Nexus Netw J (2017) 19:503–520
DOI 10.1007/s00004-017-0336-x

NEXUS NETWORK JOURNAL
Architecture and Mathematics

RESEARCH

The Façade of Paolo Soleri's Solimene Factory

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Published online: 12 April 2017

Abstract A simple geometric query provides us with the opportunity to review a symbolic work of modern architecture, the Solimene Ceramics factory by Paolo Soleri, built in 1954. A question that is perhaps marginal in some contexts, becomes fundamental when it is a matter of executing elaborate technical and project drawings that accurately describe the project. Well beyond the necessities of descriptive geometry, a study of the configuration provides knowledge about it was built, at times highlighting variances that required corrections in the course of the works and the hypothetical area of generated stress. In the specific case, it explains the origin of the 'flare' that occurs at mid-height in the forms that compose the façade, a characteristic that paradoxically has never been considered in the technical drawings or discussed in numerous studies. The aim of this research is to explain why the forms of the façade are shaped the way they are.

Keywords Paolo Soleri · Solimene ceramics · Descriptive geometry · Modelling · Conic sections · Right cylinder · Hyperbolic hyperboloid

Introduction

The Solimene ceramics factory built between 1954–1955 in Vietri sul Mare, in the province of Salerno, rises on the long and narrow terracing of the cliffs that delimit the Gulf of Salerno to the northeast (Fig. 1). Paolo Soleri (1919–2013), born in Torino, Italy, but active in the United States from 1960 until his death, is the author

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Fig. 1 Paolo Soleri, Solimene ceramics factory, Vietri sul Mare (Salerno), Italy. Views of the main façade. Photos: author

of the project. The original drawings were drawn in pencil and India ink on colored parchment, and are currently preserved in Arizona in Soleri Archives in Arcosanti. Autographed copies can be found in the Municipality of Vietri, co-signed by engineer Francesco Immormino, who verified the structural analysis that was submitted in 1954 to obtain authorization for a modification to the plan that had been previously approved (Zampino et al. 1995).

The abundant bibliography and dedicated websites testify to the importance of this building, which grew out of a fortunate, fortuitous meeting between Soleri and the Solimene family, makers of ceramics. Today the building has once again become a focus of attention, as an emblematic example of the debate over the restorations of modern works of architecture. This has led to the generation of numerous representations and models derived from both direct and instrumental surveys. One of the most recent and useful of these is the project presented in 2015 by Marzio di Pace of Amor Vacui Studio (see, for instance, http://www.amorvacui.org/restauro-della-fabbrica-di-ceramiche-solimene/), which aims to preserve the industrial characteristics of the building and improve access to it in order to turn it into a centre for cultural activities as well as an attraction for tourists.

Nevertheless, as far as we know, there are no existing studies of a geometric-configurative nature that present and discuss the structural and morphological features of the projecting volumes of the main, south-facing façade. Some studies describe the exterior surfaces, but do not interpret their configuration: do the forms indeed resemble "reverse cones", as (Sigismondo Nastri 2013) referred to them in the popular press? A geometric-configurative study, in addition to developing the horizontal surface and describing the profiles of elevations and sections, could clear up some of the misunderstandings that are so widespread in literature concerning the origin of these particular shapes. Further, it could also provide an explanation for the obvious flares that begin halfway up the structures (Fig. 2), paradoxically ignored by any analyses and graphic documentation. The flare at mid-height, replicated in

Fig. 2 Oblique views of the forms of the façade, making evident the flare that begins at mid-height. Photos: Author

all similar parts of the façade, is curious. What is the reason? Is it an aesthetic choice or one that responds to a static or functional necessity? The purpose of the present research is to answer these questions.

The History of the Solimene Ceramics Factory Building

One cannot help but feel that the building represents the kind of ceramic vases that are produced in it: "There is in this singular building a concept of circulation … that has always existed in using the potter's wheel to create and transform clay into a vase" (Venezia and Petrusch 1983: 166–167). This is an idea to which every design choice seems to refer, starting from the position of the factory's kilns, which, respecting the ancient tradition of wood-burning ovens built for this purpose, are constructed vertically and in the center of an open space around which are organized the work cycles. The vertical supports imitate trees in terms of form, function and structure (Fig. 3).

The 'forest' of pillars is conceived to support the cantilevered slabs (a cantilever of less than 3 m), which are embedded between the outer, non-loadbearing wall and the interior branches of the pillars. On the blind side of the building this cantilever becomes a ramp that connects the various level of the structure, while on the side of the main façade the projecting forms create necessary work spaces, the usable area at every level varying in a proportionate manner. The work stations are well lit from

Fig. 3 Interior of the Solimene ceramics factory. Photo: Author

the ceiling as well as indirectly from the side windows, thus protecting the interior from the heat caused by the direct rays of the sun so typical at this latitude. To this end the convex forms of the exterior help mitigate the effects of the high summer sun while exploiting the benefits of the low winter sun (Rossi 1986: 35–36, 2013). Even the choice of the facing material, terracotta, and its special processing and installation (the *mummarelli* were shaped and fired on site) contributes to revealing the features of the design solution both on the functional and the aesthetic level. From a strictly static point of view, the manner in which the wall is built confirms the validity of this choice: the form of the *mummarelli* (these will be defined and discussed in detail below) is designed to resist the stress generated by compression and tension (Rossi 1995). On the heuristic level, the hundreds of *mummarelli* made for this purpose testify to the search for an existential and psycho-physical space.

