Verification and Control of Vertical Bench Mark Applied for Settling Measurements of Large Structure Buildings

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Key words: Bench Mark, geodesic surveying, optical mechanical level, digital level

SUMMARY

The appropriate determination of altimetric data to transport heights is interconnected to the definition of one set of field points reference. This field points can have one-dimensional character, case in study, when are used References Level (RL) and/or Bench Mark (BM) with rounded surfaces. It will have one-dimensional and two-dimensional character simultaneously, when are used References Level and/or associated Bench Mark in its surrounding to two-dimensional points field. It has a three-dimensional character, when used pins hammered into stable structures or rigid bodies in an architectural structure with symmetric geometries that can serve as three-dimensional targets. A Vertical Reference System in a work of building construction is fixed by an altimetric reference surface defined by a fictitious horizontal plane and its distance to a materialized fixed point, called Reference Level (LR). In engineering works, in general way, this point of altimetric reference is defined as Bench Mark (BM). This kind of materialization of altimetric network is required when the work involves high and/or highest precision. For its implementation on site of construction requires a study of the different layers of soils in this area. For implementation of the BM is often used a metal rod, protected by an outer tube and installed in a borehole by percussion. They are usually mounted in the deep layers, through injection of cement, making it fixed. The BM should be installed so as not to be influenced by the work itself or other causes that may compromise their stability. The field of reference points materialized by Bench Mark allows the use of optic technical methods for surveying / geodetic measurements through the using of optical levels or digital levels for the transport of altimetric data. The objective of this study is to approach a methodology for the verification and control of vertical of Bench Mark. The study area consists of three Bench Mark distributed in urban parcel and in the environment contained the building construction. In this work the reference surface is represented by a horizontal plane tangent to a Bench Mark, called vertical reference "zero". All the others altimetric data of the set points in the study will be related to this fictitious horizontal reference plane. The shortage of material on the practical methodology to be used in geodetic studies of vertical building structures by means of optical measurement procedures, has been encouraging this work.

SUMÁRIO

A determinação apropriada de dados altimétricos para o transporte de altura está interligada a definição de um conjunto de campo de pontos de referência. Este campo de pontos pode ter um caráter unidimensional, caso em estudo, quando são utilizadas Referências de Nível (RN) e/ou Bench Marks (BM) com superfícies aboladas. Terá um caráter unidimensional e bidimensional ao mesmo tempo, quando são utilizadas Referências de Nível e/ou Bench Marks associadas em seu entorno a campo de pontos bidimensionais. Terá um caráter tridimensional, quando são utilizados pinos cravados em estruturas estáveis ou corpos rígidos, de uma estrutura arquitetônica, com geometrias simétricas que podem servir como alvos tridimensionais. Um Sistema de Referência Vertical em uma obra de edificação predial é fixado através de uma superfície de referência altimétrica definida por um plano horizontal fictício e a sua distância a um ponto fixo altimétrico materializado e denominado Referência de Nível (RN). Nos trabalhos relacionados à Engenharia, de uma maneira geral, este ponto de referência altimétrico é definido como Bench Mark (BM). Este tipo de materialização da rede altimétrica é requerida quando envolve trabalhos de alta e/ou altíssima precisão. Para sua implantação no local da obra é necessário um estudo das diferentes camadas de solos existentes nesta área. Para a implantação do BM geralmente é utilizada uma haste metálica, protegido por um tubo externo e instalado em um furo de sondagem à percussão. Normalmente são engastadas em camadas profundas, através de injeção de nata de cimento, onde se encontra o “indeslocável”. O BM deverá ser instalado de forma a não sofrer influência da própria obra ou outras causas que possam comprometer sua indeslocabilidade. O campo de pontos de referência materializado por Bench Mark permite o emprego de métodos técnicos ópticos de medição topográfica/geodésica por meio do uso de níveis ópticos ou níveis digitais para o transporte de altura. O objetivo deste trabalho é de abordar uma metodologia para a verificação e controle vertical de Bench Mark. A área de estudo é composta por três Bench Marks distribuídos em uma quadra urbana e estão contidos em ambientes da Construção Civil. Neste trabalho a superfície de referência é representada por um plano horizontal tangente a um Bench Mark, denominado de referência vertical “zero”. Todas as demais alturas do campo de pontos em estudo estarão relacionadas a este plano de referência horizontal fictício. A escassez de material prático referente à metodologia a ser adotada em estudos geodésicos de verticalização de estruturas prediais de edificações por meio de procedimentos ópticos de medição, vem incentivar a realização deste trabalho.

