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BUILDING MATERIALS AND VIRTUAL MODELS OF THE ETRUSCAN CITY OF KAINUA

1. Rebuilding the elevation through archaeological analysis and new technologies

A huge part of the Kainua Project has been directed toward the reconstruction of housing areas that, aside from sacred buildings, crafting settings and urban infrastructures, composed the largest portion of the ancient town (E. Govi; A. Gaucci; G. Morpurgo, C. Pizzirani, C. Mattioli; A. Muzzarelli, M. Franzoia in this volume).

The main purpose of our paper is therefore to describe the methodology we used in order to virtually recreate the houses of the city. The title itself, building materials and virtual models, openly express the starting point of our method, based on tangible archaeological evidence, fully integrated with data provided by the ancient sources and the latest technologies. Even if the usage of 3D models has become an established practice in archaeology (Campana *et al.* 2016), the innovation of this project lies in the constant philological care used in every step of the workflow: from the analysis on ancient building techniques, to their virtual reconstruction, through the validation of the ArchaeoBIM (Garagnani, Gaucci, Govi 2016).

This process led to the realization of the first data-models of the House 1 in *Regio* IV, *insula* 2 and House 5 in *Regio* IV, 1, where multiple structural solutions were explored thanks to the data provided by the building information model of the Temple of *Uni* (Garagnani, Gaucci, Gruška 2016). This reconstructing process led to two different, but yet complementary outcomes: on one hand the development of accurate models of the investigated areas, on the other hand the representation of the unexcavated portions of the city, made according to both the precise criteria emerged from the structural analysis and to the most recent studies. The 3D models of the archaeologically excavated areas were made thanks to the information provided by the data models and this entire process, based on a strong analytical approach, has been an opportunity to critically re-examine, with new methods, some previously investigated issues.

As previously stated, the scarce archaeological findings of building materials discovered in Marzabotto have been the starting point of this entire analysis. These are unfortunately limited to foundation walls, roof tiles, and short remains of mud bricks (Pizzirani, Pozzi 2010, 285-313).

The first issue that the reconstructions of these contexts have raised was the correct identification of the load-bearing walls of the domestic units,

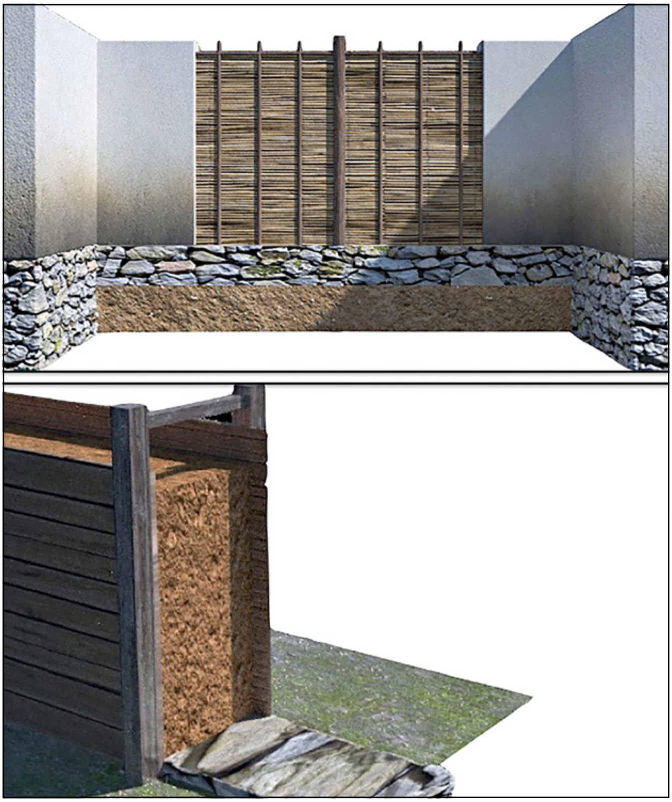

Fig. 1 – Construction techniques: a) Wattle and daub; b) Pisé.

