Friedrick II of Swabian: the castle builder. New stereotomic techniques and engineering innovation in gothic construction.

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ABSTRACT

This contribute highlights the main architectural aspects and building issues of the Federician architecture, by which we specifically mean all those constructions - most exclusively military and civil - Frederick II of Swabian had built in a very short period, from 1220 to 1250, in order to implement the plan of strengthening military infrastructures in the Kingdom of Sicily. Architecture and engineering under Frederick II comes out from a unique and original mixture of different cultures and experiences coming from all the different Mediterranean regions but coexisting in the southern Italy, from Sicilian Saracens to Nordic Normans, from Cistercian monks to minority groups of Greeks and Byzantines. This study analyses the constituent structure of all Frederick's castles realized by fundaments, that is to say all those castles which successfully express the rational architectonic values typical of the Federician architecture - architectonic-stereotomic stairs included - and tries to encode and understand the processes carried out for realizing projects and constructions from the plan to the realization of the single stony voussoirs.

We choose to deal with each part of the building process of the Suevian structures separately, the covering of the space and its fencing, in order to deepen the reasons behind some morphological and tectonic choices.The second part stresses the evolution of the stereotomic practices used into the building yards, the influences of the Swabia architecture into the Gothic formation within the Mediterranean basin and its influence in the spread of the stereotomic practices coming from the East, coded only in the sixth century thanks to some French and Spanish writers of treatises.This paper proposes an architectural and constructive reading about many castles planned and build up by Frederick II of Swabia during the final period of his reign, between 1220 and1250 throughout southern Italy.

This impressive work of fortification planning and construction took off from the necessity to defend and control an highly unstable and fragmented area, characterized by continuous rebellions of the native populations (often of different ethnic groups). It was then planned and built, in a very short time, a close network of castles, maritime forts, observation and defense towers on the main trade routers along the Apennine passes.The most significant territorial transformation concerned the construction of a fortification line in the east coast of southern Italy through the implementation of the military structures of the principal cities: from Termoli, Trani, Barletta, Bari, Brindisi, Otranto, both on the eastern shore of Sicily, with the widening and reconstruction of the castles of Milazzo, Lentini, Messina, Catania, Augusta and Syracuse.

Every town was equipped with a defensive wall, if not already present, and with a strongly geometrical *castrum,* even if there were a pre-existing defensive structures, which were substantially implemented and improved.

We can observe the adoption of a new functional plan common for all the Federician castles for rational and engineering reasons: the most common architectural typology is the castrum with quadrangular courtyard and, set in corners and in the middle of the wall, perimeter towers based on pure geometric shapes of circle, square, pentagon and octagon.

Table 1: Regnum Siciliae under Frederick II of Swabian

The Frederick's construction site revolves around the work of the *Cistercian lay brother* or *fratres conversi* recruited from the Cistercian order to overcome the physical work that the monks could not accomplish. This figure was part of the last social rank, like a serf, and performed materially the work planned and designed by the monks.

Anyway he represented the most important vehicle for the growth of Cistercian architecture principles and rules throughout Europe: they were skilled workers, teachers of the grange, laborers or masons.

Besides being able to rely on skilled educated workers , the Cistercians developed an architectural style based on a design code that can be summary in the terminology "*ad quadratum*".

We use this terminology to encode the planimetrical quality of " Bernardino style " and introducing the principles of construction derived by the text of S. Bernardo[1].

[1] Cfr. Voce" i Cistercensi". In Enciclopedia dell'Arte medievale, Vol. IV, Istituto della Enciclopedia Italiana Fondata da Giovanni Treccani, 1995) Roma; Canivez J. (1933-41), Statuta Capitolorum Generalium Ordinis Cistercensis ad anno 1116 ad annum 1786, vol 8. Lovani

Friedrick II, so close to the monastic order for the political vision and the administrative organization, made large use of these Cistercian workers for the construction of many of his castles: we know that some Cistercian were even *prepositum edificiorum* and *protomagister*[2].

The presence, on construction sites of the Swabian castles, of this monastic figure, will be crucial for the developments of geometry rules and formal choices of the new castles built by Frederick also because the *magister* were employed in various contruction sites, far away from each other, simultaneously.

So the castles in Prato, in Syracuse, such as in Catania and in Augusta have planimetrical settings and proportions very similar to each other: the same that we find in the abbeys of Murgo, in Fossanova and Casamari.

