TECHNOLOGICAL FEATURES IN GREEK FORTIFICATIONS IN SICILY

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ABSTRACT

In a historical framework archaeological structures surely occupy a position of some prominence; apart from their enormous importance from a historical and artistic point of view, they possess *structural elements* made from *materials* that are worth studying, analysing and restoring. This paper has been prompted by research that is still being carried out, and whose aim is the examination of the wall-structures of fortifications to be found in the archaeological sites of Greek Sicily. For this purpose, great importance was given to survey of the parameters of the wall that distinguish such structures, for a better understanding of the construction and technological process of the past.

1. INTRODUCTION

It is known that the defensive works of some Sicilian cities in *Magna Grecia,* such as Naxos, Lentini, Megara Iblea, Selinunte, date back to the Archaic Era. Most of them date back to the end of the sixth century B.C. and are closely connected to the tyrants age. Nevertheless, some of the towns, such as Camarina and Selinunte, present fortifications that date slightly earlier, in the middle of the sixth century B.C. or as early as the seventh century B.C. in Megara Iblea and Leontini.

This study aims at deepening historical knowledge, the typology and materials of the of major Sicilian sites, which is an indispensable prerequisite for any type of operation of restoration or fruition. For this purpose, great importance was given to survey of the parameters of the wall that distinguish such structures, for a better understanding of the construction and technological process of the past.

I'm going to analyze the construction of the remaining faced walls of the Sicilian colonies from an historical, cognitive and, above all, structural point of view. We will try (as only a few people up to now have done) to establish a relationship between history and technology by analyzing these masonries. Through a suitable historical knowledge I can more easily understand their structure and mechanical behaviour by analyzing the walls and their stability as a whole building and how history affected them.

This systematic analysis of the fortifications highlights important subjects that deal with the science of building technology and executive techniques. In fact, wall structure provides a rich and varied technological repertoire that was in use in the 4th and 7th centuries BC, helpful in understanding the practice of architecture.

Examples of the above are all the cobs and stone structures of Gela, the *cyclopean art* of Cefalù, the *polygonal art* of Naxos, and the *square art* of Selinunte, Syracuse and Lentini, which are but a few examples of artefacts of high technological value.

2. CHARACTERISTICS OF THE FORTIFICATIONS

2.1 Typology and structure of the Greek fortifications

The fortifications are highly emblematic monuments because of their size and typology and in some way, they represent the face that a vast settlement offered to whoever was entering it, being the exterior of ancient cities modelled by the defensive walls. It is for this reason that sculptural and pictorial representations have often portrayed the fortifications as a symbol of the cities. These monuments represent very complex architectonic beings, more so, as a result of their remarkable extent and resultant difficulty in having a more unified and total vision of the monuments. Unlike single monuments, that are clearly located in a circumscribed area, the fortifications are often positioned outside the circuit of the archaeological site; here lies the difficulty of their in-depth study.

The traditional structure of Greek fortifications is very well known: it generally constitutes of a foundation, a (masonry) wall and the wall crown. Towers sectionalize the masonry into various parts of reduced length that facilitate defence. Doors constitute another important element, because they allowed access into the city. Defence is therefore entrusted to the “wall”, the static and aesthetic features of which represent the strong point of a fortification.

Figure 1. Fortification of Lentini

The characteristic feature of Greek walls is the laying of the blocks: they are not randomly and lifelessly assembled one on top of the other, rather they are harmoniously organised, with a view to expressing the static dependence, which is their duty. Each wall block is part of a predetermined order. The form given to each stone, its size in relation to others and the totality of the wall, the manner of assembly, the weaving of the material and the handling of the parameters, (which is presented differently each time), constitute the elements that give the wall its special look.

Figure 2. Fortification of Mozia

Figure 3. Fortification of Castel Eurialo (Siracusa)

Figure 4. Fortification of Segesta

In contrast with prehistoric cyclopean walls and support walls, the beauty of which depend on their imposing mass, the polygonal fortification walls used small sized

geometrically formed blocks, which could be assembled without resembling each other, in form or shape. Thus their joints formed a network of curvy and broken lines that captivated the attention of the spectator in an infinite swing.

