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PREHISTORIC ARCHITECTURE, DIGITAL RECONSTRUCTION AND STRUCTURAL ANALYSIS: HUT 1 AT POSTA RIVOLTA (FOGGIA)

1. The context of Posta Rivolta

This paper is part of a doctoral research project (PASAP Med) focused on the digital reconstruction of domestic architecture in southern Italy between the late 3rd and early 2nd millennium BCE, with a specific emphasis on the Palma Campania and Protoappenninico cultural phases[1]. Within this framework, the site of Posta Rivolta represents an ideal case study for testing a digital and experimental approach applied to ephemeral architectural traces. The settlement, situated in the Cervaro stream valley at the interface between the Apennine ridges and the Tavoliere plain, is located in an alluvial plain in northern Apulia at approximately 115 m above sea level. Discovered and systematically excavated between 2010 and 2016 during the preventive archaeology investigations for the expansion of the Caserta-Foggia railway line, the site revealed a complex occupation characterized by a high density of features that marks a crucial settlement continuity in the transition from the Early to the Middle Bronze Age (Tunzi *et al.* 2012, 2020).

The excellent preservation of postholes, associated with multiple domestic structures, makes the site particularly well-suited to structural reconstruction attempts, thanks to the preservation of negative traces which allows for a coherent and precise geometric reconstruction, and the possibility of comparison with important reference sites, such as the coeval Campanian contexts where super-structure data is often preserved by volcanic deposits (e.g., Nola, Afragola). The material culture, especially ceramic types, demonstrates a strong association with the Palma Campania culture, while also displaying elements linked to the local Protoappenninico culture. Radiocarbon dates obtained through 2σ calibrated measurements place the site's occupation between the 20th and 17th centuries BCE (Tunzi *et al.* 2020; Recchia *et al.* 2024). Such chronological range synchronizes the settlement's life with the mature phases of the Campanian villages, while simultaneously documenting, through radiometric data and long-lasting

[1] Roberto Malinconico curated the project, drafted the manuscript, collected the data, developed the digital reconstruction methodology, conducted the GIS analyses, performed the CFD analyses and volumetric calculations, and prepared all figures and tables. The research was supervised by Enrico Lucci (primary supervisor) and Annalisa Treglia (co-supervisor), who also co-authored the introduction and conclusions. All authors read and approved the final manuscript.

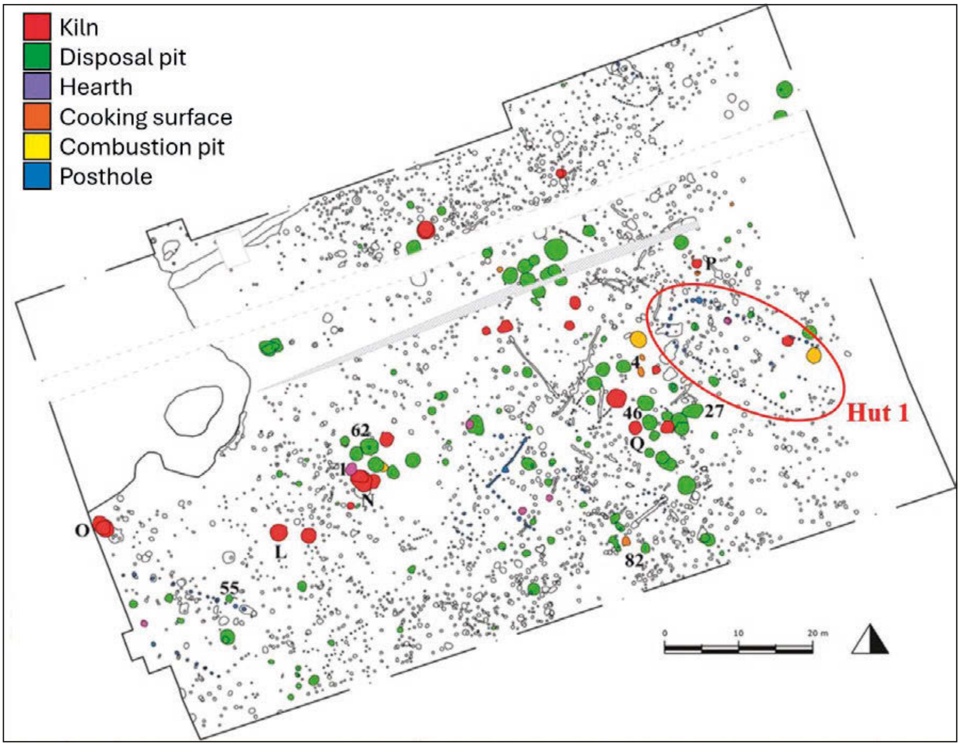

Fig. 1 – The site of Posta Rivolta (Foggia), with Hut 1 highlighted (image adapted from Tunzi *et al.* 2018).

stylistic features, the specific dynamics of cultural continuity in this area during the socio-environmental reorganization following the Avellino Pumice eruption (Tunzi *et al.* 2020).

Among the most significant features is the presence of two distinct groups of structures, primarily differentiated by size: smaller buildings approximately 10 meters long, and larger structures exceeding 20 m in length, including Huts 1, 2, and 3. These larger huts are likely contemporaneous, constitute the primary domestic units of the settlement, and share a similar orientation along the northwest–southeast axis. This specific layout finds direct architectural parallels, regarding the orientation and internal organization, with the settlements of the Campanian Plain, specifically Gricignano d'Aversa (US Navy area), Nola (Croce del Papa), and Afragola, as well as finding significant comparisons with Piani della Corona in Calabria (Marino 2023). However, unlike the other cited sites, where dimensions rarely reach such magnitudes, the significant size of the Posta Rivolta buildings (exceeding 20 m) represents a distinctive trait that testifies to a shared architectural tradition transcending regional boundaries but probably adapted to local needs.

Hut 1 (Fig. 1), located in the eastern portion of the excavation area and oriented NW-SE, was selected for digital reconstruction due to the high legibility of its archaeological traces, notably postholes, combustion pits, and disposal pits, as well as the coherence of its architectural layout. Measuring approximately 20.50×7.80 m, the hut features perimeter postholes that are relatively regular in distribution, with an average diameter of around 45 cm and a depth greater than 50 cm, dimensions compatible with the bearing capacity required for a complex roof structure. Archaeobotanical and anthracological analyses conducted at the site (Tunzi *et al.* 2018) identified deciduous oak (*Quercus* sp.) as the most attested wood essence, suggesting this was the primary timber used for the structural posts.

