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DIAGNOSTIC SONIC INVESTIGATION ON SAN GIOVANNI IN LATERANO OBELISK, ROME, ITALY, AND TOMOGRAPHIC RECOSTRUCTION OF SAME SLIDES PROJECT: TECHNOLOGY FOR CULTURAL HERITAGE

C. Cappabianca[1], V. Luprano[2], A. Tatì[1]
[1] ENEA FIM MAT QUAL CR Casaccia Rome, Italy
[2] ENEA FIM MAT TEC CR Brindisi, Italy

ABSTRACT

This report describes setup of system for acquisition signal and the dedicated software developed by our laboratory for sonic testings. The investigation have been directed to characterize mechanical properties of stone and calculate Young module.

Furthermore the sonic tomography of same flat sections made in correspondence of botton supporting plane and of couplings between stone, the obelisk is divided in more parts has allowed to show internal structure.

INTRODUCTION

Sonic testing are able to analyze the propagation of elastic waves in internal solid bodies. These kind of tests use a sonic generator, usually a pulse hammer, a probe receiver, placed to know distance, to convert sonic wave into electrical signal. By analyzing electrical signals it is possible to measure sonic speed, attenuation resonant frequency of objects.

Sonic testings replace ultrasonic testing because work with low frequency, largest wave, so that it is possible analyze higher thickness or uneven materials, like stones or concrete.

Fig. 1 Laterenense Obelisk

SYSTEM SPECIFICATION

System used and setup in our laboratori is based on: Il sistema messo a punto dal laboratorio si compone di:

1. pulse hammer with accelerometer sensor and pre-amplifier operated by 9 v battery
2. portable PC with double battery
3. oscillograph board 20 Msample per sec PCMCIA

Fig. 2 system strumentation

System is able to work up to 3 hours with battery, so it is possible to work in field easily.

The acquisition board can acquire two kind of signals:

- pulse strenght from hammer
- accelerometer ICP

Sampling rate is 500 KHz and storage buffer is 4096 dots. Acquisition of these two signals is synchronized with generated signal from internal hammer.

SOFTWARE DESCRIPTION

Developed software acquires and elaborates two signals, and at the same time it is possible to see on display, storage on hard disc and calcolate velocità or flight time of sonic waves.

Computation of flight time is done with a gate on signal by ICP sensor.

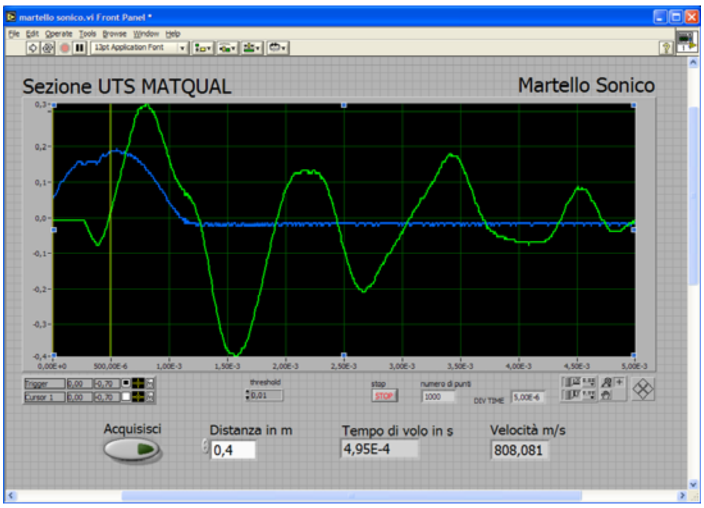


Fig. 3 Acquisition software

We developed also a software to analyze sonic signals in frequency domain.

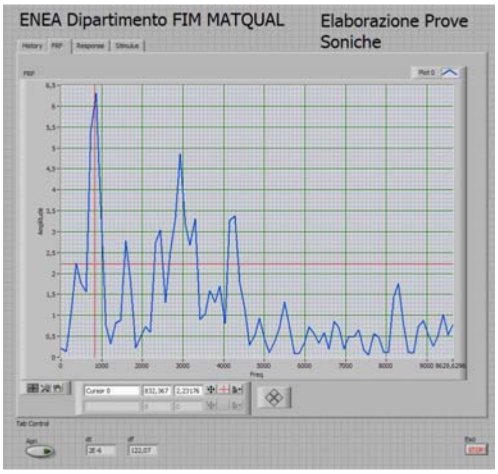


Fig. 4. Transfer function FRF

SONIC TESTING
Carried out two kind of measurements: direct and indirect. In the first case, direct measurement, mechanical pulse produces an elastic wave on one side of the object, the receiver is located on the opposite side. The probe acquires compression waves that are faster, see fig. 6.

