Reconstructing Palladio's Villas:
An Analysis of Palladio's Villa Design and Construction Process

by

Lawrence Sass
S.M. Arch, MIT (1994)
B. Arch., Pratt Institute (1990)

Submitted to the Department of Architecture in
partial fulfillment of the requirements for the
Degree of Doctor of Philosophy in Architecture: Design & Computation
at the Massachusetts Institute of Technology June 2000

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ABSTRACT

The thesis is a presentation of a method of reconstruction using a computational device to represent and evaluate two of Palladio's un-built villas in three-dimensions. The first of *The Four Books of Architecture* contains text and images explaining Palladio's design and construction systems in the form of text and graphic rules. These design guidelines or rules were written for the masons and craftsmen of the 16th century, offering one and two-dimensional data on each of Palladio's villas, palaces and churches. The text only offers general treatment of the villas; it missing construction data and rules needed to execute a full reconstruction of an un-built building.

Many have attempted to reconstruct Palladio's work in drawings, wooden models and computation. This thesis presents a new method of reconstruction through the definition of construction rules in addition to shape and proportional rules defined by previous scholars. This reconstruction of the Villaa Trissino in Meledo and the Villa Mocenigo on the Brenta River in the form of physical models, cad drawings and computer renderings from fragmented information offered in the *Four Books*. The end product will serve as a method for reconstruction in the form of a three-dimensional analysis of Palladio's design and construction rules and a demonstration of the new rules, through the two reconstructions.

The work begans with a pilot study focused on modeling Palladio's villas in three-dimensions with little detail. The next step was to reconstruct one villa in detail following the rules, which called for a complete rewriting of the rules from the *Four Books of Architecture*. These rewritten rules are applied to a simple floor plan and elevation drawing in order to reconstruct Palladio's original sketch in a CAD environment. The reconstructed sketches were used to create a three-dimensional CAD file by construction rules. Afterward, three-dimensional prints, two dimensional drawings and renderings were created from the model for evaluation. The final results of each study contain textural as well as visual information on the reconstruction of two un-built villas. The conclusions demonstrate how the results can be transformed into a full three-dimensional shape grammar composed of shape, proportion and construction rules.

Thesis Supervisor: William J. Mitchell
Title: Professor of Architecture and Media Arts & Sciences

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- To my Committee Members: Howard Burns, Kent Larson and George Stiny, for their time, devotion to great scholarship and friendship.
- To Ike Colbert, a trusted friend and the perfect mentor. "Obe Won"
- I dedicate this thesis to my wife, Terry Sass, whom I will always love and honor

CHAPTER ONE

PALLADIO'S VILLAS

1.0 INTRODUCTION

The thesis is a presentation of a method of reconstruction using a computational device to represent and evaluate two of Palladio's un-built villas in three-dimensions. The goal of the study is to reconstruct Palladio's work using a system that allows for replication and qualitative/quantitative evaluation. Learning from a simple pilot study focused on reconstructing all of Palladio's villas with little detail or reference to his rule system, the thesis will attempt construct a detailed study of two of Palladio's un-built villas from the rules. Prior to the concluding un-built studies there will be a rewriting of the first two books from Palladio's *Four Books of Architecture* followed by a construction grammar, and a presentation of the methods used to evaluate the modeled outcome. The final results of the study are multidimensional visual products that present two of Palladio's un-built works in detail.

1.1 VISUALIZING THE PAST

Some of the most fascinating designs of past master architects such as Frank Lloyd Wright, Louis Kahn and Mies van der Rohe are their un-built projects. Of the twenty-three design proposals in the *Four Books*, some of the most fascinating are the unrealized proposals representing Palladio's drive to design the ideal villa for any setting. What makes Palladio's works so astounding are the ever-changing design ideas within a design language, captured in *The Four Books of Architecture*. His first villa design for Girolamo de' Godi in 1540 differs dramatically from the projects in the later part of his life, such as the Villa Mocenigo on the Brenta, which is almost Baroque in itsr form. From few variations in his rules, Palladio represented hundreds of designs on paper.

Arguably, he never constructed his best works, and until now they have been represented only in two-dimensions or at most only in the form of physical models commissioned by C.I.S.A. for the Palladio exhibition of 1973.

The goal of the thesis is to present two of Palladio's largest and most controversial villas in detail. First is the villa Trissino, proposed for the village of Meledo, designed by Palladio in the late 1560's. Remnants of the villa still exist on the site in the form of two dovecotes at the end of what was to be the barns. The second is the Villa Mocenigo, designed for a riverside on the Brenta, near Venice. It was the largest villa in the *Four Books*, with an architectural composition that was a hybrid of a villa and a palace.

Building on past reconstruction work of others within the field of design and computation, these two case studies are documented in such a way so that the process can be reviewed and challenged by architects, non-architects and historians. This chapter briefly explains the general make up of a Palladian villa, its programmatic construct, and concludes by presenting a map of the thesis and its mission.

1.2 PALLADIO'S VILLA DESIGN

Palladio designed over forty villas of varying shapes and sizes (fig. 2.11), each as different as the personality of its patron. The first villa, design and built in 1530's in Cricoli[1], was a simple box

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[1] Palladio was said to be involved in the design with others, but there is no clear evidence to support his designing the villa alone.

with fine details. Among the last was that designed in 1570 for a site in Dolo but never built, almost Baroque in its form sometimes referred to as "a palace with villa functions"[2] (fig. 10.1).

Palladio's villas had two functions: the first was to serve as a place for entertainment and retreat in the summers from the unhealthy city, and the second was to serve as the center of a working farm which was often the owner's main source of income.[3] Some villas such as the Rotunda and the Villa Cornaro were built mainly for entertaining and living purposes, whereas the Villas Badoer and Pojana served both as a retreat and farm. Working farms helped to offset property and operating costs through the sale of grain, silk and wine. The farm was divided into a front garden,

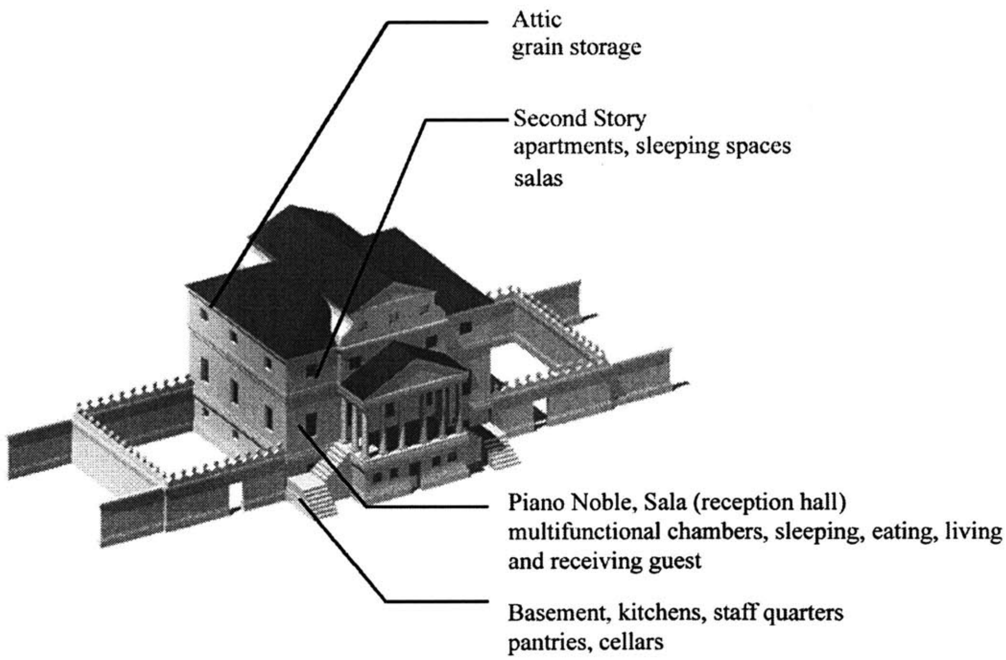

Fig. 1.1 Town Villa: Villa Foscari spatial arrangement

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[2] Ackerman, J. 1966 p.75
[3] Burns, H. 1975 pp.163-66

used to deal with animals and some crops, and an attached garden was used to grow Mulberry trees (the leaves went to feed silk worms). The property attached to the estate was the owner's principal source of income.[4] The standard organization of a villa, either farming or non-farming, was confined to three levels and two sides. The ground level or basement was reserved for servants and staff, containing kitchens and pantry spaces. The main level or the piano noble, the most visually ornate, contained decorative ceilings and frescos, used for entertaining and greeting guests. The upper level was reserved for apartments, sleeping quarters or the storage of grain high above the ground floor to ward off potential thieves (fig. 1.1).[5]

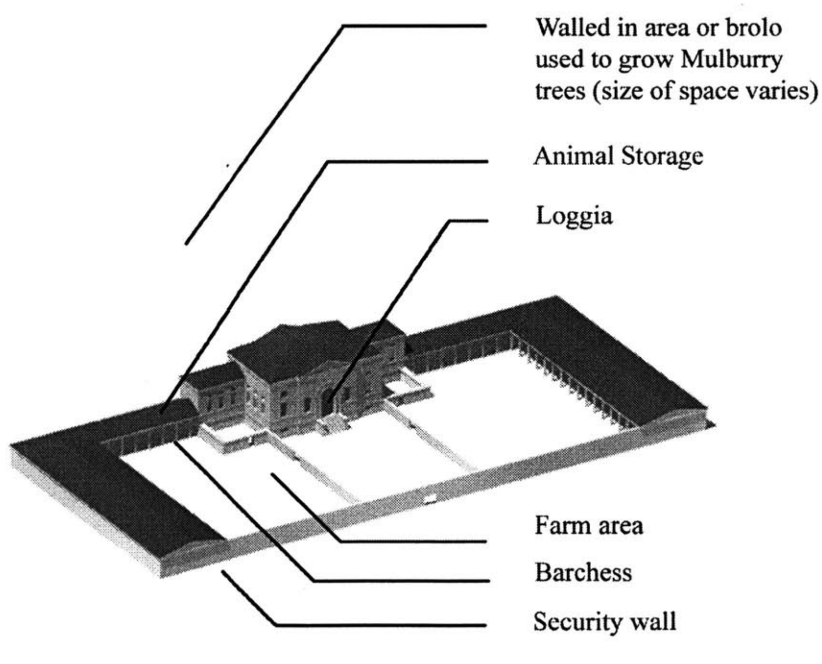

Fig. 1.2 Country Villa: Villa Pojana spatial arrangement

[4] Ibid., p. 166

Working villas were surrounded by large barn like structures now called barchess that served three functions (fig. 1.3). The first was to serve as a house for animals and equipment. These barns sometimes ended with dovecotes provided pigeons for the owner's table. The second purpose of the barns was to serve as a security wall for the whole complex. The third purpose of the barns was to cover for the owner as he and his employees moved about the site.[6] In general, the barns were a working attachment to the villa serving many people while enclosing a very important space - the central courtyard.

Formally, the symmetrical facade of a villa was formed from a central block where the right side corresponds with the left, built around a central axis.[7] This block was broken into smaller details of classical ordering and logical functions. For example, window moldings were decorative elements surrounding an exterior opening. Pediments or cornices over windows were also used to prevent rain from dripping to the inside of a space. Although the pediments can be seen as decoration, Palladio maintained its functional aspect by saying, "The integrity of the pediment above the window was not to be broken or else rain will drip in from the opening."[8] At the time many were breaking pediments, but Palladio chose not to for functional reasons. In summary, Palladian detail had two roles: decorative and functional.

Landscaping is also a critical detail in the design and execution of a villa. The ultimate goal was to insert the villa into the landscape.[9] Although some of Palladio's buildings consume a large portion of their site, this goal was accomplished by marking a portion of the territory with the building

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[5] Ackerman, J. p. 57
[6] Palladio, A. 1965 p.47
[7] Ackerman, J. 1966
[8] Ibid. p. 160
[9] Ibid. p. 170

footprint while not obstructing the land from performing its job in nature. For example, the Villa Barbaro, which cuts into the side of a steep hill, would prevent water from naturally moving down the hill. A building that cuts across a hill horizontally would typically deteriorate from the pressures of water falling upon its foundation walls. In order to counter this, Palladio allows the water to flow under the building and exit through fountains and statues at the base of the property.

Palladio's villas were indebted in their design to his intellectual mentors such as Daniele Barbaro and Giangioagio Trissino. But in the end the work was his. The villa design process began with three givens from the client: the first being the owner's site, second a budget (which determined the amount bricks and stone that can be purchased) and third, a social construct for the program (meaning the number of rooms and possible room layout). From this Palladio created a floor plan sketch reflecting these three points of departure and defined the initial shape (fig. 5.4).

1.3 CONFLICTS BETWEEN DESIGN AND THE BUILT CONDITION

The *Quattro Libri,* or the *Four Books* as it will be referred to in this text, contains illustrations demonstrating the design of the villas in book two, and construction details from book one. What the book does not contain are explanations of how the villa and its parts are assembled. For example, how was the building's footprint outlined on the site prior to construction? What are the materials in a column entablature? How thick is an interior vault, and what is Palladio's motivation for using a vault? Unfortunately, the heart of the design process was not clearly documented. No one can say for sure what procedure Palladio used to design or construct the villas. This lack of information has lead to many conflicts and contradictions between the text and the built buildings. Most of these conflicts and contradictions could have been the result of ambiguous design rules or construction rules, but some are also based on Palladio's relationship with his clients and masons.

The client changed Palladio's designs during the construction process, later to be represented in their true form within the *Four Books*. In fact all of the drawings in the text differ from the built condition. The drawings will be referred to here as the ideal condition.

The most profound conflict is the relationship between the drawings in the *Four Books* and the existing buildings. The drawings reflect Palladio's design interest, but not the built condition. It was common knowledge at the time that the owners were responsible for the construction of their villas. Records and contracts showed that Palladio had limited involvement in the construction process.[10] Although Palladio did offer many design options in the form of drawings or wooden models prior the date of construction, after the first stone was laid he would only show up on site from time to time to give the masons profile templates for moldings and some design information.[11] Palladio had a limited amount of responsibility when it came to villa construction, in contrast to his work on public buildings, which required him to be on site more often.[12] The question here is how much involvement did Palladio have in the final design of the villas. Did he hand over a set of drawings to the owner, later to be changed by the owner during the construction process due to cost or personal preference? Or was Palladio present often enough to make design changes to the constructed building and later define the drawings in the *Quattro Libri* as an ideal representation of the built condition?

The second conflict asks, what was Palladio's method of villa design. It is unclear as to how he ordered the program of his plan when designing. It is likely that he always drew the larger more important spaces when sketching a floor plan drawing, and that the stairs were placed in left over

[10] Burns, H 1991. p. 210
[11] Ibid. p. 193
[12] Ackerman, J. 1954 p.5

spaces from the combination of larger rooms (fig. 5.2). What we do know, is that the most important rooms were placed at the villa entry and the smaller rooms were pushed to the sides of the plan. We also know that the most elaborate rooms were towards the front of the house and that the lesser are towards the back. But what we don't know is what Palladio did first. Did he design a large space and work around that, or did he start with a square block as Wittkower suggests and break that into smaller pieces?[13]

The final unanswered question is, what role did construction and cost play in the final building design. The design process of the time is still a mystery to most historians. It can be argued that the *Four Books* outlines more construction principles than design principles. That brings into question the relevance of *The Four Books* as a record of design. Either way it becomes quite obvious that many decisions on the part of Palladio were due to issues of construction and cost. The owner could only spend as much as he could afford in the purchase in bricks. Vaults, which were made of bricks, had a certain cost per brick, as did the additional bricks needed to add thickness to its supporting walls. A quick assessment of the plans from *The Four Books* shows that the more brick area given for walls, the fewer vaulted ceilings in the villa. The villas with the most ornate ceilings are small, while the largest villas like Mocenigo have only three vaulted spaces.

In summary, this study is a search for answers to the three questions concerning Palladio's designs and the built conditions listed above:

Conflicts between the built condition and the drawings found in the *Quattro Libri*

Palladio's design methods and how can they be reused to build his un-built villas

The role construction played in the process of design

1.4 COMPUTATION AND RECONSTRUCTION

Since the *Palladian Grammar* (Stiny and Mitchell), computation has played a major role in the reconstruction of Palladio's work. Prior to 1978, wooden models and detailed hand drawings were the only methods used to reconstruct un-built buildings. In comparison to traditional methods of representation, computational tools offer flexibility in both input (computer modeling) and output (printing).

The *Palladian Grammar* reconstructed the plans of a Palladian villa, proposing that an unforeseen villa could be designed in the Palladian style using shape grammars Other reconstructions have followed using visualization or a HyperCard system as a method of design.[14] Few studies have

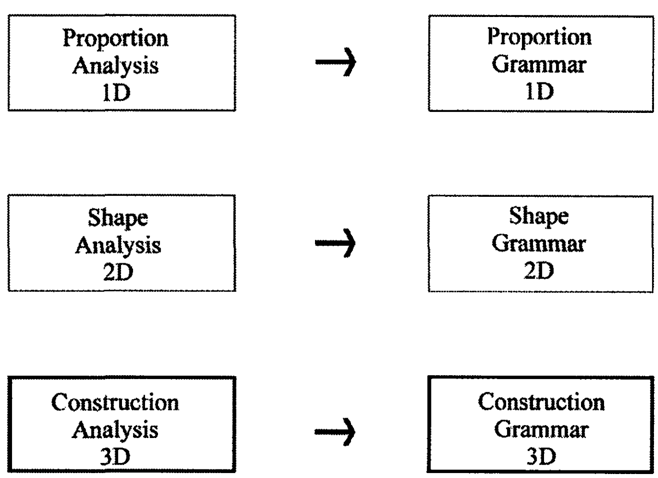

Fig. 1.3 Possible grammar types that can be used to reconstruct a villa focused on construction

[13] Wittkower, R. 1974 pp64-68

topped the utility of the *Palladian Grammar*, which refers to a systemized method for designing the villa plan and analyzing design rules. This method is also a system that does not require a computer to garnish results. The latest method for reconstructing a Palladian villa, written by Lionel March in 1997, follows a similar model as the *Palladian Grammar*[15]. His paper claims to be a system for defining Palladio and other architects' proportional systems through a greater understanding of their mathematical base. It is also a system that does not require a computer to create an outcome.

There are two stages for making a proportional or shape grammar reconstruction system: the analysis and the grammar. For example, the *Palladian Grammar* required an analysis of the floor plans from the *Four Books,* resulting in a set of shapes. These shapes are systematically used to create a language and later a new floor plan based on these shapes.[16] The system of reconstruction used in this study is focused on the concept of physical construction as a means for creating the visual material (fig. 1.3). The system will be referred to as a *construction grammar*. The thesis falls at the two outer ends of shape grammars in the categories of analysis and representation (fig. 1.4). In summary, the design and construction materials in this paper can be used after the shapes and proportions are defined in order to construct a three-dimensional representation. In contrast to the shape and proportional system, construction grammar is a system that does require computational tools to create the final material. In this case the computer is used as a tool for building and illustrating the final results of each case study, also the rewriting of *The Four Books of Architecture*.

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[14] Hersey, G. 1992
[15] March, L. 1998
[16] Stiny/Mitchell 1978 p. 6

1.5 ORGANIZATION OF THE THESIS

This study argues that construction data is a major attribute of the design process, leading to many formal decisions. The thesis is divided into three parts: the villa manual of Palladian rules (chapter 4), a demonstration of the reconstruction process (chapters 5-7) and two case studies (chapters 8 & 9)

The villa manual is a re-writing of the *Four Books* of architecture for the purpose of clarity and utility as well as related field research completed in the spring of 1999 (chapter 4). The chapter is composed of 18 sections in a different ordering than the chapters in *The Four Books,* along with a few extra sections that are not in the text. The following two chapters (5 & 6) are focused on an application of the villa manual rules to create a full villa model file or cad file. Enclosed in the file is a reconstruction of the plan and elevation followed by the construction of a three-dimensional villa model, based on a combination of the rules in chapter 4 and the reconstructed plan and elevation drawings. The next chapter (7) explains the process of documentation and evaluation, a

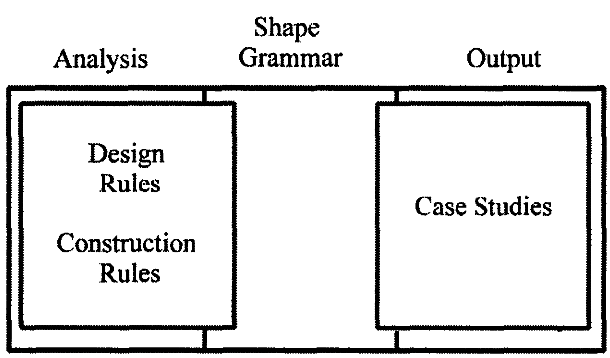

Fig. 1.4 Relationship to shape grammars, the thesis is focused on the construction aspects of a larger set of grammars point of conflict with past villa reconstructions.

There are two case studies at the end of the text whose goals are to understand the design and construction process by rebuilding known information and filling in missing areas with conjectures. The goal is not to build a presentation of un-built work, but to discuss design issues through the output (drawings and models) of the cad file. The first case study is the un-built Villa Trissino in Meledo, were two small dovecote towers and parts of a barn were (fig. 8.2) built. Many have conjectured its final form in drawings, wooden models and computer reconstruction. In this case, the conflicts in the design have always been over the representation of the upper floors.[17] The test here will be to determine the Villa's construction components and variables and to test a few schemes of the building's interior space. The final case study is the un-built Villa Mocenigo on the Brenta River, Palladio's last villa design in *The Four Books.* There is little evidence to support whether this villa was ever built.[18] the only reconstruction attempt on record was that of Bertotti Scamozzi in the 18th century. Here the goal will be to understand its construction and its details and the construct of the main hall. The conclusion will be a a summary of newfound rules and some suggestions for the transition of this work to a parametric construction grammar.[19]

1.6 CHAPTER SUMMARY

Within this chapter I outlined the construct of a Palladian villa, its purpose and its formal make up based on functions. I also discussed computation and its place in the history of Palladian

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[17] Bertotti Scamozzi. B

[18] Puppi, L., 1999 Lionel Puppi and Inigo Jones have made mention of it's construction, but currently nothing exists on the site.

[19] Stiny, G., 1980 (a) p. 349

reconstruction and how it will be applied to this study. The next chapter refers to a project that preceded this thesis.

LIST OF FIGURES

CHAPTER TWO

PILOT STUDY

2.0 THE FIRST PASS AT VILLA RECONSTRUCTION

This chapter is a presentation of the first attempt to model 30 of Palladio's villas. The process involved measuring Palladio's and Bertotti Bertotti Scamozzi's drawings by hand and transferring their measurements to a modeled representation in CAD. Missing details were filled in later with information found in photos and drawings. The end results were CAD sculptures of the villas containing many misrepresentations and no record of the process - only the final representation.

Since Bertotti Scamozzi published his selection of drawings representing the works of Palladio in 1783, there have been many attempts to reconstruct Palladio's built and unbuilt work. Results of these past studies demonstrate that a change in medium (from hand drawings to CAD) and the level of understanding of the rules determine the quality of representation. The objective of this pilot study was to construct villa models from a translation of the drawings found in the *Four Books of Architecture* and *The Buildings and the Designs of Andrea Palladio*. These villa models were constructed to serve as part of an interactive CD-Rom project on Palladio's villas.

The *Four Books of Architecture* was published (1570) fifteen years after Palladio designed the Villa Rotunda. The woodcut drawings found in *The Four Books* were representations of Palladio's ideal villas, not a representation of the built conditions. With minimal reference to photographs of the built work, the goal here was to translate measurements from two-dimensional drawings to a three-dimensional computer model. This chapter will look at the process behind the creation of the models and the flaws that lead to a more detailed probe of Palladio's construction language.

2.1 PROBLEM STATEMENT - REPRESENTING THE FOUR BOOKS

Unlike two-dimensional reconstruction, three-dimensions require many more levels of information such as building heights, and wall thickness. Unfortunately a large percentage of information needed to construct each villa model can not be found in *The Four Books of Architecture*. For the purpose of this study, missing information was generated through interpretations from three sources: *The Four Books of Architecture,* photographs, and speculation. There are three problems associated with these sources. First, there was the absence of clear dimensions from Palladio's plan and elevation drawings. This leads to a representation based on the appearance of the villa and not the construction. The second problem was a conflict between the drawings and the rules. The first of the *Four Books* contains rules for ceiling and vault types and room heights. The *Four Books* state that if the room has a ceiling, the height of the main hall can be determined by the breath.[20] If this rule were tested on the Villa Cornaro, which has a central hall and a ceiling, whose breath is 32ft, from looking at the façade elevation, it is obvious that this dimension will not work in the space (fig. 5.29). The third problem was constructing villa components or spaces that had no obvious rules, such as the barns, columns or balustrades. Many villas had segmented barns or outdoor curved spaces with no data point or relative connecting point that can be used to define a radius. Neither Palladio nor Bertotti Scamozzi includes technical data for constructing a curved barn or other curved parts such as rotundas or domes. There are no rules for finding the centers of these curves in the text or photos. Also there are no landmarks on the drawings to serve as origins. The Villa Trissino at Meledo (fig. 8.1) offers the edge of the first step in the entry garden as a point of origin for the curves of the barns. Yet the Villa Mocenigo on the Brenta (fig. 10.1) offers no such marker. In fact, the reflected upper portion of the Villa Mocenigo has a different center for the curved barnyard walls and steps than the lower portion.

Summary of modeling issues

- The absence of critical dimension from Palladio's drawings
- Rule conflicts between the text and the drawings
- A minimal understanding of the rules
- Absence of technical details from Palladio and Bertotti Bertotti Scamozzi's drawings

2.1 RECONSTRUCTING PALLADIO PAST AND PRESENT

There has been a long history of attempts to reconstructing Palladio's villas. Bertotti Bertotti Scamozzi's treatise on Palladio binds highly detailed engravings of Palladio's built and unbuilt works: villas, palaces and churches represented in plan, section and elevation. Building designs drawn by Bertotti Scamozzi are engravings were constructed from measurements taken of the built work. His drawings of the un-built buildings were detailed variations of Palladio's original drawings, drawn from a combination of Palladio's rules and his drawings. These drawings carry over a number of Palladio's design mistakes and misrepresented shapes. For example, an analysis of Bertotti Scamozzi's drawings shows that roof lines do not match in certain places, plans and sections do not line up and the un-built villas do not contain the variation in wall thickness as the built conditions do. An example of this is Bertotti Scamozzi's version of the previously mentioned Villa Trissino at Meledo. The drawings show walls all of the same thickness, and the same critical

[20] Palladio, A., 1965, Bk1. Chap. 13

dimension is missing from Bertotti Scamozzi's representation noting the width of a side room and the main stair.

In 1952, Wittkower wrote a paper on how a Palladian villa could be built from a systemized floor plan based on Palladian rule.[21] He presents eight examples of villas from the *Four Books* and claims the ninth to be an example of a new Palladian villa. Following that, George Stiny and William Mitchell wrote the *Palladian Grammar* in 1978, to demonstrate a method for creating a Palladian plan from a system of rules. It extended and added to Wittkower's study by pointing out that any Palladian villa could be built by not only reducing Palladio's floor plans to a simple grid, but that the grid could be extended to include more elements and a greater level of details. In their paper they used some of the rules from *The Four Books*, but added many of their own rules based on shapes. The Villa Foscari Malcontenta was used as an example of a villa that could lead to the development of a new Palladian plan.[22] The results are the creation of multiple floor plans based on a set of Palladian of rules.

Of the three examples and other attempts not mentioned in this paper, there has never been a representation of a full corpus of Palladian villas. In spite of this, each of the three representational methods attempts to deal with one of the following issues: (1) measurability, (2) reduction of the plan and (3) an application of rules either Palladian or invented.

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[21] Wittkower., R p 70
[22] Stiny/Mitchell (1978) *Counting Palladian Plans.*

2.2 *VILLA MODELS: 3D RECONSTRUCTIONS*

A computer-based solid modeling program was used to reconstruct the villas. The choice to model verses a parametric system[23] was made based on time and a limited understanding of Palladio's rules. The goal was to systematically build and animate the thirty models from a plan and elevation drawing, photos and other drawings.

The first task was to analyze the drawings in *The Four Books* and *The buildings and the designs of Andrea Palladio* to visually identify common elements that would lead to a modeling procedure. Six common rules were discovered from the study. The study found that all villas:

1) Are symmetrical
2) Have a base or basement with steps
3) Have windows
4) Have doors
5) Have a pitched roof
6) Many, but not all have columns

Four modeling systems were needed in order to construct the villas within nine weeks and to add details leading to a representational style similar to Palladio's designs. These four systems are: a system to create parts, a system to combine and add new parts, a layering convention and a system to handle symmetry.

The first system was to create common parts for all villas a system similar to the one found in book one of *The Four Books* except these parts are of simple geometry with no detail. Early in the

[23] Stiny, G., 1980 (a) p. 349

process four simple parts were modeled: balustrades and three types of columns (fig. 2.1). Other parts and procedures were executed during the construction of each villa model. The initial analysis was limited to a study of the drawings and not the text. Palladio had rules for defining room and roof heights, room proportions and the sizes of details such as windows and doors that

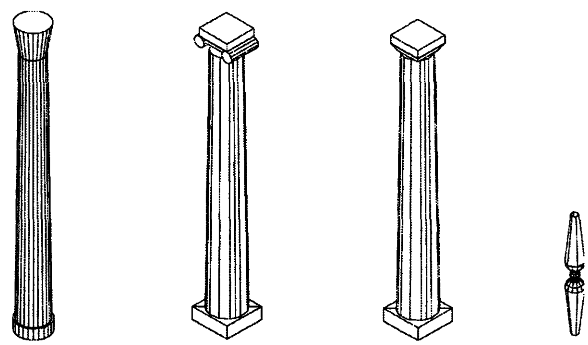

Fig. 2.1 Three column types and a balustrade

were disregarded in this study due to time issues. In fact there are rules for defining the room heights which could help to define the front elevation dimension in this study.

The second system allowed for the combination of one or more of the four parts and the creation of new parts to make a complete building. Other parts such as walls, windows, and doors were modeled differently with each villa. These parts are either a mathematical procedure or profile drawing in the *Four Books*. For expediency the choice was made to ignore the rules from the first book, and to represent the villas according to the images from the second book. As for the application of the second book, the first half of the second book shows how certain parts such as columns, entablatures and walls can be combined to make town houses, atriums and halls. The last part of book two consists of examples of villas and town houses made from the previous rules. The resulting villas in the second half of the text are a variety of building types and shapes based on differences in program, building site and cost. In summary, this system takes the parts from the first system and applies them to the floor plan and elevation, and adds more parts in order to complete the full villa.

The third and most important system was breaking the villa models into five clear layers (fig. 2.2) for easy construction:

- Base
- Columns
- Exterior walls
- Cornice
- Roof

Each part within the five layers of information was modeled separately, but all villa models contained these five layer types.

Last, in order to take advantage of Palladio's system of symmetry, only one side was modeled and reflected at the conclusion of the building process. Unfortunately Palladio's woodcuts were not the same on each side of the plan or elevation. At times one side of the woodcut would contain data missing from the other. Each of the thirty plans required careful decision making in order to prioritize modeling details. There was no system for picking the details to model.

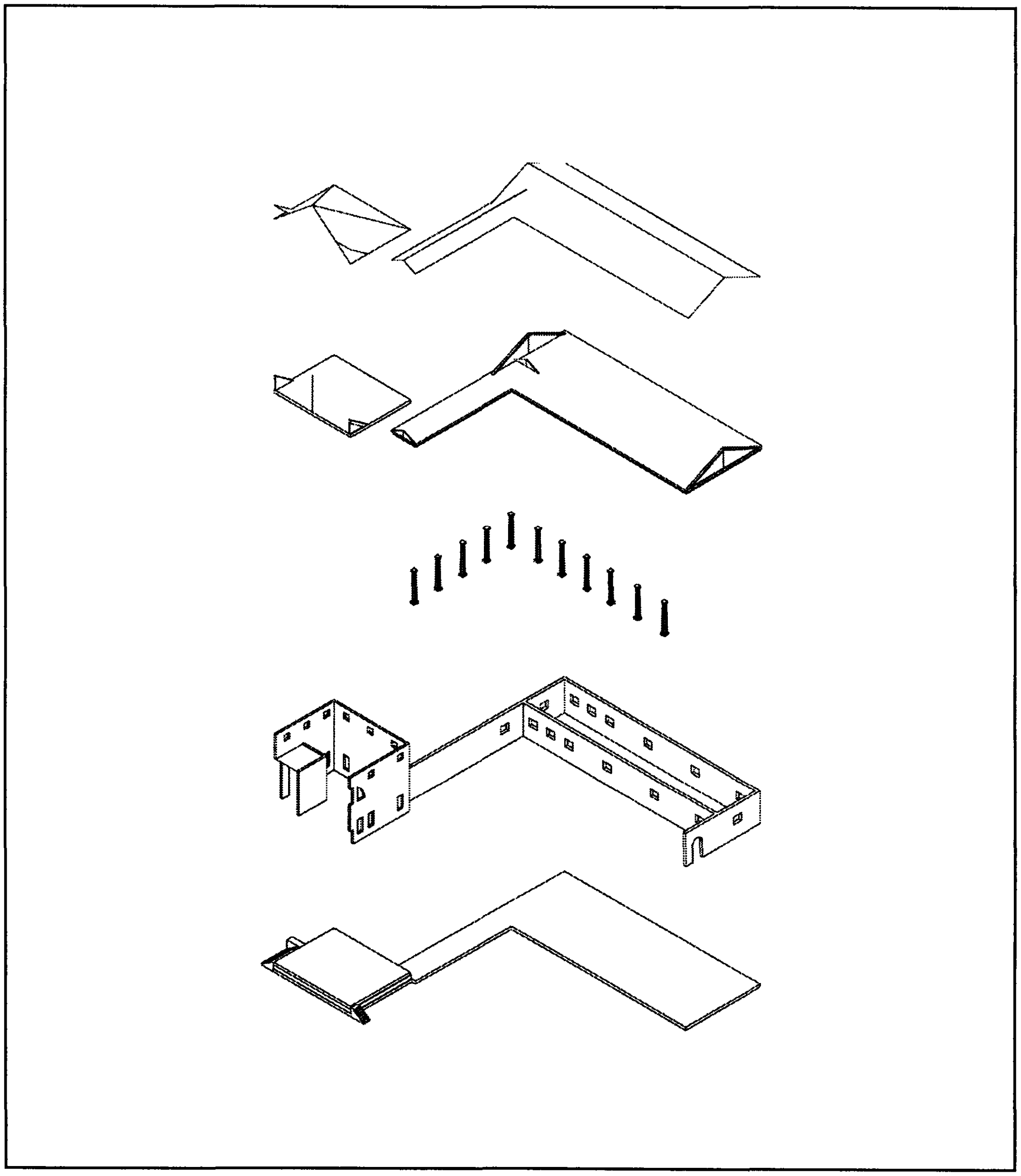

Fig. 2.2 Five layers of the villa model, roof, cornice, columns, walls and base

2.3 *CONSTRUCTION PROCEDURE: THE VILLA ZENO*

Each model was completed in series of five steps (five layers mentioned above) and many sub-steps based on complexity and detail. The process began by building one side of the model in detail, and ended by mirroring the built half to create a full villa. The last step was to render the model using a gray scale shader.

The Villa Zeno will serve as the case study to demonstrate the process (fig. 2.3). The villa model begins with the *Set-Up* file an empty modeling file with a starting point or central axis (0,0,0 - marked by an axis) for each villa model. This axis is the center of the main house, not the building's site. This means that once the model is completed, rendered and animated the villa model will rotate from the center of the house and not the central point of the site (fig. 2.8). The villa *Set-up* file also contained six basic layers of information - the ground, building base, columns, walls, cornice pieces and roof. The final villa model will contain a mixture of these layers. For example the base layer was labeled 02_bas_001. The first set of numbers represents the second of six layers, (bas) is short for base, and the last set of numbers-001 - are used for additional or associated layers within that section.

The first step was to recreate Palladio's floor plan drawing in CAD, focusing on reconstructing the exterior walls only. Measurements for the total exterior form in plan view were found by adding the room sizes listed on the original drawing together to make a plan diagram (fig. 2.4). Next, exterior walls were constructed by offsetting the plan diagram exterior walls by twelve inches in order to add thickness. Dimensions did not originate from the addition of the room sizes only, they came from a mixture of measuring and scaling an enlarged copy of the plan along with the addition of the dimension listed on the drawing. The end product is a simplification of the floor plan in line form (fig. 2.4).

The second step was to build the villa base (fig. 2.5a). Some villas have basements and some have a base. The villa Zeno has a base from which the main house and the barns are created. A scaled measurement of 3.5 feet was applied to the computer-modeled base. Palladio's drawing notes the height of the base to be 5.5 feet. The barn base was composed of a single level polygon, 1.5 feet in height, also offset from the plan of the barns by a few inches. Both heights were found from measurements taken from the drawing and not the numbers noted on the drawing.

After the three levels of the base were established, stairs were added to each side (fig. 2.5b). The bottom of the stair started from a z-axis height of zero, ending at the top of the last base piece. A different type of stair would be needed for each side. Note that the stairs were a subset of the base layer. Palladio's drawings showed 8 risers for the front stair. The height of the base was divided by the eight stairs (3.5ft.) to determine the height of the risers. Based on the numbers, the height of

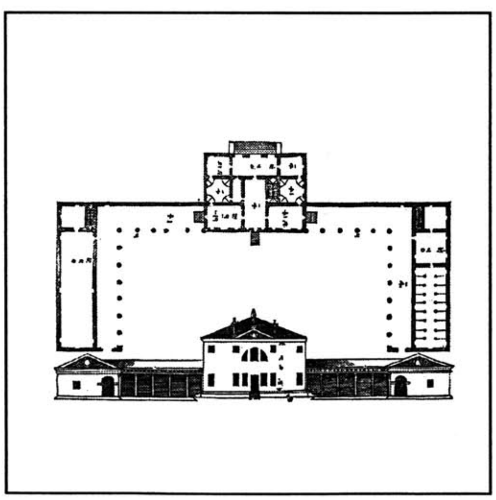

Fig. 2.3 Villa Zeno floor plan

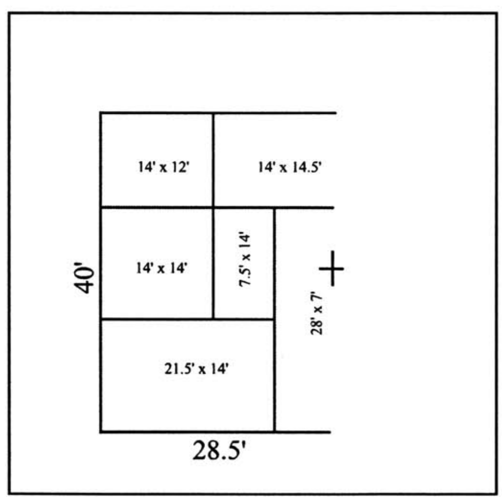

Fig. 2.4 Villa Zeno half plan diagram each stair should be 11 inches, an unacceptable dimension. The original drawing was not clear enough to scale the stair. The resulting front stair in the villa model had 7" risers and 8" treads. A rule formed from the confusion was that risers on any of the villa models would have 6" riser and a 12" tread. The back stair was a simple series of steps with the same riser and tread dimensions as the front stair. Since the stair only appears in the plan view and not on the front elevation, the design was determined from photographs of the Villa Pojana. This stair was constructed by reflecting the front stair to the back, lining the back edge of the stair up the side of the base and multiplying the stair often enough to make it 12" in width. The end block or pedestal was a 2.5' wide rectangle originated from the edge of the lowest stair, abutting the lowest level of the base. The height matched the height of the top of the third level of the base.

The exterior has four sides on the main house and two at the barns. The outer edge of the previously created base was the starting point for the front wall. All of the walls are composed of a set of planes one foot apart, offset from the original plan diagram to the inside of the plan. The height of the walls for the main house is 27 feet from the top of the base to the top of the wall. This dimension was taken from the elevation drawing. Window sizes and door openings were modeled and positioned from measurements taken from the elevation drawing. The front facade was composed of three lower level windows measuring 2.5 ft. wide, and 5 feet in height (fig, 2.5d). It also has a themal window in its center, composed of three straight openings with a semi-circular outline. The center point of the arch was struck from measurements taken from Palladio's drawing. The second story set of windows were created by cutting the tops off one and one half rectangular window opening blocks, 2.5 feet square. Their sills were 23 feet from the top of the base.

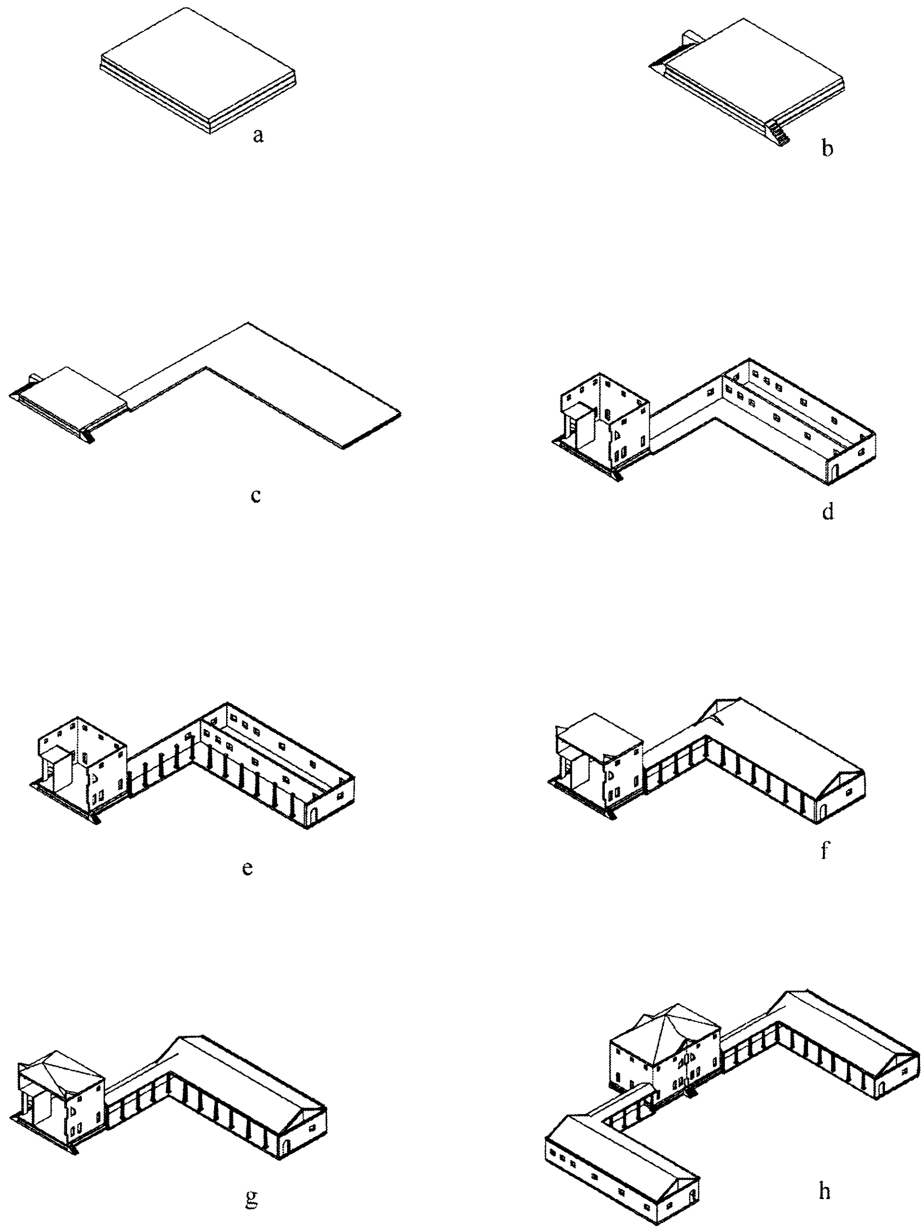

Fig. 2.5a-h Building of the Villa Zeno model

The back facade was made of a rusticated series of arched openings similar to the arched opening over the front portico. Each of the one and a half openings was 5.5 feet in width and 18 feet to the top of the arch. They were constructed by punched openings in the exterior wall. A screen wall was built behind the arches to keep light from bouncing around the inside of the hollow shell. Windows at the attic level were similar to those modeled in the front façade, made of two small windows, 2.5 feet square 23 feet from the top of the base.

Side exterior walls have punched openings similar to the front and back elevations. Barn walls are 13 feet in height and windows are punched at random from a 4-foot by 3-foot rectangle (fig. 2.5d). The only columns in the building are at the barns, which are of the Doric order on Palladio's elevation drawing. Columns added to the barns were inserted from the pre-made kit of parts (fig. 2.1). Based on a division of horizontal and a vertical lines drawn on Palladio's plan, from one end of the portico's facing edge to the other, spacing of the columns, from center of a column to center of column was 13-feet (2.5e). The cornice piece that covers the entire villa model was created from three stacked polygons at the third level of the main house and the top of the basement (fig. 2.5f). There were two roof types for the main house and two for the barns. The pediment of the portico was attached to the cornices as part of the same layer. The main house had a pediment that was 5 feet in height and the width of the lower leg of the triangle was 8.5 feet. There was a punched inset subtracted from the portico face; this gave thickness to the roof and cast shadows onto the portico face. The portico face for the barns was 10 feet in height and 17 feet from its midpoint to the end. It was also modeled with a facial inset (2.5f). Finally, the roofs were made of thin planes constructed by connecting points from the cornice. The roofs for the portico faces of the main house only required a face to be drawn over one side of its top face. The main roof for the house was constructed in a tent like manner. A line was drawn from the top of the cornice to a measured height of 15'. Triangular faces were drawn from the top of the 15' line to the four edges of the cornice. The secondary roof for the barn was constructed in a triangular form similar to the barn's main roof. False porticos were drawn at the ends of the roof and rectangles were stretched at an angle between the two triangles (2.5g). After one half of the model was built, it was copied and reflected at the center point, creating the other half of the villa model (2.5h). Once the model was mirrored, the villa model construction process was terminated.

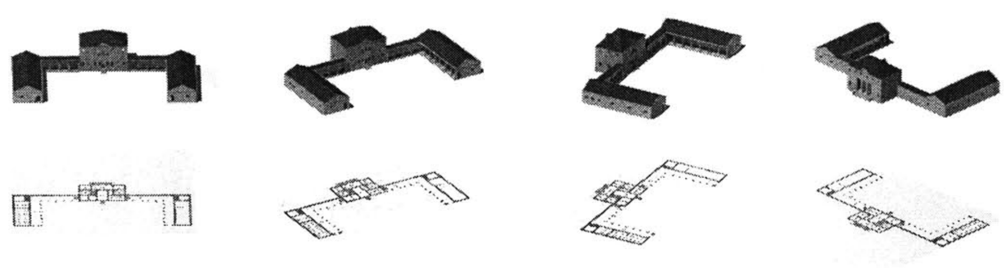

Fig. 2.6 Villa Zeno animated with an animated floor plan below

2.4 MODEL REPRESENTATION - RENDERING

The objective of the rendering component was to animate the model in such a way that all sides could be viewed from a stationary point, with a stationary light source. A script was written to render 24 images around a stationary viewing point using Radiance software. The sun's location (stationary light source) in the rendering program remained constant, while the geometry file or the villa model was turned 15 degrees around a the central axis for each of the 24 frames. Final results produced a presentation of a model appearing to be spun on a turntable under a stationary light source, rendered in various shades of gray, viewed from an isometric projection (fig. 2.6).

2.5 RESULTS OF MODELING

What was to be a modeled set of villa models, developed into a way of seeing the villa's form in ordered by date and scale (fig. 2.7 - 2.10). Through an analysis of a few Palladian plans, a few common rules were found and used to build the corpus. Those rules involved breaking down of the villas into five basic parts with associated sub parts, and using villa symmetry, to only model one side of the Villa.

What makes the models work well are their visual versatility that extended far beyond the original proposal for the CD-Rom. The models can be viewed from any axis: plan view, elevation, section, or size. Villa parts can be rendered exclusively, compared and counted; for example, only the porticos of the villas could be rendered, or just the roofs. In general the resulting models offer many ways of viewing, measuring and comparing.

