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THE CHECK OF IMPORTANT MONUMENTS WITH TOPOGRAPHICAL METHODOLOGIES

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Abstract. *The static control of architectural monuments has some important and impressive applications in topographical methodologies. Two interesting examples of the topographic control methods concern the very famous Byzantine S. Marco Basilica in Venice and the Cathedral of Como, situated in the North of Italy. The measurements carried out in the static control field are in reference to the: lengths variation, transversal variation according to a specific direction and height variation. In the paper, one can find the description of the instruments and of the methodologies employed in the static control.*

Key words: *control, monuments, measurements.*

There is certainly more than one reason for the control of the structures.

If we consider very important and very frequently ancient buildings, the conservation actions must be closely connected to the static control of the structure. The control is important not only for the reasons of the security of the structure, but also for gaining deeper knowledge of the procedures for all interested in the study of the structure. The static control is generally carried out by performing some different measurements that can indicate the movements of the benchmarks, through the repeated measuring at regular intervals. The mentioning of the benchmarks is not accidental, because it is almost impossible to establish the movements of the whole structure. Consequently, the choice of the position and the number of the benchmarks becomes very important: the movements of these points in fact indicate the movements or, better, the static situation of the whole investigated object.

The first part of the activities consists in defining the position (and the number, of course) of the benchmarks and the type of movements to be investigated.

Immediately after that, the instruments to be employed and the operation scheme must be chosen.

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It is now important to observe that the choice of the above mentioned is governed by the necessity to define the movements with a mean square error (e.q.m.) smaller than the real (or anyway expected) movements of the structure.

As to another important parameter for these activities, which is to determine the interval of repeated measuring, it is not possible to indicate the general rules: this choice must be made in any individual case, depending on the structures characteristics and the movements being investigated.

It may be said the measuring interval time is usually a result of the decision of many different specialists investigating the movements: for example the project executors, geologists, constructors and so on.

The most important rules can be indicated in the following ways:

- the interval time between two successive measurements depends certainly on the characteristics of the movements: that is the interval time is long if the movements are slow and shorter if the movements are quick;
- if the successive measurements are rather distant (for example some months), we must know that the movements obtained by the measurements can include the seasonal thermal variations.

In these cases it is a good rule to fix the interval time of the successive measurements at every three months and the global control in a few years.

In the static control field, people usually distinguish three different movements, while the measurements go as follows:

a) measures of lengths variation;
b) measures of transversal variation in according to a specific direction;
c) measures of height variation.

As to the above mentioned cases it may be said that in the first of them (lengths variation) the most important instruments are the electronic distantiometers and the extensimeters. In the case of transversal variations the employed instruments are the zenithal level and "fili a piombo" in respect to the vertical direction and the optical collimators in respect to the horizontal direction. The last case now examined (height variation) is probably the most important referring to the static control and the employed scheme is usually highly precise.

Prior to the application in reality, some facts need to be considered.

The measurement series are certainly useful for the static control, the results, or better, the corresponding interpretation must always be considered.

These three different types of static control must be very often interconnected. In our opinion, in seeking the location of the benchmarks, the completely independent single specific control method cannot be applied, but instead several of them must be well connected. In this way, the interpretation of the results can be carried out more easily, that is, with less difficulty.

There is another observation referring to the general introduction: the three types of measurements usually carried out for the static control are of equal importance; the third one is in fact the most important (measures of height variation). It is so because the static irregularity of a structure may be at all cases observed through height control measures, that is to say, level difference measurements. Besides, one must not forget that these topographic measurements are rather easy to perform and they require rather simple and inexpensive instruments.

Moreover, these topographic measures provide a very good accuracy (we are speaking about 1/100 mm).

THE S. MARCO BASILICA IN VENICE

There is an interesting application of the topographic control method concerning the S. Marco Basilica in Venice. The very famous Byzantine church is interesting for the movements caused by heavy static stress on the structure (precisely: due to the new works carried out during the last centuries the height of the domes have changed), earthquake shock and, of course, the high tide phenomenon.

The static control began about fifteen years ago with the main purpose of investigating the ground level of the church (rather irregular as people visiting the Basilica can easily confirm) and at the same time, of examining the vertical settlement of the cupolas.

In this case this is a non destructive control, because of the characteristics of the church. The control must be particularly careful because of the mosaics covering the ground level of S. Marco and the ceiling of the five cupolas apart from the precious marble covering most part of the internal walls. For these reasons, the control project has been rather long (several months) and rather difficult too.

Fig. 1. Short rods fixed on the wall and connected with a steel wire

The construction of 74 internal and external control points, aimed at high accuracy geometric leveling, has been carried out, because of the above mentioned problems, in three different ways:

1) benchmarks on the ground floor were realized in steel: over these a rod with invar tape is placed (Fig. 1);

2) benchmarks on the walls: composed of angular aluminum elements fixed on the walls and used with particular short rods.
3) benchmarks composed of a steel bracket connected with a steel wire, stretched by a weight.