In the indirect testing the probe is located step by step on the other sides referring the hammer, see fig. 7.

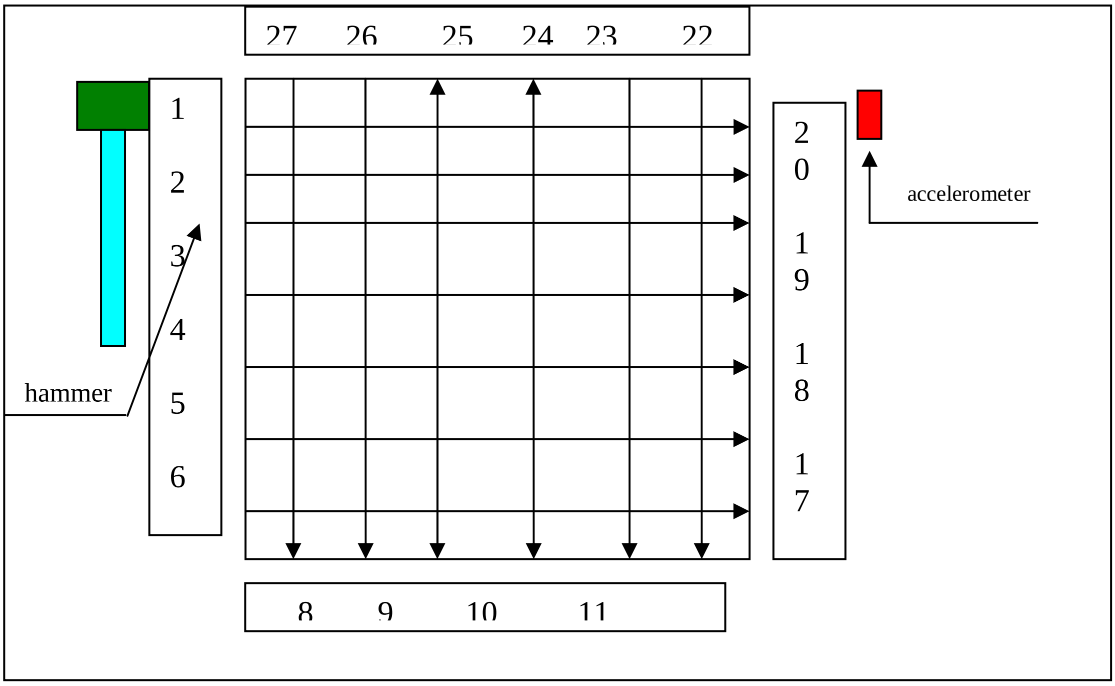


Fig. 5. Direct measurement

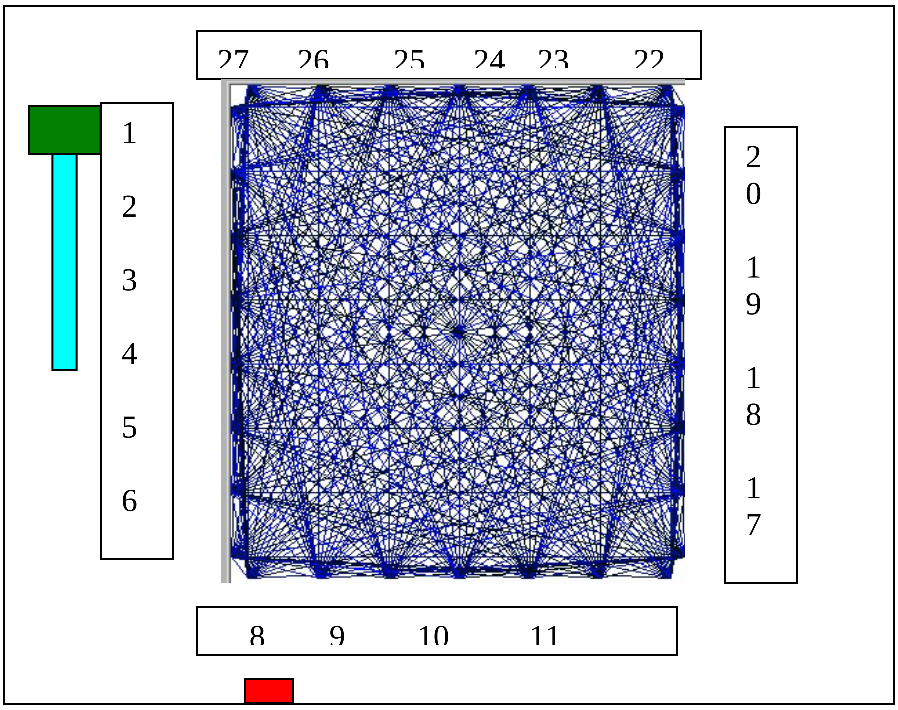


Fig. 6. Indirect measurement (Tomography)