fundamental to correctly define the perimeter of the houses. The problem itself is directly related to the common usage of continuous foundations across different rooms, and the absence of thresholds and ancient pavements, regularly removed by agricultural works that followed one another on the plateau (Govi 2010, 205-210). Even if it is easy to overcome these gaps thanks to stratigraphic data, unfortunately they are completely absent for most of the excavations conducted before the 1970s (a schematic history of excavations in Lippolis 2005, 154-157). In order to overcome this problem, it was held an overall analysis of the foundations walls across the city. It is in fact well-established that pebbles foundations differ in depth, width and construction techniques according to their structural role, and it is plausible that their thickness directly reflects the different weight exerted by the roof. Data provided by the analysis of the structural evidence of House 1, *Regio* IV, 2, recently excavated by the University of Bologna, were used as a guideline for the identification of load-bearing foundations. In this house, supporting foundation walls generally had and average width of 60/70 cm (Govi 2010, 210, fig. 355), a measure that can be found in most of the other domestic units across the plateau. Concerning the size of the foundations, the archaeological evidence points out a wide dimensional variability, an information that obviously has to be compared to the kind of elevation, thus showing a multitude of construction techniques.

The scientific attention to these techniques is one of the most recent guidelines of the research in Marzabotto, preceded by a lack of documentation due to their perishability and the consequent difficulty in their recognition. The studies and the archaeological documentation provided by the most recent excavations seem to highlight the mixed use of different techniques also integrated together (Pizzirani, Pozzi 2010, 298-301). The scarce clay portions with signs of canes testify the usage of wattle and daub or pisé technique (Massa Pairault 1997, 90-96; Govi 2010, 213-214), while the abundance of clay blocks leads to support the hypothesis that the elevation was made from mud bricks, to be used alone or as filling of a timber frame structure (Bertani 1991, 16-17) (Fig. 1).

Ancient sources and archaeological evidence testify the widespread practice of setting the mud brick walls on stone foundations (Giuntoli 1997, 27-28). Among the multiple bricks modules documented in Marzabotto, the most common one in housing areas seems to be a small rectangular brick (28 × 18-19 × 11-12 cm), which is probably based on the Attic foot (Pizzirani, Pozzi 2010, 303: 1 Attic foot long and 2/3 of Attic foot wide). This dimension perfectly fits with the evidence of the load-bearing foundations, 60/70 cm wide, on which those bricks could have been placed two by two sideways, or three by three lengthways, according to the technique of *diplinthii* and *triplinthii* mentioned by Vitruvius (*De arch.* II 8, 17; Pizzirani, Pozzi 2010, 304-306). The gap between the foundations width and the wall thickness was necessary not only for static reason, but also to apply a plaster layer. The data provided by BIM simulation of the Temple of *Uni* showed no structural differences between the usage of *diplinthii* and *triplinthii* confirming also their possible use altogether (Fig. 2). The maximum height of the drywalls made with these techniques without other substructures, and avoiding static problems of any kind, has been estimated to be around 2.8 m (about the height of buildings see Gaucci 2016 with previous bibliography).

The archaeological aspects about the roofing are better known, as both the modular and the typological characteristics have been fully studied (Pizzirani, Pozzi 2010). In Marzabotto, recent research highlighted how pitched roofs were a mixed Laconic-Corinthian structures, made of semicylindrical cover-tiles, as in the Laconic covering, associated to flat shingles, as in the Corinthian one (Ciaghi 1999, 1-5). Overall, architectural terracottas

