Architectural models and urban planning

From Hadrian's Villa maquette to the amphitheater of Caesarea of Mauretania (Cherchell)

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Abstract: During the restorations carried out between 1964 and 1972 of Hadrian's Villa it was found a strange marble handmade, broken into various pieces that once assembled seemed to be a sort of maquette of a stadium. For many years scholars and researchers tried to guess and interpret its real function (an architectural model, a marble fountain, a game, etc.) but still remained some doubts. Thanks to a new research came out some relevant outputs: first of all, the handmade was a model of a building for spectacles (*munera* and *venationes*) that was never built inside the Villa, but the second result was even more interesting because it dealt with the architectural designing of a specific typology of buildings that we can find in almost all places visited by Hadrian during his reign: Cesarea of Mauretania (Cherchell, Algeria) , Virunum (Klagenfurt, Austria) Skythopolis (Beth-Shean, Israel), Lucera (Italia).
The fragments of the marble model were surveyed by means of 3D laser scanner, and then optimized for the virtual assembling by means of reverse modeling tools. From the orthographic high resolution images of the model, together with relevant sections, it was possible to compare them with the ancient standard measures used during imperial age and we detected the presence of *actus quadratus* hidden inside the plan of the *maquette*. The modular structure for the dimensioning of the *cavea* allowed us to investigate also the design of Cherchell's amphitheater and consequently understand the deep relation between architectural design and urban planning of this important capital of the Mauritanian province. The following step of the research is to deepen the knowledge of the amphitheater built in Cesarea during the reign of Juba II by means of a photogrammetric survey with the aim to understand its relation with the un-built amphitheater of Hadrian's Villa.

Keywords: ancient models, roman imperial architecture, laser scanner survey

The *maquette* from Hadrian's Villa

This paper is the product of the collaboration between different institutions, started in 2008 with a Ph.D. thesis (FANTINI, 2009) and then turned into an international collaboration inside the general frame of the European Project ATHENA[1] on the sustainable use of ancient theatrical buildings of the Mediterranean Basin. The link between the first research and the EU action is the need to investigate in deep the ancient

[1] The ATHENA "Ancient Theatres Enhancement for New Actualities" Project (ENPI 2008/150-286 nell'ambito di EuropeAid/126266/C/ACT/Multi)

design process that lead to the construction of places for spectacle in the ancient age: how did architects plan the number of seats for spectators inside the main typologies aimed at *spectacula* (theatres, Amphitheaters, stadiums and circuses)?. From this point of view the marble maquette from Hadrian's Villa represents an *unicum* because it is one of the few architectural models coming from the Greek-Roman ancient world (AZARA 1997) and also because it keeps, hidden inside its shape, some relevant aspects of that design process used for planning and dimensioning the parts of buildings for spectacles. The fragments of the model were found by Catia Caprino (1998: 113-151) during the restorations of the Villa carried out between 1964 and 1972 in the two areas, identified as "b" and "c" in the excavation report (Fig. 1) about Pretorio and Grandi Terme. It is not clear which was the Pretorio function so as the room identified with "C" in figure 1, but it seems realistic to guess it was a workshop, active during the last constructive phase of the Villa (RICOTTI, 2001: 189); in addition a so huge site needed something like a technical office in charge of restoration, maintenance and project development and looking to the marble finds of that part of the Hadrian's complex the hypothesis of a technical department located there it seems quite reasonable.

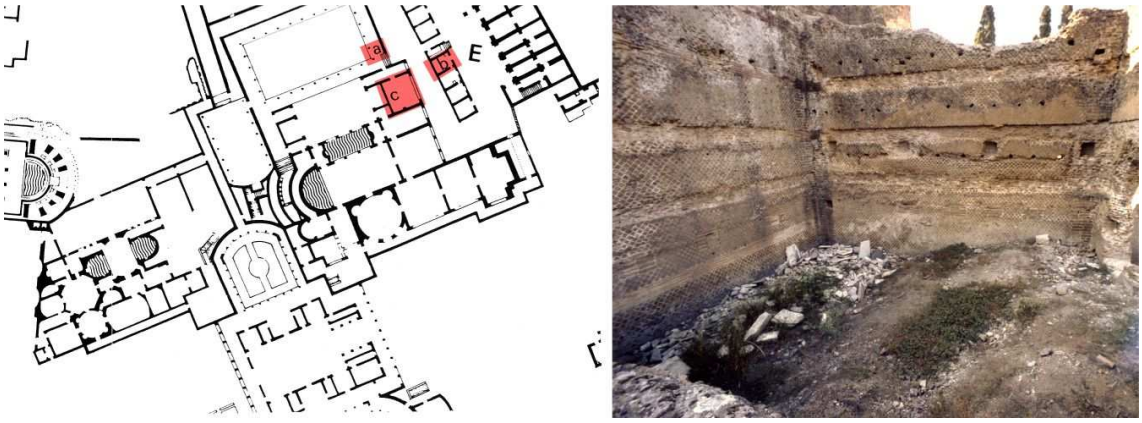

Fig. 1 – the areas of Pretorio and Grandi Terme where the model's fragments were found (image from CAPRINO, 1996) and the photo of the space called "C" in the excavation report by Catia Caprino (photo by Giorgio Verdiani).

Once collected all the fragments belonging to the marble *maquette* it was possible to understand in a better way its original shape even if some parts of the original marble slab were missing: this task it was harder than it could be thought at first sight, in fact the representation criteria adopted by the ancient architect was not comparable to the communication codes in use nowadays. Today when we talk about "scale models" of an architecture we refer to an isomorphic representation of a building or of a part of it, made with different materials if compared to the real construction, but in the case of the maquette from Hadrian's Villa it appears quite clear that the architect carried out the model using one of the many marble slabs used for the covering of the masonry walls of the site. The result of what we can define as a "recycling" is that all the measures along the vertical axis of the model are more little if compared to the plan of the building. In any case the accuracy of the carving and the general quality of the maquette let some researchers guess a possible function of the building and a realistic dimensioning of its parts: between them the deeper studies were carried out by CAPRINO (1998), SALZA PRINA RICOTTI (2001) and REGGIANI (2000). In their papers each one of them expresses a slightly different position ranging from the hypothesis of a stadium to a circus for chariot races, some other researchers, through underlining formal parallels with the terminal exedra of the

so called Gartenstadion of the Villa (HOFFMANN, 1980), come up with the possibility the artwork was not a model aimed at the construction of a new building but an decorative fountain (MACDONALD and PINTO 1997: 16). CAPRINO and SALZA PRINA RICOTTI have different positions on the real purpose of the model: the first suggested the possibility of an atypical representation (CAPRINO, 1998: 121) aimed just at providing a schematic view of the project of a stadium: bleachers, *vomitoria*, *dromos.* On a different position is SALZA PRINA RICOTTI that recognizes in the *maquette* a real architectural representation with 1:48 as scale factor[2]. Starting from the doubts emerged from the results obtained by those authors, in collaboration with the *Soprintendenza per I Beni Archeologici del Lazio* and the Professor Marco Bini[3] of the *Dipartimento di Architettura* of the University of Florence, it was decided to survey the three fragments of the marble model by means of a laser stripe technology device in order to get an accurate 3D digital representation of the *maquette*. The following text explains the methodology adopted and the results that came up from this first research that let us extend our scientific interest on other archaeological sites of the Mediterranean Basin, first of all Cesarea of Mauretania (Cherchell, Algeria).

The survey campaign

Thanks to the collaboration with Tryeco s.r.l. Servizi Integrati[4] and Benedetta Adembri, responsible of the UNESCO site of Villa Adriana for the Soprintendenza, it was possible to plan and carry out the survey of the three fragments of the *maquette*, stored inside the *antiquarium* of the Villa. It is probable they used Luni's marble for the slab which is 4,7 cm tall and measures approximately 172 cm for 90 cm. It was not possible to move the main fragment of the model from its protective box in order not to damage the delicate find, but thanks to the small size of the equipment adopted for data acquisition it was possible to move it all around the fragment without touching it. The equipment adopted was a NextEngine Desktop 3D Scanner model 2020i that uses MultiStripe Laser Triangulation (MLT) technology with an accuracy of 0,0381 cm; for the main fragment 60 scans were needed in order to complete the more detailed features of the *vomitoria* (comprehensive of stairs and arches), 47 for the intermediate piece and 25 for the smaller one. For the texturing of the mesh model we opted for an independent campaign with a Nikon Coolpix L5 in order to integrate the apparent color data captured by the scanner's camera.

[2] She obtained the reduction factor by measuring one step of the *vomitoria*, but in our opinion that measure seems to be too small in comparison with the rest of the model. For this reason 1:48 reduction scale has been reconsidered in the present research. In any case SALZA PRINA RICOTTI was the first that without any doubt affirmed the model was not an *ex voto* or some other kind of decorative object.

