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Main surveying instruments used in environmental monitoring: a classic approach of the book Topografia Geral

ABSTRACT

This paper addresses the main points inherent knowledge of surveying instruments today, as well as its evolution in history and goals. The work was carried out on the basis of Chapters I and II of the book Topografia Geral, which was held a didactic review for teaching students , teachers, researchers and surveying professionals. The book is a clear and concise language of the main elements that make up the Surveying: instruments and accessories. Objective of this study was to make an approach on the main surveying instruments and accessories used in environmental monitoring.

Keywords: surveying instruments, surveying accessories, land surveying, surveying history.

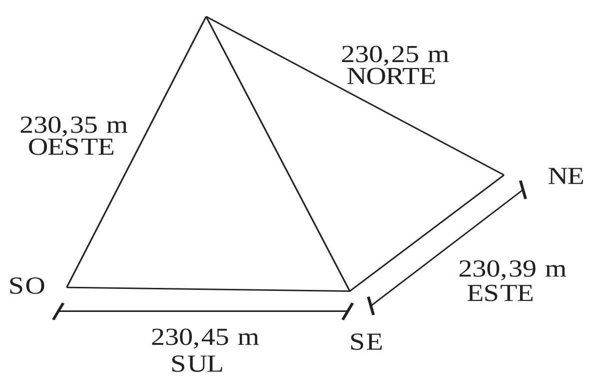
INTRODUCTION

The man has gone through several evolutionary processes of survival throughout history, from its primary forms to the current settings of society. The first people of prehistory were nomads who had no fixed residence and survived by hunting, fishing and plant extraction. Over time, there was the need for human survival change habits, for the food, which until then only exploited, were getting scarce, going to have a fixed residence and becoming a sedentary species. He learned to grow their own food and raise animals, emerging then, agriculture and livestock, thus forming more complex societies, such as towns and cities. After creating a more organized society, the human being needed specialize and demarcate their fields for use in their agricultural activities and housing. From there, the man started using Surveying, without even knowing that he had discovered. For demarcations activities of land for plantations and construction of homes were needed some instruments that would help in this work, hence the emergence of the first surveying instruments, although rudimentary.

The first people to set up and use the surveying instruments were the Egyptians and Mesopotamians, after Chinese, Hebrews, Greeks and Romans. It is not known exactly when it started, but it is believed that the Surveying was already used before 3200 a.c. having been employed in ancient Egyptian empire.

The instruments at that time were quite rudimentary and had low accuracy and precision in comparing with current instruments, but considering his time these people came to astonishing results . The Egyptians , for example, to make the construction of the pyramid of Cheops , which lasted 30 years to be built , built it with measures 230.25 m, 230.45 m, 230.39 m 230.35 me , respectively , paras their bases north , south, east and west. They missed only 20 cm entres the bases (Figure 1) (Museu de Topografia, 2002; MCCORMARC, 2010; MAYOZER, 2008; VALENTINE, 1976).

Figure 1 - Measurement of the Cheops pyramid bases and guidance.



In the case of angles, the error corresponding to 4 pyramid base angles is only 6'35". Another important consideration is that the four edges of the Khufu pyramid point to the side points NE, SE, SO, and NO, also including the other pyramids of Giza. Over the generations and time, the tools and methods have evolved technically and electronically , making the interfaces and their friendlier managements , providing more resources to the operator , controlling over the error and consequently paying off with higher accuracies and precisions. Objective of this study was to make an approach on the main surveying instruments and accessories.