Such a choice indicates both the growth of a personal search as well as the training provided by Wright, the founder and exponent of the "Organic Architecture" movement. Soleri, in fact, did a post-graduate apprenticeship with Frank Lloyd Wright that lasted 18 months, six of which, as he recounts, were spent in the kitchens to learn the language! Developing his own personal conception of architecture, Soleri returned to Italy, and traveled throughout the country in a rather singular bus modified for use as a home-office (Carbone 2013). During his travels he stopped in Vietri and, intrigued by the art of clay material, came into contact with the Solimene family who asked him to design and build the factory.

Natural and artificial elements come together in the search for an essential "frugality", one of "doing more with less": less energy resources, less pollution, less waste of space and material (Lima et al. 2004: 126). A method that allows man, as Soleri would later state, to live an ecological and sustainable life (Soleri 1969). By uniting Vitruvian *firmitas, utilitas* and *venustas*, the morphology of the factory displays "that sureness of execution, the inner necessity, the indissolubile bond between form and material that are revealed to us by the humblest of shells" (Valéry 1998: 91–92).

Attentive to the both the building site and the production cycle of ceramics, Soleri proposed "a sort of ogival spiral" (Sicignano 1998: 28) that rotates around itself, alternating straight sections (those resting on the south façade where the work cycles are organized) with upward directed ones (on the blind side facing the mountain to connect the different levels). In so doing he demonstrates that he uses what he learned and that he is inspired by the organic form that the master achieved during those years in New York while directing the construction of the Guggenheim Museum or, as has been noted, the works of the "small Anderton Court Building, but also such works by Wright as the Johnson and Johnson offices in Racine or the Larkin Building in Buffalo" (Sicignano 1998: 28).

The Surface of the Façade

Following the sloping lines of the mountainous cliffs of the site, the main façade is located halfway up the coast, and is very visible from afar, presenting characteristic full-height trapezoidal glass surfaces inserted among projecting and variably curving solid bodies. The contours described in the literature to describe its exterior aspect appear to allude to gigantic vases; in fact, the exterior walls enclose a resonating cavity in which Solimene's ceramics are manufactured (Venezia and Petrusch 1983: 166).

The exterior facing of the walls is comprised of three-dimensional forms of two colours: the red of the unfinished terracotta creating a neutral background, and green enamel outlining a kind of fretwork on the façade (Domus 1955; Polano 1991: 506) (Fig. 4).

Upon reflection, there may be technical reasons for this ornamentation: conditions being equal, the surface treatment, and thus the color, reacts in different ways to the rays of the sun (Rossi et al. 1986). The balance of energy is not in fact subordinate to the form: as the contour changes, the angle at which the rays of the sun strike also changes and has a ripple effect on the variables, finding rational justification in a mathematical calculation. The reaction of the materials (Rossi 1986: 35–36, 2013) to temperature fluctuations causes a deterioration that is emphasized by the stress that exists between the non-homogenous components.

For our purposes, well beyond the obvious inconveniences, the fragmentary nature of the "tiles" that cover the factory has the virtue of highlighting its highly original structure: what we may think of as round tiles are in fact the bottom of clay 'jugs' (called *mummarelle*, a diminutive of the Neapolitan term *mummare*, or water jug) made specifically to be installed horizontally, so that they project outward by a

Fig. 4 Details of the exterior facing on the south façade. Photos: author

few centimenters from the mortar that binds them to the infill wall (Fig. 5a–e). They are inclined outward and secured to the infill (non-load-bearing walls) between slabs, and by means of these to the progressively projecting curved slabs and the tree-shaped concrete pillars. The profile of these forms consequently flares upward and outward, and serves as the boundary for the roof garden.

Preliminary Analysis of the Original Design

First, in examining visually the swelling forms of the façade, we cannot help but notice that the projecting volumes fixed to the ends both east and west of the main southern façade are right circular cylinders and that the infill wall falls straight down. *The curves of the different levels are in fact segments of circles*; the volumes are consequently configured by the movement of a straight line (generating) to which they are orthogonal and that passes by the points of the traced curve (the generating circumference) on horizontal level *xy*. Then, initial studies performed on photographs of the original plans, cut at different levels of every structure, has allowed us to reasonably support the hypothesize that the related masonry perimeters are segments of a circle (Figs. 6, 7).

The same does not hold true however for the volumes between these two extreme bodies. The inclination of the wall, no longer falling straight down, is visible to the naked eye. This is deduced from a simple geometric construction whereby, by segmenting the curve of a single volume and finding the centers of each—after connecting adjacent sections—we obtain the range of the unique circular matrix.