[3] The Professor Marco Bini was the tutor of Filippo Fantini's Ph.D. thesis and the scientific responsible of the first 3D laser scanner survey campaigns on Villa Adriana (Grandi Terme, Palestra and Serapeo).

[4] A special thank goes to Matteo Fabbri for the high professionalism shown during the survey campaign and the help provided during the registration and optimization phase of the mesh model of the *maquette*.

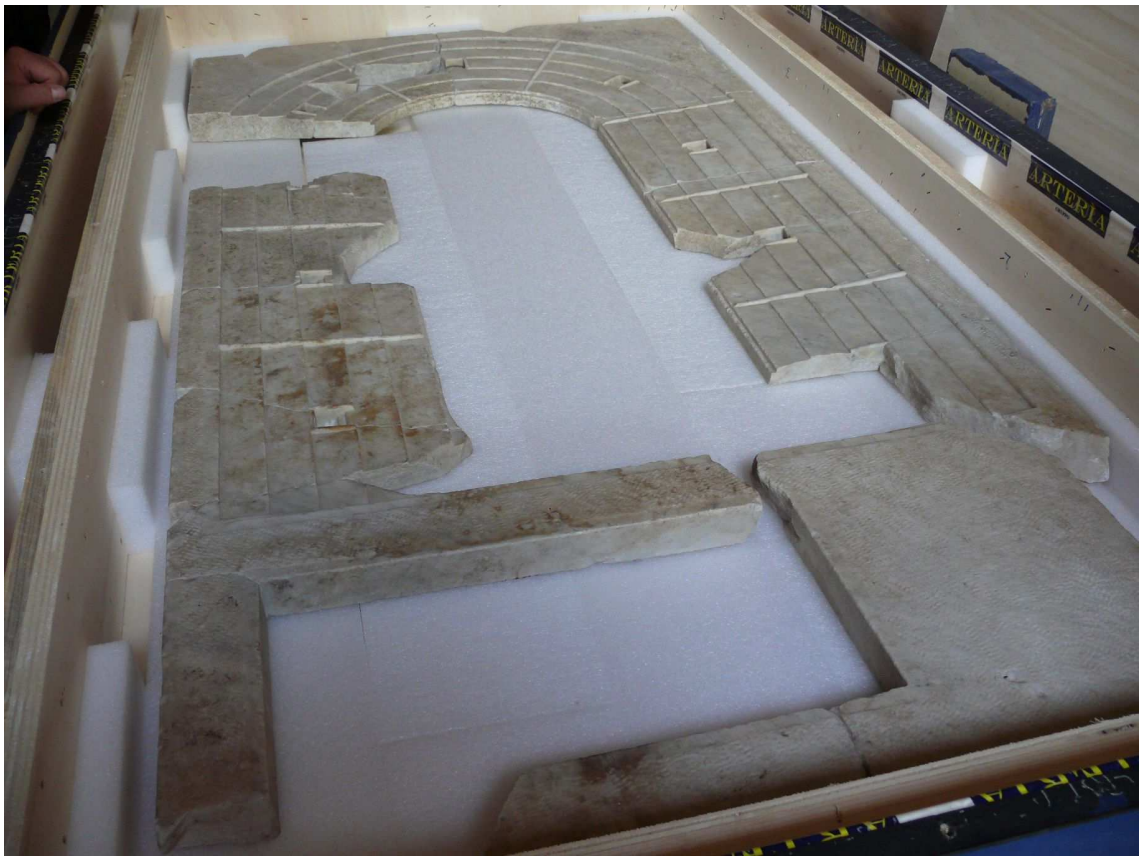

Fig. 2 – the three model's fragments inside the protective box.

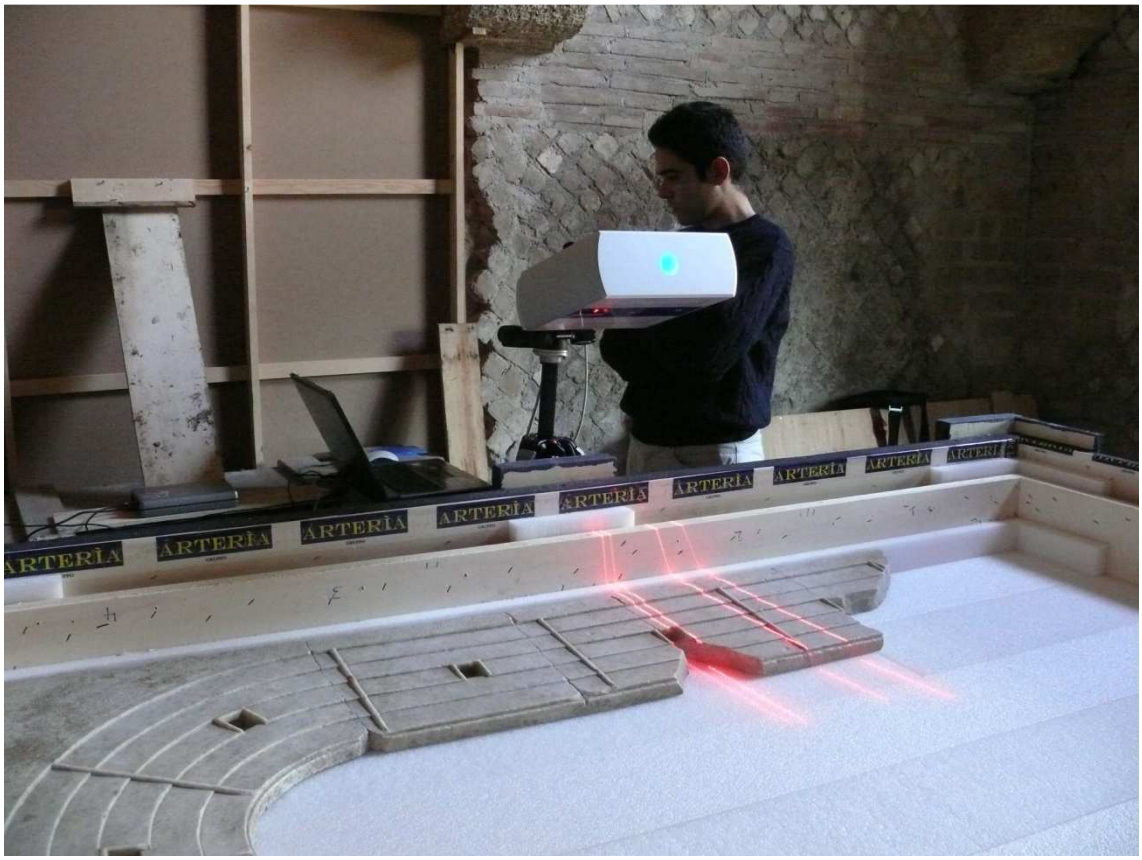

Fig. 3 – the NextEngine Desktop 3D Scanner while surveying the main fragment.

Once obtained three different models of the fragments they have been healed by topological errors as dangling faces, small polygons clusters, non-manifold faces, etc.: then all those parts not surveyed because affected by the occlusion phenomena have been integrated by means of direct modeling tools inside Luxology Modo and then exported inside the mesh processing application INUS Technology Rapidform in order to weld all the different parts by means of bridges of polygons and fill holes tools (Fig. 4).

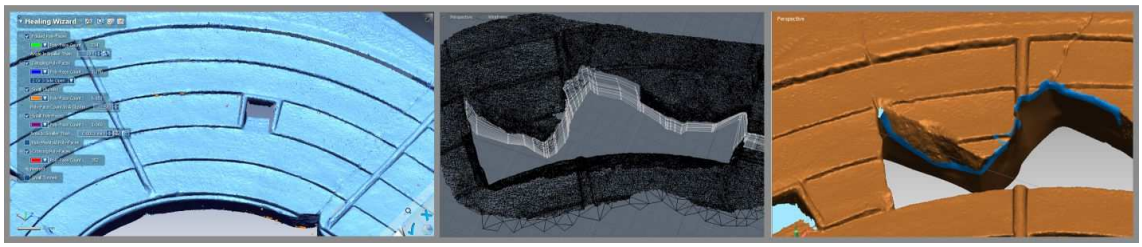

Fig. 4 – modeling phases: from topological healing to the integration of those parts of the maquette not accessible to laser rays.

For every mesh model of the fragments have been constructed two different models, one at high and another at low resolution. Every low-poly has been UV-mapped and those reference systems used for encoding the normal of the high resolution models inside conventional tangent space normal maps. The same UV references were used for storing apparent color textures, projected on the surface of the low-poly models thanks to a camera matching plugin for Newtek LightWave 3D. The textured optimized models have been reassembled inside Luxology Modo on the base of 2D references obtained by sectioning high resolution versions of the meshes inside reverse modeling application: those 2D templates helped the process of matching of all the different parts. High resolution renderings of the reassembled model were computed inside Luxology Modo and then put in the right scale for the production of drawings for documentation and analysis of the find (Figs. 5 and 6).