Palladio's Villas by date

Row 1
1534 Villa Trissino - Fully Built
1538 Villa Godi - Partially Built
1539 Villa Piovene -Fully Built (attribution uncertain)
1542 Villa Pisani Bagnolo - Partially Built
1542 Villa Caldogno - Fully Built

Row 2
1542 Villa Thiene - Partially Built
1542 Villa Marcello - Fully Built
1545 Villa Saraceno - Fully Built
1546 Villa Poiana - Partially Built
1548 Villa Angarano - Partially Built

Row 3
1550 Villa Chericati Porto - Fully Built
1552 Villa Barbaro - Fully Built
1552 Villa Pisani Montagnana - Partially Built
1553 Villa Cornaro - Fully Built
1553 Villa Ragona - Unbuilt

Row 4
1556 Villa Thiene Cicogna di Villafranca - Unbuilt
1556 Villa Badoer - Fully Built
1557 Villa Repeta - Unbuilt
1558 Villa Emo - Fully Built
1559 Villa Foscari - Fully Built

Row 5
1560 Villa Forni Cerato - Fully Built(attribution uncertain)
1560 Villa Schio - Unbuilt(attribution uncertain)
1560 Villa Zeno - Unbuilt
1563 Villa Valmarana - Fully Built
1565 Villa Sarego Santa Sofia - Partially Built

Row 6
1566 Villa Rotunda - Fully Built
1569 Villa Sarego Veronella - Unbuilt
1570 Villa Trissino - Unbuilt
1570 Villa Mocenigo – Marocco Partially Built; Demolished
1570 Villa Mocenigo at the Brenta - Unbuilt

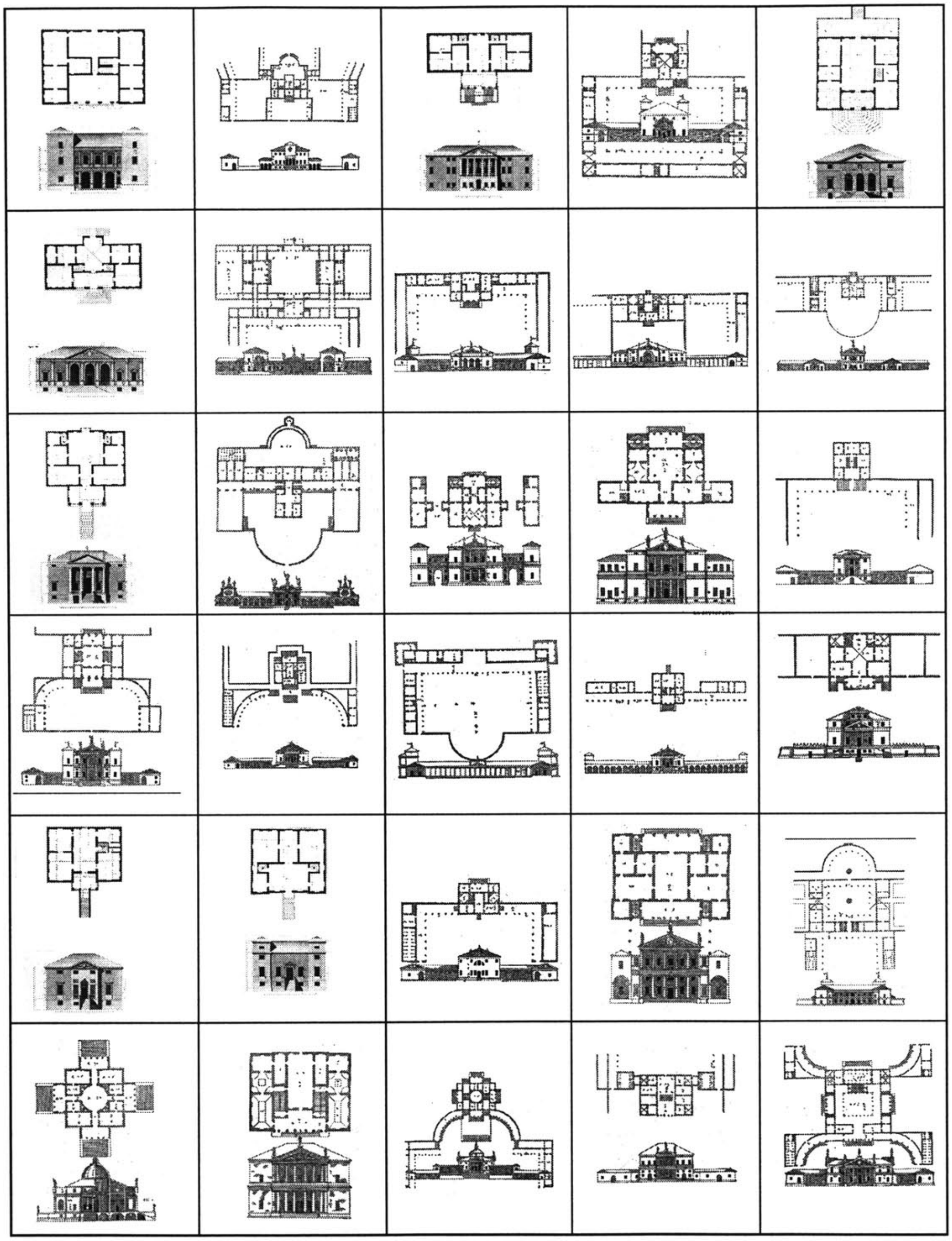

Fig. 2.7 Palladio's original drawings

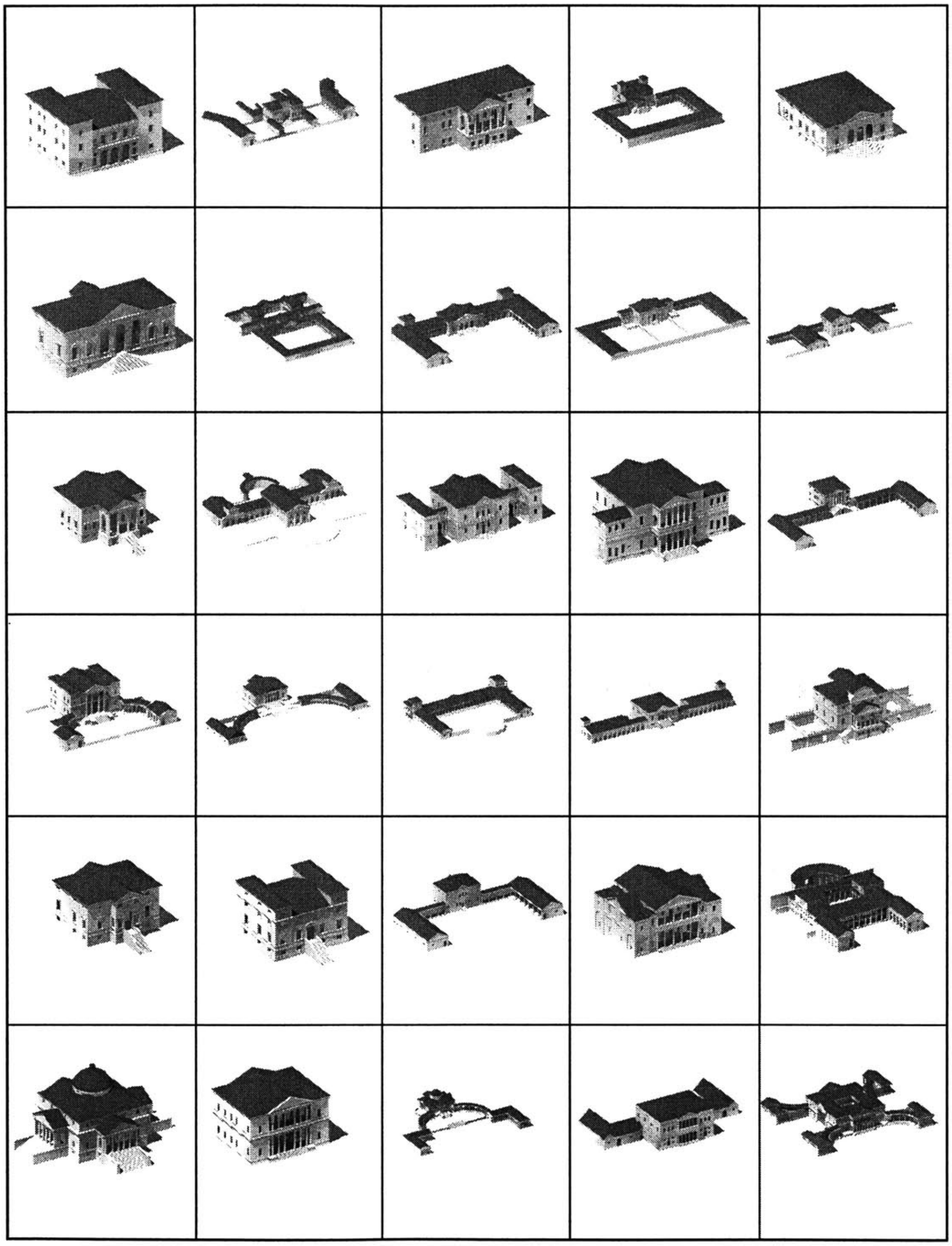

Fig. 2.8 Villa Models organized by date

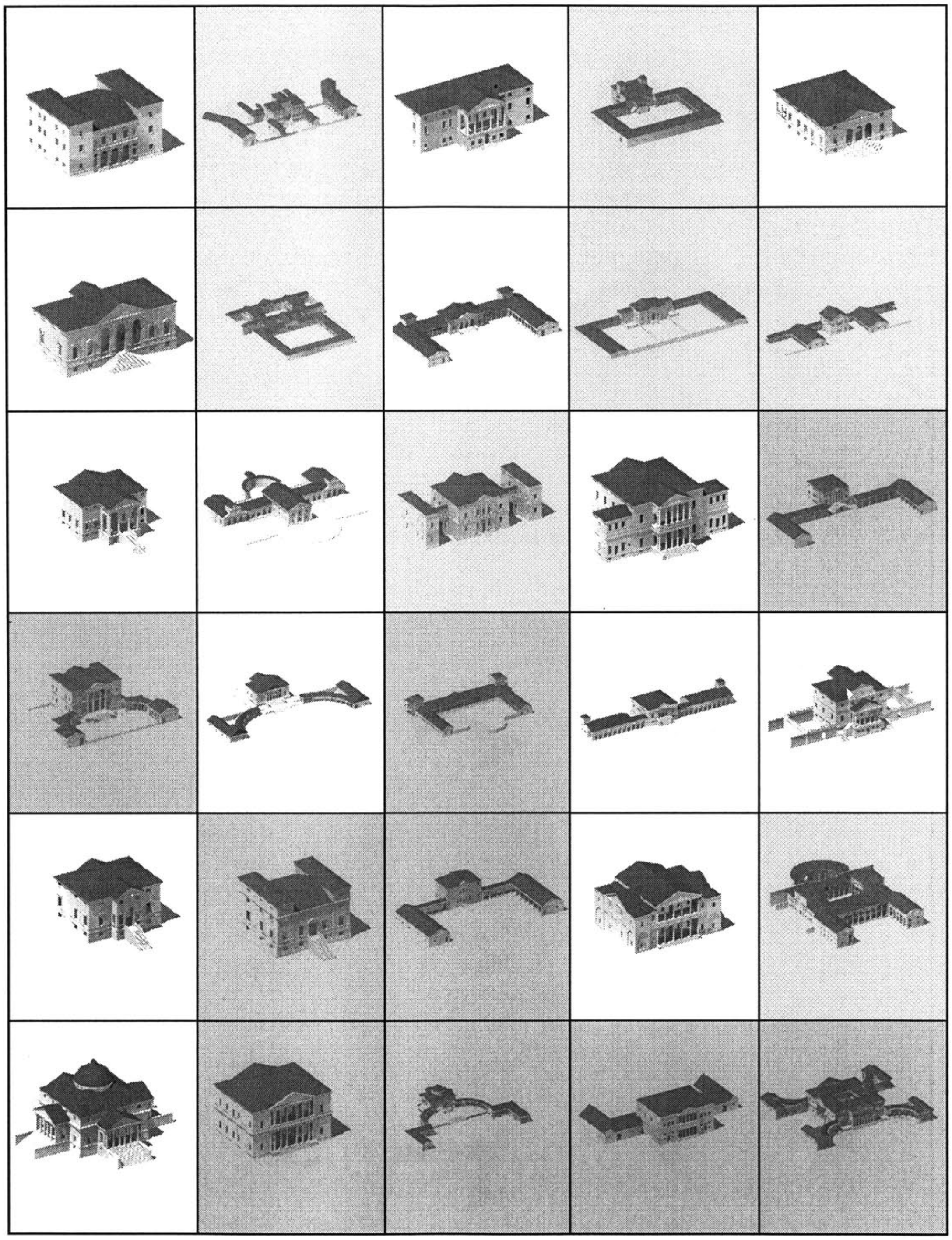

Fig. 2.9 Villa models: built in white, partially built or unbuilt in gray

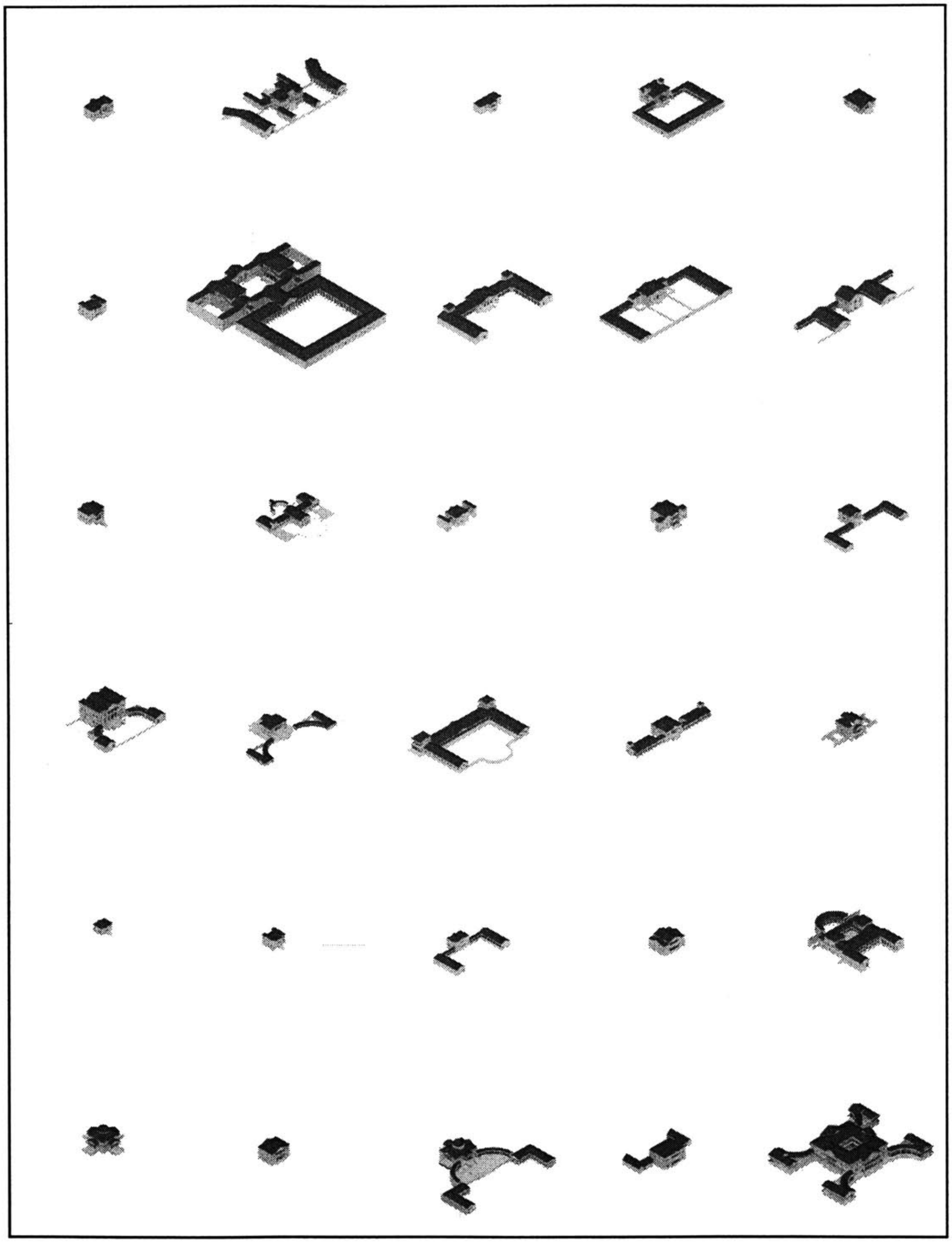

Fig. 2.10 Villa models by scale

2.6 CHAPTER SUMMARY

These reconstructions provide a finite sampling of Palladio's villa form and style. These models are a simplistic version of his work and are in no way presented as a scholarly representation of his work. The results demonstrated the limitations of a fast simple process, a compromise in accuracy, no records of decisions and a limited view of the models (since there is not an interior they can only be view from the outside). For example, the column spacing in most of the porticos do not match Palladio's rule system for proper column spacing. If the villa were to follow Palladian rule, the Rotunda villa model would have a larger spacing at the center bay. The process of making the villa models included a steep learning curve. Only at the end of the process was there enough information acquired to construct each villa model correctly. An ideal set of villa models would contain an analysis and dissection of the models. In other words it would present the models in detail. This section is a micro view of a larger issue, which is to see the unbuilt villas in detail, inside and out. As a way of improving the system, it would be useful to analyze what decisions were made in the process, and to consider alternative schemes for unbuilt projects that do not have a clear resolution.

LIST OF FIGURES

CHAPTER THREE

TRANSLATING DRAWINGS AND EVALUATING RESULTS

3.0 PROCESS OF TRANSLATION

This chapter is an overview of the reconstruction process used in this study. The pilot study of chapter two is a less complex of what will now be explored in depth and detail. The process of translation begins with a sketch and ends with a three-dimensional cad representation (fig. 3.1). To make for an academic process of translation and model construction, speculation and decisions must be recorded visually and texturally. Model creation and evaluation is both visual and textural in this case, and textural refers to numerical values as parameters. In the end, the input and output material will be evaluated by historians, architects and a few non-architects in visual and textural languages.

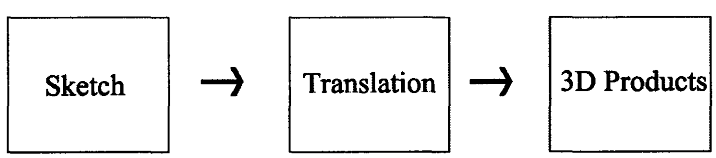

Fig. 3.1 Outline of the process

This chapter outlines the methods used to create and evaluate a villa model file which will be used to construct and evaluate the two case study villa models. Within this study, translation is referred to as a process of reconstructing the floor plan and elevation or other drawing types into two-dimensional CAD representations. Afterwards, rules are applied to the two-dimensional translated plan CAD drawing, while the elevation drawing is used as a reference for the construction of the villa model. The final outcome is a three-dimensional villa model file, output by four devices of varying dimensions.

3.1 DESIGN AND REFLECTION

The process used to reconstruct these villas is similar to the design process used to create a new building; it is one requiring action and reflection.[24] Reconstructions are a constant search for the truth using visual aids to verify findings. A good reconstruction is based on informed assumptions and documented proof demonstrating the process and methods used to arrive at conclusions. A scholarly outcome offers can offer multiple answers to a very complex problem. The final goal is not to create a single description of the building, but to represent and challenge areas of design conflict. This study falls into Schon's category of reflection-in-action by focusing the process on recording the actions in the form of rules, and to reflecting on the rules through architectural materials (drawings and models). Reflection in design and reconstruction is critical, because, the reflective moments in the process expose design issues or conflicts. This means that with each output there is a greater level of understanding and therefore an opportunity to define conflicts. Isometric drawings present more sides of a design than do two-dimensional drawings. No matter what type of output is used, it is the process used to evaluate the output and adjust or change the

[24] Schon, D.1987, This point includes Schon's notion of thinking what they are doing while they are doing. It is not a substitute, the point here is not to prove that more than just thinking occurs

input to meet the new fitness requirement that is important. Schon refers to this output as "a moment in a process of reflection-in-action." The goal is to get to the point of reflection in order to build a response. Multiple "moments" are needed in order to develop knowledge, surprise and new actions[25], leading to a greater sense of truth. It could be argued that knowledge and surprise is limited when only one representation of a reconstruction is brought to the table. In most cases there are many solutions to a single design problem.

Since the reconstruction process begins with the *Four Books*, an analysis of the rules in the *Four Books* must be addressed as an issue. Text rules from the *Four Books* are loaded with extraneous notes and references to non-construction material, and often the information is worded in such a way that it becomes difficult to determine mathematical formulas for procedural items like doorframe and ceiling heights. Graphic information is usually missing; dimensions needed to reconstruct an object in three-dimensions. For example, it is impossible to define window types on the backs of the villa drawings, as well as room heights and ornamentation.

In summary, there are three issues with past methods of representation and reconstruction that defined the method used in this thesis. First is the issue of recording design decisions so that others can reconstruct a villa model similar if not identical to the examples here. Second is the issue of villa representation, and the fact that one form of presentation does not offer enough to do a complete reconstruction and develop critical arguments. Last is the need to clarify the *Four Books* and to make the rules architecturally understandable (fig. 3.2).

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but to point out that doing and thinking in this case is similar to Schon's point.
[25] Ibid. pp. 27-28

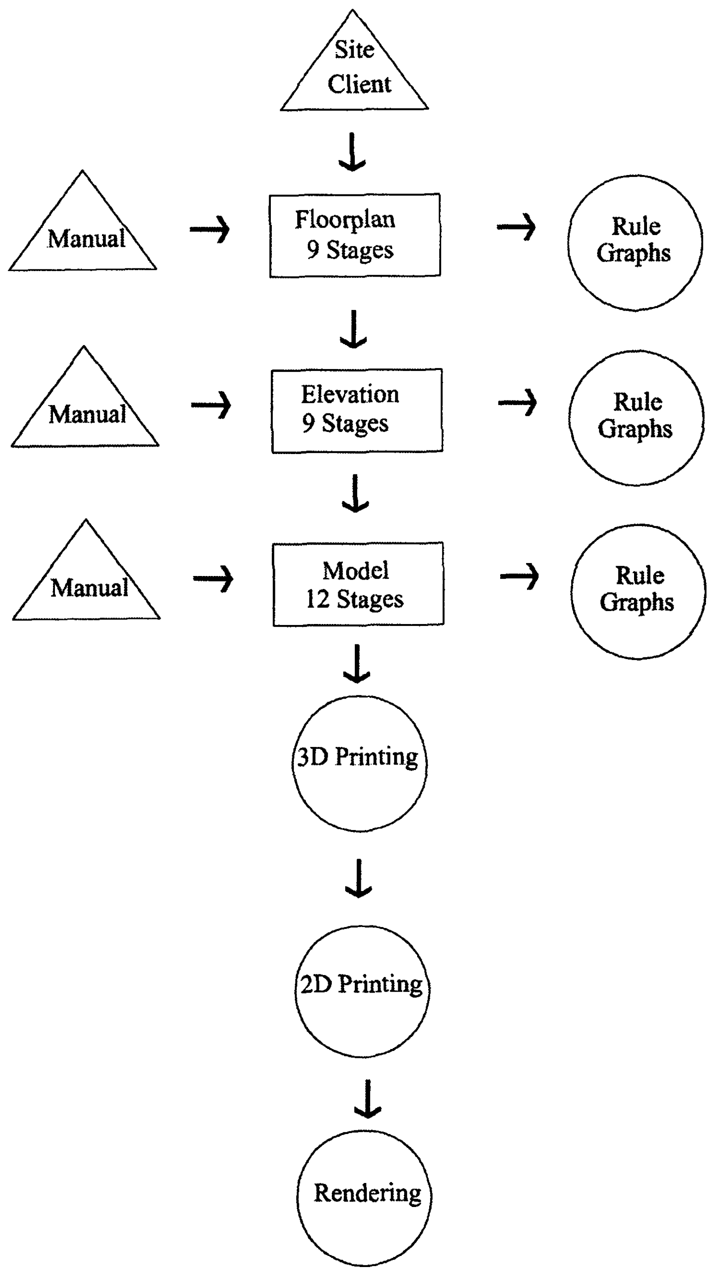

Fig. 3.2 Diagram of the reconstruction process from the beginning to end

3.2 *CREATION AND EVALUATION*

If the reconstruction process of this study will support the notion of reflection-in-action, it must be one that records and generates reflective material quickly. It is the output materials that make the evaluation/reflection process successful. The process here has three creation stages and four evaluation stages:

Creation and Evaluation Stages (fig. 3.2):

1) Creation - Reconstructing Palladio's floor plan drawing
2) Creation - Reconstructing Palladio's elevation drawing
3) Creation - Constructing a villa model from the plan, elevation and rules manual
4) Evaluation - One-dimensional record of villa model rules
5) Evaluation - Two-dimensional presentation of the villa model
6) Evaluation - Three-dimensional print of the villa model
7) Evaluation - Renderings of selected areas

Before the reconstruction process can begin there has to be a clarification of Palladio's original rules. The rules manual (chapter 4) is a rewriting of the *Four Books* accompanied by new rules that may have seemed obvious to Palladio, but are unknown to the present architectural culture. Some of these new rules demonstrate how older rules should be applied to the reconstruction. Palladio did not include variables for some of his mathematical equations. The manual offers guildlines for the assignment of numerical variables to building elements such as wall thickness, brick size, tread and riser sizes and ceiling sizes. All together the manual is composed of 18 sections organized by the order of physical construction: site, walls, ceilings, details, etc.

Chapters following the manual are focused on the construction of a villa model in three stages (plan, elevation and model). The plan and elevation are reconstructed from Palladio's original drawing. Afterwards, those drawings and the villa manual are used to construct a three-dimensional "villa model". The first stage involves an accurate reconstruction of a Palladian floor plan in nine steps. The second stage is the reconstruction of the elevation, also in nine steps. The third stage applies rules from the manual to the plan and elevation reconstructions to create a three–dimensional representation referred to here as a villa model file, or "villa model" for short. The model contains information on three-dimensional parts that range in size from a small 3" by 3" dentil molding, to a 3 ' cornice, to representations of large columns or pedestals.

Stages four through seven involve the output of reflective material. There are four different output tools used to see and evaluate the villa model results. The first is a one-dimensional text representation of the rules used to create the villa, complete with variables. Two-dimensional

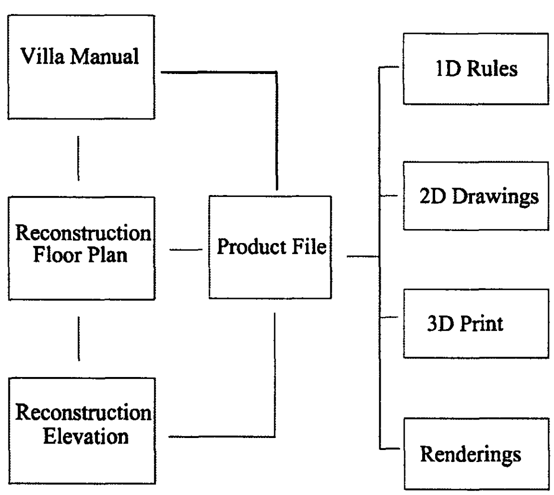

Fig. 3.3 Diagram of the reconstruction material representation - refers to the conventional methods of representing a building: floor plans, section and elevation they are used as comparative measurable materials. Three-dimensional printing offers a physical representation of the villa model file created from plastic or cornstarch. And last, renderings using high-resolution texture maps, invite the evaluator into the villa model's interior (fig. 3.3).

3.3 CHAPTER SUMMARY

This chapter sets the stage for the case studies at the end of this text and provides the overall purpose of the reconstruction process. As mentioned above, this process can also be used to design anew as well as to reconstruct. It outlines reasons for the process based on Schon's notion of reflection-in-action and demonstrates a process that offers reflective material while recording the process.

LIST OF FIGURES

CHAPTER FOUR

PALLADIO'S VILLAS IN 1D

4.0 PALLADIO'S DESIGN AND CONSTRUCTION RULES

This chapter is a clarification of the rules from the first and second books in *The Four Books of Architecture* with the addition of several new rules. The rules are clarified here in three stages. The first is a simplification of the text into smaller more manageable sentences. Second is the addition of three-dimensional figures illustrating construction details and design rules not explained in the original text or images. And last, is the addition of new rules taken from a field study of the Villa Pojana and photos.

During the Renaissance, architects were educated by the exchange and copying of information found in sketchbooks. These books were the architectural textbooks of the time.[26] *Il Quattro Libri* was different in that it had a clear pedagogical purpose. If followed correctly, the user of the text could reconstruct a villa or palace from the rules. A would-be apprentice could build a villa in accord with the site, the building materials and the owner.[27] The first of The *Four Books* presents building parts, materials, procedures for assembly and a few profiles for doorframes and columns. The second book presents spaces, some methods for measuring and examples of full buildings, both palaces and villas. Each book comes complete with two-dimensional drawings and one-dimensional text rules. In the Renaissance, formal training as an architect did not yet exist. Practice could be a system of apprenticeship pass down from architect to architect while often artists or intellectuals were entrusted

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[26] Ackerman, J., 1954
[27] Burns, H., 1975 p.101

with architectural design, because of their knowledge of drawing basic principles, and the antique. Written with masons and craftsmen in mind, as well as architects patrons, the text was meant to educate a wide fellowship: craftsmen, artist, architects, patrons and the cultivated public.[28] The stimulus for the book came from Palladio's relationship with Giangiagio Trissino and his quest to improve upon the treatise of his day by writing rules along side of drawings that explained the rules.[29] The resulting *Four Books* is an abstract representation of discussions between the patron, Palladio and the masons of his day.

Palladio's rules are described here in three ways: by text, by illustration or by mathematical equation whereby a rule is illustrated or described according to its complexity. The simplest rules can be explained in one-dimension or text. For example, Palladio's first rule for a wall that says "walls are to be carried directly upright,"[30] could be referred to as a one-dimensional rule. Here an illustration is not needed to describe the rule. In contrast, there are rules that are best described by illustration such as the entasis of a column shaft or the profile of a door. Finally, there are three-dimensional rules, most particularly mathematical rules, that are best described through three-dimensional illustrations and photos. These rules describe an object's length, width, height and construction methods. This applies to rules for stairs or vaults.

The rules are labeled in four parts, (1) by chapter (this chapter for example), (2) chapter section, (3) by paragraph and (4) by sentences or a series of sentences in a paragraph. For example in section 4.2 THE BUILDING SITE, a rule is labeled "4.2.4.pa -But if navigable rivers cannot be had, one must build near some other running water." The first - 4 - is the obvious chapter reference.

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[28] Burns, H. 1991. p. 193
[29] Ibid. p.101-104
[30] Palladio, A., Bk1, Chap 1, par 3

The second set of numbers (.2) refers to the rule section according to this chapter, and the last set of numbers (.4) is the sentence referenced from the paragraph in Palladio's text. There is also a "pa" at the end of the rule label, this is short for Palladio, just as a rule label followed by "ls" is short for Larry Sass. Rule sections in the chapter are ordered by the process of construction. The first rule section concerns measurements which are needed in order to understand the units of measurements followed by the site, followed by spaces, then walls, etc. In later chapters and the case studies, new rules will be added to the list based on new findings from villa model evaluations.

4.1 MEASUREMENTS

Although Palladio offers a ruled standard for various measurements,[31] his text is still missing information on general town sizes and dimensions for bricks and roof tiles in the Four Books. Palladio had two forms of measurement, the first based on modules and the other based on a ruled measurement system in the form of standard feet, inches, and minutes. The module is a tool for assigning the proportions of columns in terms of their height to width ratios and of indicating the relative proportions of all other parts of the order. It is also a method for dividing and proportioning door and window ornamentation. Other proportions such as the heights of rooms, dimensions listed on Palladio's drawings and thickness of objects (walls) are measured in feet, 12 inches and 4 minutes. The foot is divided into inches and minutes, which should not to be confused with the minutes used for dividing columns. The actual dimension of the foot differs from town to town. In Palladio's time he used the Vicentine foot is 35.7cm, somewhat larger than the American foot.

Understanding the brick is the key to understanding Palladio's villas. In addition to its structural cost calculating[32] qualities, bricks are used as proportioning and measuring instruments. When describing the wall thickness for the attic space, Palladio says that the walls in the second story wall should be half a brick thinner than the piano noble. The measurement of a brick can be found inscribed in a red Verona marble stele within the portico of the church of San Vincenzo across from Palladio's Basilica (fig. 4.1). This inscribed slab was by the community to registar standard measurements and therefore regulate the exchange of goods (fig. 4.2). The stone contains the measurement for a standard brick, which happens to be 30.2 x 15.5 cm or approximately 12 x 6, American inches, a yard of silk and of

[31] Palladio, A., 1965 Bk. 2, Chap 3
[32] Ackerman, J., 1957

cloth, a tile size and the Vicentine foot.[33] Based on the brick sizes for walls, vault construction and stairs can be priced before construction begins.

RULES FOR MEASURING

4.1.1.pa - Ruled measurements are in feet, inches and minutes[34]

4.1.2.ls - A standard brick measures 6" wide by 12" long

Fig. 4.1 Loggia of San Vincenzo

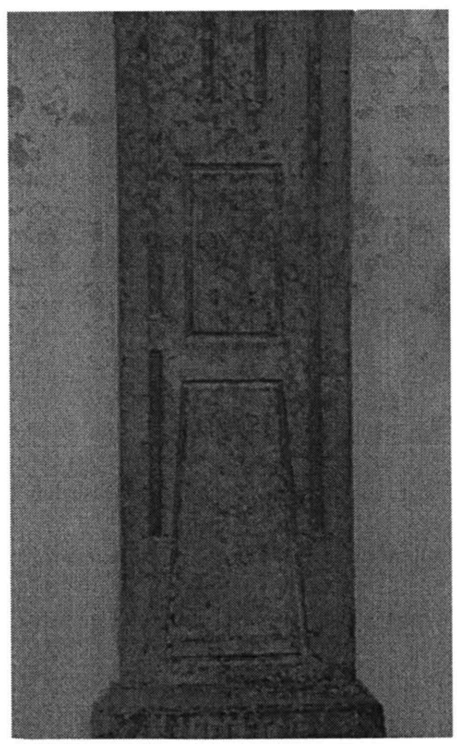

Fig. 4.2 Tall red marble slab found in the loggia of San Vincenzo the stone shows the standard size for a brick over a standard size for a roof tile

[33] Burns, H., 1975 p. 209
[34] Palladio, A., 1965 Bk2, Chap 2, par. 6

4.2 THE SITE

Palladio includes a small section in the *Four Books* on building location within the boundaries of the site.[35] In it he does not mention lesser rules needed for detailing the site, such as how to outline the building's foot print on the site. Other unanswered questions concerning the building site include: What methods were used to translate the building's footprint to the ground surface? Is there a footing under the main walls, or do exterior walls sit on the ground surface? What does Palladio offer are site rules that align the house with an object in nature, and rules that help to locate the house on the site. Palladio indicates two site situations - a hill and a flat plain.[36] He says that those (patrons) who have a site with a hill should place the villa at the top of the hill. For a flat site the villa should be placed as close to the center of the site as possible. In reality Palladio had many site conditions to challenge these rules, from a flat plain like the Villa Saraceno, to steep slopes as in the Villa Barbaro. Building alignment was an unwritten rule that said that a nearby roadway or river would determine the direction for which the building would face.[37] He altered the rules to meet the site conditions for a particular villa. Each site varied the final outcome of his design solutions and rules.[38]

As mentioned in section 1.1, the *Four Books* presents two villa types - the suburban house and the farming villa.[39] The country house has to maintain the family, the farm hands and animals, and the suburban house was only intended to maintain the lifestyle of the patron in a country setting. Both types began with a box for the main villa, but the farm villa typically has barns that surrounded the property either touching the edges of the property on all sides or breaking the property into a few smaller farming gardens.

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[35] Ibid., Chap 13
[36] Ibid., Chap 12
[37] Burns, H., 1975 p.216
[38] Burns, H., 1999
[39] Ackerman, J., p.54

Another design variable was soil conditions, which determine the height and villa volume. Soil density determines the building's depth and whether there would be a foundation with rooms (a basement) or a deep base of stone and fill.[40] If the ground were flat and solid, it villa would have a basement. If the ground were marshy, the villa would have a foundation and no basement, as is the case with the unbuilt Villas Thiene, Cicogna, and Mocenigo on the Brenta River.

RULES FOR THE SITE

4.2.1.pa - There are two sorts of fabrics required in a villa, one for the habitation of the master, and of his family, second for the management and care of the produce and animals of the villa[41]

4.2.2.pa - A convenient place to locate a villa is in the middle of the estate, so that the owner may view and improve it on every side, and that the fruits there may be the more conveniently carried by the laborers to his house[42]

4.2.3.pa -If one may build upon a river, it will be both convenient and beautiful at all times, and with little expense, the products may be taken to the city in boats, and will serve for the uses of the house and cattle[43]

4.2.4.pa -But if navigable rivers cannot be had one must build near some other running water[44]

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[40] Ibid., p. 216
[41] Palladio, A., Bk2, Chap 13, par 1
[42] Ibid., par 5
[43] Ibid., par 6
[44] Ibid., par 7

4.2.5.pa - One must get at a distance from standing water[45]

4.2.6.ls - The building's façade should face the approaching street or river-way[46]

4.2.7.ls - Townhouse or town villa

4.2.8.ls - Farm with barn

4.3 BARNS

Barns or barchesses cover the grounds of the primary farming court. The goal of the barn is to link the owner with the outer buildings or dovecotes, which house the workers.[47] Doves were kept at the roof of the dovecotes and used as a source of meat.[48] The main house faces the courtyard, usually with a portico at the entry, using the barns to surround the court with a wall and dovecote at the farthest end. The classic example of this is the Villa Trissino Meledo (fig. 8.1). Within the courtyard there are crops, animals, farm hands and rare trees containing expensive Mulburry trees sold to feed silkworms. Another example of this is the Villa Pisani Bagolo, which has a main building with a court for farming, an entry with a portico facing the court and a surrounding set of barns. In the *Four Books of Architecture,* Palladio offers few rules on how the barns are to be built and their purpose. He does not offer information on the shape, nor does he provide barn dimensions. In spite of this we know that there are two types, square or segmented, or some combination of the two. Their orders range from Tuscan to Ionic.

[45] Ibid.
[46] Examples of this are the Villa Barbaro, Saraceno, Pojana and Foscari which face a river-way
[47] Burns, H., 1975 p.180
[48] Ibid., p.175

RULES FOR BARN CONSTRUCTION

4.3.1.pa - The barns may not be any impediment to the other part of the house[49]

4.3.2.pa - The covertures must be joined to the master's habitation, that he may be able to go to every place under cover, that neither the rains, nor the scorching sun of the summer[50]

4.3.3.pa - Regard must be had in lodging the men employed for the use of the villa, the animals, the products, and the instruments, conveniently, and without any constraint[51]

4.3.4-pa - The rooms for the steward, for the bailiff or farmer, and for the laborers, ought to be in a convenient place near to the gates, for the safeguard of all the other parts[52]

4.3.5.pa - The stables for the working animals, such as oxen and horses, must be at a distance from the master's habitations[53]

4.3.6.pa - The cellars ought to be under ground, enclosed, and far from any noise, moisture, etc[54]

4.3.7.ls - Barns can be straight or curved

4.3.8.ls - Barns can terminate at the villa or with a dovecote or end with a wall

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[49] Palladio, A., 1965, Bk2, Chap 13 , par 1
[50] Ibid., par 3
[51] Ibid., par 4
[52] Ibid., par 5
[53] Ibid., par 6

4.3.9.ls - Dovecotes can be made of two or more stories

4.4 SPACES

Of all the rules found in the *Four Books of Architecture*, Palladio's rules for spatial organization are his greatest achievement. The quality of a Palladian spaces is spectacular, giving rise to the villas' grand presence. Palladio's organization of space begins with the villa's exterior façade by first assigning a front and back to the villa block. This is done by way of designing the loggias so that if there are two, one may be recessed and the other projected. Second, upon entry the most beautiful spaces are seen first, while the lesser spaces are moved to the back. Palladio's organization of space takes the patron through a hierarchy of rooms from the most important to the least.[55] These spaces, arranged by order of importance, are divided into three types: entertainment, everyday spaces, and service spaces. These three spatial types are ordered vertically and horizontally. The most important is the piano noble, second is the top and last is the service space in the basement.

In *The Four Books of Architecture* Palladio talks about spaces or rooms in chapter 21 of book one and chapter 2 of book two. The spaces he notes are loggias, halls, cellars, and smaller rooms. Vertically the service areas are at the bottom while sleeping and entertainment areas are at the top. Horizontally the most important rooms such as the sala, are located at the front and back of the villa and the least important or the smaller rooms are located at the back. Lower levels or basements are composed of utility spaces for storage, larders (pantry), kitchen, servant dinning halls, laundries, bread ovens, and other services. There are two means of access to this level. The first is through a

[54] Ibid., par 8
[55] Ibid., p. 54

small set of steps or minor stairs. The second is typically through a side opening in the exterior façade or under the loggia stairs. The second level or piano noble is composed of the loggia (out door receiving place), halls and camere (small rooms): studies, libraries, sleeping, and eating rooms for receiving guests with fireplaces. The third level or the apartment for the master(s), is composed of salas (large rooms over the entry hall - with out fireplaces - used for festivities and banquets, plays, weddings halls and camere rooms).

Horizontal organization is based on the location of the primary loggia or entry. In the case of the Villa Pojana, the primary entry is the drawn elevation from *The Four Books of Architecture*. Here the patron enters an inset loggia followed by a barrel vaulted hall. Off of this hall are receiving rooms, two in the front with fireplaces, and two in the back without fireplaces. The largest and most important rooms are in the front and the rooms in the back are smaller studies or bedrooms. The original purpose of each room is unknown. Stairs are tucked away in the back of the villa out of view.[56]

The difficulty in assigning rooms to a villa is that Palladio has rules for some spaces but not others. Although they are used as central spaces, rooms such as rotundas and courts are not assigned rules. There are no rules for determining the dome height in the villas Rotunda or Trissino Meledo. Most courtyard arrangements within the built conditions are variations of halls or courtyards seen in Palladio's drawings on courtyards and halls found in book two. For example the main hall in the Villa Cornaro is similar in design to Palladio's Hall with Four Columns.[57] They do differ in order; Palladio's hall with four columns has Corinthian columns while the Villa Cornaro has ionic. In spite of this they are similar in that they are large spaces with central columns and coves for statues.

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[56] Ackerman, J., 1965 p.168

RULES FOR THE DESIGN OF SPACES

4.4.1.pa - The principal spaces are the loggia, halls, courts, magnificent rooms, and ample stairs, light and easy of ascent[58]

4.4.2.1.pa - Loggia's, for the most part, are made in the fore and back front of the house, and are placed in the middle, when only one is made, and on each side when there are two[59]

4.4.2.2.pa - They are not to be made less than ten foot wide, or more than twenty[60]

4.4.3.pa - In the length of halls I use not to exceed two squares, made from the breadth; but the nearer they come to a square, the more convenient and commendable they will be[61]

4.4.4.1pa - The rooms ought to be distributed on each side of the entry and hall[62]

4.4.4.2.pa - And it is to be observed, that those on the right correspond with those on the left, that so the fabric may be the same in one place as in the other, and that the walls may equally bear the burden of the roof[63]

4.4.5.pa - The most beautiful and proportional manners of rooms, and which succeed best, are seven.

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[57] Palladio, A., 1965, p.44, plate XXV
[58] Palladio, A., 1965 p. 38 Bk2, Chap 2, par 1
[59] Ibid., Bk1, Chap 21, par 1
[60] Ibid., par 2
[61] Ibid., par 6
[62] Ibid., par 7
[63] Ibid.

Because they are either made round (but seldom) or square, or their length will be the diagonal line of the square, or of a square and a third, or of one square and a half, or of one square and two thirds, or of two squares[64]

4.4.6.1.pa - The most beautiful are in places most exposed to view, and the less comely more hidden[65]

4.4.6.2.pa - Put the principal and considerable parts, in places the most seen, and the less beautiful, in places as much hidden from the eye[66]

4.4.6.3.pa - The lowest part of the fabric, which I make somewhat underground, may be disposed the cellars, the magazines for wood, pantries, kitchens, servants-halls, wash-houses, ovens, and such like things necessary for daily use[67]

4.4.6.4.pa - The apartment above should be free, at a distance from the damp ground[68]

4.4.6.5.pa - Rooms may be great, middle-sized, and small. All near one another, so they may reciprocally be made use of

4.4.7.pa - Small rooms may be divided off, to make closets where studies or libraries may be placed, riding accoutrements and lumber[69]

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[64] Ibid., par 8
[65] Ibid., Bk2, Chap 2, par 1
[66] Ibid.
[67] Ibid.
[68] Ibid.

4.4.8.pa - The small rooms for summer use should be ample, spacious and turned to the north[70]

4.4.9.pa - But those for which we would make use of in spring and autumn, must be turned to the East, and ought to look over greens and gardens. In this particular part, studies and libraries ought also to be[71]

4.4.10.ls - Rooms are placed one next to the other

4.4.11.ls - Rooms are designed without consideration of wall thickness

4.4.12.ls - Halls are square or rectangular rooms. They can be at the entry or along side of another hall.

4.4.13.ls - Large cameres are rectangular rooms off the entry hall with fireplaces

4.4.14.ls - Salas are larger rooms over the entry hall

4.4.15.ls - Small cameres are square or rectangular rooms off of main halls or larger camere.

4.4.16.ls - Rotundas are circular spaces located at the center of the villa with four or eight door openings.

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[69] Ibid., par 2
[70] Ibid., par 3
[71] Ibid., par 4 Here is a bit confusing because it is not specified which rooms are best for the East.

4.4.12.ls - Rooms can be rectangles, squares or circles

4.5 WALLS

Rules for villa walls are not explained in the *Four Books of Architecture*. Most important is that there is no standard size for a villa wall in terms of its thickness, but Palladio does offer an explanation of there construction.[72] He states that the method of construction for any wall should be of cross courses binding the inner to the outer wall.[73] If we look at a surveyed plan of Palladio's villas we will find that wall thickness varies.[74] Wall thickness has been the most confusing and controversial issue amongst Palladian scholars. It determines the true size of a space in contrast to the dimensions offered in Palladio's drawing.

There are different examples of how people have treated this issue of wall thickness. Wittkower ignores the issue, instead choosing to go with the ideal measurements of Palladio's rooms to create perfect floor plan diagrams by single line representation. These plans ignore the fact that Palladio's dimensions do not mathematically add up.[75] In contrast, Stiny/Mitchell grants a generic two-foot thickness to the walls in their villa plans.[76] Bertotti Scamozzi's plans and sections of the built villas demonstrate a variation of thickness from interior walls to exterior walls. Of the built villas, wall thickness varies with each room. Bertotti Scamozzi's survey drawings of the existing conditions provide accurate measurements of room from face of wall to face of wall (Bertotti Scamozzi does not dimension the thickness of the walls). In contrast, his unbuilt villas are granted a generic wall thickness for all walls. As in the case of the unbuilt villa Trissino in Meledo and Mocenigo on the

[72] Palladio, A., p. 7
[73] Ibid.
[74] See Bertotti Scamozzi drawings of built buildings
[75] Wittkower 1952 p. 62 -68

Brenta, he does not vary the thickness to support the weight of the vaulted spaces.[77]

Wall thickness matters when reconstructing the villas. It helps to determine the ceiling type and configure basement wall thickness. Rules for walls at the basement state that the walls are to be twice as thick at the foundation as the piano noble.[78] If we were to ignore the thickness as Wittkower did, the walls would be twice the width of a pencil. If we granted generic sizes as Bertotti Scamozzi had the walls at the basement would be four feet thick all around. Most important, is that the wall thickness does matter when measurements written in *Four Books* are used to reconstruct the plan. The question here is, are the numbers listed on the woodcuts for room sizes, center of wall to center wall, or face of wall to face of the opposing wall? Palladio offers internal dimensions of rooms, but in many cases the sum of the smaller areas do not add up to the size of the adjacent larger space. For example, in the Villa Cornaro, in Piombino Dese, Palladio labels the central space 32 ft. wide by 27-1/2 ft. high (figure 5.29). The smaller adjacent spaces are 16 ft. and ten ft. in width, adding up to 26 ft. and leaving 18 inches for the wall or three bricks thick. In the opposite direction the width of the adjacent space is also 16ft. Half of the large space is 16ft. wide adding up to 32ft. The two smaller spaces below are 26' 6" and 5ft.adding up to 31'-6", which leaves only 6" for a wall or a one brick thick wall.

There are clues leading to the definition of a standard wall thickness for the villas. The key to understanding the system is to understand the Vicentine brick which is 6" x 12" (See 4.1 Measurements). The wall thickness is based on the number of bricks used to support the wall. For example, a 12" thick wall represents two bricks in width, an 18" wall represents three bricks and so on. The thickness is based on lateral forces applied to each wall [W1 or W2]. The greater the force,

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[76] Stiny/Mitchell 1978 p. 5-18

[77] Bertotti Scamozzi, B., 1719-1790 - wall thickness varies in the built villas. The heavier the ceiling the thicker the wall

the thicker the wall (fig. 4.3). Vaults require walls thick enough to carry their weight and the weight of the walls and roof above without buckling. Two vaults pressing on one wall (one on each side of the wall) leads to a wall that is thicker than a wall supporting wooden beams on one side and a small barrel vault on the other. Walls on the interior of a villa typically carry brick vaults in rooms and halls making for walls 24 to 48 inches in thickness (fig. 4.4). Exterior walls typically carry wooden ceilings at outer rooms requiring a thinner wall. From an onsite survey of the Villa Pojana, its wall thickness was found to be greatest at the walls closest to the center of the villa and the thinnest at the ends. The inner walls measured at 24" (4 bricks thick) in width, while the exterior walls at measured in at 18" (3 bricks thick).

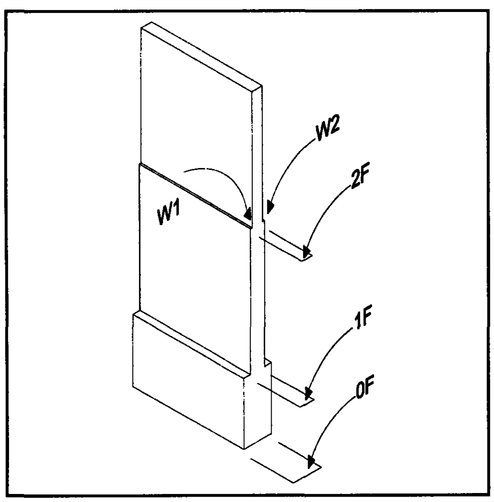

Fig. 4.3 Wall section showing pressure points from vaulted ceilings

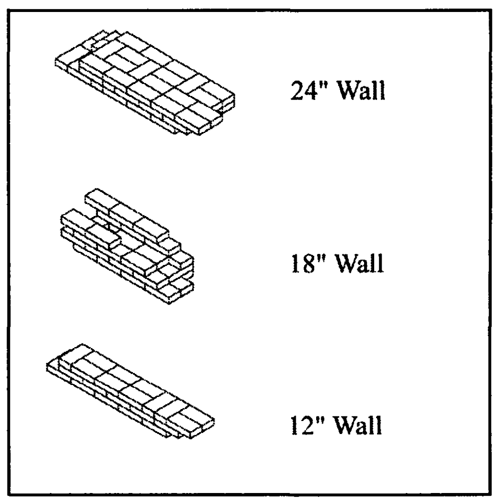

Fig. 4.4 Brick walls based on the number of bricks

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[78] Palladio, A., 1965 Bk1, Chap 8, p. 7

RULES FOR WALL CONSTRUCTION (figures 4.3 - 4.6)

4.5.1.pa - Walls are to be carried directly upright[79]

4.5.2.pa - Walls should diminish in proportion as they rise[80]

4.5.3.pa - Walls at the second story are half a brick thinner than the walls of the first[81]

4.5.4.1pa - The middle of the upper walls ought to fall directly upon the middle of the lower[82]

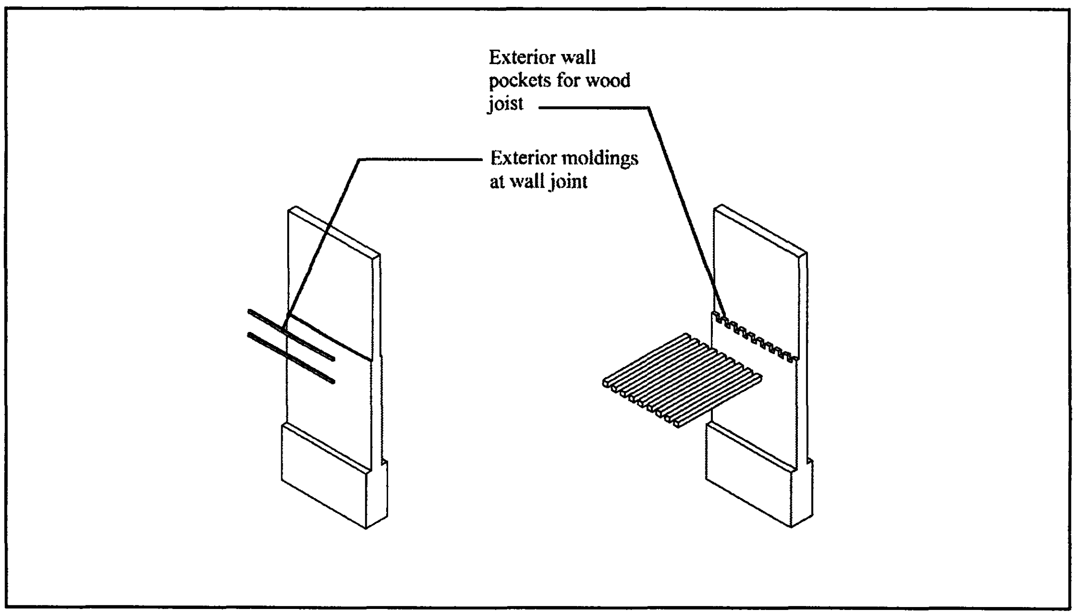

Fig. 4.5 Exterior wall connections - moldings-joist pockets & joist

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[79] Ibid., Chap 1, par 3
[80] Ibid., par 2
[81] Ibid.
[82] Ibid.

