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"Different ways to find the first delineations of fortresses". Italian, French, and Dutch bastions in the Trattato di Fortificatione by Guarini

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Abstract

Guarini's Trattato di Fortificatione provides an up-to-date international overview of military culture and art in the field of tracing the elements of modern fortifications. The bastions, which represent one of its main elements, have been investigated in the present work through the graphic analysis and geometric decomposition of the bastions' tracings, including the variants found in the treatise. Moreover, graphical reconstructions of all the bastions aim to discover the Guarinian vocabulary of shapes and define the shape of the bastions, the relationship between the shape of the bastion and that of the fortress, and the defensive power concerning the musket's fire.

Keywords: Reconstructive drawings, Bastions, Trattato di Fortificatione, Guarini.

1. Introduction

The Trattato di Fortificatione (1674) by Guarino Guarini is one of the numerous books about modern fortifications written in Europe since the fifteenth century in response to innovations in artillery. A feature of modern fortifications is the concatenation between the fortress' elements: it expresses the link between architecture, geometry and ballistics. In Guarini's period, the fortress' shape in relation to that of the bastions and shooting trajectories was the centre of interest among military architects. Indeed, the modern fortification arose as a geometric system in which the change of an element affected the whole (Fara 1989). This concept was perfectly consistent with Guarini's design method based on geometric concatenations (Portoghesi 1970; Millon 1970). Guarini draws his experience from knowledge of military architecture in Italy, France, and Flanders and, about the latter, refers to the treatises of Goldman, Pagan, Dögen, and Fritach.

He faces the bastions issue immediately after describing the construction of a regular pentagonal fortress, the object of previous research by the author (Spallone 2015, 2017). Explaining the methods for tracing Italian, French and Dutch bastions, he develops a fundamental repertoire of bastion shapes, foreseeing their application to different regular figures of fortresses (5, 6, 7, 8, 9... sides). Indeed, he illustrates models, variants and personal proposals in the text and plates.

The treatise is one of the least studied among Guarini's books. From the historical point of view, we can remember the studies by McQuillan (2014) and Scotti Tosini (2006). Insights into fortification tracing come from Fara (1993, 2001, 2014), who highlights Guarini's role in the debate on the second flank and Sciolla (1970), who offers some graphical reconstruction of the bastions. Concerning the latter reference, the present paper carries out the graphic analysis and geometric decomposition of the bastions' tracings, including the variants found in the treatise and not examined in Sciolla's essay.

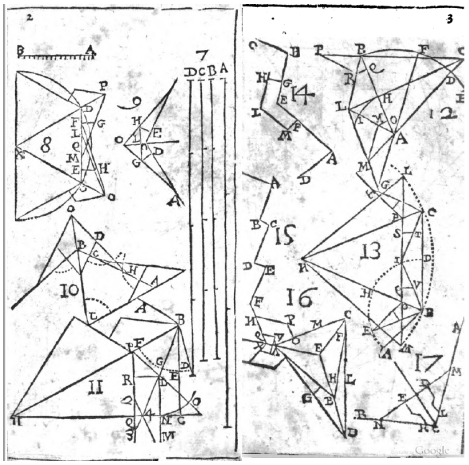


Fig. 1- Plates 2 and 3 showing the bastions' tracings (Guarini, 1676)

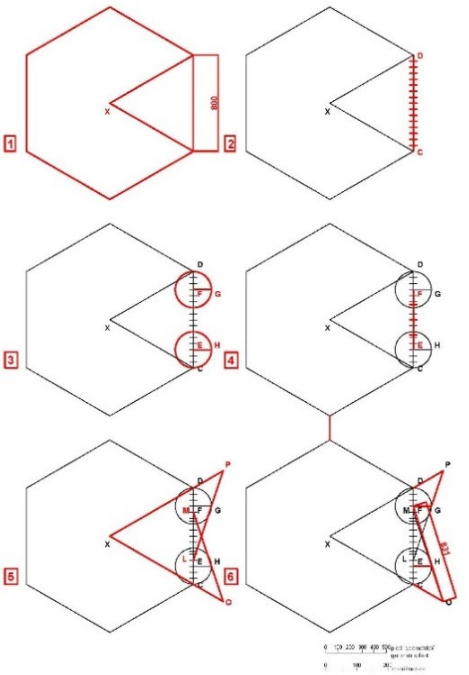
Moreover, graphical reconstructions of all the bastions aim to discover the Guarinian vocabulary of shapes and define the shape of the bastions, the relationship between the shape of the bastion and that of the fortress, and the defensive power concerning the musket's fire.

