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The dimensional analysis of the bricks. The case study of Lucera between the thirteenth and fourteenth century.

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***Abstract* – In a project aimed to the historic reconstruction of the medieval landscape of Capitanata, particularly of fortified sites, the swabian – angevin fortification of Lucera was the subject of targeted archaeological investigation in order to identify the material parameters present in the walls. This investigation allowed to outline the production dynamics, in relation to the resources of 'landscape', the design choices, and the social and cultural implications of the building work organization. The dimensional analysis carried out on the brick buildings in the center of Lucera has contributed to identify the role that the Angevin fortification may have played in the development of reactivated clay cycle. It also helped to focus on typical relationship between dimensional features and production, circulation and use of bricks, starting from to late middle age to early modern age.**

keywords: building brick; dimensional analysis; dating methods; historical architecture; building work.

I. THE BUILDING MEDIEVAL AND POST-MEDIEVAL BRICK

The production and commercial dynamics of brick manufacturing in southern Italy, from the late antiquity to the Middle Ages, are still relatively little known compared to those of the central and northern parts of the country (in particular Tuscany and Liguria). Studies on the history of construction point to a rather widespread, reduced brick production up until the Early Middle Ages, showing signs of recovery only in the first half of the 12th century with the introduction of a new rectangular brick type (one foot long and half foot thick), which is smaller and more ductile.

Isolated studies linked to specific economic and social realities of central and northern Apulia point, also for this territory, not so much to a decline as to a transformation of the early medieval manufacturing processes and to the dissemination mechanisms of the fictile architectural material. The few production centres examined appear to be strongly ruralised, often meeting just domestic needs and thus not bound by commercial obligations and the clientelism typical of brick manufacturing in the Roman age [1]. Between the 10th and the 11th century the type of brick attested indicate a use almost restricted to the roofing and to the noble parts of the buildings [2].

Starting from this premise, in consideration of the relevant role played by the mensiochronological analyses in retracing the history of medieval brick production in central and northern Italy, this research has identified in the historic town of Lucera (FG) one of the most interesting subjects for the study of brick types in medieval and post-medieval era, as well as for the application of mensiochronology, a type of analyses which has never hitherto been used in Apulia or southern Italy. This paper represents, in fact, the early stage of an investigation which, based on statistical results, necessarily demands a numerically consistent and certainly superior corpus of data compared to the body of information available for a single urban centre [3].

The town of Lucera (FG) lies close to the Apulian Tableland, on an area characterized by the abundance of clay, therefore this urban centre has always had a great availability of the raw material essential for the fictile production. Long after the Classical period, the presence of kilns for clay firing are recorded again between the 12th and the 13th century in the Diplomatic Code of the Saracens [4] and in the Registers of Royal Chancery [5], in relation to the fortification built by the Angevins between 1271 and 1284. The fortress stands exactly on the westernmost corner of the town and consists of a long, irregularly shaped polygonal curtain wall (around 900m long), interspersed with towers and macroscopically divided into two parts marked by two different construction techniques. The shorter segment, facing eastwards towards the town centre, is built with stones and is fitted with seven pentagonal towers and two round towers placed respectively at the northern and southern corners of the fortress; the rest of the walls is, on the other hand, built with modular bricks (29/30x15x4,5/5,5 cm) and is articulated in thirteen quadrangular towers and two twin towers placed on the northern and western angles, all clad with the same brick

type [6] [7] (Fig. 1 -2).

Fig. 1. Walls Angevin (XIII century)

Fig. 2. Brick walls Angevin (XIII century)

With the construction of the fortress, from the second half of the 13th century, up until the modern and contemporary times, the brick seems to have played a key role in Lucera's urban development, as it was used in several types of architectures. During the first half of the 14th century the brick was again the first choice for the Angevins who commissioned the construction of both the Cathedral of S. Maria Assunta and some of the eleven parish churches instituted by Robert of Anjou [8]. Until the end of the 15th century several monastic orders, such as the Franciscans, the Dominicans, the Augustinians and the Benedictines, erected important buildings, many of which built with brick.

Between the 16th and the 18th century, this type of urban construction has been without interruption the main feature of the town's architecture, as can be observed in the palaces of the wealthy landowning bourgeois and aristocracy, many of which owe their stylistic imprint to the use of brick [9], something that made it the basic construction element of Lucera's architecture throughout the pre-industrial era.