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1. INTRODUCTION

Accidents (collapse, landslide, subsidence of soil, as well as displacement) have been increasingly found in urban environments, where the development is notorious for large vertical buildings. As a result, it can be seen in recent years, besides the performance of geotechnical and structural engineering, growth and enhancement of the use of surveying methods in the brazilian civil construction environment.

It should be noted here that in the Metropolitan Region of Recife (RMR), it is clear the construction of building structures comprised 20 to 45 floors, here named large vertical structures. In those areas of urbanized sites are observed two striking features: first, the presence of a variety of soil types, the second presence of a remarkable agglomeration of buildings of vertical large structures.

The physical establishment of fixed points defining a reference altimetry type Bench Mark in the vicinity of the building structures, provide for studies of the vertical movements of these buildings. The definition of a Reference System from a coordinate system and a set of points is of fundamental importance for the analysis of measurement and monitoring of the work with respect to vertical displacement.

The update of the NBR 6122/96 to NBR 6122/2010 implied, among others, the requirement of measurements settling in buildings for building with more than twenty floors. This increased demand for vertical control surveys for large buildings. To achieve this control is necessary in the vicinity of the pillars of the building to be monitored that there is a Reference Level (RL) appropriate and with good quality. The stability of a Reference Level that (RL) can be achieved is defined as Bench Mark.

In this work was chosen a large area of booming real estate, where the change is visible from a residential area to an area of large buildings. It consists of a block of built up area with three implemented Bench Mark materialized in environments of civil construction. They are implemented and distributed in a building, which already operates normally in a second building, which is nearly complete, and starting in another building to be built.

The objective of this study is to deal with a methodology for the verification and control vertical Bench Mark. To study the Bench Mark implemented, it was necessary to choose at least two measurement periods to illustrate the work done. From the data collected and their calculations, one can say that their results are satisfactory, according to NBR 6122/96 and according to the classification of the digital level used. However, more measurements should be conducted later this year, thus completing the work of the verification and vertical control of the Bench Mark. For this, it is estimated to realiza at least seven sets of measurements during this year. Therefore it will be presented here, partial results corresponding to two sets of measurements. The first occurred in December 2011 and the second in February 2012. Besides the presentation of partial results of a real case study, the study emphasizes the importance of controlling and verifying the stability of Bench Mark used to measure settling.

Following are presented the basic concepts, the methodology used and the final results.

2. BENCH MARK FOR SETTLING MEASUREMENTS OF LARGE STRUCTURE BUILDING

It is of great importance the analysis of field observations in geodesic structures (SANTOS, 1999) as a reference to the precise positioning of objects, so that different works of engineering can be studied and analyzed, such as in the studies of the vertical displacement, making possible more appropriate solutions to the stability of the building constructions. These structures are constituted by a field of reference points and by a field object-points (FERREIRA et al., 2004).

The determination of appropriate altimetric data for transportation of heights is linked together to define a set of field reference points. According to the use of instrumentation and materialization, this field points can be classified as: one-dimensional, one-dimensional and two-dimensional and/or three-dimensional.

a) One-dimensional: it will have a one-dimensional character, case study, when are used as Reference Level (RL) and/or Bench Mark (BM) in round surfaces. In this case, it uses an instrumentation that carries out a measurement system which materialize, in the field, a horizontal plane. All the observations are made to this horizontal plane. In this way the device works in only one dimension, which in this study represents observations distance in vertical direction. As an example of equipment for field measurements are employed optical mechanical levels and/or digital levels. Here are interested only in the determination of these altimetric points.

b) One-dimensional and two-dimensional: it will have a one-dimensional and two-dimensional character at the same time, when used Reference Level and/or associated Bench Mark in his around the field of two-dimensional points. The latter in order to find out two-dimensionally References Level. In this case are used instrumentation, as above, in combination with other equipment, working in three dimensions, such as a Total Station. Here we are interested in determining altimetric and planimetric, both considered separately.

c) Three-dimensional: it will have a three-dimensional character, when used pins driven into stable structures or rigid bodies, of an architectural structure with symmetric geometries that can serve as targets in three dimensions, when worked with Total Station and/or Robotic Total Station. Here we are interested in determining planialtimetric the same time. It is noteworthy that studies are being conducted so that in the near future GNSS measurements achieve an altimeter precision properly and can thus define the field of 3D points of high and/or highest precision.

