.3-1998 – Geospatial Positioning Accuracy Standard, Part 3, National Standard for Spatial Data Accuracy.

6. Standards for deformation measurements

FIG Commission 6 Working Group 6.1 on Deformation Measurements plays an important role in providing a forum for the exchange of information on the new developments in deformation surveys by organizing technical sessions during the FIG Congresses and by organizing specialized international symposia. The Working Group has been one of the most active international groups dealing with the problems of monitoring and analysis of deformations in engineering and geosciences projects. WG6.1 concentrated its efforts on the development of new monitoring techniques and on geometrical analysis of geodetic deformation surveys. One of the most important outcomes was the development of a *generalized method of geometrical deformation analysis* 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 modeling of displacement and strain fields. The current activity of WG6.1, concentrates on the automation of deformation surveys, use of Synthetic Aperture Radar (SAR) in interferometric determination of displacements, and in monitoring and analysis of structural vibrations and cyclic deformations.

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. But for the moment this activity did not result into the proposal of specific standards for deformation measurements and analysis, although deformation measurements and analysis are very important applications of engineering surveying. It must be noted though, that any standardization efforts in the field of Engineering Surveys are difficult due to the wide spectrum of appropriate surveys and the rapid technological developments. Still, there is a number of draft or proposed standards to the engineering community:

- DIN 18709 – Concepts, Abbreviations and Symbols, part 1 “Generalities”, part 2 “Engineering Surveys”, part 3 “Hydrographic Surveying”, part 4 “Adjustment of Observations and Statistics” and part 5 “Evaluation of continuous series of observations”
- DIN 18710-1:2000 -10 – Engineering surveys - Part 1: General requirements
- (Draft standard) DIN 18710-2:1998-10 – Engineering surveys - Part 2: Detail surveys
- DIN 18710-3:2000 -03 – Engineering surveys - Part 3: Setting out

- (Draft standard) DIN 18710-4: 2002-07 – Engineering survey - Part 4: Deformation measurements.

The standard DIN 18710 “Engineering Surveys” consists of four parts. Part 1 is called “General Requirements” and can be seen as the underlying basis of the other three parts, which are dealing with detail or topographic surveys (part 2), setting out (part 3) and deformation measurements (part 4). All statements in these standards are more or less general recommendations. Even so, before creating DIN 18710 there were no sufficient official general documents establishing technical requirements about Engineering Surveys in Germany. Therefore the necessity of this standard seemed to be given from the point of Engineering Surveys and also from the point of Civil and Construction Engineering.

The basic content of part 1 "General Requirements" is the summary of the most important terms and definitions for Engineering Surveys. The given requirements are dealing with the organization of a survey, the personnel, the instruments and techniques to apply, the accuracy aspects, the evaluation and the necessary documentation. Part 2 “Detail surveys” deals with the recording of geometrical quantities of the states of objects and their documentation, for instance in a GIS (e.g. Building Information System, Network or Utility Lines Information System). Part 3 “Setting out” gives recommendations about the realization of geometric quantities in the field based on a planning and the proper procedures for the points to mark at the site. Finally, Part 4 “Deformation Measurements” deals with the determination of movements and distortions of an object including all necessary efforts of planning, execution and evaluation of such kind of surveys. DIN 18710-4 mentions that the result of a deformation survey is the quantification of the geometric behavior of an object with respect to time but the task can be seen in the explanation of the changing geometric behavior because 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 statistical tests. In this standard, some basic requirements about the control network and points, the survey instrumentation and measurement techniques as well as the necessary accuracy of the measurements and the organization of a monitoring program are described.

Geometric quality is a property of buildings and other constructions as a whole, especially of complex constructions. Requirements about the geometric quality are usually defined by tolerances and Engineering Surveys can be used to ensure the adherence of the quality claims. Geodetic monitoring of structures can give an enormous potential to avoid damage and to prolong the operation time of constructions. Engineering Surveys can contribute in producing "quality" mainly by the following subjects:

- Determination of geometric quality requirements and testing procedures
- Surveillance of keeping the geometric quality requirements

- Documentation of the several phases of a building or a construction.
- Determination of defects in planning
- Evaluation of offences against acknowledged technical rules
- Computation of deviations from the construction plans during execution.