4.5.4.2.pa - The middle of the wall above may fall plumb upon the middle of that below[83]

4.5.4.3.pa - But when you are willing to make the surfaces or face of the upper walls to fall directly upon the lower it must be done towards the inside of the building so as to support beams and vaults[84]

4.5.5.pa - The discharged part or set-off, which is on the outside may be covered with a fascia and a cornice[85] (fig. 4.5 & 4.6)

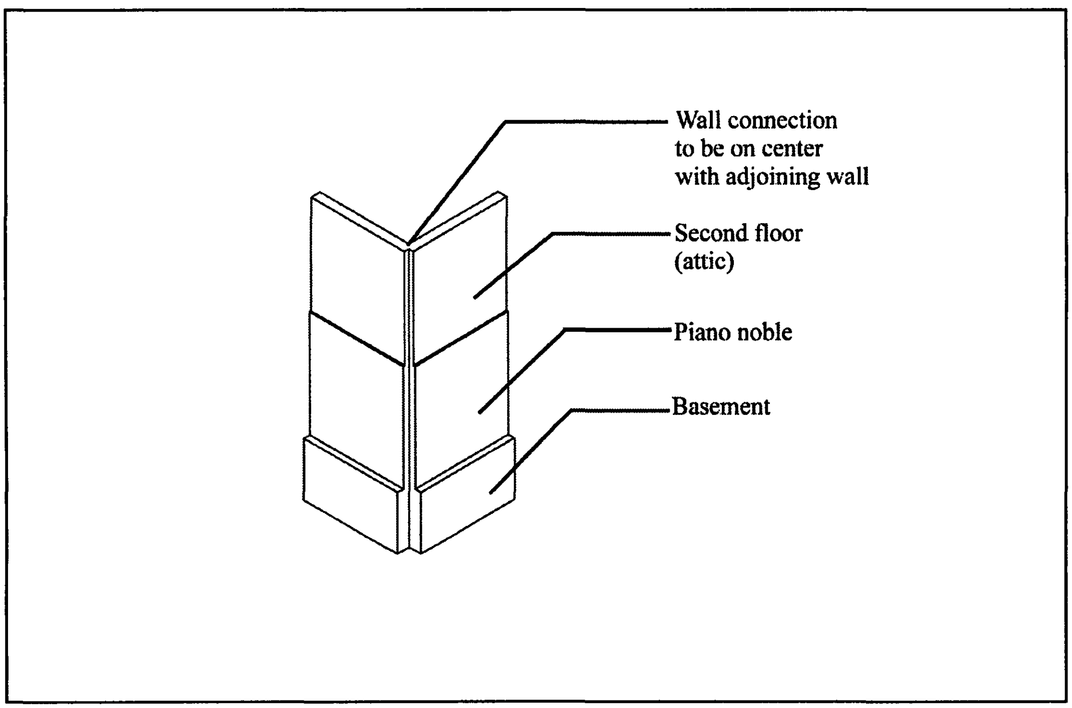

Fig. 4.6 Wall section of adjoining walls - center of wall to center of wall

[83] Ibid., Chap 11, par 1
[84] Ibid., par 1
[85] Ibid., par 2

4.5.6.1pa - Surrounding all the building will be both an ornament and a kind of bond to the whole[86] (fig. 4.5)

4.5.7.pa - Foundations ought to be twice as thick as the wall to be built on them[87]

4.5.8.pa - Foundations must be made sloping that is diminished in proportion as they rise[88]

4.5.9.pa - Foundations must not exceed the sixth part of the height of the whole edifice, if there are no cellars or subterraneous offices wanted[89]

4.5.10.ls - If a wall supports joist on both sides or only one side at the first or second levels it should be 18" thick

4.5.11.ls - If a wall supports a joist on one side and vault on the other or a vault on one side and nothing at the other it is to be 24" thick

4.5.12.ls - If a wall supports a vault on both sides it is to be 24" thick or greater

4.5.13.ls - Walls are measured from center of wall to center of wall (fig. 4.6)

4.5.14.ls - Heights of walls are measured from floor to the floor

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[86] Ibid., par 3
[87] Ibid., Chap 8, par 1
[88] Ibid., par 3

4.5.15.ls - Wall thickness variables (fig. 4.4)

of = thickness of basement floor

1f = Thickness of first floor

2f = thickness of second floor

RULES FOR WALL THICKNESS

if W1 = ceiling & W2 = ceiling 1F = 18"

if W1 = ceiling & W2 = vault 1F = 24"

if W1 = vault & W2 = vault 1F0 = 36"

4.6 CEILINGS

Ceilings refer to the large wooden beam used in rooms and barns. Palladio wrote few rules on the composition of ceilings, noting "There must be a sufficient number of joist to frame the floors of the halls and chambers," and that the spacing should be the width of one and one half of a joist.[90] Ceilings are constructed from bands of square wooden members of no specified width, or depth, spaced at 1-1/2 times their thickness. However, the height of the ceiling specified in *The Four Books of Architecture* is a simple math formula that says that the height of a ceiling is the depth of the space. On many occasions this rule causes conflicts with dimensions on the front elevation drawing. For example, in the Villa Cornaro, the main hall has a ceiling and a room depth of 32ft. Therefore the room should be 32ft in height. The front elevation says that the height of the first floor should be approximately 21ft.

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[89] Ibid., Chap 7, par 4
[90] Ibid., Chap 1, par 6

RULES FOR CEILING CONSTRUCTION

4.6.1.pa - The pavements are usually made either of terrazzo, as is used in Venice, bricks or live stones. Those with terrazzo are are made of pounded bricks, and small gravel, and lime of river pebbles[91]

4.6.2.1.pa - If with a flat ceiling, the height from the floor to ceiling must be equal their breath[92]

4.6.2.2.pa - The rooms above must be a sixth part less in height than those below[93]

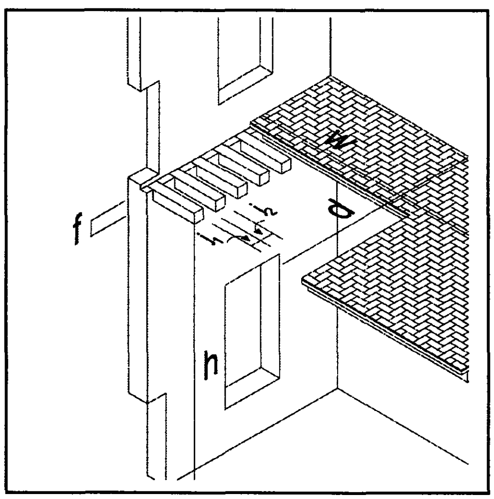

Fig. 4.7 Floor joist with brick flooring above

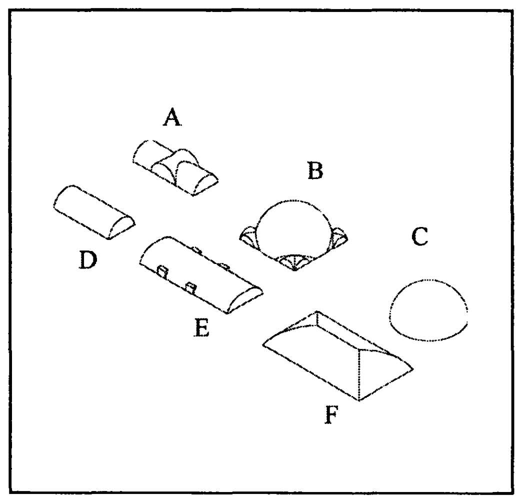

Fig. 4.8 Six vault types

[91] Ibid., Chap 22, par 2
[92] Ibid., Chap 23 par 1
[93] Ibid.

4.6.2.3.pa - Where it is necessary to observed that these beams ought to be distance one from another on thickness and a half of the beam[94]

4.6.3.ls - Ceiling variables (fig. 4.7)

f = thickness of floor and joist

j1 = thickness of joist

j2 = thickness of spacing

w = width of room

d = depth of room

h = height of room (floor to the bottom of ceiling joist)

4.6.4.pa - Determining flat ceiling height [h]:

$$h = d$$

4.6.5.pa - Undefined flat ceiling variables

f j1 j2

[94] Ibid., Chap 22, par 6

4.7 VAULTS

Vaults are masterful creations of brick that transform a simple room into a three-dimensional canvas for frescos framed in plaster moldings. Villa vaults are constructed exclusively of brick and mortar. This section covers the various vault and dome types.[95] Palladio specifies six vault types, each with a different purpose, based on location within the villa and client budget. Of the six vaults presented in *The Four Books of Architecture* it is unclear as to which drawing matches with which description. The six vault types in the text are (fig. 4.8):

A. Cross vault - Loggias, small spaces

B. Lunettes or coves - small spaces

C. Dome - small spaces

D. Barrel vault - central spaces, entry halls, loggias

E. Segmented vault - basements

F. Flat vault - large spaces (mostly found in the sala)

Visual descriptions needed to capture Palladian vaulting and dome styles require information on the thickness of the vault from the underside of the vault, or ceiling to the floor above. Mathematical notations offered in the *Four Books of Architecture* are also necessary. In addition we need to know the width and height of the vault from the face of the floor to the face of the ceiling, and the depth from the vault's spring point to its center.

Palladio provides three methods for finding the heights of the six vaults in the *Four Books of Architecture*. There are two specific problems with these rules. The first is that he does not offer a specific reasoning for why each vault formula should be used. Second, as with the ceilings, the ratio of room's width to length does not always add up to a useful vault height.

Palladio does not offer information on the thickness of vault, the angle of the spring from the wall or thickness of the vault from the underside of the ceiling to the floor of the space above. Vault measurements and rules used in this section were taken from field measurements of the Villa Pojana (fig. 4.9). The Villa Pojana in Maggiore is perfect for studying vaults. It contains five of Palladio's six vault types listed above. Its interior walls at the piano noble follow classic Palladian villa construction, with thicker walls towards the center and thinner walls at the end. The thicker center walls support a barrel vault and a cross vault at the entry portico. Palladio's decision to make the outer walls as thin as he did caused the vaults on the side rooms to push the outer wall away from the building. Tie rods were added to the building in the 19th century to prevent it from collapsing (fig. 4.13). Vault types and the quantity of vaults in a villa were based on a patron's budget. Since they were of brick and stucco they were costly and time consuming.

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[95] Here I am referring to smaller domes found in smaller rooms, not rotundas.

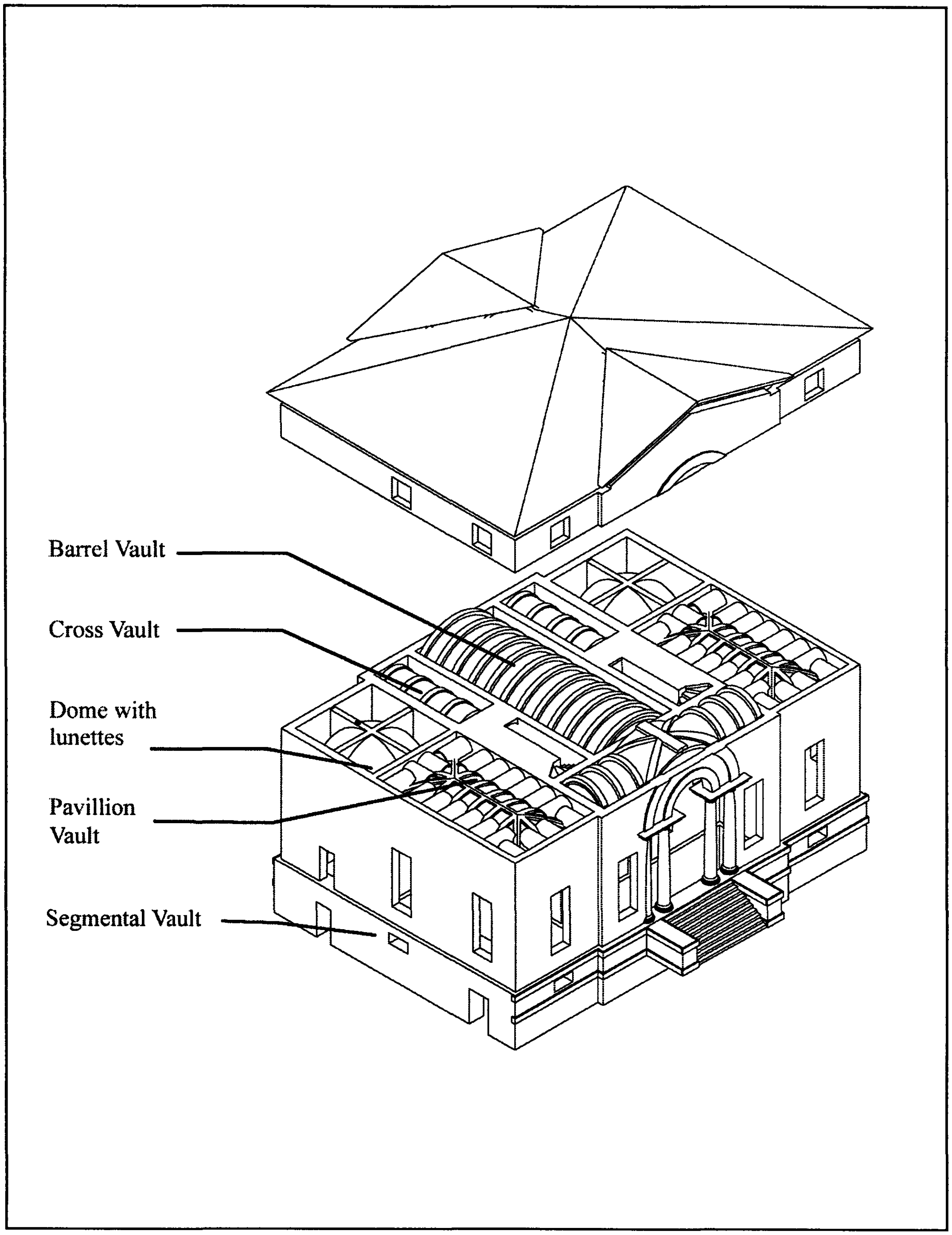

Fig. 4.9 Exposed vaults at the villa Pojana

RULES FOR VAULT HEIGHTS

4.7.1.pa - For rooms that are square the vault is a third part more that the breath of the room[96]

4.7.2.1.pa - But in those which are longer than they are broad, it will be necessary from the length and breadth to seek for the height, that they may bear a proportion to each other[97]

4.7.2.2.pa - This height will be found in adding the breadth to the length, and dividing the whole into two equal parts, because one of those halves will be the height of the vault[98]

4.7.3.1.pa - Another height that would be in proportion both to the length and breadth of the room will also in this manner be found[99]

4.7.3.2.pa - c b, the place to be vaulted, being set down, we'll add the breadth to the length, and make the line b f[100] (see illustration in *Four Books*)

4.7.3.3.pa - Afterwards divide it into two equal parts in the point e, which being made the center[101]

4.7.3.4.pa - Make the half circle b g f, and lengthen a c until it touches the circumference in the point g, and a g will give the height of the vault of c b[102]

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[96] Ibid., Bk2, Chap 23, par 1
[97] Ibid., par 2
[98] Ibid.
[99] Ibid., par 3
[100] Chapter 1, p.28 for diagrams
[101] Ibid.
[102] Ibid.

4.7.4.1.pa - By numbers it will thus be found: The length and breadth of the room in feet being known, we'll find a number that has the same proportion to the breadth as the length has to the number sought[103]

4.7.4.2.pa - This we find by multiplying the lesser extreme with the greater, because the square root of the number that will proceed from the said multiplication, will be the height we seek[104]

4.7.4.3.pa - But it is to be observed that it will not be possible always to find this height in whole numbers[105]

4.7.5.2.pa - Another height may be found that will fall short of this, but nevertheless will be in proportion to the room

4.7.5.1.pa - Draw the lines a b, a c, c d, and b d, that describe the breadth and length of the room, and the height will be found as in the first method[106]

4.7.5.2.pa - Which is c e, this join to a c, then draw the line e d f, and lengthen a b until it touches e d f in the point f, and b f will be the height of the vault[107]

4.7.6.1.pa - The height being found, from the length and breadth of the room, according to the first method (which in a foregoing example was nine) the length, breadth and height must be placed as

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[103] Ibid., par. 4 For example 4 x 9 = 36
[104] Ibid.
[105] Ibid.
[106] Ibid., par 6: See p.28 for diagrams
[107] Ibid. See p.28 for diagrams

they are in the figure[108]

4.7.6.2.pa - Then nine is to be multiplied with twelve and with six, and that which will proceed from twelve is to be placed under the twelve, and the product of six under the six[109]

4.7.6.3.pa - Afterwards the six is to be multiplied with twelve, and the product, which is seventy-two, placed under the nine[110]

4.7.6.2.pa - Then a number being found which multiplied by nine amounts to seventy-two, which in our case would be eight, we'll say eight foot to be the height of the vault[111]

RULES FOR PAVILION VAULTS

A pavilion vault is the most common of the six vault types. Mostly found in the sala or side rooms covered with plaster and frescos it is constructed of a main brick shell, a serious of brick ribs at the vault's edges and a few at points in the middle. A series of smaller empty vaults over the main vault are used at the Villa Poiana in place of solid fill, and serve to support the brick floor above. A formula for finding the vault height says to add the lenght of the room and the width then divide that number by two. The results are for the height of the vault from the face of the floor to the face of the vault. Palladio's formula does not give the depth of the vault from its highest point to its lowest, nor does it provide the thickness of the actual ceiling from face of the vault to the brick floor above (fig. 4.10 - 4.13).

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[108] Ibid., par 7
[109] Ibid.
[110] Ibid.
[111] Ibid.

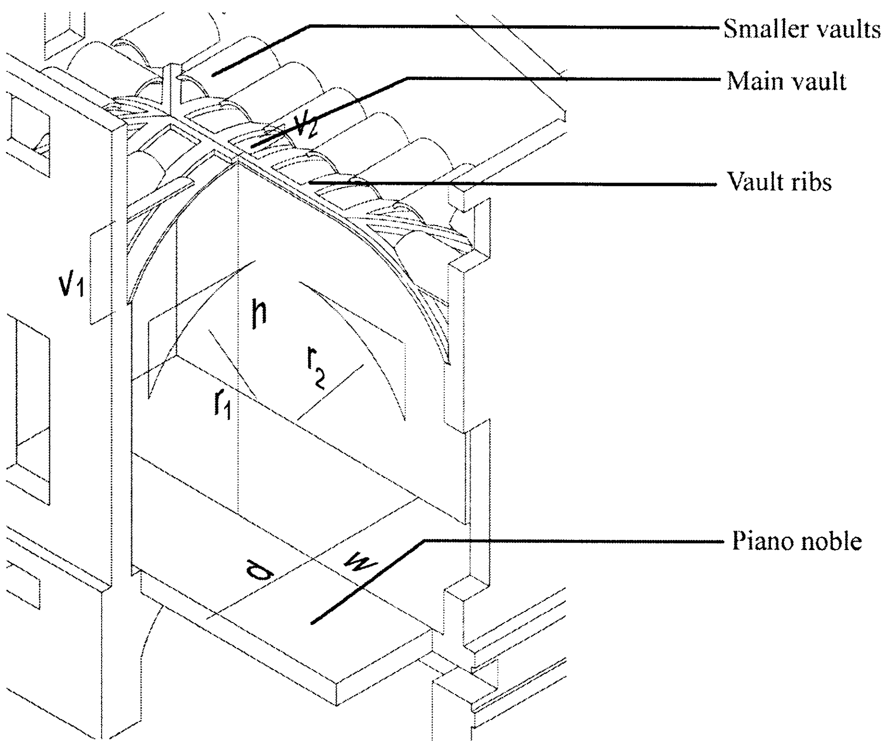

Fig. 4.10 Pavilion vault diagram at the villa Pojana without brick flooring

4.7.7.1.ls Flat Vault variable (fig. 4.10)

v1 = depth of vault

v2 = depth of vault and brick floor above (could be as many as 4 bricks thick)

r1 = radius of dome (width)

r2 = radius of dome (length)

d = depth of room

w = room width

h = height of room (floor to the bottom of vault)

4.7.7.2.ls - Determining flat vault height [h]:

$$\frac{w + d}{2} = h$$

4.7.7.3.ls - Undefined flat vault variables

v1 & v2

r1 & r2

Fig. 4.11 Side room at the piano noble of the Villa Pojana

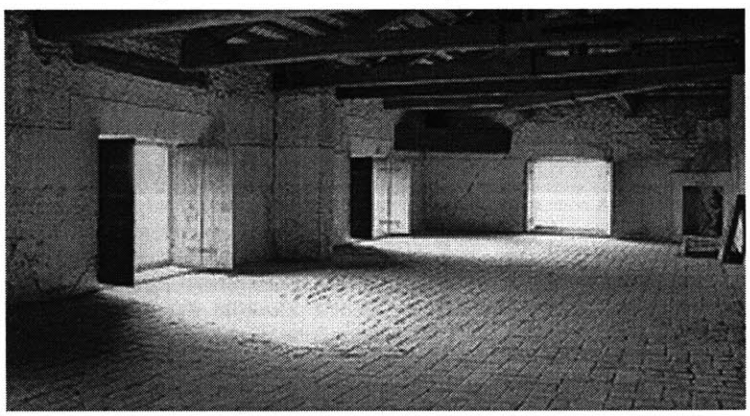

Fig. 4.12 Attic of Pojana above the side room with brick flooring

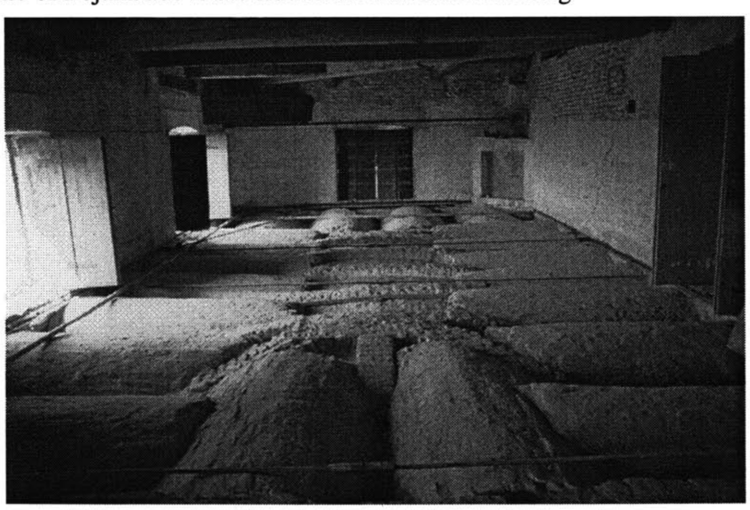

Fig. 4.13 Attic of Pojana above the side room without brick flooring exposing smaller vaults that are empty. Typically fill is placed over these followed by brick

RULES FOR A BARREL VAULT

Barrel vaults are very heavy and most common in halls and central spaces. They are also used in smaller rooms such as mezzanines. Pojana's central space contains a barrel vault. During my field study, the top of the vault was still covered by a brick floor and fill. In spite of this, it is not clear whether or not they have brick supporting ribs as do the flat vaults. It is questionable whether or not it has smaller vaults above the main vault as the flat vault did (fig. 4.14 & 4.15).

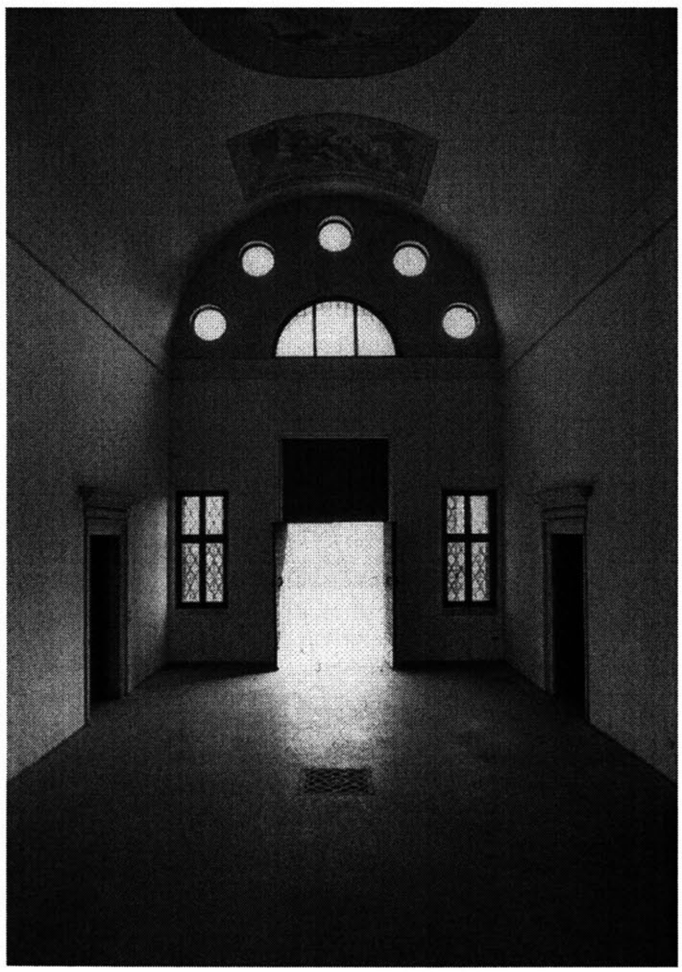

Fig. 4.14 Barrel vaulted central space at the Villa Pojana

4.7.8.1.ls - Barrel vault variables

f = depth of vault from face of vault at the piano noble to face of brick floor above

r = radius of dome (width)

d = depth of room

w = room width

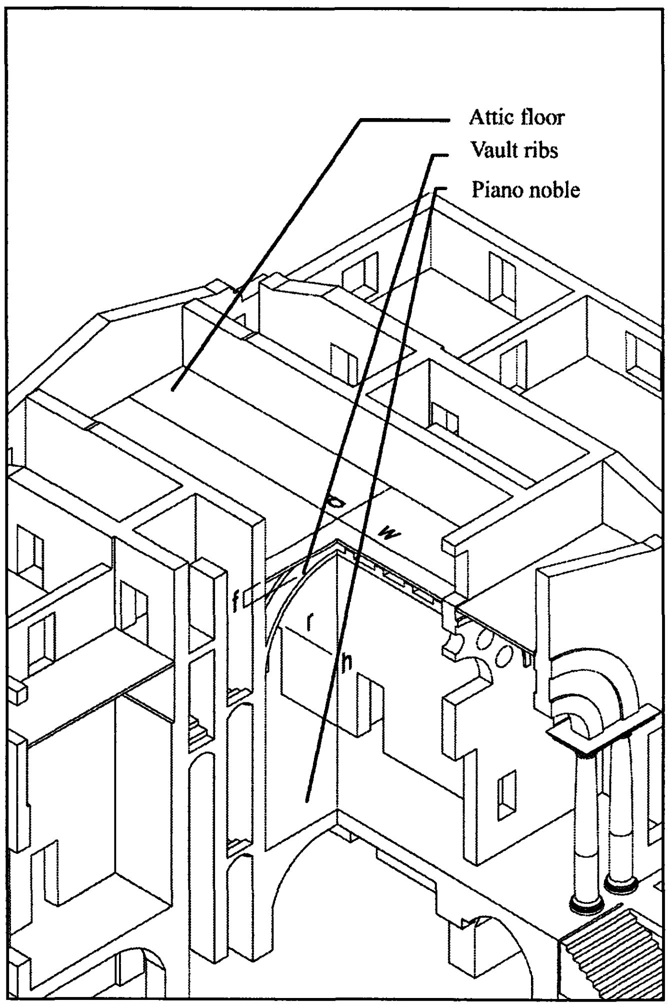

Fig. 4.15 Cross section of barrel vaulted central hall h = height of room (floor to the bottom of vault)

4.7.8.2.ls - Determining barrel vault height [h]:

$$\frac{w + d}{2} = h$$

4.7.8.3.ls - Undefined barrel vault variables

f & r

RULES FOR CROSS VAULTS

Cross vaults are found at the entry to the Villa Pojana and in the first level of the smaller rooms in the back of the building. They are composed of two intersecting barrel vaults, strengthened by ribs (fig. 4.16 & 4.17).

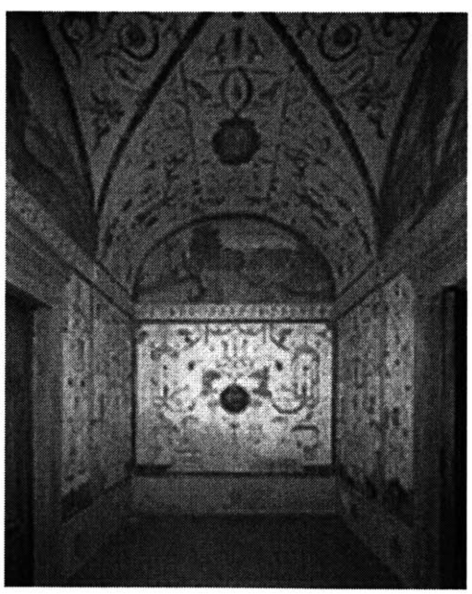

Fig. 4.16 Cross vault in back room of villa Pojana

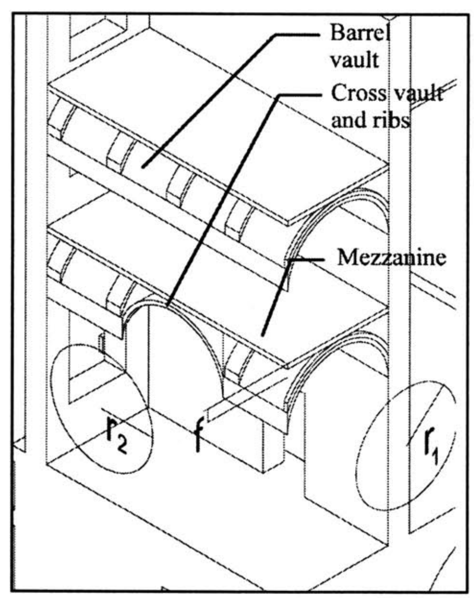

Fig. 4.17 Barrel and cross vault constructions at back rooms

4.7.9.1.ls - Cross vault variables

f = depth of vault from face of vault at the piano noble to face of brick floor above

r1 = first radius of dome (width)

r2 = second radius

d = depth of room

w = room width

h = height of room (floor to the bottom of vault)

4.7.9.2.ls - Determining cross vault height [h]:

$$\frac{w + d}{2} = h$$

4.7.9.3.ls - Undefined cross vault variables

f

r1 & r2

DOMES & COVE VAULT

Two domical vaults are found in the rear half of the Villa Pojana, covering the large square camere. They are constructed of bricks and a supporting brick cross bracing. They do not have smaller vaults over the main vault. There are a series of larger brick braces and fill, covered by a bricks floor. Cove vaults or lunettes are semi-circular niches inserted into the base of the dome (fig. 4.18 - 4.22).

4.7.10.1.ls - Dome variables

f = depth of dome from face of vault at the piano noble to face of brick floor above

v = depth of dome

d = depth of room

h = height of room (floor to the bottom of vault)

4.7.10.2.ls - Determining dome height [h]:

$$\frac{\underline{w + d = h}}{2}$$

4.7.10.3.ls - Undefined dome variables

f & v

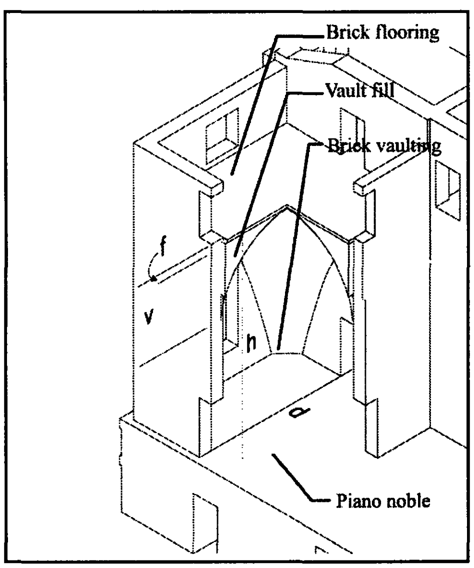

Fig. 4.18 Section through the domical with brick flooring over vault

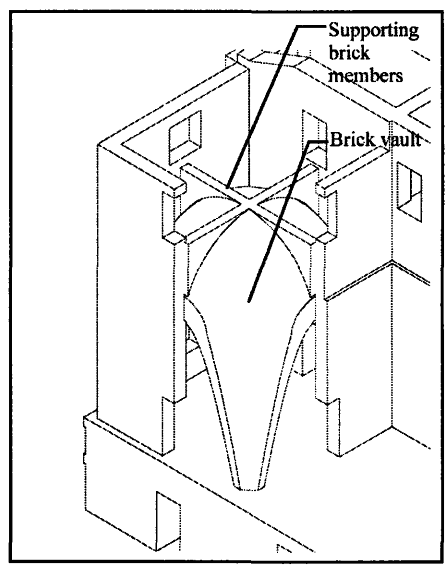

Fig. 4.19 Section through domical vault showing brick support

4.7.11.1.ls - Cove vault variable (fig. 4.21 - 4.23)

f = depth of dome from face of vault at the piano noble to face of brick floor above

v = depth of dome

r1 = radius of dome

r2 = radius of cove

d = depth of room

h = height of room (floor to the bottom of vault)

4.7.11.2.ls - To determining dome height [h]

$$\frac{w + d}{2} = h$$

4.7.11.3.ls - Undefined cove vault variables

f & v

r1 & r2

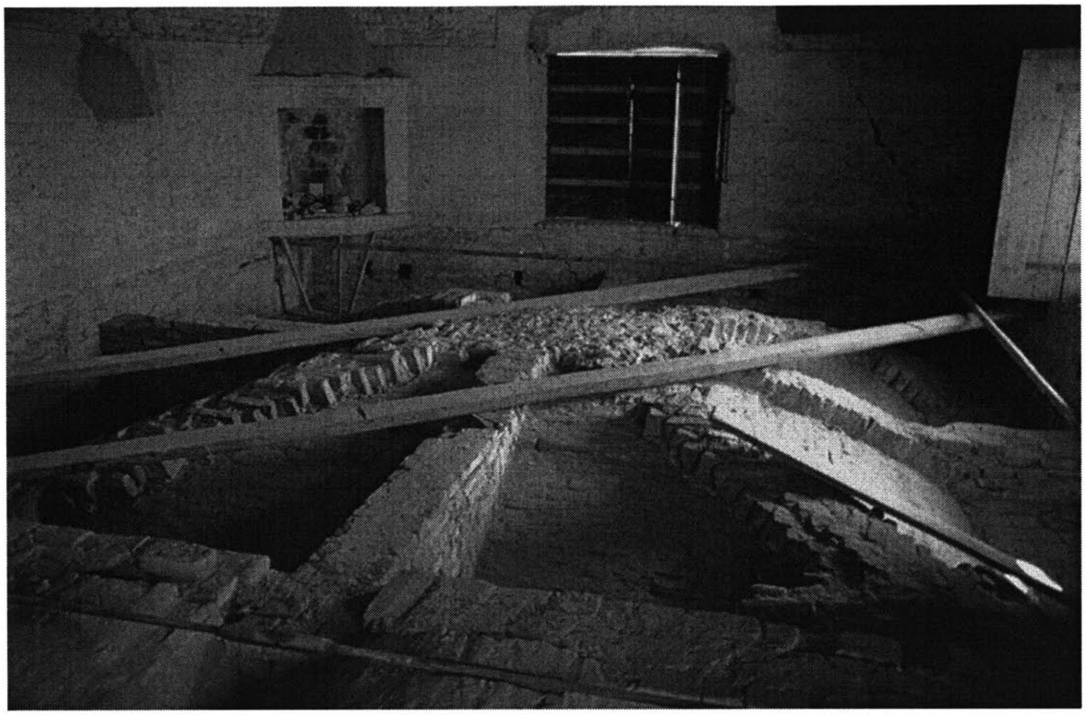

Fig. 4.20 View above dome without brick flooring in back room, with brick bracing over dome

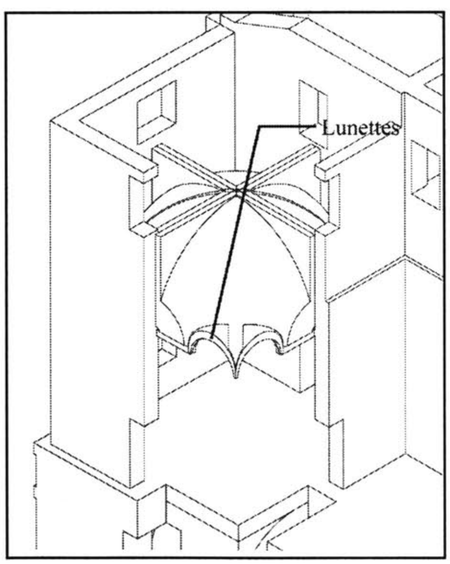

Fig. 4.21 Cross section showing lunette construction

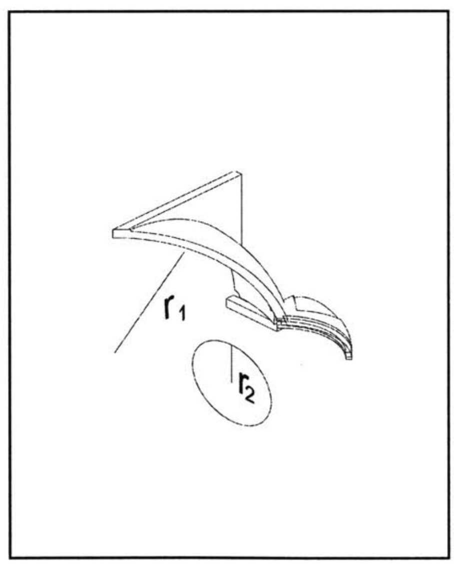

Fig. 4.22 Quarter section of lunette and variables

SEGMENTAL VAULT

Segmental vaults are found in basements broken in certain spots to make openings for windows and doors. There are no rules for this type of vault construction (fig. 4.23 & 4.24).

4.7.12.1.ls - Segmental vault variables

f = depth of vault from face of vault at the piano noble to face of brick floor above

r = radius of vault

d1 = depth of room at the piano noble

d2 = depth of room in basement

4.7.12.2.ls - Undefined segmented vault variables

f & v & r

d1 & d2

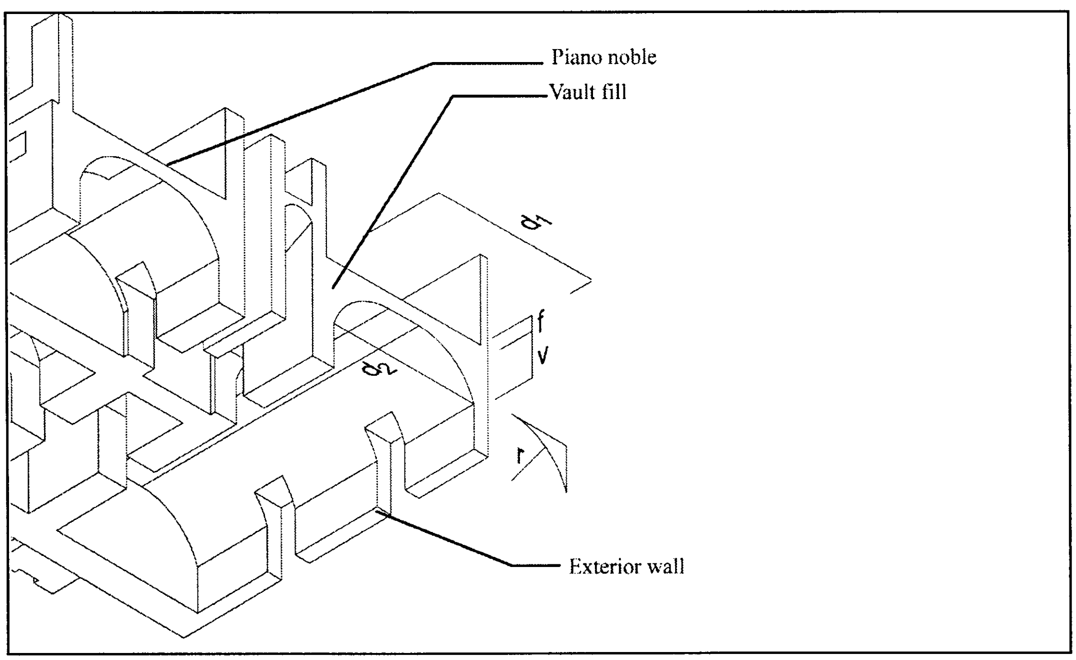

Fig. 4.23 View under segmental vaults at the basement level

Fig. 4.24 Segmental vaults in basement

4.8 STAIRS

Palladio designed eight villa stair types: rectangular, triangular, oval, square, straight parallel, scissors - no wall, scissors with wall and u-shaped. Staircase construction is a system of brick steps over a series of brick arches spanning between two walls (fig. 4.31). Most stair runs measure 3' to 5' in width, the ideal being 4' in order for two people to pass.[112] Palladio writes that steps should not be more than 6"(the width of a brick) in height, nor should the tread be more than 12" in depth (the length of a brick). The built conditions found in the Villas Pojana and Cornaro (fig. 4.30) closely match the drawings and rules found in *The Four Books of Architecture*. Both staircases are constructed of 6" high by 12" (size of one brick) deep steps resting on arches that span between the center dividing wall and the exterior wall of the stair space (fig. 4.29).

RULES FOR STAIRS

4.8.1.pa - Staircases may not obstruct other places, nor be obstructed by them[113]

4.8.2.1.pa - They should be hidden from those that enter the house[114]

4.8.2.2.pa - They should be in a place so that the most beautiful part of the house is seen first[115]

4.8.3.1.pa - Three openings are required in staircases[116]

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[112] Palladio, A 1965 p. 34
[113] Ibid., Bk1, Chap 28, par 1
[114] Ibid., par 2
[115] Ibid.
[116] Ibid.

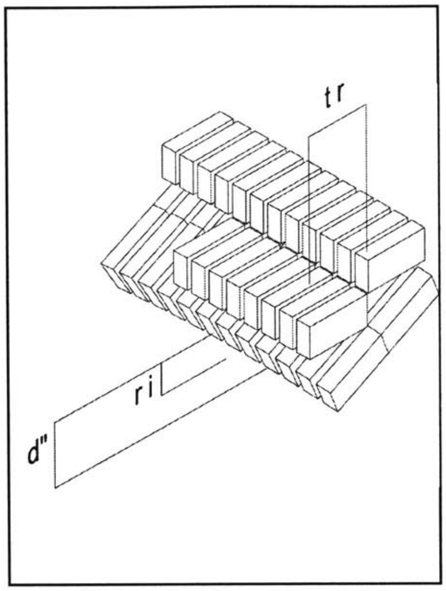

Fig. 4.25 Detail of stair and supporting arch

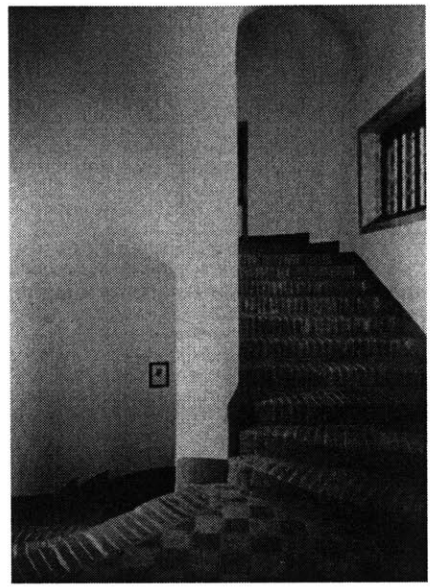

Fig. 4.26 Stairs at the Villa Cornaro - notice the vaulted ceiling supporting stairs above

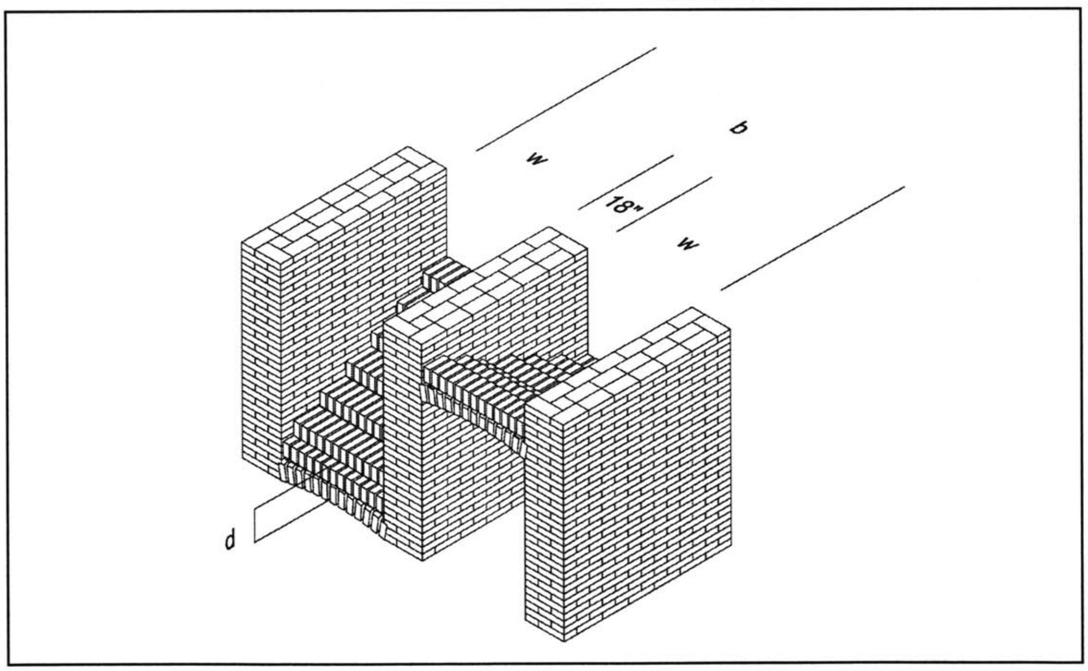

Fig. 4.27 Stair detail showing supporting arches and bracing walls

4.8.3.2.pa - The first is the door through which one goes up to the staircase[117]

4.8.3.3.pa - The second opening is the window that is necessary to give light to the steps, the window should be in the middle, and high, so that the light may be spread equally[118]

4.8.3.4.pa - The third is the opening through which one enters into the floor above[119]

4.8.4.pa - Steps are never to be made less than four foot wide, that if two persons meet, they may conveniently give one another room[120]

4.8.5.pa - Staircase length must be twice its height[121]

4.8.6.1.pa - The steps ought not to be made higher than six inches of a foot[122]

4.8.6.2.pa - They must never be made lower than four inches[123]

4.8.6.3.pa - The breadth of the steps ought not to be made less than one foot, nor more than one and a half[124]

4.8.7.1.pa - Make the steps uneven in number, that beginning to go up with the right foot, one might

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[117] Ibid.
[118] Ibid.
[119] Ibid.
[120] Ibid., par 4
[121] Ibid., par 3
[122] Ibid., par 4
[123] Ibid.

end with the same[125]

4.8.7.2.pa - The number of steps is not to exceed eleven, thirteen at most (6' 6" max)[126]

4.8.8.1.pa - Staircases are either made straight or winding[127]

4.8.8.2.pa - A stair case can be straight are either made to spread into two branches, or square, which turn into four branches[128]

4.8.8.3.pa - To make these, the whole place is to be divided into four parts, two are given to the steps, and two to the void in the middle, from which these stairs would have light if it were left, uncovered[129]

4.8.9.1.pa - The winding staircases are in some places made round, in others oval, sometimes with a column in the middle, and sometimes void, in narrow places particularly[130]

4.8.9.2.pa - Staircases with a void in the middle are better because they can have the light from above[131]

4.8.9.3.pa - Those that have a column in the middle, are made in this manner. The diameter being

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[124] Ibid.
[125] Ibid., par 5
[126] Ibid.
[127] Ibid., par 6
[128] Ibid.
[129] Ibid.
[130] Ibid., par 8

divided into three parts, let two be left to the steps. One given to the column, as in the design or let the diameter be divided into seven parts, and three given to the column in the middle, and four to the steps[132]

4.8.9.4.pa - Those that are void, the diameter must be divided into four parts; two are given to the steps, and two remain for the place in the middle[133]

4.8.10.pa - Oval staircases are also divided in the very same manner as the round[134]

4.8.11.pa - Many other sorts of stair-cases are to be seen in ancient edifices, such as triangular; of this kind are the stairs that lead to the cupola of Santa Maria Rotunda, and are void in the middle, and receive the light from above[135]

4.8.12.1.pa - Stair variables (4.29)

t r = treads

r i = riser

d = depth of riser and brick subsurface

w = width of risers

w1 = riser length (1)

w2 = riser length (2)

k = stair width - Given in drawings

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[131] Ibid.
[132] Ibid.
[133] Ibid.
[134] Ibid., par 10
[135] Ibid., par. 15

l = stair length - Given in drawings

ff = floor to floor height - Given in drawings

Constructing a stair case (fig. 4.25 - 4.29)

4.8.13.ls - Stairs span from wall surface to wall surface

4.8.14.ls - Riser and treads are best when calculated to the size of a brick - 6" riser & 12" tread.

4.8.15.ls - b & ff are Defined in floor plan

4.8.16.ls - (w = b /2 - 18" or w = b/3)

4.8.17.ls - (w1 = 2w - l)

4.8.18.ls - (w2 = 2w - b)

4.8.19.ls - d = r i + 6"

4.8.20.ls - r i = [(w1 x2) + w2] / ff

4.8.21.ls - t r = w1/r I

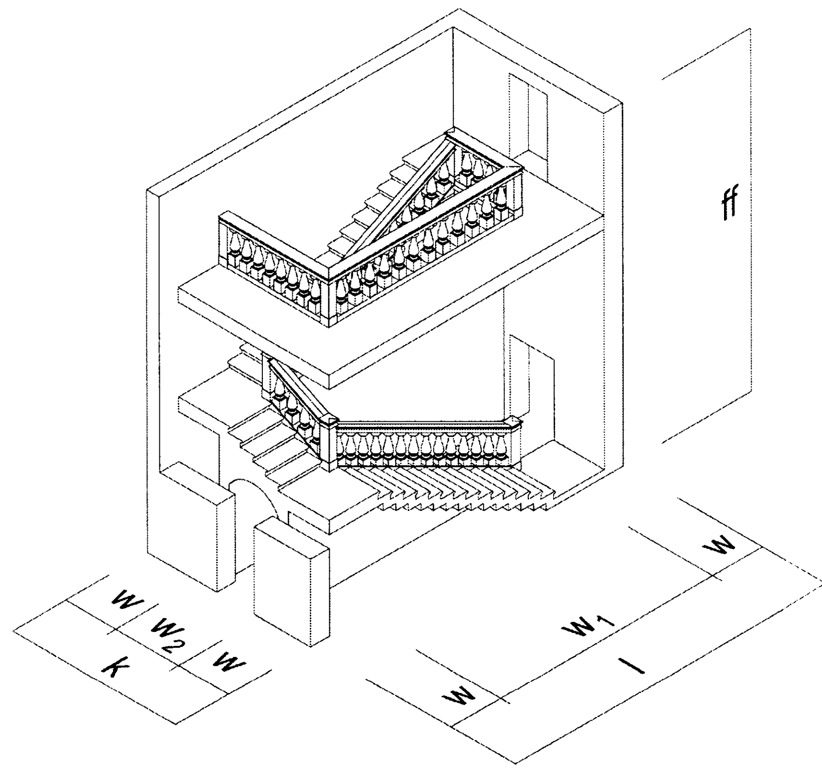

Fig. 4.28 Proposed stair case in the Villa Trissino at Meledo

4.9 COLUMNS AND INTERCOLUMNATION

The design and treatment of the villa portico has been Palladio's greatest triumph. It is also one of Palladio's most complicated design elements, composed of many rules and an endless quantity of detail. Built of steps, columns, pilasters, an entablature and pediment, it marks the villa entry, protecting the patron from all godly elements as he views his crops. In his text Palladio provides rules, shape descriptions and details for making a portico that can accommodate many design types.[136] There is also a description for constructing the shaft, intercolumniation parameters and a detailed description of each of the four column types used in villa construction (Tuscan, Doric, Ionic and Corinthian). Palladio does not mention how the pediment is designed or constructed, nor does he speak of the materials used in each part of the portico construction, such as wedged shaped bricks used for column construction, or of certain types of stones.[137] He discusses the column's proportions and profiles in great depth. In the sections on columns, Palladio describes the columns first, breaking the details into a discussion on entasis on how to calculate column circumference and column capitals and architrave.

Columns hold a place of major importance in all of Palladio's buildings. They serve different functions depending on their location and order. If they were to be stacked one on top of the other, (as if to make a four story building) they would be organized by strength, with Tuscan always at the bottom, and Doric, Ionic and Corinthian at the top. When a freestanding column is needed, the text prescribes that pilasters of the same order should be used as a substitute, and they are commonly used at the ends of porticos.[138]

[136] Type refers to villas, palaces and churches
[137] Burns, H., 1975 p.210

Palladio's discussion on column detail is the most obsessive section in the first book. Palladio begins the chapter on columns by saying that all columns are to be given a swelling in the middle,[139] and, that the midpoint of the column should swell in proportion with its height. He gives two sets of parameters to define the swell. The first is to create a diminishing of the column by making the top of the shaft smaller than the bottom, which is done by dividing the upper and lower parts of the shaft into a certain number of parts. The thickness of the column at the top is decreased by a proportion of the divisions at the bottom. The taller the column, the less the column will diminish. Also the taller the column, the more it creates the appearance of diminishing on its own. So a taller column will not need to diminish as much as a smaller one. The second parameter is to define the profile of the column. This calls for a division of the column shaft into three parts. The swelling begins at the top of the first third and ends under the upper Cibima.