19th-century archive sources provide us with cadastral lists of names and numbers of *kiln workers* (*fornaciari*) [10] [11]. With the industrialization of the manufacturing process, early 20th-century records become particularly rich and detailed, allowing an understanding of the broad outlines of: the organization of work in the brickworks, the technical characteristics of the product and the location of other production sites distinguished from pottery craft shops, which were built almost inside the urban area in compliance with the deliberative acts passed by the town council. The kilns, on the other hand, locally known by the name of ''*furnaciotte*'' (Fig 3), between the end of the 19th century and the early 20th century were located at the foot of the fortress, probably occupying the same area of the 14th-century kilns [12].

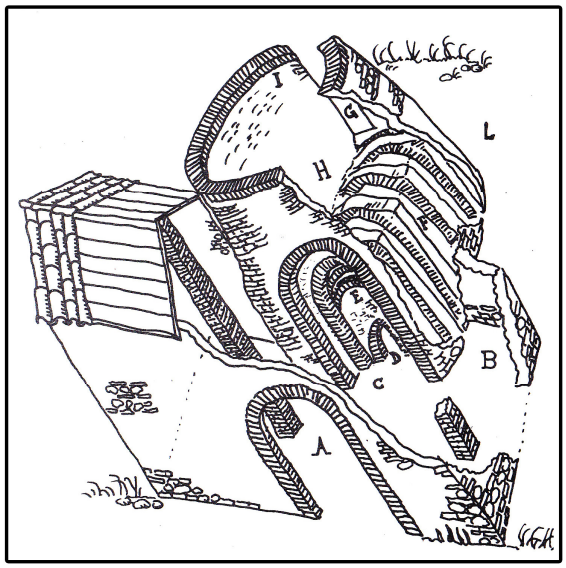

Fig. 3. Representation of a 'furnaciotta'

II. SAMPLING CRITERIA AND STATISTICAL ANALYSIS

Lucera's rich medieval and post-medieval civic and religious architecture and the presence of buildings whose construction chronology has been determined by historical documents or archive records, have represented the starting point for the processing of statistical analysis whose object of study is the relation between dimensional characteristics and the methods of brick production. The mensiochronological analysis has been focused on civic and religious buildings, located in Lucera's historic town centre (Fig. 4), dated through written documents. Homogeneous wall samples on which have been carried out fifty measurements with pinpoint accuracy, for each dimension, have been selected according to an autoptic interpretation of the parameters.

In order to highlight the diachronic - dimensional variation of the brick samples, the constructions examined cover a rather broad time span which goes from

the 13th century up until the first half of the18th century: 20 buildings have been examined, though only 13 of them, dated with more certainty through archive records, documents and bibliographic sources, have been deemed statistically relevant. For the collection of data has been created a graph datasheet linked to the OR-DBMS model, specifically structured for the storage of architectural data [13].

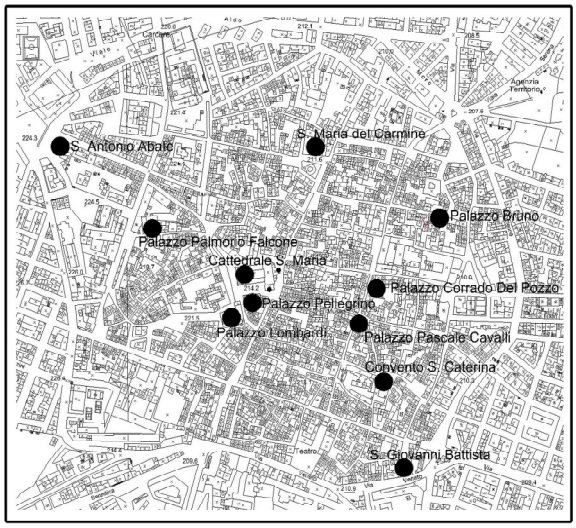

Fig. 4. Positioning on regional technical map of sampling

The recorded dimensions have been analyzed according to statistical methods proper of the mensiochronological analysis: with respect to each dimension, for each sample have been calculated the arithmetical average, the median, the maximum and the minimum value. In order to increase the efficiency of statistical operations and assess the degree of measuring dispersion of samples compared with the average, the reliability of data has been verified by calculating the standard deviation and the interquartile, highlighting the eventual presence of outliers and the potential disturbing factors of the average trend of values over time.