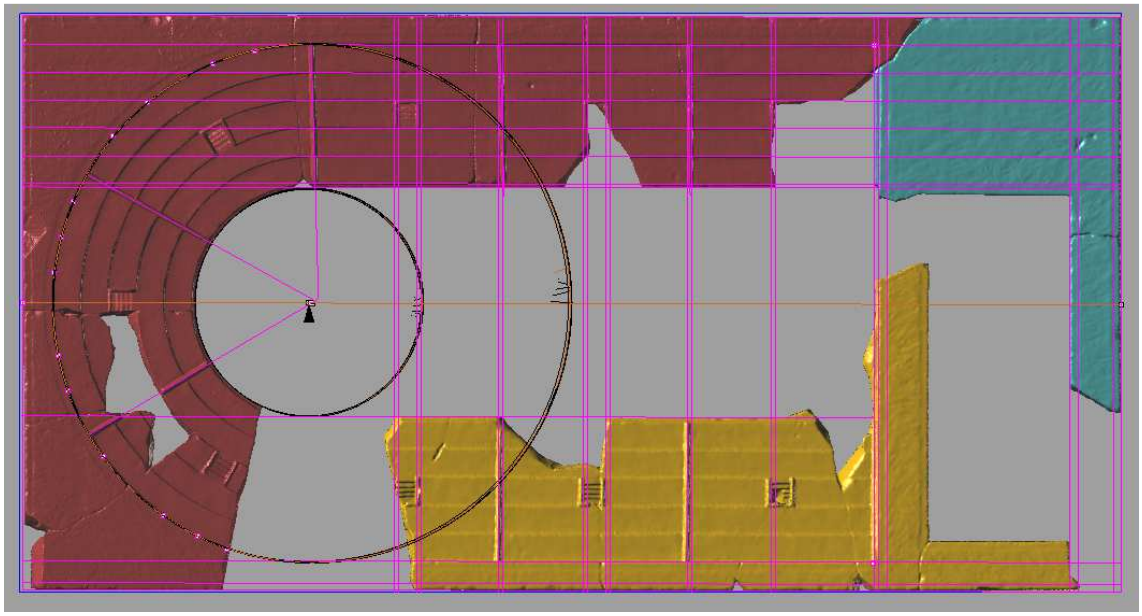

Fig. 5 – 2D reference used as template for reassembling the fragments.

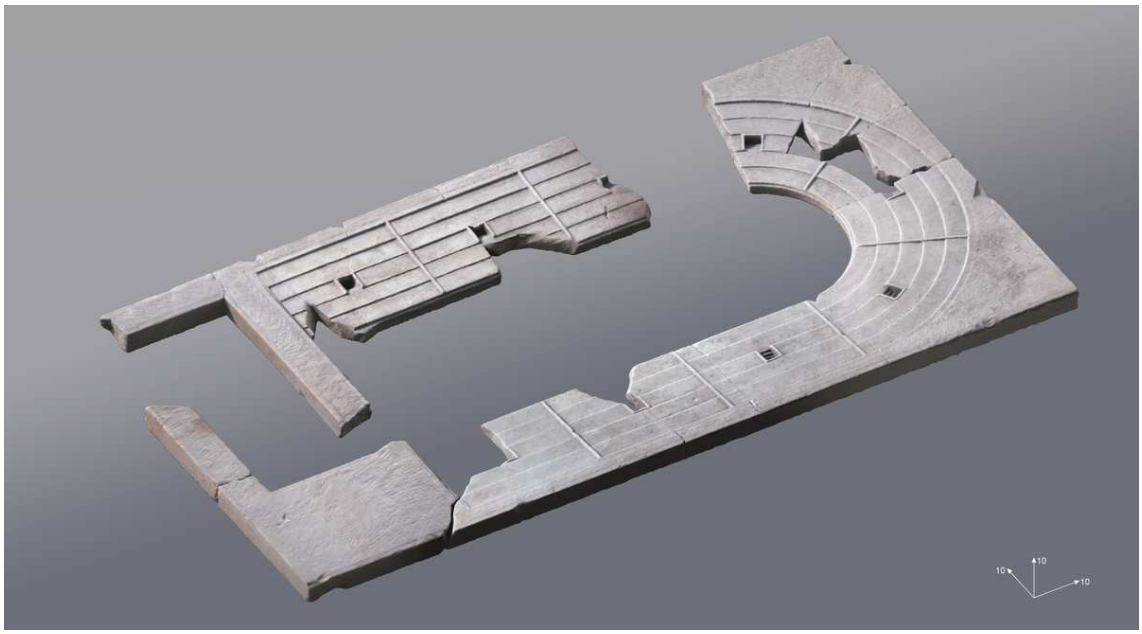

Fig. 6 – rendering of the low-poly textured model with normal and color maps applied.

The set of drawings formed the base for the following steps of the research that needed an accurate survey and a high quality texturing in order to document all the parts of the ancient models but also the traces carved by the architect at the time of the maquette construction. In fact it is not possible to notice some relevant information for the interpretation of the model without seeing it from close as in the case of the vertical lines carved on the external surface of the slab in order to determine the position of the two centers used for carving the original semicircles (one is partially present as explained in the following text).

Was it a scale model of a stadium?

Before going on with the achieved results it is important to underline some relevant aspects of this research: when it is not possible to apply a conventional methodology, as the comparison between similar finds belonging to the same category or age, it is important to develop a different approach where the knowledge about the design process used by ancient architects, as in this case, may be helpful in finding a possible reading key. The few architectural models coming from the Greek-Roman age that have survived to the action of time have been catalogued and studied by AZARA in the catalogue of an interesting exhibition held at the Centre de la Cultura Contemporània of Barcelona during 1997. Apart the maquette from Hadrian's Villa should be mentioned the following scale models of building: a temple from Ostia (CAPRINO, 1998: 124-125 and SALZA PRINA RICOTTI, 2001: 407), the Adyton of the A Temple from Niha (Lebanon), a fragment of the Great Altar of Baalbek shrine, the cavea of a theatre from the same ancient town and a bas-relief of a *frons scaenae* stored at the Museo Nazionale Romano in Rome. In general those models are quite distant in comparison to *ex voto* or other objects of common use that also during the ancient age were decorated using architectural features (SARDO, 2004).

Apart the use of high accuracy equipment as laser scanner, it is important to underline the combination of different tools applied in this research:

- the role of ancient treaties, in particular Vitruvius and Heron from Alexandria
- the ancient measuring systems in use during the construction of Villa Adriana
- the typological comparison

On the whole thanks to this approach we achieved different results concerning the nature and the function of the marble *maquette* in comparison to what other researchers affirmed. The technical content of architectural models let them distinguish from the great amount of small terracotta or marble handmade found in archaeological sites: in general they are built in order to communicate to a larger number of persons rather than a small group of technicians (architects, collaborators, builders) as in the case of 2D drawings which always needed special skills and a deep knowledge of the graphic technical codes.
Vitruvius uses the word *exemplar* with to describe a scale model in the 10th book of his treatise: it was a scale model of a machine aimed at the defense of the town of Rodi in case of siege. Another word used in ancient writings with the meaning of model is *simulacrum* (the same used for statues), but in our opinion is even more important to focus our attention on the three aspects of another term used by Vitruvius: the *dispositio* (GROSS, 1997). *Dispositio* is a technical word used by Vitruvius in order to indicate three different aspects of how an architectural design should be carried out; these three forms of representation are: *ichnographia*, *orthographia*, and *scaenographia*. It is important to underline the sequence in which they have been listed by the Latin author because they form part of a cause-effect process that at that age, more than now characterized the approach to architectural design because they deal with a programmed phase set that starts with the creation of a sort of map (*ichnographia*), then an elevation (*orthographia*) and at the end a still not clear three dimensional evaluation of the perceived space. In general scholars tend to distinguish between the meaning used by Vitruvius and the contemporary homologous terms used by contemporary architects, but in any case the parallelism is evident even for those who are not specialized in Latin philology. In our opinion it is very important to keep it in mind: the importance of the plan (ichnographia), as first step for the design process was fundamental because it formed the base for dialoguing, negotiating and approval of the project. The rigid design process, divided into three phases, expressed by Vitruvius may also reflect the need to verify within the design staff (architects) and the client (a community or a single person) every advancing of the proposed design of a new building and as consequence to convert 2D drawing of difficult interpretation into hybrid forms of representation that still keep the roughness of a basic preliminary 2D design and by the other side have to be clearly understood: the main building parts, their proportions, etc..
From this point of view the strange shape of the model and the evident lack of proportions of the elevation begin to be clearer, from the point of view of ancient architects, because the model should go through the evaluation of the Emperor. The importance of the promoter of the construction let us imagine the reason why the architects decided to build the maquette in marble and did not use a cheaper material. It is quite probable that Hadrian never seen the maquette or hadn't enough energy at the end of his life to give the architects his suggestions and the final approval (it is important to remind that the Emperor died in Baia and not in his villa in Tivoli). Also the model of a peripteral temple from Ostia seems to confirm to the same hypothesis because it is not a 3D isomorphic representation of a temple as it follows the same principles that we found in the model from Hadrian's Villa: it is an ichnographia converted in a simplified three-dimensional representation (Fig. 7).