Fig. 7,8,9. On site testing

RESULTS

Results are obtained by various software:

1. Excel for velocity calculation and presentation of raw Matlab per l'immagini in falsi colori
2. Labview for 3D presentation and statistical analysis
3. Statistica-6 for statistical correlations

In a granite stone without defects sonic velocity is about 5500 m/sec; in case of lower velocità, like as half, it do not necessary mean that the granite is poor, but it can be the waves are trepassing different stones linked with or without mortar, or similar materials. Furthermore, also little micro voids can be affect total velocity of whole thickness. In the air sonic velocity is 330 m/sec, so that the ratio with granite velocity is 1/16, we found in corrispondence of joint, the obelisk is divided in more parts, medium velocity lower than stone without defects. This ratio will considered in the FEM model (...........) of obelisk for the properties of material also to valutate sismic vulnerability in accordance with "*guide line for valutation and reduction of cultural heritage*" by Ministero per i Beni e le Attività Culturali (December 2006)

TABLE 1
Parte1.ipt Statistics

Dimensions	2,87 m 2,98 m 31,14 m
Massa Part	4,755e+005 kg
Volume of Part	176,1 m³
Setting mesh Relevance	-1
Nodes	3685
Elements	2112

Table 2
granite

Modulo di Young	1,2e+010 Pa
Coefficient of Poisson	0,23
Density	2700 kg/m³

TABLE 3
Results on frequencies

Name	**Mode**	**Frequency FEM**	**Real Frequency**
Mode Frequency 1	1	1,28 Hz	1.27 *Hz*
Mode Frequency 2	2	1,333 Hz	1.27 *Hz*
Mode frequency 3	3	5,97 Hz	6.15 *Hz*
Mode Frequency 4	4	6,226 Hz	6.73 *Hz*