2.1 Bench Mark

2.1.1 Definition

In the works related to engineering this point of Reference Level (RL) is defined as Bench Mark (BM). This type of realization of the altimetric network is required when involves work of high and/or highest precision (MOESER et al., 2000).

2.1.2 Implementation and realization in the Field

The behavior observation and instrumentation of the group formed by structural elements of the superstructure and the foundation and the soil mass can be assessed for performance by studying the control and monitoring of settlings.

For the determination of the settlings of the works and its control were performed three Bench Marks with depths of 18m, 24m and 12m for residential buildings San Telmo with twenty-nine floors (ENSOLO, 2004), San Tiago twenty-nine floors (ENSOLO, 2004) Villa Firenze with thirty-one floors (ENSOLO, 2009) and Villa Carmel with twenty-nine floors (ENSOLO, 2011) respectively.

For its implementation on site requires a detailed study with the description of the geotechnical soils in different layers of crossed and support. Its implementation is performed by a metallic rod to drive in by percussion or to base embedded in mortar with cement and sand in a stable layer of soil. This Reference Level must be installed so as not to be influenced by the work itself or other causes that may compromise to move around. Thus, the metallic rod is coated with an external pipe protection and lubricant grease in the whole extension thereof, to prevent rubbing with the reference rod.

2.1.3 Measurement of Bench Marks through the geometric leveling of high precision

The increasing progress in the area of micro measurements, based on geodetic instrumentation, are perceived by the instrumental measurement directions, angles and distances by means of sensors, adapted to different circumstances of construction and self-control. This instrument is to encourage the development of new techniques and methods of three-dimensional measurement, aiming to increase the degree of automation, system flexibility and control in the measurement. In (DE SEIXAS et al., 2007) are described different possibilities for determining vertical displacement and/or transportation of altitude or heights by means of optical systems for measuring hybrid manual and motorized.

In this study for the interconnection of altimetric points object will be used the classic method of geometric leveling. With this method are determined by means of horizontal target, the height differences (unevenness) between points close to each other (KAHMEN, 2005).

It is worthwhile to stand out the existence of digital levels with completely automatic readings on rods with code bars division (binary standard) by means of digital image treatment and calculations of correlation (INGESAND, 1990).

Leveling can be executed with greater economy with digital levels in short space of time and exempt from errors of readings and writing because of the automatic register of the largeness measurement (SCHWARZ, 2002). The rotation of digital levels can be commanded by engines, thus being able automatically to carry through with these instruments the measurement of predefined heights of points-object during repeated measurements of monitoring of stationary constructions. Each target point is marked with a rod level. Under normal conditions of measurement, a precision of < 0,1mm could be reached (SCHWARZ, 2002). This type of geodesic technology, certainly, revolutionizes all environment of measurement, allowing the monitoring on-line in structures, as for example, in risk areas, providing, moreover, adapted innovative solutions to each type of object.

In the design intended, is incorporated into the work a high precision digital level (Leica - DNA03). With readings made on invar rod of 2m, with a system for reading bar code (LEICA GEOSYSTEMS, 2002).

The Leica DNA03 digital level has a higher accuracy of measurement. It enables the electronic measurement of the height of the sight. At each position of the instrument, just a spirit level is enough to start the leveling. The fine adjustment of the LASER beam is carried out automatically by the compensator of high precision. The electronic measurement is done via the touch of a button. The measurement principle of this equipment is made, so that the bar code of the rod is stored in the instrument as the reference signal. During measurement, the visible section of the crosshairs in the field of view of the rod is captured by the decoder lines and interpreted as measuring signal. The measurement signal is then compared with the reference signal. This comparison gives the value of the height and horizontal distance. During measurement, the rod should be in the upright position, as for the optical leveling work. With the proper artificial lighting for the cod, it is possible to make measurements in the dark. The measurement of height with invar rod has a standard deviation of 0.3mm per Kilometer and the distance measurement has a standard deviation of 5mm. The measurement time is three seconds and the minimum distance of the target is 0.6m (LEICA GEOSYSTEMS, 2002).