By relating the constituent elements of these buildings, as the measures of the cross-spans or the relations between the thicknesses of the walls and the relation between the full and the empty, it was discovered that often they are linked by the *aureus number* (1.618025 ...). The existence of this number is known from the buildt of Parthenon, up to Vitruvius. The name of Leonardo Fibonacci, one of the most important figure of Federician's court, is strictly related to the *golden number and golden section* due to the fact that he first discovered a mathematical series associated with this proportional relations, decoding from arithmetic in a geometrical feature, and recognized the value and properties related to the natural growth.

Using these geometrical knowledge, the Cistercian lay brothers were able to plan, almost automatically, a masterplan going on the construction by juxtapositions of areas, adding or subtracting lengths without compromise the original relationship.

Standardization and optimization in design and construction process in Federician castles

The design as a support to the project developed only in the Renaissance and then medieval *magister*, who knew only a virtual geometric model project to be carried out, worked on site to calculate any constraints and variations. He possessed a *ordinatio*, a grid pattern and applied case by case to define a *dispostitio* for each project.

Once you define the location and then implanted the construction site, the work was divided into teams, coordinated, which were advancing simultaneously. The knowledge of rules of geometrical and mathematical progressions was the primary tool for the control and optimization of the construction site, both during the tracking of the plants, both in elevation, in the design of the *traitè geometrique* of the vaults, that were all equal to each other and in golden proportion with the rest of the elements of the building.

This made possible to prepare at first the already shaped blocks for all vaults, the ribs, the doorways and windows splayed, the stone making up the stairs.

This is therefore a process of optimization of the construction site. This process is the basis of the decision to use regular, symmetrical floor plans for the construction of castles ab fundamentis of Frederick.

Many researchers have misunderstood this choice as a simple rational or artistic will , connected with the eclectic figure of the Emperor, with his centralizing policy and pragmatic, forgetting, however, the contingent construction choices responding fully to the needs of Frederick. He had to prepare a powerful organizational machine that goes from the extraction of the stones, the pre-fabrication of the elements directly in the stone quarry, to the distribution and installation of them among the construction sites across the country.

2 Cfr. Kantorowicz E. (1976). Federico II Imperatore. Milano: ed Garzanti, 80-81. cfr. Farina F., Vona I. (1988). L'organizzazione dei Cistercensi nell'epoca Fedudale. 11. Casamari.

It is therefore logical that the provision and use of pre-fabricated elements, needed a project set on the basis of predetermined size and length ratios: a kind of standardization of that we'll meet only many years later in Catalan Gothic. It's for this reason that, comparing homogeneous architectural elements (windows, doors, arches and lintels) in different castles far from each other, many dimensions appear to be coincident.

For example in the castle of Catania, the perimetral curtain walls are marked with regular rows of bricks made of small pieces, which regulate the proportions of the entire structure. All the cut stones were "standards": the pieces of diagonal cruises of the umbrella vaults of all the towers, the splayed windows and stairs, and were made in cut stone, and are simply applied and juxtaposed in this perimeter wall respecting the rhythm from the lines above. New buildings by Frederick are, almost all, set on a central and symmetrical plan (square or octagonal) and the modular scaling reaches levels of perfection unknown to the medieval European architecture.

The basic module used for each castles is constantly repeated to define the plan and the spatial configuration as a three-dimensionally cross ribbed vault.

These cross-span, joining in rows, are the basic elements that generate different kind of spaces, depending on the function of the building: Castel Maniace is a hypostyle hall, the Ursino Castle and the Augusta are square *castrum*, articulated around a central square courtyard, Lucera was a quadrilateral *donjon* on several levels. Evidence that the new Swabian castles were constructed starting from the tracking of the cruise (which were all equal and pre-fabricated) was clearly visible from the study of irregularities of Castel del Monte's plan.