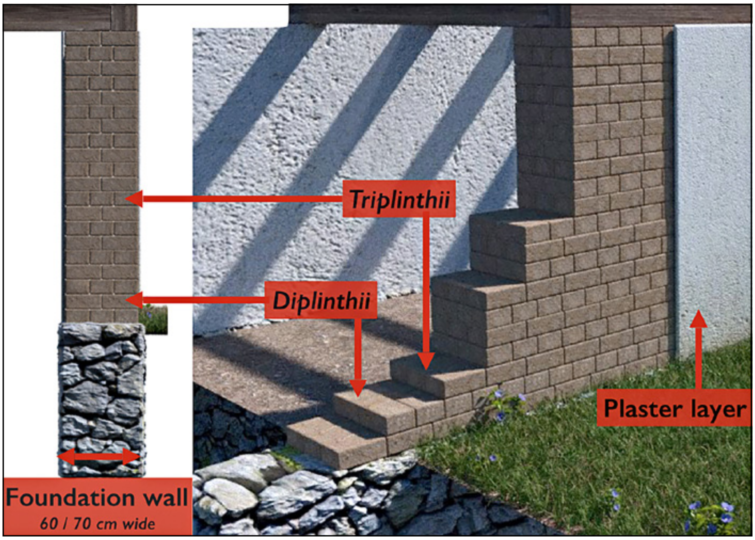

Fig. 2 – Mud brick walls on stone foundations and superficial plaster layer.

from Marzabotto perfectly fit into "Phase 3B" outlined by Ö. Wikander for the development of Etruscan roof coverage, which begins in the second half of the 6th century BCE and represents the most advanced roofing technique in the Etruscan world (Wikander 1993). Since the modules mostly used in domestic context completely fall into that typology, for all the other housing areas was arbitrary used the same module for tiles and cover-tiles.

B.G.

2. The roof structure

Despite the abundance of data concerning the tiled roofs, the reconstruction of their wooden structural work has been very problematic due to the complete absence of every archaeological record concerning the roof entablature. In general, the reconstruction of this specific aspect of the ancient buildings is still problematic regardless of the cultural aspects and the chronological period. Still, the need to provide a visual reconstruction of the houses in Marzabotto has pushed us to suppose a likely structure, compatible with data provided by the ancient sources and the BIM simulation of the Temple of *Uni* (Garagnani, Gaucci, Govi 2016; Garagnani, Gaucci, Gruška 2016).

It is well established that the archaeological sources available to reconstruct the wooden structural work of the Etruscan buildings are fundamentally three: fictile and litic models of temples and houses, architectural decorations in chamber tombs, and the well-known Vitruvian description of the Tuscanic temple (Chiesa, Binda 2009, 66). At first sight it is clear that none of these constitute a precise comparison for our case. In templar models the wooden entablature is just roughly-hewed and in house shaped urns is possible to recall a mixture of different elements used altogether to intensify the funerary meaning of the monument (Maggiani 2016, 138-139); the same happens in chamber tombs' architectural decorations (whose architectural elements are in most cases symbolically revised) and, at last, the Vitruvian description is mostly based on different techniques for the elevated structures, built with the usage of mortar. All this considered, it has been decided to carefully use these sources under the assumption that roofing solutions comparable to those used in Marzabotto should have had a similar wooden structure in order to support the roof.

The most complete source available remains the Vitruvian description of the wooden structural work of the Tuscanic temple. Even if the author describes building techniques used in the 1st century BCE, Roman tiles appears to have similar characteristics to the one used in Marzabotto (Adam 1984, 229-230; Pizzirani, Pozzi 2010). Therefore, according to Vitruvius (*De arch*. IV 2, 2), if the span of a roof was large, a ridge piece (*columen*) was laid on top of the king post, and a tie beam (*transtrum*) and struts (*capreoli*) were necessary. If the roof was of a moderate span, only the ridge piece and rafters (*cantherii*) were needed, these last of sufficient projection at their feet to throw the water off the walls. Then, on the rafters were laid purlins (*templa*), and again on these, in order to receive the tiles, were placed common rafters (*asseres*), which must be of sufficient length to cover the walls and protect them. So, under a structural point of view, the choice proposed by Vitruvius is between a self-bearing structure, close to a truss (Gros 1997, 444), and an externally supported one; it has been pointed out that this second solution must be structurally integrated with an external support placed under the roof ridge such as pillars, columns, poles or walls (Giuliani 2006, 92). It must be underlined that in a proper truss the king post never lies on the tie beam, but it is either separated and attached to it by a clamp. Since this solution is never specifically described by Vitruvius we have preferred to identify the self-bearing structure he described with the definition of truss-like structure, in order to enhance this important distinction (for the structural difference between the two see Giuliani 2006, 89-96).