The measurements of each dimension of a single sample are illustrated on histograms obtained by plotting the numeric values of measured results on the x-axis, while on the y-axis represents the percentage of the frequencies compared to the overall population. The curve plotted on frequency graphs (histograms) represents the distribution of measurements, according to which have been selected samples whose values create a bell curve that highlights a convergence of the measurements towards their own average, showing only random dimensional variations (Fig. 5).

The statistical assessment of the variations recorded for each dimension (of each sample) has pointed, in most contexts, to scarce data dispersion (a low deviance and interquartile range), illustrated in the frequency graphs by curves with a general normal tendency, evidence of the homogeneity of specific modular products used in the construction of single buildings. In the absence of a reference curve and of dimensional information drawn from statutory norms, it was deemed appropriate for the final processing to consider the samples in their totality, avoiding a too arbitrary data discarding and restricting the analysis to those areas which are more reliable in terms of statistics and chronology.

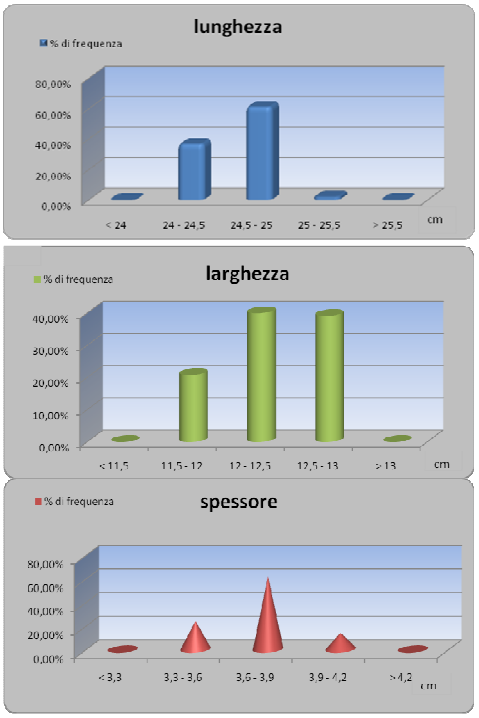

Fig.5 Variation of dimension o f the bricks. Sample Cthedral S. Maria

The synoptic reading of the analyzed data has led to the creation of Lucera's ''first'' mensiochronological curve for the period spanning from the 14th to the 18th century. Three curves have been drawn, which correspond to the trend of the average value for each dimension (length, width, vertical pitch or height) of the brick in relation to the chronological progression: on the x-axis have been plotted the chronological intervals while on the y-axis have been reported the values in cm of the analysed dimension. The overall curve represents all three dimensions, highlighting the interval between the maximum and the minimum value of each sample compared to the relative dispersion degree (Fig. 6). The three values have shown a general contraction of the dimensions: length, more sensitive to variations, has underlined with a marked tendency a better correlation between the analysed measurements and the chronological interval; the variation of width has shown the same trend but to a slightly less marked degree; the

values of height, on the other hand, follow a completely irregular pattern compared to the chronological intervals which have been considered without positive or negative peaks, but rather with frequent and unstable dimensional changes.

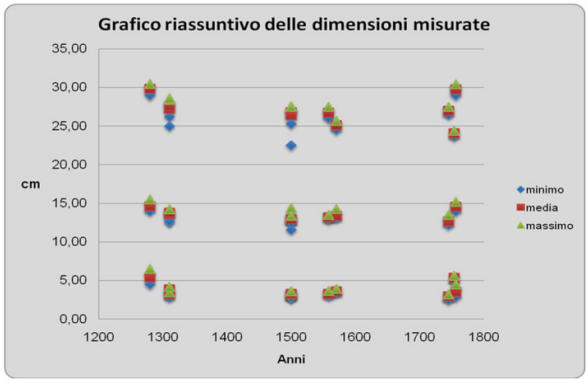

Fig. 6. Variation of the each dimension of the bricks in relation the dating if buildings