2. Tracing methods for the bastions

Guarini introduces the exemplification concerning the tracing of bastions (Ch. 4) by specifying that the Italian method, which he describes in two variants, is the easiest, and the French one is the least estimated. The Dutch one, also deployed in two different constructions, is highly appreciated.

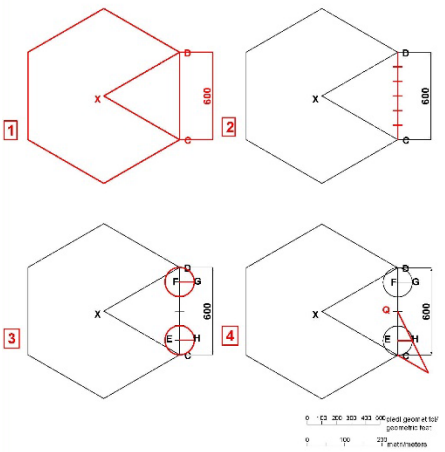
Two of his personal constructions are interspersed in the overall description. The first is inserted after the French mode and seems intended to be a summa of the Italian and French methods, the second after the two Dutch methods, again drawing from them.

Two plates (Fig. 1) represent the different tracings. Worth noting is the use of two different units of measurement to describe the constructions: the geometric foot (hereafter abbreviated as gf), equal to about 0.256883 m, is the reference for the Italian, French, and Guarini-proposed constructions; the Dutch foot (hereafter abbreviated as Df), equal to approximately 0.283133 m is the reference for the Dutch constructions. The seven constructions that follow in the text are flanked by a table describing each consecutive step aimed at realising the overall design of the bastions. In analysing the constructions, it should be borne in mind that Guarini first made syntheses of texts and drawings of fortifications to pass on to his readers established methods of tracing in different areas and military schools. The reconstructions made today are, therefore, except in the two cases where the Theatine proposes constructions he invented, the outcome of analyses of the reconstructive syntheses made by Guarini.



n.	**Geometric construction | *Part of the bastion***
1	Draw a hexagon. *Interior polygon, Capitals* CX *and* DX
2	Divide the side CD into sixteen equal parts (each part = 50 gf). *Semi-gorges* CE, FD, *Curtain* EF, *Flanks* EH, FG.
3	Draw the lines EH and FG perpendicular to CD from E and F (3/16 CD)
4	Divide EF into four equal parts.
5	From points L and M (4/16), draw lines from L through H and from M through G, obtaining P and O. *Faces* HP and GO, *Semi-bastion* FHDP, *Razant line of defence* PL and OM.
6	Draw a line OF and verify its dimension < 850 feet. *Fichant line of defense* OF

Fig. 2- Steps for constructing the Italian bastion following the first method. Graphic reconstruction and description of the steps and the part of the fortress created (Drawing and text: R. Spallone).

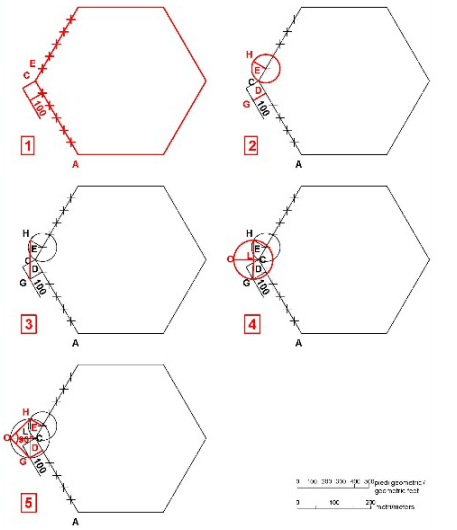


n.	Geometric construction | *Part of the bastion*
1	Draw a hexagon; the side CD is 600 geometric feet). *Interior polygon*
2	Divide CD into six equal parts.
3	Draw the lines EH, FG perpendicular to CD from E and F (1/6 CD). *Semi-gorges* CE, FD, *Curtain* EF, *Flanks* EH, FG
4	Draw a line from Q midpoint of the curtain through H obtaining P. *Faces* HP, *Semi-bastion* FHDP.