So, if according to Vitruvius, the choice between the two kinds of structures above mentioned was made only according to the extent of the roof slope, it was probable that the houses in Marzabotto adopted the second solution. A compared analysis between the extension of single constructions in our housing context and Etruscan-Italic temples has shown that an average domestic building was around 75 m^2, an area directly comparable to the temples of the first group (the smallest one) pointed out by M. Rendeli, whose overall area does not exceed 150 m^2 (Rendeli 1989, 51-53). Therefore, even if the Vitruvian description could fit the case of the houses in Marzabotto, the complete absence of archaeological traces concerning external supports inside the single buildings seem to address toward the adoption of a self-bearing solution. This hypothesis is supported also by the architectural decorations visible in the Etruscan chamber tombs, particularly the painted tombs in Tarquinia, where the king post is frequently depicted from the last quarter of the 6th to the end of the 5th century BCE. This is one of the elements that compose the truss, with the important function to support the ridge piece (Giuliani 2006, 92-93) and is depicted at the center of the pediment, mostly in the shape of an altar (Colonna 1986, 445; Roncalli 1990, 234). Among the numerous Tarquinian tombs that show its representation must be at least remembered the tomb of the Lionesses, of the Auguri, of the Baccanti, Cardarelli, of the Baron, Francesca Giustiniani and Lerici 5513 (Steingräber 1985). According to the latest readings, this element must not be intended as the true representation of an architectural element, but as its burial interpretation, directly inspired by the real architectural element (Naso 1996, 388). Therefore, the meaning of these representations must not be directly related to the shape, but to their position and to their direct relation with the ridge piece. Another representation of a slightly different truss-like structure is visible in Peschiera (Tuscania) on a tomb externally shaped like a house with a gable roof, whose pediment is externally decorated with 5 vertical posts (Colonna 1986, 444; Maggiani 2016, 141-142).

All this considered, nothing prevents us to imagine a truss-like structure to support the roof also in the houses of Marzabotto. The sources to define the small armor of the roof are more comprehensible, thanks to the Vitruvian description (*De arch.* IV, 7, 4-5). In our reconstruction, in order to support the roofing system, has been put in place a minimal structure composed by *mutuli*, *cantherii* and *asseres*, this last necessary to fix the pan tiles by the usage of nails (Donati 1994, 92) (Fig. 3).

Unfortunately, there are no sources to define the measures of each structural element, therefore the reconstruction has been run on arbitrary measurements, derived by the modern building techniques. It is still to be investigated how these components were connected to each other; at the moment the main hypothesis consists either in some kind of embedment or through the usage of cramps, nails and strings; two different kinds of solution that are not to be necessarily considered as alternative (Garagnani, Gaucci, Govi 2016, 259). The possible slope reached by these pitched roofs was ranging from 10 to 20 degrees, in order to always provide a correct water disposal system, and mostly to avoid the accumulation of snow during the winter (Bianchini 2010, 91-95).

Fig. 3 – Reconstruction of a truss-like structure.

Fig. 4 – Reconstruction of the roofing and the water disposal system of the Houses 2 and 3 of the *Regio* IV, 1.

The reconstruction of roofs has always considered the Vitruvian instruction concerning their extension, specifically about the *stillicidium* (*De arch*. IV, 7, 5). According to this source it was supposed to partially cover the underlying structure in order to preserve and protect the walls overhanging for one third of the entire slope of the roof. The specific interpretation of this passage has raised several doubts, mostly due to the large dimension of the slopes reached by Tuscanic temples (Andrén 1940, LXIV-LXVIII). In the housing context of Marzabotto the *stillicidium* has never reached a length larger than 1.3 m (approximately two rows of tiles). Nevertheless, the proximity between different buildings inside the block (often separated by a partition 60-70 cm wide) has required in some cases a drastic reduction of the *stillicidia*, sometimes even lower than a single row of tiles.