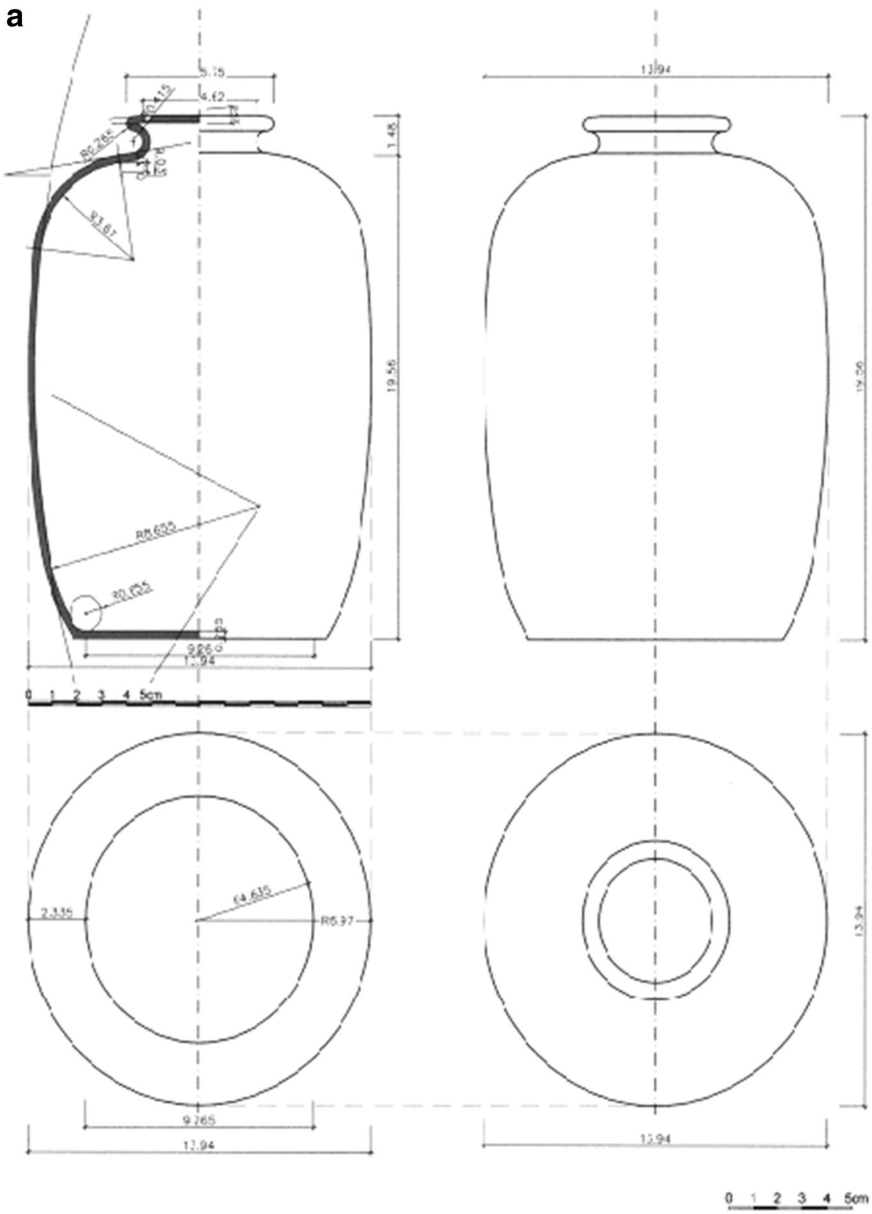

Fig. 5 Author's survey of the small *mummarelle* used on the façade. **a** Plan and section, **b** sections at levels 1.55 and 9.80 m. of a segment of the façade, **c** axonometric schematic view of an element, **d** (above the geometry of the form of traditional *mummarella*; below) with stress simulation generated by compressions and tension (Rossi 1995), **e** geometric model of a segment of the façade Images: author

We are able to confirm that the range extends from approximately 2.09 m at the height of the roof garden, to approximately 1.67 m at the intermediate level, cut at 8.40 m of the total height; it then goes to a range of 2.02 m on the two lower levels.

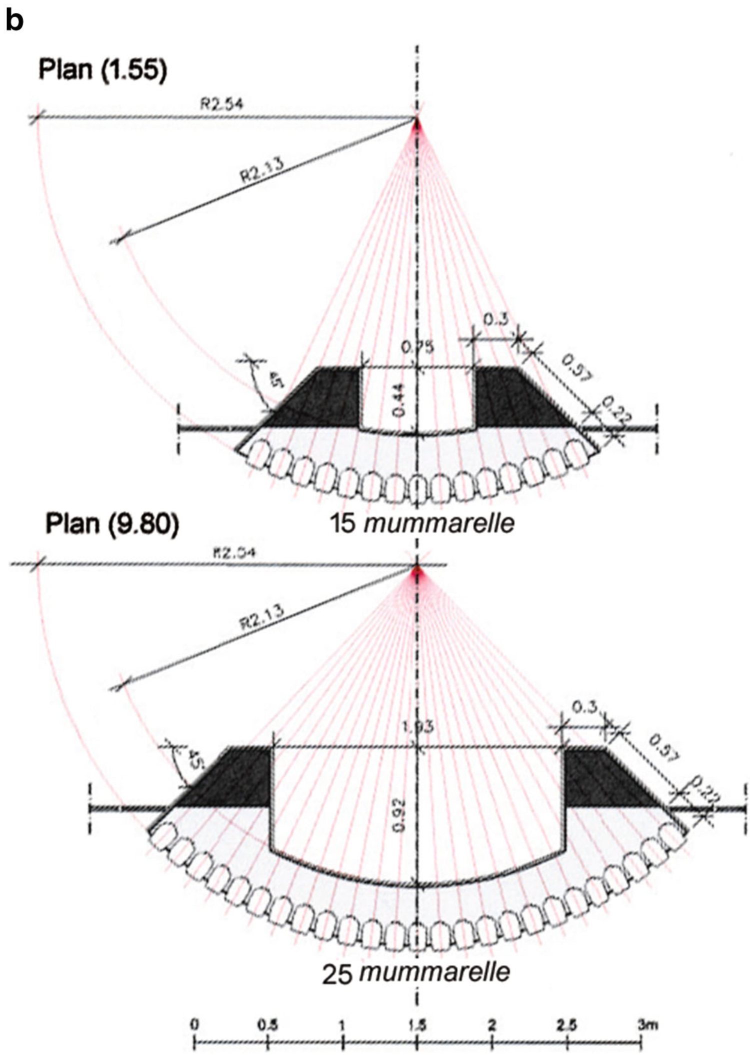

Fig. 5 continued

Their succession indicates that the five levels above ground are, respectively: sections of a hyperbolic hyperboloid; a doubly-ruled surface, since the generating curves (rulings*)* are two and different; opposing circles of equal range that guide the reciprocal movement of two generating straight lines, in our case the first located on the roof and the second in a diametrically opposite position.