DIN 18710-4 has a strong relationship with the so-called Eurocodes at a level of European pre-standards, for instance the EC 7 "Geotechnical Design", part 1 "General Rules" (EVN 1997, 1994) in building industry. In this Eurocode, emphasis is given to the observation method for controlling the behaviour of constructions under loads and improving the respective computation models. In other sections of EC 7, the geometric quality of constructions is concerned or at least mentioned in an implicit way, obviously underlining the importance of Engineering and Deformation Surveys.

A series of ISO standards about tolerances for buildings is also related to the deformation measurements:

- ISO 3443-1:1979 – Tolerances for building – Part 1: Basic principles for evaluation and specification
- ISO 3443-2:1979 – Tolerances for building – Part 2: Statistical basis for predicting fit between components having a normal distribution of sizes
- ISO 3443-3:1987 – Tolerances for building – Part 3: Procedures for selecting target size and predicting fit
- ISO 3443-4:1986 – Tolerances for building – Part 4: Method for predicting deviations of assemblies and for allocation of tolerances
- ISO 3443-5:1982 – Building construction – Tolerances for building – Part 5: Series of values to be used for specification of tolerances
- ISO 3443-6:1986 – Tolerances for building – Part 6: General principles for approval criteria, control of conformity with dimensional tolerance specifications and statistical control – Method 1
- ISO 3443-7:1988 – Tolerances for building – Part 7: General principles for approval criteria, control of conformity with dimensional tolerance specifications and statistical control – Method 2 (Statistical control method)
- ISO 3443-8:1989 – Tolerances for building – Part 8: Dimensional inspection and control of construction work
- ISO 7976-1:1989 – Tolerances for building – Methods of measurement of buildings and building products – Part 1: Methods and instruments
- ISO 7976-2:1989 – Tolerances for building – Methods of measurement of buildings and building products – Part 2: Position of measuring points
- DIN 4107: 1978-01 – Subsoil; Settlement observations during and after construction of structures

In addition, a number of national organizations have introduced guidelines and specifications for topographic surveying, GPS networks and measurements as well as control networks. Some of these procedures can be applied to deformation measurements. In any case these procedures cannot be considered standards but they could be the base for the preparation of international standards. Some examples are:

- Federal Geodetic Control Committee – "Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques", 1989
- California Geodetic Control Committee – "Specifications for Geodetic Control Networks Using High-Production GPS Surveying Techniques", 1996
- Inter-Governmental Committee on Surveying and Mapping – "Standards and Practices for Control Surveys (SP1) v1.5", ICSM publication No. 1, 2002
- Canada Center for Surveying. Surveys, Mapping and Remote Sensing Sector – "Guidelines and Specifications for GPS Surveys", 1992
- US Army Corps of Engineers – "Topographic Surveying", Engineer Manual, 1994.
- US Army Corps of Engineers – "NAVSTAR GLOBAL POSITIONING SYSTEM Surveying", Engineer Manual, 1996
- US Army Corps of Engineers – "Geodetic and Control Surveying", Engineer Manual, 2002

Finally, special reference must be made to an engineering manual published by the US Army Corps of Engineers about "Structural Deformation Surveying" (2002). The primary emphasis of this manual is placed on the technical procedures for performing precise monitoring surveys in support of the Corps periodic inspection and dam safety programs. General planning criteria, field and office execution procedures, data reduction and adjustment methods, and required accuracy specifications for performing structural deformation surveys are provided. These techniques are applicable to periodic monitoring surveys on earth and rock-fill dams, embankments, and concrete structures. This manual covers both conventional (terrestrial) and satellite (GPS) deformation survey methods used for measuring external movements.

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