Figure 5. Fortification of Selinunte

More so, apart from their state of the art composition, Greek walls integrated themselves into the surrounding landscape:

their blocks were almost always extracted from natural rock from which they would later rise like living beings.

The block parameter, which is initially raw, (that is in its cave form), or roughly worked upon with a hammer, especially along the joints, gives the wall a look of strength and vigorous resistance; this is perfectly convenient for fortification and support walls. The use of the polygonal form persisted in the fortification walls even when the rectangular form was predominant. In the same periods that city fortification walls and support walls were built in polygonal form, temple walls were rectangular constructions.

2. 2 The mechanical behaviour of stone masonries

The static performances of a stone structure can be outlined considering the following parameters:
-frameworks;
-type of stone arrangement;
-mechanical characteristics of building materials;
-execution modes.

The determination of physical and mechanical characteristics of stones and the identification of the type of framework that affects the bearing capacity present some difficulties. In fact, it is not easy to determine the resistance of a highly heterogeneous material, like a wall, experimentally without taking several samples to extract a statistically representative result; which would remove a substantial amount of material, certainly harmful to the masonry, especially in the presence of archaeological founds. Then their characteristics are not reproducible with laboratory experiments.

Some aspects of the structural response of masonry can be estimated first through a direct inspection, observing some peculiar feature of expert construction. There are rules regarding stone arrangement that grant satisfactory results of stability.

The building rules refer mainly to stone laying.

An expert construction consists of the search for the expedient uses of a better mechanical behaviour of the construction, such as, for instance, a precise stone tooth on the facade and, above all, along the thickness through transversal bindings; these make the building monolithic and help in arranging the stones, including those that are particularly irregular, with stone flakes to fill the empty spaces or to re-balance a shapeless masonry made of quite unlikely sized stones. The masonries are often made of the sort of stone available in the region. Sedimentary rocks flake off in parallel planes forming a stone wall very similar to a brick. Another sort of rock produces lenticular flakes. River pebbles, whole or broken, are very often used. Several masonries are made of heterogeneous material, yet discreetly homogeneous inside every type, except for the quality of the wall.

The lack of monoliths in a transversal direction represents the worst defect of a wall: it happens in walls made of pebbles or of two orderly assembled surfaces, connected through a shapeless fill. This makes the wall so frail, that it can't resist external forces perpendicular to its plane.

Laboratory experiments should be carried out to create prototypes: using them could show the effect of a force on a real structure. I've already touched upon the limits of these experiments and that is the reason why only a few experiments and theoretic analyses on stone masonries have been carried on.

2.3 Analysis of the masonries in the greek fortifications of Sicily

A systematic analysis on the mechanical behaviour of masonry is based on searches and tests of the building technologies and the several kinds of masonry sections which affect the structure response. The analysis identifies the several kinds masonry facing and connections that are (or are not) between the layers. The whole behaviour depends, above all, on attitude changes of the system units.

The collapse mechanisms of block structures are caused by a crisis of local resistance because of a contact release among the units.

These mechanisms are affected by the dimensional relationships among the blocks and by their arrangement:

this demonstrates the excellence of the traditional building rules. Then it can be stated, that the shape, the arrangement and the orientation of single units must always be considered.

So the mechanical quality of masonries, in the broadest sense, is determined by an "interior structure": this is composed of the framework and the arrangement of the components and gives the requested cohesion of the whole work through the mesh. On the basis of block shapes and the assembly methods we have identified the following patterns:

On the basis of block shapes and the assembly methods I have identified the following patterns: *lesbia masonry*, *trapeziform masonry*, *rettangolare masonry*.

Lesbia masonry. Lesbian masonries (Fig. 6) are composed of irregular blocks that have joints with sinuosities. This kind of building is similar to the polygonal structure (blocks with over four joint faces, straight-line edges as long as the blocks that can be cut obtaining precise angles). But in comparison with the polygonal one, has curvilinear blocks, and joints that

meet with sharp corner blocks. Generally, they exactly join through the cut and bend.