At this point, how is it possible to justify the obvious complication that results from designing structures similar to hyperboloids? What static, functional and naturally aesthetic purpose can be attribtued to this form hypothetically achieved by

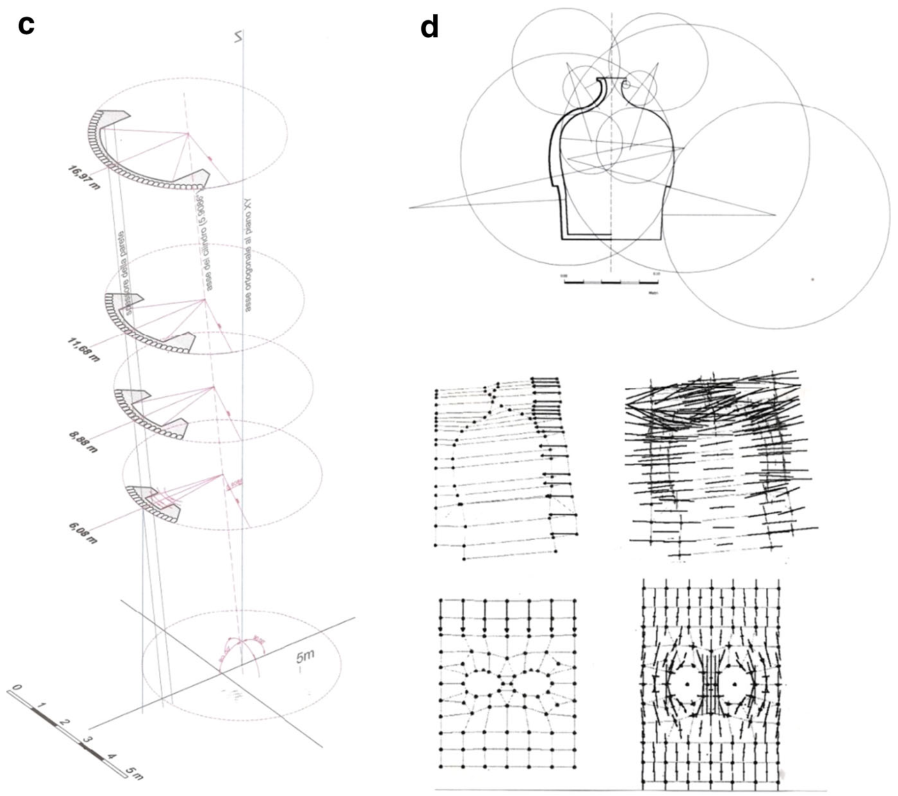

Fig. 5 continued

correlating the plans at different levels? Was there no simpler solution, a more "frugal" one, as Soleri would have said, and thus one that is more "ecological and sustainable", that could fulfil the same needs? One wonders what could have been the projected geometrical genesis for this decision? No help is offered by the elevation drawn by the architect (Fig. 8), which betrays a certain lack of determination that the perspective does not clarify. The reduced scale and the objectively small dimensions of the drawing prevent any reliable conclusions, justifying alternative theories: are the readings of the blurry photos of the project designs an error or are they purposely approximate executions? Or are they deliberate choices?

Since Soleri died and thus cannot resolve this doubt, we must rely on a critical analysis, one that can elicit from what appears to be smooth and indistinct (in Latin, *laevo*), what actually stands out according to the specific object (*re-laevo*). In other words, what is needed is an accurate survey.

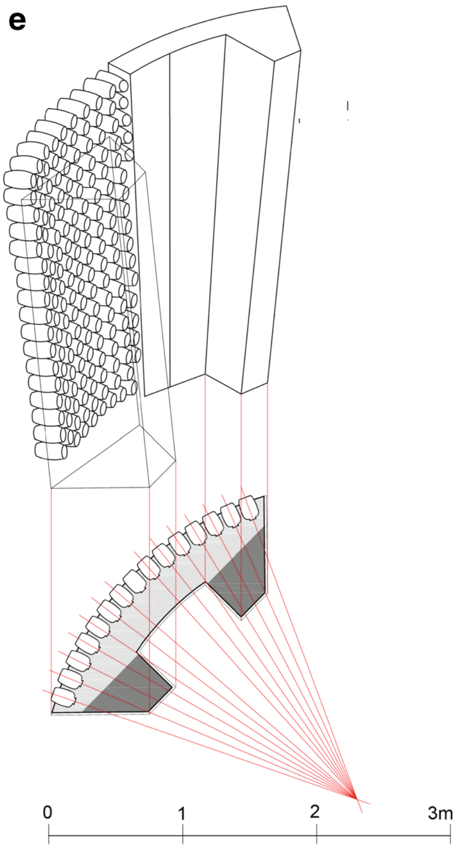

Fig. 5 continued

The Survey Data Used to Study the Profile of the Projecting Forms

Considering the characteristics of the wall and the precision required in view of the pre-established objective, the technical drawing can only be instrumental. The robotic video monitor of the station used, a Trimble Vision S6, provides a tridimensional scan of the mathematical surface. By quickly rotating the head, the optical instrument visualizes what it measures on the display. Its features (Dr-Plus) automatically correct the sight, thus ensuring a correct recording of the data, obtained by a simple stroke on the touch screen. The video transmission in real time also prevents most errors and allows us to later review the recordings. Partial results from the survey are shown in Figs. 9, 10, 11.

In processing the data, concentrating on the three axes of the points noted for a single intermediate projecting body, we can study the geometrical genesis in a vectorial environment, obtaining a cylindrical surface on the façade, with a central axis inclined at 5°52′.