Furthermore, the analysis of the structure suggests complex formation dynamics involving not just its use but also its termination. As discussed in recent studies on the archaeology of domestic abandonment (Tunzi *et al.* 2014), the presence of specific depositional patterns in the postholes and disposal pits indicates ritualized abandonment practices. These involve the intentional dismantling or 'closing' of the domestic space at the end of its lifecycle, where the structured deposition of materials marks the transition of the building from a living space to a defunctionalized space. The structure was dated through calibrated radiometric analysis performed on connected external cooking structures, which returned a chronological range between 1900 and 1730 BCE (2σ confidence interval, 95.4%) (Tunzi *et al.* 2020) (Fig. 1).

2. Reconstruction workflow

As part of the doctoral research project, a custom digital reconstruction method was developed and applied to the structure of Hut 1 at Posta Rivolta, utilizing Blender (versions ranging from 4.x to 5.0.1). This methodological choice stems from two primary considerations. First, there is a notable absence of consolidated and universally applicable protocols for the digital reconstruction of prehistoric contexts, with existing approaches often remaining limited to specific case studies or more recent historical periods. Second, the research is grounded in the principle that the object of study should define the approach, rather than the reverse. The methodology must therefore be developed in coherence with the specific characteristics of the archaeological context under investigation.

Hut 1 was selected as the initial case study due to its completeness and structural clarity, making it an ideal pilot for establishing the methodological framework. However, this context-specific approach does not preclude

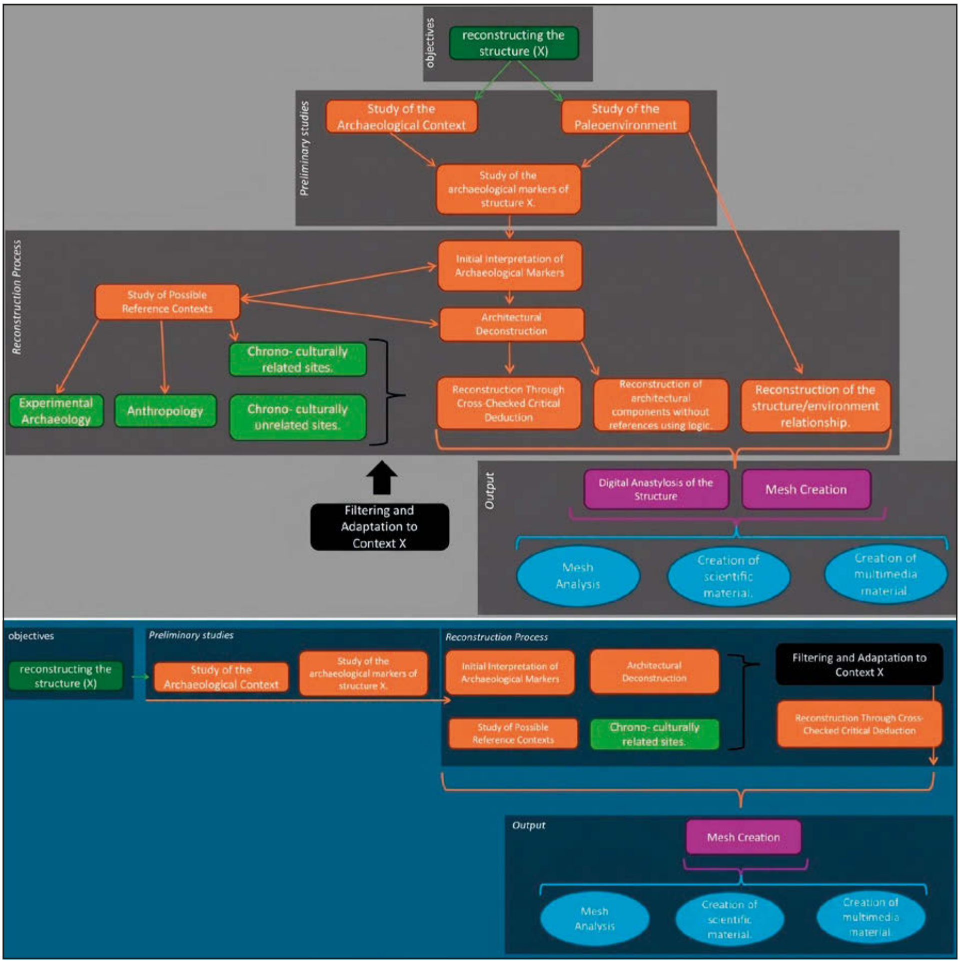

Fig. 2 – Colour-coded workflow for the digital reconstruction of Hut 1 at Posta Rivolta. Top panel (grey): complete methodological pipeline developed during the doctoral project; bottom panel (blue): sub-workflow dedicated to modelling the wooden framework of Hut 1.

broader application. If proven compatible, the adopted method could potentially be adapted to other contexts within the same territory or cultural horizon, thereby establishing a flexible standard rather than a rigid protocol. Following this initial application, the method will be progressively tested on Hut 2 of Posta Rivolta, and subsequently on Hut 3, once its form can be hypothesized despite its incompleteness, as the structure extends partially beyond the excavation limits. The intention is to continue refining and applying this workflow to other culturally related sites, contributing to the development of more robust reconstruction practices for prehistoric contexts.