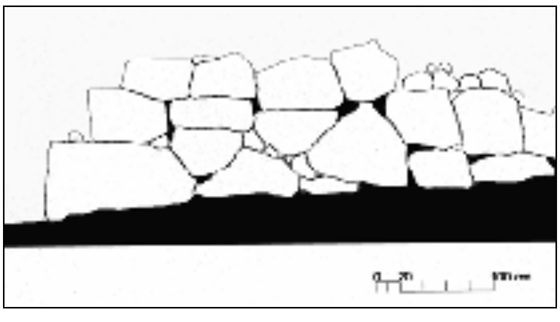

Figure 6. Naxos: *Lesbia masonry*

Trapeziform masonry. The blocks of a trapeziform masonry (Fig. 7) have four faces: two of them are parallel and horizontal; the other two faces are oblique and generally convergent, to form a trapezium.

There are three versions of the trapezoidal masonry: *irregular*, *isodomos*, *pseudisodomos*.

- *Trapeziform irregular masonry*. This is a transition structure between a polygonal structure and a structure made of four faced-blocks.
- *Trapeziform isodomos masonry*. The blocks are arranged in continuous rows of the same height.
- *Trapeziform pseudisodomos masonry*. The blocks are also arranged in horizontal rows but of unequal heights.

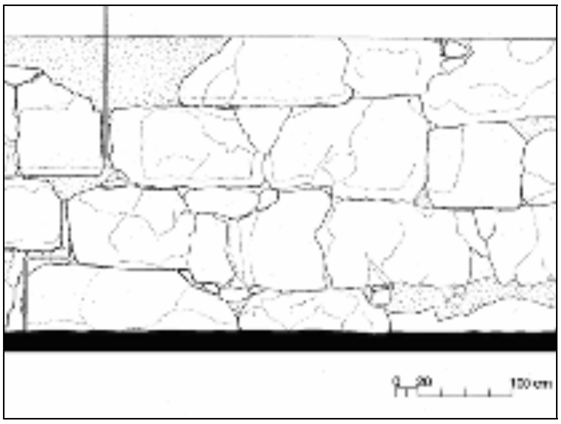

Figure 7. Cefalù: *trapeziform masonry*

Rectangular masonry. It is the best and more widely diffused building structure. Using parallelepiped blocks this masonry is easier to build than the others

and its reactions to gravitational thrusts are easy to control. There are three versions of block arrangement for rectangular masonries: *irregular*, *isodomos*, *pseudisodomos*.

- *Rectangular irregular masonry*. This arrangement presents horizontal joints and blocks cut at right angles (Fig. 8). The row height and the block length are irregular.
- *Rectangular isodomos masonry*. The blocks are generally cut at a right angle, (εγγώνιοι). Starting from the fifth century, they have regular height and length, a part of the angle stones. This arrangement method is easy, almost mechanical. It is also considered the best assembling system of the ancient ages. This version presents several ways to assemble the blocks, and several kinds of *diatoni* and *ortostati* arrangement (Fig. 9).