REVIEW

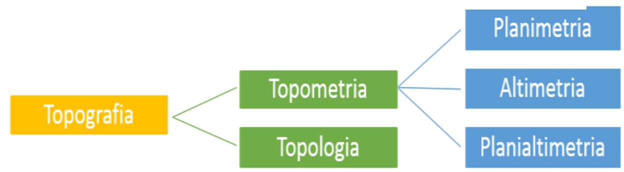
1. Definitions and divisions

The word Surveying is derived from the Greek language *Topos graphen*. After translation into Portuguese to have *Topos* meaning place or region and *graphen* equivalent to description, or description of a place. Currently there are several definitions of the meaning of Surveying. Véras Junior (2003) defines as the science that aims to understand, describe and represent graphically on a flat surface, parts of the earth's surface, disregarding the curvature of the Earth. Doubek (1989) states that the Surveying aims to study the tools and methods used to obtain a graphical representation of a portion of land on a flat surface. Espartel (1987) in turn says the Surveying object is to determine the shape, size and relative position of a limited portion of the earth's surface without taking into account the resulting curvature of the earth's sphericity. Analyzing these definitions, we can understand that the Surveying is a science that studies, designs, is, measures and performs a limited portion of the earth's surface not taking into account the curvature of the earth, to where the error sphericity may be negligible, considering the perimeters, size, geographic location and position (orientation) and objects of interest that are within this portion. The geodesy, the science that studies the Earth as a whole or in part, is divided into three branches: Geodesy Physics, Geodesy Geometrical Geodesy and satellite. The Surveying is a branch of Geodesy Geometrical, and these two sciences study, many times, the same methods, using the same tools to determine portions of the earth's surface. However, only limited studies Surveying of the land surface portion, while Geodesy admits a larger studying larger portions limited to the Surveying, or even the entire earth. It is important to note that when we fail to disregard the curvature of the Earth, we work not with the surveying plans (planimetric dimensions, altimetry, position, orientation and local coordinates), meaning that we are no longer working with the Surveying. The use of GNSS (GPS, GLONASS, etc.) and geodetic datums demonstrate the use of Geodesy, confused by many authors (COMASTRI E GRIPP, 1998; GARCIA e PIEDADE, 1989; ZANETTI e FAGGION, 2012).

The geometric boundary portion delimiting the Surveying with the Geodesy varies from author to author , in accordance with the allowable error and whether it is economically feasible for Surveying . So if you can use the surveying plan without generating considerable errors are using the Surveying where this portion is limited to a distance of up to 20 km . The Surveying is divided into two branches: Topology and Topometry . The topology is defined by Véras Junior (2003) as part of the Surveying that is concerned with the outward forms of the earth's surface and the laws governing their modeled. Already Topometry is a branch of Surveying which aims measurements of characteristic elements of a given area. This branch is divided into : planimetry and altimetry Surveying maps (Figure 2) .

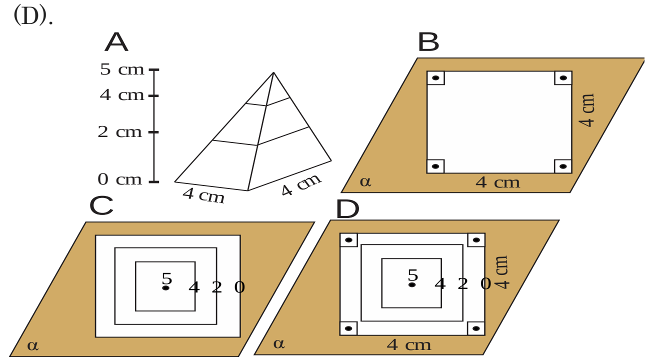
The Planimetry is the part of the Surveying that studies the land taking into account only dimensions

Figure 2 - Division and subdivisions of Surveying .



and planimetric coordinates. In this case there is no terrain relief idea in question by studying only their distances and horizontal angles, geographic location and position (orientation). The altimetry is part of the Surveying that studies the land taking into account only dimensions and altimetric coordinates. In this case you have of the land of the idea in question by studying only their distances and vertical angles. The Surveying maps is part of the Surveying that studies the ground taking into consideration the dimensions and planimetric and altimetric coordinates. In this case you have of the land of the idea in question, by studying its horizontal and vertical distances, horizontal and vertical angles, geographic location and position (orientation). Figure 3 below shows a pyramid being represented in planimetry, the elevations and planimetry and altimetry.

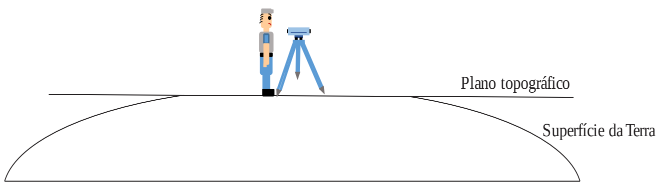
Figure 3 - Pyramid in space (A) being represented planimetric (B) , altimetry (C) and planialtimétricamente.
(D).



2. Error sphericity

Survey works as surveys and rentals are carried on the surface of the earth curve, but the collected data is projected onto a flat surface , the Surveyingsurface. Because of this, an error occurs called sphericity error (Figure 4).

Figure 4 - Representation of horizontal distance (Surveying plan) and distance curve (Earth's surface) .



In Surveying, the professional should evaluate what should be the limit of the area to be imaged to evaluate the disregard of the error, because the farther from the origin of the Surveyingsurface , the greater this error. Below is a table 1 with the geographic coordinates values , distance on the earth's surface , also called distance curve (DC) , horizontal distance in the Surveying plan (DH) and the error corresponding to the difference between DC and DH (Table 1). However , it is known that the economic factor weighs when choosing to use the Surveying or geodesy , then it must be something to consider.