The proposed workflow is illustrated in Fig. 2. The upper section of the diagram presents the complete methodological sequence developed during the doctoral research, while the lower portion highlights the specific section dedicated to the reconstruction of the wooden framework of Hut 1, which constitutes the focus of this paper. The process is structured into three main phases:

1. Preliminary analysis of the structure ('X'). The selected structure, in this case Hut 1, was analysed both from an archaeological and paleoenvironmental perspective. These two dimensions were considered inseparable, as they are deeply interrelated in terms of the materials used and the spatial organization of the built environment. A key component of this phase involved the systematic cataloguing of archaeological evidence left by the structure, such as postholes and any associated stratigraphic evidence.
2. Interpretation and comparative analysis. Starting from an initial interpretive hypothesis based on the local evidence and existing knowledge of the architectural traits of the cultural phase in question, specific comparisons were made with other archaeological contexts. When possible, priority was given to sites that were chronologically and culturally related; in their absence, morphologically comparable but non-contemporary contexts were also considered. The structure was analytically deconstructed into individual architectural components in order to identify targeted parallels for each element. This process was supported by ethnoarchaeological, anthropological, and experimental archaeology literature sources, which were useful in identifying functional and constructional issues and in guiding a coherent reconstruction.
3. Digital output production. In this phase, a three-dimensional reconstruction of the structure was produced through digital anastylosis and high-resolution mesh modelling within the Blender environment. The resulting model provided the basis for subsequent analyses, including hydrological assessments, Computational Fluid Dynamics (CFD) simulations, which were performed using Ansys Discovery (version 2024 R2), and volumetric calculations. Beyond advancing scientific research, the mesh model will be employed to fulfil the university's Third Mission, understood as the transfer of knowledge and the valorisation of cultural heritage for the benefit of society. Indeed, one of the envisaged outputs of the project is the integration of these reconstructions within museum exhibitions, supporting a public outreach programme that envisages the production of explanatory videos on Hut 1 at Posta Rivolta and, more broadly, on Protohistoric domestic structures in the region; the creation of queryable three-dimensional informational models; and the fabrication of tactile replicas through 3D printing. These tools will enable non-specialist

audiences to understand a Protohistoric context composed chiefly of post-hole markers that are otherwise difficult to interpret, while simultaneously contributing to the cultural enhancement of the area.

This paper focuses on the specific part of the workflow dedicated to the wooden framework of Hut 1, as shown in the lower section of Fig. 2. The general context of the site, already outlined in the introductory section, will not be revisited here in detail; for further information, reference is made to the dedicated scientific literature (Tunzi *et al.* 2012, 2018, 2020; Recchia *et al.* 2024). Instead, the discussion will explore the interpretation of archaeological traces, the modelling choices, the comparative analysis with chronologically related structures, and the evaluation of the results, particularly those derived from the CFD simulation and the volumetric analysis of the timber components.

3. Reference site: Nola-Croce del Papa (Southwestern Italy)

Within the methodological workflow, a fundamental reference for defining the wooden framework of Hut 1 was the site of Nola-Croce del Papa in Campania. The exceptional preservation of domestic structures, due to the sudden burial caused by the Avellino Pumice eruption, an event dated to 3945±10 BP (Di Vito *et al.* 2021), allowed for the direct study of timber components and structural configurations (Albore Livadie *et al.* 2005, 2020). The rapid deposition of cineritic material and subsequent mudflows sealed the village, resulting in the excellent preservation of negative moulds of organic elements. This phenomenon permitted the preservation of actual portions of the hut's super-structure, revealing the position of most wooden substructures but also suggesting their volume, inclination, and the texture of vegetal building materials, particularly in the case of architectural elements such as the perimeter wall.

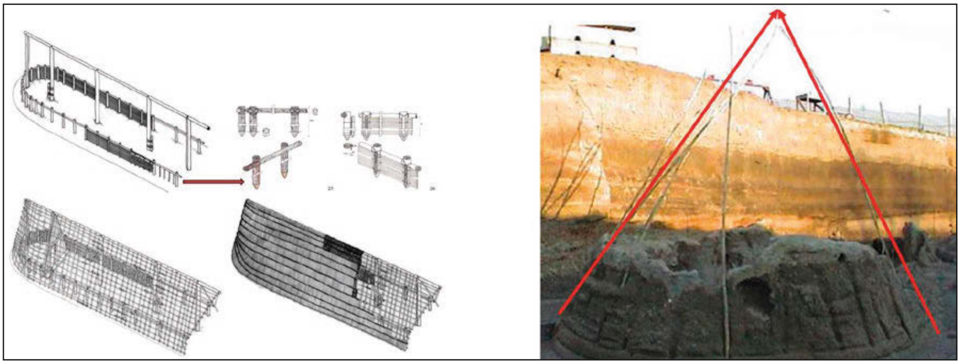

Fig. 3 – 1) Wooden structural elements of Hut 4 at Nola-Croce del Papa; 2) height reconstruction based on the negative imprints of vertical beams (images adapted after Castaldo 2020a).

Among the three large huts identified at the site, particular attention was devoted to Hut 4 (Castaldo 2020a, 2020b). This structure, characterized by an apsidal or 'horseshoe' plan typical of the Palma Campania culture, features a complex configuration evident in the arrangement of the load-bearing elements. The archaeological evidence clearly distinguishes between various types of structural posts. The perimeter posts define the footprint of the living space, though not necessarily the total extent of the structure. Inserted horizontally onto these perimeter posts, using joints and lashings made of organic cordage, were the base posts; these elements were positioned at an above-ground structure corresponding to approximately one-third of the structure's total height. The backbone of the structure was represented by the axial posts, which functioned as supports for the ridge beam. Positioned at the apex of the structure, this element guaranteed support at the summit. From here, the 'roof-wall' system started, which then rested on the base posts before reaching the ground, giving a continuous form to the structure's wall.

Specifically, this 'roof-wall' was supported by a dense weave of horizontal beams, typically spaced 22 cm apart, running along the perimeter of the structure up to the top, and vertical beams, typically spaced approximately 44 cm apart. These elements were bound together by organic material and extended from the ridge beam down to the base posts and the ground, following a sophisticated load-distribution logic designed to support a heavy thatched roof, specifically composed of *Phragmites australis* arranged in bundles approximately 1.2 m long (Fig. 3, 1).