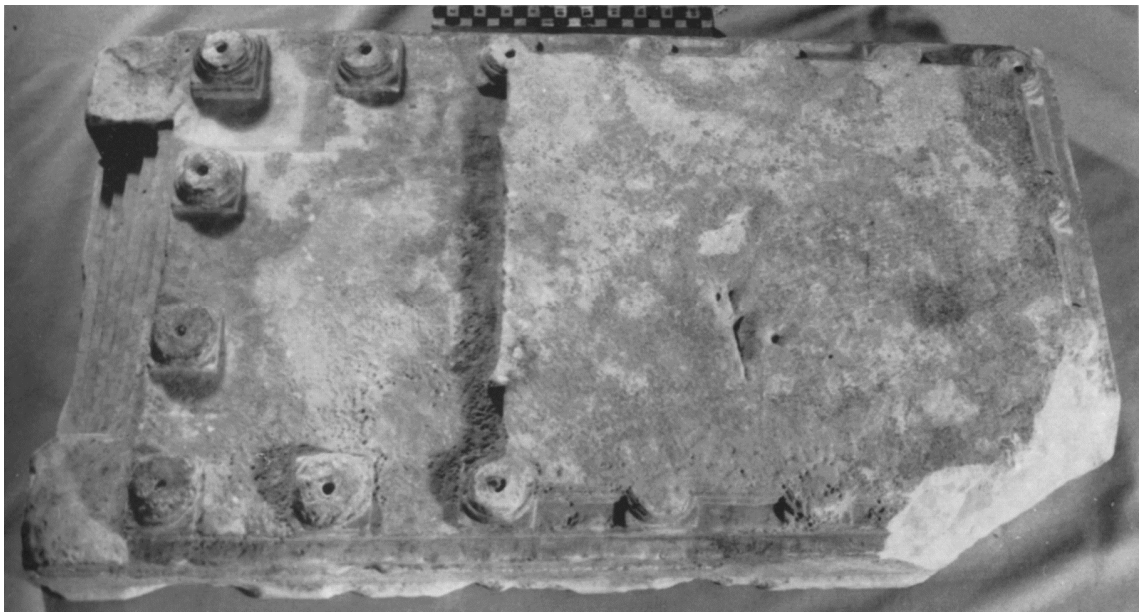

Fig. 7 – A photo of the model from Ostia, as the model from Hadrian's villa it seems to be constructed with the aim to communicate not the whole design, but the Vitruvius's ichnographia.

Other scholars put in doubt the validity of the measures of the marble model of a building for spectacles by adding the justification that it was just aimed at communicating the typology of the building and not its real proportions because, in case it had to represent the design of a stadium, it would have been totally different proportions in comparison to the Greek typology for athletic competitions. The ratio between length and height of *dromos* in Greek stadiums is statistically 1:6 while in the *maquette* is approximately 1:2 (CAPRINO, 1998: 121). In our opinion the model do not represent a stadium and its proportions should be considered correct but only from the point of view of its *ichnographia*, in other words its plan, but the only way to confirm other hypothesis is to go in deep in the field of ancient standard measures. Many Latin authors wrote about their contemporary measuring systems in particular inside the *Corpus agrimensorum romanorum* are gathered all the survived ancient texts concerning regulations, laws and technical topics that deal with territory and its measurement (MASCI, 2004). The *Corpus* was developed with the aim to be a didactic tool for the management of territory; the first writings contained there, date back to the first century A.D. and starting from that time, every successive author belonging to this set of books explains geometrical rules and formulas for the measurement of lengths and areas of different shapes. Depending on many different factors (the author, his origin, the time in which he writes, etc.) the list of standard areas changes or have different overlapping terms with same meaning. Also other authors not belonging to the *Gromatici veteres* as Varro and Columella included in the frame of their different kind of topics standard areas for the measurement of terrain. The measurement of lengths, perimeters, areas by means of geometry and mathematical formulas also formed part of the know-how of architects that worked together with surveying experts for the measurement of buildings and not just for the division of terrains or for the construction of roads, as clearly expressed by Columella (CALZECCHI ONESTI and CARENA, 1977: 334-338):

> *"Quod ego non agricolae sed mensoris officium esse dicebam, cum praesertim ne architecti quidem, quibus necesse est mensurarum nosse rationem, dignentur consummatorum aedificiorum, quae ipsi*

> *disposuerunt, modum conprehendere, sed aliud existiment professioni suae convenire, aliud eorum, qui iam extructa metiuntur et imposito caluclo perfecti operis rationem computant; […].* "

This brief Columella's writing forms part of the introduction to the fifth book of his treatise on the Art of Agriculture and is placed before one of the more complete lists of standard measures, *areae mensura*, that can be found (also in comparison to *Gromatici veteres*). The more relevant aspect is that he makes reference to the professional collaboration, as nowadays, between architects and surveyors with the aim to calculate the cost of a new construction or in order to evaluate the measures of built architectures. On the active role of surveyors inside the general frame of profession of the architect, in particular when it was needed high accuracy for tracing the *ichnographia*, can also be quoted Balbus, perhaps one of the best known between the *mensores aedificiorum*. At the beginning of the II century A.D. he writes (MASCI, 2004: 102):

> "*Ex pluribus circulis forma sine angulo, ut harenae ex quattuor circulis: ex pluribus quam quinque, ut in opere picturarum aut architectura* "

It is an explicit reference to the oval shape of the amphitheatre's *arena*, geometrically built by means of a compass with two different radiuses, in order to achieve a continuous curve as clearly explained by DOCCI and MIGLIARI (1998). In the following table are summarized some of the most important standard areas for the measurement and planning of both territories and urban areas during Roman Empire (Tab. 1).

Pes Constratus PC (GV)	Passus (GV)	Actus Minimus (GV)	Clima (C)	Actus Quadratus (GV)	Iugerum (GV)	Porca (C)	Heredium (V)	Stadium (GV)	Centuria (GV)
1x1 pedes	1x5 passi	120x4 predes	60x60 pedes	120x120 pedes	240x120 pedes	180x30 pedes	240x240 pedes	125 passi	200 iugeri
1 PC	5 PC	480 PC	3600 PC	14400 PC	28800 PC	5400 PC	57600 PC	625 PC	5760000 PC

Tab. 1 – standard areas from *Gromatici Veteres* (GV), Varro (V) and Columella (C).

The interpretation problem concerning the *maquette* from Hadrian's Villa deals with the identification of measures and shapes that had to be considered by the architect for the development of the *ichnographia* of that project. From this point of view should be also quoted an interesting study on the Emperor's Villa in Tivoli from DI TONDO (2007) that put in evidence how different constructive phases of the Hadrian's dwelling have been planned through an evident use of *actus quadratus.*