Table 1 - Earth's curvature distance , horizontal distance and roundness error to 1 and 1 ' of geographical coordinates.

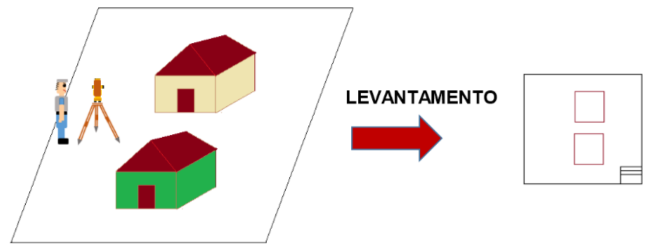
Coordenadas Geográficas	Distância na curvatura (DC)	Distância horizontal (DH)	Erro = DC - DH
1º	111.188,763 m	111.177,473 m	11,29 m
1'	1.852,958 m	1.852,957 m	0,02178 mm

3. Main work areas and exploring

The main objective is the Surveying planialtimetric representation of a given land area , on an adequate scale , following the local, regional or national standards . The main work of Surveying are surveying and Surveying location .

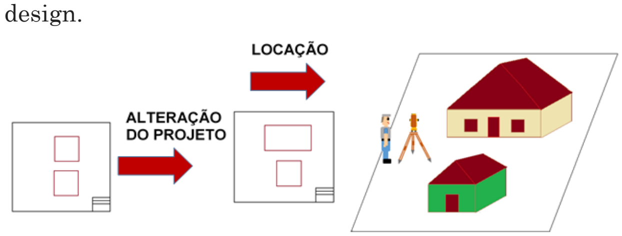
The survey , in general , is to collect all the data and important features that are in the ground in a given area , for later representation faithful by drawing on paper or graphical environment, in appropriate scale and orientation, all natural detail and artificial that have been raised (Figure 5).

Figure 5 - Representation of the survey of two properties .



The Surveyinglocation is the reverse process to the survey . Also divided into planimetric , altimetric and planialtimetric . Before all Surveying location should be carried out survey . After the survey , the surveyor or engineer will carry out the project to the office , creating the future necessary changes on the ground for the implementation of works in the area. It is important to point out that all the important data and characteristic design values should be implemented faithfully on the ground according to the scale used . The Surveyinglocation is more expensive and labor-intensive in relation to the survey (Figure 6)

Figure 6 - Two properties Plant Representation raised previously , changed and then leased according to your design.

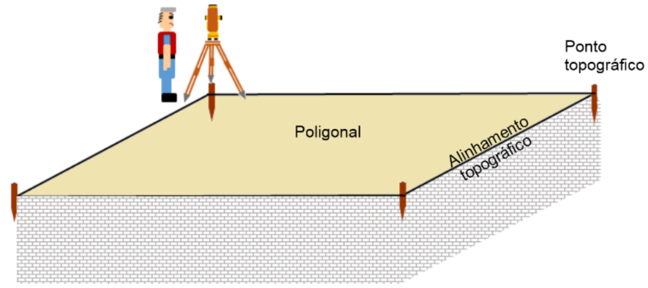


As an example, in Figure 6 a plant with two properties previously raised (Figure 5). From the project was the Surveying location of the paper to the field, being implemented on the ground the size of a house. They could also drop or insert new houses, poles, swimming pools, or a myriad of things that could be changed on paper and implemented on the ground. Upon completion of the survey work and / or Surveying location should be attached to the project / work the descriptive memorial. descriptive memorandum is a document attached to the work that informs all the features of a property or area. This memorial indicates the milestones, coordinates, main roads bordering the property, etc. It is used to describe, in text form, the polygonal limiting property in a way that is understood and understand its characteristics and what was accomplished without the need to verify graphically or in tables. The Surveying can be used in various areas, for example, from the Agronomy, Cartography, Agricultural Engineering, Surveying Engineering, Environmental Engineering, Civil Engineering, Forestry Engineering, Mechanical Engineering, Animal Husbandry, Fisheries Engineering and even in medicine. In the latter case is the representation of the human body, its organs, or parts thereof, through images, not in your detail purpose of this book.

4. Surveying as a geometric representation

The Surveying relies on applied geometry where imagine themselves regular or irregular geometric figures geoespacializadas. When a survey is done, gather up all data and terrain features in the form of geometric figures with its dimensions, perimeters and positions (orientations) and geographic locations. The basic geometric figures are composed of point, line and polygon (Figure 7).