Beyond this structural arrangement, Hut 4 at Nola also provided a proportional model for estimating the height of the structure, a datum usually missing in hut contexts where only negative traces survive, yet essential for the three-dimensional reconstruction proposed by this project. The insertion of wooden elements within the negative impressions of vertical posts (Fig. 3, 2) made it possible to formulate a reconstructive framework corroborated by evidence from additional structures at the site. The determination of structural height represents a critical component of this analysis. The dimensional examination described demonstrates systematic proportional relationships: Structure 2 exhibits dimensions of 7 m in length and 3.75 m in height, and Structure 3 measures 14 m in length and 7.5 m in height. These measurements reveal a consistent 2:1 proportional ratio (length to height). Structure 4, on the other hand, presents an initial phase with a length of approximately 11 m and a height of 4.20 m, respecting this ratio, which was subsequently modified by extending the structure to 15.50 m in length through the addition of a further modular section. This evidence likely indicates adherence to standardized architectural principles that could be adapted based on the specific function of the building or the mechanical properties of the available timber (typically deciduous oak, *Quercus* sp., samples of which emerged from analysis; while its use for structural posts is not certain, it is considered highly probable).

This model was adopted as a primary reference for the reconstruction of Hut 1 at Posta Rivolta, although it was critically adapted and proportionally modified based on the local archaeological evidence. While the Nola model provides the vertical dimension, the specific planimetric layout remains obviously that of the evidence of Hut 1, where the postholes and various references were followed and redrawn precisely.

The arrangement of the axial posts in the huts at this site presents a significant difference compared to those found at Nola. At the Campanian site, it has been hypothesized that an axial post was positioned along the external perimeter of the perimeter posts (Castaldo 2020a, 2020b), shifting the apse anteriorly relative to the main structure and preventing it from resting directly on the base posts. In the case under examination, however, the perimeter axial post is absent. This construction choice was adopted for several technical and functional reasons that merit in-depth reflection. In the case of Hut 1, there would not be an optimal alignment with a hypothetical axial post on the row of perimeter posts. The central axis of the posts would, in fact, pass between two adjacent perimeter posts. This peculiarity would make the insertion of a post of considerable load-bearing capacity and weight problematic, as it would have to be supported simultaneously by two very tall posts, approximately 10 m high in this specific case.

Such a solution would be not only counterproductive from a structural point of view but potentially damaging to the integrity of the entire construction, especially considering that this part is subject to the greatest wind load stresses. The consideration of this alignment issue stimulated an in-depth reflection on the length of the rafters and, more generally, on the overall height of the structure, which for Hut 1 results in being greater than the Nola models. In this perspective, an apse anchored directly to the base posts would confer significantly superior stability to the hut, mirroring the technique and global form of the structure where the rafters in the long lateral walls are always anchored to the base posts. This solution would allow for better load distribution and greater resistance to external stresses.

The absence of the perimeter axial post could therefore be interpreted as an evolution in construction techniques. This choice might indicate a greater understanding of structural dynamics by the builders, who opted for a softening of the apse inclination combined with reinforcement through the connection with the base posts. A further modification was the extension in length of the ridge beam relative to the path dictated by the axial posts. This was implemented both on the short side featuring the opening, where a canopy designed to protect the entrance was provided, a construction element securely attested at the Afragola site, and in the section of the last axial post towards the apse, where the distance necessary to allow for the easy insertion of the vertical rafters into their support on the ridge beam was calculated.

4. The reconstruction of Hut 1 at Posta Rivolta

From the initial phases of the spatial analysis, a recurring geometric pattern was identified in the arrangement of the archaeological markers, which became a key element in developing the reconstruction model. As visually highlighted by the red rectangles in the planimetric diagrams (Fig. 4A-C), a distinct layout was recognized based on a modular logic, specifically a 2:1 ratio observed between the positioning of the axial posts and other structural elements, such

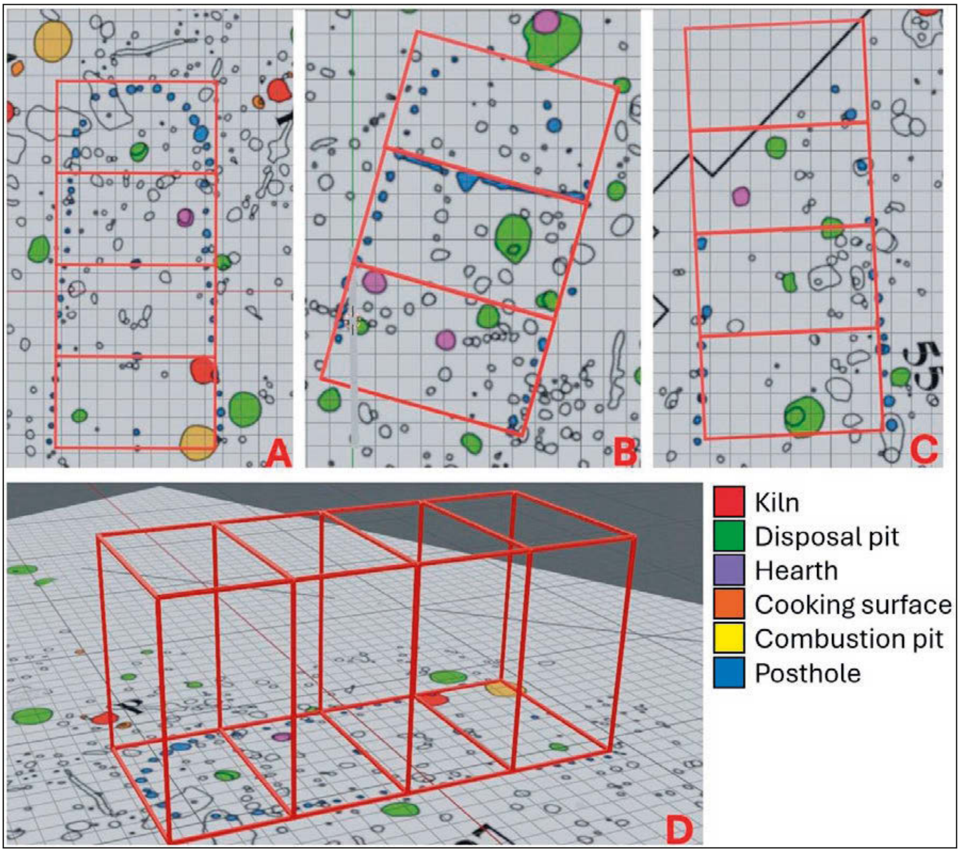

Fig. 4 – Graphic reconstruction of the proportional model applied to: A) Hut 1; B) Hut 2; C) Hut 3; D) three-dimensional reconstruction based on the layout of Hut 1 (plan adapted from Tunzi *et al*. 2018).

