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The Technology for the Raising of the Broken Obelisks: The Cases of the San Giovanni in Laterano Obelisk (Roma 1587) and the Axum Stelae (Tigray 2006)

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ABSTRACT: After the transfer of the Vatican's obelisk monolithic happened in 1586, Sisto V, between 1587 and 1589, arranged the elevation of other three broken obelisks that lay to ground near the mausoleum of Augusto and inside Circo Massimo. The technological effort in order to raise the titanic weight of obelisk of piazza San Pietro was the result of the full application of the stratified technological cognitions from the antiquity until to the Renaissance. The procedure idea for Vatican's obelisk, the only one remained erect and monolithic, must necessarily be modified to raise the obelisks that lay to ground broken.

The present contribution explains like a new monolithic shape given back to obeliscus fractus is the result of the use of highly flexible technology by Fontana. It wants to analyse differences and analogies of the technology of the sixteenth century compared with those estimated in the Axum stelae (disassembled in Rome in the 2003 according to the project of Croci's engineering group) to raise and to reassemble it in the Tigray Archaeological Site Ethiopia.

1 INTRODUCTION

Domenico Fontana (1543-1607), in his book *Della Trasportazione dell'Obelisco Vaticano* (Roma 1590), delivers to building history the chronicle of the epic operation (happened between april and september 1586) of the transfer of the monolith from circo di Nerone to piazza San Pietro.

No construction site had ever been described and illustrated with a similar detail. The book aim corresponded to author's self promotion wish, but it aimed also to translate his own experience in a repeatable and then transmissible process; then text and drawings explained in a popular way, according to the synoptical succession of the number of building sites in which the operation had been done, the process for the transfer of the monolithic obelisks (Fontana 1590)

2 THE ANCIENT TECHNOLOGY

Only to recall dimensions and weight we are discussing of, the Vatican obelisk is 25 meters high and with basis square side of 2.7 meters; its weight that reaches 326 tonnes needed, in order to be transferred, the use of 44 winches (each of them had to lift 6.7 tonnes), 907 people, 75 horses; by considering that the evaluation of "woods, iron fittings, cables and other instruments" had been calculated in excess in order to guarantee the resistance of materials, instruments and machines used for the aim of this project. (Curcio 2003)

By simplifying, the innovations introduced by Fontana for the transfer of the Vatican obelisk were founded on the use of a wooden castle which, as happens with the modern metal scaffolds, could be quickly mounted and dismantled without the sizzlings of the precious material, by exploiting the capacity of winches and the lift instruments such as blocks and pulleys, Fig. 1.

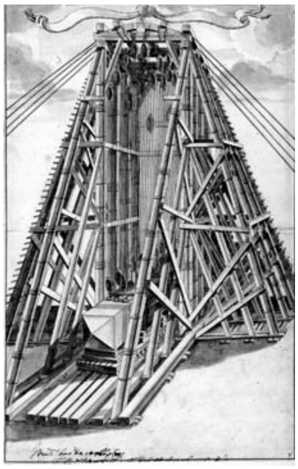

Figure 1 : Natale Bonifacio, The Vatican's obelisk transfer, etching.

The castle was made by two rows of four pillars (the "aerials", 36 meters high), realized with several woods linked by tap bolts and iron belts and not by usual nails. The aerials were stabilized by eight "ropes" tight from their head and the ground, as well as struts, crosses, crossbars and by four props set at different heights and orthogonal to the scaffolding bed; the aerials put at the corners were stabilized also by a second order of props set according to the obelisk dragging direction. At the top of the temporary work there were four double crossbeam trusses, necessary to clash the aerials and support the superior blocks to six pulleys which multiplied the size of the applied forces; these blocks, through cables, were linked both to other blocks fixed to the obelisk's shaft (which had to divide the weight in different parts "so many are the wires of the ropes passing through them"), and to the pulleys fixed to the castle basis and then to the winches controlled by men and horses (Carugo 1978, Zabaglia 1743, Fontana 1694).

The obelisk's shaft was protected by a double coat of mats, covered by boards 5 cm thick and hardened by iron bars (section 11x5cm); all of this was hardened by metallic belts.

The aerials were planted into ground by eight holes in pedestal foundations; this one hardly appeared from an artificial round pad, built in order to bridge the height gap (8 meters) between the original seat and piazza San Pietro, on which it the Vatican obelisk had been dragged for 260 meters.

The detailed description becomes a fundamental technical heritage for the monolith lift in the following centuries: for example the votive pillars in piazza Mignanelli (1856) in Rome or in piazza dell'Ammigliarato in San Petersburg (1837) (D'Onofrio 1992, Navone 2003).

More interesting, also for the presence of a technical literature, is the change that Domenico Fontana himself makes to this technology to adapt it to the building of the broken obelisks of San Giovanni in Laterano, Santa Maria Maggiore and Popolo (Dibner 1952, Kastl 1973, D'Amelio 2002).