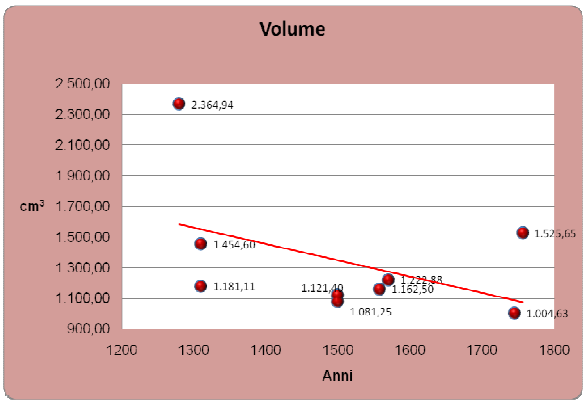

Fig. 7. Variation of the volume (calculated as the product of the average values of the measured dimensions) for each sample of brick, compared to the dating of the construction of the building considered.

In order to outline the identified decreasing tendency with a higher degree of statistical reliability, the most effective volume variation curve possible has been drawn up (Fig. 7), which has shown in a linear manner the progressive contraction from the 15th to the 17th century, as confirmed by the regression line applied to the curve.

A further degree of detail has been achieved by calculating the ratio, in per cent, between the deviance indexes and the average length values, considered a more reliable dimension (Fig. 8). The deviance indicates the degree of measuring dispersion in relation to their average, therefore by calculating the ratio between dispersion and the mean it was possible to quantify the average percentage of brick waste (random variation proper of a pre-industrial modular brick production) with respect to the average value of the analysed sample. A lower ratio generally indicates a lower presence of random dimension-related waste, pointing to a better control during the construction phases. The results obtained are quite interesting: with the exception of two peaks, which probably are due to the presence of reused or damaged material, the ratios dwindle progressively, becoming lower for the bricks of the latest type. This calculation, absent in other mensiochronological studies, could be useful for the assessment of the development stage of production technologies. In this respect, the interestingly low percentage (1.83%) of production with reference to the Angevin fortress, despite it being located at the beginning of the curve and featuring the larger bricks ever attested among the buildings examined, indicates a relevant technological level.

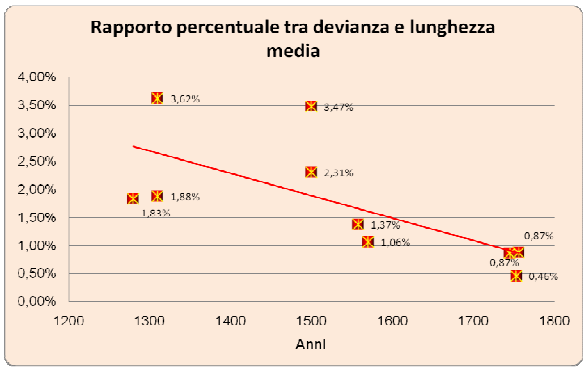

Fig. 8. Chronological variation of the ratio for each sample of bricks, between deviance and average length, compared to the dating of the construction of the building considered

II. THE WALL BRICKS MEASURE-CHRONOLOGY CURVE

The plotting of a mensiochronological curve of a single urban centre or especially of an entire territorial area increases the solidity of the dataset. The present paper aims at starting the gradual statistical process useful for pinpointing the existing relation between the dimensional aspects and the methods of implementation, production and distribution of brick in Lucera's urban area. This first group of samples has already allowed the identification of certain dynamics: the volume, length, and width of bricks gradually decreases from 1300 to 1800, and this progressive contraction of dimensions goes parallel with the technological advancement which determines the production of increasingly homogeneous bricks.

The bricks manufactured for the construction of Lucera's fortress from 1273 to 1284 were beyond a doubt the result of a specific commission, carried out by workers who set their kilns at the foot of the construction site, as it was the practice with high-level commissions for which were ordered specific batch of bricks. In fact, the data samples about the Angevin fortress are always on an

isolated position within the curves: the module adopted is most assuredly the expression of a commission or a specific building function, very different from the use made in other buildings, civic or religious ones; after all, such dimensions (except for the width) are not to be found in any other building in Lucera. It must have not been difficult for the significant economic and contracting power of the Angevin crown to impose on the contracting craftsmen a larger-sized and probably cheaper brick type, whose use seem to have been identified up to that time in the Angevin public works in Lucera, Ordona and Melfi [14] [15]. This modularity finds confirmation also in a decree issued by Charles I in 1278, featured in the brick order for the palace of Melfi, which prescribes the use of bricks of the same dimensions as those from Lucera (*longitudins 1 pedis manualis, amplitudinis, ½ pedis manualis, grossitudinis, 3 digitorum*), and notifying the dispatch of wooden mouldings to Lucera from the central administration [16].