Fig. 5 – A) Placement of the central axial posts and ridge beams; B) perimeter posts and base posts; C-D) detail of the socket carved into the perimeter posts to receive the base posts; E) positioning of horizontal and vertical beams; F) roof covering made of bundled vegetal material.

as the partition wall in the apse (Fig. 4B) and the rhythmic arrangement of the perimeter posts. This modularity could suggest a pre-conceived architectural design rather than a casual accumulation of structural elements. However, while the planimetric data provided the footprint, it was only through the comparative analysis with the well-preserved super-structure of Nola-Croce del Papa that a scientifically grounded three-dimensional model could be developed to accurately define the volumetric limits of the hut (Fig. 4D).

The Nola model, particularly the proportional ratio of approximately 1:2 between height and length observed in the Nola structures, served as the primary reference algorithm for estimating the Super-structure. Applying this ratio to Hut 1 at Posta Rivolta, which measures approximately 20.50 m in length, a hypothetical total height of 10 m was established. Consequently, the height of the base posts was set at approximately 3.33 meters. This measurement corresponds to exactly one-third of the total height, a proportion that mirrors the structural configuration documented at the Campanian site and ensures the static equilibrium of the heavy 'roof-wall' system. As outlined in the methodological workflow (§2), the application of the Nola model was critically adapted to address the specific differences between the two sites discussed in §3. The digital reconstruction of Hut 1 proceeded through a sequential assembly logic:

1. Axial posts and ridge beam. The process began with the virtual placement of the central axial posts and the ridge beam (Fig. 5A). The ridge beam, a horizontal timber element, was secured atop the axial posts through a system of mortise joints and organic cordage lashings. While excavation data documented depths exceeding 50 cm, the specific depth of axial posts could not be determined archaeologically. Given their structural function as primary load-bearing elements supporting the ridge beam and considering the estimated post diameter, a foundation depth of 10% of the total height was adopted, following observations from Nola and comparative evidence from Posta Rivolta. Accordingly, a 1 m depth was established for the longitudinal spine, which serves as the structure's primary bearing axis and defines its maximum height.
2. Perimeter definition. The perimeter posts were positioned according to the exact distribution and dimensions of the postholes documented in the archaeological plan. Each post was modelled with sockets designed to receive the base posts (Fig. 5B-D), incorporating a foundation depth of 0.8 m.
3. Secondary framework. For the support structure of the roof-wall, the vertical beams (rafters) were modelled first. They extend from the ridge beam to the base posts and anchor to the ground, shaping the continuous slope of the roof-wall structure (Fig. 5E). Their interaxial spacing was set attempting to respect the Nola dimension but adapting it to the specific composition of the perimeter posts at Posta Rivolta. Subsequently, the horizontal beams were added above them, following the form imposed by the vertical elements to create a cohesive grid.
4. Covering and roof geometry. The final modelling phase involved the digital simulation of the thatched roof covering (Fig. 5F), using bundles of vegetal material (*Phragmites australis*) to replicate the texture and volume documented at Nola. The resulting roof geometry implies a pitch of approximately 21.4 degrees, markedly different from the 59 degree inclination observed in the Nolan huts. Despite this shallower pitch, the roof would have ensured both effective water runoff and adequate wind resistance.

5. Structural testing through CFD analysis

In addition to the presence of the apse, one of the most distinctive architectural features of Hut 1 is the undulating profile of its long walls, clearly visible from the three-dimensional reconstruction. While the apse finds parallels within the architecture of the Palma Campania culture, the undulating perimeter has no documented counterparts in known Campanian contexts, suggesting a local adaptation or a specific design solution developed at Posta Rivolta. This wavy outline derives directly from the height relationship between the ridge beams and the base posts, which determines the inclination of the rafters in the roof-wall system. The rafters start from the ridge beams, which constitute the highest points of the structure, rest on the base posts at intermediate elevation, and continue to the ground. The inclination of each rafter is therefore defined by the height difference between these two key structural elements and the position of the perimeter posts, thus generating the characteristic undulating profile of the entire structure (Fig. 6).

A further significant observation concerns the relationship between certain pit features and the distinctive undulating outline of the hut's wall profile. The presence of these pit structures, likely contemporary with Hut 1 (Tunzi *et al.* 2012, 2020), may support the application of the Nola architectural model at the Posta Rivolta site. Their placement, never interfering with architectural elements and consistent with use in the non-inhabited area of the hut outside the perimeter posts, supports the idea of a structure equipped with base beams, possibly serving additional functions that remain unclear. One particularly revealing aspect is the fact that the perimeter of the pits closest to the points of contact between the vertical beams and the ground precisely follows the hut's undulating wall layout. This is clearly visible in the zenithal renderings along the vertical axis (Fig. 6). The correspondence validates the reconstructed proportions, especially regarding the height of the ridge beam and the base beams, which determine the slope of the vertical beams as previously noted. The curvature of the walls appears fully compatible with the position of the pit structures, so much so that even a displacement of just a few decimetres would have created stratigraphic or functional inconsistencies.

This specific undulating wall configuration has suggested multiple functional hypotheses. The first concerns structural resistance, as it is well known in engineering that a relatively thin supporting wall can significantly increase its strength with an undulating profile, thus the profile would increase the resistance of the roof-wall system with a smaller quantity of material. The second reason could be linked to water collection, as the internal undulations might have been congruent with a technique of canalization and subsequent collection of water. This is plausible for several reasons, including the climatic crisis or general thermal instability proposed for this specific historical period (Di Rita, Magri 2009; Aprile 2015), and the nearby Cervaro river, which could be considered seasonal or dry during many periods of the year. The third thesis concerns aerodynamics, linking this characteristic to the overall structural performance.