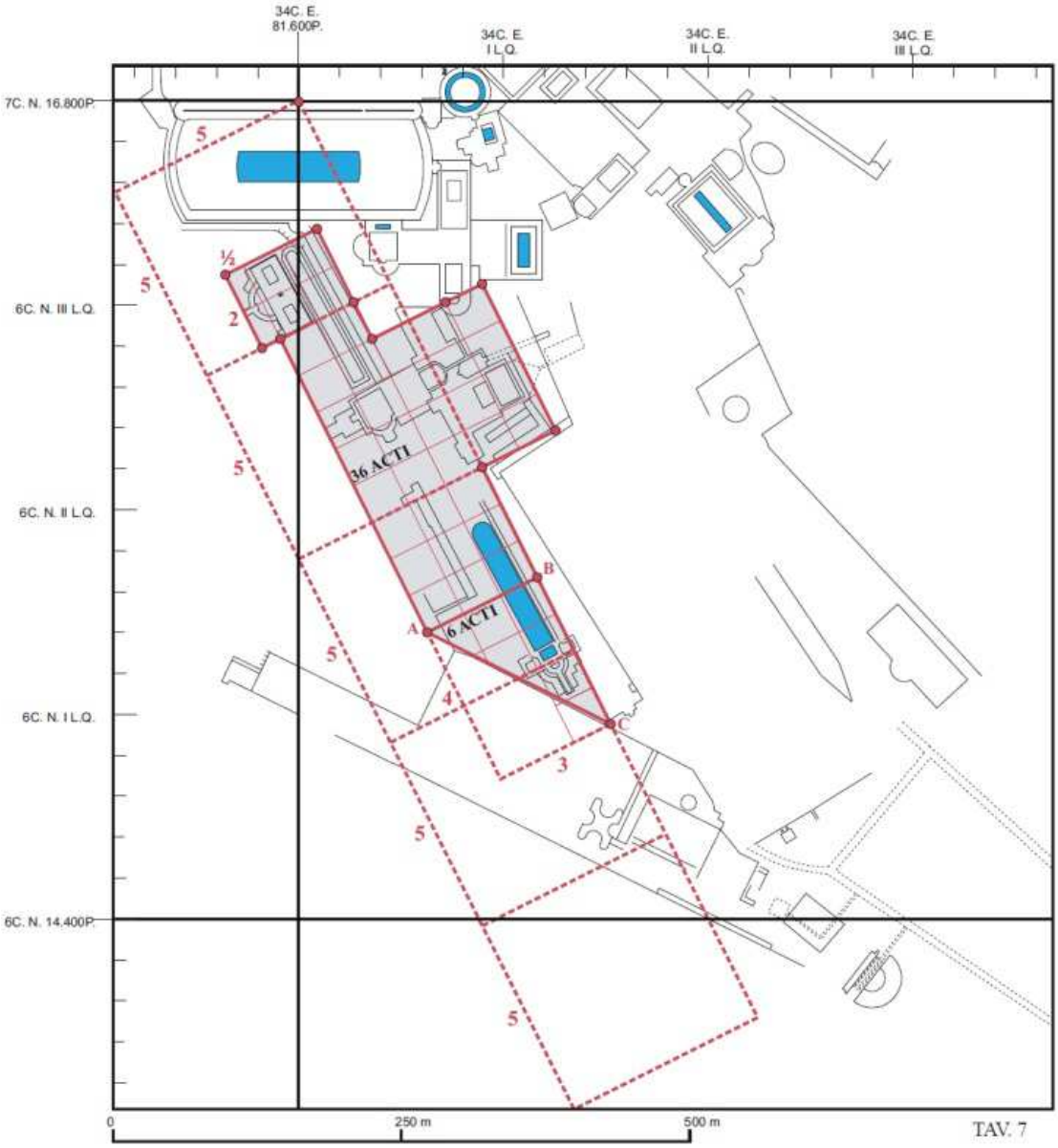

Fig. 8 – Interpretation of one of the design planning sequence of the Hadrian's Villa by DI TONDO (2007). A*ctus quadratus* has to considered a constant presence in architectural design and not just specific tool for the management and

In general the approach of researchers and scholars interested in ancient topography is based the use of those measures for the determination of planning phases and subdivision of territories, but it is not so common to find a similar methodology (based on areas) to the interpretation of single buildings even if ancient authors underlined the importance of surfaces computation also for architectures; in fact Balbus wrote (MASCI, 2004: 86):

> "*Planum est quod Graeci epipedon appellant, nos constratos pedes, in quo longitudinem et latitudinem habemus; per quae metimur agros, aedificiorum sola, ex quibus altitudo aut crassitudo non proponitur, ut opera tectoria, inauraturas, tabulas et his similia*".

"Agros", but also "*aedificiorum sola"* can be measured by means of "*constratos pedes"* and in our opinion also the *maquette* of a building for spectacle may reflect this approach to construction and planning: all things considering it would have been strange not to consider areas, in addiction to linear measures, as a fundamental part of the design process. The abundance of standard measures of small entity as for example the *clima* seems to fit more with buildings than urban planning or subdivision of territories being a square of 17 by 17 meters (Fig. 9).

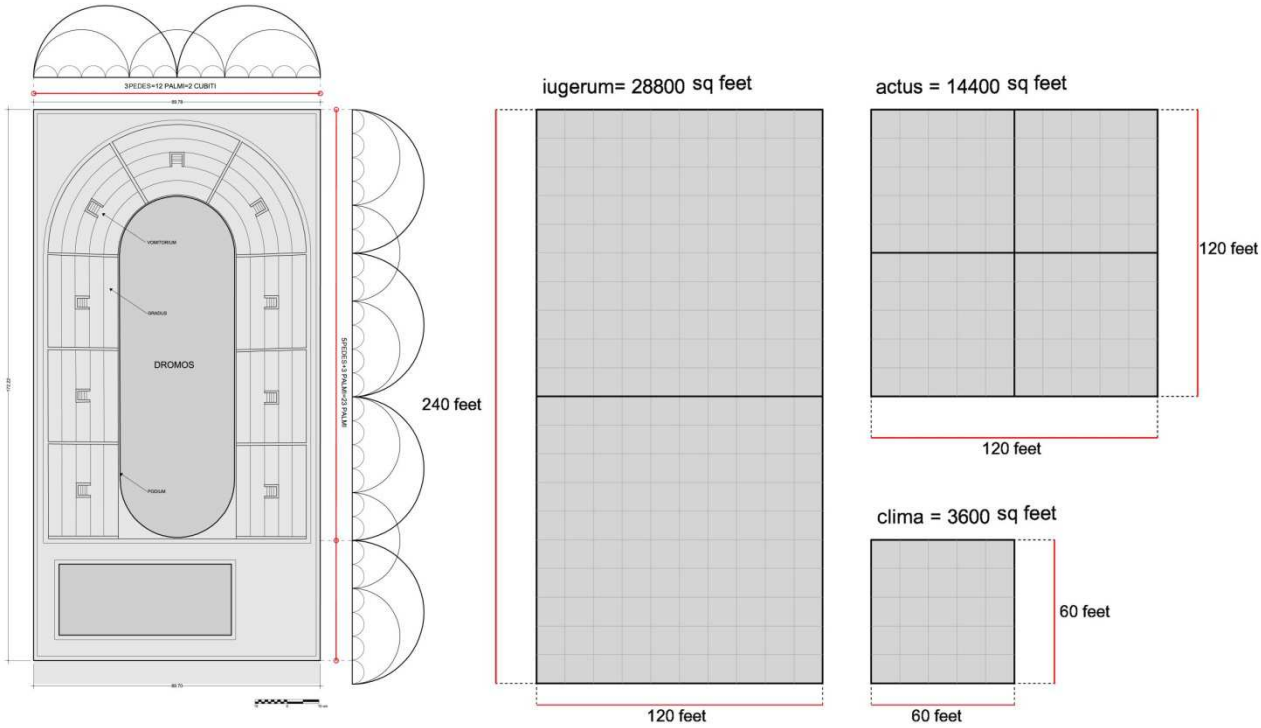

Fig. 9 – The 2D drawing of the model of building for spectacle scaled in order to compare it with the set of ancient measures *iugerum*, *actus* and *clima*. Those areas have been used for calculating the areas of terrains, but they were also for the planning of building constructions.

Once obtained high resolution ortho-images of the marble model we made hypothesis of how standard measures of areas could fit with that design: the result was that the whole marble slab (three by almost six feet) may have represented the total area assigned for the construction of the building. In this case the shorter edge of the slab, perfectly equal to three feet may represent in the real construction 120 *pedes* (35,4 meters). Further developing this assumption the representation scale of the ichnographia would be 1:40 and the whole model seems to be designed using a modular grid equal to 3/5 of a *palmus* that in the building would have been exactly 6 *pedes* (Fig.10).

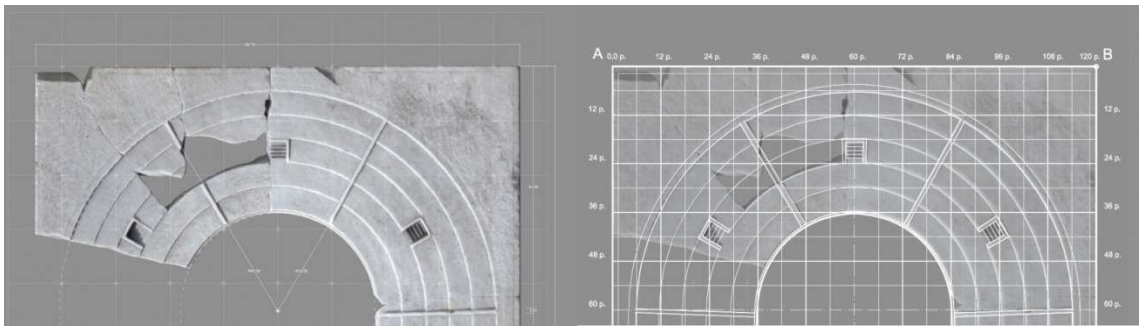

Fig. 10 – A zooming on the cavea of the marble model: on the left an ortho image of the mesh with texture applied and on the right the modular grid used for proportioning every part of the construction. The grid is formed by squares of 3/5 of *palmus* that correspond to 6 feet in the reality being the maquette e 1:40 scale representation.