According Deumlich and Staiger (2002) the digital levels are rotational LASER levels interconnected to positional sensors. Its technology is divided into two methods: active and passive. The first carries out the measurement with the aid of a LASER (LASER diode) is used as the light beam which is projected on a horizontal line or a plane, may be visible. The second uses an optically vertical encoded rod, so that a portion of this image rod is received by an electronic sensor and from the method of digital image processing is performed the computation of the reading. According to these authors the basic principle for the automation of the geometric leveling took place in Bonn in 1966. From there began studies and research, so that in 1982 in Dresden, was conceived the first prototype instrument, performing in 1987 also in Dresden its geometric principle. In 1990 the firm Leica starts selling in the market the first digital level NA 2000. The measurement procedure with digital levels is divided into four steps: 1. Detection of the image, 2. Analog to digital conversion. 3. Interpretation of the coding target, and 4. Results (target height and horizontal distance).

2.2 Especifications of the implemented Bench Marks

The work for the implementation of the Bench Mark building San Tiago and San Telmo was performed in the following steps detailed below:

• Pre-drilling: Drilling of the soil to a depth of 18m designed and planned with the use of drilling equipment through movement of water or bentonite slurry, being used to stabilize the borehole. The drilling was partially coated with 0.00m to 3.00m depth to the work carried out by coating steel tube with an internal diameter 101.60mm (4"). Drilling with a minimum diameter of 101.60mm (4") in depths between 3.00m to 18.00m was carried out through movement of bentonite slurry to ensure stability of the soil surrounding the borehole.

• Protective Coating: Introduction of PVC pipes with a diameter of 50.80mm (2") and total length of 16.00m to protect the reference rod to exclude the occurrence of friction between the rod and the surrounding ground.

• Positioning the reference rod: Introduction of the reference rod of galvanized iron with a diameter of 25.40mm (1") and total length of 18.00m for the reading of the deformations during and after the period of construction work monitored. During the process of installing and positioning of the rod, the entire length of it receives a cover of lubricant grease between 0.0m and 16.00m to exclude friction of the coating protection. Only the final stretch of the rod between 16.50m and 18.00m does not receive the cover with lubricant grease used for fixation in the soil.

• Preparation to fix in the base the reference rod: Injection of 30liters of fluid mortar combined 1:2 (cement: sand) through the drilling equipment (motor-pump and rod of 1”) between 16.50m and 18.00m deep.

• Preparation of the head of reference rod (head Bench Mark): Construction and fixing of cylindrical stainless steel with a height of 80mm and diameter 2½" in beginning extreme of the reference rod for positioning the invar rod used in measurements of control settlings.

The work of implementing the Bench Mark of the building Villa Firenze was performed in the following steps detailed below:

• Pre-drilling: Drilling of the soil to a depth of 24m designed and planned with the use of drilling equipment through movement of water or bentonite slurry, being used to stabilize the borehole. The drilling was partially coated with 0.00m to 3.00m depth to the work carried out by coating steel tube with an internal diameter of 101.60mm (4"). Drilling with a minimum diameter of 101.60mm (4") between depths 3.00m to 24.00m was carried out through movement of bentonite slurry to ensure stability of the soil surrounding the borehole.

• Protective Coating: Introduction of PVC pipes with a diameter of 50.80mm (2") and total length of 20.00m to protect the reference rod to exclude the occurrence of friction between the rod and the surrounding.

• Positioning the reference rod: Introduction of reference rod of galvanized iron with a diameter of 25.40mm (1") and total length of 24.00m for the reading of the deformations during and after the period of construction work monitored. During the process of installing and positioning the rod, the entire length of it receives a cover lubricant grease and from 0.00m to 20.00m to exclude friction of the coating protection. Only the final stretch of the rod between 20.00m and 24.00m does not receive the cover with lubricant grease used for fixation in the soil.

