UTILIZAREA METODELOR ŞI INSTRUMENTELOR DE MĂSURARE MODERNE ÎN CONSTRUCŢII ŞI ORGANIZAREA TERITORIULUI

THE USE OF MODERN METHODS AND MEASUREMENT INSTRUMENTS IN CONSTRUCTION AND LAND MANAGEMENT

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Abstract: *The use of a 3D scanner in measurement optimises design, architecture, town planning and cadastre-related activities. The measurement instruments make use of a quick laser and a video camera to capture a large number of points and video images. The 3D images consisting of points can be changed into objects that in turn can be analysed, processed and registered in a database, together with a series of attributes and data. Such applications can be used in the study, the comparative chronological analysis and the inventory of an object, taking into account that for a high resolution either millions or only several points can be captured for high resolution. Also, point density can be selected for objectives like roads, streets, bridges or tunnels, where distances vary.*

Rezumat: *Utilizarea metodelor de măsurare cu ajutorul unui Scanner 3D aduce avantaje în optimizarea şi planificarea lucrărilor de proiectare, arhitectură, urbanism şi cadastru. Aceste instrumente de măsură folosesc un laser rapid şi o cameră video pentru a capta un număr mare de puncte şi imagini video. Imaginile tridimensionale create din multitudinea punctelor înregistrate pot fi transformate în obiecte care pot fi analizate, prelucrate şi înregistrate într-o bază de date adăugându-le diferite atribute sau informaţii.Aceste gen de aplicaţii pot fi utilizate şi punctual în studiul, analiza cronologică comparativă şi inventarierea unui obiectiv, ţinând cont de faptul că se pot captura milioane de puncte, pentru a obţine o rezoluţie sporită, fotografică sau se pot captura doar câte puncte ai nevoie. De asemenea, se poate alege densităţii ale punctelor pentru obiective ca drumuri, străzi, poduri sau tuneluri unde distanţele pot fi diferite.*

Key words: *scanning, subsidence, rotation, inclination, resolution*
Cuvinte cheie: *scanare, subsidenţa, rotaţie, înclinare rezoluţie.*

INTRODUCTION

The importance of Laser Scanner GS 200 in construction surveillance is revealed in the present paper that deals with a monument that has been studied, analysed and admired for centuries – The Tower of Pisa.

In time, the site has suffered major transformations. The oldest human traces date back to the 3rd millennium b.C., and the first buildings were attested b.C., towards the end of the 8th century. The river then running through the Square changed its course along the years and gradually moved its bed eastwards.

Until the Middle Ages, the Square underwent several urbanisation and reorganisation stages, well-documented by diggings and archaeological investigations. Upon the demolition of some buildings, the Square took an aspect that it has preserved until today. The Tower and the belfry were started in the second half of the 12th century.

MATERIALS AND METHOD

Laser Scanner GS 200 is made up of a unit powered by a generator, as it doesn't have internal accumulators. The instrument is controlled with a notebook or a palm with POINTScape dedicated software.

The software allows the user to command horizontal sweeps (given by the rotation of the whole unit) and vertical sweeps (given by the camera inclination) and to select the surveying area.

Before the sweep (scanning movements) launch, the finality of the surveying must be known in order to determine its accuracy, namely the surveying point network. The laser scanner enables detailed sweeps of smaller objects at 360°.

The instrument allows the creation of several stations and the surveying of the same object from various angles. With the help of an application called RealWorks, the stations are united in an exclusive digital model that is more detailed and does not have shading cones. There are four ways to unite the stations:

1) Targets or green adhesive with a central cross that the tool recognises and changes into a known point;

2) Spheres supplied separately from the instrument, with very precise dimensions and whose centre the tool determines by itself;

3) Known points, with known altimetric plane coordinates;

4) Points common to various stations and further elimination of the most possible error.

Once the surveying finished and the stations united, a digital model can be created from simple points over which the photographs taken in situ can be overlapped.

The following study is a brief introduction preceding the largest possible amount of information about the 800-year-old tower of Pisa.