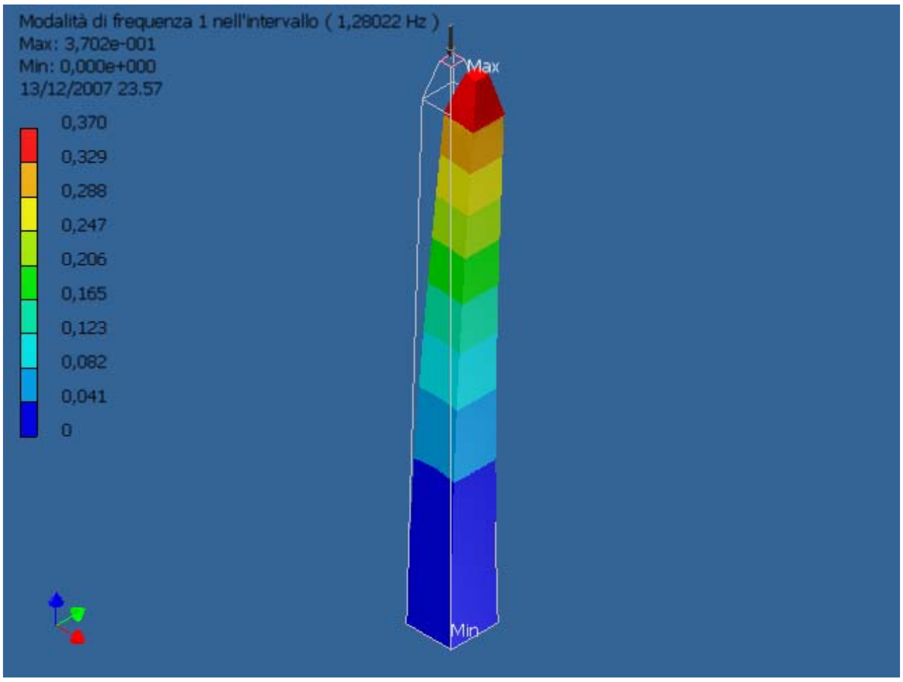
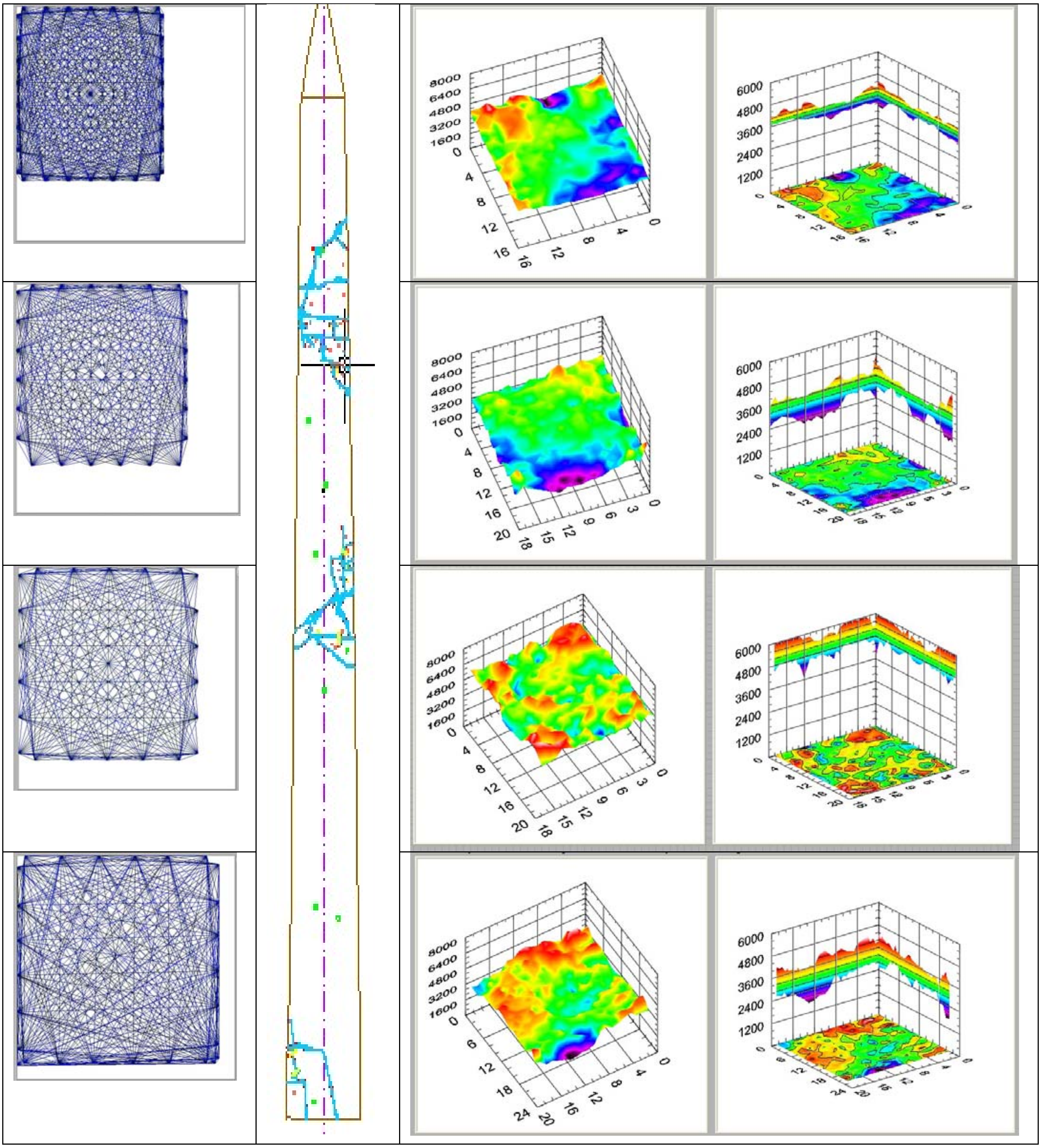
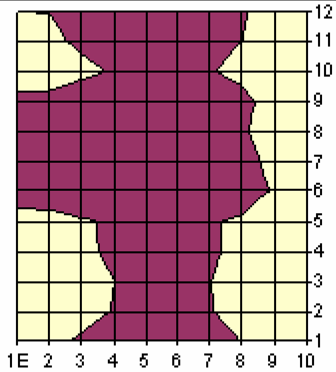
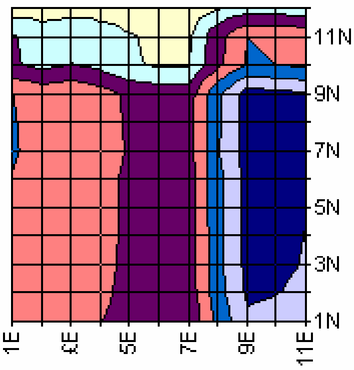
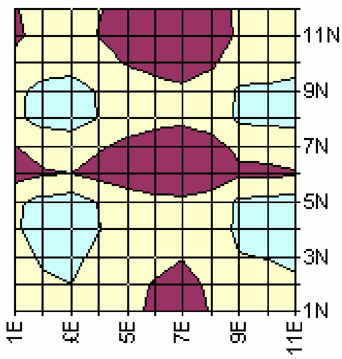
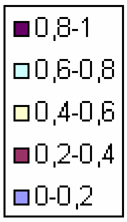
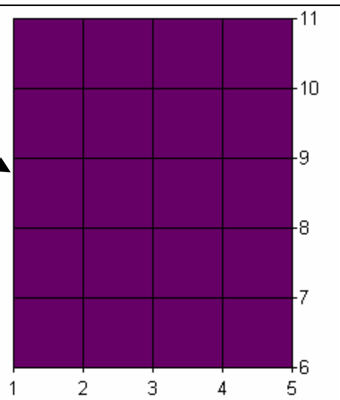
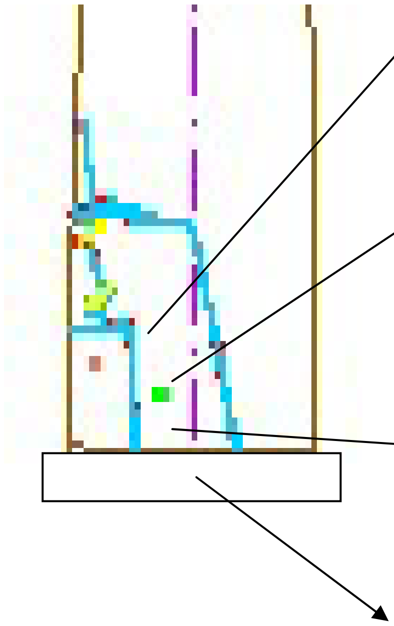
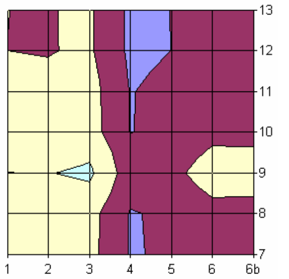
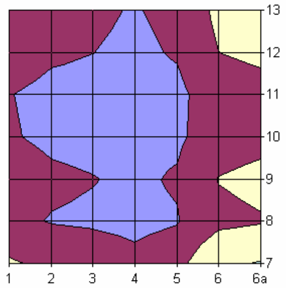
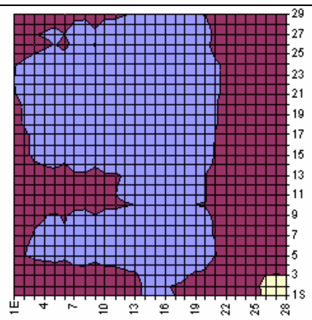
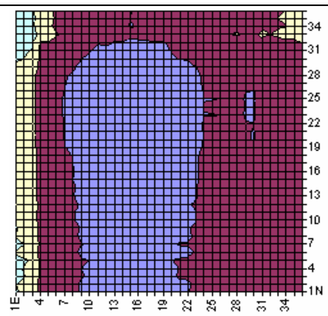