The three obelisks, in fact, had been found dejected and broken. This specification is fundamental as unlike the monolith of piazza San Pietro, which remained erect behind the Basilica and then transferred, the raising of a "obeliscus fractus" (which is the most frequent case) happened through raising, overlapping and subsequent juxtaposition of fragments; in yard practise this generated less effort to move weights, but also a greater complexity to rebuild by different stumps the clear shaft-pyramidal volumetry of the obelisks.

Fontana describes briefly the technological changes that regard mainly the castle dimensioning for the Lateran obelisk (32 meters high , found broken into three pieces of 14.6, 9.7 e 8.7 meters) which had to be higher and longer than the one necessary to raise an obelisk, however monolith, of the same height (Fontana 1590).

In fact, if for this obelisk (as happened for the Vatican's obelisk) the raising on a pedestal had been made at the geometric centre of the scaffolding, in order to raise a broken obelisk into pieces the provisional structure had to be put in an eccentric way respect to the basis on which it had to be raised; this allowed to leave the space useful in order to drag the different pieces below the castle (it is an area for additional manoeuvre as is shown in Fig. 2) and to raise them not much higher than the juxtaposition height, without the obstruction of rocks already set .

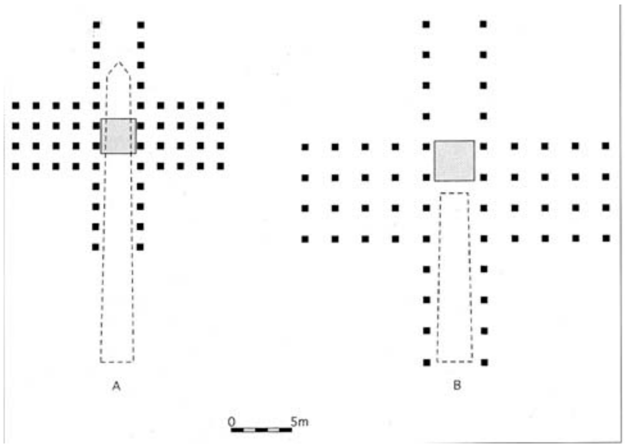

Figure 2 : Plans of the provisional structure for the raising of Vatican's obelisk (A) and of San Giovanni in Laterano one (B), elaborated by M.G. D'Amelio

Once the raising have been done, the block was temporary suspended on two beams (this explains the greater height of the castle), and was then transferred horizontally till the plumb of the lower rock. For greater safety, the fragment was slinged with ropes which passed at the top and under the foot of the piece in special cavities (the "casse"), so digged into the stone as Domenico Fontana requested. The hawsers so positioned, once overlapping was concluded, could be easily taken out without obstructing the surfaces of pieces in contact. This solution, studied in order to obtain a more safe raising, created the space for gravestones pins used to remake the cohesion among the obelisk fragments. In fact, the "plugging" was carried out with the wedging of granite pieces made then solid through a lead dripping, such as "if it had been possible to lift the obelisk by its top, there would have been all pieces as the obelisk was a whole piece" (Mercati 1589).

3 THE CONTEMPORARY TECHNOLOGY

The idea used by Fontana to recover the monolithic structure to the pieces of the obelisks of San Giovanni in Laterano, Santa Maria Maggiore and piazza del Popolo, could not be proposed after 350 years after, for the development of preservation and repair methods, when in 1937, Benito Mussolini ordered the rebuilding, in Roma, of four pieces of Axum stelae. In fact, the elements of the stelae were recomposed, in a less hard way, with the use of bronze pins 90 mm in diameter, put in blocks for about 30 cm and made solid with cement mortar, the missing parts were replaced by gravestone plugs taken from stelae basis.

The stelae in basaltic stone, dated between I-IV century B.C. with a rectangular section and 23,50 meters high (of which only 21,10 outside the ground) with a weight of 152 tonnes, belonged to the Axum archaeological complex which shows the extraordinary concentration of 176 funerary monoliths, many of which lied broken on the ground.

Ethiopia had been asking for it since 1947, so the stelae was given back in april 2005, after a complex and unusual operation of dismantling into pieces, as it was impossible to transfer it whole. The project carried out by Croci's engineering group, proposed a solution, so simple as difficult, to "break again" (not to cut) the stelae where corresponding to those surfaces of minimum resistance already present in ancient fracture surfaces.

The shaft disarticulation into three parts in order to obtain the same number of blocks homogeneous for dimensions and weight (compared with the four ones arrived in 1937) has been carried out through the application of combined stresses of flexion and bending in order to overcome the resistance of cement mortar and linking pins, Fig. 3; in order to give a home picture, the movements provided for the “décollement” of the joints are similar to those applied to the cap of a champagne bottle, in the stelae case , but it happened by modulating the force that voiding the upper stump could bend excessively or could be pulled so high that it could not be stopped.

Figure 3 : Axum stelae in Rome, disjointing operation

The only cut made (with diamond wire) regarded the concrete foundation glass in which, in 1937, the stelae had been fixed for 2,10 meters.
For safety, all forces necessary to disarticulate the stelae into three elements have been applied, nor directly on the stone, but on the metallic structure linked up to gravestone trunk near fracture areas; such areas had been previously protected with fibro-reinforced mortar (with a thickness variable from 3 to 12 cm) and a link in aramid fiber and carbon. Over this contact area, the system for disarticulation has been prepared, that’s to say a metallic carpentry assembled in shop, whose coupled horizontal elements have been put together by dywidag bars, put at 135° on the stelae corners. Among metallic carpentries, put on the same stump, several vertical bars have been set in order to give an axial precompression able to compensate for possible traction stresses originated during disarticulation phase or during following transfer.