The analytical process necessary for the virtual reconstruction of the houses brought us to model an independent roofing system for each individual building that composed the domestic unit, covered with a mono-pitched roof or a gable one depending on their specific measure or position. This solution surely allowed a fine control on rain water drainage in order to carry it inside or outside the house. The attention to the water draining system has been one of the criteria used to sort between different types of roofs. As a rule, it has been decided to direct most of the rain water flow outside of the house (towards the public canalization system) or to the partition between different domestic units (*ambitus*). The only exceptions have been the houses where the archaeological evidence testified the presence of tanks or other water collection systems, as well as fragments of angular tiles; in this case *compluvia* roofs were positioned. The analytical reconstruction, carried out according to the above-mentioned data, has provided multiple confirmations regarding the structures of single houses, but has contemporary raised some issues about the relationship between contiguous domestic units inside the same block. The partition between different houses seems insufficient for the rain water disposal of multiple and opposite pitched roofs, where these tent to pour rain water onto the opposite wall (Fig. 4); an aspect that is yet to be explored with new virtual simulations.

The analytical reconstructive process here illustrated has therefore allowed us to create plausible reconstructions of individual houses, according to the archaeological and architectural sources available. However multiple and individual problems, especially about the roofing system, still remain unsolved; those could be better explained in the future by testing this, and other possible solutions, with the ArchaeoBIM method. It should also be stressed that extending the scope, and addressing the reconstruction of entire blocks, additional simulations are needed, in order to take into account also the relationship between different houses and public infrastructures.

G.M.

3. The reconstruction of the unexcavated areas

In addition to the reconstruction of excavated areas of the city, the Kainua Project contemplated also the recreation of not yet excavated regions with the best possible approximation (Gaucci in this volume). Our aim

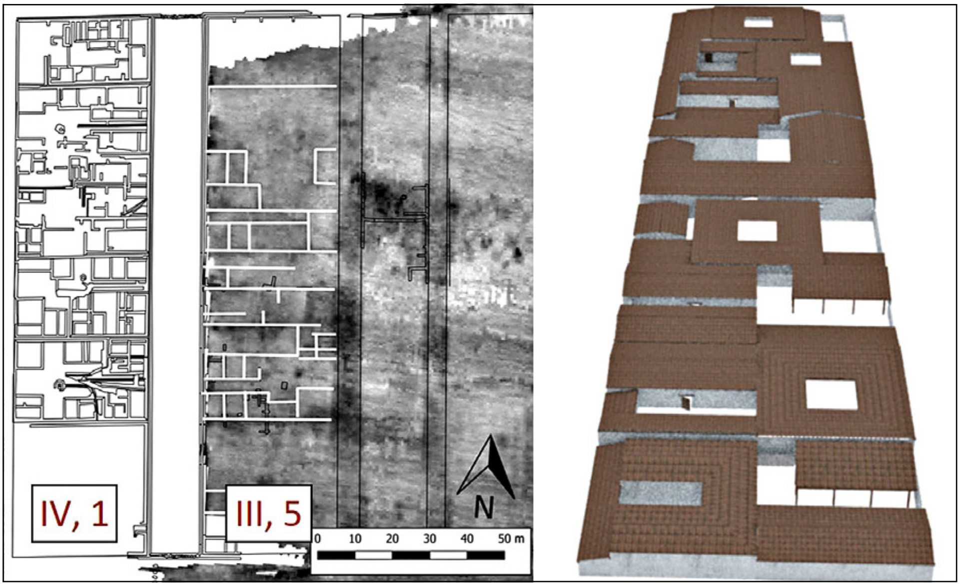

Fig. 5 – The reconstruction of the *Regio* III, 5: on the left the interpretation of the geophysical surveys, on the right the virtual model.

was to offer also for these areas a visual restitution of hypothetical buildings but yet compliant with the same realistic criteria used for the explored ones. The most recent studies have highlighted the complexity of the ancient urban environment that had to be properly enhanced. The unique housing solutions, their constant relationship with the urban infrastructure and the high variability of excavated contexts have shown that a purely procedural approach did not fit the peculiar case of Marzabotto. The first step towards the restitution of the ancient urban landscape was reconstructing (with the best possible approximation) the original parcelization of the city blocks. The analysis of the excavated context, and a recent campaign of geophysical surveys, led Elisabetta Govi to identify an uneven but modular subdivision of the housing spaces throughout the city grid, as a reflection of the ancient parcelization (Govi 2016, 196-203).