In a particular position a little cylinder is fixed stopping a short rod (named wire-rod).

In this case, the automatic level Zeiss Ni 1 (Fig. 2), was used, and this is probably the most precise level (the last estimated figure is 1/100 mm).

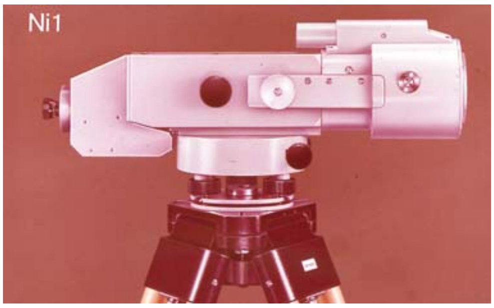

Fig. 2. High precision level Zeiss Ni 1

After eight series of measurements in a total period of two years it was possible to observe that, although the ground floor appeared irregular the observed movements were rather little.

Consequently, it was decided to choose a longer interval time for the measurements: only two series every year instead of four. The new measurements were carried out in spring and in autumn following technical suggestions about the seasonal thermal changes (and excluding for this reason the summer/winter combination). The trend of the movements was about the same in this case too, that is there was little movement, so one control measurement year was considered enough. As to the vertical control of the cupolas, the first problem was the choice between two different methods: mechanical or optical direction for the referring direction. In this case the choice of the second method was forced by the characteristics of the ground floor of the Church (totally covered by mosaics as well as the ceilings of the five cupolas to be examined). Consequently, the risk of damaging the wonderful and precious mosaics of the cupolas had to be avoided; in any case it would be impossible to put a benchmark on the ceiling of the cupolas. For this reason we decided to designate in each cupola a reference point considering the drawings of the mosaics of the cupolas ceiling.

Fig. 3. Zenithal level Wild ZL

The instrumental point station for the zenithal level (Fig. 3) (an instrument with optical collimating axis referred to the vertical direction instead of the horizontal direction as we can find generally in the levels) was located on the ground floor.

Now we had two problems: the first regarding the measure scheme, that is to say the possibility to measure the vertical movements, and the second one regarding the accuracy of the instrument.

Both the problems found a suitable solution in using a mechanical tool fixed on a benchmark of the ground floor and connected with the zenithal level; this instrument can move itself following the two orthogonal directions (Fig. 4).

The lecture resolution is in this case 1/10 mm.

The accuracy of the vertical control is determined by the precision of the mechanical construction of the mechanical tool. We must in fact observe that the zenithal level is not provided (because it is impossible to perform) with the optical arrangement (plane parallel plate) as it is the case with the usual level, like the above mentioned Zeiss Ni 1.

THE CATHEDRAL OF COMO

In the case of the Cathedral of Como the static control regards all the three control types above mentioned: length variation, transversal variation and height variation.

The town of Como (North of Italy, near the Swiss border) situated on Lake Como is affected by a lowering ground level. For this reason the most important monument of the town, the Cathedral, presents some static problems and certainly needs an accurate static control.

For the same reason mentioned for S. Marco Basilica a suggested time interval for the measurements was three months. The height control follows the scheme of the figure (Fig. 5) connecting 46 benchmarks; in this case too, some closed rings may be observed.

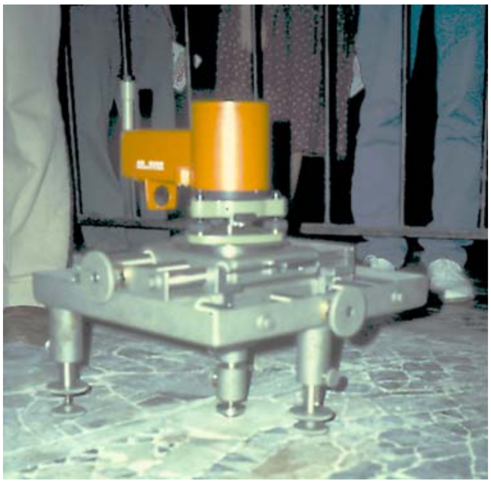

Fig. 4. Zenithal level fixed with mechanical tool

We used the same level Zeiss Ni1, while the rods were located in some cases on benchmarks fixed on the ground floor and in other cases they were hanging on the steel bolts fixed in the walls of the church.

The second static control (vertical control) was carried out with the same zenithal level Wild ZL fixed on the same mechanical tool mentioned for S. Marco case.

The vertical static control regards 8 control points located in the internal area of the church, as we can see in the Fig. 6.

The results of the series of measurements are usually included in apposite schedules, but the same results may be the object of a vector representation as in the same figure.

There are other cases of vertical control - the initial observation of another type of measurement using a plummet, that is to say mechanical instrumentation: a steel wire hung at the top of the structure and stretched by a weight together with a coordinatometer for the measures.

This method can be used when it is possible to fix in a permanent way a metal plate for next connection with the coordinatometer (Fig. 7).

In the architecture applications it's rather difficult to use this destructive method.