Fig. 3- Steps for constructing the Italian bastion following the second method. Graphic reconstruction and description of the steps and the part of the fortress created (Drawing and text: R. Spallone).

2.1. First Italian method

The first method of tracing in the Italian manner (see construction 8 in Fig. 1) is drawn from a hexagonal interior polygon with a side equal to 800 geometric feet. From this starts the construction of the bastion, which is divided into six steps. Through these, the main elements of the bastion (semi-gorges, flanks, faces), of the fortress (curtain), and the razant and fichant lines of defence, which delimit the second flank equal to 1/16th of the side of the interior polygon, are defined. Other dimensional data that emerge from this construction include the length of the curtain equal to 5/8 of the side of the interior polygon, the size of the flank similar to that of the semi-gorge and equal to 3/16 of the interior polygon, and the angle at the vertex of the bastion of about 83° (Fig. 2). In addition, the fichant line turns out to be about 831 gf, less than the 850 gf that Guarini in an earlier point of the text (Ch. 2, 2) indicates as the limit of musket fire.



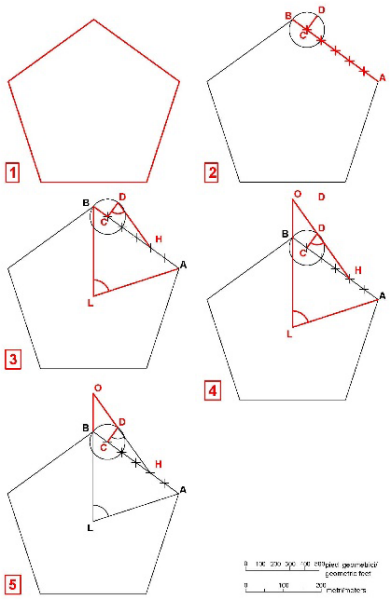
n.	Geometric construction | *Part of the bastion*
1	Draw a hexagon and divide the side AC into six equal parts (each part is 100 or 140 geometric feet). *Interior polygon*
2	Draw two lines perpendicular to AC, from D and E (1/6 AC); EH and DG are equal to CE. *Flanks* EH, DG
3	Draw line GH. *Semi-gorges* CE, FD, *Curtain* EF, *Flanks* EH, FG
4	Draw a line LO perpendicular to GH from L midpoint of GH and equal to LH. *Vertex of the bastion* O
5	Draw OH and OG; HOG is 90°. *Faces* OH and OG

Fig. 4- Steps for the construction of the French bastion. Graphic reconstruction and description of the steps and the part of the fortress created (Drawing and text: R. Spallone).

2.2. Second Italian method

The second Italian tracing method, not drawn but only described in the text, is a variation of the first.

Here again, the starting figure is the hexagon, the side of which is reduced to 600 gf. The steps of the construction are simplified to only 4. The division of the side into six parts results in a curtain equal to 2/3 of the side of the interior polygon, while the semi-gorge and the flank are worth 1/6 of the curtain. The relatively small angle at the vertex (about 67°) results in the enlargement of the second flank, which is equal to half the curtain (Fig. 3).



n.	Geometric construction | *Part of the bastion*
1	Draw a pentagon. *Interior polygon*
2	Divide the side AB into six equal parts.
3	Draw a line perpendicular to AB from C (1/6 AB). *Gorge CB, Flank CD*
4	Draw angle CDH equal to ALB. *Capitals* NB and NC
5	Extend HB and LB, obtaining O. *Face DO, Semi-bastion CDOB*

Fig. 5- Steps for the construction of the first Guarini's method. Graphic reconstruction and description of the steps and the part of the fortress created (Drawing and text: R. Spallone).