Figure 7 - Surveying Point , Surveying alignment and polygonal .



5.1. Point

The point is the smallest unit in a geometric figure. Surveying are represented by Surveying points. Surveying points on a Surveying survey or lease can be materialized by picket stake, nail, screw or ink.

5.2. Alignment or line

The line is a geometric figure formed by the union of several points on the same line. In Surveying, this line forming one side of a Surveying polygon is called alignment. This Surveying alignment is formed by two Surveying points. In a triangle with vertices A, B and C have three alignments in the same direction (AB, BC, and AC), and may be three in the other direction (AC, BC and AB). In a rectangle, we have four alignments in each direction, and so on. The union of two or more alignments polygonal form. Two alignments will form an open polygonal. Three on, may form open or closed polylines (plans).

5.3. Polygons

Polygons are used to define both the Surveying polygon as the terrain or property. The former is constructed as an auxiliary to give the latter.

The Surveying polygon can be open or closed, may appear together in the same survey. Closed always allow the calculation of angular and linear errors. Linear may also enable calculation of such errors, but the coordinate values of start and end points of such polygon are needed.

6. Accessories and instruments

Surveying equipment are indispensable for withdrawals and locations. They are divided into instruments (equipment used in measurements) and accessories (equipment to help in the measurement). Examples of instruments have been: total station, aluminium staff, theodolite, measuring tape, GNSS receiver (Geodesy instrument), among others. Examples of accessories have been targeted speaker (when used to assist the level of scope and theodolite using its wires) level bracket, beacon, picket stake, witness stake, stick with light, tripod, etc.

7. Accessories

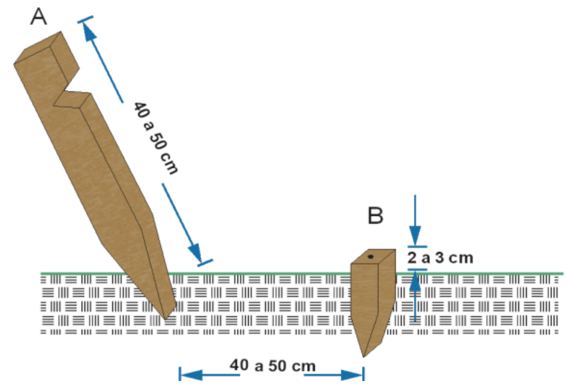
7.1. Pickets, stakes, stakes witnesses, points of nails, paint points and points screws.

Pickets (Figure 8) are used to materialize the Surveying points. They can be hand-crafted in good quality wood to penetrate the soil. Also they are manufactured by specialized companies using plastic in their composition. When they are made of wood, the center dot is marked by a nail or ink. To obtain a good stability and visibility to the ground, they should be buried leaving 2 to 3 cm exposed.

The stake witnesses have 40 to 50 cm, presenting as characteristics a cut at the top. Its function is to assist the location of pickets, because in large grounds or cities with vegetation, it is not so easy to find the pickets. They should be placed 40 to 50 cm away from the paddocks and the section of the upper part facing the opposite side where the paddock (Figure 8).

Stake (Figure 9) are usually made in good quality wood, measuring about 40 to 50 cm . They serve to

Figure 8 - In The stake witness and B picket .



stakeout work , which is a technique where you put all stakes aligned , aiming to the survey . After the assessment and realization of the project , are written on the stakes the corresponding values of cuts and embankments in altimetry lease.

Figure 9 – Stake.

Paint of nail, paint points and points screws serve to materialize the Surveying points where there is resistance of the material being penetrated , where the pickets would not be able to be placed.

As for examples of these materials have been concrete in general, roads, streets, house floors, sidewalks, buildings, among others.

Must be fixed the materializing points in permanent locations so that the actions of man, animals and nature do not interfere removing them from the places of interest. These sites should be preserved for a possible return to the workplace aiming to corrections.

7.2. Baliza

The baliza is an accessory used for easy viewing of Surveying points, materialized by pickets at the time of measurement of horizontal angles (Figure 10). It is also used to assist in alignment of a polygonal profile, cross section and in measuring the horizontal distance across the tape (Figure 11) and also along with the tape measure, used to measure angles 90 (Figure 12). It features red and white color to contrast with the vegetation and the clear sky, facilitating their identification in the field. 4 is divided into segments of 0.5 m, having the total length of 2 m, and iron, aluminum or wood.

Figure 10 - In A, the baliza serving to assist the measurement of the horizontal angle. In B , the correct position that puts the baliza of the picket .