So the housing spaces of the city model are based on this evidence, always holding in consideration the spatial heterogeneity registered in the excavated areas. The lots were consequently filled with hand-modeled buildings in full compliance with the structural features as previously established.

The archaeological records highlight that the urban fabric includes distinct types of houses, developed in response to the complex social articulation and hierarchically distributed according to precise viability and visibility criteria (Govi 2016, 198-202). Therefore, this ratio has been one of the basic guideline followed during the recreation of the urban texture (Govi in this volume). Thus, the house type characterized by the aggregation of formerly-scattered buildings around an inner courtyard, the same type as the recently published House 1 in *Regio* IV, 1 (Govi, Sassatelli 2010), was the most widely used across our city model.

Inside the lots the buildings have been modeled respecting the maximum height of drywalls around 2.8 m; their roofing system followed the rules of extension, direction and maximum slope previously explained. Special attention was also paid to the ratio between the closed and open spaces inside the houses. An analysis carried out on excavated buildings (in particular the House 1 in *Regio* IV, 1; the so-called "Isolato Mansuelli"; the houses excavated in *Regio* V, 3 by the École française of Rome) revealed that an average courtyard occupied almost 35% of the overall area of the house, a ratio that we tried to maintain as much as possible.

The *Regio* III has been treated differently, in order to reflect, as closely as possible, the results of the excavations carried out between the 1950s and the 1970s (De Maria *et al.* 1972, 313-317) and the recent geophysical surveys (Govi 2014, 81-111; Boschi 2016, 85-100). These investigations revealed that the urbanization of this area was limited to the block facing onto the *plateia* A, whose important role in the urban layout has already been stressed. The geophysical surveys reveal that *insula* 5 was divided in housing units similar, and sometimes even specular, to the ones of the opposite block, i.e. *Regio* IV, 1 (Govi 2016, 198). From this perspective, it was decided to model these houses according to the interpretation of the geophysical explorations (Fig. 5). As a result of this operation, we rebuild large housing units, occupying the block for the entire length in the EW direction, trying to recreate as much as possible the houses provided by the facing block. It should be stressed the limit of this reconstruction, conducted without the metric data provided by the foundations analysis, essential to precisely define the load-bearing walls and the extension of single buildings.

A final mention should be directed to the approach taken towards the south-western portion of the plateau, collapsed long ago (Lippolis 2005, 143-146). In absence of any kind of information about this area, the parcelization used for the rest of the city has been extended to the missing part of the blocks facing the *plateiai* A and D in order to return a comprehensive and conceivable overview of the ancient urban form.

Coming to a conclusion, the virtual model of the entire town has proved itself as a functional tool to display poorly preserved archaeological evidence, excellent for dissemination purpose of a complex context such as the Etruscan town. The analytical approach used to reconstruct the excavated areas has proven extremely useful to critically re-examine, with new methods, some previously investigated issues. The same method has been successfully applied to the virtual reconstruction of both excavated and unexcavated areas, allowing us to create plausible virtual models of the ancient buildings. Therefore, the model of the entire town becomes a powerful new tool for the analysis of the ancient city landscape and the urban fabrics.

E.Z.

Bojana Gruška
Università degli Studi della Repubblica di San Marino
bojana.gruska2@unibo.it

Giacomo Mancuso
Sapienza Università di Roma
Dipartimento di Scienze dell'Antichità
giacomo.mancuso@uniroma1.it

Enrico Zampieri
Alma Mater Studiorum – Università di Bologna
Dipartimento di Storia Culture Civiltà
enrico.zampieri2@studio.unibo.it

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ABSTRACT

The paper aims to explain the analytical method used to virtually recreate the houses of the Etruscan city of Marzabotto. As stated in the title, the starting point of the process was the analysis conducted on the tangible archaeological evidence of building materials; these latter were fully integrated with data provided by the ancient sources and the latest technology. Next, the problems and the solutions adopted in order to recreate the houses are presented. In the last section the criteria used for the visual restitution of the unexcavated context of the ancient city are explained.