• Preparation to fix in the base the reference rod: Injection of 60liters of fluid mortar combined 1:2 (cement: sand) through the drilling equipment (motor-pump and rod of 1") between 21.00m and 24 00m deep.

• Preparation of the head of reference rod (head Bench Mark): Construction and fixing of cylindrical stainless steel with a height of 80mm and diameter 2½" in the beginning extreme of the reference rod for positioning the invar rod used in measurements of control settlings.

The work of implementing the Bench Mark of the building Villa Carmel was performed the following steps detailed below:

• Pre-drilling: Drilling of the soil to a depth of 12m designed and planned with the use of drilling equipment through movement of water or bentonite slurry, being used to stabilize the borehole. The drilling was partially coated with 0.00m to 2.00m depth to the work carried out by coating steel tube with an internal diameter of 127.00mm (5"). Drilling with a minimum diameter of 127.00mm (5") between depths 2.00m to 12.00m was carried out through movement of bentonite slurry to ensure stability of the soil surrounding the borehole.

• Protective Coating: Introduction of PVC tubes with a diameter of 63.50mm (2½") and length of 9.00m to protect reference rod to exclude the occurrence of friction between the reference rod and the surrounding soil.

• Positioning of the reference rod: Introduction of reference rod with galvanized iron with a diameter of 25.40mm (1") and total length of 12.00m for the reading of the deformations during and after the period of construction work monitored. During the process of installing and positioning of the rod, the entire length of it receives a cover of lubricant grease between 0.00m and 9.00m to exclude friction of the coating protection. Only the final stretch of the rod between 10.00m 12.00m does not receive the cover with lubricant grease used for fixation in the soil.

• Preparation to fix in the base the reference rod: Injection of 80liters of fluid mortar combined 1:2 (cement: sand) through the drilling equipment (motor-pump and rod of 1") between 10.00m and 12.00m deep.

• Preparation of the head of the reference rod (head Bench Mark): Construction and fixing of cylindrical stainless steel with a height of 80mm and diameter 2½" in the beginning extreme of the reference rod for positioning the invar rod used in measurements of control settlings.

2.3 Measurement of settling of very large buildings

In (DE SEIXAS et al., 2006 and DE SEIXAS et al., 2007b) are referred to the objective of settling measuring. The analysis of vertical displacement of the study area as a whole is possible, when the altimetric points are interconnected by means of measurement procedures applied to the transportation of heights from a determined fixed altimetric reference (DE SEIXAS et al., 2007a).

During the accomplishment of the construction it is important that the measurement be executed in a unique planimetric and altimetric system of reference. This vision has a great importance on the accompaniment large size works. For special constructions the planimetric and altimetric networks, with respect the points densification and their precisions, supplied by competent public agencies are not enough. The accomplishment of a special networks of points is necessary (SCHWARZ, W., 2002).

For the control and monitoring of foundations the measurement of field settlings is essential. This measurement allows the investigation of the foundation as well as the structure of the building. The measured magnitude then will be compared with the estimated settling. During the construction the presence of fissures in the structures not yet harmful to the stability of the systematic accompaniment of the work with the objective is stand out here to guarantee the security against its rupture. The control of during the accomplishment of the work in this context, was been presented in (DE SEIXAS et al., 2008) and (DE SEIXAS et al., 2009), the study base of a executed real case on direct foundations, methods for control, monitoring and evaluation of the foundations, beyond the presentation of excellent results on the object of study in question.

Please note that due to the geological complexity of the soil in the Metropolitan Region of Recife, and in view, the construction of large building structures that are occurring in the region, it is important to implement these new technologies in geodetic control and monitoring of foundations and structures.

The data generated from the surveys will feed a local information system, which related to other data, cartographic or not, will be object of analysis in decision making.

3. METODOLOGY FOR VERIFICATION AND CONTROL OF VERTICAL BENCH MARKS

This item presents the methodology used in the experiments and analyzes of their results. In the study area are implemented three Bench Marks (cf. item 2.2), which define the field of points observed by the leveling of high precision (cf. section 2.1.3). Is given below the description of the materials and method used, the characteristics of the area as well as partial results and analysis of experiments accomplished.