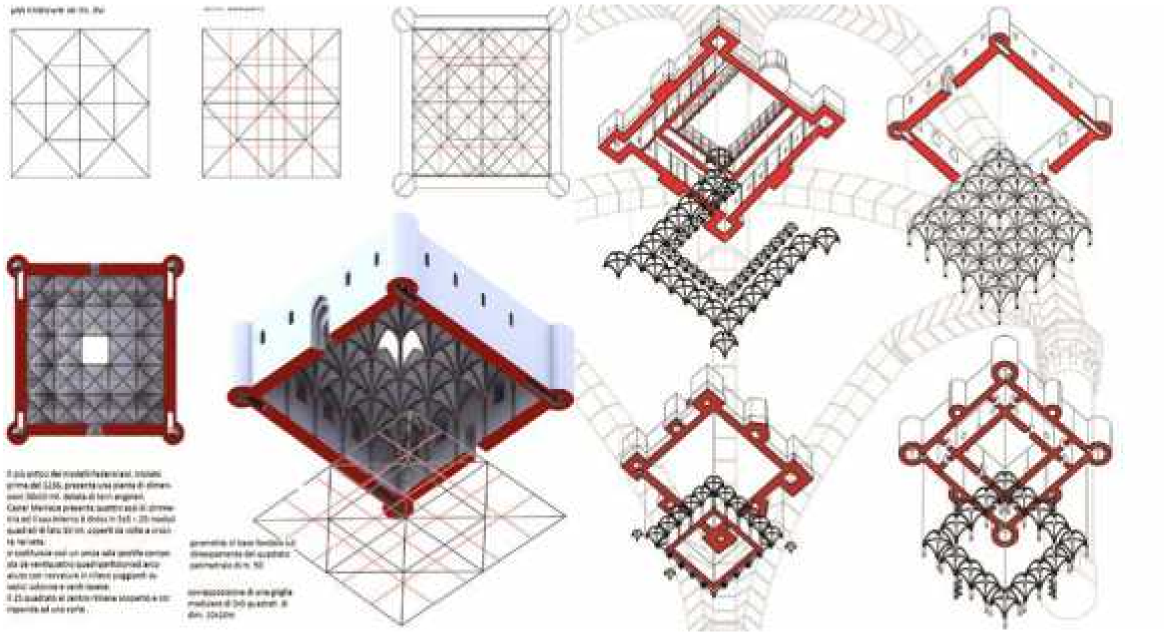
The perfect geometric plan of Castel del Monte, when get into the reality of construction is "corrupt" and we can notice that there are remarkable dimensional anomaly. The octagonal atrium presents one of the eight sides shorter than the others. This irregularity is due to the insertion of the metallic gate of the main portal (of 40 cm of space) in one of the eight perimetral wall. That insertion, caused the thickening towards the inside of the perimetral wall of the first room.

For this reason, all the dimensions of the room is slipped of the same size (40 cm) towards the inside of the atrium. This special device can only be explained if we assume that the amplitude of the rooms (6.40 m.) must be kept constant (as appears from the surveys).
The reason for this choice is that, at the time of raising the internal walls, the cutted stone for the ribs of the cruises that were supposed to cover the rooms had been cut in the quarry a priori. Studying in detail the spans of Castel del Monte, Castel Maniace, Castello Ursino Castle, and Augusta, was observed as the cruise is given by the union of the arcs that act as ribs, that if in the previous cases are arcs of an ellipse or oval in this is perfect semicircles.

The only geometric trace it takes to build all times covering spaces of the individual rooms is given by one parameter: the semi-diagonal of the square inscribed in trapeze, magic measure given by √ 2 (diagonal side x = √ 2). The semi-diagonal therefore constitutes both the inner radius of the semi-circumference subtended by ribs, both the same radius of curvature of the pointed arcs in the basic square. The segment C'-C" represents the difference between the measure of semi-diagonal (radius of the circumference of the ribs) and the side of the square. The distances between the side BC and points c 'and c" represent respectively the height of the key of the arcs ogivi perimeter and height of the key of cruises.

Table 3 : geometric model of Castel Maniace in Syracuse: the building's plan is obtained with a modular square grid 10 meters per 10 and each element is obtained by

halving the original square generator. The square cross vaults as a constructive paradigm of modular newly constructed castles by Frederick. Exploded axonometric of the castles of Augusta, Maniace, Prato and Ursino.