Within this framework, the coexistence of the apse and the undulating wall profile has been interpreted as a possible technological response to aerodynamic load. To test this hypothesis, a Computational Fluid Dynamics (CFD) simulation was conducted. The 3D mesh model of the hut was imported into

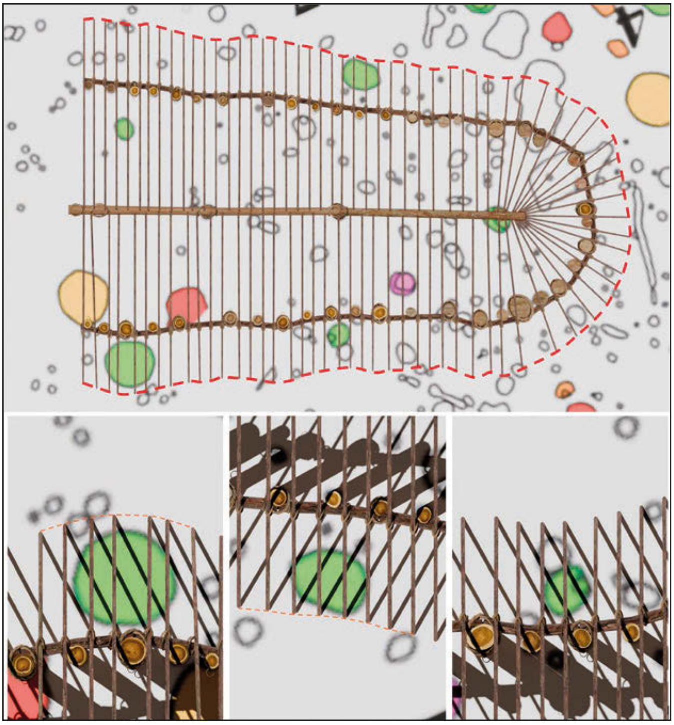

Fig. 6 – Top: orthophoto of the reconstruction of Hut 1 showing only the vertical beams, which outline the sinusoidal perimeter; bottom: relationship between the depression features and the perimeter of Hut 1.

Ansys Discovery (version 2024 R2) to perform the fluid flow analysis. The physical setup of the simulation assigned 'Air (Gas)' as the fluid medium and 'Wood, Oak' to the structural elements. Gravity was included in the calculation. The boundary conditions were strictly defined: a Flow Inlet velocity of 30 m/s (approximately 110 km/h) was set to replicate severe wind loads from the NW-SE direction, consistent with wind conditions proposed for the Campanian region by Castaldo (2020a), while the Flow Outlet was set to a relative pressure of 0 Pa. To accurately capture boundary layer effects and friction, the ground plane and the hut surfaces were configured as 'Non-Slip Walls', with the outer fluid domain bounding box set to default extents. The fluid flow simulation was run in Explore mode using the default turbulence model (k-omega SST), consistent with Ansys Discovery's recommendation for wall-bounded and aerodynamic flows. Convergence criteria are managed internally by the GPU-accelerated solver. Pressure was calculated in Pascals (Pa) and visualised using a colour scale from -977 (blue) to +558 (red).

Both the five transverse sections of the apse (Fig. 7, views 1-5) and the lateral view (Fig. 7G) demonstrate that the greatest aerodynamic pressure is concentrated in the lower third of the structure, precisely in the zone where the base posts are located. This supports the hypothesis that these elements served a specific load-bearing function in response to wind pressure, and confirms their reconstructed placement at approximately one-third of the hut's total height, as anticipated by the proportional model.

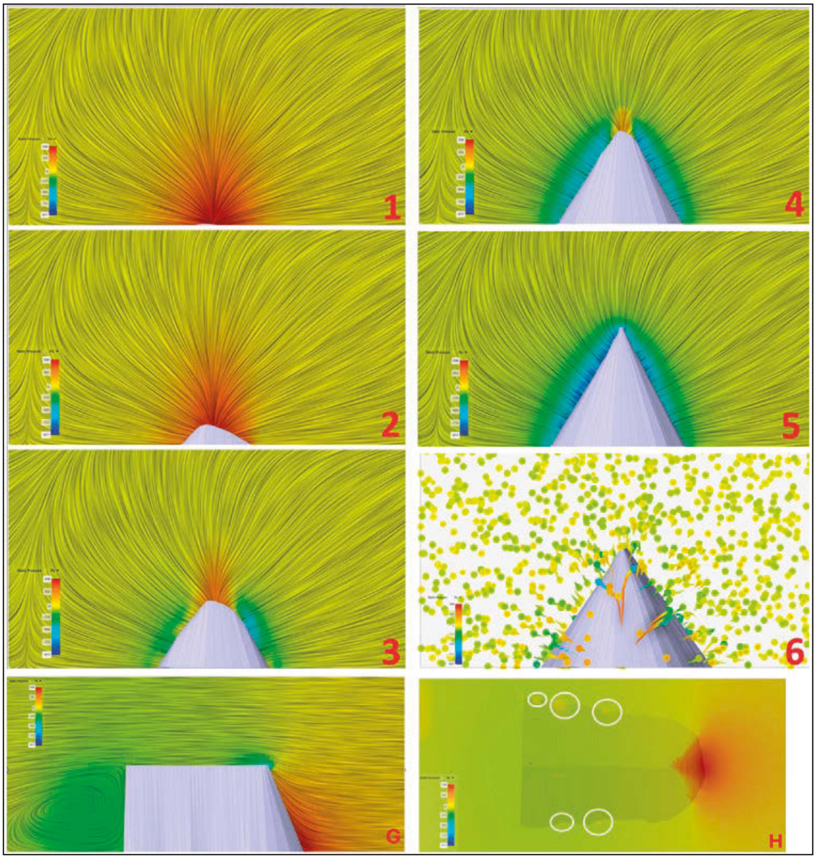

Fig. 7 – Results of the CFD (Computational Fluid Dynamics) simulation on Hut 1. 1-5) Five transverse sections of the apse at increasing heights; 6) frontal view with vector representation of flow deviation; G) lateral view; H) zenithal pressure map; white circles indicate zones of localized pressure variation along the sinusoidal lateral walls, where the undulating profile generates alternating pressure differentials rather than a single concentrated load, consistent with the energy-dissipation mechanism described by Li *et al.* 2025 for macro-corrugated surfaces. Simulated wind from NW-SE at 30 m s^{-1} (~110 km h^{-1}). Static-pressure scale (Pa): +558 (red), +302 (orange), 0 (yellow-green), –210 (light green), –466 (cyan), –722 (blue), –977 (dark blue).