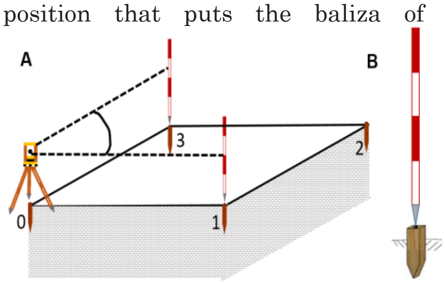


Figure 11- Balizas assisting in measuring the horizontal distance with a tape measure on a slope and aiding the "perfect " alignment between points A and B.

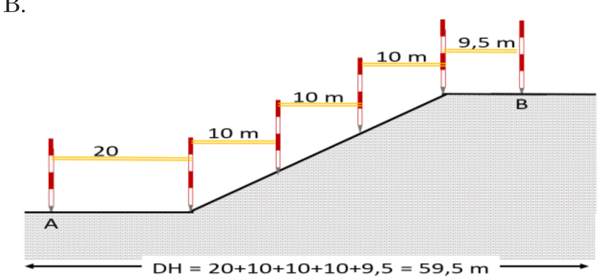
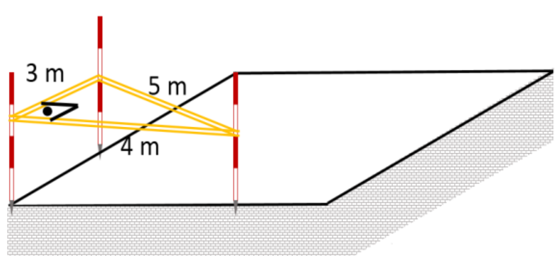


Figure 12- Baliza assisting in the formation of 90 ° angle through the Pythagorean theorem.

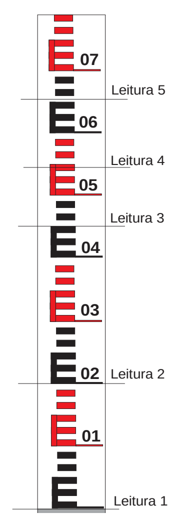


7.3. Level staff

The level staff, scopes also called estadimétricas or stay centimetradas are rules that serve to assist the measurements of horizontal distances through tacheometry, using the upper threads, middle and bottom and vertical distances using the wireless medium.

Its reading is conducted in millimeters, where each centimetrada rod is 10 mm. It should be placed entirely vertical and over the point to be worked. There are several sights speakers sizes and its material can be wood or aluminum. The latter is most commonly used due to the lower weight. It is also important to note, because of the metal material, its use should be avoided on rainy days for danger account due to lightning, because the material may serve as a lightning rod. Figure 13 shows some examples of readings made in speakers rasters with the use of the theodolite telescope or level. Readings 1, 2, 3, 4, and 5 are about 0 mm, 200 mm, 450 mm, 545 mm and 653 mm, respectively.

Figure 13. Simulation of 5 readings of stadia lines in the level staff .



7.4. Level bracket

It is a small accessory with a spirit level that can be coupled to the beacons , speakers poles and sticks aimed at vertical integration of these accessories .

7.5. Tripods

They are wooden or aluminum accessories that serve to support theodolite , telescope levels , total stations and GNSS's antennas. Furthermore they assist in the liming instruments. The timber tripods are usually heavier and more robust , while the aluminum is present with more modern designs and easier to carry in the field, they are much lighter than wood . This accessory is composed of three claws, one in each leg, which serve to fix the tripod on the ground. His legs are divided into two parts joined by a butterfly to decrease / increase in size as well as help in liming. The last part consists of a tribrach , also called the plate where to install surveying instruments (Figure 14).

8. Instruments

8.1. Tape measures

The measuring tapes are widely used instruments for measuring level differences and mainly horizontal distances . If used properly provide good answers for accuracy . Handling of tape measures should avoid the following errors catenary error (Figure 15) which is caused by the weight of the tape. Due to the weight of the tape, it tends to form a convex curve facing downwards. The error occurs because instead of measuring a distance on the plane (DH) is measured by an arch. To avoid it, they must apply greater forces at the ends of tape measures.

Another error that occurs is the lack of horizontality of the tape (Figure 16 and 17). In areas that are not flat, the trend surveyor or assistant is holding the tape closest to the ground. This error occurs quite often. In this case the distances are larger than the actual value. To minimize the error, they use beacons to help in the horizontality of the tape.