Here are some of the Tower's characteristics and historical references:

- the height of the building from its foundation to the belfry is 60 m;
- the annular foundation stone has an exterior diameter of 19.6 m;
- the Tower weighs about 14,500 tons;
- it is a hollow cylinder formed by two concentric marble walls that contain inert materials and mortar;
- the spiral stair between the two walls leads to the arcaded storeys and the summit;
- the thickness of the wall is 4.1 m at the first level and 2.7 m at the higher level;
- the present inclination is 5.5° towards the southwards, indicating that the first cornice protrudes about 4.5-m over the first cornice;
- the Tower was finished in about 200 years;
- the history of the edifice is only partially documented and has been reconstructed based on indirect sources;
- the foundation was started on August 9, 1173;
- the works were interrupted around 1178;
- around 1272, the building work was taken up again, only to be interrupted at the seventh level in 1278;
- the belfry (the eighth level) started around 1360 and was finished after 10 years;
- the Tower subsided by 2.80 m because of the unstable soil underneath; the base of the tower was freed in 1838 to reveal the bases of the column that had been covered in earth for centuries;
- the differential subsidence is 1.89 m, meaning that the extremes north and south have subsided by 1.86 and 3.75m

The Tower was built in three stages, interrupted by two long breaks. Its inclination became visible as early as the second stage (1272-1278), as the curve towards the north of the axis indicates. This was caused by the corrections the builders made to reduce the total deviation. Also visible is the correction made in 1360, when the belfry was erected. Its base, horizontal at the time, has six steps to the south and only four to the north, which corresponds to the correction of a rotation of 1.5° southwards.

The evolution in the inclination of the Tower in time can be determined only based on the surveys of Vasari in 1550, Cresy and Taylor in 1817 and Rouhalt de Fleury in 1859. Rouhalt de Fleury lowered a plum line from the seventh level. The comparison of the two measurements in the 19th century leads to the hypothesis of a relatively quick rotation concomitant with the digging around the catino in 1838-1839. However, it is impossible to determine whether before those years the Tower was straight or maintained a small south-oriented speed rotation.

In 1911, the Tower was first measured with tools and methods that were able to determine the evolution of its inclination more accurately. In that year, the inclination was 5°14'46", corresponding to a 4.22 projection from the seventh level to the first. The first measurements were based on the "α" angle measured between the first and the seventh level (figure 1). It is important to underline the great sensitivity of the Tower to any variation in the soil condition and the works performed at the base. The rotation speed increased from 4"/year in the 1930's to 6"/year towards the end of the 1980's.

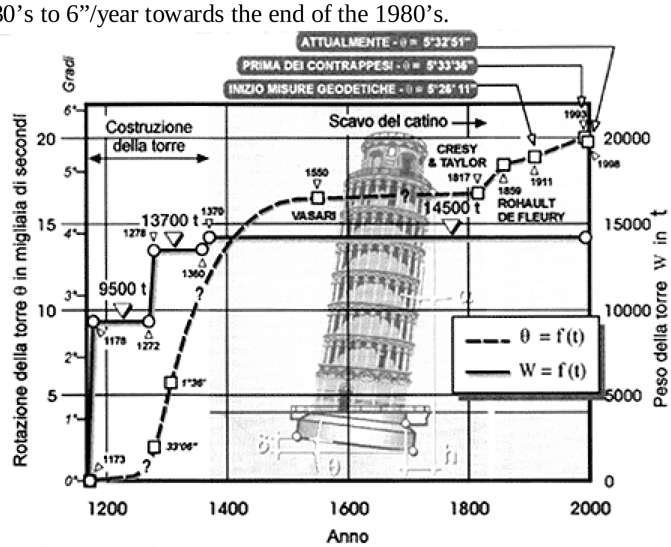

Figure 1. The evolution of the Tower of Pisa

In 1993, a 600-ton lead counterweight was placed at the north side of the Tower's base to counterbalance its rotation to the south. Consequently, a 60'' movement northwards occurred and the Tower was stabilised for the first time in eight centuries. A contained perturbation occurred in 1995, due to the unexpected effect of the connection between the Tower and the steel cables installed in 1945 to make the foundation waterproof. In 1995, the committee that supervised the restoration of the monument tried to replace the unaesthetic counterweights with underground cables. The engineers froze the earth with liquid nitrogen, which caused a high increase in the inclination and the project was cancelled. This time, the southward inclination was stopped with a 870-yon counterweight. Figure 2 shows the relations between the inclination"α" of the axis of the Tower between the first and the seventh cornice and the projection "h"; between the inclination "θ" of the base of the foundation and the differential subsidence "δ" between the southern and northern borders. The values of the "α" and "θ" angles never coincide because of the axis inclination.