Modularity, which is called *symmetria* by Vitruvius (GROS 1997: 26-27), is the way ancient, but also contemporary architects approach the problem of proportions: it is a way to drive the design of the building, its plan, its façade. Inside the frame of ancient design process *symmetria* had also other important features because it facilitated the computation of areas and quantities useful for the requirement of the building to construct. It was not just a methodology for achieving an aesthetic result, but also for making easier the computations that also nowadays form part of the task of an architect. In the case of building for spectacles can be useful to take in consideration two manuals (more than treaties) from Heron from Alexandria: *De mensuris* and *Stereometrica*, both them have been included by J. L. Heiberg (1976) inside five books entitled "*Heronis Alexandrini, Opera quae supersunt omnia*".

De mensuris provides formulas aimed at measuring different objects related to architecture: theatre, amphitheater and hippodrome are the three typologies that Heron briefly treated from the point of view of numerical calculation, for instance *De mensuris 24*, entitled "Measurement of theatres" (Fig. 11):

> "*We can measure a theatre in this way: it the bigger perimeter of a theatre is equal to 100 feet and the smaller is 40 feet, we can know how many people get into it. Calculate in the following way: the bigger perimeter plus the smaller perimeter is equal to 100+40=140 feet, 1/2x140=70 feet. Count the rows (steps) of the theatre and we find out they are 100; 100x70=7000 foot; this is the number of people that fit, 7000.*"

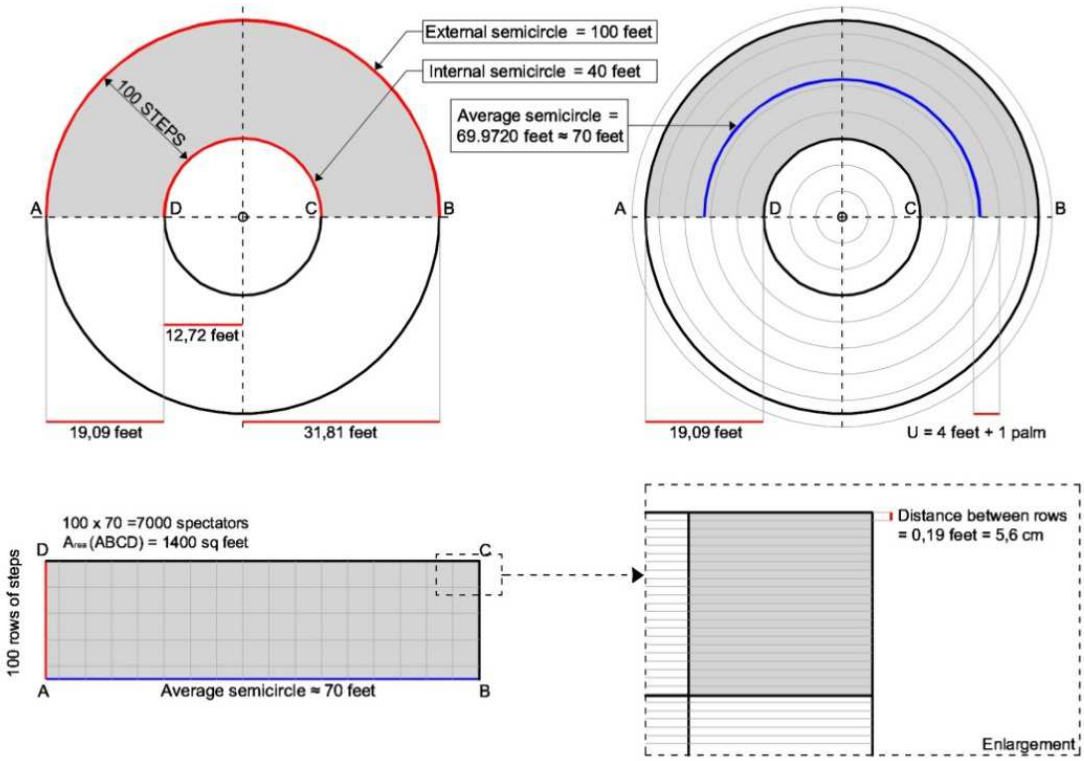

Fig. 11 – De mensuris 24, entitled “Measurement of theatres. Scheme by LARA-ORTEGA and FANTINI (2013).

The paragraphs from 40 to 43 of the Stereometrica provide interesting examples related to the computation of theatre capacity; also the title of the chapter is indicative: “different way for calculating basins”. The first example at the paragraph 42 is quite similar to Metrica 24 (Fig.12):

> *“A theatre whose external circumference is equal to 420 feet and the internal is 180 feet is provided with 280 rows of sits; if we want to determine the capacity of spectators it should be done like this: the external circumference plus the internal circumference is equal to 420+180=600 feet; 600/2=300; the number 300 multiplied by the number of rows, that is 280, leads to 300x280=84000 spectators; because each foot corresponds to a person. In the case we had on the whole 600 feet, we divide them in two, in order to obtain the average. 1/2x600=300. If we have 50 rows: 50x300=15000 feet. This is the number of persons that fit because the space for a person is equal to the width of a foot.”*

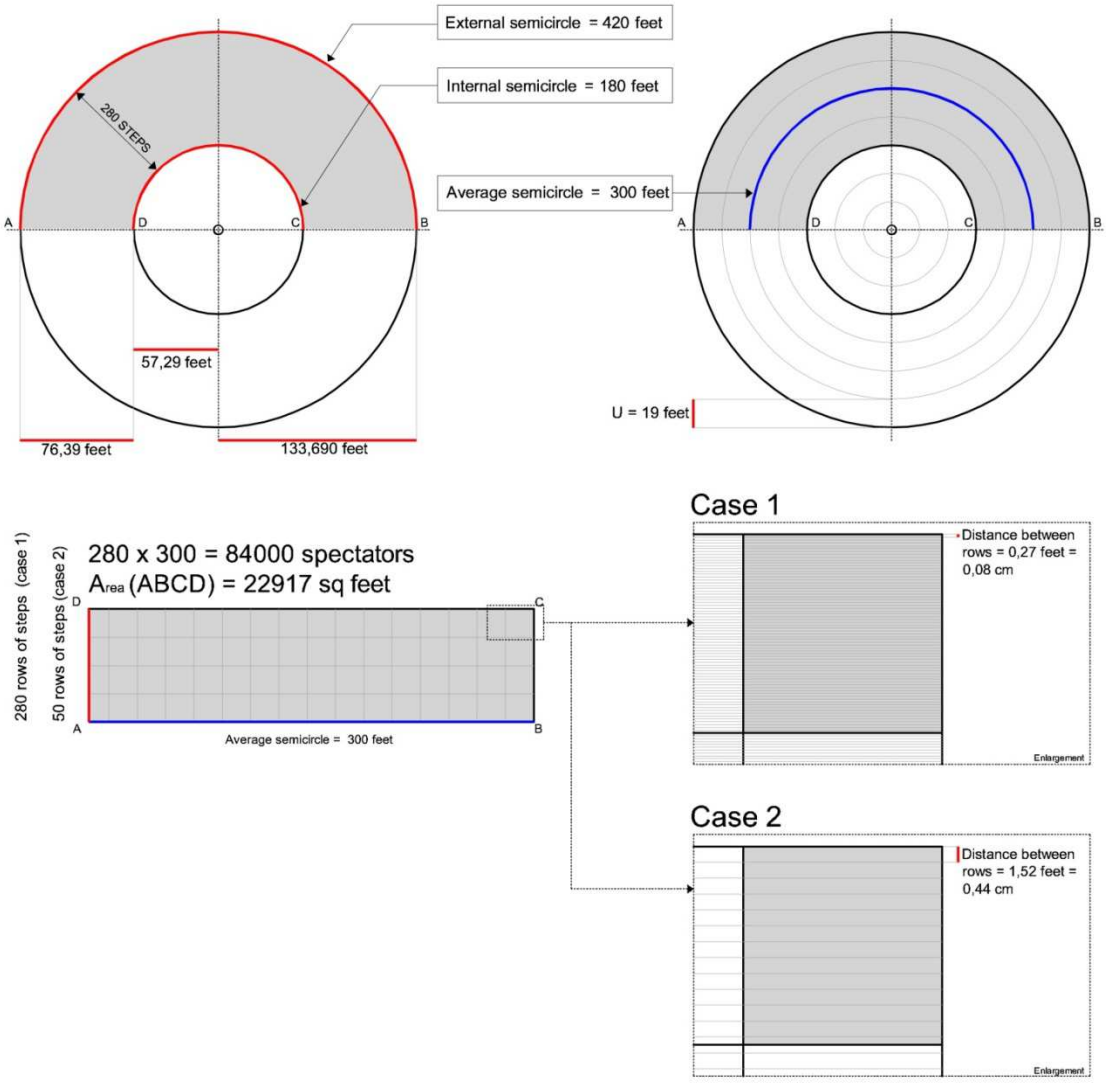

Fig. 12 – Graphic interpretation of the "Different way for calculating basins" contained in Stereometrica by Heron. Scheme by LARA-ORTEGA and FANTINI (2013).