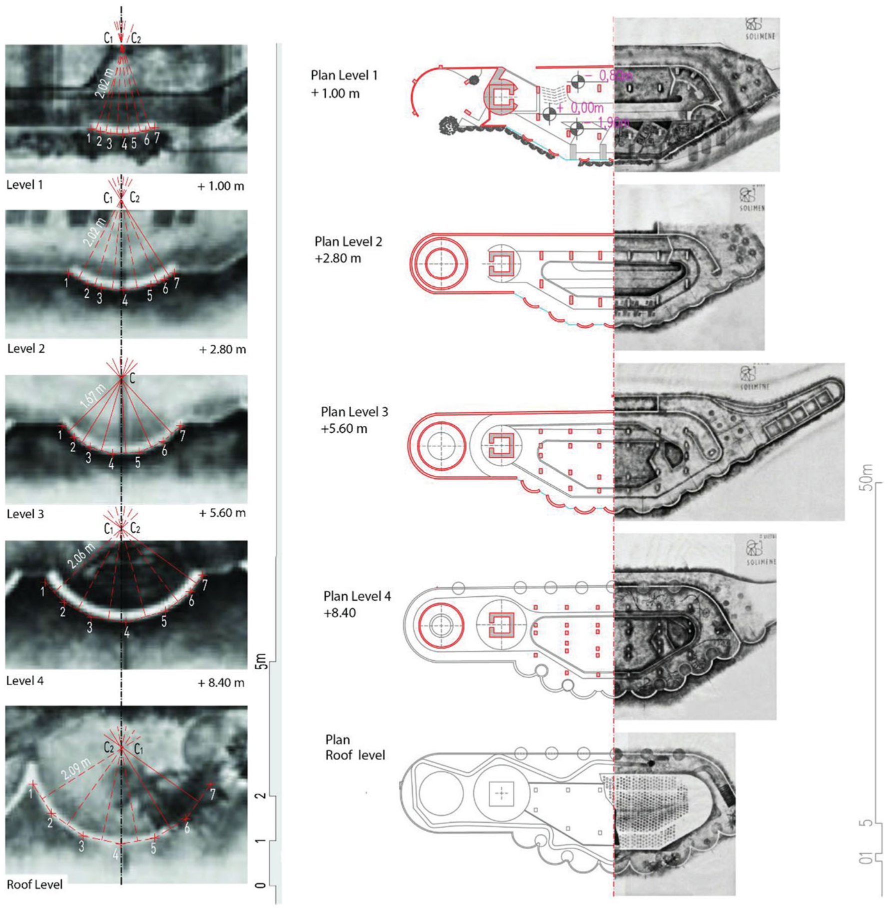

Fig. 6 Exterior segment of the façade on the south: orthogonal projections of an element. Image: author

Using the coordinates of the points, we obtain an equation that trigonometrically verifies the calculation of the conical section on the vertical level perpendicular to the horizontal plane of reference *xy* (geometric) of the type $z = k$.

Such premised, assuming the height of the cylinder (H) to be 1270 cm and the radius of the circumference in respect of the axis (r) to be equal to 254 cm (elements taken from the basic instrumental drawing), we establish, to calculate chord C, and thus semi-chord c variable with the height, that is:

$$a \leq \frac{H}{2} = \frac{254\text{cm}}{2} \leq 127 \text{ cm}$$

where: a is the distance from the center of the circle to chord C, confirming—by direct observation—that this is never greater than half the radius and that k is the trigonometric tangent of a rectangular triangle whose sides are a and H.