The lack of goal of verticality (Figure 18) is another error that occurs quite often. Surveyor / helper can tilt the goal at the time of measurement, causing error in this measurement. The distance may be underestimated or overestimated, depending on how is the lack of vertical integration. Verticalization for a shot, the surveyor can do in three ways: the first is using a level angle, the second is verticalization through the vertical wire or also called collimator and the third solution is to use gravity. In this case the rod person to secure beacon and let gravity work and will gradually dropping until the point and vertical way.

Another common mistake is the expansion of the material of tape measures caused by excessive stresses in the material. To minimize this should be selected good quality tape measures.

Figure 15- Catenary error.

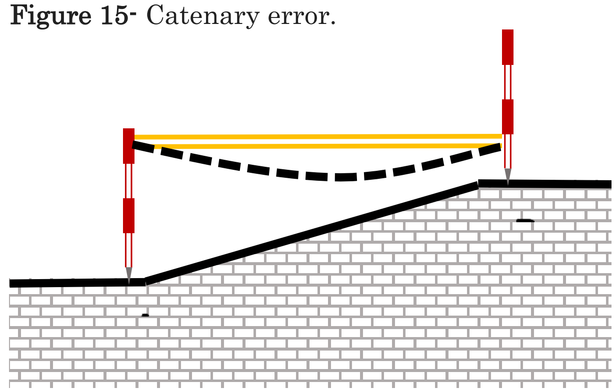


Figure 16- Lack of horizontality of the tape .

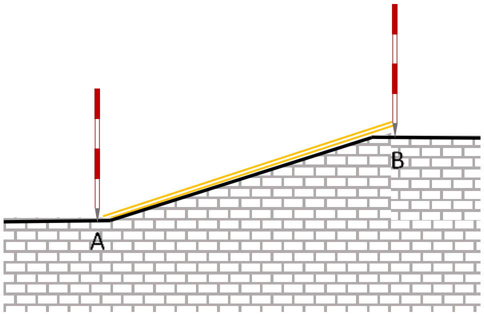


Figure 17- Lack of horizontality of the tape .

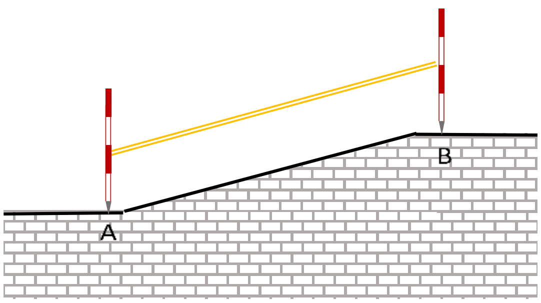
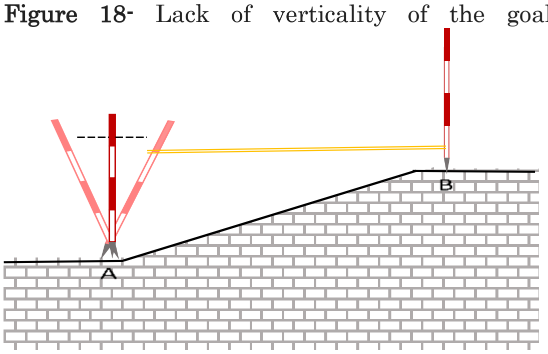


Figure 18- Lack of verticality of the goal .



8.2 Theodolites

The goniometer are instruments only the measurements of vertical and horizontal angles , they do not have the stadia lines . Already theodolite (Figure 19) are instruments for measuring horizontal and vertical angles (with the aid of beacons) and with the help of speakers scopes, also make the measurement of horizontal distances (using the planimetric tacheometry) and vertical (taqueométrico leveling and trigonometric leveling) , as have the stadia lines .

The theodolites are classified according to their purpose and may be Surveying astronomical or geodetic and also classified in accordance with accuracy and can be low (below 30") , averaged between 07 'and 29' ' and upper equal to or below 02".

Figure 19 - Theodolites

8.3. Level Surveying

Level Surveying, engineer levels or automatic levels (Figure 20) are instruments used to measure vertical distances between two or more points. They can also be used for measuring horizontal distances with the aid of the speaking aim, applying the planimetric tacheometry . These instruments are made up of a spyglass associated with a spherical level of average precision, and pendulums system , which are inside the appliance , and have the function to correct liming in automatic optical levels , leaving them quite close to the plan Surveying. They also have the ability to measure horizontal angles , especially when they are done work in cross-section , but the accuracy for these angles is 1 .