Four vertical dynamic-oil jacks for each stelae side and two horizontal put alternatively on two different opposite fronts, linked by manifold high pressure pipes to electric pumping control units, have given to metallic carpentries the forces in vertical direction (in order to pull) and in horizontal direction (in order to bend).

It’s interesting to remind that in the inverse operation, that’s to say in the obelisks’, John Dixon had been the first to introduce jacks together with steam engine force, by explaining their use from the naval and railway industry, for the erection of the London obelisk happened in 1880. (Dibner 1952, Iversen 1972, D’Amelio 2002 and 2005)

Stone fragility in Axum stelae imposed a control of the applied forces and given effects, in real time, through a network of sensors; monitoring permitted the comparison among surveyed parameters and values foreseen during the project, in order to avoid critical events such as the excessive inclination, stress at break limit, the crush of compressed limb, Fig. 4. The force to be applied calculated during the project revealed overestimated, for mortar preservation state used in 1937, both on fracture sides and on the housing of bronze pins.

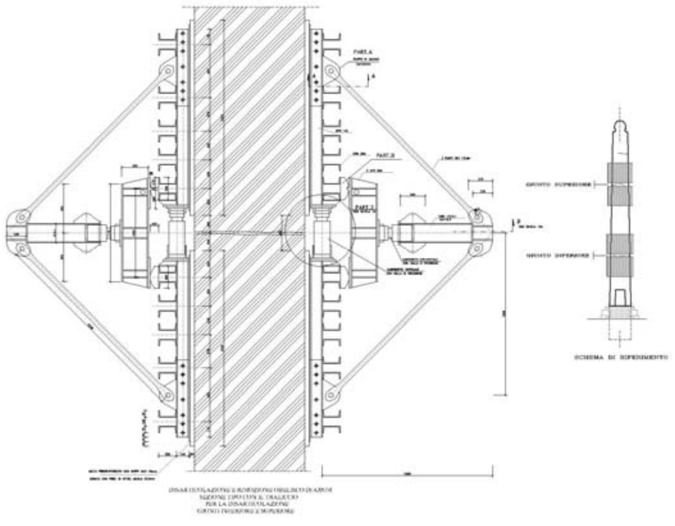

Figure 4 : Axum stelae in Rome, disjointing operation

The three stumps (the upper part of 7 meters and 47 tonnes metallic carpentries included, the second segment of 8.9 meters equal to 71 tonnes and the third one of 8.50 meters and 77 tonnes) once disjointed were transferred to Ethiopia by three Antonov 124 cargo flights.

The new erection of Axum's obelisk, foreseen for 2006, not treated for the sake of brevity, presents difficult problems in organization such as the moving of the blocks in an archaeological site with cavity and appearing finds and with a steep-and-rugged orography, the lack of mechanical machines in that area suitable for stump transfer, the absence of qualified workers and of temporary structure in order to prepare a bridge crane suitable for raising the three stumps.

4 CONCLUSIONS

Nevertheless when updating techniques and technologies it is interesting to verify as modern procedures refer to a past practise tested in building site. In fact, in the project of Croci's engineering group, the metallic carpentry with bridge crane for vertical load raising braced by a scaffold to pipes and joints and operation sequences recall the procedure applied by Domenico Fontana for broken obelisks, Fig. 5. For them space for dragging and delayed raising of gravestone pieces was found in the scaffold greatest length, let the obelisk basis in a decentralized position respect to castle plan: "As the first piece is already fixed on the basis, it's impossible to pull the second piece due to the great weight, not the third piece over the second one, being the area occupied by the first piece". (Mercati, 1589).

A "modern-ancient" and "ancient-modern" procedure which, from different centuries, has made monolithic dozens of broken obelisks.

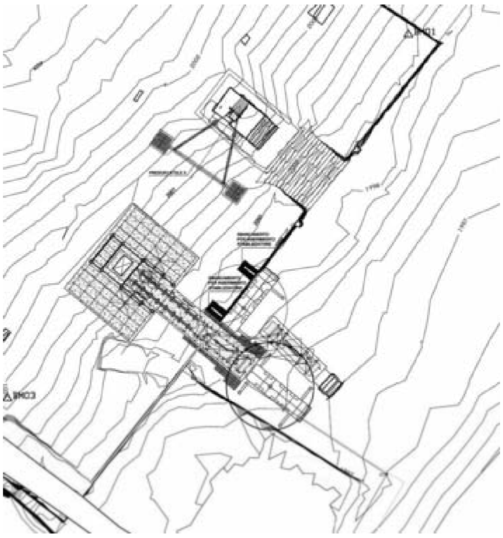

Figure 5 : Axum stelae, project planimetry.

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