Columns are also constructed in two parts; the shaft and the capital. The shaft of the column is made of brick, and in many cases, of a wedge shaped brick covered in stucco.[140] Capitals are made of finer stones carved by the best masons on site.[141]

The intercolumniation is the spacing of the columns in the loggia described in detail towards the ends in chapter eight of the *Four Books*. This variation in column spacing in terms of its width, is achieved by use of large wooden beams, which serve as the architrave of the entablatured.[142] As can be seen in the Villas Foscari and Badoer, Palladio chose to build the architrave of the entablature of wood, and the frieze and cornice of brick or stone. Stone would if the spacing were too great. Although in many

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138 Burns, H., 1975 p. 226
139 Palladio, A., 1738 p. 12
140 Burns, H., 1975 p. 209,210
141 Ackerman, J., 1965. p. 68

cases buildings such as the Palazzo Chericatti manage to construct architraves, using flat arches. Sizes for the spacing of the columns varies with each building. The wider the space the wider the column, the Tuscan order having the widest spacing, and only to be used for barns with a wooden entablature.

The loggia is not complete without a set of stairs and a pediment over the entablature. The rules for stairs - defined in the previous section-are applied to any arrangement of stairs in the portico. There are no rules for finding the slope of the pediment, or its construction. If we are to follow Palladio's drawings, we see that the pediment typically follows the line of the roof in some but not all cases. This can be seen in the Villas Saraceno, Pisani, Montaganna and Cornaro. There is also the issue of the loggia ceiling, which is based on client budget. It can be formed of wood rafters as found in the Villa Foscari, or of a vaulted ceiling as in the Villa Pojana that are constructed of coffers.

RULES FOR COLUMN PLACEMENT ORDER

4.9.1.1.pa - Place the upper columns directly over those underneath[143]

4.9.1.2.pa - The Doric must always be placed under the Ionic[144]

4.9.1.2.pa - The Ionic must be under the Corinthian[145]

4.9.2.pa - Tuscan is seldom used above ground except in villas where one order only is employed[146]

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[142] Burns 1975. p.227
[143] Palladio, A., 1965 Bk1 chap 12, par 1
[144] Ibid.
[145] Ibid.

4.9.3.pa - The columns in each order ought to be formed in such a manner, that the diameter of the upper part of the column may be smaller than at the bottom, with a kind of a swelling in the middle[147]

4.9.4.pa - The higher the columns, the less they diminish[148]

COLUMN DIAMETER

4.9.5.1pa - If the column be fifteen foot high the thickness at the bottom must be divided into six parts and a half, five and a half of which will be the thickness for the top[149] (fig. 4.29)

4.9.5.2pa - If from fifteen to twenty foot high, divide the diameter at the bottom into seven parts and six and a half will be the diameter above[150]

4.9.5.3pa - The same must also be observed in those from twenty to thirty feet high. The lower diameter must be divided into eight parts and seven given to the upper[151]

RULES FOR COLUMN SWELLING (fig. 4.30)

4.9.6.1.pa - The method I use in making the profile of the swellings is this I divide the first of the column into three equal parts[152]

4.9.6.2.pa - Leave the lower part perpendicular to the side of the extremity of which I apply the edge

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[146] Ibid., par 2
[147] Palladio, A. 1965., Bk1 chap 13, par 1
[148] Ibid., par 2
[149] Ibid.
[150] Ibid.
[151] Ibid.

of a thin rule of the same length or a little longer than the column[153]

4.9.6.3.pa - Bend that part which reaches from the third part upwards until the end touches the point of the diminution of the upper part of the column under the collarino[154]

4.9.6.4 - I then mark as that curve directs which gives the column a kind of swelling in the middle and makes it project very gracefully[155]

4.9.6.5.pa - a, b, the third part of the column, which is left directly perpendicular, (fig. 4.34)

b c, the two thirds that are diminished,

c, the point of diminution under the collarino[156]

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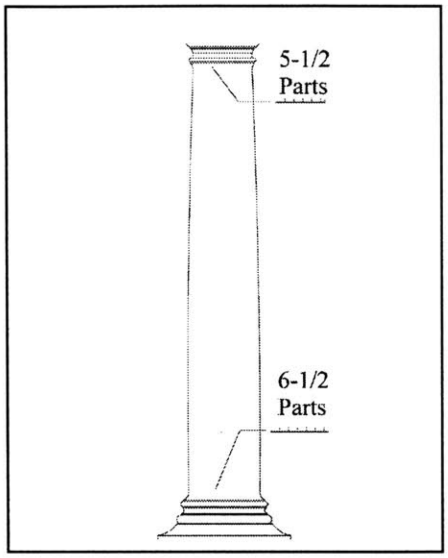
152 Ibid., par 5
153 Ibid.
154 Ibid.
155 Ibid.
156 Ibid.



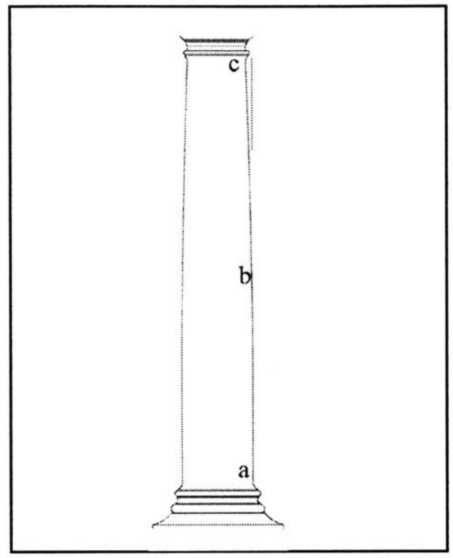


Fig. 4.29 Column detail showing column diameter notations

Fig. 4.30 Column swelling detail

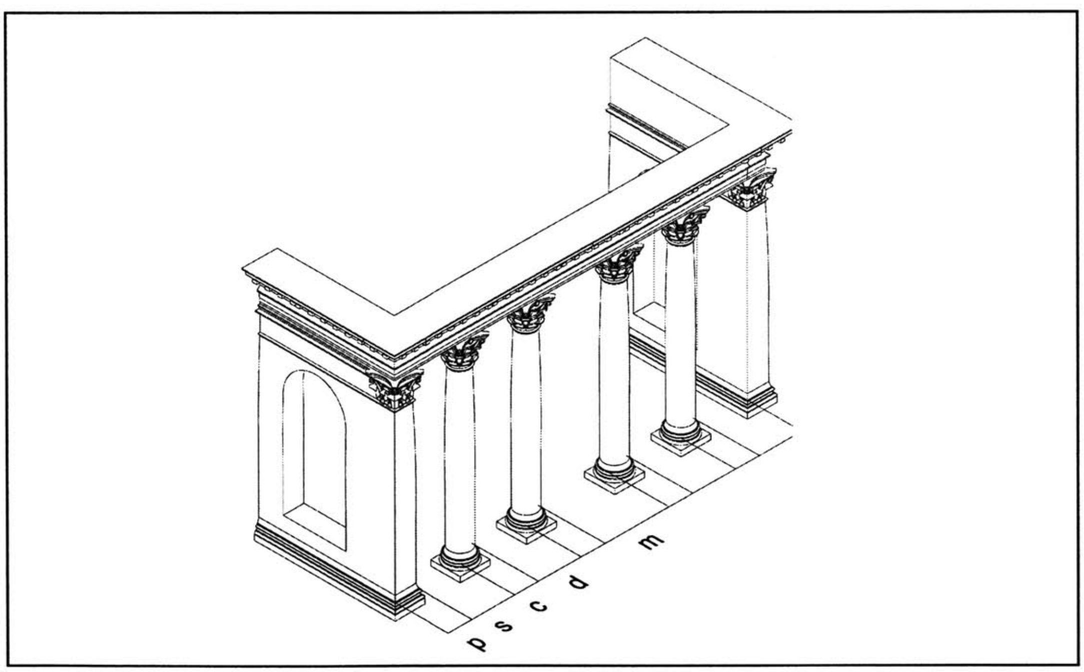


Fig. 4.31 Intercolumniation

RULES FOR INTERCOLUMNIATION (fig. 4.31)

4.9.7.1.pa - The inter-columniations or the spaces between the columns may be of one diameter and a half of the column - the diameter being taken at the lowest part of the column[157]

4.9.7.2.pa - They also may be of two[158]

4.9.7.3.pa - They also may be two and a quarter[159]

4.9.7.4.pa - Three or more diameters[160]

4.9.7.5.pa - The intercolumniation should not be less than one diameter and a half[161]

4.9.8.1.pa - The intercolumniation that was of two diameters and a quarter are fine[162]

4.9.8.2.pa - If the spaces exceed three diameters the thickness of the columns ought to be a seventh part of their height as I have observed in the following Tuscan order[163]

4.9.9.1.pa - If the spaces are three diameters the columns ought to be seven and a half or eight

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[157] Ibid., par 7
[158] Ibid.
[159] Ibid.
[160] Ibid.
[161] Ibid.
[162] Ibid., par 8
[163] Ibid.

diameters high[164]

4.9.9.2.pa - As in the Doric order If two and a quarter the height of the columns must be nine diameters[165]

4.9.9.3 - As in the Ionic, if but two, the height of the columns should be nine diameters and a half as in the Corinthian[166]

4.9.10.1.pa - An even number of columns ought always to be placed in the fronts of edifices[167]

4.9.10.2.pa - An inter-columniation may be made in the middle somewhat larger than the others that the doors and entries usually placed in the middle may be the better seen[168]

RULE FOR PILASTERS

4.9.11.1.pa - If loggia's are made with pilasters, they ought to be to disposed, that the thickness of the pilasters be not less than one third of the void or space between pilaster and pilaster[169]

4.9.11.2.pa - The thickness of those placed in the corners to be two thirds of the said space, that so the corners of the fabric may be both strong and solid[170]

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[164] Ibid., par 9
[165] Ibid.
[166] Ibid.
[167] Ibid., par 10
[168] Ibid.
[169] Ibid., par 11

4.9.12.1.pa - And when they are to sustain an exceeding great weight, as in very large buildings, they ought then to be made as thick as half the void. Otherwise their thickness may be two thirds of the said space[171]

4.9.13.1.pa - In private buildings they must not be less in thickness than the third part of the void, nor more than the two thirds, and ought to be square[172]

4.9.13.2.pa - To lessen the experience, and to make the place to walk in larger, they may be made less thick in the flank than front to adorn. Half columns and pilasters may be placed in the middle; to support the cornice over the arches of the loggias whose thickness must be in proportion to their height, according to each order[173]

RULES FOR MODULE & MINUTES

4.9.14.1.pa - The module shall be the diameter of the column at bottom, divided into sixty minutes[174]

4.9.14.2.pa - Except in the Doric order where the module is but half the diameter of the column divided into thirty minutes[175]

4.9.15.ls - Loggia variables (fig. 4.35)

p = thickness of pilaster

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[170] Ibid.
[171] Ibid., par 12
[172] Ibid., par 13
[173] Ibid.
[174] Ibid., par 15
[175] Ibid.

s = spacing between pilaster and column

c = module size

m = entry spacing

d = space at column

4.9.16.ls - Determining pilaster sizes

$s/3 < p < 2(s/3)$

4.9.17.ls - Undefined loggia variables

x, s & m

4.10 TUSCAN ORDER

With an architrave constructed of wood, the Tuscan order is the least ornate of the four orders used in villa construction.[176] The wooden entablature allows for great spans for equipment and animals to pass. Sometimes confused with the Doric order, the Tuscan is considered the strongest and least decorative of the orders. The Tuscan order is typically used in the barns or other utility like spaces (fig. 4.32 -4.33). The order is never used at the portico.

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[176] Ackerman, J., 1983, p. 15

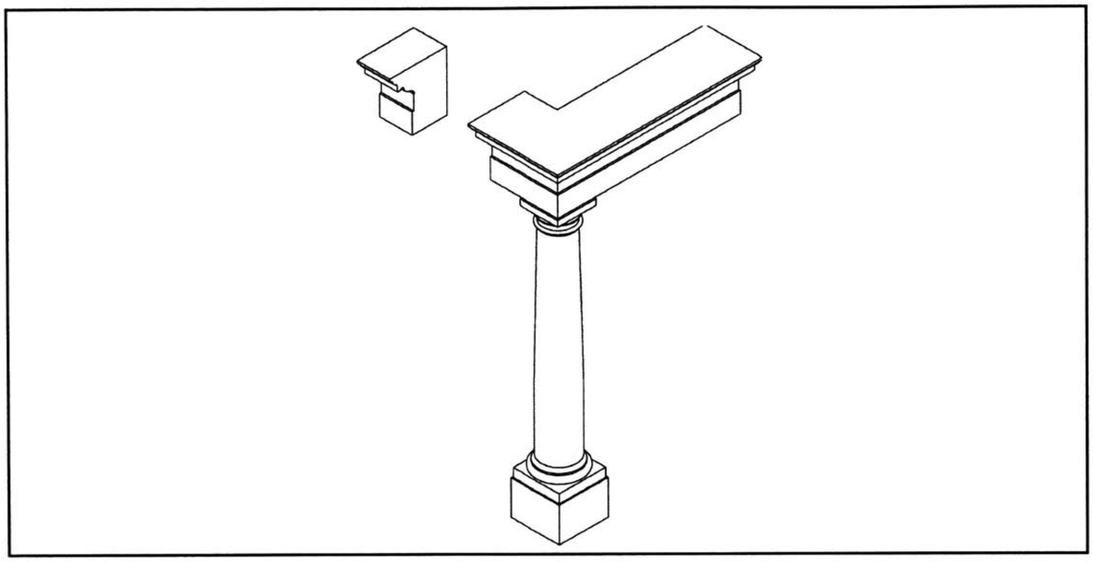

Fig. 4.32 Tuscan column and architrave profile

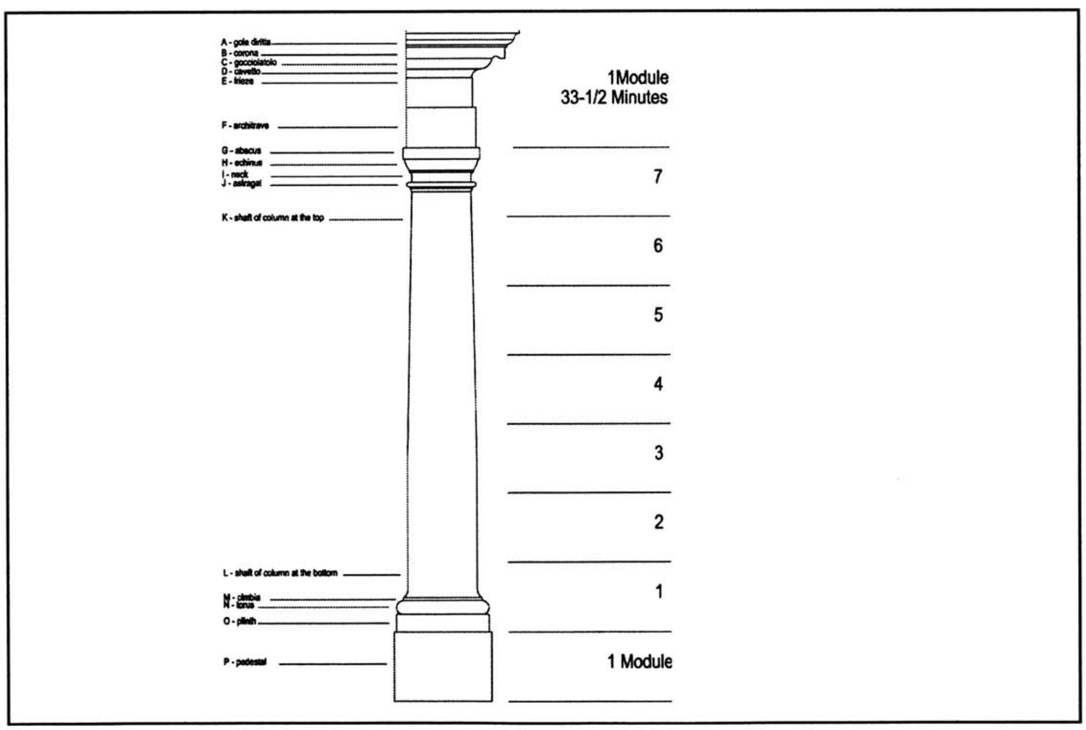

Fig. 4.33 Tuscan column elevation

RULES OF FOR THE TUSCAN ORDER

4.10.1.pa - Tuscan columns with their base and capital ought to be seven modules in height and to be diminished at top a fourth part of their thickness[177]

4.10.2.pa - If a simple colonnade is made of this order the spaces or inter-columniations may be very wide[178]

TUSCAN PEDESTALS

4.10.3.1.pa - The pedestals placed under the columns of this order are to be made plain one module in height[179]

RULES FOR A TUSCAN COLUMN BASE

4.10.3.2.pa - The height of the base is half the diameter of the column[180]

4.10.3.3 - This height is to be divided into two equal parts[181]

4.10.3.4 - One to be given to the plinth, which is made with a compass and the other, is divided into four parts[182]

4.10.3.4.pa - One to be given to the fillet also called the cimbia, which may sometimes be made less

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[177] Palladio, A., 1965, Bk2, Chap. 14, par 3
[178] Ibid., par. 4
[179] Ibid., par 6
[180] Ibid.
[181] Ibid.
[182] Ibid.

and in this order only is part of the base that in all the other is part of the column[183]

4.10.3.5.pa - The other three parts are for the torus or bastone[184]

4.10.3.6.pa - The projection of this base is the sixth part of the diameter of the column[185]

RULES FOR TUSCAN CAPITALS

4.10.4.1.pa - The height of the capital is half the diameter of the lower part of the column, and is divided into three equal parts[186]

4.10.4.2.pa - One is given to the abaco (which from its form is usually called the dado)[187].

4.10.4.2.pa - The second to the ovolo[188]

4.10.04.3 - The third is divided into seven parts[189]

4.10.4.4.pa - Of one the fillet under the ovolo is made, and the remaining six is for the collarinos[190]

4.10.4.5.pa - The height of the astragal is double that of the listello or fillet under the listello and its

[183] Ibid.
[184] Ibid.
[185] Ibid.
[186]Ibid., par 7
[187] Ibid.
[188] Ibid.
[189] Ibid.

center is made upon the line that falls perpendicularly upon the said listello upon which also falls the projection of the cimbia which is as thick as the listello[191]

4.10.5.1.pa - The projection of this capital answers to the shaft of the column below[192]

4.10.5.2.pa - The architrave is made of wood, equal in height as in width, and not to exceed in width the shaft of the column at top[193]

4.10.5.3.pa - The projection of the joists that form the gronda or drip, is a fourth part of the length of the column[194]

RULES FOR USE OF THE TUSCAN ORDER

4.10.6.ls - The Tuscan order is to be used at the barns only

4.11 DORIC ORDER

Vitruvious writes that the Doric order derived its form from timber construction.[195] Complete with a detailed entablature and pedestal, the Doric order is the only order of the four, whose shaft is two modules thick. The order is sometimes used in barns but mostly used as the first order when two or more orders are stacked on top of one another. For example the Villa Pisani Montaganna, which is made up of two orders, uses the Doric order at its base and the Ionic above that. This order is not used above the first floor of any Palladian building (fig. 4.34 - 4.35).

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[190] Ibid.
[191] Ibid.
[192] Ibid., par 8
[193] Ibid.
[194] Ibid.

GENERAL RULES

4.11.1.1.pa - If the columns of this order are made alone, and without pilasters, they ought to be seven diameters and a half or eight in height[196]

4.11.1.2.pa - The inter-columniations are something less than three diameters of the column[197]

4.11.2.1.pa - But when they are supported with pilasters, their height ought to be seventeen modules and one third, including the base and capital[198]

4.11.2.2.pa - The diameter of the column divided into thirty minutes, and in all the other orders it is the whole diameter divided into sixty minutes[199]

4.11.3.1.pa - No pedestal is to be seen in ancient buildings to this order, although there are in the modern[200]

4.11.3.2.pa - Therefore when a pedestal is required, the dado ought to be made square, from which the measures of all its ornaments must be taken. Because it is to be divided into four equal parts, two of them shall be for the base with its zocco or plinth, and one for the cimacia, to which the orlo of the base must be joined[201]

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[195] Adams, R., 1990 p. 70
[196] Palladio, A., 1965 Bk2 Chap. 15, par. 1
[197] Ibid.
[198] Ibid., par 2
[199] Ibid.
[200] Ibid., par. 3
[201] Ibid.

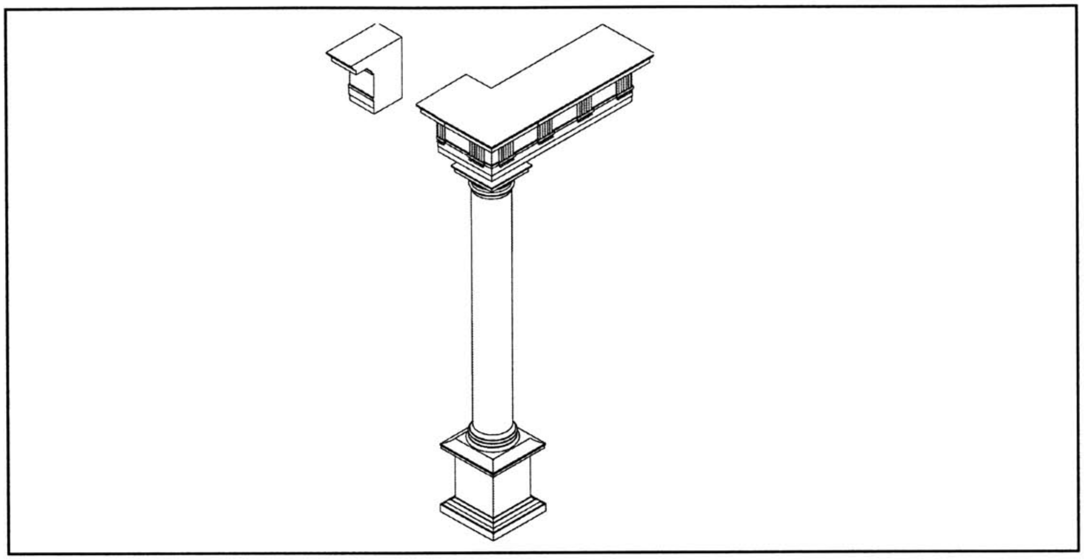

Fig. 4.34 Doric column and architrave profile

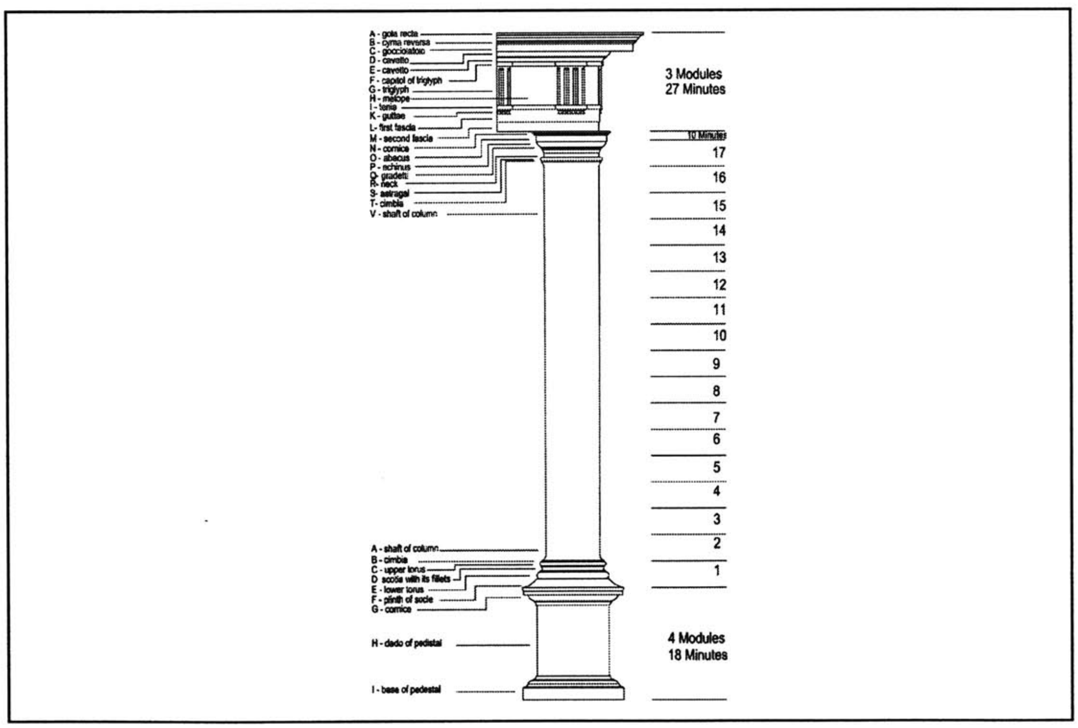

Fig. 4.35 Doric column elevation

RULES FOR DORIC COLUMNS

4.11.4.1.pa - But the attic base is sometimes joined to it, which adds to its beauty; and the measures are thus[202]

4.11.4.2.pa - The height must be half the diameter of the column, which is to be divided into three equal parts[203]

4.11.4.3.pa - One goes to the plinth or zocco, the other two are divided into four parts[204]

4.11.4.4.pa - One of which is for the upper bastone; the remaining three are again divided into two equal parts[205]

4.11.4.5.pa - One of which is for the lower torus, the other to the cavetto with its listello's[206]

4.11.4.6.pa - Therefore must be divided into six parts, the first for the upper listello, the second for the lower, and four remain for the cavetto[207]

4.11.5.1.pa - The projection is the sixth part of the diameter of the column[208]

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[202] Ibid., par 6
[203] Ibid.
[204] Ibid.
[205] Ibid.
[206] Ibid.
[207] Ibid.
[208] Ibid., par 7

4.11.5.2.pa - The cimbia is half the upper torus[209]

4.11.5.3.pa - If it is divided from the base, its projection is one-third part of the whole projection of the base[210]

4.11.5.4.pa - but if the base and part of the column make one entire piece, the cimbia must be made thin: As may be seen in the third design of this order, where there are also two different sorts of imposts of arches[211]

RULES FOR DORIC CAPITALS

4.11.6.1.pa - The capital ought to be in height half the diameter of the column, and is to be divided into three parts[212]

4.11.6.2.pa - The upper part is given to the abaco and cimacio[213]

4.11.6.3.pa. - The cimacio is two of the five parts thereof, which must be divided into three parts, with the one the listello is made, and with the other two the gola

4.11.6.4.pa - The second principal part is divided into three equal parts[214]

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[209] Ibid.
[210] Ibid.
[211] Ibid.
[212] Ibid., par 8
[213] Ibid.
[214] Ibid.

4.11.6.5.pa. - One to be given to the annelli or annulets, or gradetti, which three are equal[215]

4.11.6.6.pa - The other two remain for the ovolo, which projects two thirds of its height[216]

4.11.6.7.pa - The third part is for the collarino[217]

4.11.7.1.pa - The whole projection is the fifth part of the diameter of the column[218]

4.11.7.2.pa - The astragal or tondino is as high as all the three annelli, and projects equal to the lower part of the shaft of the column[219]

4.11.7.3.pa - The cimbia is half the height of the astragal or tondino, and its projection is directly plumb with the center of the said astragal[220]

RULES FOR THE DORIC ARCHITRAVE

4.11.8.1.pa - The architrave is placed upon the capital, the height of which must be half the diameter of the column, that is, a module. It is divided into seven parts[221]

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[215] Ibid.
[216] Ibid.
[217] Ibid.
[218] Ibid., par 9
[219] Ibid.
[220] Ibid.
[221] Ibid., par 10

4.11.8.2.pa - With one the tenia or benda is made, whose projection must be equal to its height[222]

4.11.8.3.pa - Then the whole is again divided into six parts[223]

4.11.8.4.pa - One is given to the goccie, which ought to be six, and to the listello under the tenia, which is a third part of the said goccie[224]

4.11.9.1.pa - From the tenia down wards the remainder is again divided into seven parts[225]

4.11.8.2.pa - Three are to be given to the first fascia, and four to the second[226]

4.11.8.3.pa - The frieze is a module and a half in height[227]

4.11.8.4.pa - The breadth of the triglyph is one module, and its capital the sixth part of a module[228]

4.11.8.5.pa - The triglyph is to be divided into six parts[229]

4.11.8.6.pa - two of which are for the two channels in the middle, one for the two half channels at the

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[222] Ibid.
[223] Ibid.
[224] Ibid.
[225] Ibid., par 11
[226] Ibid.
[227] Ibid.
[228] Ibid.
[229] Ibid.

ends and the other three for the spaces between the said channels[230]

4.11.9.1.pa - The metopa, or space between triglyph and triglyph, ought to be as broad as it is high[231]

4.11.9.2.pa - The cornice must be a module and one sixth in height, and divided into five parts and a half, two of which are given to the cavetto and ovolo[232]

4.11.9.3.pa - The cavetto is less than the ovolo by the width of its listello[233]

4.11.09.4.pa - The remaining three parts and a half are to be given to the corona or cornice, which is vulgarly called gocciolatoio, and to the gola or cima recta and reversa[234]

4.11.10.1.pa - The corona ought to project four parts in six of the module, and have on its soffit, that looks downwards, and projects forward, six drops, or guttoe, in length, and three in breadth, with their listelli over the triglyphs, and some roses over the metope[235]

4.11.10.2.pa - The gutter are round, shaped like bells, and answer to those under the tenia[236]

4.11.11.1.pa - The gola must be an eighth part thicker than the corona, and divided into eight parts[237]

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[230] Ibid.
[231] Ibid., par 12
[232] Ibid.
[233] Ibid.
[234] Ibid.
[235] Ibid., par 13
[236] Ibid.

4.11.11.2.pa - Two are to be given to the orlo, and six remain for the gola, whose projection is seven parts and a half[238]

4.11.12.3.pa - Therefore the height of the architrave, frieze and cornice is a fourth part of the altitude of the column[239]

4.12 IONIC ORDER

It would take hundreds of rules to create a description for the Ionic order. Its is a slenderer column, than the Doric, with a capital and a set of attached horns known as volutes. Palladio explains this as best as he can in the text, but the text description does not reflect the level of complexity in his drawings. The base of the shaft is one module in diameter, and when used within the intercolumniation it comes with a square base. The shape of the spiral is not a true spiral nor is the volute a true horn shape. The volutes will not be described in detail here (fig. 4.36 - 4.37).

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[237] Ibid., par 14
[238] Ibid.
[239] Ibid.

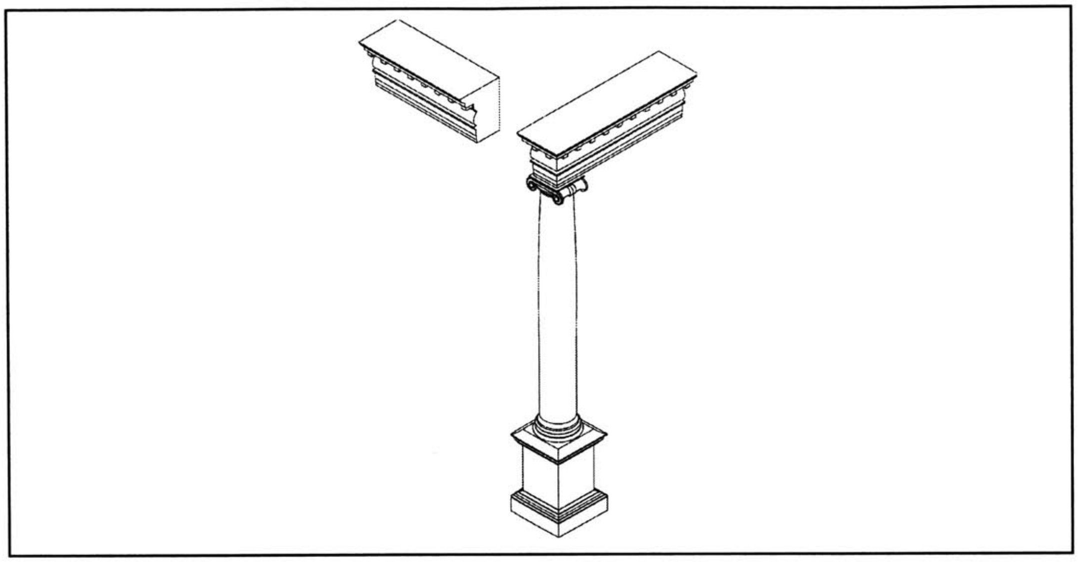

Fig. 4.36 Ionic column and architrave profile

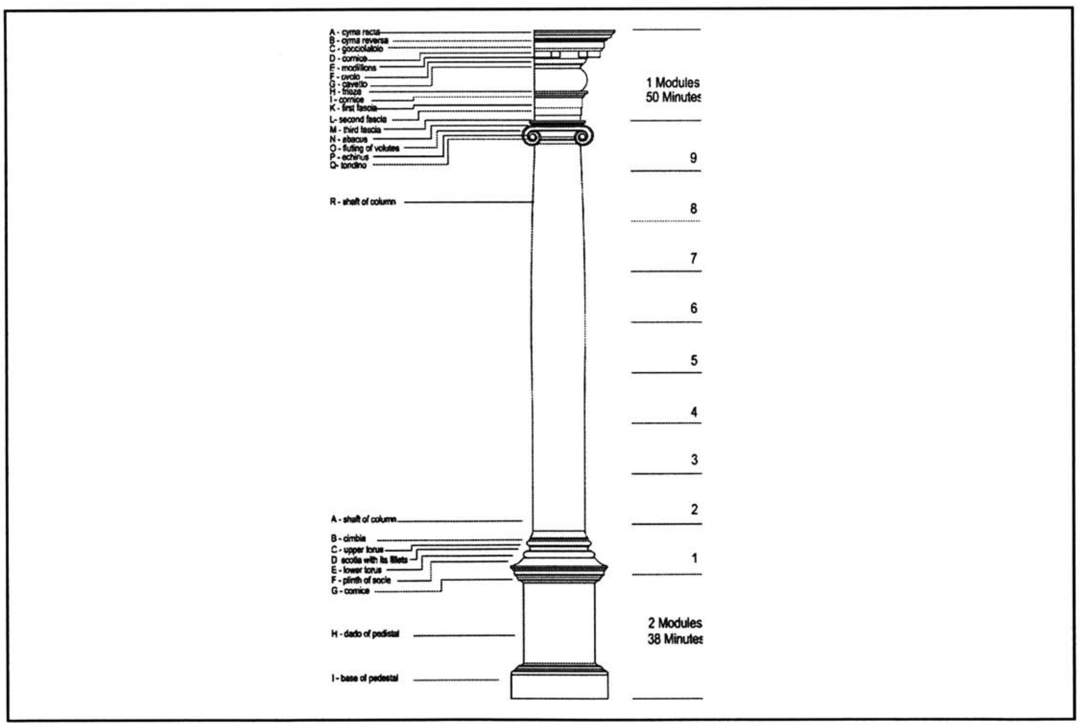

Fig. 4.37 Ionic column elevation

GENERAL RULES

4.12.1.pa - The columns, with the capital and base, are nine modules high[240]

4.12.2.pa - The architrave, frieze, and cornice are a fifth part of the altitude of the column[241]

4.12.2.pa - In the designs of simple colonnades, the inter-columniations are of two diameters and a quarter, in the design of arches the pilasters are a third part of the void, and the arches are two squares high[242]

4.12.3.pa - If a pedestal is to be put to Ionic columns, as in the design of arches, it must be made as high as half the width of the arch. And divided into seven parts and a half; two of which are for the base, one for the cimacia, and the remaining four and a half for the dado that is the middle plain[243]

4.12.4.1.pa - The base of the Ionic order must be half a module in thickness, and divided into three parts[244]

4.12.4.2.pa - One to be given to the plinth whose projection is the fourth and eighth part of the module[245]

4.12.403.pa - The other two are divided into seven parts, three of which are for the bastone or

[240] Palladio, A., 1965 Bk1, Chap 16, par 1
[241] Ibid. par 2
[242] Ibid.
[243] Ibid., par 3
[244] Ibid., par 4
[245] Ibid.

torus[246]

4.12.4.4.pa - The other four are again divided into two, of one is made the upper cavetto, and with the other the lower, which must project more than the other[247]

4.12.5.1.pa - The astragal must be the eight part of the cavetto[248]

4.12.5.2.pa - The cimbia of the column is the third part of the bastone or torus of the base[249]

4.12.5.3.pa - But if the base is joined with part of the column, then the cimbia must be made thinner, as I have said in the Doric order[250]

4.12.6.1.pa - Attic bases are seen placed under the columns of this order. I have drawn the said base upon the pedestal, with a little torus under the cimbia[251]

4.12.6.1.pa - The designs marked L are two different profiles, to make the imposts of arches, the dimensions of each of which are marked in numbers, showing the minutes of the module, as it has been observed in all the other designs. These imposts are half as high again as the pilaster is thick, which supports the arch[252]

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[246] Ibid.
[247] Ibid.
[248] Ibid., par 5
[249] Ibid.
[250] Ibid.
[251] Ibid., par 6

RULES FOR IONIC CAPITALS

4.12.07.1.pa - To form the capital, the foot of the column must be divided into eighteen parts, and nineteen of these parts is the height and width of the abaco, half thereof is the height of the capital with the volute, which is therefore nine parts and a half high[253]

4.12.07.2.pa - One part and half must be given to the abaco with its cimacio, the other eight remain for the volute, which is thus made[254]

4.12.08.1.pa - One of the nineteen parts is to be allowed from the extremity to the inside of the cimacio, and from that place where the point was made, a line must fall perpendicular, which divides the voluta in the middle, called catheto[255]

4.12.08.2.pa - And where the point is upon the line which separates the superior four parts and a half from the interior three and a half, the centre of the eye of the voluta must be made, whose diameter is one of the eight parts[256]

4.12.08.3.pa - And from the said point a line must be drawn, which intersecting with the catheto at rectangles, divides the voluta into four parts[257]

4.12.09.1.pa - Then a square ought to be formed in the eye of the voluta, half the diameter of the said

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[252] Ibid., par 7
[253] Ibid., par 8
[254] Ibid.
[255] Ibid., par. 9
[256] Ibid.
[257] Ibid.

eye in bigness, and diagonal lines drawn[258]

4.12.09.2.pa - Upon which lines the points are marked whereon the fixed foot of the compasses must be placed in forming the voluta[259]

4.12.09.3.pa - These are thirteen in number, including the center of the eye of the said voluta. The order that ought to be observed in them will plainly appear by the numbers placed in the design[260]

4.12.10.1.pa - The astragal of the column is in a direct line with the eye of the voluta[261]

4.12.10.2.pa - The thickness of the voluta in the middle must be equal to the projection of the ovolo, which projects beyond the abaco just as much as the eye of the voluta

4.12.10.3.pa - The channel of the voluta is even with the shaft of the column[262]

4.12.11.1.pa - The astragal of the column goes quite round under the voluta, and is always seen, as appears by the plan[263]

4.12.11.2.pa - For it is natural, that a thing so tender as the voluta is supposed to be, should give way

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[258] Ibid., par 11
[259] Ibid.
[260] Ibid.
[261] Ibid., para.12
[262] Ibid.
[263] Ibid., par. 13

to a hard one, such as the astragal, from which it must always be equally distant[264]

4.12.12.pa - Capitals are generally made in the angles of colonnades and porticos of this order. With volute not only in front, but also in that part which would be the flank; by which means they have the fronts on two sides, and are called angular capitals[265]

RULES FOR THE IONIC ARCHITRAVE

4.12.13.pa - The architrave, frieze and cornice are, as I have said, a fifth part of the height of the column, the whole to be divided into twelve parts, of which the architrave is four parts, the frieze three, and the cornice five[266]

4.12.14.1.pa - The architrave is to be divided into five parts[267]

4.12.14.2.pa - Of one its cimacio is made, and the remaining four divided into twelve parts, three of which are given to the first fascia and its astragal[268]

4.12.14.3.pa - Four to the second and its astragal, and five to the third[269]

RULE FOR THE IONIC CORNICE

4.12.15.1.pa - The cornice is to be divided into seven parts and three fourths; two must be given to the

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[264] Ibid.
[265] Ibid., par 14
[266] Ibid., par 15
[267] Ibid., par 16
[268] Ibid.
[269] Ibid.

cavetto and ovolo, two to the modiglion, and three and three fourths to the corona and gola or cima. Its projection is equal to its height[270]

4.12.15.2.pa - I have designed the front, flank, and plan of the capital; as also the architrave, frieze, and cornice, with there proper ornaments[271]

4.12.16.1.pa - The soffit of the cornice is where the roses are between one modiglion and the other[272]

4.13 CORINTHIAN ORDER

The Corinthian order is the most elegant of the four orders. It is composed of two rows of leaves, volutes and a flower attached to a very slender shaft. It is of the highest order, being used in the upper spaces of double height villas and as the main order in villas with only one story. The Corinthian .order is typically used in the most elegant buildings for the wealthiest of clients (fig. 4.38 - 4.39). The base is one module in diameter. There are few rules for the construction of the leaves or other details.

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270 Ibid., par. 17
271 Ibid.
272 Ibid., par. 17

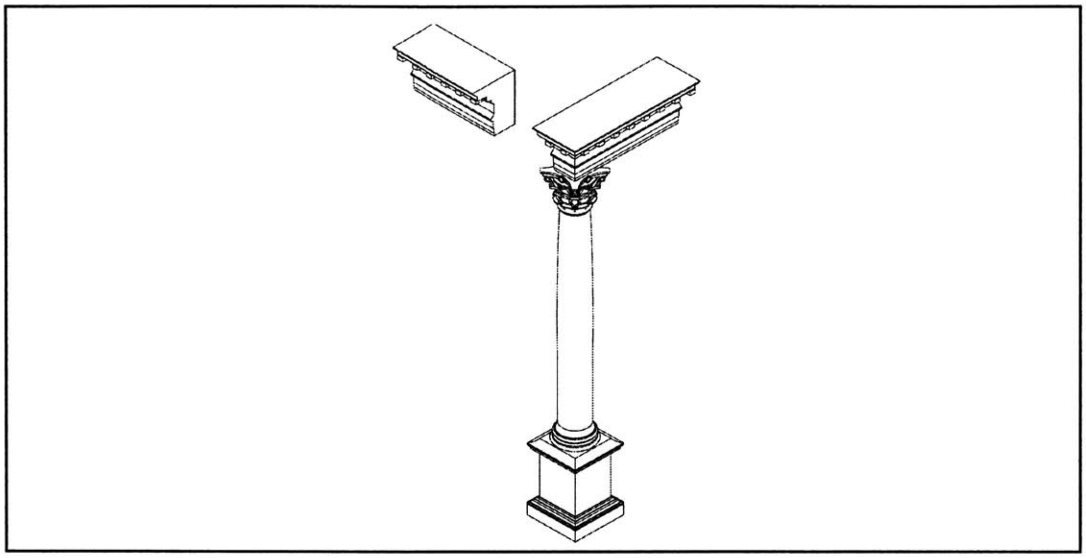

Fig. 4.38 Corinthian column and
architrave profile

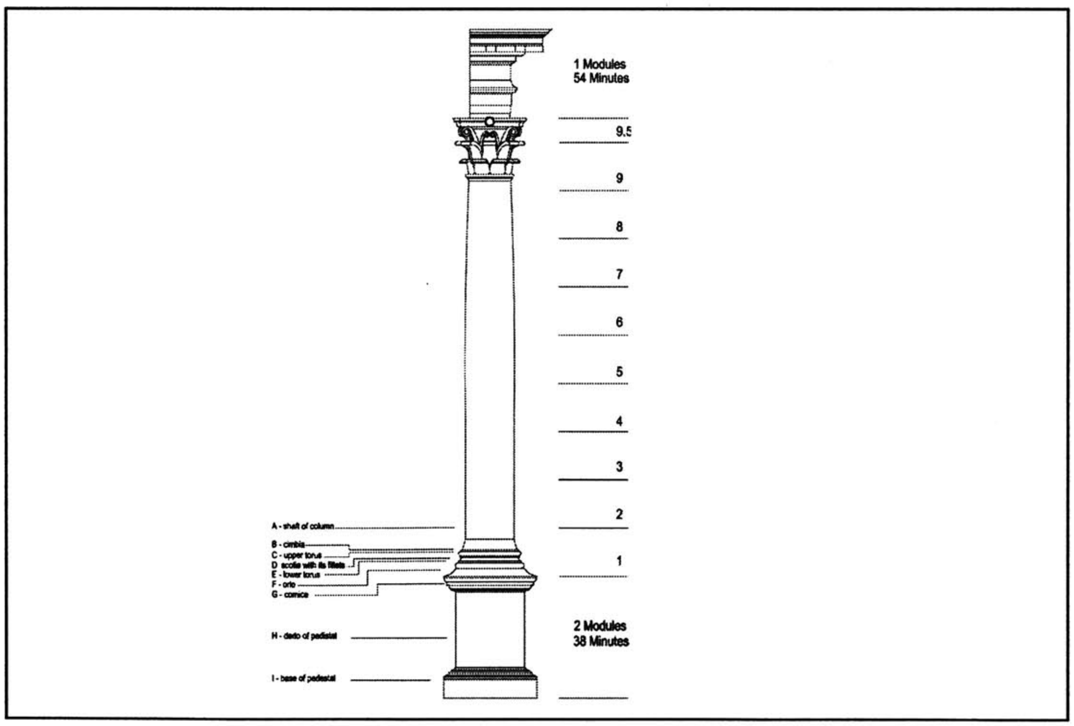

Fig. 4.39 Corinthian column elevation

GENERAL RULES

4.13.1.1.pa - The columns are like those of the Ionic order, being five modules and a half in height, including their base and capital[273]

4.13.1.2.pa - When they are to be fluted, they ought to have twenty-four channels or flutes, whose depth must be half of their width[274]

4.13.1.3.pa - The spaces between two flutes must be one third of the width of the said flutes[275]

4.13.2.1.pa - The architrave, frieze and cornice are a fifth part of the height of the whole column[276]

4.13.2.1.pa - In the design of a simple colonnade the inter-columniations are of two diameters, as they are in the portico of St. Maria la Rotunda at Rome. The pilasters are two fifths of the void. This void is two squares and a half, including the thickness of the arch[277]

4.13.3.1.pa - The pedestals to be placed under Corinthian columns ought to be one fourth of the height of the columns, and divided into eight parts[278]

4.13.3.2.pa - One part is given to the cimacia, two to its base, and the remaining five for the dado[279]

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[273] Palladio, A., 1965 Bk1, Chap 17, par 2
[274] Ibid.
[275] Ibid.
[276] Ibid., par 3
[277]Ibid.
[278] Ibid., par 4

4.13.3.3.pa - The base must be divided into three parts, two to be given to the zocco or plinth, and one to the cornice or molding[280]

4.13.4.1.pa - The attic is the base to these columns, but differs from that which is placed under the Doric order, its projection being but one-fifth part of the diameter of the column[281]

4.13.4.2.pa It may also vary in some other parts; as is seen in the design, where the imposts of the arches are also profiled, whose height is half as much again as the thickness of the members or pilasters that support the arch[282]

RULES FOR THE CORINTHIAN CAPITAL

4.13.5.1.pa - The height of the Corinthian capital ought to be the diameter of the column below and a sixth part more, which is allowed to the abaco[283]

4.13.5.2.pa - The remainder is divided into three equal parts[284]

4.13.5.3.pa - The first is given to the first leaf, the second to the second, and the third is again divided into two parts[285]

4.13.5.4.pa - In that part nearest to the abaco must be made the caulicoli or stems with their leaves,

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[279] Ibid.
[280] Ibid.
[281] Ibid., par 5
[282] Ibid.
[283] Ibid., par 6
[284] Ibid.

which seem to be supported by them and from which they arise[286]

4.13.5.5.pa - The shaft or stem from whence they spring should be thick, and diminish gradually in their folding, imitating thereby the plants, which are thicker in the part from whence they sprout, than at the extremities of their branches[287]

4.13.6.1.pa - The campana, which is the body of the capital under the leaves, ought to fall directly perpendicular with the bottom of the flutes of the columns[288]

4.13.6.2.pa - To form the abaco and to give it a suitable projection, a square is to be made. Every side where of must be a module and a half, within which let diagonal lines be drawn[289]

4.13.6.3.pa - In the middle or center where they intersect the fixed point of the compass ought to be placed. And towards every angle of the square a module is to be marked[290]

4.13.6.4.pa - Where the points are lines that intersect the said diagonals at rectangles must be drawn so as to touch the sides of the square. These will be the bounds of the projection, the length of which will also give the width of the horns of the abaco[291]

4.13.7.1.pa - The curvature or diminution is made by drawing a thread from one horn to the other, and

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[285] Ibid.
[286] Ibid.
[287] Ibid.
[288] Ibid., par 7
[289] Ibid.
[290] Ibid.

taking the point where the triangle is formed whose base is the diminution[292]

4.13.7.2.pa - Then a line is to be drawn from the extremities of the said horn to the extremity of the astragal or tondino of the column, which line the tip of the leaves is to touch, or they may come out a little more, and this is their projection[293]

4.13.7.3.pa - - The width of the rose ought to be a fourth part of the lower diameter of the column[294]

RULES FOR THE CORINTHIAN ARCHITRAVE

4.13.08.1.pa - The architrave, frieze, and cornice, as I have said, are one fifth of the height of the column[295]

4.13.8.2.pa - The whole is to be divided into twelve parts[296]

4.13.8.3.pa - But the cornice is to be divided into eight parts and a half[297]

4.13.8.4.pa - One of which is given to the intavolato or cima reversa, another to the dentello or dentels, the third to the ovolo, the fourth and fifth to the modiglion, and the remaining three and a half to the corona and gola[298]

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[291] Ibid.
[292] Ibid., par 8
[293] Ibid.
[294] Ibid.
[295] Ibid., par 9
[296] Ibid.
[297] Ibid.
[298] Ibid.

4.13.9.pa - - The projection of the cornice is equal to its height[299]

4.13.10.pa - - The panels for the roses placed between the modiglions must be square, and the modiglions half as broad as the plane of the said roses[300]

4.13.11.pa - The members of this order are not marked with letters, as the foregoing[301]

4.14 ARCHES

Palladio specifies arch types for each order alongside the drawing for the column in the text. It is seldom that Palladio uses an arch in a given villa with as much detail as prescribed in the text for each order. In the text he prescribes moldings and proportions not found in any of the built or unbuilt villas. Palladio uses arches at two places in a villa - at the end of a portico and as an opening at the ends of the barns. Arches used at the end conditions of a portico usually do not match the arches prescribed in the text. They tend to be narrower and with no moldings. There is little certainty of the proportional sizes of the arched openings in barns and their relationship to the text. Here, an arch is described as a square opening with an arch above, in a wall with two variables (fig. 4.40).