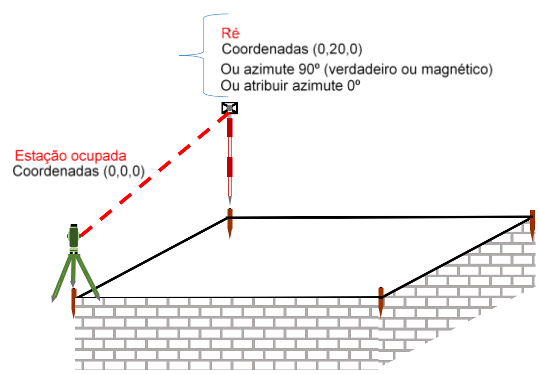
Figure 20 – Levels Surveying .

8.4. Total station

Total station (Figure 21) is an electronic instrument used to obtain angles, distances and coordinates used to plot a land area, without notes, because all data is stored inside and downloaded to a PC through a software and can be worked with the aid of other software. This instrument can be considered as the evolution of the theodolite, which added an electronic EDM, a temporary memory (processor), a fixed memory (hard disk) and a connection to a PC, mounted on a single block. The total station is empowered to collect and run the data still in the field, using a notebook, in order to do all the work in the field without the need for electricity. With a total station it is possible to conduct surveys, leases, determine horizontal and vertical angles, vertical and horizontal distances, location and position of the area to be imaged. The measurements is used bat and prism assembly, put the points to be raised and / or leased. Cane is an accessory of metal material, which is coupled at its top the prism to aid in measurements with total station. To make a survey by coordinates, you must enter the total station the point where it is in the coordinate system, these may be UTM (true) or local (assigned). The allocation or point of information where you will find the total station in the coordinate system is called busy season. After setting the busy season, is a guide to the total station in the coordinate system by AFT is needed (reference), which puts the bat + prism at a point with known coordinates (X, Y and Z) or attribution if azimuth value 0º or tells the true value of azimuth that place, being one of those values entered in the total station, the space destined to enter the aFT. After these procedures, you only get to measure all points of interest shaking always dial measure or its corresponding (depending on the brand of the station) (Figure 22).

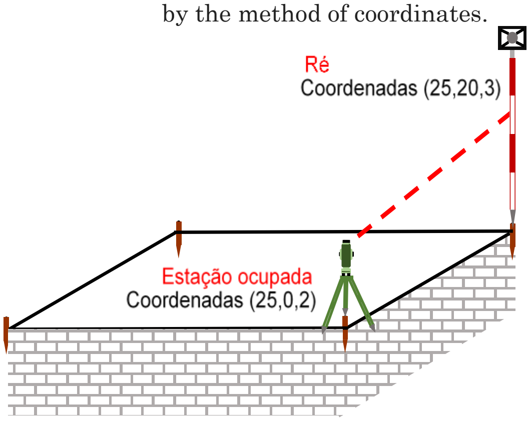
Figure 21 - Total Station.

Figure 22 - First station using the total station survey by the method of coordinates.



When there is need to make the switch station (occupied point), it takes two points already measured, one with the total station (stating the coordinates of that point in the busy season) and another with the prism (stating the coordinates of that point in RE). Once carried out the measurements of all points of interest. It should be noted that the use of azimuth (true or magnetic assigned), can be performed to effect orientation of the total station at the first station (busy period). In the other values are used already obtained and entered their respective coordinates (Figure 23). It is important to understand that station, total station and busy season are different nomenclatures. total station is the instrument; station is the place where the instrument; and busy season are the coordinate values for the location of the instrument. Both station as busy season are Surveying points.

Figure 23 - Second station using the total station survey by the method of coordinates.



8.5 - GNSS Global Navigation Satellite System –

GNSS (Global Navigation Satellite System) are systems that allow the three-dimensional location of an object anywhere on the Earth's surface, through devices that receptam radio waves emitted by their respective satellites. The GNSS includes several systems , they are: GPS , GLONASS , Galileo and COMPASS . which does not encompass the whole earth , composed of IRNSS (Indian Regional Navigational Satellite System) , QZSS (Quasi-Zenith Satellite System) and Beidou (Beidou - In addition to the GNSS regional navigation systems (RNS Regional Navigation System) it has Navigation System) , the latter stop expanding to COMPASS operation.