We assume therefore the following geometric-mathematical relationship

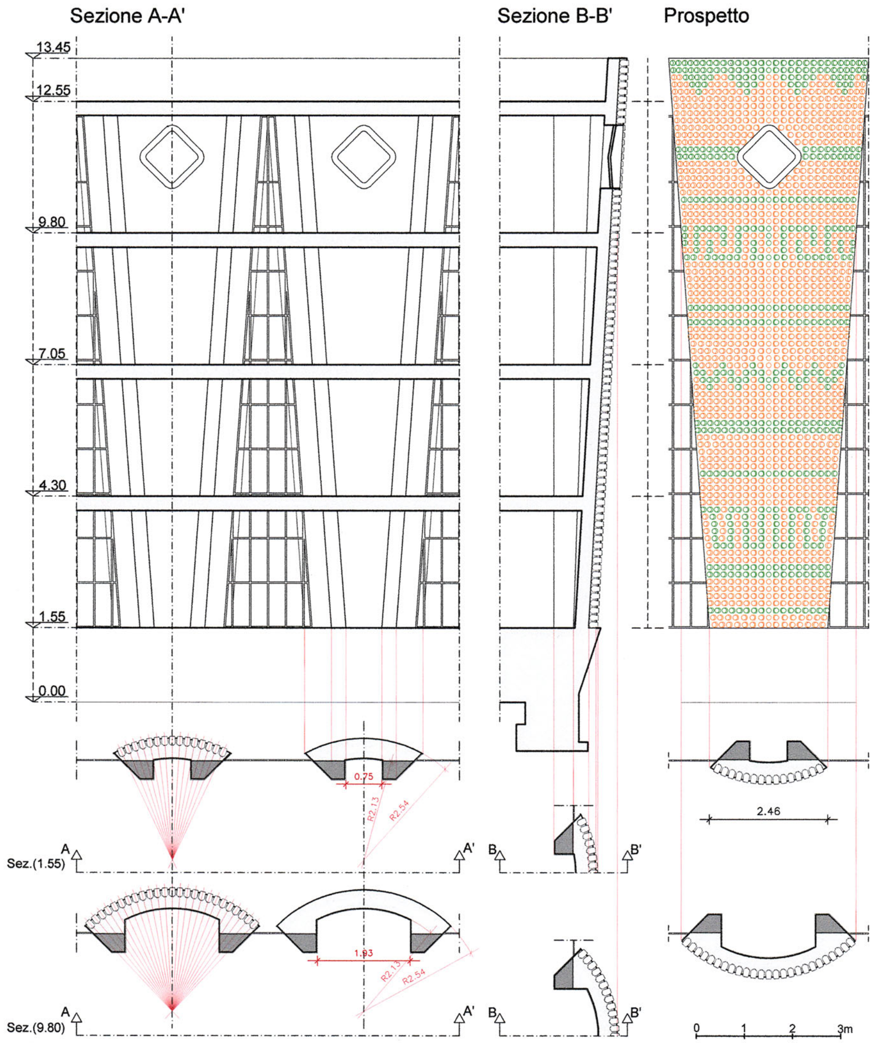

Fig. 7 Author's survey of the *mummarelle* used on the façade. Images: author

$$\frac{a}{H} = \frac{127 \text{ cm}}{1270 \text{ cm}} = \frac{1}{10} = 0.1 \ tg(6^{\circ}) = K$$

to calculate the semi-chord at level z, increasing from 0 to 1270 cm, that is, the arch under the segment between the pillars of the foundation on the five levels above ground, we have:

$$c = \sqrt{r^2 - a^2} = \sqrt{r^2 - \frac{z^2}{100}}.$$

This gives the following results (Fig. 12):

Fig. 8 Paolo Soleri's original drawing for the front elevation of Ceramica Artistica Solimene elevation. In the lower right "VEDUTA"; in the upper right Paolo Soleri logo, dated Vietri 2/52 (February 1952), black and color china ink on velum paper, 85.7 cm × 35.2 cm. Was taken apart into three pieces to be framed [unknown date], in Feb. 2017 unframed and scanned with pieces lined up. Drawing is stored in the Soleri Archives at Arcosanti. Reproduced by kind permission of the Soleri Archives

- height 0.00 range R = 228 cm;
- height 6.35 range R = 272 cm;
- height 12.70 range R = 285 cm.

We also performed a finite element simulation (Fig. 13) that completely illustrates the spatial geometry of the cylinder-surface level-window intersection.

Since the average of the extreme values (228 + 285)/2 = 256.5 is less that the value at mid-height (272), we deduce that the line of intersection is not straight but is the branch of the ellipse that touches the pillars.

The swelling forms that appear on the façade between the trapezoid glass windows are, for this reason, inclined outward, while the sections of windows are straight and thus perpendicular to the geometric line (level of reference *xy*). The resulting section plan is oblique in respect of the axis of the inclined cylinder for the degrees identified, that is $5°52'$. Thus, if the generating curve is a circle, the lines intercepted by the ceilings at the different levels will be ellipses, though barely pronounced due to the slight pitch of the axis of the cylinder.

Photographs taken by Colli Soleri during construction confirm the structure (see https://arcosanti.org/node/4606), showing a curved foundation at every level, progressively projecting upward from below.

As the surfaces of the pillars are not large enough to contain the entire progression of the curves-intersections, this creates stress, resolved during construction by decreasing the radius of the cylinder where necessary in order to prevent the vertical branch of the intersection curve from exiting the osculating pillar.

This resulted in flares at mid-height because the cylindrical walls in elevation are guided by the borders of the successive, previously-constructed projecting ceilings, ending directly along the side of the pillars, as confirmed by photos at the construction site. The flared form is thus obligatory rather than an insignificant