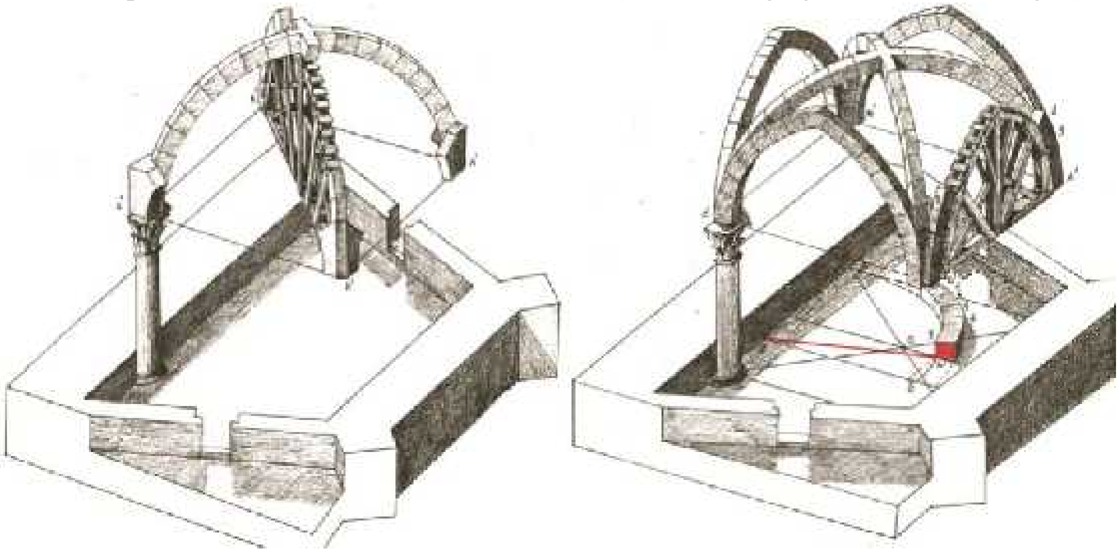


It uses the same path for all ribs of the castle, which thus could be produced in series before the construction of the perimeter walls.

Prefabrication equipment walls is also explicit, as we have already mentioned, in the equipment of plastic discontinuity walls (windows, round windows, fireplaces).

First phase of construction of vaults of the rooms was the construction of the centering for mounting the ribs: the adoption of a single radius of curvature for all ribs allows to build a single centering, to be positioned along the diagonals of each square by turn, for mounting all diagonals arcs of the castle.

Table 4: Construction of the Swabian cross vaults; assembly of semicircular diagonal ribs and pointed arch with the same curvature (ink drawing of Ubaldo Occhinegro).



When the assembly of the first arc was completed, masons proceeded to disarm, repositioning the centering on the other diagonal. They then proceeded to the positioning of the stones elements that form the four perimeter ogive arches in each room. Even these arcs follow the same semicircular curvature already used for the diagonals cross of the vaults and were then cut in the same ways. The ribs have not purely static function, but they were necessary for the construction of the vault, considered as a “*stone centering*”: the construction such complex surfaces would be possible only with complicated three-dimensional wooden centering. This technique, instead, allows to organize the space quickly and mechanically.

Stereotomic innovation

In the width of walls of the Swabian castles were built the most complex stereotomic equipment: pavilion vaults or stone staircase, complex intersections of ogive vault and helical vault like in Maniace castle the octagonal and hexagonal umbrella or domed vaults, located inside the towers, represent various digressions on the same subject, as well as the splayed windows, the complex lozenges, ecc..

The elementary act of closing the space becomes an occasion, for magister an stonemasons, to invent high architectural experimentation and stereotomical complex detail.
In the articulation of walls has a series of Stereotomical solutions of great constructive value: some solutions that we can observe in castles built by Frederick represent advances of tecniques that will be decoded only two hundred years later in some French and Spanish stereotomic treaty.
The construction of the stairs was one of the most complex experiment in Swabian site because of the specific geometrical knowledge.

The staircase present in Swabian castles can be referred to three tipology, later codified in treaties of stereotomy:

1) the spiral staircase with central column, present in most of the scalar towers of the Swabian castles

2) the spiral staircase with helical barrel vault, unique stereotomic of admirable workmanship found in the east tower of the Castle of Maniace in Syracuse

3) the scale with a single ramp with a barrel inclined vault that we can see in Syracuse, in the castle of Lombardy in Enna, and in the castle of Prato.

1) "*the spiral staircase in the center column is an architectural element that could better show the evolution of the stereotomic techniques from antiquity to the fifteenth century.*"

Using a single pseudo-triangular quoin that is, at the same time, the step-type, the cylindrical central column, and the support for the subsequent steps.

Another feature of the model is the Swabian constant presence along the outer curved walls of the stairs, of a special molding / shelf that draws on the jagged surface of the cylinder wall in a continuous frame shots.

The relative simplicity of execution of this staircase, which could be cut in series on quarry, is one of many examples of advanced techniques of standardization and optimization of the Swabian site.

2) The second type of staircase, of which there remains the only example in one tower of Maniace (but is not to exclude the presence in other castles, now destroyed, as Lucera and Foggia) is the highest point of the Swabian stereotomic culture and complexity.