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[299] Ibid., par 10
[300] Ibid., par 11
[301] Ibid., par 12

4.14.1.ls - Arch variables

x = width of opening

z1 = height of arch (not to top of arch)

z2 = distance from floor to bottom of arch

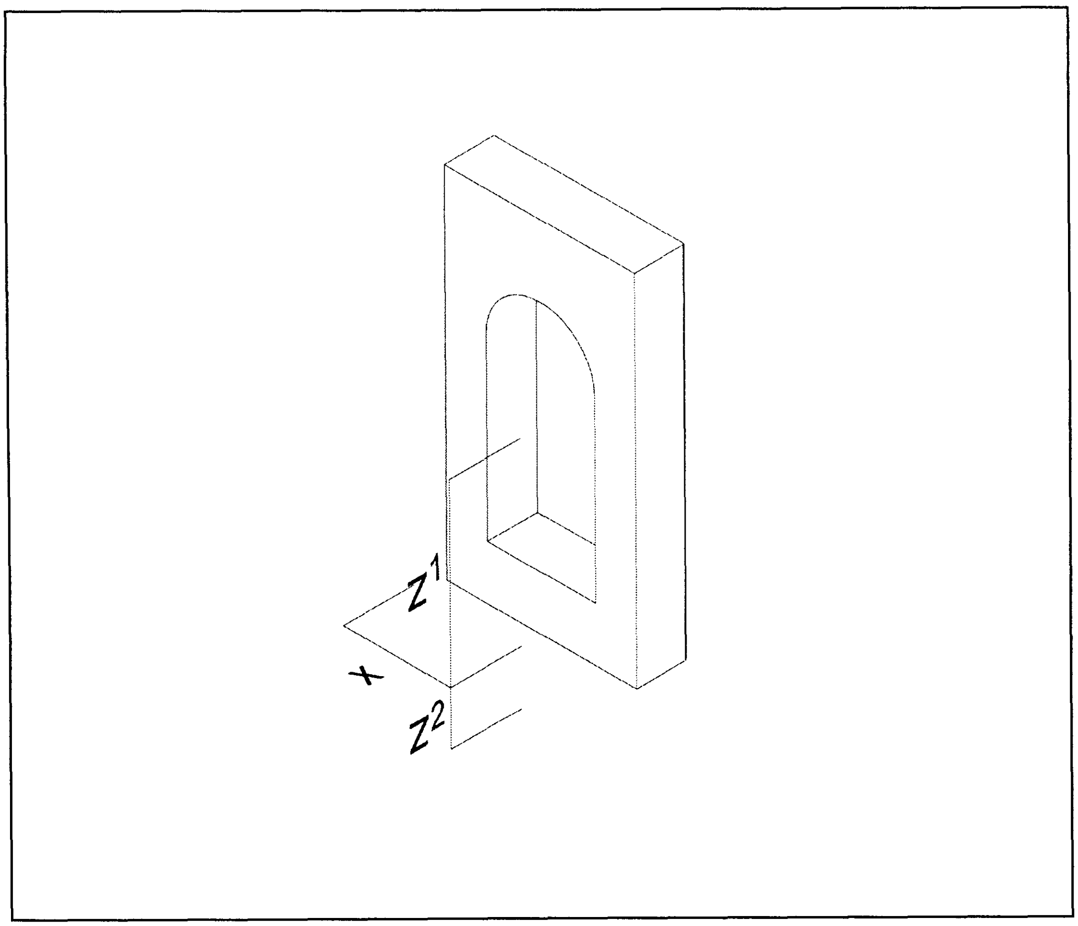

Fig. 4.40 Generic arch with x & z variables

4.15 DOORS

There are two door types in a villa, the main entry door and those that lead to rooms, each with its own frame type and sizing procedures. Door openings to rooms are generally 6'6" in height and 3' in width. Doors at the entryways are much larger, typically 3'6" to 6'0" in width and 12' in height. The formula for the main entry door, which is quite complicated, states that the space from the floor to the surface of the joists should be divided into three parts and a half. Two of the three parts define the height, and one to the breadth or width of the opening. A twelfth of the height is to be removed from the final height of the door.[302] The doors themselves are made of wood with metal hinges, and they must be spaced as far from a corner as the size of the opening. Unfortunately, most original doors in the built buildings have not survived. They were burned for firewood during war times.[303]

RULES FOR DOORS

4.15.1.pa - The openings of the doors and windows should be exactly over one another. Solid be upon the solid, and the void over the void[304]

PRINCIPLE DOOR (fig. 4.41)

4.15.2.1.pa - The best way to find the size of a principle door opening, is to divide the space from the floor to the surface of the joists, into three parts and a half[305]

---

[302] Ibid. p. 30
[303] During my travels to various villas throughout the Veneto the owner of the Villa Pisani, Montagnana told us of the story behind the doors in the villas. He stated that the original doors were burned for fire wood during World War II
[304] Palladio, A., 1965 Bk1 Chap I, par 3
[305] Ibid. Chap 25, par 2

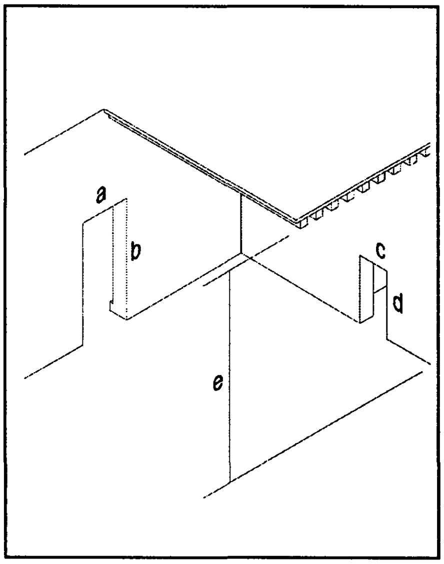

Fig. 4.41 Detail of principle and room door openings

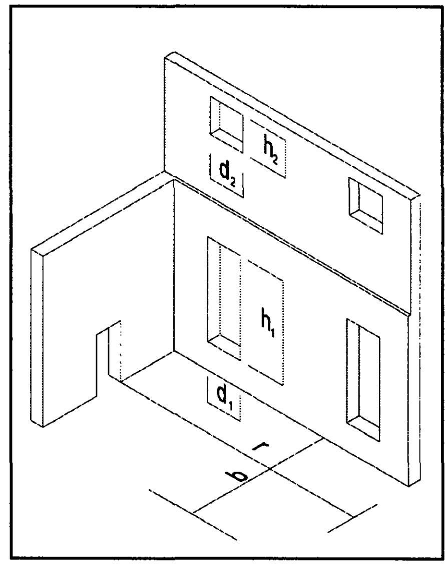

Fig. 4.42 Detail of window openings

4.15.2.1.pa - Allow two to the height, and one to the breadth of the opening, minus a twelfth part of the height[306]

4.15.3.pa - The place to be chosen for principal doors, is where a free access may be had to it from all parts of the house[307]

ROOM DOORS (fig. 4.41)

4.15.4.pa - The doors of rooms are not to be made wider than three foot, and six and a half high; nor less than two foot in breadth, and five in height[308]

---

306 Ibid.
307 Ibid. par 4

4.15.5.ls Door variables

a = width of principle door

y = variable

b = height of principle door

c = width of room door

d = height of principle door

e = height of space

4.15.6.ls - Determining principle door width [a]:

$$a = e/3.5$$

4.15.7.ls - Determining entry door height [b]:

$$y = 2a$$

$$b = y - y/12$$

4.15.8.ls - Determining room door width [c]:

2'-0" > c < 3'-0"

4.15.9.ls - Determining room door height [d]:

5'-0" > d < 6'-6"

---

[308] Ibid. par 5

4.16 WINDOWS

Palladio specifies that window openings control light and temperature. He did not mention to what degree they control the aesthetics of the elevation, meaning how they aid in proportional balance and beauty. There is a formula for defining window size, based on room size. The rules in the text state the window width [d1] at the piano noble must not be more than one quarter of the width of the space [r]. The problem with the formula is that room sizes vary: similar to the issues of a generic room height is the problem of window height. Palladio addresses this by saying that once a generic size has been determined, that same size is used for all windows surrounding on that level. Palladio does not provide much detail on window construction, but he does mention that openings should be braced with a lintel or an arch for greater strength.

RULES FOR WINDOWS (fig. 4.42)

4.16.1.1.pa - Therefore the windows ought not to be wider than the fourth part of the breadth of the rooms, or narrower than a fifth[309]

4.16.1.2.pa - Windows are to be made two squares and a sixth part of their breadth more in height[310]

4.16.1.3.pa - And although the rooms in a house are made large, middling, and small, the windows, nevertheless, ought to be equal in the same order or story[311]

4.16.2.1.pa - I like rooms whose length is two thirds more than the breadth. For example, if the

[309] Palladio, A., 1965 Bk1, Chap 25, par 7
[310] Ibid.
[311] Ibid.

breadth should be eighteen foot, the length should be thirty, and I divide the breadth into four parts and a half[312]

4.16.2.1.pa - One I give to the breath of the void of the window[313]

4.16.2.2.pa - Two to the height adding one-sixth part of the breath more and according to the largeness of these I make those of the other rooms[314]

4.16.3.1.pa - The windows above these, that is, in the second story, ought to be a sixth part less in the height of the void, than those underneath[315]

4.16.3.2.pa - And in the same manner, if other windows are placed higher, they ought to diminish still a sixth part[316]

4.16.4.1.pa - Windows ought to be void on top of void, solid on top of solid[317]

4.16.4.2.pa - And all face one another, so that standing at one end of the house one may see to the other[318]

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[312] Ibid., par 8
[313] Ibid.
[314] Ibid.
[315] Ibid., par 9
[316] Ibid.
[317] Ibid., par 10
[318] Ibid.

4.16.5.pa - The windows ought to be distant from the angles or corners of the building as possible[319]

4.16.6.ls - Window variables

r = room width

b = room length

h1 = height piano noble window

d1 = width piano noble window

h2 = height second story window

d2 = width second story window

4.16.7.ls - Determining window width [d1]:

$$d1 = b/4.5$$

$$r/4 > d1 > r/5$$

4.16.8.ls - Determining window height [h1]:

$$h1 = (2\ (d1)) + b/6$$

4.16.9.ls - Determining second story window width [d2]:

$$d2 = d1$$

4.16.10.ls - Determining second story window height[h2]:

$$h2 = h1 - h1/6$$

---

[319] Ibid., par 12

4.17 DOOR AND WINDOW ORNAMENTATION

Door and window frames for interior spaces and exterior window framing are stone profile attached to wall surfaces as specified in chapter 25 of the *Four Books*. These profile specifications are flexible and change from door to door or window to window. Profiles are divided into three sections - architrave, cornice and frieze, all based on Doric, Ionic or Corinthian orders. Rules used to determine these profile shapes are quite complicated and not always consistent. The physical construction of a doorframe involves an irregular cut of stone inserted into a regular brick wall. Although the latter method would be easier to construct, a fully carved door or window profile is harder to transport from a quarry. Palladio presents four profiles in the *Four Books* also presented here (fig. 4.48).

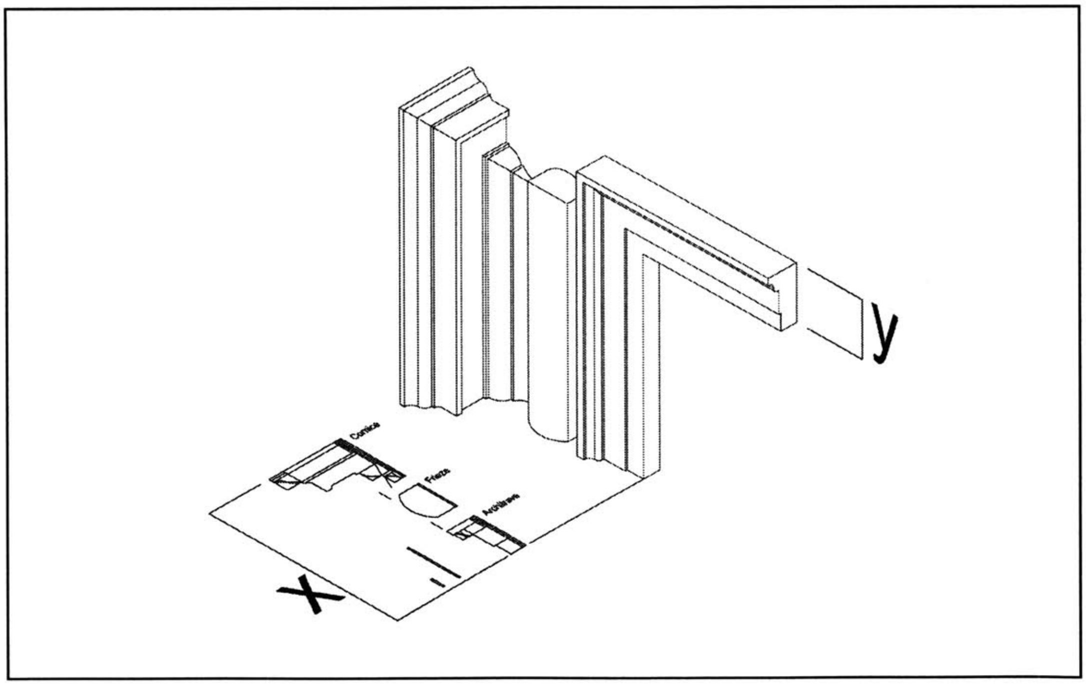

Fig. 4.43 Window and door profile

GENERAL RULES FOR ORNAMENTATION

4.17.1.pa - Ornaments are designed in all five orders[320]

4.17.2.1.pa - The ornaments given to doors and windows, are the architrave, frieze, and cornice[321]

4.17.2.2.pa - The door architrave goes round the door[322]

4.172.3.pa - The architrave must be as thick as the jamb or pilaster. This ought not be less thick than the sixth part of the breadth of the void, nor thicker that the fifth[323]

RULES FOR FRAME TYPE - A (fig. 4.44)

4.17.3.1.pa - The architrave is divided into four parts, three of which are for the height of the frieze, and five for that of the cornice[324]

4.17.3.2.pa - The architrave is again divided into ten parts, three of which go to the first fascia[325]

4.17.3.3.pa - Four to the second, and the remaining three parts are subdivided into five[326]

4.17.3.4.pa - Two are given to the regolo or orlo, and the remaining three to the gola reversa, which is

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[320] Palladio, A., Bk1, Chap 26, par 1
[321] Ibid., par 2
[322] Ibid.
[323] Ibid.
[324] Ibid., par 4
[325] Ibid.
[326] Ibid.

otherwise called intavolato[327]

4.17.3.5.pa - Its projection is equal to its height. The orlo projects less than half its thickness[328]

4.17.4.1.pa - The intavolato is in this manner marked[329]

4.17.4.2.pa - A strait line must be drawn that ends at the extremities of that under the orlo, and upon the second fascia, and to be divided in the middle, making each of the halves the base of a triangle of two equal sides[330]

4.17.4.3.pa - Then place the fixed foot of the compasses in the angle opposite to the base, draw the curve lines which form the said intavolato

4.17.5.pa - The frieze is three parts of the four of the architrave, and is to be marked with a segment of a circle less than half a circle, and with its swelling comes directly to the cimacio of the architrave[331]

4.17.6.1.pa - The five parts which are given to the cornice, are in this manner distributed to its members[332]

4.17.6.2.pa - One is given to the cavetto with its listello, which is a fifth part of the cavetto: the cavetto

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[327] Ibid.
[328] Ibid.
[329] Ibid., par 5
[330] Ibid.
[331] Ibid., par 6
[332] Ibid., par 7

projects three parts in two of its height[333]

4.17.6.3.pa - To mark it a triangle must be formed of two equal sides, and the angle made the center, so that the cavetto will be the base of the triangle[334]

4.17.6.4.pa - Another of the said five parts is given to the ovolo, whose projection is two parts in three of its height[335]

4.17.6.5.pa - To mark it a triangle must be formed of two equal sides, and the point made the center[336]

4.17.6.6.pa - The other three are divided into seventeen parts, eight are given to the corona or gocciolatoio, with its listelli, of which that above is one of the said eight parts. And that below which makes the hollow of the gocciolatoio, is one of the six parts of the ovolo[337]

4.17.6.7.pa - The other nine are given to the gola diritta, and to its orlo, which is one part of the three of the said gola[338]

4.17.6.8.pa - To form it well, and make it graceful, the straight line AB must be drawn, and divided

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[333] Ibid.
[334] Ibid.
[335] Ibid.
[336] Ibid.
[337] Ibid.
[338] Ibid.

into two equal parts, in the point C[339]

4.17.6.9.pa - One of these must be divided into seven parts, six of which must be taken in the point D, to form the two triangles A E C, and C B F, and in the points E and F[340]

4.17.6.10.pa - The fixed foot of the compasses must be placed to describe the segments of a circle A C and C B, which forms the gola[341]

RULES FOR FRAME TYPE - B

4.17.7.pa - The architrave likewise, in the second invention, is to be divided into four parts, three of which make the height of the frieze, and five that of the cornice[342]

4.17.8.1.pa - The architrave must be divided into three parts, two of which must be subdivided into seven, and three given to the first fascia, and four to the second[343]

4.17.8.2.pa - The third part must be divided into nine[344]

4.17.8.3.pa - With two the tondino is made, and the other seven are to be subdivided into five, three of which form the intavolato, and two the ovolo[345]

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[339] Ibid.
[340] Ibid.
[341] Ibid.
[342] Ibid., par 8
[343] Ibid., par 9
[344] Ibid.

4.17.9.1.pa - The height of the cornice is divided into five parts and three quarters, one of these must be divided into six, and five given to the intavolato over the frieze, and one to the listello[346]

4.17.9.2.pa - The projection of the intavolato is equal to its height, as also of the listello[347]

4.17.9.3.pa - Another is given to the ovolo, whose projection is three parts of four of its height: the gradetto over the ovolo is a sixth part of the ovolo and its projection the same[348]

4.17.9.4.pa - The other three are divided into seventeen, eight of which are given to the gocciolatoio, whose projection is four parts of three of its height[349]

4.17.09.5.pa - The other nine are divided into four, three of which are given to the gola and one to the orlo: the three-quarters that remain must be divided into five parts and a half[350]

4.17.09.6.pa - With one is made the gradetto, and with the other four and a half its intavolato over the gocciolatoio. The projection of this cornice is equal to its thickness[351]

RULES FOR FRAME TYPE - C

4.17.10.1.pa - The architrave of the first, marked with F, must likewise be divided into four parts[352]

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[345] Ibid.
[346] Ibid.
[347] Ibid.
[348] Ibid.
[349] Ibid.
[350] Ibid.
[351] Ibid.
[352] Ibid. par 11

4.17.10.2.pa - Three and a quarter are given to the height of the frieze, and five to the height of the cornice. The architrave must be divided into eight parts. Five go to the piano, and three to the cimacio[353]

4.17.10.3.pa - Which is also divided into eight parts, three of which are given to the intavolato, three to the cavetto, and two to the orlo[354]

4.17.10.0.pa - The astragal or tondino over the frieze, is a third of one of the said six parts, and that which remains between the gocciolatoio and tondino is left to the cavetto[355]

4.17.10.5.pa - The height of the cornice must be divided into six parts. Two are given to the gola diritta with its orlo, and one to the intavolato; then the said gola must be divided into nine parts, with eight of that is made the gocciolatoio and gradetto[356]

RULES FOR FRAME TYPE - D

4.17.11.1.pa - In the other invention the architrave marked with H, is divided into four parts[357]

4.17.11.2.pa - Three and a half are given to the height of the frieze, and five to the height of the cornice: the architrave is divided into eight parts[358]

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[353] Ibid.
[354] Ibid.
[355] Ibid.
[356] Ibid.
[357] Ibid., par 13
[358] Ibid.

4.17.11.3.pa - Five go to the piano, and three to the cimacio: the cimacio is divided into seven parts; with one is made the astragallo, and what remains is divided again into eight parts, three are given to the gola reversa, three to the cavetto, and two to the orlo[359]

4.17.11.4.pa - The height of the cornice must be divided into six parts and three-quarters. With three parts are made the intavolato, the dentello and ovolo[360]

4.17.11.5.pa - The projection of the intavolato is equal to it's thickness: the dentello, two parts of three of its height, and of the ovolo three parts of four: with the three quarters the intavolato between the gola and gocciolatoio is made[361]

4.17.11.6.pa - And the other three parts are to be divided into seventeen, nine of which make the gola and orlo, and eight the gocciolatoio[362]

4.17.11.7.pa - The projection of this cornice is equal to its height, as also the above said cornice[363]

4.17.12.pa - Profile variables

x = full profile entablature

y = architrave

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[359] Ibid.
[360] Ibid.
[361] Ibid.
[362] Ibid.
[363] Ibid.

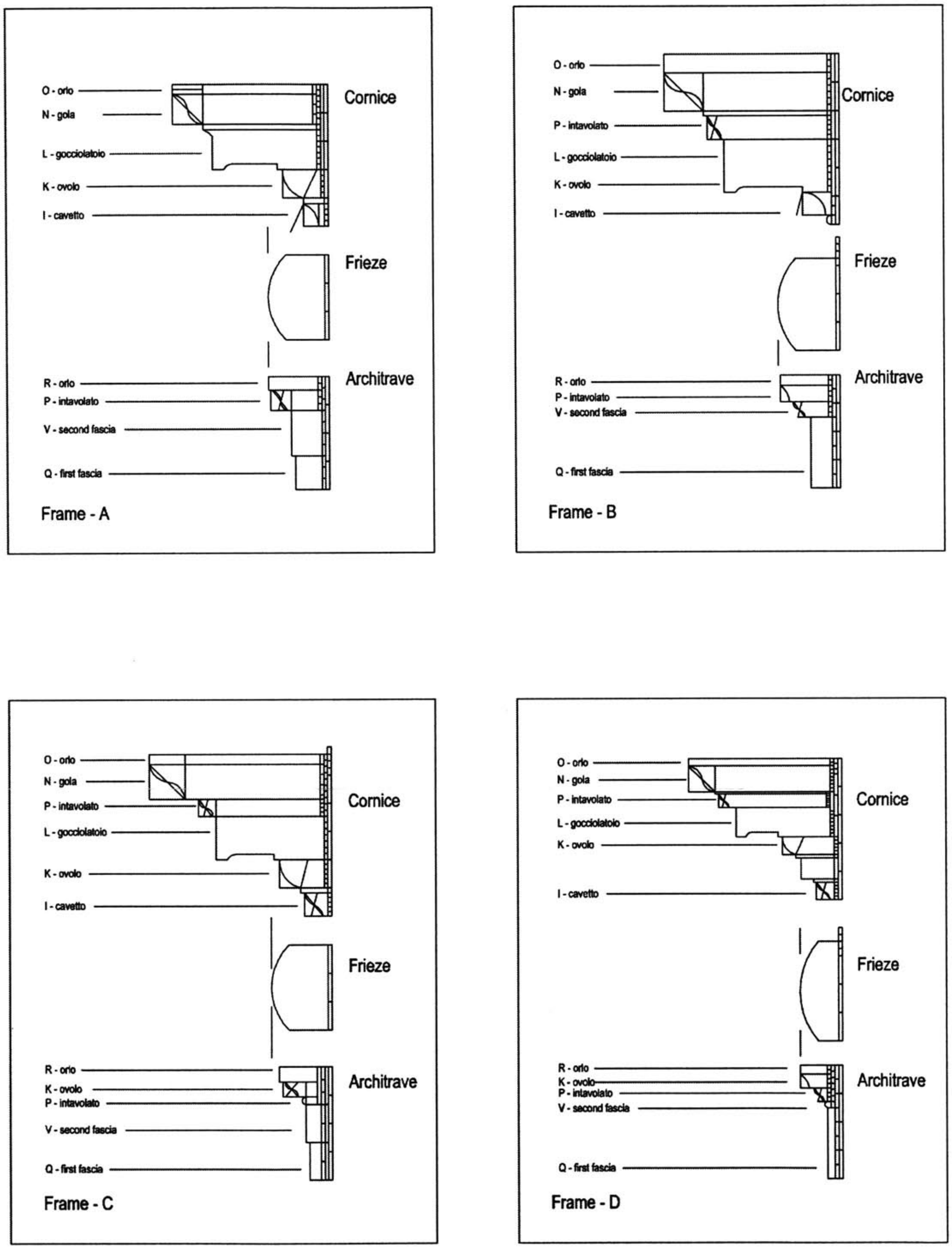

Fig. 4.44 Profile drawings from *The Four Books of Architecture*

4.18 BALUSTRADES

As important as they are to the composition of the building, Palladio or others have written little about balustrades.[364] Constructed of stone, balustrades are used for railings at stairs and balconies. There are two basic types. The first has a symmetrical top and bottom and the second is a bulb with a tip suspended over a cube at the bottom. Both are used in stairwells and balconies without specified dimensions or profile rules (fig. 4.49).

4.18.1.ls - Balustrades are used at the balcony edge

4.18.2.ls - Balustrades are used in grand staircases or staircases more that four feet in wide with an opening.

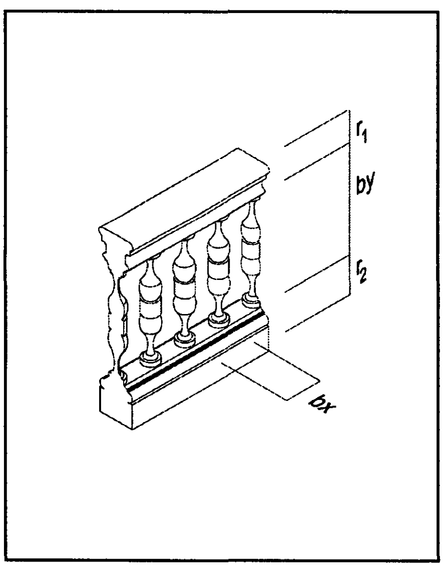

Fig. 4.45 Non-standard – Balustrade type

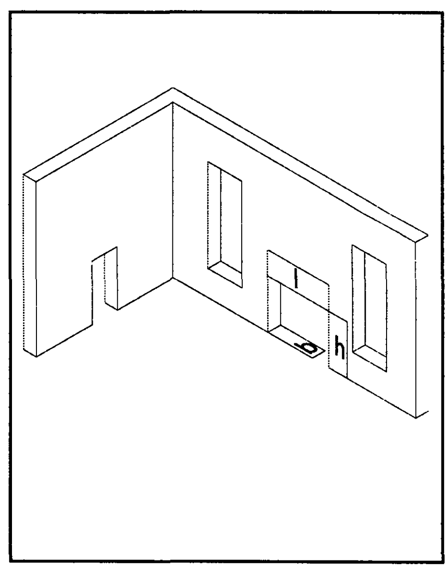

Fig. 4.46 Fireplace opening

[364] Wittkower, R. 1974

4.18.3.ls - Balustrade variables

r1 = upper rail thickness

r2 = lower rail thickness

by = balustrade height

bx = balustrade spacing

4.18.4.ls - Undefined balustrade variables

r1, & r2

by & bx

4.19 FIREPLACES

Fireplaces are major elements of a villa space, but unfortunately they are also not mentioned in *The Four Books.* As with the case of many outer rooms, the fireplace is the dominant element in the space. They are large openings in the outer wall decorated with life size plaster moldings and or stone figures. There are no fixed dimensions or rules for a fireplace or its ornamentation. Below is a rule newly created set for defining the fireplace opening (fig. 4.44).

4.19.1.ls - Fireplaces are located on the outer wall of an outer space.

4.19.2.ls - Fireplaces are spaced between two windows.

4.19.3.ls - A typical size for a fireplace is 4ft in length, by 5ft. in height by 2ft. in depth.

4.19.4.ls - Fireplace variables

l = Length

h = height

b = Depth

4.20 ROOF

The roof and its cornice are just as much functional objects as they are decorative. The roof and the cornice work together, keeping water from damaging the building by projecting it away from the exterior wall (fig.4 47). The cornice is composed of specially formed bricks stacked in a variety of configurations (fig.4.51 - 4.52). The roof is made of half round baked clay tiles over an array of flat tiles, supported by large wooden members. Large timbers used to support the roof are typically 10 - 12 inches square, and carry the weight of the roof to the exterior and interior walls of the main house. In the barns these same members carry the weight of the roof to a wooden entablature or a stone wall at the rear of the barn. The formula given by Palladio for the slope of the roof states that 2 of 9 parts of the width of the building should go towards finding the peak of the roof. In summary, the slope is 9 parts of the total width of the building and two parts high. It is not clear, based on Palladio's drawings, that this formula can be applied to the barns or the portico (fig. 4.48).

ROOF RULES

4.20.1.pa - Walls that have been made before are necessary to make the roof[365]

4.20.2.pa - It should embrace every part of the fabric[366]

4.20.3.pa - The weight of the roof should press equally upon the walls[367]

4.20.4.pa - The breadth of the place to be roofed, must be divided into nine parts[368]

Fig. 4.47 Cornice and roof tiles at the Villa Pojana

365 Palladio, A 1965 Bk. 1, Chap. 29, par. 1
366 Ibid.
367 Ibid.

4.20.5.pa - Two are given to the height of the ridge[369]

4.20.6.ls - Roof variables (fig. 4.53)

w = width of the building

d1 = roof thickness with joist and tiles

d2 = roof thickness with tiles

z = slope

Fig. 4.48 Underside of roof showing tiles under roof tiles and wooden supports

[368] Ibid., par. 4
[369] Ibid.

4.20.7.pa - Roof slope

w/9 x 2 = slope = z

4.20.6.ls - Cornice variables (fig. 4.49)

x = overall height of cornice

y = brick thickness

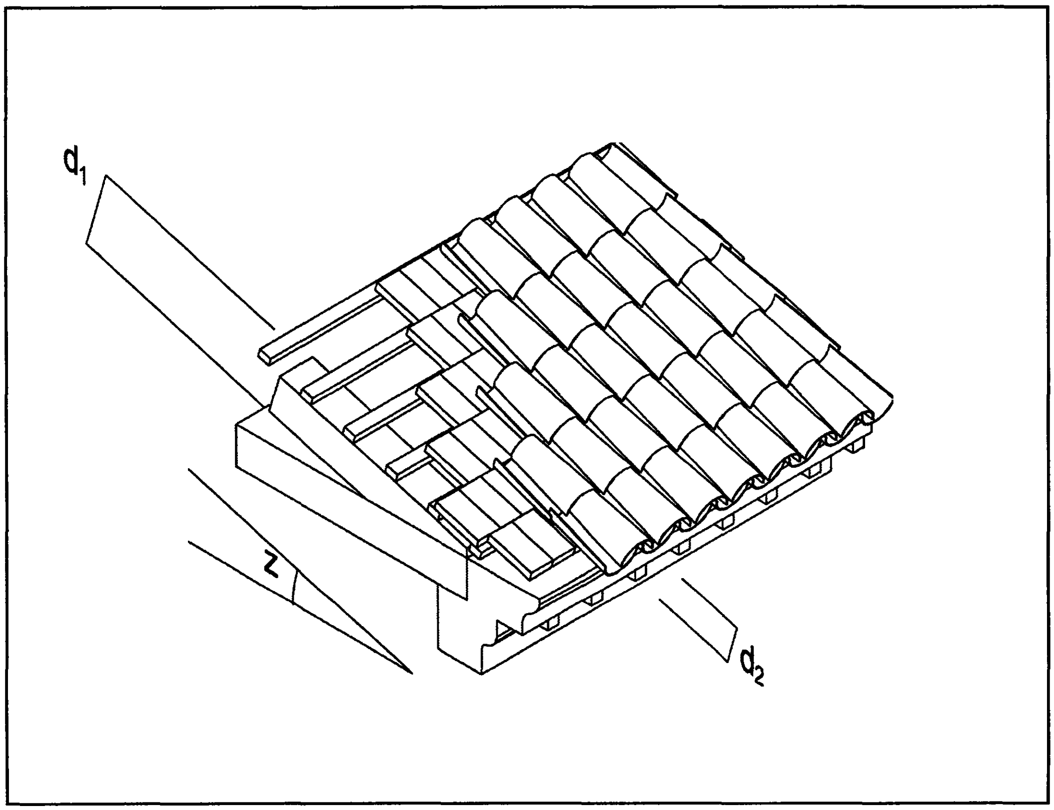

Fig. 4.49 Roof detail showing tiles and sloping calculations

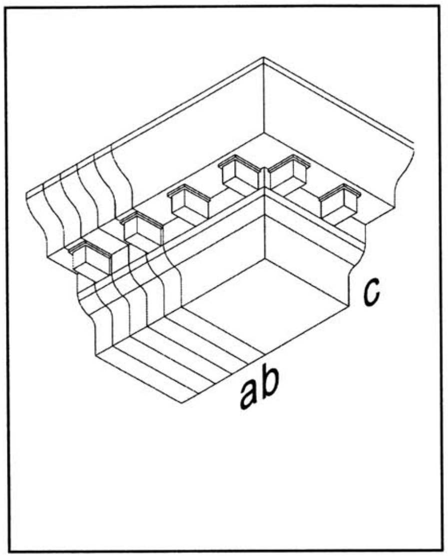

Fig. 4.50 Cornice detail showing brick construction and stone piece at end

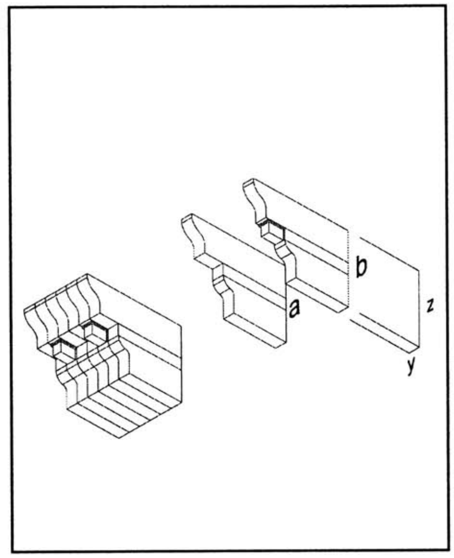

Fig. 4.51 Cornice detail showing individual brick

Fig. 4.52 Brick detail of cornice and stone end piece

4.21 CHAPTER SUMMARY

This chapter consists of an analysis of Palladio's design and construction language. The materials here are described as multi dimensional rules with variables that can easily be converted to a shape grammar system.[370] In order to use the rules in this chapter as a design grammar, they will need a more dynamic representation, a simpler presentation of the elements and functions. The next chapter uses these construction rules to rebuild a two dimensional representation of Palladio's plan and elevation drawings and later a three-dimensional representation by applying the rules from this chapter to the two-dimensional CAD representations.

[370] Stiny, G. 1980 (a)

LIST OF FIGURES

APPENDIX

SUMMARY OF DESIGN AND CONSTRUCTION RULES

Design rules (39 Rules)

Site Design Rules

- Site - Two building types
- Site - Placed in the middle of the site if flat
- Site - If hill place on top of the hill
- Site - It should be near a river or source of water
- Site - Must be a distance from standing water
- Site - Façade should face the approaching street or river-way
- Site - Town house or a Farm

Barn Design Rules

- Barns - Barns may not be an impediment to the other parts of the house
- Barns - The barns may not be any impediment to the other part of the house
- Barns - The covertures must be joined to the master's habitation, that he may be able to go to every place under cover, that neither the rains, nor the scorching sun of the summer
- Barns - Regard must be had in lodging the men employed for the use of the villa, the animals, the products, and the instruments, conveniently, and without any constraint
- Barns - The rooms for the steward, for the bailiff or farmer, and for the laborers, ought to be in a convenient place near to the gates, for the safeguard of all the other parts
- Barns - The stables for the working animals, such as oxen and horses, must be at a distance from the master's habitations

- Barns - The cellars ought to be under ground, enclosed, and far from any noise, moisture, etc
- Barns - Barns can be straight or circular
- Barns - Barns can terminate at the villa or with a dovecote or end with a wall
- Barns - Dovecotes can be made of two or more stories

Rooms and Space Design Rules

- Space - The principal spaces are the loggia, halls, courts, magnificent rooms, and ample stairs, light and easy of ascent
- Space - Loggia's, for the most part, are made in the fore and back front of the house, and are placed in the middle, when only one is made, and on each side when there are two
- Space - They are not to be made less than ten foot wide, or more than twenty
- Space - In the length of halls I use not to exceed two squares, made from the breadth; but the nearer they come to a square, the more convenient and commendable they will be
- Space - The rooms ought to be distributed on each side of the entry and hall
- Space - And it is to be observed, that those on the right correspond with those on the left, that so the fabric may be the same in one place as in the other, and that the walls may equally bear the burden of the roof
- Space - The most beautiful and proportional manners of rooms, and which succeed best, are seven Because they are either made round (though' but seldom) or square, or their length will be the diagonal line of the square, or of a square and a third, or of one square and a half, or of one square and two thirds, or of two squares.
- Space - The most beautiful are in places most exposed to view, and the less comely more hidden
- Space - Put the principal and considerable parts, in places the most seen, and the less

beautiful, in places as much hidden from the eye

- Space - The lowest part of the fabric, which I make somewhat underground, may be disposed the cellars, the magazines for wood, pantries, kitchens, servants-halls, wash-houses, ovens, and such like things necessary for daily use
- Space - The apartment above should be free, at a distance from the damp ground
- Space - Rooms may be great, middle-sized, and small. All near one another, so they may reciprocally be made use of
- Space - Small rooms may be divided off, to make closets where studies or libraries may be placed, riding accoutrements and lumber
- Space - The small rooms for summer use should be ample, spacious and turned to the north But those for which we would make use of in spring and autumn, must be turned to the East, and ought to look over greens and gardens. In this particular part, studies and libraries ought also to be
- Space - Rooms are placed one next to the other.
- Space - Rooms are designed without consideration of wall thickness.
- Space - Halls are square or rectangular rooms. They can be at the entry or along side of another hall.
- Space - Large cameres are rectangular rooms off the entry hall with fireplaces.
- Space - Salas are larger rooms over the entry hall
- Space - Small cameres are square or rectangular rooms off of main halls or larger camere.
- Space - Rotundas are circular spaces located at the center of the villa with four or eight door openings.
- Space - Rooms can be rectangles, squares or circles

Construction rules (16 Rule Sections)

	Section	Types	Operation
Walls	5.0	2	Procedure
Flat Ceiling	6.0	1	Procedure
Vaults	7.0	6	Procedure
Stairs	8.0	8	Procedure
Columns and intercolumniation	9.0	1	Procedure
Tuscan order	10.0	1	Object
Doric order	11.0	1	Object
Ionic order	12.0	1	Object
Corinthian order	13.0	1	Object
Arches	14.0	1	Procedure
Door Openings	15.0	1	Procedure
Windows Openings	16.0	Multiple	Procedure
Door and window ornamentation	17.0	4	Profile
Balustrades	18.0	Multiple	Profile
Fireplaces	19.0	1	Procedure
Roof	20.0	4	Procedure

CHAPTER FIVE

2D RECONSTRUCTION

5.0 SKETCHES AND DESIGN PRODUCTS

An architect's drawing is an arrangement of lines and shapes, from which rules can be developed and applied to reconstruct a design or to create a new one.[371] This chapter is focused on presenting and explaining techniques for reconstructing two of Palladio's ten construction drawing types (plan drawing, elevation drawing, column base profile drawing, etc). Shape grammars of the type defined by Stiny (1980a) are used to reconstruct what would be considered a loose sketch drawn by Palladio into a CAD drawing. These methods are tested at the end of this chapter by reconstructing a plan diagram of the Villa Cornaro, after which construction rules are applied to the diagram and elevation, resulting in a reconstructed plan and elevation drawing. The following chapter will use the reconstructed two-dimensional drawings to create a three dimensional model.

The goal of this study is to reconstruct a villa in the style of Palladio, in three dimensions, by translating his drawings int three-dimensional products (fig. 5.1). The recreation of an object requires an understanding of its [1] shape(s), [2] proportions (also refers to as sizes), and [3] its physical construction. In this study, the products are three-dimensional CAD based models, photo realistic CAD based renderings and three-dimensional prints of plastic or cornstarch. These products are created from a combination of two or more of Palladio's ten sketch types. There are two steps towards the production of the first product - the three-dimensional cad model. The first step is to capture Palladio's design style through shape, size and construction rules. Stylistic design techniques based exclusively on shape definition are captured by parametric shape grammars, referred to here as diagrams (plan diagram, elevation diagram, column profile diagram, etc) of the kind listed in *Palladian Grammar*.[372] An example of this would be a floor plan or door molding, as well as other objects that can only be described by their shape.

In the second step, construction rules and shapes found in chapter four of this text are applied to that shape diagram to give it three-dimensional form. For further accuracy a proportional system[373] can be applied to the shape grammar diagram before construction rules are applied, to insure that all of the spaces in the plan are of Palladian proportions. The reconstructed drawing will allow for the construction of accurate CAD models. In summary, the three rule types that can be used to translate Palladio's two-dimensional drawings into cad representations are two-dimensional shape rules (parametric shape grammars),[374] proportional rules[375] and construction rules originating from chapter 4.

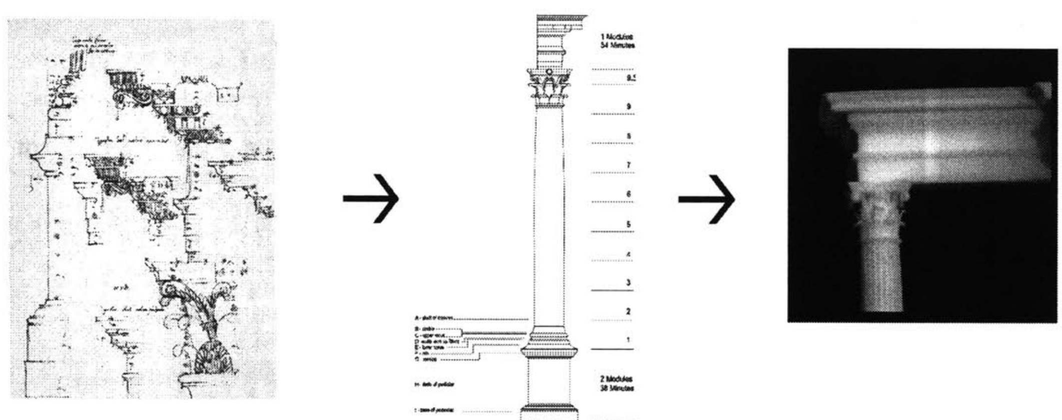

Fig. 5.1 Process of sketch to cad to three-dimensional product representation (3d Print)

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[371] Stiny, g. 1980
[372] Stiny/Mitchell, 1978
[373] March, L. 1998
[374] Ibid.
[375] March, L., 1999, The proportional system defined by March is not used in this study

To summarize the process, in the case of the floor plan that will be reconstructed at the end of this chapter, two-dimensional shape rules taken from the *Palladian Grammar* are used to recreate the plan diagram from a serious of shapes and shape rules.[376] Next construction rules are applied to the resulting plan diagram. If the sizes of the spaces on the plan are not clear or the sketch is arbitrarily defined (fig. 5.2), a proportional system would have to be applied to clarify the sizes in the plan diagram.

A close analysis of Palladio's sketches and the construction methods of the time helped to determine Palladio's methods for quick design and the rapid production of his buildings. This process was based on a system of quick sketching and the use of construction procedures, standard to all masons. One way to understand this, is by looking at Palladio's sketches, and not the finished drawings published in the *Quattro Libri*. Drawings published in the *Four Books* are finished presentations, meant for display, not for design representations. For design, Palladio used line drawings noting walls, stairs, spaces, columns and ceilings or what could be called a "plan diagram sketch"(fig. 5.2), again referred to as a loose sketch. In the case of our translation process mentioned above, the sketch would have to be shaped properly so that lines are straight and that walls are parallel or perpendicular to other lines. Mechanical information such as window sizes and doors are applied to the diagram after the program has been set. Plans constructed in a sketchy fashion were given construction sizes and labels based on information in the *Quattro Libri.*[377]

[376] Stiny, g. 1980
[377] Burns, H. 1991

This chapter will first examine the power and potential of Palladio's sketches and demonstrate how these sketches are translated into a computational representation. There are ten sketch types, each containing the possibility of being translated by the three systems: shape, proportion and construction into three-dimensional products. The Villa Cornaro will serve as a test case of the process outlined in this chapter. The site plan, floor plan and elevation will be constructed using shape and construction grammars. Rules and rule variables are recorded on a spreadsheet found in the appendix of this chapter.

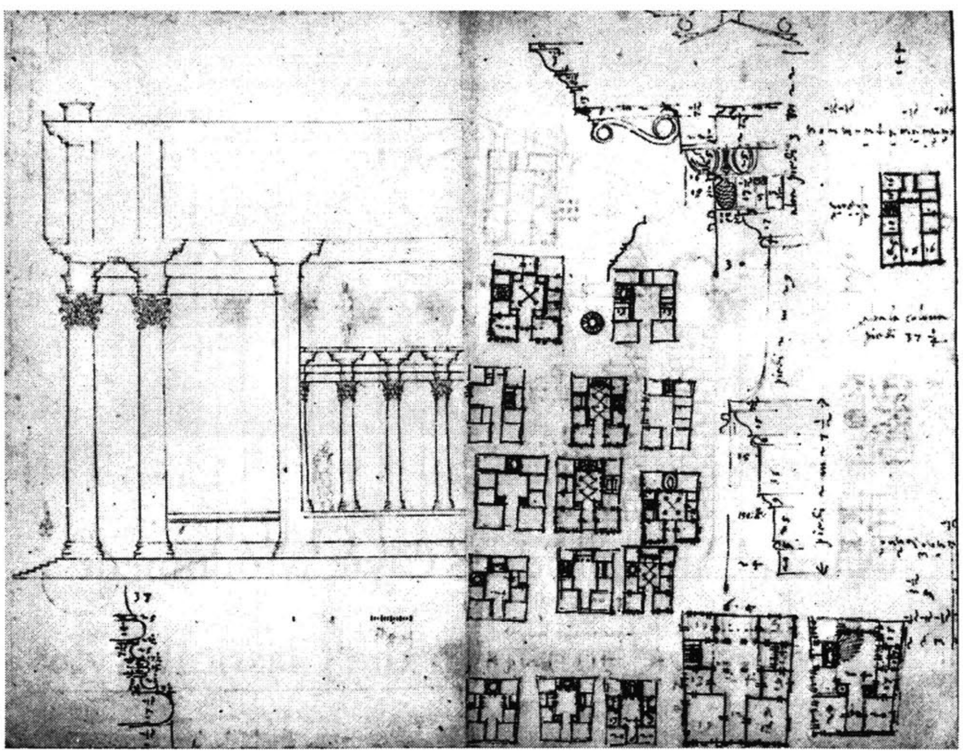

Fig. 5.2 Palladio's sketch for the façade of a palace and misc. floor plans

5.1 *TEN SKETCHES, THREE SYSTEMS*

Palladio drew ten different types of sketches for both the design and construction phases of his work.[378] In order to construct models from the loose sketch, they must be transformed into digital form, clarifying sizes and shapes. These transformations are applied to one of ten sketch types resulting in clarified two-dimensional CAD based drawings with measurable proportions, referred to here as a two-dimensional diagram. Of the ten sketches, the most important is the plan and elevation (fig. 5.3).

Drawings not published by Palladio are detailed sketches of elevations, cornices, door profiles, window profiles, and column profiles and elevation details (fig. 5.2). Most are orthogonal sketches with some dimensions or proportions noted on the drawing. Sketches were used to graphically inform the masons of areas too complicated for words i.e. cornice moldings, elevation details, etc. In many cases Palladio created these drawings on site, as the building was under construction. At times Palladio would present drawings, a template or a wooden model representing the type of detail of his interest during the constructing.[379] This was especially done on a larger building such as a palace or large villa. It is possible to reconstruct an entire villa from a combination of each sketch type once computational parameters are set.

[378] Ten sketches is a number based on a survey of drawings in Lewis, D., 1982
[379] Burns, H. 1991 p. 193

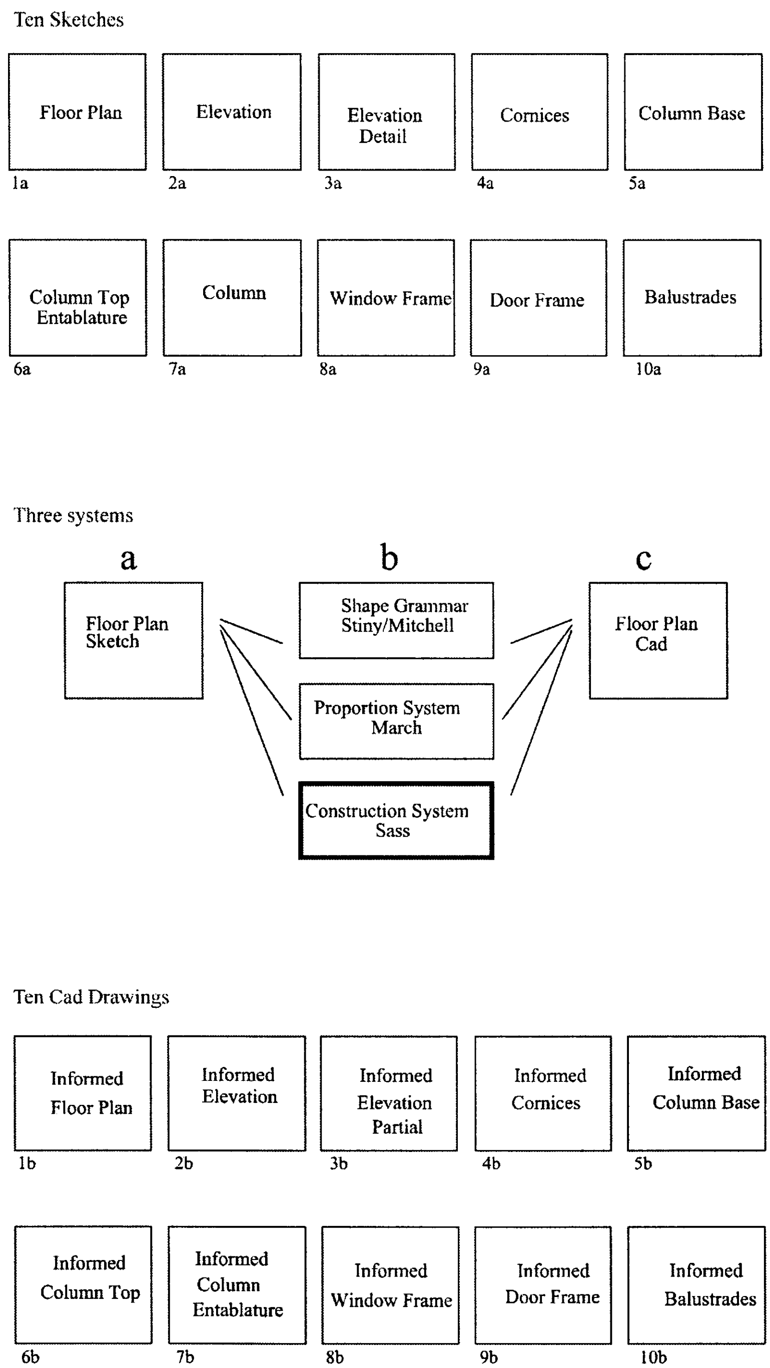

Fig. 5.3 Process of two-dimensional transformation

Palladio's Sketch Types

1. Plan Diagram
2. Elevations
3. Partial elevations (typically the portico)
4. Cornice moldings
5. Column - Base of shaft moldings
6. Column - Top of shaft molding
7. Column - Entablature moldings
8. Window frame moldings
9. Door frame moldings
10. Balustrade moldings

The process begins once the initial shape of the plan has been drawn and located on the site, which is marked with a grid (fig. 5.6). This grid is transformed into a plan diagram of the type published in Wittkower's paper - one represented in lines. Next, each design system is applied to the plan diagram one at a time, each system building on information from the previous system. For example, site information is needed to lay the grid. This grid is used to as a base for the shape grammars. The proportional system defines the sizing of the bays and gives the proper sizing, and the construction system is applied to the resulting diagram to create a plan from which a three-dimensional model can be constructed.

5.2 *THE SITE PLAN AND THE INITIAL SHAPE*

The site plan determines the design parameters used to place the main house and barn on the site and define barn orientation and size. For instance, the fact that Villas Badoer and Foscari Malcontena elevations face their respected streets or waterways is an example of an unwritten rule using a site element as a guiding feature in the design.[380] Another unwritten rule was that the barns are to extend themselves to the boundaries of the site, which can be seen in both the unbuilt Villas Trissino in Meledo and Mocenigo on the Brenta. Both have barns that span the width of the property, acting as arms reaching the outer ends of the properties. Both rules require a working knowledge of the site and its features in order to apply the rule.