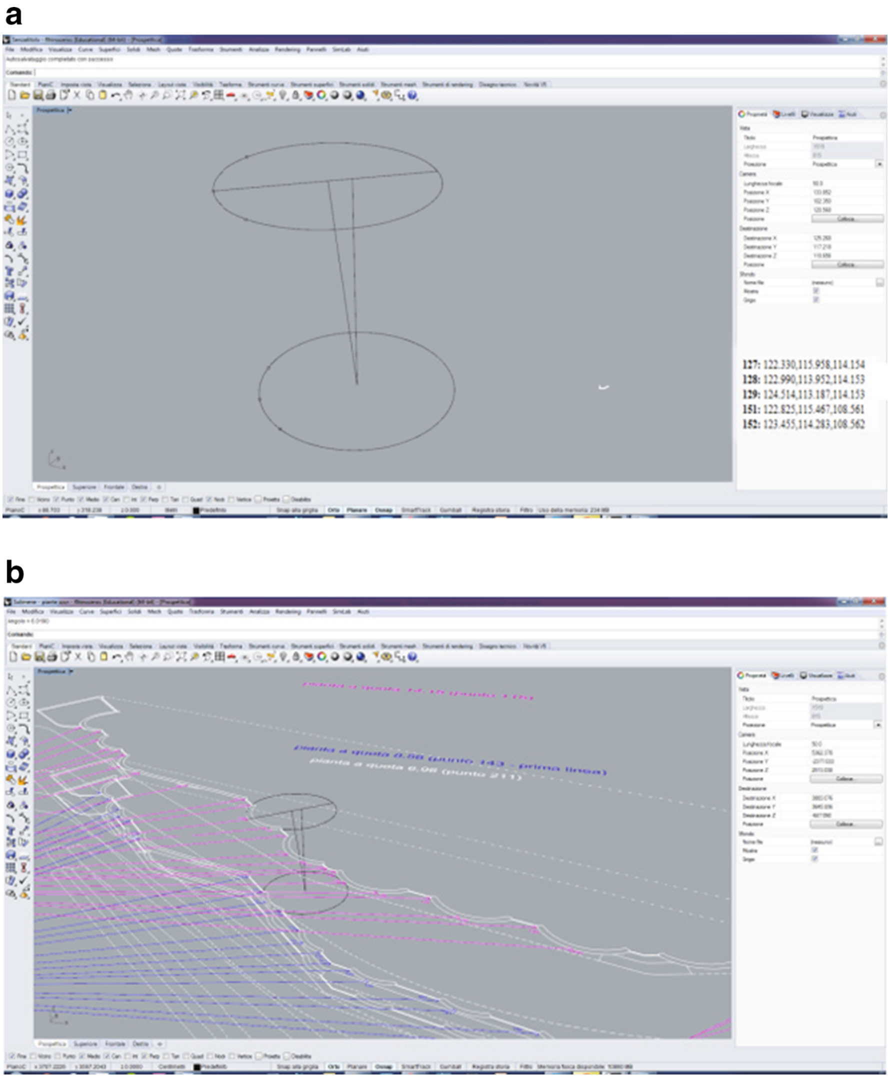

Fig. 9 Screen shots of the data reported with station Trimble Vision S6

whim. Paradoxically neglected so far by analyses, by confirming that the cylinder-surfaces-glass windows intersections could not be other than ellipses, these flares provide structural static information useful for restoration.

Conclusions

Far from being an exclusive curiosity of descriptive geometry, the interpretation of the geometric model was necessary in order to acquire a correct knowledge of the manner in which the surfaces and structures were developed. Plans and sections

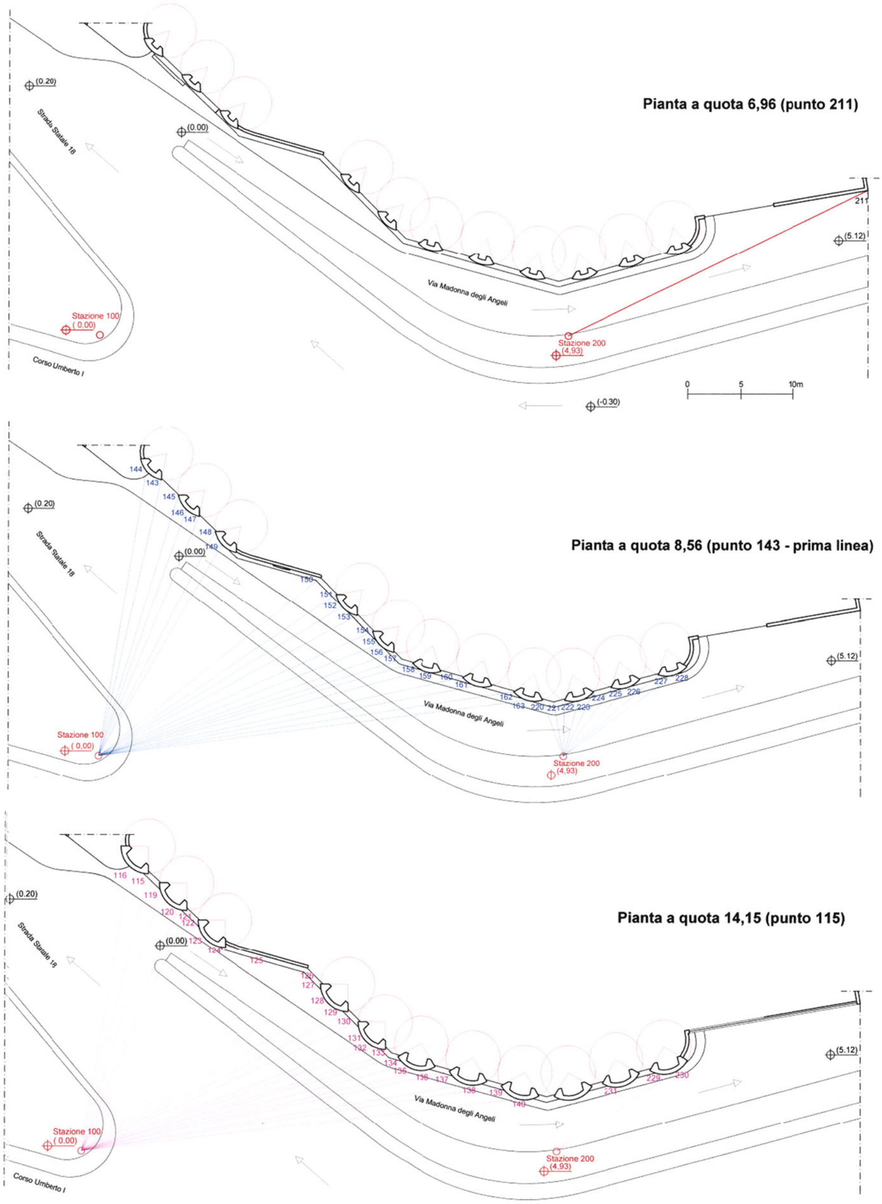

Fig. 10 Processing of plans to different levels. Images: author

continue to be the privileged place to direct the analyses and guide the project. The information gathered, in this specific case, turned out to be crucial, as it justifies the form of those unusual projecting bodies, explaining their static and structural origin. Conforming to the rule of transferring weight to the ground, the intersections between the levels and the structures required adjustments during construction. Such