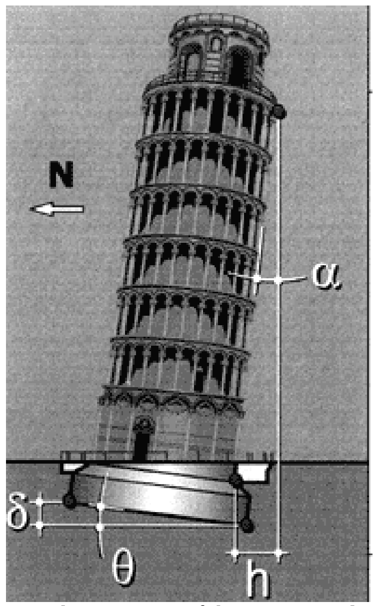

Figure 2. Characteristics of the Tower's inclination

The characteristics of the inclination of the tower of Pisa
The maximum inclination before the counterweights were placed in May 1993.
$\theta = 5^{o}\,33'\,36''$; h = 4.47 m;
"α" – inclination of the axis
"θ" – inclination of the base
"δ"- differential subsidence between the southern and northern borders;
"h " – the projection measured at the seventh cornice
$H (\alpha = 1'') \approx 0{,}22$ mm
$1^{o} = 60' = 3600''$
$\theta_{1998} = 19971'' = 5^{o}\,32'\,51''$

RESULTS AND DISCUSSION

Due to the effect of the water pumped from the subsoil, the earth surface has become increasingly unstable on the whole Pisa Plain. From 1886 to 1986, in the Cathedral Square, a subsidence of 150 mm was recorded. The soil movement is not uniform, but increases from north to south and contributes to the increase on the inclination of the Tower. In 1968-1974, water pumping was intensified. As a result, the Tower rotated more rapidly.

Definitive geotechnical intervention and structural considerations

The definitive geotechnical intervention is the reduction in the inclination of the Tower by working on the earth around the foundation. The reduction will be 0.5° compared to the current 5.5º, to preserve the present aspect of the monument. The intervention will be the execution of inclined bore holes (figure 3).

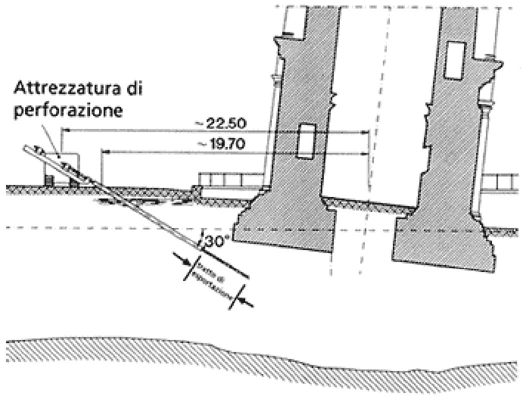

Figure 3. Works at the foundation of the Tower

The inclination of the Tower causes a concentration of vertical compression forces on the lower levels. This affects the first floor in particular, because:

- the door to the loggia and the passage to the spiral stair reduce the resistance of the region;

- the interruption in the exterior wall causes the concentration of the pressure and reduces the resistance of the interior wall;

- the numerous holes in the wall reduce the resistance of the region.

CONCLUSIONS

Figure 4 presents the evolution in the inclination following the restoration or intervention works at the foundation and the tower itself.

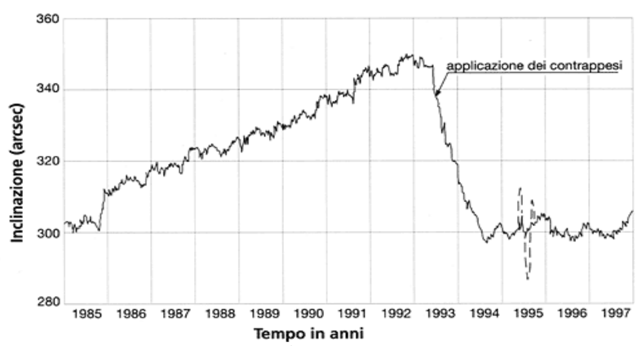

Figure 4. The evolution of the Tower's inclination in time

Laser Scanner GS 200 allowed the surveillance of the consolidation works of the Tower. The changes in its inclination and the possibility to study them in time were underlined. The overlapping vectorised images enabled the analysis of the differences and the timeliness of the interventions. The 3D scanning tools allow space resolution selection, a major aspect in monument and historical building restoration, where details are essential.

LITERATURE

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