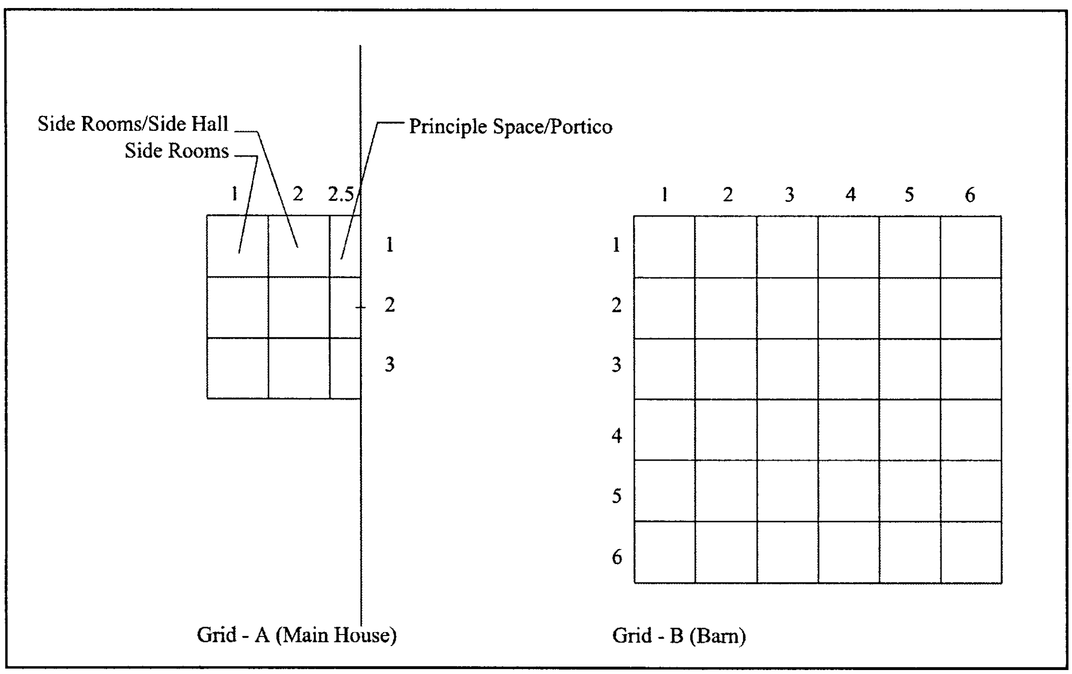

Fig. 5.4 House and barn grid

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380 Burns, .H 1975 p.216

It is unclear what impact the site had on all of Palladio's designs during his initial sketching phase. Did the site come before the design of the main house plan, or did the program influence the orientation of building on the site?

In order to reconstruct the plan using shape grammars, one or two grids are applied to a site. In this study the first grid (a), which is similar to the grid type specified in the *Palladian Grammar,*[381] is used to reconstruct the piano noble floor plan. The second grid is used to reconstruct the barns. The application of each of grid type to the site plan depends on the definition of the villa type (suburban or farm).

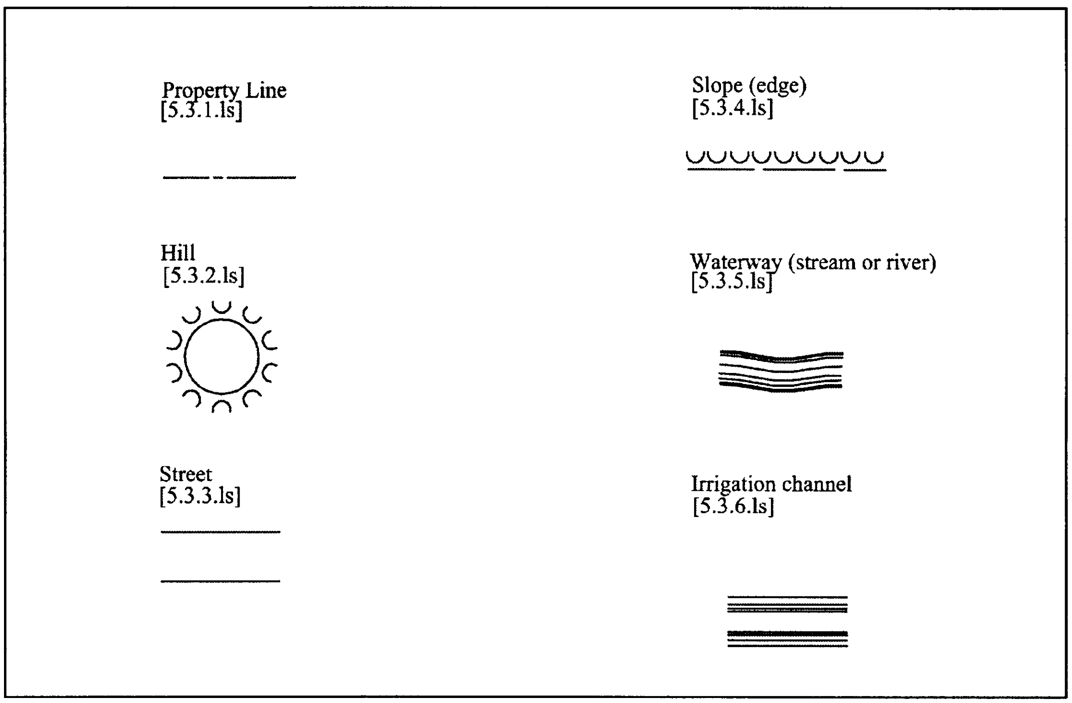


Fig. 5.5 Site notation elements - six site features used to define important areas of the site

[381] This grid is used to reconstruct the plan of the main house using shape grammars.

These grids are parametric grids[382] used to define walls of the villa and barns. Parameters are taken from the plan in the *Four Books* of the villa to be reconstructed and applied to the grid. For example, room sizes from the Villa Cornaro are applied to the plan grid to reconstruct Palladio's plan into a plan diagram representing the sizes of the rooms listed on Palladio's drawing (fig. 5.29).

Rules for Grid application

[4.2.1.pa]	Town Villa	(grid a)
[4.2.8.ls]	Farming Villa	(grids a & b)

The placement and siting of the villa house is based on six site features (fig. 5.5) used to determine the location of main building and barn as well as their sizes and orientations. Rules in chapter 4 are used to determine their placement of the grid in relation to these symbols. For example, Palladio says that a convenient place for a villa is in the middle of the estate, so that the owner may be able to view his property and that the fruits may be more conveniently carried to the house [4.2.2.pa]. But if there is a hill the villa should be placed on top of that hill, i.e.: the Villa Rotunda. A sample site and site grid was constructed in figure 5.6. In this case the house grid sits atop a hill in the middle of the site and its façade faces the adjacent road.

[382] Stiny, G., 1980 p.349 & Stiny/Mitchell 1978 p.8

Site Notation rules

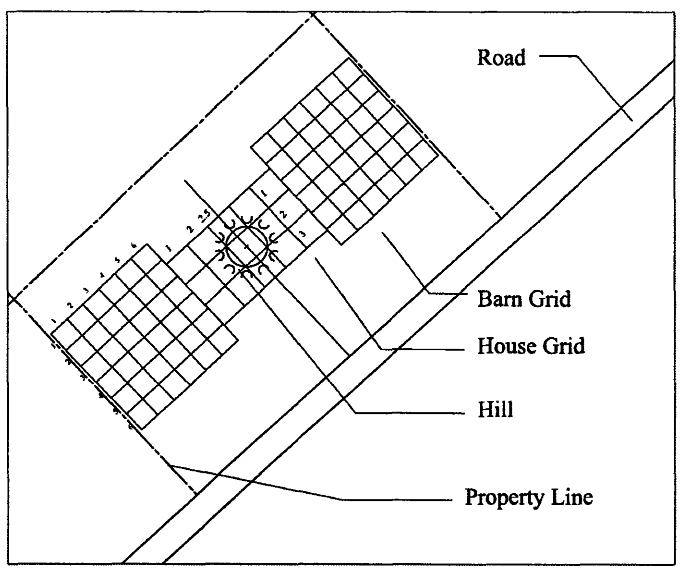
[5.3.1.ls]	1-Property line
[5.3.2.ls]	2-Hill
[5.3.3.ls]	3-Street
[5.3.4.ls]	4-Slope
[5.3.5.ls]	5-Waterway
[5.3.6.ls]	6-Irrigation channel

After the grid has been placed on the site, the floor plan is reconstructed using design rules. Of the ten sketches used to reconstruct a villa, the floor plan is the most important. It tells all. It is used to describe villa spaces, its volumes and details. Theoretically, most of Palladio's villas can be reconstructed with only the floor plan and the rules from the *Four Books*. This is a sharp contrast to a modern day set of construction documents which contain many layers of information in order to construct a shed.

Although other drawings such as elevations and details accompanied the plans in the *Four Books*, based on an understanding of architectural practice and the workings of the tradesmen of the Renaissance, masons were able to extract information exclusively from the plans to define an object's size. There are two factors leading to this conclusion. First, is that Ackerman writes that a close examination of the drawings from the High Renaissance demonstrates that few drawings were used to construct a building.[383] A large number of drawings of the time were first presentation renderings given to the client and second, sketches given to the masons. Drawings for masons were construction plans void of details, but detailed enough to be estimated for cost, and later proceed

[383] Ackerman, J. 1954

with the construction. In each case it was rare to find a full elevation drawing of a Palladian villa. The second factor which leads one to think that a building can be created exclusively from a plan, is that Ackerman also wrote that the plan dominated the architectural practice of the time, many design issues were resolved by just the plan drawing alone.[384] Adding to that, Burns writes that a client for a palace or a villa was responsible for the construction and management of his own project.[385] Palladio is said to offer the client a set of drawings or just a floor plan, from which the owner would hire a separate estimator to calculate the amount of bricks to be used to construct the building. In some cases thinner walls (which also means no vaulted ceilings) meant that a client could get a bigger villa with less decoration.[386] In all accounts the floor plan offered information on the heights of spaces and objects, the thickness of walls and the number of columns and in many cases tells more about the building's make up than the elevation.



~~Fig. 5.6 An example of a villa placed~~ on a site based on site notations

[384] Ibid. p.9

[385] Burns, H. 1991 p. 208

[386] Ibid.

5.3 *THE INITIAL PLAN - FLOOR PLAN DIAGRAM*

Shape grammars can be used to reconstruct floor plans in the Palladian style from a loose sketch or no sketch.[387] Shapes and shape rules are applied to a grid resulting in a plan diagram, in line form similar to plans found in the *Palladian Grammar.* The Stiny/Mitchell grammar applied rules and shape to a grid of three bays by five bays.[388] Since a Palladian plan has bilateral symmetry, in this study, only the left side of the main house is reconstructed, whereas the *Palladian Grammar* constructed both sides. Two shapes (rectangle and quarter circle) are applied to the site grid using rules [5.3.1sm] through [5.3.7.ls] (fig. 5.6). This is followed by rules for adjusting the sizes or proportions of the original shapes in the grid and to add new walls (fig. 5.7).

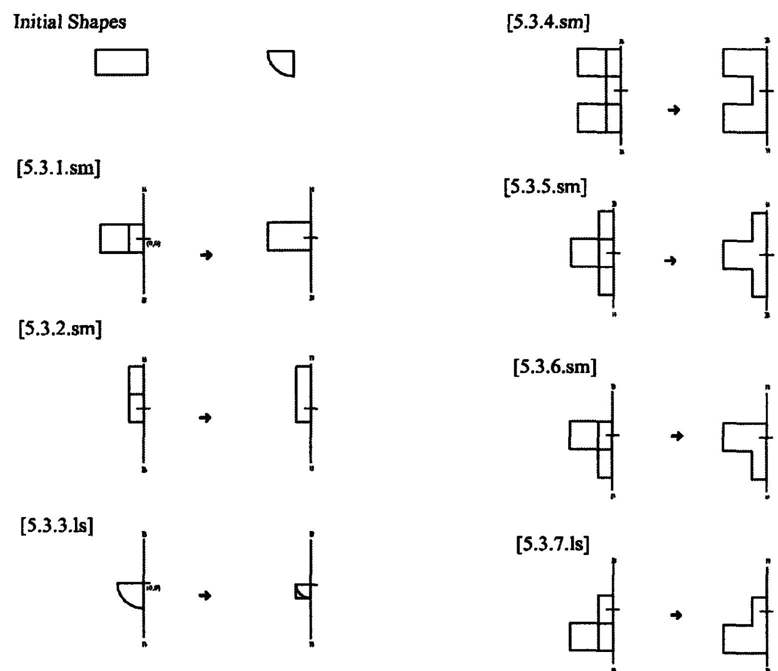


Fig. 5.7 Shape rules for wall generation and concatenation

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[387] Stiny, Mitchell, 1978
[388] Ibid.

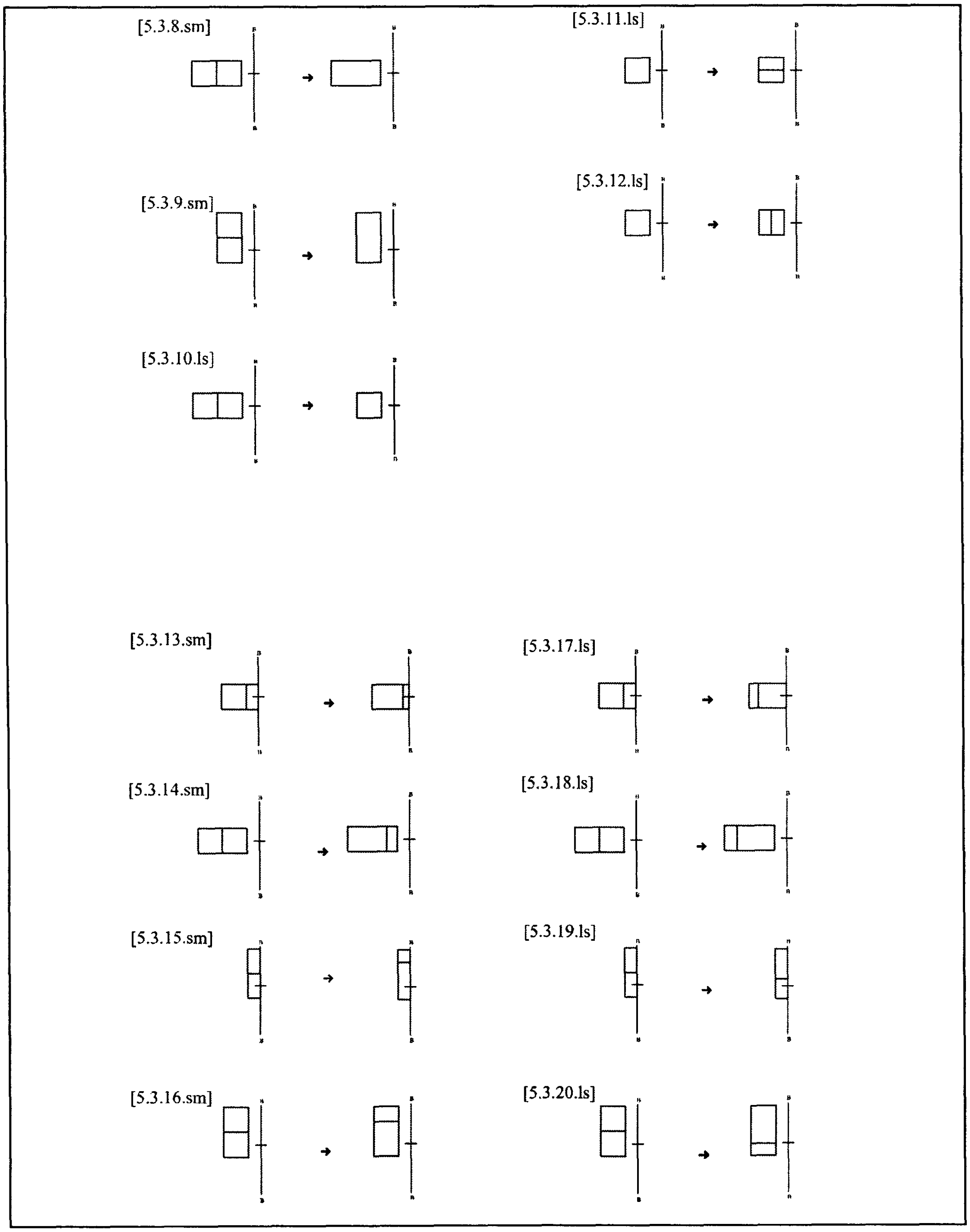

Fig. 5.8 Shape grammar used to concatenate spaces and add walls at the top, rules for wall adjustment at the bottom

When reconstructing the main house plan, the first step is to apply two shape types (rectangle and a quarter circle) to the grid in a sequence similar to the order described by Palladio for the user of the space. For example, the *Four Books* noted that "the most beautiful (spaces) are in places most exposed to the view, and the less commonly more hidden, put the principal and considerable parts in places most seen and the less beautiful in places as much hidden from the eye as possible." [389] The rules are applied in order from the central spaces or halls to the outer spaces - side rooms and stairs. There are three categories of shape rules used to transform the grid into a plan diagram of walls. The first set (fig. 5.6) defines halls and loggias or porticos; the second set (fig. 5.13) is used to define or concatenate side rooms and side halls; and the last set (fig. 5.14) is used to adjust existing walls.

An analysis of all villa plans shows that there are five basic hall types that can be created using four shapes and the shape rules found in the *Palladian Grammar* (fig.5.10 - 5.11). Shape rules taken from the *Palladian Grammar* (rules 12 through 25 with the exception of rule 21) will be used on the shapes to create five room types: rectangle, I shape, T shape, O shape and a + shape (fig. 5.11).[390] Rules taken from the *Palladian Grammar* are labeled with "sm" for Stiny/Mitchell. If there are two grids on one site, the house grid is completed first and the barns (grid b) second. Expected results of this process are the creation of a plan diagrams defining walls and room sizes (fig. 5.31).

[389] Palladio, A. 1965, Bk2, Chap 2, par 1
[390] Stiny, Mitchell, 1978 p.9

Fig. 5.9 Villa plan diagrams identifying the shapes of the main halls

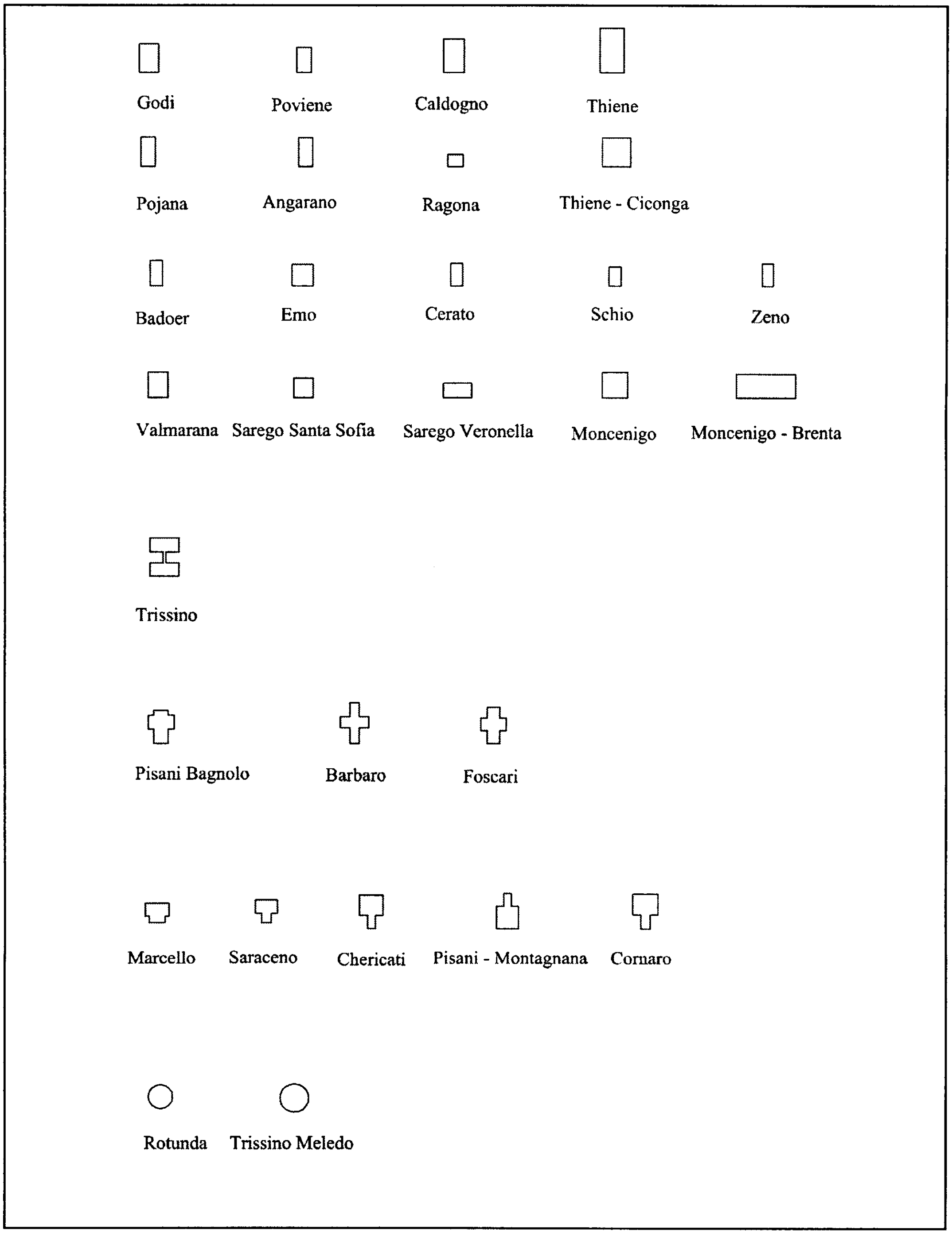

Fig. 5.10 Resulting hall shapes, rectangles, I, +, T,O

5.4 PROPORTIONING SYSTEM

March[391] and Wittkower[392] write extensively on Palladio's systems of proportion. Although the proportioning system will not be a serious component in this thesis it is worth talking about in order to understand the potential of its application. As scholars have noted, many dimensions are missing from Palladio's drawings. Some scholars argue that there are few systematic methods of for finding the missing dimensions. March suggests that the missing dimensions can be reconstructed by using Palladio's proportional system by his system of ratios.[393] It is a system that works by analyzing the numerical relationships, of the dimensions in rooms or spaces noted on Palladio's drawings. In the case of this study, the system could also be applied to one of the ten sketches mention in section 5.1 of this chapter. The resulting ratios are applied to the plan for sizing. The goal is not to get the exact size of the unidentified space, but to use the ratio to get a close approximation. The Villa Cornaro contains some spaces with a clear ratio such as the side rooms, which measure 24 feet long by 16 feet wide. The ratio of this space is 3:2, whereas the front and back porticos (which measure 32 feet by 11 feet) are close to a 3:1 ratio.

Burns writes that the proportioning of the rooms is a critical component in the planning process. Palladio's proportional numbers were (1:2, 2:3, 3:5, 3:4, etc) mostly used for rooms, or focused on structure and beauty.[394] In all cases scholars admit that the proportional system is not consistent in Palladio's drawings. Some spaces have a numerical relation and some don't, and while there are a few villas that can be narrowed to a critical numerical relationship, but most can not.

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[391] March, L. 1998
[392] Wittkower, R, 1949
[393] Palladio, A. 1965 p.27 par. 8
[394] Burns, H., 1975 pp.224-225

5.5 CONSTRUCTION NOTATIONS (PLAN)

The construction system is a set of parametric shapes systematically applied to the plan diagram once the proportions and general shapes have been constructed. The end of the construction system is to create a finished plan of walls, ceilings, porticos and stairs (fig. 5.11 - 5.29). These shapes are plan views of construction items and new rules created in this chapter. They are scalable, stretchable images representing design and construction rule sets that depend on the completion of the previous set for their parametric assignment. For example, wall thickness is defined by the ceiling type assigned to the plan, but door or window placement does not depend on wall thickness, only placement. So in this case, wall thickness can not be assigned to the plan until the ceiling type is defined on the plan diagram. The construction system is based on the representations of parametric parts. New shapes do not emerge from these fixed shapes, but their size can change. For example, a circular stair can not be transformed or substituted for an oval stair.

Order of Steps (plan)

1. Assignment of spaces
2. Ceilings notation
3. Wall thickness notation
4. Portico
5. Columns and arches
6. Stairs and stair pedestals
7. Door notation
8. Window notation
9. Detail notations

5.5.1 Assignment of Spaces

There are nine room types that can be assigned to the villa and barn diagrams. There are no clear rules for the assignment of each spatial type. For example, in the Villa Cornaro there is confusion over the labeling of the front two spaces to the right and left of the entry hall, There is no agreement as to whether they should be classified as halls or side rooms.

Space options

[5.5.1.1.ls] MH = Main hall

[5.5.1.2.ls] IP = Inset Portico

[5.5.1.3.ls] EP = Extended Portico

[5.5.1.4.ls] SH = Side hall

[5.5.1.5.ls] SR = Side Room

[5.5.1.6.ls] ST = Stairs

[5.5.1.7.ls] SP = Site Plan

[5.5.1.8.ls] BS = Barns space

[5.5.1.9.ls] BL = Barn Loggia

See: Sections 4.4 for purpose and space types

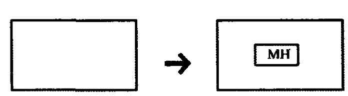


Fig. 5.11 Room Notation

5.5.2 Ceiling notations

Ceiling notations are added to the plan as per Palladio's original drawing. Symbol notation here is similar to Palladio's original drawings, except that rooms without a vault are represented and labeled with an abbreviated description.

Ceiling options

[5.5.2.1.ls] FC = flat ceiling Rectangular Halls, side rooms, and square rooms

[5.5.2.2.ls] FV = flat vaultRectangular side rooms

[5.5.2.3.ls] BV = Barrel Vault Main halls & smaller mezzanines

[5.5.2.4.ls] DL = dome/lunettes Square side rooms

[5.5.2.5.ls] CV = Cross Vault Square side rooms

[5.5.2.6.ls] DM = Dome Halls

[5.5.2.7.ls] ST = Stair (arched ceiling)

See: Sections 4.6 & 4.7 for ceiling and vault rules and details

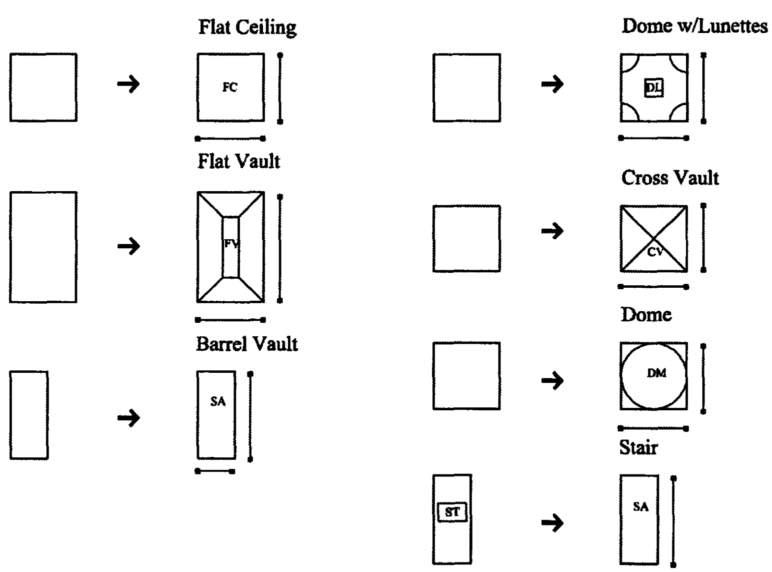


Fig. 5.12 Ceiling notations

5.5.3 Walls

Wall thickness is represented by lines offset from 9" to 15" from the original lines on the plan diagram. In the end, wall thickness is determined by the type ceiling applied to the space. Palladio's goal was to make the walls as thin as possible to save on cost. The more ornate the ceilings the thicker the walls, and the greater the cost. If all walls were to have flat ceilings or ceilings, with wood joist, walls could be as thin 18." If a vault is introduced to the space, thicker walls are needed to account for the lateral forces of the vault: 24" or greater.[395] The greater the weight bearing on the abutting walls, the thicker tehyshould be.

Wall options

[5.5.3.1.ls] 18" Wall — Interior and exterior - Flat Ceiling

[5.5.3.2.ls] 24" Wall — Interior and exterior - Stair wall, exterior wall with vault

[5.5.3.3.ls] 30" Wall — Interior - Wall between two spaces with vaults

See: Section 4.5 for details on wall rules and construction

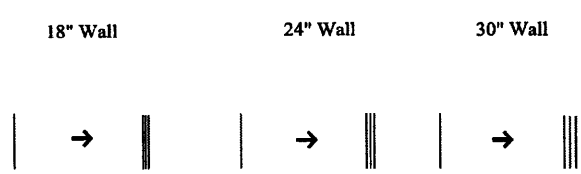


Fig. 5.13

[395] Burns, H., 1991 p.209 Walls are priced according to their thickness and the amount of openings. The thicker the walls, the greater the cost. Vaulted ceilings added a lot to the cost since

5.5.4 Porticos

Porticos are constructed of stairs leading to the piano noble and a landing. In some cases a pedestal is added to the outer edge of the steps. There are four portico types.

Portico options

[5.5.4.1.ls] Portico with landing and pedestal

[5.5.4.2.ls] Corner portico

[5.5.4.3.ls] Corner portico with diagonal step

[5.5.4.4.ls] Straight stair and landing

See: Section 4.9 for intercolumniation details and construction

a = landing

b = pedestal (x)

c = pedestal (y)

d = stair width

x = overall width

y = overall depth

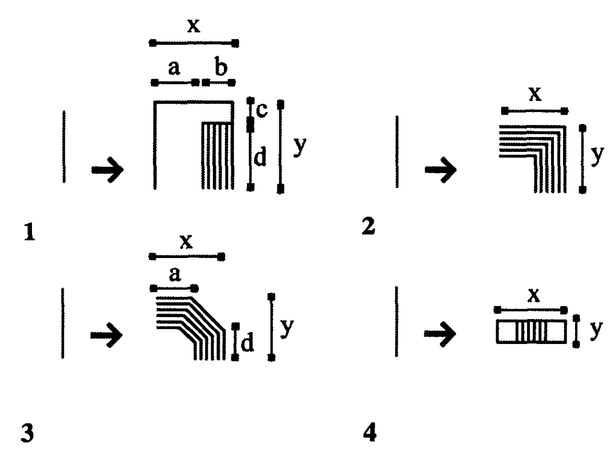


Fig. 5.14

they required thicker walls for support and many bricks to construct the vault.

5.5.5 Columns and arches

Columns support balconies, pediments, and upper floors, aligning themselves with adjacent walls. In the floor plan view the column is noted as a circle, and the assignment of its order occurs in the or in the elevation. Arches are used at barns and as entryways for loggias given a rusticated finish or half column decorations. Dimensions are noted on the derivation drawing.

Column and arch options

[5.5.5.1.ls] Column (no prescribed order)

[5.5.5.2.ls] Arch

[5.5.5.3.ls] Arch with Column

[5.5.5.4.ls] Pilaster for end condition

[5.5.5.5.ls] Arch with a pilaster

See: Section 4.9 for details on intercolumniation rules

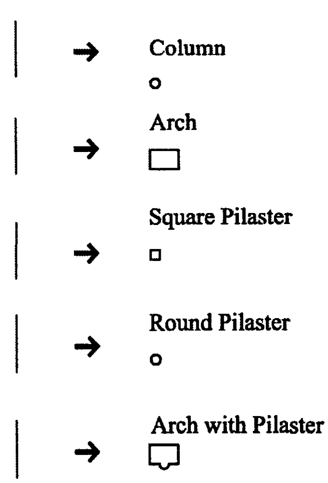


Fig. 5.15

5.5.6 Stairs

Stairs are made of brick arches covered by another set of bricks used to create a tread and riser.

Typical stair set contains a 12" tread and 6" riser. There are nine types.

Stair options

[5.5.6.1.ls] Rectangular

[5.5.6.2.ls] Triangular

[5.5.6.3.ls] Oval

[5.5.6.4.ls] Square

[5.5.6.5.ls] Straight parallel

[5.5.6.6.ls] Scissors wall

[5.5.6.7.ls] Scissors no wall

[5.5.6.8.ls] U - shaped

[5.5.6.9.ls] Spiral

See: Section 4.8 for stair details

x = stair width

y = stair height

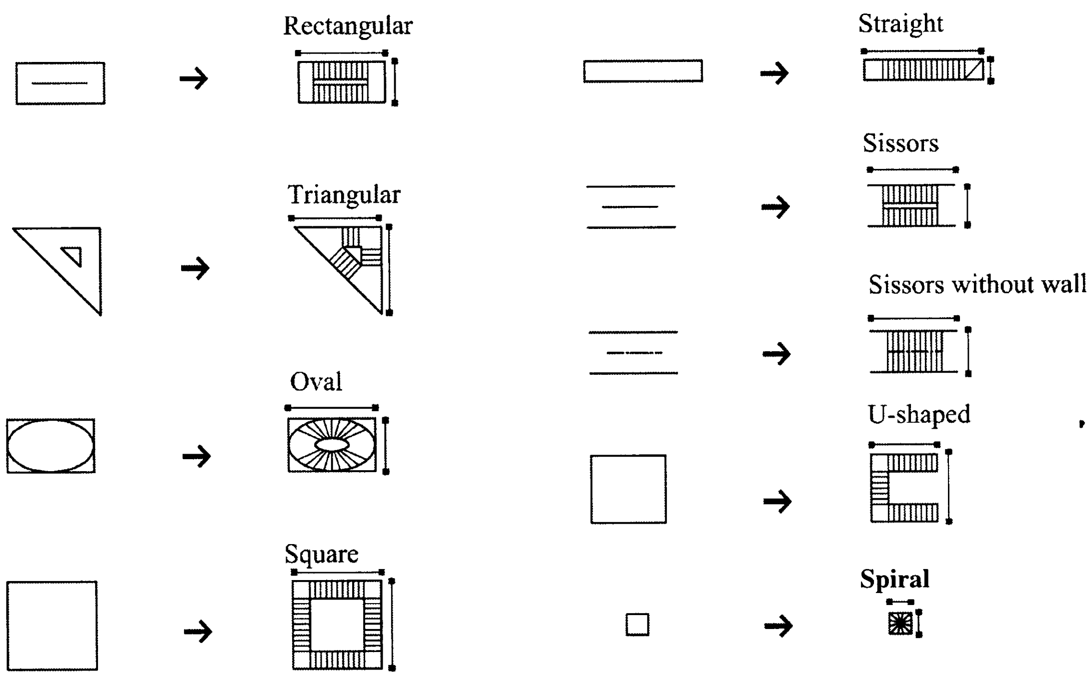

Rectangular
Triangular
Oval
Square
Straight
Sissors
Sissors without wall
U-shaped
Spiral

Fig. 5.16

5.5.7 Door notations

Separate formulas are used to find the Principle door and room doors.

Door options

[5.5.7.1.ls] Entry door (p)

[5.5.7.2.ls] Room door (r)

See: Section 4.15 for stair sizes

p = principle door width

r = room door width

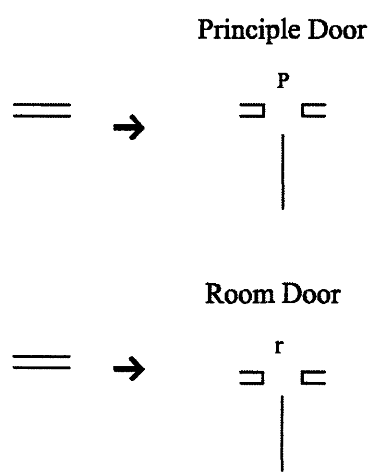


Fig. 5.17

5.5.8 Windows notations

The formula in section 4.15 determines window height and width. The options for windows are in the placement and number of windows in a space.

Window options

[5.5.8.1.ls] Center

[5.5.8.2.ls] Double

[5.5.8.3.ls] Double Hall

See: 4.16 for sizes and details

x = window width

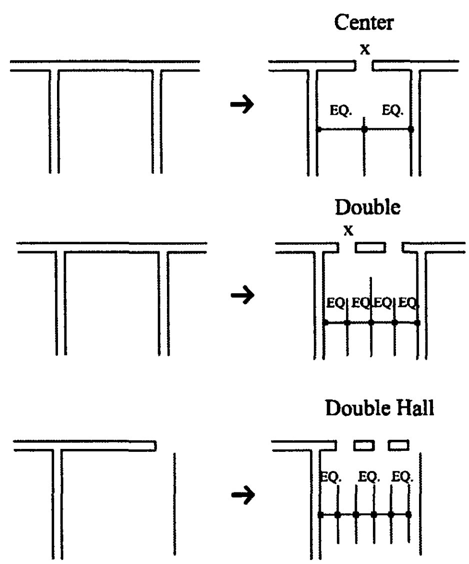


Fig. 5.18

5.5.9 Detail notations

Detail symbols are visual notations. Variables are noted on the three dimensional model.

Detail options

[5.5.9.1.ls] Fireplace

[5.5.9.2.ls] Cove

[5.5.9.3.ls] Window seat

See: 4.18 for fireplace details

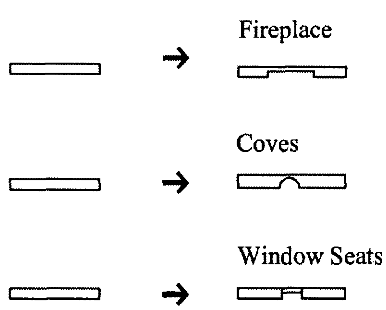


Fig. 5.19

5.6 CONSTRUCTION NOTATIONS (ELEVATION)

Palladio's elevations are pictorial representations of the plan, projecting and adding elements from the piano noble. The elevation design sketch is transformed to an informed sketch in nine steps, each focused on representing some aspect of the construction, such as wall variation and column location. Most are focused on a pictorial representation, locating window, doors, pediments, moldings and entablatures. Steps listed below for this system were taken from a survey of villa drawings in book two of the *Quattro Libri*. Most steps in this section are symbolic notations that can be applied to the initial shape and not parametric shapes.

Order of Steps (elevation)

1. Initial Shape
2. Walls and Floors
3. Cornices
4. Portico Steps
5. Columns
6. Moldings
7. Doors and Windows
8. Roof and Pediment
9. Details

5.6.1 Initial Shape

The initial shape pertains to outer most limits of the main box, or the house in the plan, and the overall height noted in the drawing from the *Quattro Libri.*

Initial Shape

[5.6.1.ls] Initial Shape

x = the width of the finished construction plan

y = the height of the piano noble and the second floor

k = the distance from the ground plane to the piano noble

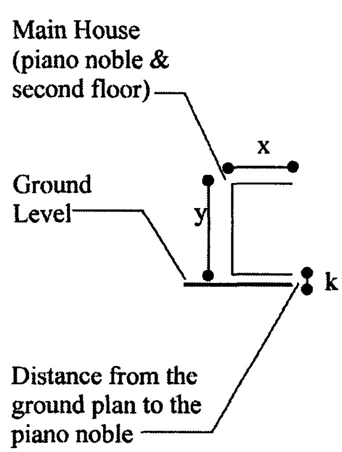


Fig. 5.20

5.6.2 Wall and Floor Notation

Walls extend outward at the basement level due to the added wall thickness, as taken from the rules on basement walls in chapter 4 on walls (fig. 4.6). Basement walls are always thicker than those at the piano noble, just as walls at the second story are thinner than the walls at the piano noble.

Wall and Floor

[5.6.2.1s] Wall and Floor Notation

See: Section 4.5 for details on wall rules and construction

c = depth of basement offset

d = depth of second floor offset

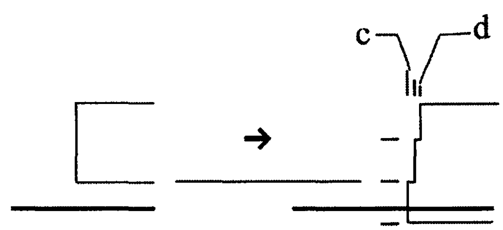


Fig. 5.21

5.6.3 Cornice

There are three cornice type selections. Each is made of brick and serves to cap the upper part of a wall that ends at the second floor or the roof.

Cornice

[5.6.3.1.ls] Cornice - A (One Stack)

[5.6.3.2.ls] Cornice - B (Two Stacks)

[5.6.3.3.ls] Cornice - C (Three Stacks)

See: Section 4.20 for cornice details and construction

y = overall depth of the cornice

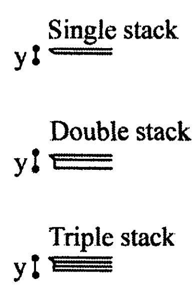


Fig. 5.22

5.6.4 Portico Steps

There are three portico elevation types to choose from. The first is the most common, containing a set of steps ending with a pedestal. The second is a straight run of stairs, and the third is an octagonal or circular set of stairs similar to the type found in the back of the Villa Pojana.

Portico Steps

[5.6.4.1.ls] Portico - A (Pedestal and Steps)

[5.6.4.2.ls] Portico - B (Stairs)

[5.6.4.1.ls] Portico - C (Stepping Stairs)

See: Section 4.8 for step details and construction

k = pedestal width

l = stair width

d = stair height

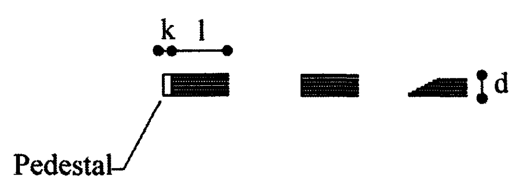


Fig. 5.23

5.6.5 Columns

Villas are created from one or more of four column types and arches. Proportions set at the base of the column should scale to the proper height once inserted into the proper location (this only applies to the elevation reconstruction and not the three-dimensional model). If stacked one on top of the other, the ordering of the columns would start with the Tuscan and end in with the Corinthian. The entablature is excluded from these elements so that different designs can be used while the column notation stays the same. Arches have no standard size hence they are inserted and adjusted by eye.

Column Notation

[5.6.5.1.ls] Tuscan

[5.6.5.2.ls] Doric

[5.6.5.3.ls] Ionic

[5.6.5.4.ls] Corinthian

[5.6.5.5.ls] Arch

See: Section 4.9 for columniation or 4.10 - 4.14 for details

d = column or arch depth

x = column width

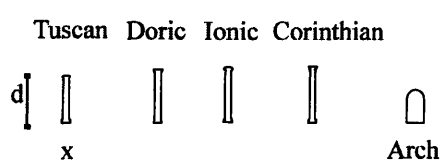


Fig. 5.24

5.6.6 Moldings

Moldings are brick or stone projecting from the outer wall, mostly used to cover joints or to offset the building's base from the ground. They are also used to shed areas of the building from water while offering a decorative touch. There are five molding types offered here each composed of bricks projecting 6" to 18" from the building's façade.

Molding Notations

[5.6.6.1.ls] Single stack

[5.6.6.2.ls] Double stack

[5.6.6.3.ls] Triple stack

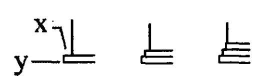
[5.6.6.4.ls] Double molding

[5.6.6.5.ls] Triple molding

See: Section 4.20 for similar construction details

x = distance of molding from wall

y = thickness of molding



Stacked Moldings

Wall Moldings

Fig. 5.25

5.6.7 Doors and Windows

Doors and windows are composed of the same rectangular shape, except for windows with an arch at the top or a window that is part of an arched system of windows. This system can be found on the backside of the Villas Foscari, Pisani, and the front side of the Villa Ragonia.

Door and Window Notation

[5.6.7.1.ls] Rectangle (window or door)

[5.6.7.2.ls] Semi circle (window)

See: Section 4.15 and 4.16 for details

x = window width

y = window height

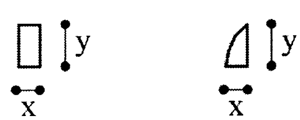


Fig. 5.26

5.6.8 Roofs and Pediments

There are three roof types and a dome. The formula for finding the slope of the roof can be found in 4.20. There are no rules for finding the height or size of a dome. The gable is typically used at the portico, the pyramid for square buildings and the hip on villas with a rectangular shaped plan.

Roof and Pediments

[5.6.8.1.ls] Hipped

[5.6.8.2.ls] Gable

[5.6.8.3.ls] Pyramid

[5.6.8.4.ls] Dome

See: Section 4.20 for details

x = depth of half of the overall roof, x/2 = roof width used in reconstructions.

y = height of roof

t = angle of roof slope

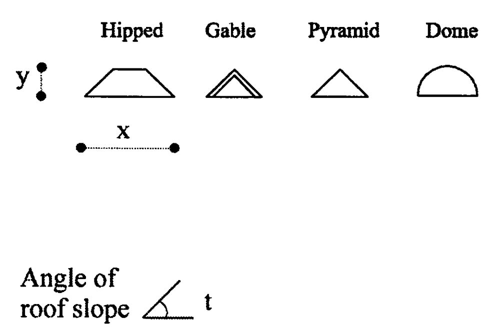


Fig. 5.27

5.6.9 Details

A Palladian elevation has many details, from simple carvings to statues on pedestals. There are window and door ornamentations, coves and half columns. In addition, here are details outside of the main building of the type found on the walls of the Foscari barns. In this study, the selection is narrowed to the most common - the pedestal and balustrades. Other shapes will be treated as a new rule in each case study.

Details

[5.6.9.1.ls] Balustrades

[5.6.9.2.ls] Pedestal

See: Section 4.1 for sizes and details

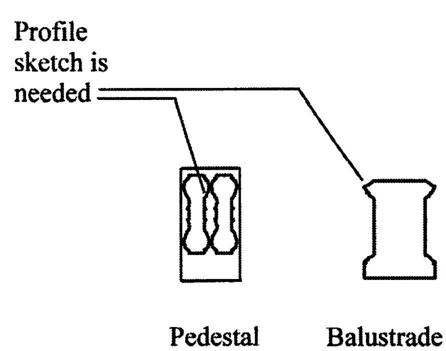


Fig. 5.28

5.7 CONSTRUCTION NOTATIONS (DETAILS)

There are eight sketch types remaining that can be applied to the detailed areas of the plan or elevation drawing. All but two sketch types (plan and elevation) are profiles of a detail that would normally be constructed of brick or stone. Palladio gives proportional notes for door and window frames, column bases, capitals and entablatures. A reference to this can be found in Palladio's sketches (fig. 5.4). He handled details such as a villa entry (Villa Pojana), dovecote (Villa Barbaro) or windows (as is the case with the dormer at Malcontenta) with special drawings. These special drawings can be handled by the three transformation systems listed above. Construction rules can also be applied to the resulting diagram.

5.8 RECONSTRUCTING THE VILLA CORNARO IN TWO DIMENSIONS

To demonstrate the reconstruction process described in this chapter, the Villa Cornaro (fig. 5.29) is reconstructed in two dimensions using shape grammars and construction notations. The goal here is to reconstruct the site plan, floor plan and elevation using the rules built this chapter. Some rules from chapter four will also be used. The theoretical basis of the reconstruction is focused on inputting Palladio's drawings into a digital form. The goal here is not to resolve construction issues through the two dimensional representation, but to input the design, record the variables and design issues. Conflicts and contradictions will be addressed in the three dimensional phase of the work.

The Villa Cornaro, Piombino is a town house villa similar in type to the Villa Rotunda in Vicenza. This villa has a central hall, three side rooms and an outer side room added after Palladio's death (as seen in Palladio's drawing from the *Four Books*). The building's plan is set close to the center of the site, but aligned with adjacent buildings.[396] This adjustment of the building's axis and off centering breaks two rules. One rule written in the *Four Books* says that the building should be placed at the center of the site [4.2.2.pa], and the other rule taken from an analysis of Palladio's other built works that says that the villa should be aligned with the street or waterway [4.2.7.ls]. Of the villas in the *Quattro Libri*, the Villa Cornaro is the closest match to the built conditions. Most of the executed buildings in the text differ dramatically from the drawings. The test here will be to see if the reconstruction process results in a three-dimensional model similar to the built condition.

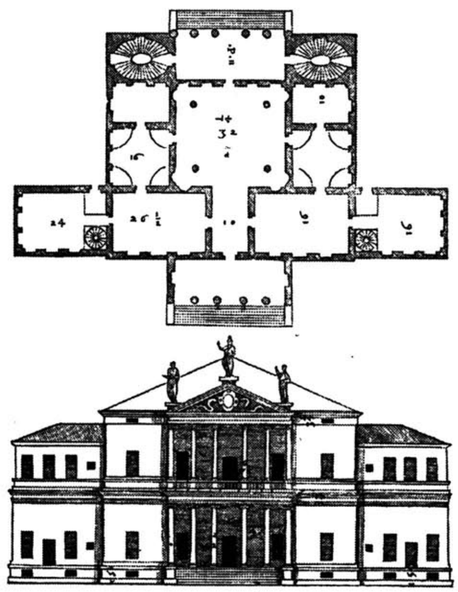


Fig. 5.29 Plan and elevation of the Villa Cornaro

396 Burns, H. p.216 Palladio's villas were aligned with the street, and not adjacent buildings.

This reconstruction will use the shape grammar rules outlined in section 5.3 to reconstruct a diagram of the plan first. Construction notations will be applied to the plan diagram to create the finished representation in both the plan and elevation drawing. The first step in the plan reconstruction will be to construct the site plan by applying site features, such as a street, property lines, etc. (fig. 5.5) and the grid (fig. 5.30) to the site plan. The given site supports the Palladian rule of centering the building in the site [4.2.2.pa]. Grid-a is applied to the site with horizontal bays set at 24', 16', and 16' to the center of the main hall. The vertical bays are set at 16', 32' and 11' (fig. 5.30).

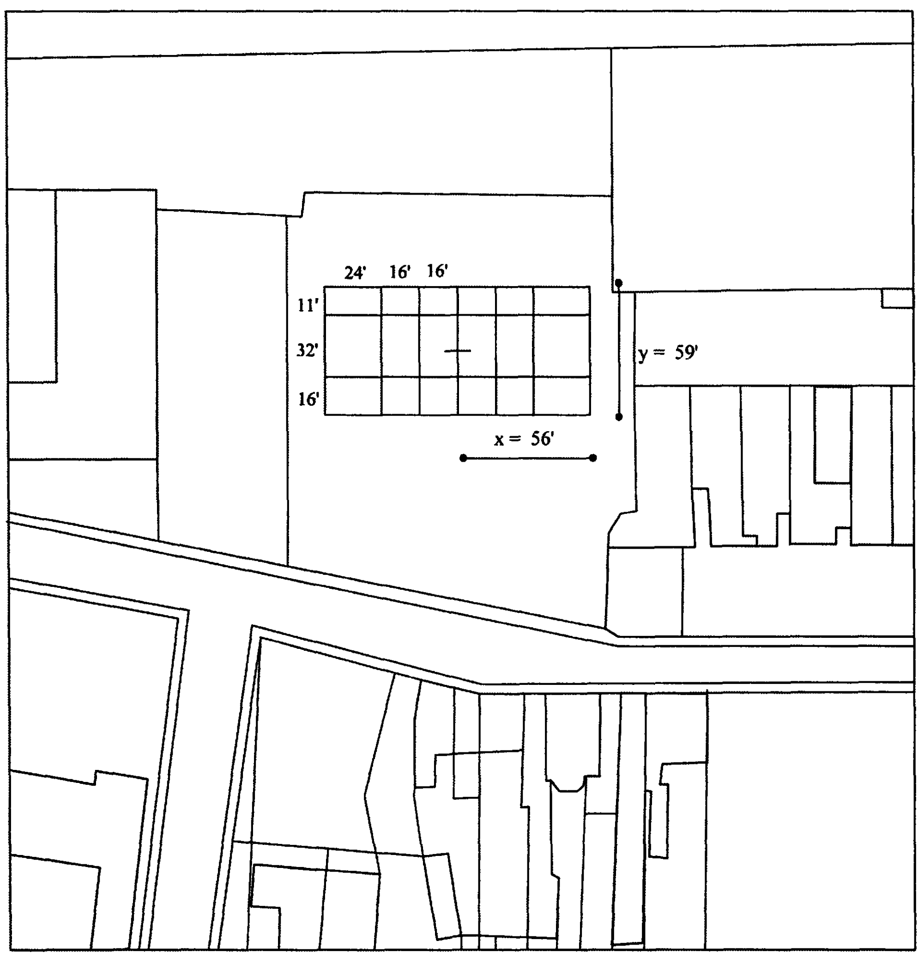


Fig. 5.30 Grid for the main house of the Villa Cornaro applied to the site

The second step is to apply shapes and shape rules from section 5.3 to the grid. The derivation will yield a plan diagram like that in figure 5.31.

The third step is the application of construction notations and rules to the finished diagram in the order prescribed in section 5.5 of this chapter. Within the nine steps of the reconstruction it was found that. Palladio breaks another rule, that being the width of the loggia. He specifies in the *Four Books* that the loggia is not to be more than twenty feet in width, however, the villa Cornaro's loggia is 32 feet on Palladio's drawing and 30 feet on the final plan or this study.[397] The final part of the plan requires the insertion of details from the predetermined set (fig. 5.28).