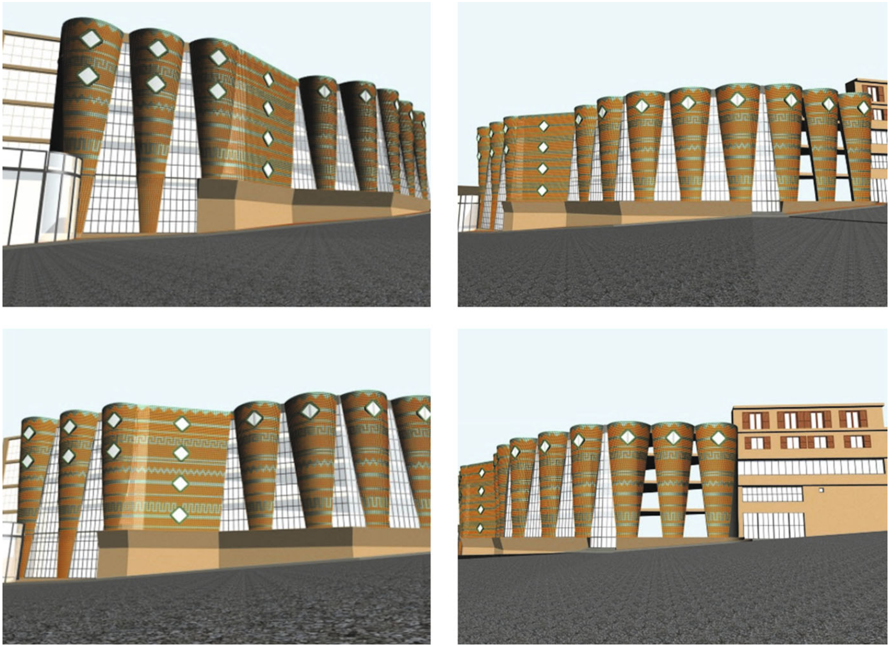

Fig. 11 Rendering of models derived from 3D scanning. Images: author

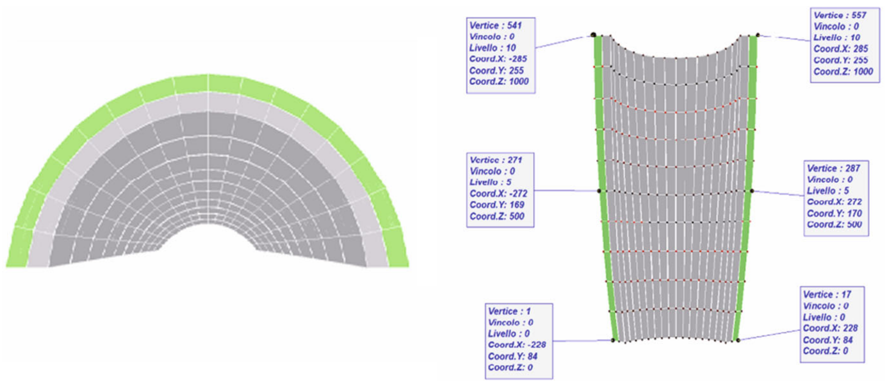

Fig. 12 Processing of the detected coordinates within a dedicated calculation program. *Left* seen from above all the arcs are segments of a *circle*; *right* seen from the interior, the width at the centre is not the average of the widths of the ends (256 against 272)

adjustments that had probably not been considered, although predictable with foresight. By decreasing the radius of the cylinder to intercept the branch of the resulting ellipse taken as a line common to the cylinder in contact with the pillar this causes narrowing at mid height. The flaring profiles, anything but poetic licenses, confirm a geometric law that renders corrections obligatory during construction, generating local stress, a probable contributing cause for the external degradation of

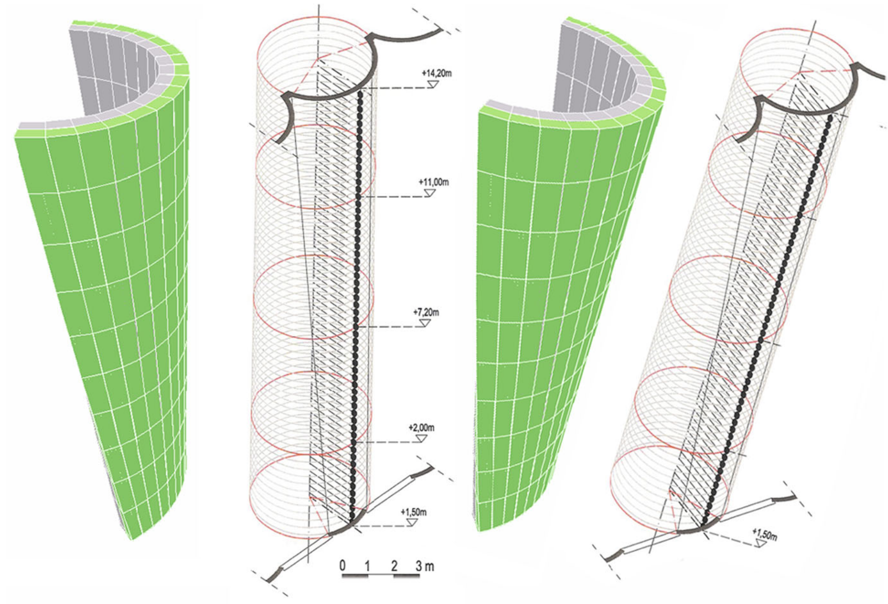

Fig. 13 Finite elements simulation that illustrates completely the spatial geometry of the cylinder-surface level-window intersection. Trompe-l'oeil: the form deceives the eye (cone instead of cylinder)

the *mummarelli* that cover the surface. This is in fact principally attributable to the detachment of the jug bottoms that cover the infill wall, constructed overhanging intermediate ledges, where the structure-facing is modified in order to cover the external borders of the reinforced foundations previously cast with the pillars.

Acknowledgements The survey with the Trimble Vision S6 was carried out with the aid of Sergio Deviato and Nicola Fontana students in the course "Scienza e tecnica dell'edilizia", Dipartimento di Ingegneria Civile Design Edilizia e Ambiente, Seconda Università degli Studi di Napoli (SUN), Aversa, during the 2015–2016 academic year. All quotations given here from Italian sources are translated by the author.

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