2.3. French method

The right angle at the vertex of the bastion characterises the French method (see construction 9 in Fig. 1). The size of the semi-gorge is between 100 and 140 gf while remaining unchanged in the construction, which is developed in 5 steps.

This results in varying sizes of the side of the hexagonal interior polygon (from 600 to about 839 gf), of the curtain, equal to 2/3 of the side (from 400 to 560 gf), of the semi-gorge and the flank, both equal to 1/6 of the interior polygon (from 100 to 140 gf), of the face (from about 194 to 272 gf), of the fichant line of defence (from about 607 to 848 gf) and of the second flank, much reduced because of the wide angle at the vertex (from about 41 to 47 gf) (Fig. 4).

2.4. First Guarini's method

The method proposed by Guarini is, following the graphic scheme in the table (see construction 10 in Fig. 1), applied to a pentagonal interior polygon. This choice should come as no surprise since the constructions in Planches 2 and 3 follow that of the regular fortress, pentagonal, found in Planche 1. However, the construction of the bastion follows different rules.

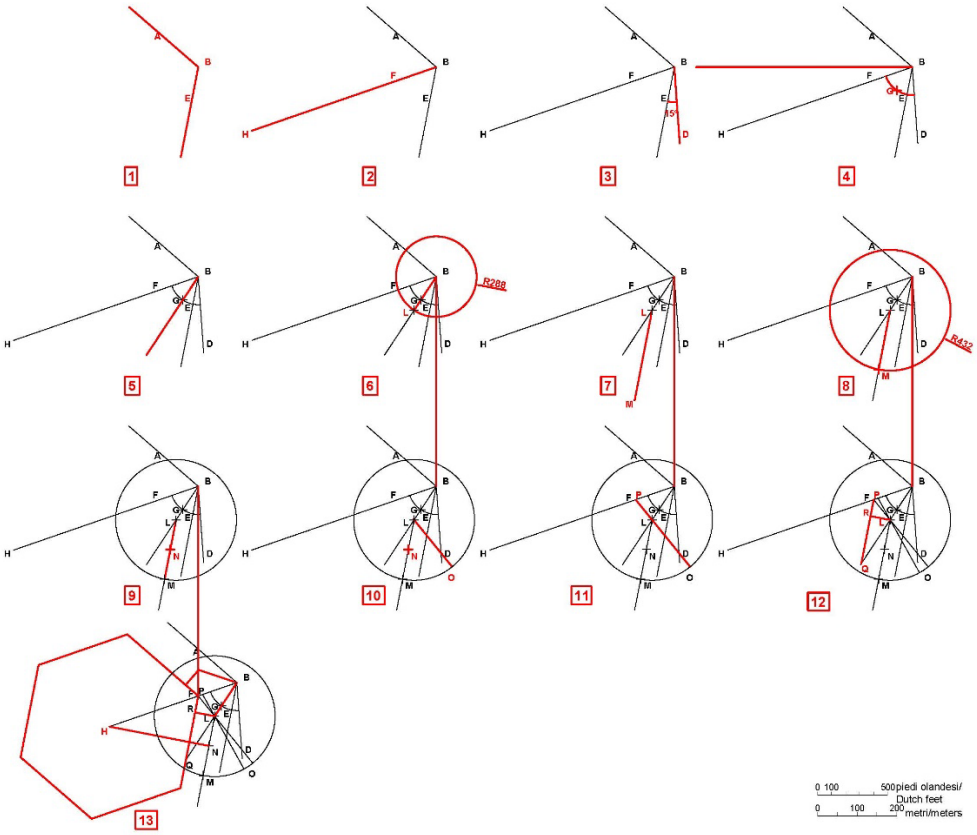
The side of the pentagon is worth 720 gf. It is divided into six parts, four attributed to the curtain and the remaining two to the semi-gorges, one on each side, the measurement of which is also applied to the side. The angle at the vertex turns out to be about 71°, the fichant line about 782 gf.