The last step is to reconstruct the elevation from the line and symbol representation on the plan. As mentioned earlier, it is possible to build most of the elevation from the plan drawing. In this case, Palladio's elevation is needed to define moldings and roof forms. There are nine steps starting with the volume of the main house. Rules from the first book help to define object heights and widths such as the walls that project from the piano noble. These walls for the basement project 9" from the face of piano noble, while walls at the second level are recessed 6," or the depth of half a brick.[398] Each step in the elevation reconstruction is a mixture of information taken from the plan and Palladio's elevation drawing (fig. 5.29). The final drawing is a measurable reflection of the rules from chapter four combined with graphic information from this chapter.

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[397] Palladio, A. 1965 Palladio writes that the loggia is not be made less than ten feet wide nor more that twenty. Bk1, Chap 21, par 2
[398] Palladio, A., 1965 Bk1, Chapter 11, par 1

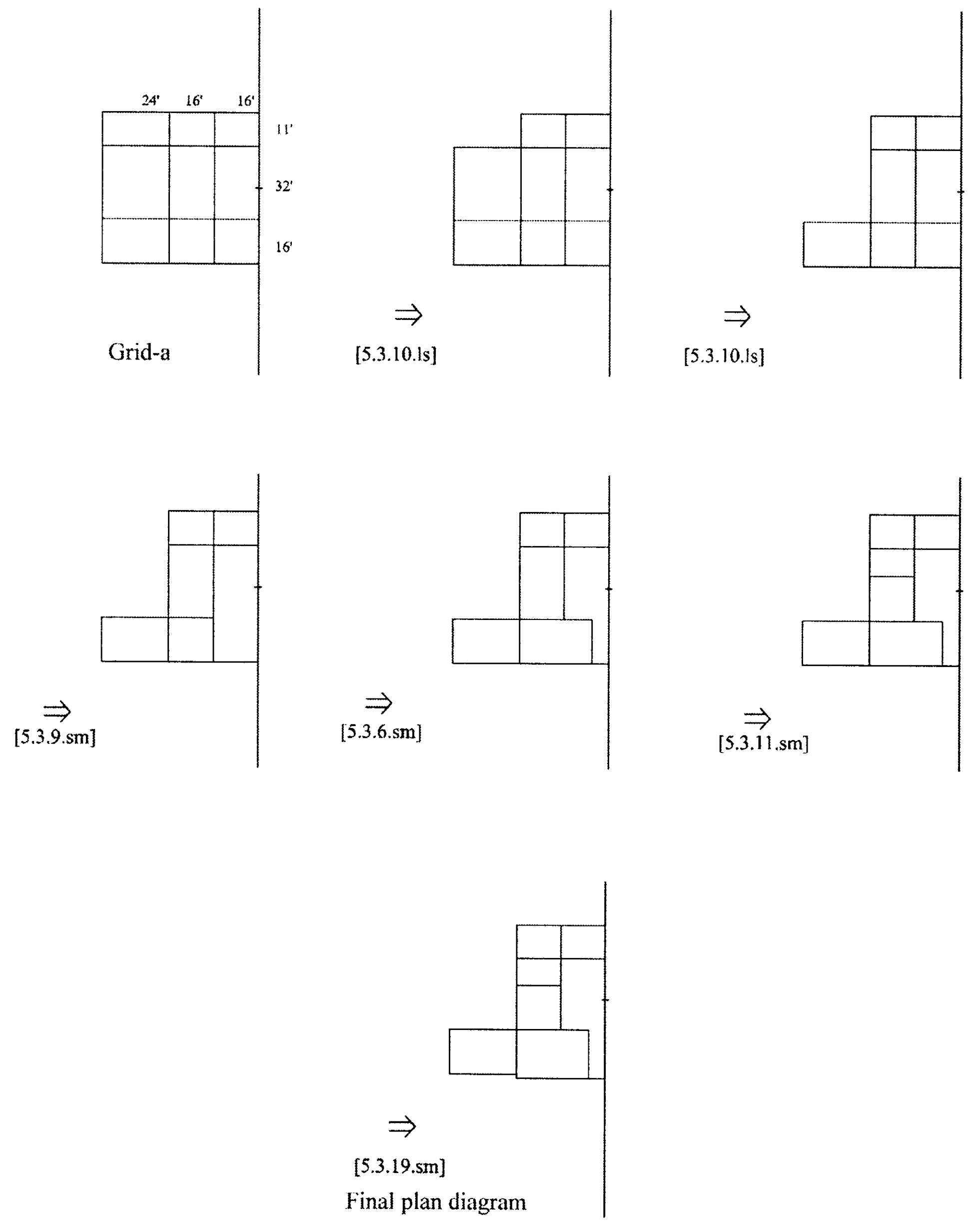

Fig. 5.31 Shape rule derivation of the plan diagram

Fig. 5.32 Plan reconstruction derivation

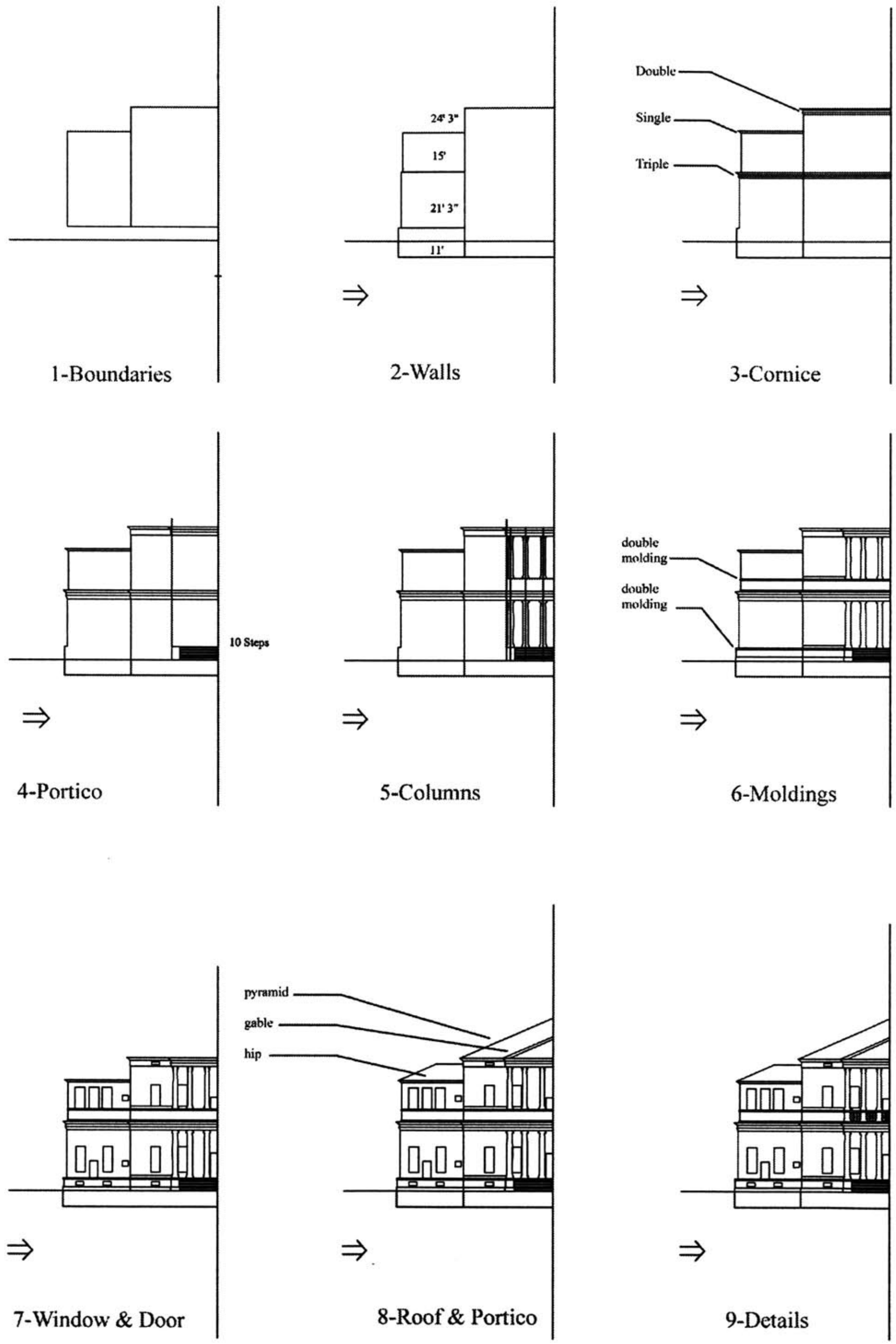

Fig. 5.33 Elevation reconstruction derivation

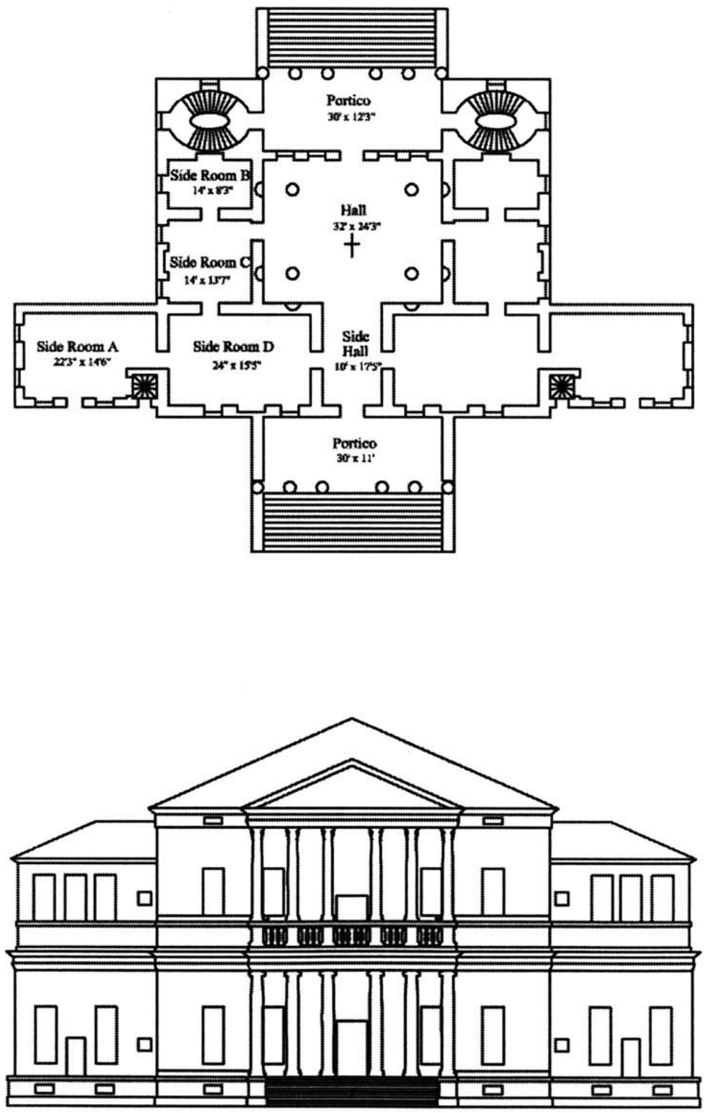

Fig. 5.34 Resulting plan and elevation

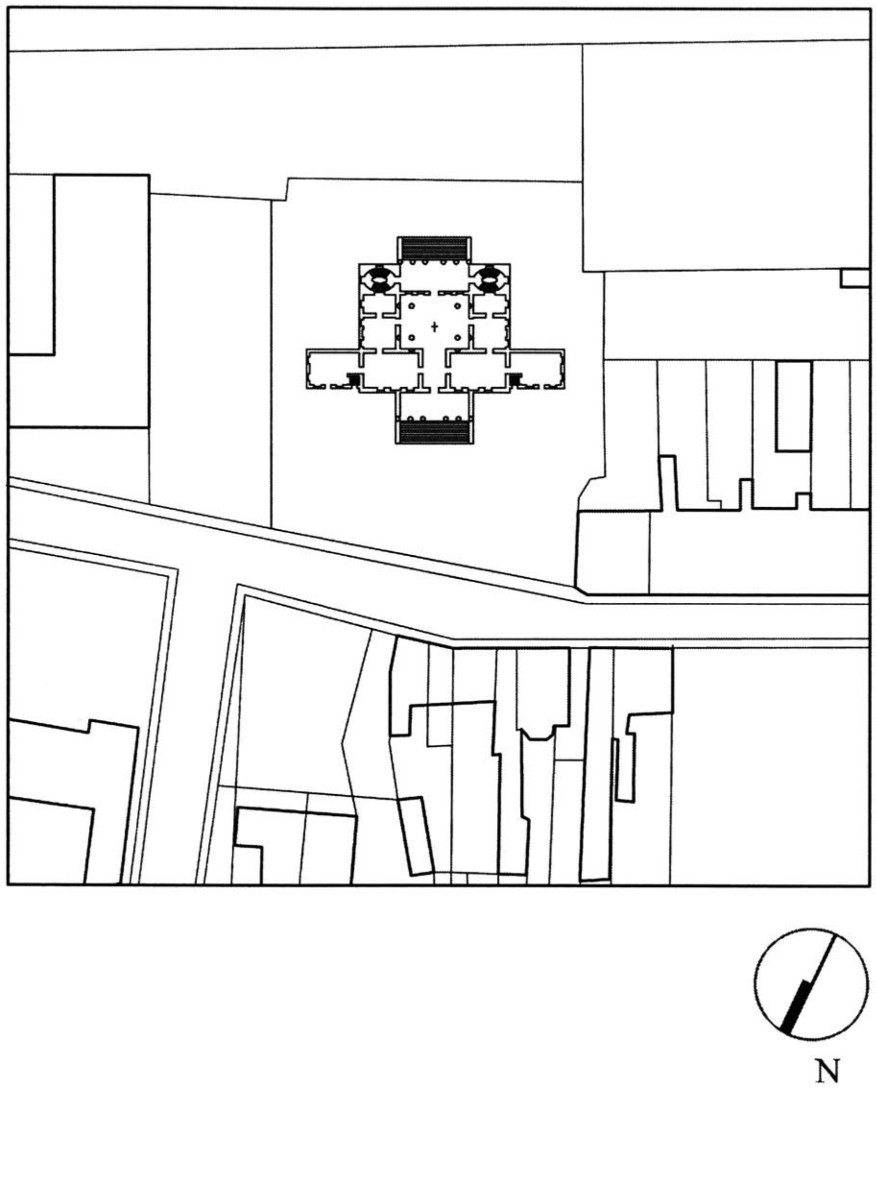

Fig. 5.35 Final site plan

5.9 CHAPTER SUMMARY

This chapter was a presentation of two reconstruction systems - shape grammars and construction notations - with an emphasis on the second. Each of the two can be used to transform Palladio's loosely sketched drawings into two-dimensional CAD representations, needed to make the three-dimensional model. The chapter also claims that Palladio had 10 loose sketch types that can be transformed using shape grammars into a hard lined drawing known as the plan diagram initial plan diagram. The two grammar systems were used to reconstruct the floor plan and elevation drawings of the Villa Cornaro. The final reconstruction differed slightly from Palladio's drawing in the *Four Books*, this is necessary to proceed to a three-dimensional model. The next chapter defines the three-dimensional aspects of the villa.

Summary of the 2D process

1. The owner provide the architect with the initial site shape, and a grid(s) is placed on the site
2. Shapes and shape rules are applied to the site grid
3. Construction symbols are applied to the plan diagram to create a finished plan
4. Construction symbols are used to reconstruct the elevation from an initial shape

LIST OF FIGURES

APPENDIX

VILLA CORNARO, PIOMBINO DESE

LIST OF TABLES

Table 5.1 Site and Floor Plan Rules

rules	element	function	variables & equation	fig.
0-Site Plan				
4.2.1.pa	site	assignment (general villa)	-	-
5.3.3.ls	site	assignment (street)	-	5.5
4.2.7.ls	grid-a	assign grid -a to site	x = 59' y = 56'	5.4
4.2.6.ls	grid-b	rotation of shape (broken rule)	0 degrees	5.30
1-Plan				
5.5.1.1.ls	rectangle	assign main hall	32' x 26'	5.24
5.5.1.2.ls	rectangle	assign inset portico	16' x 12'	5.24
5.5.1.3.ls	rectangle	assign extended portico	NA	5.24
5.5.1.5.ls	rectangle	side rooms	varies	5.24
5.5.1.6.ls	rectangle & oval	assign front and back stairs	varies	5.24
4.4.4.1.pa	rooms	mirrored	-	-
4.4.6.2.pa	stair	placement	-	-
4.4.11.ls	lines	initial wall thickness	-	-
2-Ceilings				
5.5.2.1.ls	symbol - flat ceiling	assignment	varies	4.8
5.5.2.2.ls	symbol - flat vault	assignment	varies	4.10
5.5.2.3.ls	symbol - barrel vault	assignment	varies	4.17
5.5.2.4.ls	symbol - dome/lunette	assignment	varies	4.23
3-Walls				
5.5.3.1.ls	wall thickness	assignment	18"	5.13
5.5.3.2.ls	wall thickness	assignment	24"	5.13
4.5.10.ls	wall thickness	assignment		
4.5.11.ls	wall thickness	assignment		
4.5.12.ls	wall thickness	assignment		4.4
4-Portico				
5.5.4.1.ls	stair		a=12' b=10' c=3' d=15'	5.14
4.4.2.1.pa	loggia	assignment		
4.8.14.ls	riser & tread	size	ri =6" ti =12"	4.25
4.4.2.2.pa	portico	size (broken rule)	portico < 20'	
5-Column				
5.5.5.1.ls	column	assignment	24" diameter	5.15
5.5.5.5.ls	arch & plaster	assignment	-	5.15
4.9.10.1.pa	column	even number of columns	-	4.13
4.9.10.2.pa	column	middle column space larger	-	4.35

rules	element	function	variables & equation	fig.
4.9.16.ls	pilaster	size	s=6' p=3' s/3<p<2(s/3) 2'<3'<4'	4.35
6-Stairs				
5.5.6.3.ls	oval stair	assignment	-	5.16
5.5.6.9.ls	spiral stair	assignment	-	5.16
4.8.1.pa	stair	location	-	
4.8.2.1.pa	stair	location	-	
4.8.3.1.pa	stair	openings	-	
4.8.13.ls	stairs	span walls	-	4.27
4.8.14.ls	riser size		ri=6" tr=12"	4.25
7-Doors				
5.5.7.1.ls	principle door	assignment	-	5.17
5.5.7.2.ls	room door	assignment	-	5.17
4.15.2.1.pa	principle door	size	-	
4.15.3.pa	principle door	location	-	
4.15.4.pa	room door	size	-	
4.15.5.ls	room door	size	e=18 a=5'1"	4.45
4.15.6.ls	room door	size	e/3.5=a 18/3.5=5'1"	
8-Windows				
5.5.8.1.ls	window center	assignment	-	5.18
5.5.8.2.ls	window double	assignment	-	5.18
5.5.8.3.ls	window double hall	assignment	-	5.18
4.16.5.ls	window location	assignment	-	
4.16.6.ls 4.16.9.ls	window variables (width)	size	d1= 3'6" d2=3'6" b =16'	
4.16.7.ls	window typical	size	b\4.5 = d1 16/4.5 = 3'6	4.50
9-Details				
5.5.9.1.ls	fireplace	assignment	-	5.19
5.5.9.2.ls	cove	assignment	-	5.18
5.5.9.3.ls	window seat	assignment	-	5.18
4.19.1.ls	fireplace	location	-	
4.19.2.ls	fireplace	location	-	
4.19.4.ls	fireplace	size	l = 5' d =18"	4.50

Table 5.2 Elevation Rules

rules	element	function	equation variable	fig.
1-Bound.				
5.6.1.ls	initial shape	assignment	x = 56'9" y = 45'6"	5.20
2-Walls				
4.5.2.pa	walls - piano noble	sizing	c = 9"	5.21
4.5.3.pa	walls - second story	sizing	d = 6"	5.21
4.5.7.pa	walls foundation	sizing		4.6
5.6.2	wall	assignment		5.21
3-Cornice				
5.6.3.1.ls	cornice -second story	assignment & size	y = 12"	5.22
5.6.3.2.ls	cornice - second story	assignment & size	y = 3'4"	5.22
5.6.3.3.ls	cornice -first story	assignment & size	y = 3'4"	5.22
4-Portico				
5.6.4.1.ls	pedestal & step	assignment & size	k = 2' l = 15' d = 5'	5.23
4.8.13.ls	stairs	span walls		4.31
5-Columns				
5.6.5.3.ls	Ionic column	assignment & size	d = 18' x = 24'	5.24
5.6.5.4.ls	Corinthian column	assignment & size	d = 16' x = 24'	5.24
4.9.1.2.pa	column	location		
6-Molding				
5.6.6.4.ls	molding	assignment & size	x = 6" y = 9"	5.25
7-Wind & Door				
5.6.7.1.ls	rectangle	assignment		5.26
4.15.5.ls	rectangle (principle door)	variables	a=5'1" y=10.2 b=9'4"	
4.15.7.ls	rectangle (principle door)	size	y=2a b=a-y/12 10.2=2(5.14) 9.35=10.2-10.2/12	
4.16.4.1.pa	window	location		
4.16.4.2.pa	window	size		
4.16.6.ls	window (height)	variables	h1=9'8" b=16' d1=3'6"	4.46

			h2=8'	
4.16.7.ls& 4.16.10.ls	window	equation	h1=(2(d1))+b\6 9.7=(2(3.5))+16\6 h2=h1-h1\6 8.09=9.7-9.7\6	4.46
8-Roof				
5.6.1.ls	pediment	assignment & size	x =37'8" y =8'4"	5.27
5.6.2.ls	roof	assignment & size	x =68'9" y =15'3"	5.27
5.6.3.ls	roof	assignment & size	x =24'4" y =6'3"	5.27
4.19.7.pa	roof	slope	t =23.9	4.59
9-Details				
5.6.9.ls	balustrade	assignment		5.28
5.6.9.ls	pedestal	assignment		5.28

CHAPTER SIX

VILLAS IN 3D

6.0 RULE, DRAWINGS AND MODELS

Ulrick Flemming wrote a paper on reconstructing Queen Anne houses in 1986 that defined the building's style through the use shape grammars. The grammar has two basic functions. The first defines the spatial layout in two dimensions, and the second applies an extrusion rule to two-dimensional shapes to create a three-dimensional part.[399] In his case, any two-dimensional shape marked with an "x" was extruded, resulting in a three-dimensional object.

In this study, a similar process was followed, but in more detail. One-dimensional rules (from chapter 4) are applied to two-dimensional drawings (from chapter 5) to create a three dimensional CAD representation. This chapter will serve as a demonstration for the two case studies to follow by reconstructing the Villa Cornaro as per Palladio's drawing in the *Four Books.* As mentioned earlier in chapter 5.2, most of Palladio's villas can be created from rules applied to the floor plan. The elevation is used to define measurements vertical dimensions missing from the floor plans. For example, the distance from the floor to the bottom of the windowsill is a dimension missing from the plans and the rules in chapter 4, and the elevation is the only place to find this measurement. To demonstrate I have included a list of items taken from the elevation drawing used to reconstruct the Villa Cornaro at the end of this chapter. The villa drawing is very similar to the built building, so in theory the final model should be the same if not similar to the built condition.

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[399] Flemming, U., 1986 p. 337 In his paper the rule says that a shape marked with an x is to be

All but 10 decisions used to construct the model were taken from the plan. Here is a list of the few materials taken from the elevation used to build the villa model:

1 - Height of side room (15'-0")

2 - Height of basement (11'-0")

3 - Height of first floor (21'-4")

4 - Height of second floor (24'-3")

5 - Distance between the floor and the base of the window sill

6 - Cornice thickness

7 - Column types

8 - Basement and attic window heights

9 - Molding types

10 - Roof type

Documenting the events of this section of the reconstruction process differs from the two-dimensional method used in chapter 5, in that the reconstruction of the plan and elevation involved a top down decision process - one that breaks the whole into parts and adds new parts or rearranges the existing parts. The three-dimensional reconstruction is more bottom-up, where a rule is applied to lines or objects, that are also combined with other parts or lines to make the whole. Conflicts in the rules arise when fitness requirements assigned to newly combined objects. If the object does not fit, modifications are made to the object or rule in order to meet that fitness requirement. Meeting a fitness requirement creates a vast amount of data, in my case in drawing form, which is difficult to sort and present.

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extruded.

There are many decisions involved in the translation from two-dimensions to three: this study will attempt to present as many of them as possible. The challenge presented in the two to three-dimensional translation process is analogous to the challenge faced by a mathematician presenting a proof. One must take an equation that demonstrates each step in detail and reduce the solution to a simple equation, with out loosing too much detail and clarity in the process. This chapter seeks a balance between providing the details of the reconstruction, and simplifying the notations involved in the process.

Another challenge to the two to three-dimensional translation process is the fact that Palladio omits certain critical information that is necessary to create the three-dimensional object, and uses linguistic terms that assume a knowledge of the culture of that time period. *The Four Books of Architecture* were written with the assumption that the reader had the knowledge and skills of a 16th century mason in Italy.

In spite of the omission and contradictions in the *Four Books*, Palladio was an exception to the norm of his time as an architect who documented his work in graphically and in text. Historically, architects have created models and drawings more as stage sets than as scientifically explained and recorded products. This study builds on Palladio's groundwork, creating a three-dimensional product that differs from the typical architectural "virtual stage set" model by being an academic reconstruction - i.e. documented, and therefore replicable.[400]

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[400] Burns, H 1975. Here scholarly reconstruction process is one where all steps are recorded-scientific method. Burns refers to this point in a wooden reconstruction of the villa Trissino Meledo. He says that the model can not be used for scholarly study.

6.1 MODEL CONSTRUCTION

The *Queen Anne Grammar*[401] and the *Frank Lloyd Wright Grammars*[402] use parametric grammars to specify shapes in the styles of the architects. The difficulty with the use of these grammars here is that the origin of the sizes for the shapes is unclear. There is little documentation defining the sizes of the objects and the reasoning behind their fitness requirements.

To address the issue, this study created a spreadsheet will be used containing variables missing from the drawings and generated a different list of the twelve steps necessary to construct a villa model from the two-dimensional representations. Each step requires sizing and location information from the plan and elevation. Just as with the Queen Anne grammar, a building part is assigned a set of variables also listed on a spreadsheet (see appendix). These variables are defined differently with each case study. The rule application developed here is not formed from many pre made objects that are combined to make a final product, but formed from procedures and profiles designed in the Palladian style.

Order of Steps (3D model)

1. Initial plans
2. Walls
3. Ceilings
4. Cornice
5. Portico
6. Staircase
7. Columns

---

[401] Flemming, U. 1987

8. Moldings

9. Doors

10. Windows

11. Details

12. Roof

6.1.1 Initial Plans

The villa model process starts by applying rules to extrude the initial floor plan. Since the wall rules vary with the thickness of the floor, there is a different plan for each floor. Before the extrusion can happen, the wall width at each floor must be determined as per Palladio's rules on wall width at the various levels. Structurally walls are predominately in compression, so they should diminish as they rise, meaning the plans at the bottom floors will have thicker walls than those at the top floors.

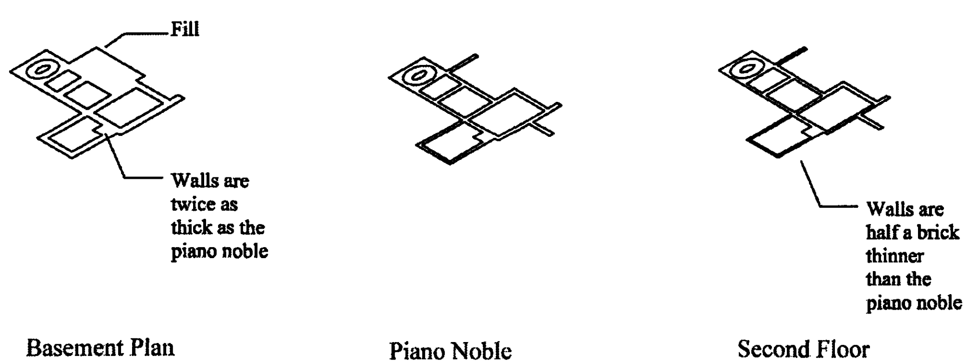

Fig. 6.1 Results of plan derivation

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[402] Koning, H., 1981

6.1.2 Walls

Walls are extensions of the plan with a few variations. The rule states that the second story walls are a brick thinner in some spots, and the basement is twice as thick in all places except for the inside of the stair. The second story of the outer wing and the height of the second floor of the main house is a violation of Palladio's rule. There is a rule in chapter twenty-three of book one that states that the ceilings in the rooms above the piano noble should be a sixth part less in height than those below. It is unclear whether the formula is specific to the rooms above flat ceilings only, or if this rule pertains to the vaulted areas as well. In this case, the second floor side room is 9'-3" shorter than the extension of the walls.[403] See Section: 4.5

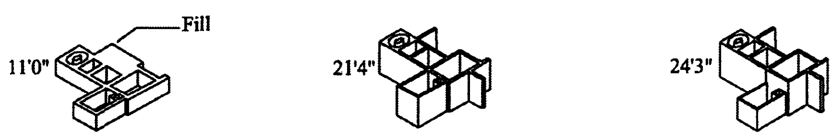


Fig. 6.2 Results of wall derivation

[403] Palladio, A., 1965 p. 28

6.1.3 Ceiling, vaults and floors

The Villa Cornaro is composed of four ceiling types; a flat ceiling, barrel vault, flat vault and a dome vault with lunettes. See Section 4.7

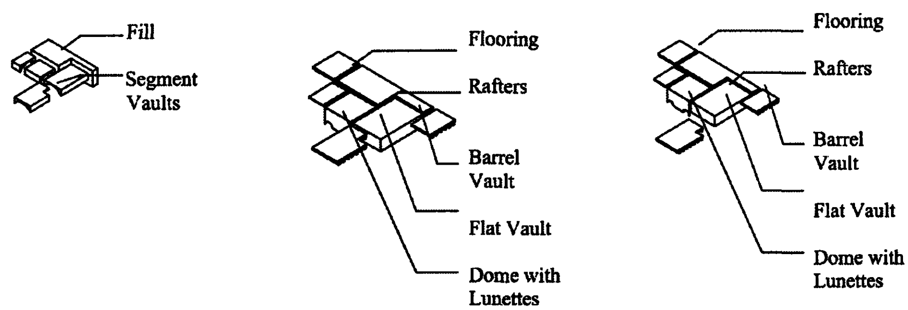


Fig. 6.3 Results of ceiling derivation

6.1.4 Cornice

There are four different cornices protecting the upper and lower level walls. To define profile shapes a logical principle could say that the cornices are to follow the order of the column type. Therefore the first story profile would be the shape of the ionic order and the upper story in the

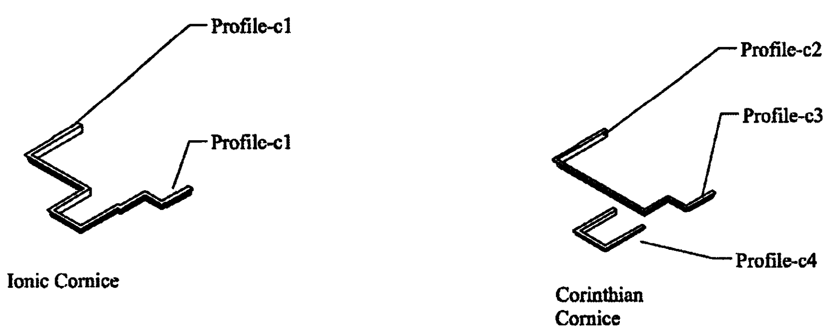


Fig. 6.4 Results of cornice derivation

Corinthian order. Photos of the existing conditions demonstrate this at the piano noble and a similar profile at the second story. Each floor has a partial extension of the cornice at the loggia to announce the entry. At the top level, the cornice profile follows the Corinthian order at the loggia and simplifies as it raps the wall with a flattened version of the entablature. This was a detail picked up in the drawings and the built condition. The profile of the cornice is documented in chapter 7. See Section 4.20 for construction details

6.1.5 Portico & Steps

It can be assumed that the space under the portico was used as a pantry or general storage. The portico requires a vault supported floor and a vault supported set of stairs which start six feet above the basements floor. See Section: 4.8 for steps

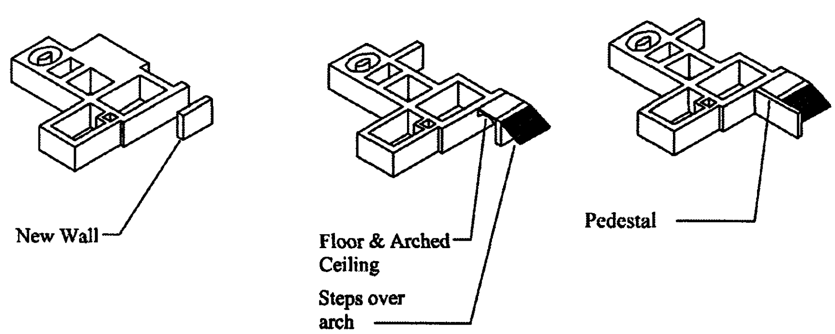


Fig. 6.5 Build up of porticos (rear portico not in view)

6.1.6 Staircases

There are two stair types, both circular in design, but different in construction. The staircase in the front of the villa is a spiral service stair most likely of the type found in a palace, which is a very narrow stair in which each riser rests on the riser below. The staircase in the back is a standard stair constructed of brick arches and brick treads (fig 4.26). See Section: 4.8

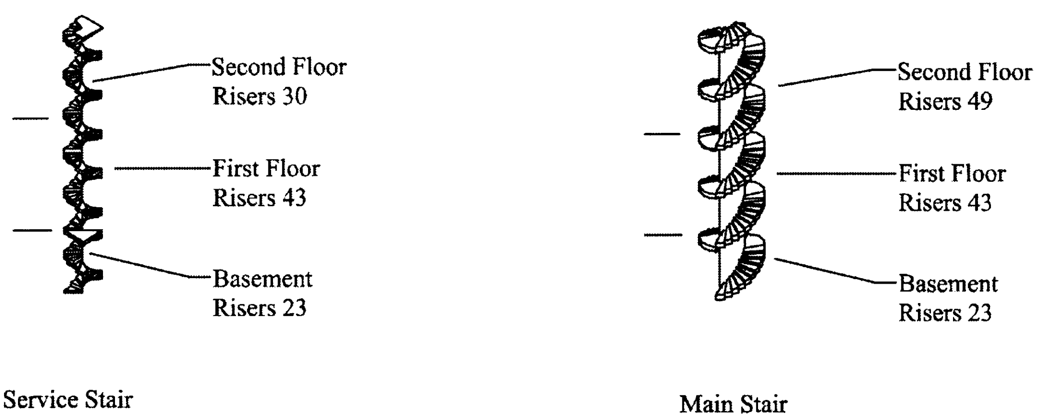
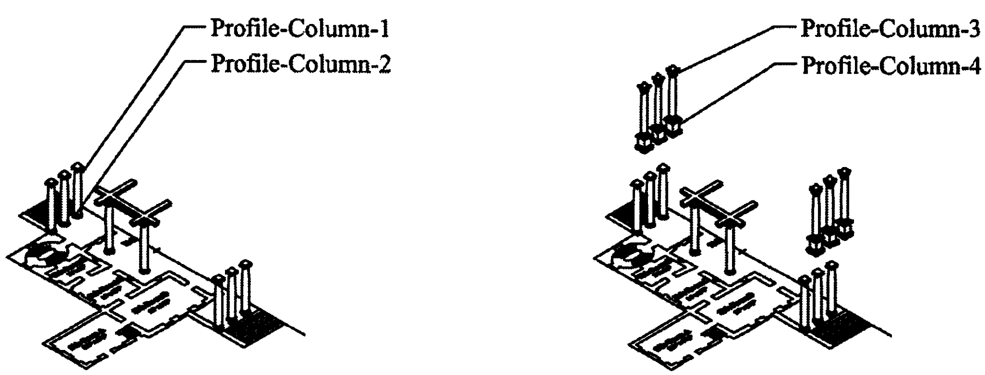


Fig. 6.6 Staircases: service stair in front room and rear stair

6.1.7 Columns and Arches

In this case, columns are conceptually pre made building components inserted and scaled according to the space between the portico or hall floor and the architrave. The shaft of the column is not scaled, and in many cases it is necessary to construct a new column shaft using the rules found in section 4.9 of this text. The conflict was that the columns did not line up in the model as per the drawing in the *Quattro Libri*. Palladio's drawing required the column to be partially inserted into the exterior wall at the end column, the entablature above and the stairs conflicted with this rule. See Section 4.9, 4.11, 4.13



Ionic Order

Corinthian Order

Fig. 6.7 Interior and exterior columns, as well as the molded joist at the main hall

6.1.8 Moldings

There is not much written on moldings or how they are to be used in a building. Palladio talks about them as visual elements used to fill joints between the floors in chapter eleven of book one. This section states that "the discharged part or set-off which is on the outside may be covered with a fascia and a cornice; which surrounding all the building, will be both and ornament and a kind of bond to the whole." This is in reference to the stair stepping at the joints of the exterior walls. Sizes of the exterior moldings are speculated. See Section 5.6.6

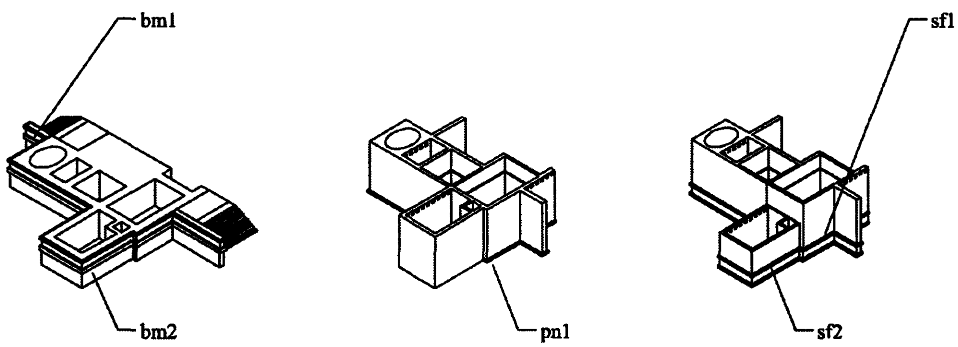


Fig. 6.8 Exterior moldings at basement, first and second stories

6.1.9 Doors

Dimensions for the principle door were found during the reconstruction of the elevation. Rules for the sizing of interior doors are found in chapter twenty-five of the *Four Books.* There is no set size for a room's door width or height. See Section 4.15

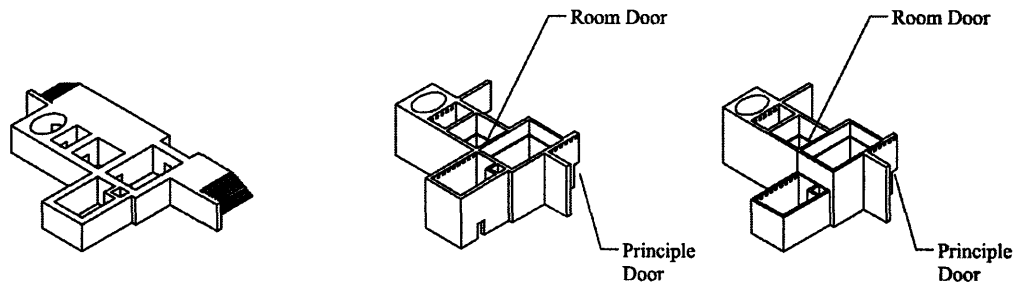


Fig. 6.9 Door subtraction

6.1.10 Windows

There are four window types in this villa; basement windows, first and second story windows and a service stair window. Of these, windows on the piano noble are the only ones to have an associated rule. The final size of the windows at the second story differs from the reconstructed elevation (which was 9'8"). The final size of the second story window is 7'6".

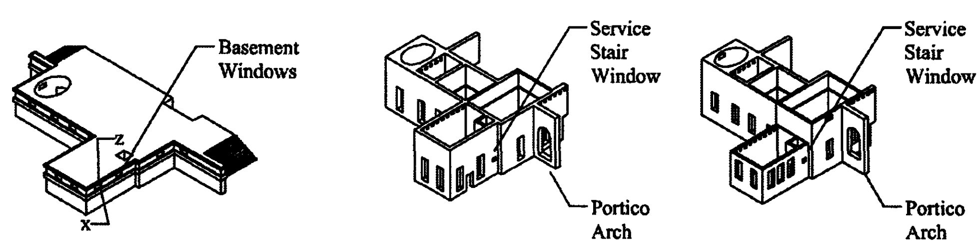


Fig. 6.10 Creation of window openings

6.1.11 Details

There are three details associated with this villa; balustrades, coves, door ornamentation and fireplaces. The *Four Books* do not have rules for their construct. Sizes and notations are taken from Bertotti Scamozzi and photographs. See Sections 4.17, 4.18,4.19

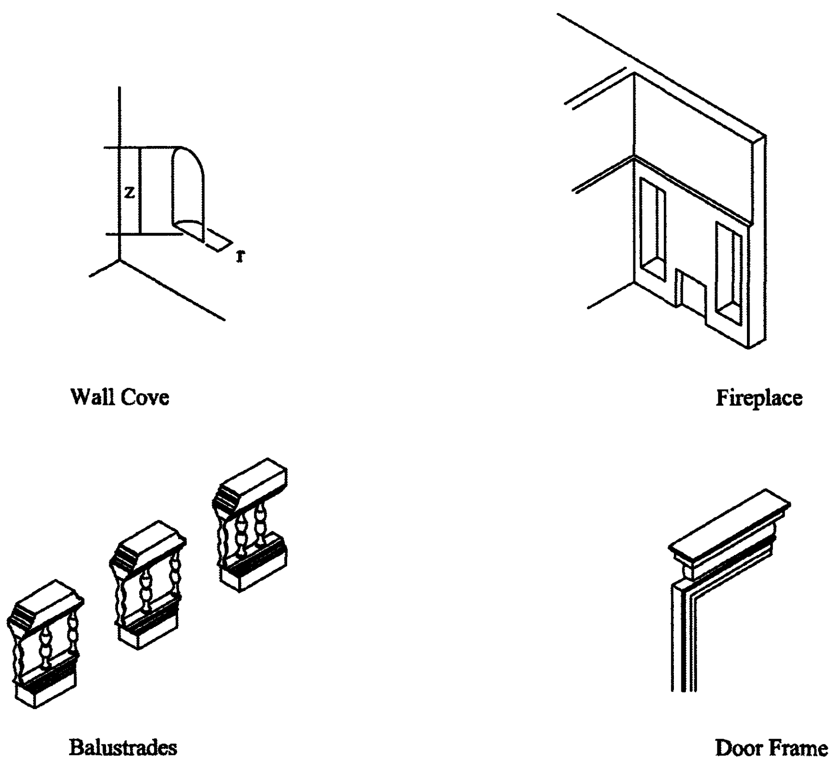


Fig. 6.11 Details

6.1.12 Roof & Pediment

There are three roofs of different shapes with the same pitch. The pitch of the roof should be two parts of the breath of the roof. The confusion comes from trying to determine whether to use a pyramid roof as in Palladio's drawings or to use a hipped roof as in Bertotti Scamozzi's drawing.[404] The pediment is of the same order as the column entablature. Here the roof follows Palladio's drawing, which shows a pyramid style roof supported by a series of rafters. The only rules related to the rafters are that they rest on the walls of the main house.

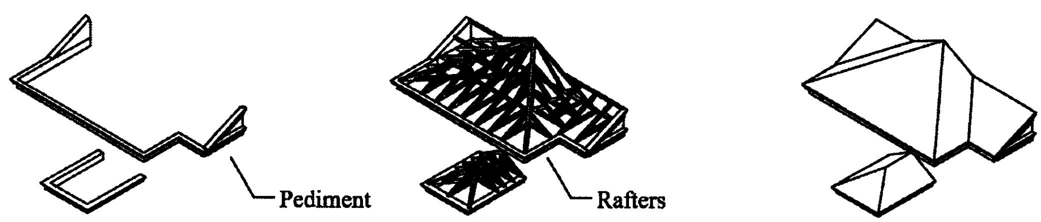


Fig. 6.12 Roof buildup from pediments to the final covering

[404] Bertotti Scamozzi, B. 1719

6.2 MODEL RESULTS

The final result or product is a three-dimensional representation of rules and decisions (fig. 6.13). There were many conflicts and contradictions in the process, mostly between the elevation and the final model. They occur when two or more objects meet and a conditional procedure has not be stated in the original rule set as to how to handle the conflicting parts. For example, the collision between the entablature, upper level columns and the wall. Here the drawing requires that one quarter of the column be inserted into the wall that places the center of the columns on the same plane as the wall. The rule for the entablature requires that the entablature to be offset from the wall by 10"-12." The conflict is that the entablature is also required to be aligned on center with the columns, yet extend itself from the center of the columns. In the end, this requires many hours of remodeling in order to meet the conditions of the conflicting joint. These conflicts are resolved at the detail level in the form of enlarged renderings or enlarged 3D prints.

6.3 THE FITNESS TEST - CONSTRAINTS IN THE THIRD DIMENSION

Little has been written on the issue of fitness requirements and rule, which are critical to the reconstruction process. The process of the reconstruction begins and ends with issues of fitness, also referred as a constraint model.[405] Starting with the site and ending with a pyramid style roof that must fit atop a set of villa walls, creating a three-dimensional model is loaded with constraints. In the end, fitness requirements determine the extent of the design problem. In this study fitness pertains to two or more objects that come in contact with other objects, requiring that one or more objects fit inside, next to, along side of or between two or more objects.[406] There are also degrees

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[405] Gross, M 1987
[406] Ibid., p. 95

of fitness based on accuracy, as in the case of the roof rafters. (fig.4.12) The fitness requirements are focused on a definition of the rafter based on structural loads, the shape of the space between the roof and the top of the wall. Each rafter section is made of three to four smaller members bearing loads on each other. The farther from the corner the more members a section will contain. In addition the angles of each member must support the vertical forces of the roof and the rafters must be placed 6' to 8' apart. The problems found with generating the roof rafters was that in most cases, a formula used for the creation of one roof rafter did not work for others. Each rafter was constructed independent of the other. Although the fitness requirements were clear for all, many conditional rules will be needed to create a clear system for constructing all of the roof rafters in one computation.

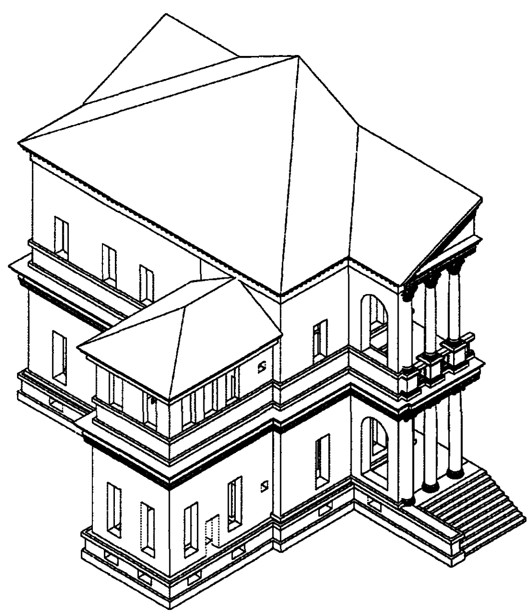

Fig. 6.13 One half of the final model

Finally, dimensions of spaces or objects applied to the three-dimensional representation did not match those noted on the two-dimensional representation. For example door and window sizes differed between the elevation drawing and the three-dimensional model. The model required them to be smaller to account for ceiling rafters and lintel stones used to support openings.

Summary of Conflicts

1. Defining the intentions of Palladio's rules
2. Notation of construction variables
3. Quantity of data presented in the study
4. 3D fitness requirements
5. 2D to 3D translation

6.4 SUMMARY OF RECONSTRUCTION PROCESS

The evolution of the 2D - to - 3D process began with a reconstruction of the site, followed by the use of a shape and construction system to reconstruct the plan and elevation, followed by an application of rules to the plan, resulting in a villa model. While most parts were extrusions of the floor plan, other parts were inserted and scaled or created anew. Conflicts resulted from fitness requirements for objects such as roof rafters, balustrades and profiles. The resulting model appears to have little conflict with built condition or Palladio's drawing. The evaluation process in the next chapter proves otherwise.

LIST OF FIGURES

APPENDIX

VILLA CORNARO, PIOMBINO

LIST OF TABLES

Table 6.1 Modeling Rules

rule	element	function	variables & equations	fig.
1-Plans				
4.5.7.pa	foundation walls	Double wall thickness of piano noble		6.1
4.5.3.pa	second story walls	Reduction of floor plan walls by 6'		6.1
2-Walls				
4.5.2.pa	walls diminish			6.2
4.5.7.pa	foundation walls	extrusion of basement plan by 11'-0" extrusion of piano noble plan by 21'-4"		6.2
4.5.3.pa	second story walls	extrusion of halls and side room by 24'-3" extrusion of side room by 15'-0"		6.2
4.5.15.ls	wall variables		0f=36"-48" 1f=18"-24" 2f=12"-18"	6.2 4.3
3-Ceilings				
4.6.2.3.pa	ceiling thickness	creation of rafters creation of flooring over rafters	f=18" j =12"x12" j2=18"	4.7
4.7.11.ls	segmented vault	creation of four segmented vaults in basement - extrusion of room fill by 11'-0"	f = 6" v = 3'-6" r = varies	4.23
4.7.7.2.ls	flat vault	creation of flat vault	v1 = 6'-0" v2 = 6'-0" r1 = 10'-0" r2 = 10'-0"	4.10
4.7.8.2.ls	barrel vault	creation of barrel vault	f = 1'-0" r = 5'-3"	4.15
4.7.10.2.ls	dome & lunette	creation of dome vault with lunettes	f = 1'-6" v = 7'-0' r1 = 6'-2" r2 = 1'-6"	4.22
4-Cornice				
4.20.8.ls	cornice variables	extrusion of cornice profile c1 extrusion of cornice profile over colonnade c2 extrusion of cornice profile c3 extrusion of cornice profile c4	Ionic cornice z = 3'-2" y = NA Lower Cor. cornice z = 2'-5" y = NA Upper Cor. cornice z = 3'-3"	4.54

rule	element	function	variables & equations	fig.
			y = 4"	
5-Portico				
4.8.13.ls	tread and riser size	creation of 10 steps creation of pedestal	12" x 6"	4.29
4.8.8.2.pa	stair type			
4.5.10.ls	wall	creation of new wall		
4.7.11.ls	segment vault	creation of segmented vault creation of flooring over segmented vault	f = 6" v = 3'-0"	4.27
6-Staircases				
4.8.2.pa	hide stairs			
4.8.3.1.la	three openings			
4.8.4.pa	staircase > four feet			
4.8.9.1.pa	oval or round stair			
4.8.13.ls	stair span walls			4.31
4.8.14.ls	tread and riser	12" x 6"		
4.8.12.ls	stair variables	creation of 12 steps copy 12 steps 3 times creation of 12 steps copy 12 steps 3 times	front service stair w =2'-0" b = NA d = 12" ri = 6" tr = 12" rear stair w =3'-4" b = 2'-0" d = 12" ri = 6" tr = 12"	
7-Columns				
4.9.1.1.pa	upper col. over bottom			
4.9.1.2.pa	Ionic over Corinthian			
4.9.10.1.pa	even numb of col.			
4.9.10.2.pa	larger space in mid.			4.31
4.9.13.2.pa	pilaster at end			4.31
4.9.15.ls	loggia variables	insertion of one Ionic column scale Ionic column copy Ionic column eight times create two support beams insert Corinthian column scale Corinthian column copy column 6 times	p = 2'-0" s = 3'-6" c = 2'-2" m = 6'-0"	4.31
4.14.1.ls	Arch variables		x = 9'-6" z1 = 6'-0" z2 = 3'-0"	4.44
8-Moldings				

rule	element	function	variables & equations	fig.
4.5.6.pa	moldings noted			
6.1.8.ls	molding variables	basement- creation of top molding first floor- creation of bottom molding creation of base molding second story- creation of bottom molding creation of top molding	bm1=6"x9" bm2=6"x1'6 p1 = 6" x 9" sf1 = 6"x 9" sf2 = 6"x 9"	6.3 7.13
9-Doors				
4.14.1.ls	door openings	basement- subtraction of 8 door openings piano noble- subtraction of 10 door openings second floor- subtraction of 9 door openings		
4.14.4.pa	room door height		3' x 6'-6"	4.45
4.14.6.ls	principle door width		5'-1"	4.45
4.14.7.ls	principle door height		9'-4"	4.45
4.14.8.ls	room door width		3'-0"	4.45
4.14.9.ls	room door height		6'-6"	4.45
4.14.5.ls	door variables		a = 5'-1" b = 9'-4" c = 3'-0" d = 6'-6" e = 18'-0"	4.45
10-Windows				
4.15.4.1.pa	window			
4.15.6.ls	window		3'-6"	4.49
4.15.7.ls	window		9'-8"	
6.1.10.1.ls	basement window	subtraction of 10 window subtraction of 12 large wind. subtraction of 1 small wind. subtraction of 1 arch subtraction of 13 large wind. subtraction of 1 small wind. subtraction of 1 arch	z = 1'-6" x = 3'-6"	6.4
6.1.9.2.ls	service stair window		xz=18" x18"	6.4
11-Details				
4.19.2.ls	fireplace			
4.19.4.ls	fireplace	subtraction of fireplace from wall	l = 3'-7" h = 4'-0" w = 8"	4.50
4.18.3.ls	balustrade	insertion of balustrade scale of balustrade copy balustrade 9 times	r1 = 1'-11" r2 = 1'-11" by = 2'-2"	4.49

rule	element	function	variables & equations	fig.
		creation of railing copy upper railing to lower railing	bx = 1'-6"	
6.1.11.1.ls	cove	subtraction of cove from wall	r = 16" z = 5'-0"	6.4
4.16.12.ls	ornamentation	insertion of door profile scale of door profile extrusion of door profile	x = 1'-9" y = 7"	4.47 7.13
12-Roof				
4.19.2.pa	roof cover building			
4.19.3.pa	roof bear on walls			
4.19.4.pa	divide into 9 parts			
4.19.5.pa	slope equals 2 parts			
4.19.7.pa	roof variables	creation of pediment cornice creation of pediment creation of 3 rafter types copy middle-horizontal 3 times copy middle-vertical 3 times create side room rafters 3 types copy side room rafters 4 times create pediment rafter copy pediment rafter five times creation of main roof creation of pediment roof creation of side room roof	d1 = 9" d2 = 10" z =24 degree sl.	4.53

CHAPTER SEVEN

DOCUMENTATION AND VISUALIZATION

7.0 REFLECTING ON THE DESIGN

This chapter is a presentation of the four methods of representation used to evaluate the villa models, each method addressing both qualitative and quantitative issues (fig. 7.1).[407] The methods also address Schon's points on action-in-reflection in that this process is one of learning by doing.[408] The four methods include rule graphs, also known as spreadsheets, used to hold object variables and equations, 3D printing of the model file followed, by 2D documentation and finally rendering used for areas of spatial conflict.