The Global Positioning System - GPS (Global Positioning System), is currently the best known and North American origin, was considered fully operational in 1995. It has currently 24 satellites 20200 km of the Earth's surface in six orbital planes, each plane Sedo 4 orbiting satellites (Figure 24). GPS was originally created for military purposes, but over time has been released for civilian use. Currently is not charged any fee for its use, even for use extramilitar or any country. The Globalnaya Navigatsionnaya Sputnikovaya System - GLONASS, of Russian origin, was considered fully operational in 2011. It has currently 24 satellites at 19,000 km from the Earth's surface in three orbital planes, each orbital plane with 8 satellites (Figure 25). The other global systems, European (GALILEO) and Chinese (COMPASS) are still under construction, but it is expected to be in full operation in 2020. . The satellites send analog signals in the form of radio waves carrying calls to communicate with antennas on the Earth. The GPS system issues two carrier waves L1 (1575.42 MHz and wavelength $\lambda \cong$19 cm) and L2 (1227.60 MHz and wavelength $\lambda \cong$24 cm). GLONASS also has two carriers: L1 (between 1602.0 and 1615.5 MHz) and L2 (between 1246.0 and 1256.5 MHz). The L1 carrier is decoded by the C / A code (GPS and 1.023 to 0.511 for GLONASS) and P (10.23 GPS and GLONASS to 5.11), while the L2 carrier is decoded by the code Q. There is also a secret code called W which equated to P code form the Y code, used only for military purposes. To get the location of an object on Earth are needed at least four satellites, but the greater the number of satellites visible to the receiver, the better the accuracy of the geographical location of the receiver antenna on Earth's surface (BERBARDI et al., 2002; LAGO et al., 2002).

Figure 24 - Constellation (left) and the orbital plane (right) GPS

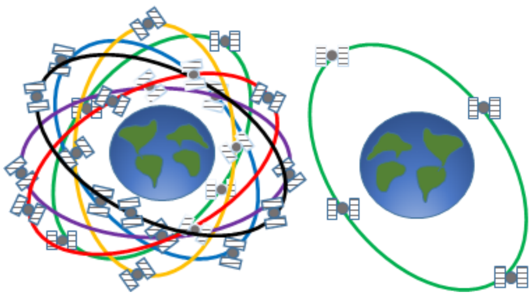
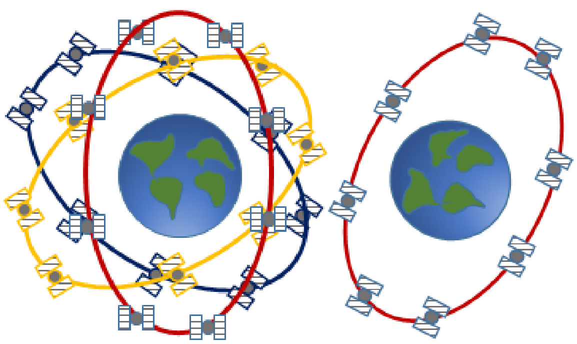


Figure 25 - Constellation (left) and the orbital plane (right) GLONASS



REFERENCES

BERNARDI, J. V. E.; LADIM, P. M. B. Aplicação do Sistema de Posicionamento Global (GPS) na coleta de dados. Universidade Federal de Rondônia. 2002.

COMASTRI, J. A. & GRIPP JR. J. Topografia aplicada: Medição, divisão e demarcação. Viçosa: UFV, 1998.

DOUBEK, A. Topografia. Curitiba: Universidade Federal do Paraná, 1989, 205p.

ESPARTEL, L. Curso de Topografia. 9 ed. Rio de Janeiro, Globo, 1987.

GARCIA, G. J. & PIEDADE, G. R. Topografia aplicada às ciências agrárias. 5. ed. São Paulo, Nobel, 1989. 256 p.

LAGO, I. F. do; FERREIRA, L. D. D.; KRUEGER, C. P. GPS E GLONASS: Aspectos teóricos e aplicações práticas. Boletim de Ciências Geodésicas, Curitiba, v.8, n.2, p. 37-53, 2002.

MAZOYER, M.; ROUDART, L. História das Agriculturas no Mundo. Do Neolítico à crise contemporânea. São Paulo, Editora UNESP, 2008.

MCCORMAC, J. Topografia. 5 ed. Rio de Janeiro, Editora LTC, 2007. Museu de Topografia Prof. Laureano Ibrahim Chaffe. 2010.

Museu de Topografia Departamento de Geodésia – IG/UFRGS. Disponível em: http://www.ufrgs.br/igeo/m.topografia. Acesso em: 19/01/2014.

VALENTINE, T. A Grande Pirâmide. Rio de Janeiro: Nova Fronteira, 1976. Pré historia, Historia antiga. VEIGA, L. A. K.;

ZANETTI, M.A.Z.; FAGGION, P. L. Fundamentos de Topografia. Universidade Federal do Paraná. 2012.

VÉRAS JÚNIOR, LUIS. Topografia - Notas de aula. Universidade Federal Rural de Pernambuco, Recife – PE. 2003.