The second flank occupies approximately 1/6 of the curtain, confirming Guarini's attention to the proportioning of that element. Guarini stated, "should never be forgotten... because as the artillery mostly occupies the first wing; if there were no second flank, few musketeers would remain to defend the opposite side, with the consequence of a serious danger" (Guarini 1676: 40; author's trans.). In the final part of the paragraph, Guarini affirms the universality of his procedure: this will apply to other regular polygons, with the caveat, for polygons with seven or more sides, to divide the side of the inner polygon into five parts, rather than six (Fig. 5).

2.5. First Dutch method

Dutch methods of bastion construction are characterised by considerable complexity.

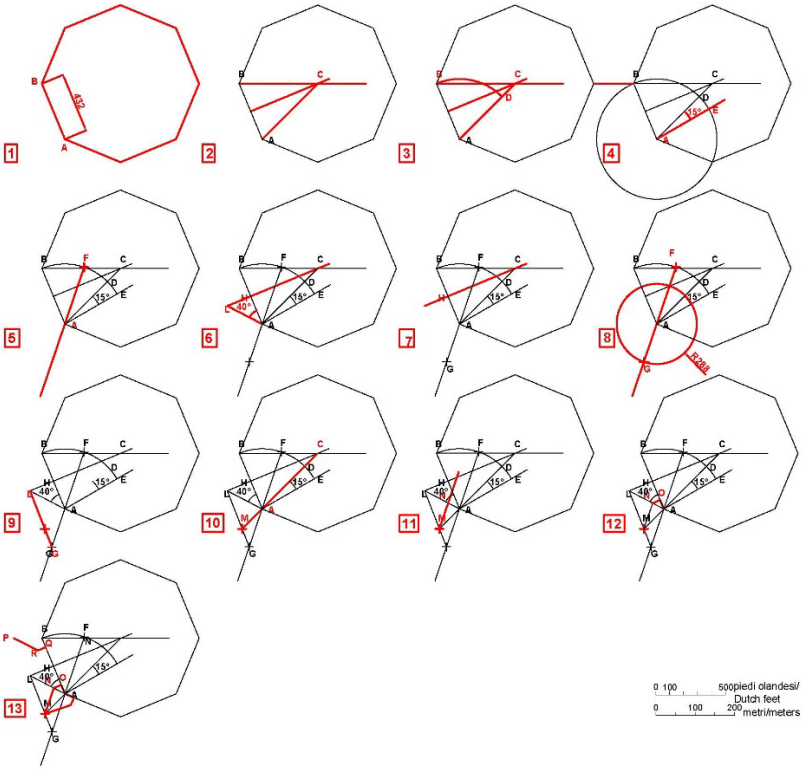
The reconstruction of the first example of a Dutch bastion (see construction 11 in Fig. 1) engages as many as thirteen steps. Some discrepancies between the drawing and text were noted and resolved by the author of this paper. The construction suggested by the text leads to a graphic outcome different from the usual proportional ratios between bastion and curtain, while Guarini's drawing appears consistent. In particular, we point out that the point defined as D in the text is E, that the OLN angle should measure 50° instead of 40°, and that LM should measure 432 Dutch feet. With these corrections from the text, it is possible to construct the figure correctly.



n.	Geometric construction | *Part of the bastion*		
1	Draw the angle ABE of the hexagonal exterior polygon	8	Divide LM into two equal parts, obtaining LN
2	Divide the angle into two equal parts (bisector BF)	9	Add 50° to LN, obtaining OLN
3	Add 15° to the angle FBE obtaining FBD.	10	Extend OL to BH obtaining OP
4	Draw an arc from FD and divide it into two equal part	11	Draw PQ parallel to LM and LR perpendicular to PQ. *Semi-gorge* PR, *Mid-curtain* RQ, *Flank* RL
5	Draw a line from B through G	12	Draw a line perpendicular to MN from point L, obtaining H. *Centre of the fortification* H
6	Measure 288 Dutch feet on BG, obtaining BL. *Face* BL	13	Mirror RLB and PQ. *Bastion*
7	Draw a line from point L parallel to BE obtaining LM (432 Df, i.e. one and ½ BL)		

Fig. 6- Steps for the construction of the first Dutch method. Graphic reconstruction and description of the steps and the part of the fortress created (Drawing and text: R. Spallone).