Regarding the undulating wall, the zenithal view (Fig. 7H) reveals a complex aerodynamic behaviour. As demonstrated by Li et al. (2025) for macro-scale corrugated structures on airfoil surfaces, undulating profiles generate a controlled, fluctuating pressure distribution rather than a uniform one. The corrugations create alternating pressure peaks and troughs within their concavities that dissipate aerodynamic energy and prevent the accumulation of a single concentrated load. This mechanism is further corroborated by the broader aerodynamic literature on corrugated profiles (Lurans *et al.* 2025). While both studies primarily address aeronautical applications operating in flow regimes distinct from those modelled in the present simulation, the underlying fluid dynamic principles governing pressure redistribution across corrugated surfaces are universally applicable. They provide a coherent physical framework for interpreting the pressure distribution observed here as consistent with an active aerodynamic load management mechanism. This capacity to actively manage aerodynamic stress, rather than passively resisting it, suggests that the undulating profile may have acted as a functional adaptation rather than a purely incidental feature.

The present simulation is intended as an exploratory analysis consistent with the established use of CFD in heritage and archaeological research, where single-scenario simulations are commonly employed to test interpretive hypotheses rather than to provide engineering-grade validation (Grau-Bové *et al.* 2019). While this single-scenario approach provides significant preliminary insights into aerodynamic behaviour, it is acknowledged that a definitive validation of the aerodynamic advantage provided specifically by the undulating profile requires a comparative baseline. A comparative simulation with a counterfactual model, a structurally equivalent hut featuring a smooth, non-undulating perimeter wall, under identical wind conditions is planned for a forthcoming contribution. This future comparative analysis will rigorously isolate the load-management effects of the wall curvature from those generated by the overall geometry, orientation, and roof pitch.

6. Volume estimation and structural considerations

One analysis that supports digital reconstruction is volume estimation, which can offer insights into the daily life organisation of past communities, though always with due caution. In this case, two main calculations were carried out: a general estimation of the total timber volume required to build the entire hut, and a second, more focused calculation regarding only the perimeter posts. In the first analysis (Fig. 8), the model includes 93 elements among perimeter and base posts, 8 axial and ridge posts, approximately 1,000 horizontal beams, 89 vertical beams, and a hypothetical wooden partition that likely separated the domestic area from the external covered space. Although relatively thin (about 7 cm), this panel would have extended along the full length of the hut up to the height of the base posts (3.33 m), contributing significantly to the overall timber volume. The total volume of the structural timber, excluding the panel, amounts to 42.43 m³. This estimation, while based on digitally modelled data, must be interpreted with caution: the dimensions of the posts are not derived from direct measurements but from proportions extrapolated from comparative models.

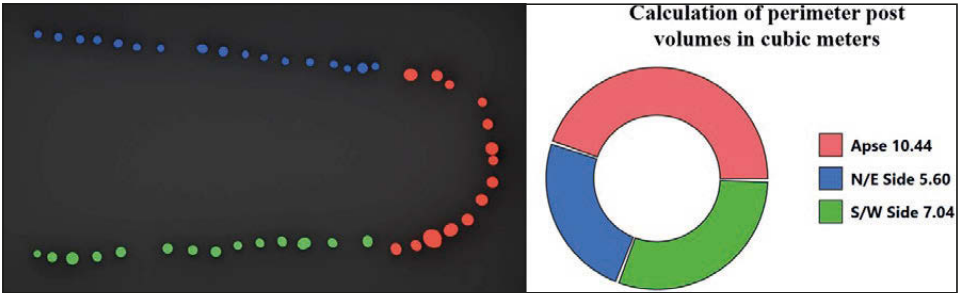

Fig. 8 – Sankey diagram showing estimated timber volumes (in m³) in the overall structural reconstruction of Hut 1. The volume considered excludes the hypothetical perimeter wall.

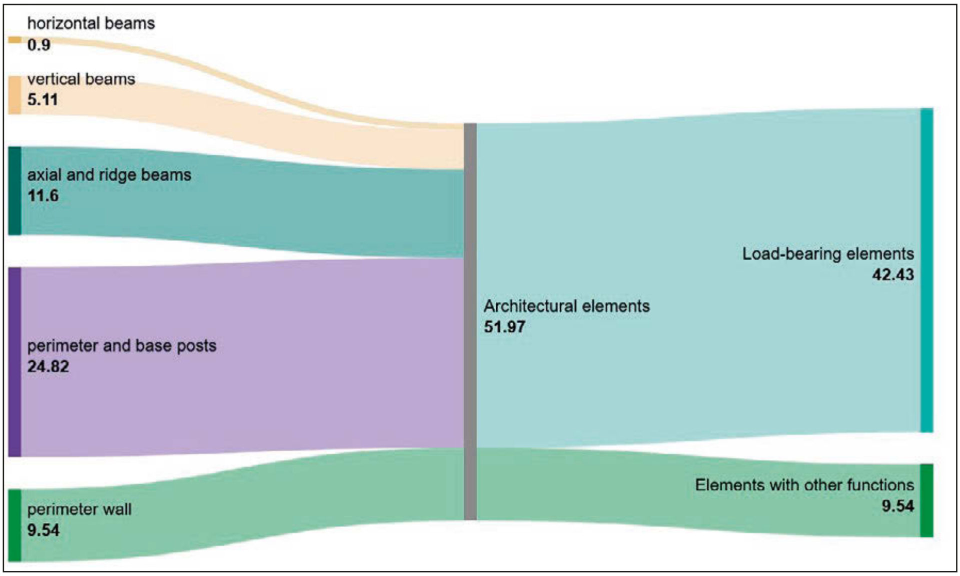

Fig. 9 – Comparison of perimeter post volumes (in m³) Hut 1, grouped by zone. The chart shows a clear increase in volume for the apse posts, consistent with their structural role and distribution. Colour code: red = apse; green = southwest side; blue = northeast side.

Some direct comparisons with oak trees, presumably available during the chronological horizon under investigation (Tunzi *et al*. 2018), can be illustrative. A standard oak, with a trunk height of about 20 m and a diameter of 2 m, yields a volume of approximately 62.83 m^3. A larger oak, 25 m tall with a diameter of 2.5 m, can reach 122.72 m^3. Moreover, even larger specimens are known, and major branches could also have been used for construction, further increasing the usable timber. Cross-referencing these figures with the volumetric data of the hut (42.43 m^3) suggests that, with careful wood processing, a large and complex structure like Hut 1 could have been built using one to two adult oak trees, depending on their size and the efficiency of timber processing.