As first general statement on these relevant formulas for *cavea*'s design we can say that Heron basically applies the same methodology in the two books: he explains by means of numerical examples special cases of circle's squaring. Drawing the examples is possible to notice the presence of a common module, a greatest common divisor of the *cavea*, that starts from the *orchestra*'s circumference and arrives to the upper *praecintio*. In other words Heron converts the architectural problem of spectator's capacity of theatres into a geometrical/mathematical problem where semi-circular rings have been converted into rectangles whose sides are respectively the number of rows of the bleachers and the average between circumferences: it is not a problem of areas because rows are a scalar quantity but we know from Vitruvius that the standard depth of every sit of a theatre ranges from 59,2 to 74 cm, which are two feet and two feet and a half (GROSS, 1997:570-571):

"*latitudines eorum ne plus pedes duo semis, ne minus pedes duo constituantur*."

Now the “equation” or the “algorithm” that lays below the marble *maquette* can be solved through a set of new tools directly coming from ancient manuals and treatise: in case the first assumption was correct (1:40 scale) we could calculate the areas of the bleachers and find some relation between them and the standard measures contained in table 1, or some other quantity in relation to a whole number of spectators (for example 1000, 5000, or similar as happens nowadays with building requirements). The two linear bleachers and the semicircular one (Fig. 13) have the same areas and if we assume the 1:40 scale, as the correct reduction factor, the result is quite surprising because each one of the three sectors measure 3600 *pedes constrati* which correspond exactly to the standard area called *clima* by Columella *(*CALZECCHI ONESTI and CARENA, 2013: 338-339).

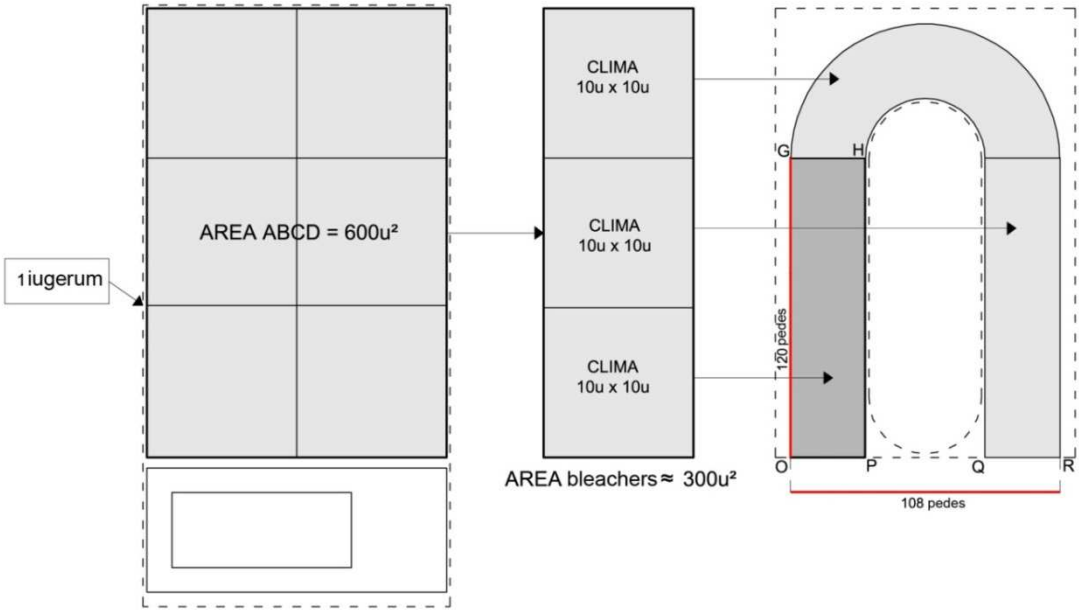

Fig. 13 –*iugerum* and the *clima,* the standard measures for areas calculation form part of the design of the whole building and of the bleachers (FANTINI, 2009: 93).

Caesarea of Mauretania and its Amphitheatre

For a long time the *maquette* from Hadrian’s Villa was not considered a real scale model, but thanks to a metrological approach was possible to add a possible new solution to its strange system of proportions: now we front the other problem concerning the building that is its typology. There are a few number of stadiums characterized by the double semicircles (*sphendonai*) in the smaller sides: Nysa (Caria, Turkey), Nikopolis (Epiro, Greece), Afrodisias (Caria, Turkey), Laodicea ad Lycum (Frigia, Turkey). CAPRINO (1998) made the *maquette* fit with that typology of building for sports, but there are also other buildings with same features (double *sphendonai*) and with proportions quite similar to the model from the Villa; we speak of not oval amphitheaters that seem short stadiums, it is possible to find them in: Scythopolis (Beth-Shean, Israel), Lucera (Italy), Virunum (Klagenfurt, Austria), Flavia Solva (Steiermark, Austria), and Caesarea (Cherchel, Algeria). This last one seems to be the first one characterized by double *sphendonai* (Fig. 15); it belonged to the African province of Mauretania and was built by Juba II between 25 and 15 BC. The survey on the dimensioning system adopted for the construction of Roman public buildings of Caesarea was carried out

using a 1/10.000 map of the town and confirms the presence of *actus quadratus* in each one of the three main developments phases of Caesarea (CHENNAOUI, 1994: 73-85).

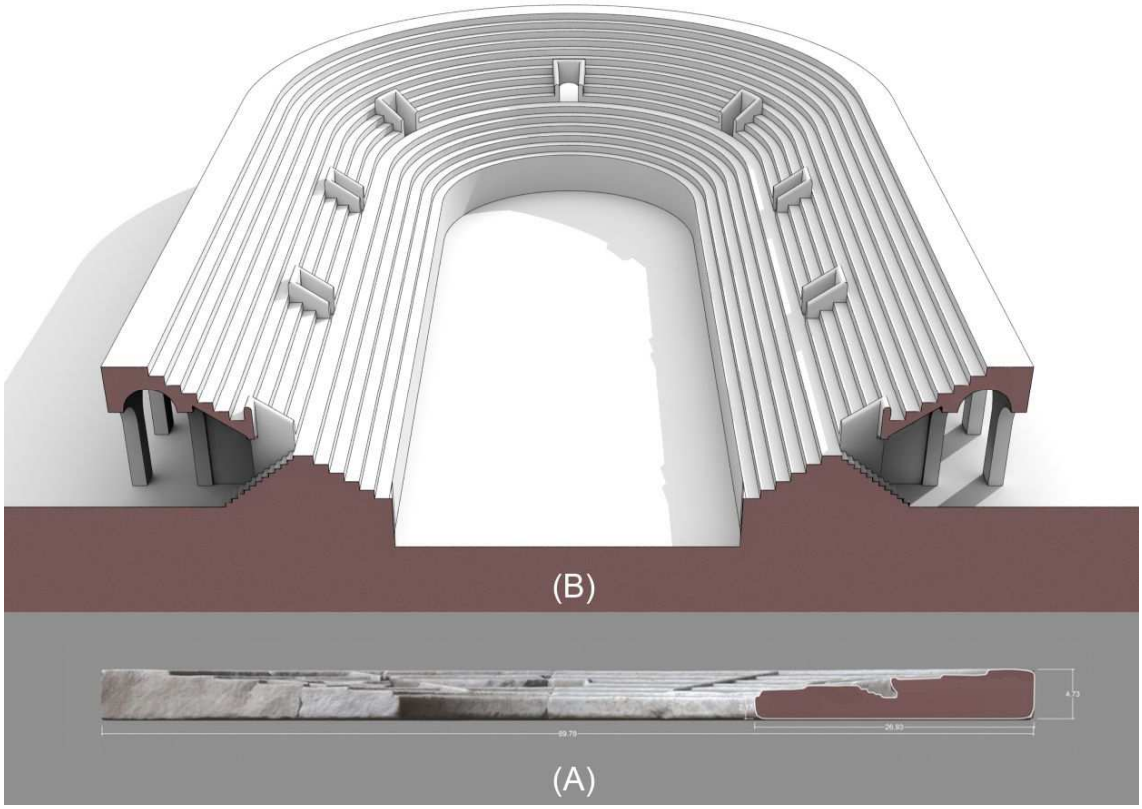

Fig. 14 – (a) cross section of the 3D model representing the *maquette*. (B) a perspective of an interpretation of how the building could be. The marble model was aimed at representing an amphitheater similar to the one of Caesarea of Mauretania.