3.1 Definition of the experiments area

The experiments were performed in the vicinity of an urban block fully built. This area is located in the Casa Amarela District, which includes a set of three Bench Marks implemented in the buildings San Tiago, San Telmo (all already executed) and Villa Carmel (under construction), all located at Rua Evaristo da Veiga and Villa Firenze building (being finished) located at Rua Antônio de Castro, street parallel to the above one. Figure 1 an aerial view show the location of these buildings. and lines L1, L2 and L3 of the geometric leveling and the field points materialized by BM. The justification for adopting this test area in question is to take an urban area that has a reasonable number of Bench Marks near each other, where access to them was permitted to conduct the survey.

Figure 1: Aerial view of the lines L1, L2 and L3 of the geometric leveling and the field points materialized by BM. Source: Google (2010).

3.2 Definition of the altimetric reference system

The altimetric reference system or vertical in the work of civil construction of buildings, is fixed through of one altimetric reference surface defined by one fictitious horizontal plane and its distance from an materialized altimetric fixed point, called Reference Level (RL).

In this work the reference surface is represented by a horizontal plane tangent to the Bench Mark of residential buildings San Telmo and San Tiago (BM_ST) called vertical reference "zero" of the work. All other heights of the field points (Bench Mark building residential Villa Carmel (BM_CARMEL) and residential building Villa Firenze (BM_FIRENZE), respectively, are related to this fictitious horizontal reference plane.

3.3 Measuriments of the field of points

The survey was carried out starting from the altimeter reference Bench Mark of residential buildings San Telmo and San Tiago (cf. item 2.1). The geometric leveling was done by urban pathway around the urban block, involving different Bench Marks (Figure 1). With relation to the first set of measurement was used three Bench Marks (BM_ST - BM_CARMEL - BM_FIRENZE - BM_ST) according to Figure 1, performing a closed circuit of 1109.040m, composed by three lines of leveling. The first line from BM_ST to

BM_CARMEL with 245.375m accomplished by eight stations (minimum of 15.790m, maximum of 41.045m), the second line from BM_CARMEL to BM_FIRENZE with 434.820m accomplished by 13 stations (minimum of 11.440m, maximum of 52.300m) and the third line from BM_FIRENZE to 428.845m BM_ST accomplished by 11 stations (minimum of 13.080m, maximum of 72.590m). The measurements were performed with the invar rod continuously, starting from the stations through the pathway, realizing backward and forward sightings. Measurements were carried out with the equipment and accomplished as follows: the instrument is programmed to perform four successive measurements, are presented the mean and standard deviation of the measurement of height and is informed the distance from the equipment to the invar rod. The results of measurements arranged in the display is considered the influence of earth curvature, i.e., the function was activated "EC" to correct the curvature of the earth. It means that the heights of sights measurements electronically are automatically corrected for the curvature of the earth. Was then carried out another set of measurements, in order to obtain a confirmation of data. The measurement on the first measurement campaign lasted five (5) hours with a team of four people. In addition to the digital level were used: two supports (one for reading the invar rod backward and another for readings the invar rod forward) a invar rod of 2m, a tape measure, two tripods (one for the installation of equipment and other to support the operator's arm at the time of the vertically of the invar rod for data collection, this allowed a greater stability of the vertically invar rod).

As regards the whole of the 2nd measurement were used the same Bench Marks, making a closed circuit of 1102.385m. Composed of three lines of leveling. The first (L1) from BM_ST to 239.735m BM_CARMEL performed with 7 stations (minimum of 13.100m, maximum of 54.020m), the second line (L2) from BM_CARMEL to 443.345m BM_FIRENZE performed with 12 stations (minimum of 15.185m, maximum of 57.925m) and the third line (L3) from BM_FIRENZE BM_ST to 419.305m conducted with 12 stations (minimum of 13.310m, maximum of 57.845m). We used the same measurement procedure described for the 1st measurement. Differing from this for the duration of 4 (four) hours with a team of five people.

3.4 Processing and analysis of data

By calculating compensation and the distribution of errors incurred in geometric leveling, was determined the heights of the Bench Marks. The error of closure of the geometric leveling with high accuracy is ≤ 3mm (L)½, where L is the perimeter of the circuit during the measurement in Km (IBGE, 1983). For closing values greater than this, it is recommended a new geometric surveying.