The most reliable analysis concerned only the perimeter posts, as these elements are directly attested in the archaeological record. To highlight possible structural or planning differences, the posts were divided into three groups: those from the apse (14 elements, in red in Fig. 9), those from the southwest side (14 elements, in green), and those from the northeast side (17 elements, in blue). The comparison between volumes clearly shows that the apse posts are significantly more massive, with a volume ratio of approximately 2:1 compared to each of the long sides.

The result, illustrated in the chart in Fig. 9, is particularly revealing. It highlights, within the broader structural planning already discussed, the deliberate placement of larger perimeter posts in the apse area of the structure, almost respecting the 2:1 ratio previously observed in other architectural elements. The chart shows that the apse posts have approximately 1.5 to 1.9 times the volume of those on the lateral sides (with the northeast posts averaging 5.60 m^3 and southwest posts 7.04 m^3, compared to the apse posts at 10.44 m^3). This differentiation demonstrates a clear hierarchical approach to the structural design, with the entire layout appearing well balanced between the main body and the terminal apse, accounting for some variation likely due to periodic maintenance over the structure's lifespan. This proportional choice has been hypothesized for three main reasons:

1. As shown in the CFD (Computational Fluid Dynamics) analysis, the apse is the part most involved in resisting and absorbing strong airflow and the resulting pressure. It is therefore plausible that thicker posts were used here to reinforce this critical zone. In contrast, the sinusoidal side wall, already managing and channelling the airflow, did not require additional structural support.

2. The curved base beams required deeper insertion sockets for proper installation. Larger-diameter posts could provide sufficient material for cutting curved notches, without compromising structural strength.

3. In the foremost part of the apse, two closely spaced perimeter posts are present; their placement at the point of highest wind impact suggests a local reinforcement strategy and further justifies the use of posts with a larger diameter.

7. Conclusions

This paper has presented the application of an experimental digital method to the architectural reconstruction of a Bronze Age domestic structure at Posta Rivolta. Hut 1 proved particularly well-suited for this exercise due to the clarity of its archaeological markers and the consistency of its structural layout. The proposed reconstruction integrates direct archaeological observation, typological comparisons with Nola-Croce del Papa, and parametric digital modelling. The three-dimensional reconstruction employs the 1:2 proportional ratio observed at Nola to estimate a total height of 10 meters for Hut 1, though this proportion may have undergone local adaptations in response to specific functional needs, material availability, or building traditions of the Tavoliere territory. Archaeobotanical and anthracological analyses conducted at the site anchored the digital modelling to concrete data from the specific context of Posta Rivolta.

The preliminary CFD analysis tested, for the first time, the aerodynamic behaviour of previously hypothesized architectural elements: the apse, the base posts, and the sinusoidal wall profile. The simulations, based on environmental parameters derived from studies on the Campanian region (wind speed of 110 km/h), revealed a complex aerodynamic response. Specifically, the undulating perimeter wall, confirmed both by the distribution of perimeter posts and correlation with adjacent pit structures, and the apse appear to function synergistically to manage wind loads. Drawing on principles from macro-corrugated aerodynamics (Li *et al.* 2025; Lurans *et al.* 2025), we hypothesize that the wall's concavities actively dissipate aerodynamic energy, reducing overall structural strain. While these single-scenario exploratory findings are highly promising, a definitive validation requires further investigation. Future work will therefore prioritize comparative simulations utilizing counterfactual smooth-walled models, aiming to rigorously quantify these structural advantages. Beyond aerodynamic load management, the undulating profile represents one of Hut 1's most distinctive features. It may have served complementary functions such as rainwater collection and channeling, a hypothesis that warrants further investigation and is supported by the thermal instability and climatic crises proposed for this chronological horizon, particularly relevant given that the Cervaro is a seasonal river.

The volumetric analysis provided quantitative assessment of construction materials, revealing a coherent balance between architectural form and structural function. The timber volume required (approximately 42 cubic meters for the load-bearing structure) could be obtained from one to two large oak trees with efficient processing. The deliberate placement of larger posts in the apse area, respecting the 2:1 ratio observed throughout the structure, demonstrates sophisticated structural planning responsive to wind pressure distribution. The monumental dimensions of the Posta Rivolta huts (exceeding 20 m in length) suggest a high level of collective coordination and advanced technical skills. Future analyses could explore the socio-economic implications of these projects, including possible construction timelines, resource procurement strategies, and potential symbolic significance.

The methodology will be progressively tested on Huts 2 and 3 at Posta Rivolta, then extended to other culturally related sites of the Palma Campania and Protoappenninico culture to verify its replicability and identify regional building patterns. The digital model serves as a heuristic tool facilitating scientific discussion, continuously updatable with new evidence. Its dissemination potential offers significant opportunities for site valorisation and public education, bridging the gap between scientific investigation and public perception of prehistoric archaeology through museum exhibitions, educational videos, and tactile replicas.

In conclusion, this reconstruction demonstrates how integrating traditional archaeology, comparative analysis, and digital technologies opens new interpretative perspectives. The results highlight a coherent and intentional design compatible with structural and environmental requirements, transforming fragmentary archaeological traces into a verifiable architectural hypothesis and contributing to our understanding of the technical and organizational capacities of late 3rd and early 2nd millennium BCE communities in southern Italy.

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ABSTRACT

This article presents the results of a digital reconstruction of Hut 1 from the Bronze Age site of Posta Rivolta (Foggia), conducted as part of an ongoing doctoral research project. The study employs an integrated methodology combining archaeological data, three-dimensional modelling, and structural simulations to propose a scientifically grounded and verifiable architectural hypothesis. The focus is on the analysis of the wooden framework, developed through comparison with the site of Nola-Croce del Papa and adapted to local archaeological markers. The validity of the hypothesis was tested through Computational Fluid Dynamics (CFD) simulations to assess the aerodynamic response of the structure to environmental stresses. Additionally, volumetric calculations of the timber used were performed, with particular attention to the functional distribution of the perimeter posts. The results highlight a coherent and intentional design, compatible with structural and environmental requirements, laying the groundwork for further research and valorisation efforts.