Every new addiction is characterized by a slightly different direction aimed at approximating the natural shape of the shoreline: the, so called, *secundum naturam* approach, which was alternative to *secundum caelum* based on cardinal points (DI TONDO, 2007: 22-25). The first *centuria* corresponds to the center of the town and lays between the theatre and the river-bed at the east, the second *centuria* lays at the west of the first one, starting from the theatre until the end of the circus. The rotation center corresponds to the western side of the theatre and the angle of approximately 10 degrees is produced by a *ratio* of 1/7 between the two *centuriae*. The *post scaenium* wall of the theatre lays on the *decumanus maximus* so as one of the sides of the amphitheater. The third *centuria* at the west presents a rotation produced by a 2/5 *ratio.* Spaces generated by the rotation of the *centuriae* were driven primarily by topographic features of the site, including geo-morphological features of the river or of the shore in order to create continuity in the urban development. Apart from these two rotations, small water courses with small spans beds do not seem to cause an impact on the direction of the grid..(CHENNAOUI, 1994: 73-85). The main urban development of Caesarea dates back to the first century BC. in particular during the reign of Juba II that wanted to establishment of a new urban design, by superposing new structures, new public buildings on the former Phoenician town, called Iol. Juba II wanted to give its capital all the buildings for spectacles that he sought during his presence in Rome: between them a theatre and an amphitheater. Both those public buildings are aligned to the *cardo maximus*

and *actus quadratus* is a tangible presence not just in their orientation but also in their physical boundaries (Fig. 15).

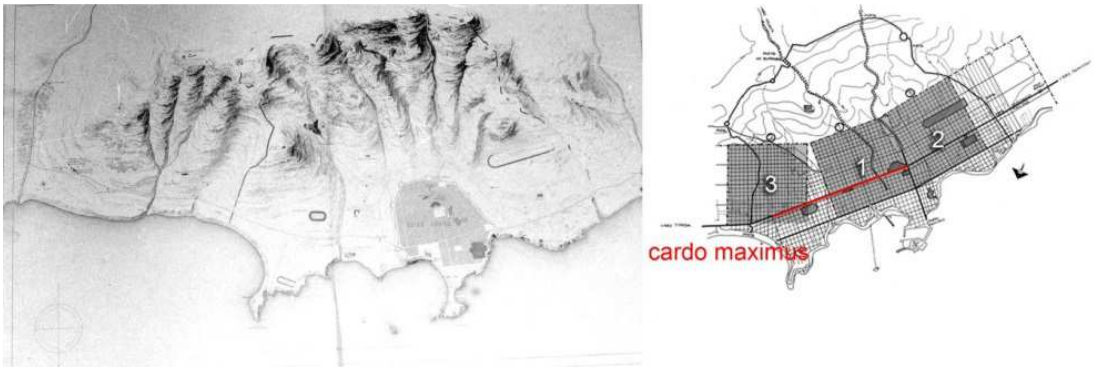

Fig. 15 – historical map of Caesarea of Mauretania (Cherchell) and the three urban development phases. Theatre and amphitheater are aligned to *cardo maximus*; circus and another supposed (but not excavated) have other orientations in accord to others *centuriae*. .(CHENNAOUI,1994).

Fig. 16 – the system of public buildings of Caesarea and their alignment to the urban chessboard whose basic module is *actus quadratus.* .(CHENNAOUI, 1994).Legend: 1. Circus-2. The western vicus of Kaïd Youcef-3. The western thermae-4. Theatre-5.Thermae-6. The roman forum-7. The eastern thermae- 8. Amphitheatre- 9. Residential district. 10. Hypothetical stadium. 11. Commercial harbor- 12.military harbor.

Our aim is to provide a key reading for the dimensioning of buildings for spectacles and in particular how ancient architects obtained their *ichnographia* for solving the problem of dimensioning, the building capacity.

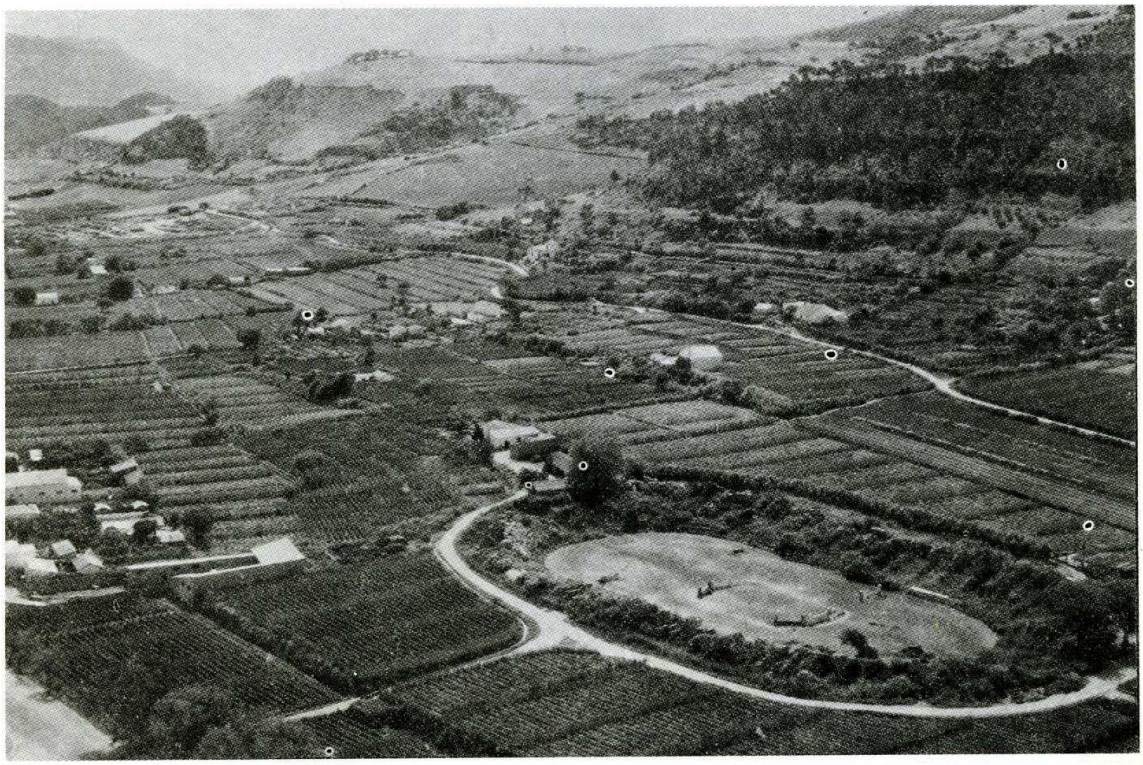

Fig. 17 – Arial view on the amphitheatre of Caesarea of Mauretania in the seventies. *Cherchel. Tourist guide. Ministère de la Culture, Algiers, 1983.*

From this point of view we applied the same criteria that came up from the results of the investigation carried out on the *maquette*: is it possible to find some relation between linear and bended sectors of bleachers? Have the bleachers any relation with standard areas as *actus* or *clima*, or did they just helped ancient constructors for the building alignment?

The first step was aimed at finding a common module inside the plan of the amphitheater, and we found a repeated quantity all over the building starting from the two centers of the *sphendonai*. This module is equal to 5 *cubiti* (1 *cubitus* = 1,5 *pedes*). Each linear bleacher is equal to 2 *climata and also* the semicircular ones can be divided by the same standard area equal to 3600 *pedes constrati* and the result is that they were equal to 3 *climata.*

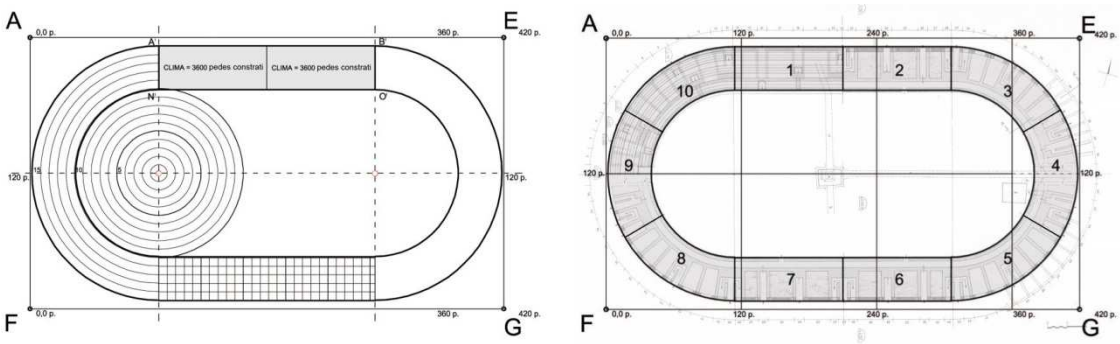

Fig. 18 – the modular structure of the amphitheater: 5 *cubiti*. The whole area of the bleachers is equal to 10 *climata*

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