The starting point is the interior angle of a hexagon taken as an exterior polygon whose side dimension is not defined. The first measure introduced by Guarini is that of the face (which must be between 260 and 300 Df), which he fixes at 288 Df. From this, by successive constructions, are derived the measures of the semi-gorge (about 120 Df) and the side (about 143 Df). The angle at the vertex is 75°. The measurements of the side of the interior polygon (about 672 Df), of the curtain (432 Df), of the fichant line of defence (about 743 Df) and the second flank (about 143 Df) is determined only at the end of the construction process (Fig. 6).

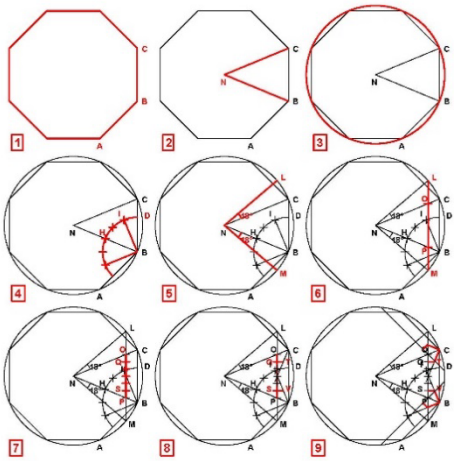


n.	Geometric construction | *Part of the bastion*		
1	Draw the side AB of the octagonal interior polygon (432 Dutch feet)	8	Add 40° to AB, obtaining HAL
2	Draw the angle CAB (C is the polygon centre)	9	Draw a line from G to L
3	Draw the arc CD with the centre in point A	10	Extend CA to LG obtaining M. *Vertex of the bastion* M
4	Add 15° to the side DA, obtaining DAE	11	Draw MN parallel to GA. *Face* MN
5	Divide the arc EF into two equal parts, obtaining F, and draw a line from F through A	12	Draw NO from point N and perpendicular to AB. *Flank* NO
6	Measure 288 Dutch feet (2/3 of 432) on FA obtaining G	13	Mirror ONM obtaining QRP. *Semi-Bastions*
7	Draw a line perpendicular to AB from the mid-point H of AB.		

Fig. 7- Steps for the construction of the second Dutch method. Graphic reconstruction and description of the steps and the part of the fortress created (Drawing and text: R. Spallone).

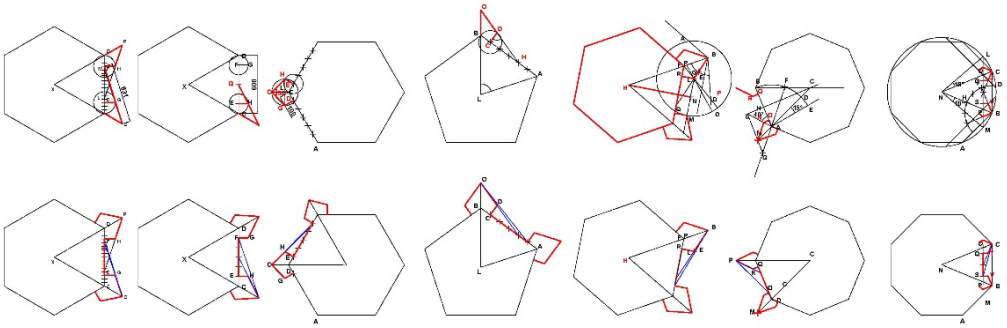
2.6. Second Dutch method

The second Dutch method involves giving the side and inner angle of the interior polygon (see construction 12 in Fig. 1). The starting figure in this case is an octagon whose side is fixed at 432 Df. The curtain turns out to be about 293 Df, the semi-gorge about 69 Df, the side about 58 Df, and the face about 195 Df. The angle at the vertex is decidedly tiny and is worth about 52°. This results in a fichant line that is also reduced and equal to about 478 Df. In comparison, the second flank is expanded to nearly 227 Df (Fig. 7). Guarini concludes his discussion of Dutch bastions with a clarification of the different opinions of Dutch architects concerning the relationships between the measure of the face and that of the curtain wall, the angle of the bastion, and the presence or absence of the second flank.