The same production sites, founded at this time as temporary work places, could have become permanent over time thanks to the religious building development that Lucera experienced between the 14th and the 15th century, which demanded a greater brick production (despite the restoration works the buildings underwent from the 18th century make the stratigraphic interpretation and the identification of the original layout more complex and difficult).

From the 13th century onwards, brick production seems not to have left Lucera's urban area anymore, while from the 14th to the 18th century the progressive technological improvement goes parallel with a gradual reduction of brick dimensions, perhaps evidence of a progressive stabilization of the production facilities. In the 16th century, the activity of brick manufacturing became part of an urban market able to support an ongoing demand, no longer seasonal, by a rich social class from whose prestige and economic influence could depend the terms and conditions of the general supply and the brick modules themselves. This consideration could also explain the divarication of the curve showing a sharp rise, which corresponds to an increase in length for the bricks used in the construction of the Monastery of St. Catherin and Palazzo Lombardi. The two peaks refer, in fact, to two rich 18th-century clients, the Lombardi family and the Benedictine nuns [17], who ordered huge amount of bricks for the construction of their large buildings (which took up whole blocks and were made up of several building volumes). Such an economic investment allowed for a severe inspection of brick dimensions, something that avoided size reduction.

At the current stage of research it is not possible to outline the development stages of medieval brick production for Lucera or the surrounding territorial area. It can be agreed though, that the Angevin fortress was a decisive catalyst for the reintroduction of brick as a building material. The predominantly clayey consistency of the subsoil has unquestionably stimulated the use of brick: the exploitation of the morphological and geological features of the territory was a hallmark of the large construction works of the Angevins and the medieval fabrics, especially as far as defensive structures are concerned, characterized by an obvious contingency. It is impossible though, not to take into account the sudden efficiency, until then not documented, that Lucera's brick production experienced in the 13th century due to another fundamental factor: the availability of workforce. According to what's recorded in the Chancery's Registers, the Angevin fabric could draw on a diverse, large and qualified local workforce; the Curia repeatedly promted the *iusticiarius* of Capitanata and the neighbouring *iustiteriati* to send *magistri, boni fabri, carpentatores, magistri lapidum, boni laboratories et ingeniatores (…)*[18]. It cannot be excluded though, that a decisive contribution to an increased productivity was made by the Saracene manual labourers transferred to Lucera by emperor Frederick II, which Charles I could employ after the capture of the city. Renowned potters and crafters of Arab ceramics, the Saracen of Lucera are thought to have already run craft shops for tile and clay firing, located at the entrance to the old town, which were recorded in the *Diplomatic Code of the Saracens* [19].

Furthermore, from the registers of the Curia emerges that manufacturing of bricks seems to have ben very often entrusted to the Saracen workforce, to such an extent that this occasionally acquired contracting power towards the Angevin crown [20] [21].

This research is still not able to outline a coherent general framework of the production and commercial dynamics of Lucera's brick market, although the problems and the issues raised by this mensiochronological curve are numerous. The general estimates call, on one hand, for an improvement of the reliability of the curve, so it can become a useful tool for the dating of buildings lacking a chronological record, as well as for the study of both the urban fabric and the territory; on the other hand, the results should be necessarily linked with other research scenarios.

The analysis on the reintroduction of brick as a building material and the role played in this respect by the fabric of the Angevine fortress, give a detailed overview of the construction activity and its technical aspects in southern Italy, which have often been overlooked. From the requests of the Crown addressed to the *iusticiarii* of the kingdom, emerge that the Angevins tried to draw resources from the workforce of the Capitanata, presumably to cut the costs. From 1274, with the probable boost of construction activities, the territory from which to draw the workforce was enlarged to the Apulian and Campanian *iustizierati*, except for highly qualified jobs whose selection followed a more strict set of expertise criteria. The qualification and the sheer

numbers that such a territory was able to deploy triggered several new production cycles, bringing about a high degree of efficiency and systematic approach. Brick manufacturing was just one of the many, an evidence of the presence of an active, local class of variably qualified builders, in terms of competence and general administrative and managerial organization.

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