According to the NBR 13.133/94, which has four categories of class levels, the classification of DNA03 digital level used according to the standard deviation of 1Km double leveling precision is very high value ≤ 1mm/Km.

According to DIN 17823, which has five categories of class levels, the classification of DNA03 digital level used according to the standard deviation of 1Km double leveling is very highest precision value ≤ 0.5mm / Km.

Table 2 below shows the error of circuit closing formed by three lines passing through the three Bench Marks.

Table 2: Closing Error and perimeter of the circuits made by geometric leveling.

CIRCUIT	LINES	PERÍMETER [m]	CLOSING ERRER[m]	READING	READING DATA
I	L1, L2 e L3	1109,040	0,000205	1ª	22/12/2011
I	L1, L2 e L3	1102,385	0,000130	2ª	24/02/2012

Table 3 shows the heights of the respective Bench Marks for both measurements.

Tabela 3: Heights of the BM.

CIRCUIT	HBM_ST [m]	HBM_CARMEL [m]	HBM_FIRENZE [m]	READING
I	0,00000	-0,52850	0,04300	1ª
I	0,00000	-0,52830	0,04280	2ª

It is observed that the differences are obtained within specifications of the instrumental errors committed. Verification and control of Bench Marks should be pursued with a greater time interval between meter readings.

4. PARTIAL RESULTS

Table 4 and Table 5 below show information on the leveling lines accomplished during the two measurement campaigns.

Table 4: Differences in level between BM and level lines: 1st measurement.

FROM	TO	ΔH[m]	LINE	Nº of stations	LINE LENGTH [m]
BM_ST	BM_CARMEL	-0,52850	L1	08	245,375
BM_CARMEL	BM_FIRENZE	0,57150	L2	13	434,820
BM_FIRENZE	BM_ST	-0,04300	L3	11	428,845

Table 5: Differences in level between BM and level lines: 2nd measurement.

FROM	TO	ΔH[m]	LINE	Nº of stations	LINE LENGTH [m]
BM_ST	BM_CARMEL	-0,52830	L1	07	239,735
BM_CARMEL	BM_FIRENZE	0,57111	L2	12	443,345
BM_FIRENZE	BM_ST	-0,04280	L3	12	419,305

There have been some difficulties during the measurement campaigns. Below are listed them and the solutions to overcome these difficulties:

• Because it is an urban area there are passing cars, pedestrians and the presence of obstacles such as trees and poles. When possible, along the sidewalks was used to perform the measurements.

• The Bench Marks are implemented in the basement of buildings. Because the unevenness of the surface between the underground and street level, it was necessary to reduce the distances among the stations for the measurements.

• Because it is work in progress, there are the presence and flow of workers and trucks in the

works. Thus it was necessary to verify these moments to ask during the measurements not passage of workers and building materials, and request the shutdown of machines of concrete or elevators, which produce vibrations in the work.
• Measurements were made during the day (morning and early afternoon). As the Bench Mark is located in the basement, these environments do not have adequate lighting so spotlights or flashlights were used to enable the measurement of invar rod.

5. FINAL CONSIDERATIONS

According to the data collected during the two measurements, one can say that their results are satisfactory, according to NBR 6122/96, NBR 13.133/94 and IBGE (1983). However, should be performed to check and control of BM for a period longer. For this, it is estimated to carry out at least five sets of reading this year. The work fulfills its purpose, which was to address a methodology for the verification and control vertical Bench Marks.

There is a necessity of definition and materialization of geodetic network and/or topographical planialtimetric of good quality as well as the interconnection of local planialtimetric reference implemented in the engineering works of large structure. These geodesic networks are of great importance as they help to control risk areas in urbanized environments, which can be studied and observed on the design of an information system.

The area of operation for the use of Bench Mark is very large. Its use has many advantages, some are mentioned as follow: implementation of vertical control points of high precision, which may be interconnected with References Levels operated by the IBGE, and thus referred to the Brazilian Vertical Datum; vertical control points of high precision for testing and verification of optical-mechanical levels and/or digital levels; checking Bench Mark; vertical control points for high precision studies of foundations and settlings of pillars of building besides altimetric control points.

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