n.	Geometric construction | *Part of the bastion*
1	Draw the sides AB and CD of the octagonal exterior polygon.
2	Draw the centre N of the octagon.
3	Draw a circle with the centre in point A, inscribing the octagon. *Interior polygon*
4	Divide the angles NBA and NBO into three equal parts, obtaining EB and BI. *Capitals* NB and NC
5	Add 18° to BE and BI, obtaining CL and BM
6	Draw ML, obtaining O and P. *Curtain*
7	Divide OP in six equal parts.
8	Draw perpendicular lines SV and QT from P and S
9	Mirror SVB and QTC. *Bastions*

Fig. 8- Steps for the construction of the second Guarini's method. Graphic reconstruction and description of the steps and the part of the fortress created (Drawing and text: R. Spallone).



	Italian 1	Italian 2	French	Guarini's 1	Dutch 1	Dutch 2	Guarini's 2
Polygon	hexagon (interior)	hexagon (interior)	hexagon (interior)	pentagon (interior)	hexagon (interior)	octagon (interior)	octagon (exterior)
Polygon side	800 geometric feet	600 geometric feet	600÷ab.839 gf	720 geometric feet	about 672 Dutch feet	432 Df	n.d.
Curtain	10/16 side (500 gf)	4/6 side (400 gf)	4/6 side (400÷560 gf)	4/6 side (480 gf)	432 Df	about 293 Df	4/6 side of interior octagon
Semi-gorge	3/16 side (150 gf)	1/6 side (100 gf)	1/6 side (100÷140 gf)	1/6 side (120 gf)	about 120 Df	about 69 Df	1/6 side of interior octagon
Flank	3/16 side (150 gf)	1/6 side (100 gf)	1/6 side (100÷140 gf)	1/6 side (120 gf)	about 143 Df	about 58 Df	1/6 side of interior octagon
Face	about 309 gf	about 248 gf	ab.194÷272 gf	about 288 gf	288 Df	about 195 Df	n.d.
Vertex angle	about 83°	about 67°	90°	about 71°	75°	about 52°	90°
Fichant line of defence	about 831 gf	about 657 gf	ab.607÷848 gf	about 782 gf	about 743 Df	about 478 Df	n.d.
Second flank	1/16 side (50 gf)	2/6 side (200 gf)	ab.41÷47 gf	ab.1/6 side	about 87 Df	about 227 Df	2/6 side of interior octagon

Fig. 9- Comparison between the bastions' features in Guarini's treatise (Drawing and text: R. Spallone).

2.7. Second Guarini's method

Guarini's second method is characterised by greater complexity than the first. It seems to want to distinguish itself in terms of scalability since there are given dimensions to be assigned to the elements, but only proportional ratios and angular values.

In this case, the initial figure of the construction is the exterior octagon of the undetermined side, as noted above (see construction 13 in Fig. 1).

Following the construction of the interior polygon, ratios proportional to the side of the latter govern the extensions of the curtain (2/3 of the side), the semi-gorge and flank (1/6 of the side), and the second flank (1/3 of the side). The angle at the vertex of the bastion results in 90° and involves a relatively broad second flank (Fig. 8).

4. Conclusions

Guarini's Trattato di Fortificatione provides an up-to-date international overview of military culture and art in the field of tracing the elements of modern fortifications. The bastions, which represent one of its main elements, have been investigated in the present work individually and through a synoptic and comparative table, both graphic and tabular, which highlights their singularities and peculiarities (Fig. 9). Further foreseeable developments will concern: a comparison with the construction of bastions in the regular fortress, an invention of Guarini, whose discussion in the text immediately precedes that of the bastions, and the development, from the description of the second Dutch method, of the constructions of different Dutch authors.

Acknowledgement

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