There is yet an example of this: the vertical control of a bell-tower realized by fixing the steel wire at the top of the structure and building an appropriate pillar for the metal plate of the coordinatometer.

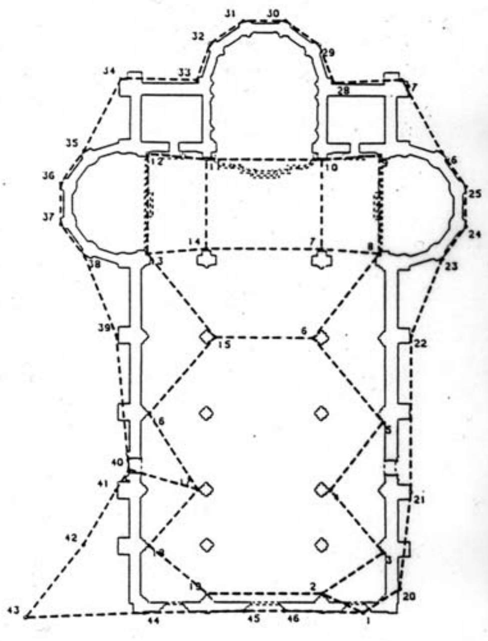

Fig. 5. Leveling net scheme

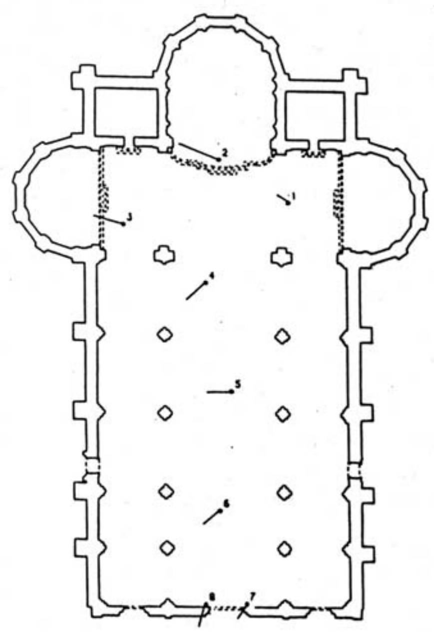

Fig. 6. Vertical control points scheme

Of course, this is a control method difficult to realize because it means destructive control (the bell-tower is occupied by the pillar).

The last static control in the Cathedral of Como was carried out with reference to the following scheme including 22 distance measures (Fig. 8).

These measures are performed with a strain gauge.

The instrument consists of a steel wire of 1 mm stretched across the horizontal direction.

While connecting the two benchmarks concerned in the measurements, the thread is fixed on a suitable and precise device.

On the second end the thread tension device is fixed as well as the measuring one: a disc strongly locked on the thread and employed for the measure with a comparator that has the precision of 1/100 mm. The steel wire is stretched up with a proper weight while taking the measures (Fig. 9).

Fig. 7. Mechanical instrumentation for the vertical control

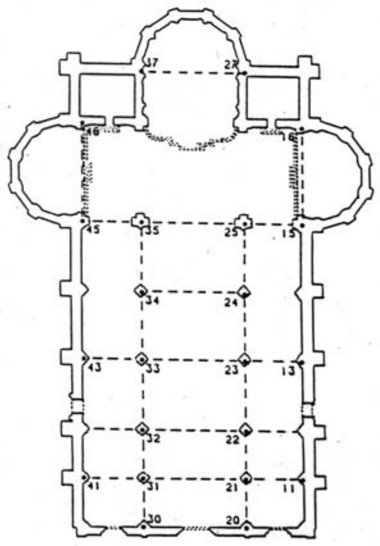

Fig. 8. Strain gauges net

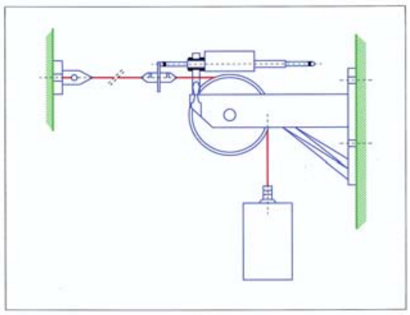

Fig. 9. Strain gauges scheme

ISPITIVANJE VAŽNIH SPOMENIKA TOPOGRAFSKOM METODOLOGIJOM

Giorgio Bezoari

Statička kontrola arhitektonskih spomenika ima važne i uticajne implikacije u topografskim metodologijama. Dva interesantna primera topografskih metoda kontrole tiču se veoma poznate vizantijske Crkve Svetog Marka u Veneciji i Katedrale u Komou, koja se nalazi na severu Italije. Merenja izvedena na polju kontrole statike su uvezi sa: Varijacije dužine, transverzalna varijacija u odnosu na speicifični pravac i varijacije visine. U radu možemo naći opis instrumenata I metodologije koje se upotrebljavaju u statičkoj kontroli.

Ključne reči: *kontrola, spomenici, merenja.*