It’s a spiral staircase with twisted rampant vault due to the type of Vis de Saint Gilles[3] in France and has virtuosity that does not seem to have immediate comparisons for the

[3] Fundamental to encode the model of vis de Saint Gilles are treated by Alonso de Vandelvira and Philibert de L’Orme who wrote in 1567 The premiere tome de l’arquitecture, presenting the first drawings of the vis de saint Gilles with two different constructive resolutions. The manuscript of Vandelvira, Libro de las cortes de Trazas y Canteria, dated around the

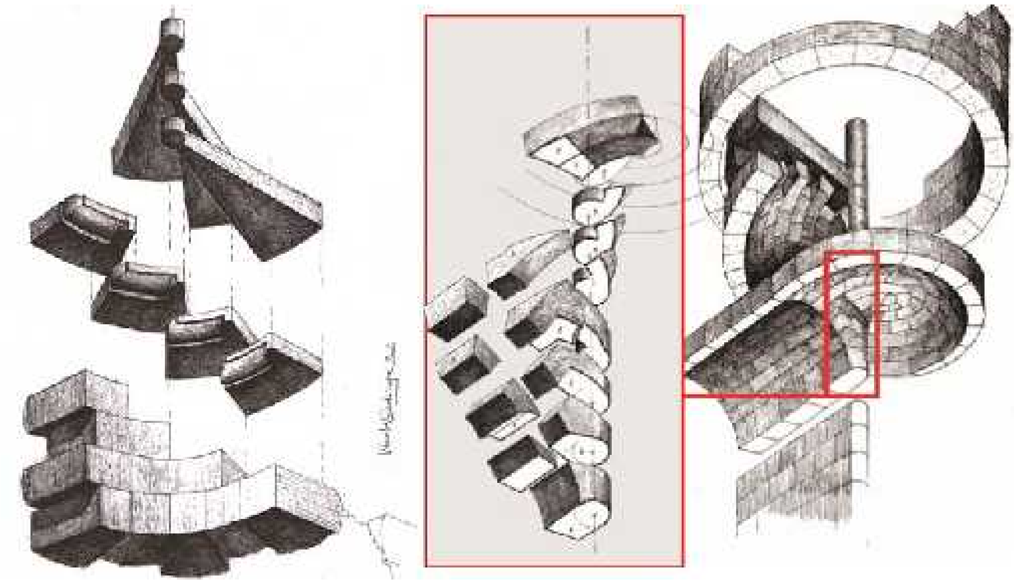
1575-1580, it's important for the systematic analysis of the techniques and Stereotomic processes of late medieval building, listing examples such as the vis de Saint Gilles. See J.Palacios, Trazas y cortes de Canteria renascimiento en el espanol, 1st ed, 1990, Madrid 2003, pp.149-184. Many

extraordinary complexity in the cut of the stones of the junction between the access vault and the scale vault.

The presence of this unusual scale has still not a unique reason: its complexity does not make it justifiable or for economic and functional reasons.

The techniques used by the workers to built the Maniace staircase were taken by two different cultural areas are known: if the finding of some signs carved on the blocks by the stonemasons, including the spiral of Archimedes[4], shows that they knew the building techniques used in the French constructions of the twelfth century (recorded in the famous notebook of Villard de Honnecourt), other geometrical-Stereotomic practices was more advanced in the East, especially in Syria, where the Crusaders found important masons schools. Since the beginning of the twelfth century, thanks to the commercial and cultural exchanges between the two shores of the Mediterranean (southern Italy was the bridge between the two worlds) the art of projecting solid and cutting complex surfaces in stone, began to move on the West Europe.

Table 5: la scala elicoidale con colonna centrale



3) The *Descenda de cava recta* is a vault system of scalar rooms constituited by an unique ramp with longitudinal development constituted by two arcs of circumference to all sixth, parallel, with sets of inclined plane.

The criterion of the cut of the stones, surely derived by the method of tracking the ground and drawing the profiles of the faces of the elements thanks to the *"panneau"*, is similar to that used for the embrasures of the windows, already used in Romanesque Architecture, and implemented in various Swabians sites.

other authors have dealt with this topic, including: G. Desargues, Brouillon project of examples ... pour la coupe de Pierres ..., Paris 1640; M. Jousse, Le secret d'Architecture, La Fleche 1641; G. Monge, Géométrie descriptive, Paris 1799; J.B. Rondelet, Traité théorique et pratique de l'art de Batir, Parigi1802.

[4] The Archimedean spiral is a uniform spiral type, in which the width of the turns is constant. The simplicity of the track helped popularize the use for the design of many complex architectural elements.

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