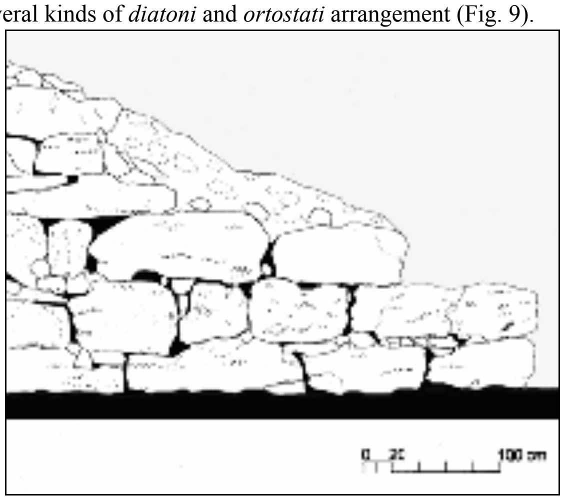

Figure 8. Mozia: *irregular masonry*

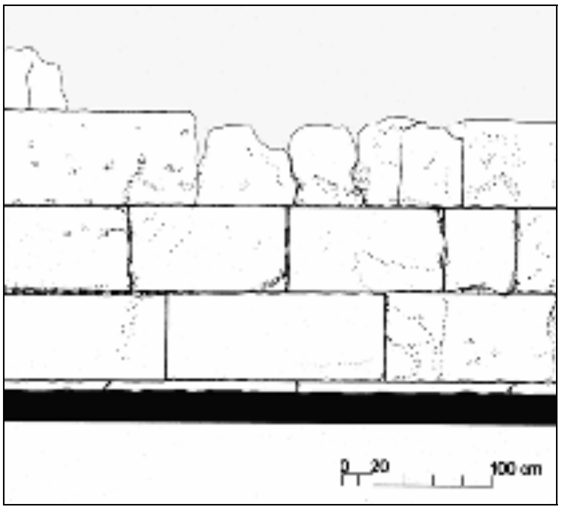

Figure 9. Castel Eurialo (Siracusa): *rectangular isodomos masonry*

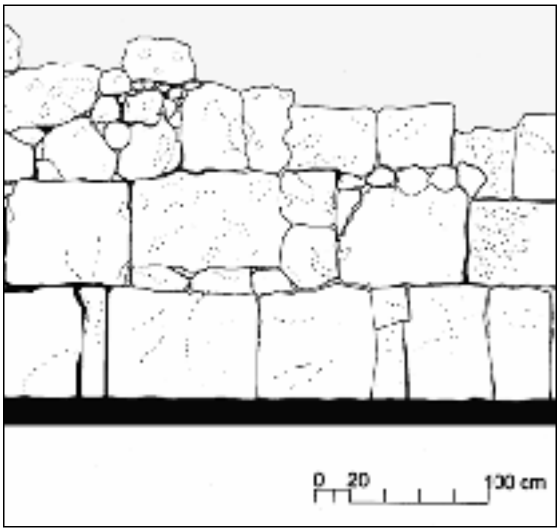

Figure 10. Eloro: *rectangular pseudoisodomos masonry*

Rectangular pseudisodomos masonry. The rows aren't arranged at the same height: between two or more high rows, shorter rows are arranged. The lateral joints are between the lower and upper blocks. The blocks of the lower rows are always *diatoni*, that means they are as thick as the wall (Fig. 10).

Diatoni blocks are used not only for saving reasons, but also to make the wall more resistant.

This system, that was adopted from the Archaic Era to the Hellenistic Era, presents several assembling methods and, like the *rectangular isodoma masonry,* depends above all, on *diatoni* and *ortostati* arrangement.

We think it's appropriate for a structural analysis to classify the different masonry sections in homogeneous groups of structures depending on the shape of the section and, more importantly, on the mechanical behaviour of this section. In fact, the word "masonry" refers not only to well-arranged stone structures, but also to the endless amount of stone aggregates. Moreover, we think, that the interior framework is a decisive factor in the case of local, then too global, collapse.

The masonry sections we have considered are essentially made according to an *emplekton* (Fig. 11) pattern: providing two faces and a fill of tiny pieces of stones, earth and flakes.

Figure 11. Gela: masonry section (*emplekton*)

There are two versions of this pattern:

- two walls (an outside wall and an interior one) and an inside fill;
- an outside wall and an inside fill leaned against a natural declivity.

Here the stresses are distributed on the section in a non-uniform way: for this reason the load on the outside wall, the stiffest one, is heavier than on the interior wall (more irregular). The more the interior wall buckles, the more the load eccentricity increases: the collapse is reached because of the instability of the stiffest wall and of the lateral stress produced by the inside fill.

3. CONCLUSIONS

It' very difficult to carry out an analysis on the masonries of Greek fortifications in Sicily, as archaeological founds are involved. The research I've carried out allowed me to survey some blocks assembling methods; that was necessary to understand the mechanical behaviour of a masonry. The survey can be carried out without damaging the wall, since it aims at giving above all visual outcomes: it will be anyway useful to get a lot of masonry building rules.

But further tests *in situ* are necessary to carry out an in-depth structural study, and they have not to damage such important material. It aims not only at enlarging the knowledge about our archaeological heritage, but also at restoring it.

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