Fig. 10. Model FEM of the Obelisk



Tab 4. Indirect measurement (Tomography)

Position	Height in meter	Section	1 no-defect granite <1 restored granite	Average index
	**20**			**0,39**
	12,40			**0,55**
	12			**0,44**
	10			**1**

	**1,30**			**0,27**
	0,5			**0,36**
	0			**0,20**
	Base			**0,25**

Tab 5. direct measurement

CONCLUSION

The carry out testing on four vertical section of the obelisk show the structure have different areas distinguished by very different velocity according to damaged blocks and/or restored by Fontana architect.

It is clear by sonic maps obtained from base obelisk, included marble curb, see fig. 1, measured velocities on the corners are higher than the same on the center and on the sides. In consequence of these results, and after removal of plastering cement, four metallic brackets are detected between corners and curbs.

Fig. 32,33. Metallic brackets on the corner of obelisk

At 10 m height and in no defect area, the sonic velocity are clearly superior to botton area and are almost constant for all map, see fig. 24-25.

Sonic map relative to the area between junction 1° and 2° stone block shows a drawing like a cross; this confirm that architect Fontana used grooves to place stones by hemp ropes, see RT 32/07.

Calculated values are in m/sec and give sonic velocità in the internal of obelisk. These values can be correlated with elasticity modulus, Young' modulus, and are used for finite element simulation.

Following table resumes the results in the inspected sections and maps show normalized elasticity modulus as to section of no defect area. In right column are showed average values normalized as to any section. These values will be used to estimate the obelisk vulnerability against sismic and traffic stress, also with support of parametric studies: changing elasticity modulus value in no defect area fit the strnght values in the other section.

Back to Top