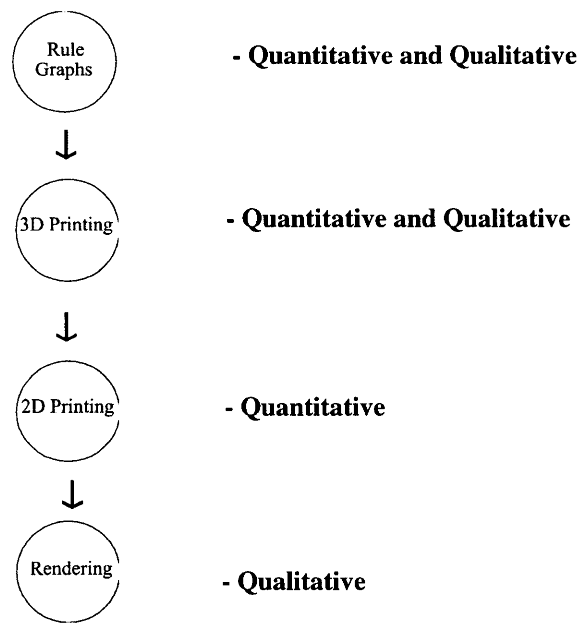

Fig. 7.1 Evaluation materials and the order of output used to evaluate the villa model

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[407] Tufte, E R, 1997

[408] Schon 1987

From physical representation in the form of plastic models to images, to animations, the methods used to view design artifacts vary dramatically. Each has its own advantages and disadvantages. In this study the principle followed is that the more opportunities offered to visualize the design, the better the design results. Computer models are difficult to visualize from a single viewing point. The margin of design error increases based on the number of methods used to see the file. Architectural evaluation is a visual process of observing space and form inside and out, followed by the editing of the design based on the evaluation of the drawings or models. The process of reconstruction is no different. It is also a process of action-in-reflection.

7.1 THE OBSERVER

Filmmakers and artists forever attempt to change the viewer's position in relation to the artificial world using such techniques as stereoscopic glasses and virtual reality. Their mission is to visually engage the viewer in the subject matter by changing the viewpoint of the object to viewed. In design, it is the visualization of an unbuilt space or form that sparks critical discussions. Crary reviews various methods for representing images, from the camera obscura in 1646, to the stereoscope of the 1870s, all focused on viewer engagement and a realigning the viewer's position. The portable camera obscura did what the life-size version has done by projecting an object or landscape on to a surface such as a canvas or paper.[409] It allows artist and architects to study space without having to construct a perspective grid. Following this theme, in the 1820's, the viewer was introduced to the diorama, which was to replace the panorama painting as a method of shifting the viewer's point of observation. Later, the modern day camera replaced these. In this study, rendering and model making tools as output materials from a CAD file are used to create different architectural perspectives from a variety output materials. Model printing, spreadsheets, two-dimensional projections (plans, section, and elevation - referred to here as documentation) and renderings are the output used here to inform the evaluation process by repositioning the viewer around the design product. All four methods will be used for each of the two case studies. The end results of each villa model study will be a qualitative and quantitative presentation of a design issue.

7.2 *DOCUMENTATION, PRINTING AND VISUALIZATION*

Enhanced visual output is the result of constant development of the product's representation through trial and error. It is a process in search of visual clarity of design issues through the production of multiple iterations of reflective materials. In the case of computer renderings, the first rendered image never captures the full extent of an issue. The process requires production of multiple iterations of the image before the issue is clearly presented. The same holds true for two and three-dimensional output.

1D Output

One-dimensional output refers to the graph presentation (spreadsheet) of text rules used to build each villa model (found in the appendixes of the previous two chapters). They are accompanied by graphic descriptions, but are not meant to serve as a substitute for the geometric material.[410] Each graph contains the rule, the element upon which the rule is applied and a reference number for pointing to the rules definition. The rules in this case serve more as text functions applied to determined shapes, to define an undefined building element. This method of presenting the textural rules along with the graphic representation is similar to a method used to describe shape grammars

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[409] Crary, J. 1990 p.39
[410] Mitchell, W J., pp. 137-153

where the element is described along side its function.[411] This method is a good way of tracking and evaluating decisions, and the creating of new design rules or elements. Text representation in this study will be used as a quantitative means for evaluating the villa models.

2D Output

Two-dimensional output refers to conventional drawings used by architects - plans, sections and elevations. These are also used as a comparative tool for evaluating the villa model file against past study drawings, such those of Bertotti Scamozzi. Plans are cut four feet above the finished floor. Sections are taken at the mid-point of both axes and elevations are taken at the extent of the property lines. A bar scale and a north arrow accompany each drawing when necessary. These drawings are a quantitative means of representation.

3D Output

Three-dimensional output refers to physical model output from machines or printers in the form of plastic or cornstarch. Three-dimensional printing or Fuse Deposition Modeling (FDM) stands as the moment of truth in CAD modeling and detail. Flaws created by miscalculations in the creation of the CAD file, reveal themselves once printed in three dimensions. The output process is similar to conventional printing with the exception of the material and the output platform. The villa model or CAD file is cut into many plan-sections at intervals of 1/100 of an inch per section. Each plan-section represents one print file. Each plan-section file is sent to the printer one layer at a time and printed upon the previous layer. The final output is in the form of a plastic or cornstarch three-

[411] Stiny, G. 1981

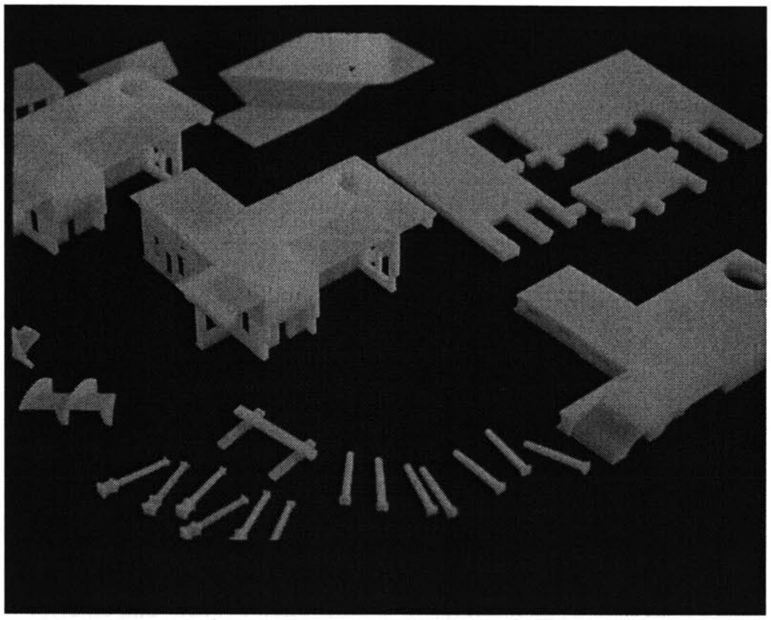


Fig. 7.1 Villa Cornaro: 3D Model in parts

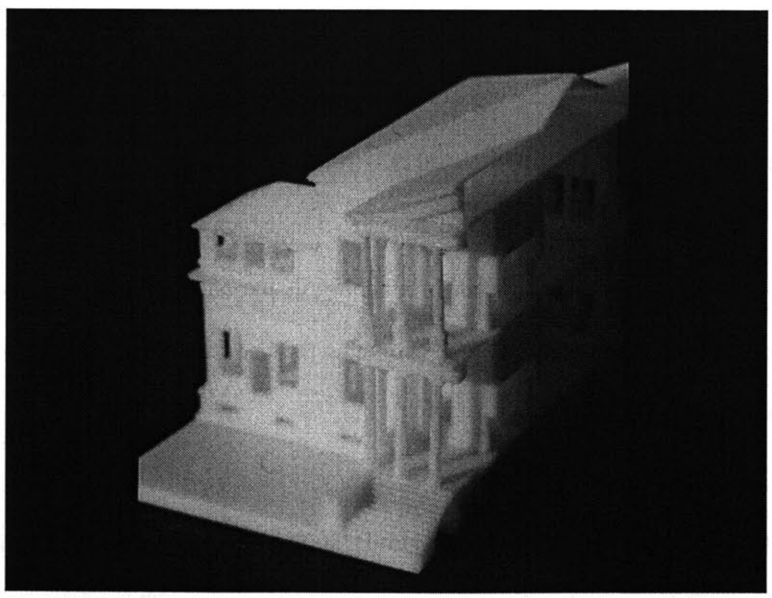


Fig. 7.3 Villa Cornaro: 3D Model assembled dimensional object. The final model has a maximum size of 10" x 10" x 10" per part. Large models are printed in pieces and glued together. If the villa model is printed at a prescribed scale it stands as both a qualitative and quantitative means of representation (fig.7.1 & 7.2).

Rendering

Renderings are used to simulate various design conditions such as lighting, surface textures and form, as well as placing the viewer inside of the space. Rendering output here is focused on design issues and not on representing the full building. In most cases, the issue is about the lighting conditions of an indoor space or the formal qualities of an outdoor spaces such as the loggia. Each study uses alternative geometric models altered from the original in order to explain the issue. Renderings are used here to qualitatively evaluate interior spaces and exterior forms.

The rendering process uses radiosity models created from the CAD model, whose surfaces are texture mapped and raytraced. In order to save on computer processing time, the full CAD file is copied, and areas not within the view of the rendering camera are erased from the file. The goal is to create a stage set of geometric surfaces from the villa model, upon which textures can be applied. The process starts with a solid geometry file, which is translated to a facial representation, and all solid information is removed. In other words the only geometry translated from the CAD representation to the radiosity program contains the geometry of the space and adjacent spaces within the frame of the camera.

Texture maps are used to create surface similar to those in the built conditions. These maps allow the viewer to evaluate rendered images on that architect's terms. This means the walls appear to be the walls of the built condition. High-resolution texture maps are applied to each geometric surface within the frame of the camera. Each starts as a photograph taken from an existing villa wall, floor or detail surface, photographed on a cloudy day using a conventional 35mm camera and a 50mm lens.

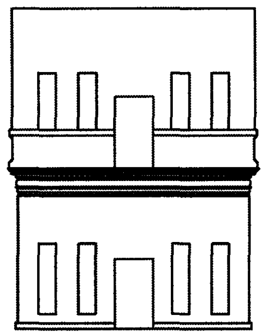
Ideal day lighting conditions are needed to define surface texture, color and smoothness. The goal is to infuse the model or space with just enough light so as not to over illuminate a surface or to under illuminate, which creates dark patches in detailed areas. A contrast of dark and light is key, in fact moldings are defined from a contrast of dark surfaces against lighter surfaces. The final step is to raytrace the radiosity model and texture mapped surfaces, resulting in a high-resolution image.

7.3 THE VILLA CORNARO

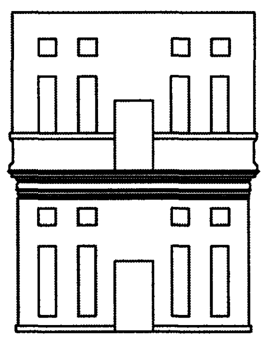
Thirteen two-dimensional prints, one three-dimensional print and three renderings were used to evaluate the model file for the villa. Of the four out-put types, renderings defined a majority of rule/design issues. They visually exposed flaws and contradictions in the villa model. These issues were discovered while testing two lighting conditions in the main hall. The villa model's interior was tested against the built condition. The first stage of the operation was a simulation of Palladio's drawing (fig. 7.4) by using texture maps and a conjecture about the lighting condition of the space against Palladio's image of the space (fig. 5.29). The conflict here is the variation in window numbers and size based on a comparison between the built condition and Bertotti Scamozzi's drawings. The built condition has two bands of windows in the main hall, an arched set at the bottom and a smaller square set above that. Palladio's drawing shows one set of windows on the elevation, and that set has rectangular windows without arches. The test was to define differences in lighting levels with and without a second set of windows. It is important to keep in mind that

Palladio drew his elevation drawing with one set of windows long after the villa was built. The drawings were design proposals, and not a reflection of the built condition. The final output (fig. 7.5) of the space with only one set of windows demonstrates that there is little difference in lighting due to the change in window design. Most likely Palladio was not concerned with lighting, but more with the aesthetic of the façade – window alignment with the external columns.

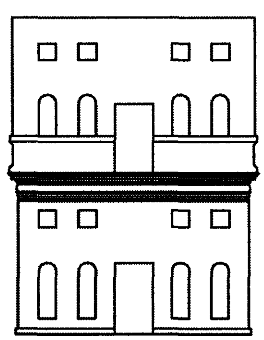
More important, once compared to the built condition, renderings expose design details not found in the *Four Books*. One example of this is the ceiling rafters to the column supports and walls. The computer model shows the ceiling rafters running in a direction that differs from the existing conditions. The existing conditions show that Palladio placed a ceiling trim just under the rafters where they met the wall. This was probably used to cover the joint between the rafter and the wall. In summary, once compared to the built condition, the output materials presented structural and decorative issues not outlined in the *Four Books*, but addressed through critical discussion in the case studies.



Solution - A



Solution - B



Solution - C

Fig. 7.4 Villa Cornaro: Drawings reflecting proposals of difference window patterns at the rear façade. Solution A reflects Palladio's drawing, Solution B is a random test, and Solution C is the built condition

Fig. 7.5 Villa Cornaro: Rendering of hall reflecting Palladio's drawing - Solution A

Fig. 7.6 Villa Cornaro: Rendering of space with small windows above, used as a test - Solution B

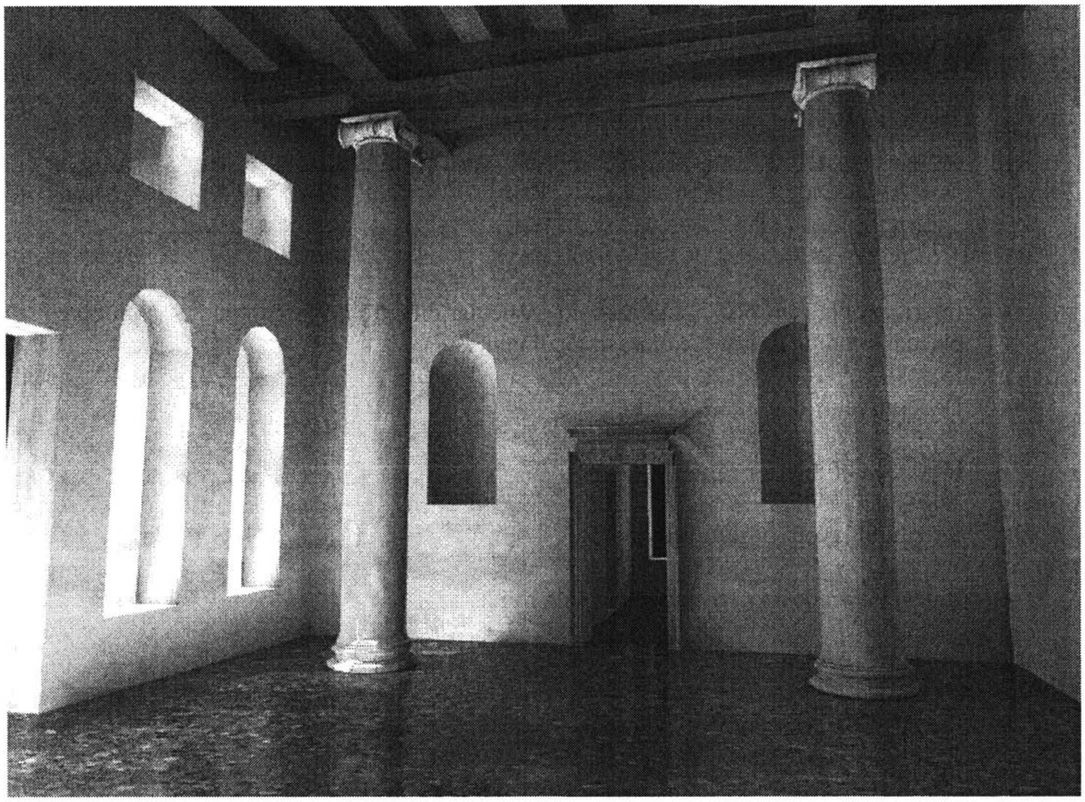


Fig. 7.7 Villa Cornaro: Rendering of existing conditions - Solution C

Summary of Findings

Resolved

- Window layout in hall
- The Villa Cornaro can be built by the construction rules in chapter 4

Unresolved

- Interior Ionic capitols should face no particular direction. They should contain diagonally placed volute that face the opposing column.
- Decorative trim at interior rafters
- Direction of interior rafters
- Structural layout of rafters at the roof
- Rules for windows in the attic and side room
- Rules for service stairs
- Rules for exterior cornice moldings

7.5 CHAPTER SUMMARY

This chapter outlined four types of output devices that can be used to evaluate the villa model. Each type offers qualitative and or quantitative materials that can be compared with past study drawings made by Palladio or others, and compared with photos of the existing conditions. One-dimensional text rules catalogue decisions made during the construction of the villa model. Since this is the first study to record the decision making process, these rules can only be compared to other villa model studies within this thesis. Two-dimensional output is used quantitatively as a comparative tool. Three-dimensional physical output can be both a quantitative and qualitative object used to evaluate the entire villa model at a glance, while renderings offer qualitative output used to expose form, material and lighting issues. Renderings can be used as a comparative tool against photos and other rendered simulations. The final study package for each case study will include by default, one and two-dimensional output. Renderings and three-dimensional output are used based on their effectiveness in presenting the issue to be studied.

LIST OF FIGURES

APPENDIX

VILLA CORNARO, PIOMBINO
Documentation

LIST OF FIGURES

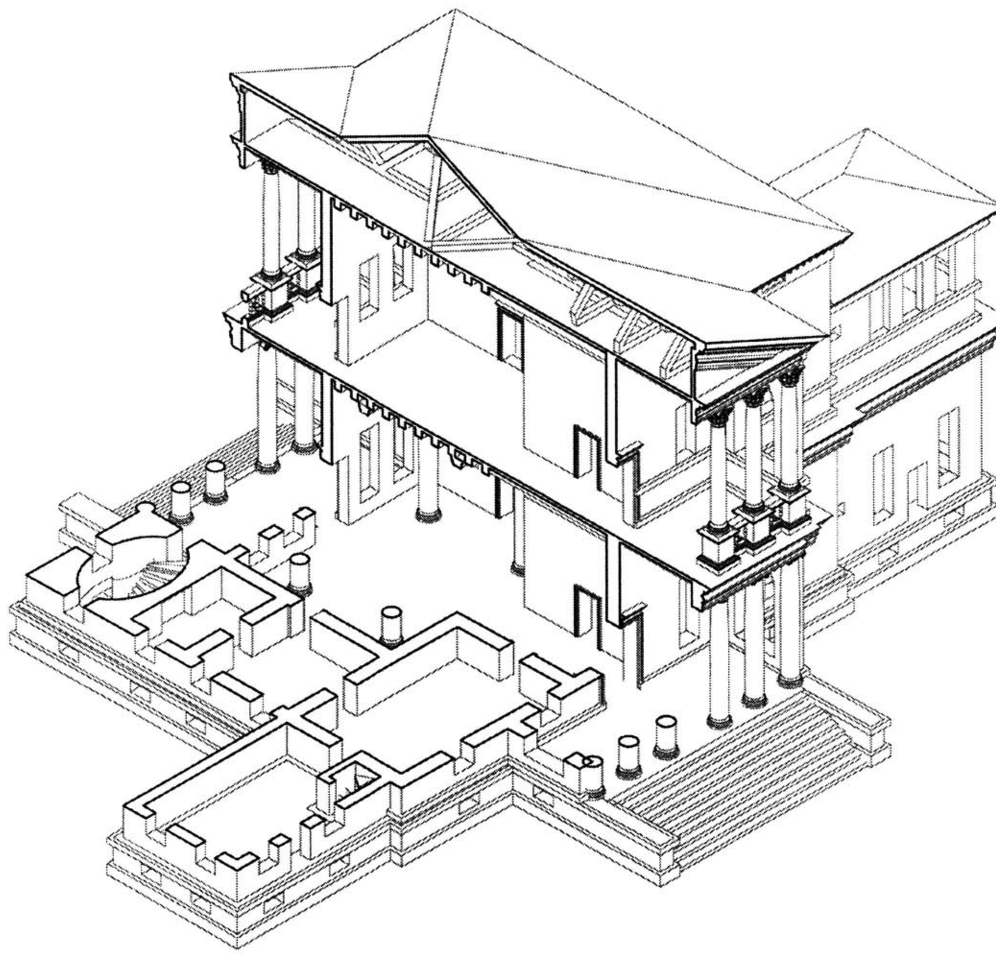


Fig. 7.8 Villa Cornaro: Isometric projection of villa model

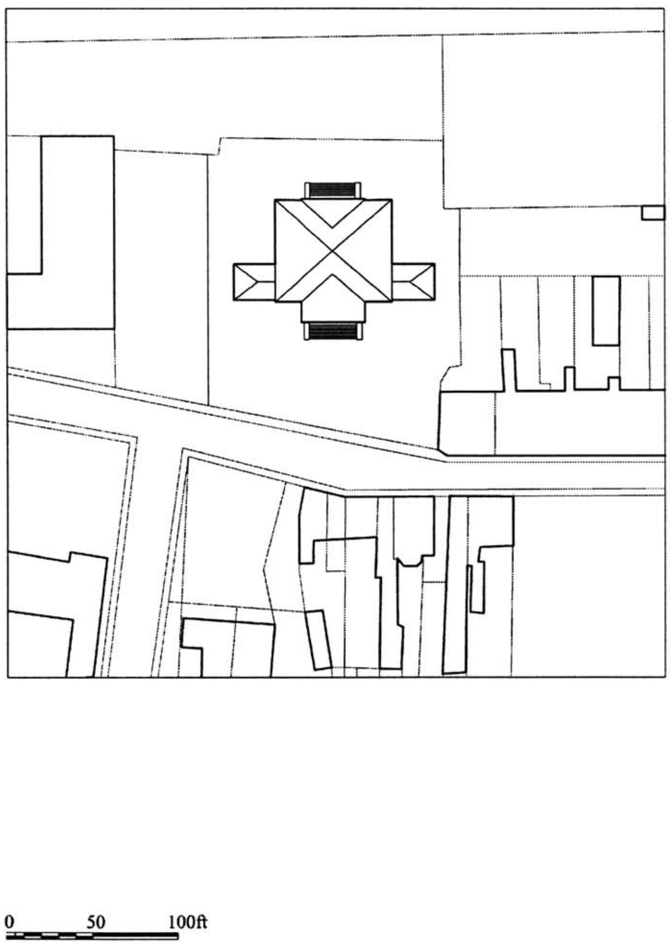


Fig. 7.9 Villa Cornaro: Site plan

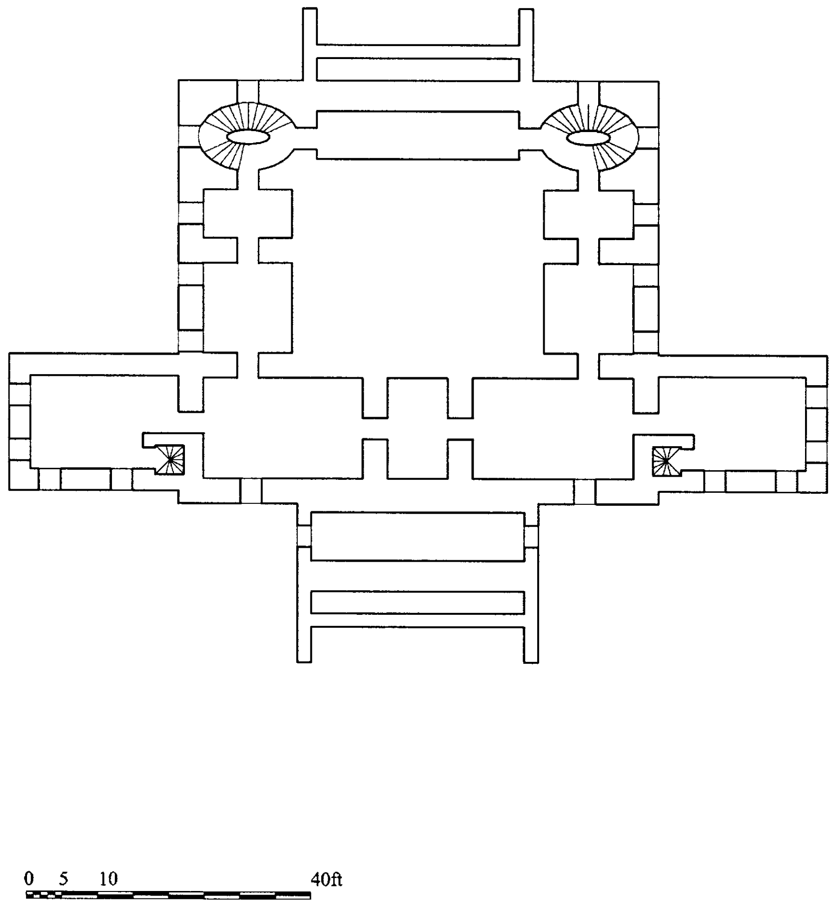


Fig. 7.10 Villa Cornaro: Basement Plan

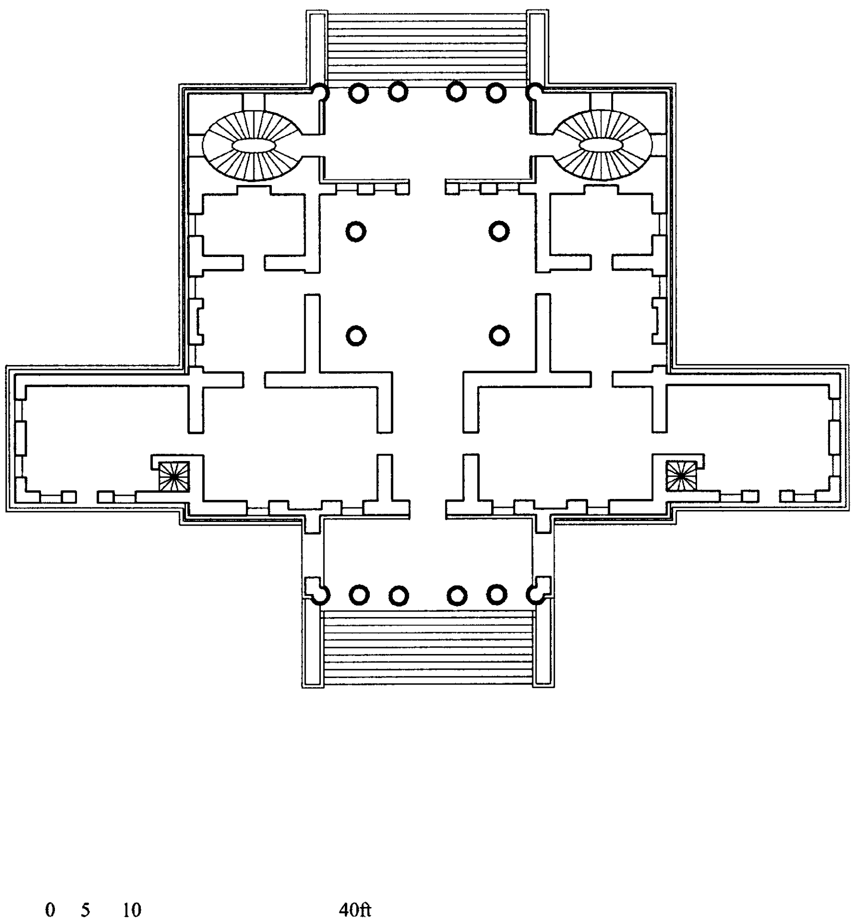


Fig. 7.11 Villa Cornaro: Piano noble floor plan

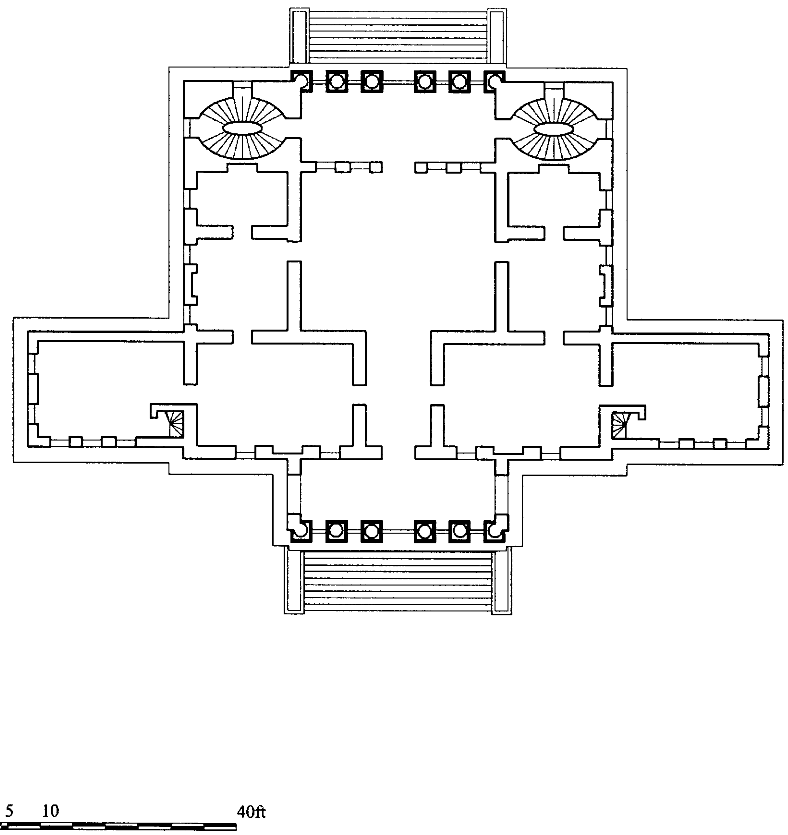


Fig. 7.12 Villa Cornaro: Second floor plan

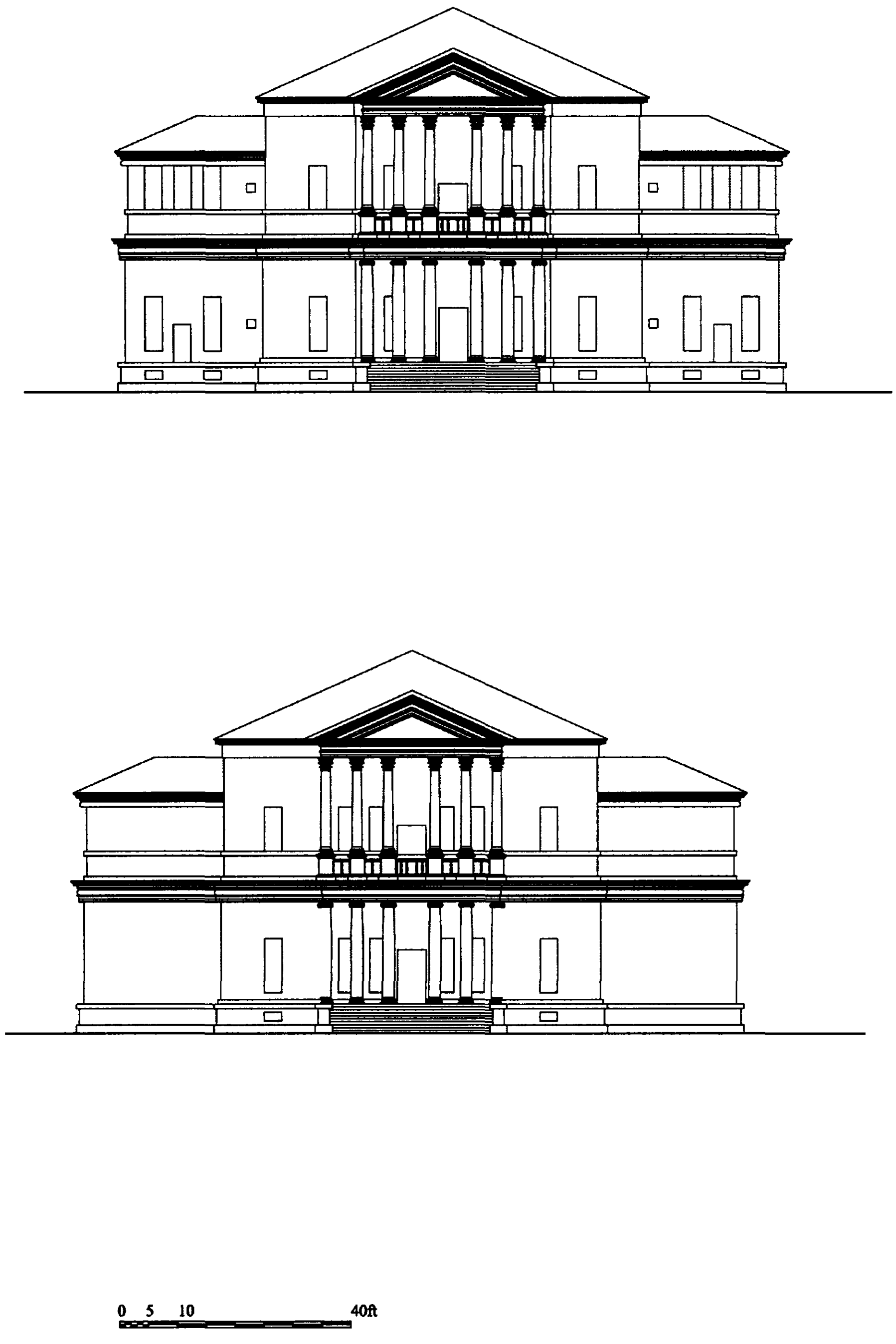


Fig. 7.13 Villa Cornaro: Front and rear elevations

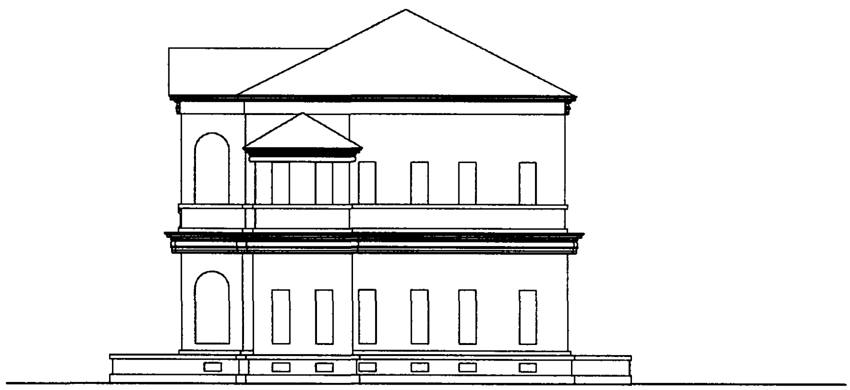


Fig. 7.14 Villa Cornaro: Side elevation

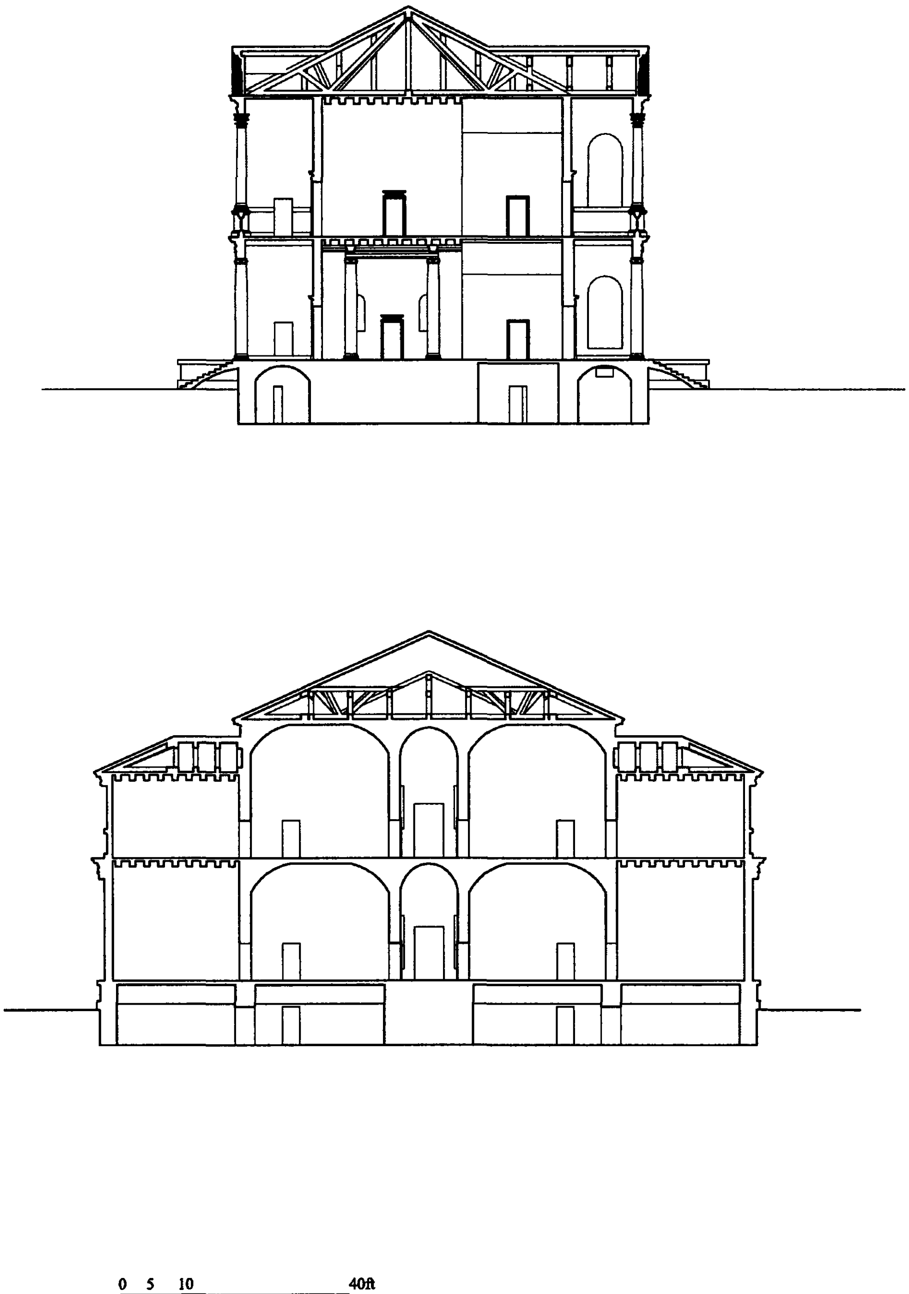


Fig. 7.15 Villa Cornaro: Section-longitudinal and transversal

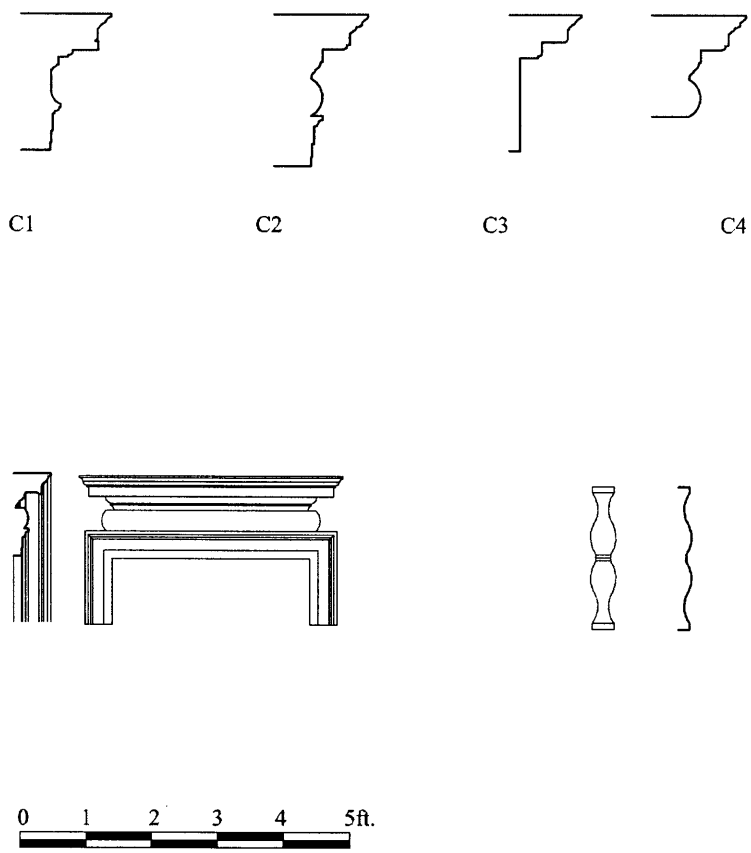


Fig. 7.16 Villa Cornaro: Details and profiles

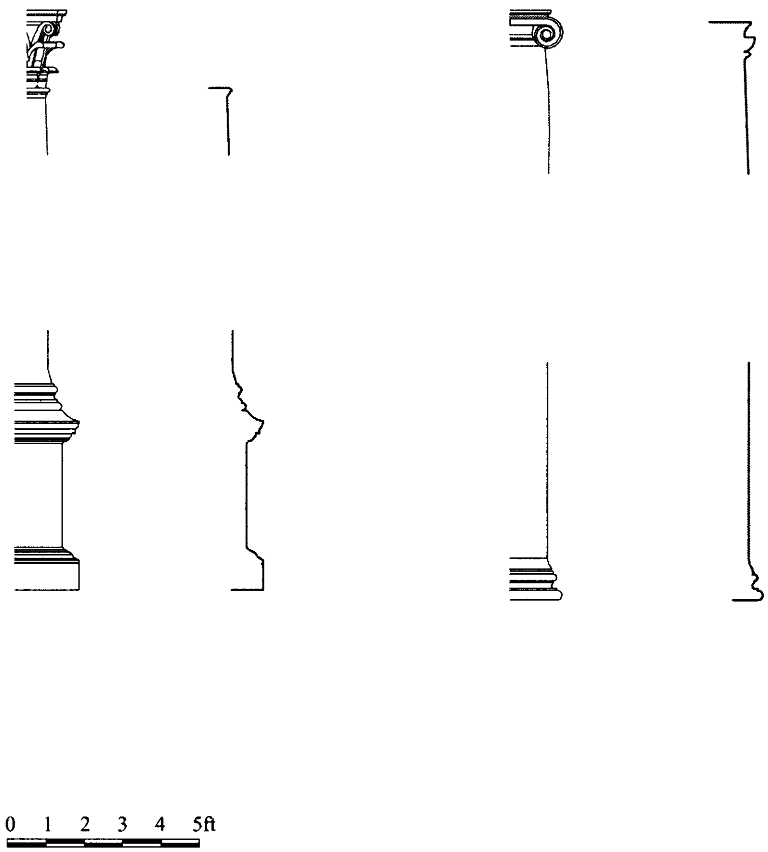


Fig. 7.17 Villa Cornaro: Column Profiles

CHAPTER EIGHT

THE VILLA TRISSINO, MELEDO

Case Study A

8.0 THE WORKING PALACE

This chapter is a presentation of the last of four attempts to reconstruct the unbuilt villa Trissino in Meledo here at MIT (fig. 8.1). This final version is the best reflection of how the villa would have been built using the rules in chapter 4. The three previous reconstruction attempts were evaluated in rendering or 3D print form only. Each past study presented similar results. These results differed slightly based on each persons interpretation of the rules, and the amount of output used to evaluate the resulting model file. The first attempt, listed in chapter two, was part of the simple representations constructed for the CD-Rom project. There were no interiors or detail such as column or cornice moldings. The second reconstruction was undertaken in a workshop here at MIT. Students reconstructed parts of the villa, later combining those parts to create a full villa. The final results were composed of interior and exterior renderings and a three-dimensional print. There were no attempts to record decisions or a documentation of the final model. The third version, completed by Isaac Persley an undergraduate architectural student, was a research project focused on building by the rules and recording the steps in graphic and textural form. The rules used in this study were recorded on a spreadsheet along with a drawing file defining the application of the rule, visually. The version presented here was recorded as per specifications presented in previous chapters. There are one, two and three-dimensional records of all decisions used to reconstruct the villa.

The existing site for the Villa Trissino contains two dovecotes and parts of the lower barns and a fence (fig. 9.2). It has been debated whether the designs of the barns are Palladio's, or that of a lesser architect.[412] History has it that the villa was never constructed and that Palladio never designed the existing dovecotes (fig. 9.2). The goal here has been to rebuild by rule and to present the findings and conflicts visually. The site is magnificent. As described by Palladio, the main house sits atop a beautiful hill over looking farms and small waterways.[413] The villa itself is similar in design as that of the Rotunda, a suburban villa with a circular hall and adjacent hall spaces. One dramatic difference is that Trissino was intended to serve as a farm with its outwardly stretched terracing set of barns. Where Trissino dramatically differs from the Rotunda is in the hall - Palladio used real half columns in Trissino where the rotunda was originally undecorated, then covered with frescos. The design of the main hall is similar in detail to that of the Tempietto Barbaro at Maser, especially at the portico.

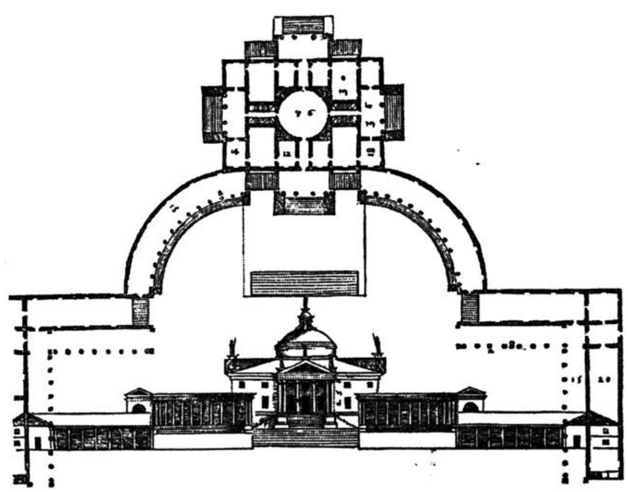


Fig. 8.1 Palladio's plan of the villa Trissino in Meledo

[412] Puppi, L. 1973, pp.384-385
[413] Palladio, A., 1965 p.51

The villa Trissino in Meledo combines a sense of dramatic theater like that of the Villa Rotunda, with the workings of a true farm like that of the Villa Pojana Maggore (fig. 1.2).[414] Staying true to his rules, Palladio places the villa atop the highest point on the site from which barns cascade down and around to the outer ends of the site. The architectural inspiration was derived from sketches and final drawings of the reconstruction of the Temple of Fortune at Palestrina.[415] There are two sketches from which information leading up to both the Villas Trissino and Mocenigo are derived. First, is the plan sketch of the upper terrace of the Fortune Primegina, in Palestrania, that shows a plan reconstruction drawn mechanically and in freehand.[416] This sketch also shows three sets of steps ending at a small Tempietto with four false fronts similar to the Villa Trissino, Meledo plan. Palladio's second sketch of the same temple was to be the most inspirational reference to the plans of both Trissino and Mocenigo on the Brenta as noted by Burns and Lewis.

Fig. 8.2 Aerial view of the site showing the two barns and dovecotes

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[414] Ackerman, J, 1966, p.73
[415] Burns, H. 1975, p.250
[416] Lewis, D. 1981, p.145

In the process of reconstructing the villa, the initial grid was placed on the hill along with the barn grid that was placed at a lower point on the site. The measurements for the villa plan where taken from Palladio's drawing (fig. 8.1), while the barn grid was an interpretation of the dimensions (fig. 8.3) from the drawing. The barns are divided into two sections, one circular and the other half square. There are two methods that could be used to find the center point of the circular barns. The first method is to add up the distance between the columns and the diameter of the column defining the barn circumference. The second is to measure the distance from the edge of the steps leading to the lower terrace to the first column in the circular barn. The length of the barn is found by adding the columns and their diameters. This section refers to the number of columns in Bertotti Scamozzi's drawing and the spacing between the columns to define the length of the barns. The villa barns also sit alongside of a thin waterway, specified in Palladio's description of the villa.[417]

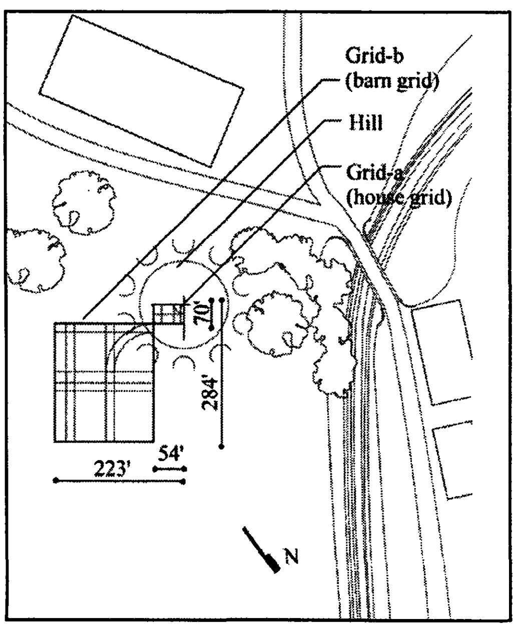

Fig. 8.3 Site plan with grid-a and grid-b

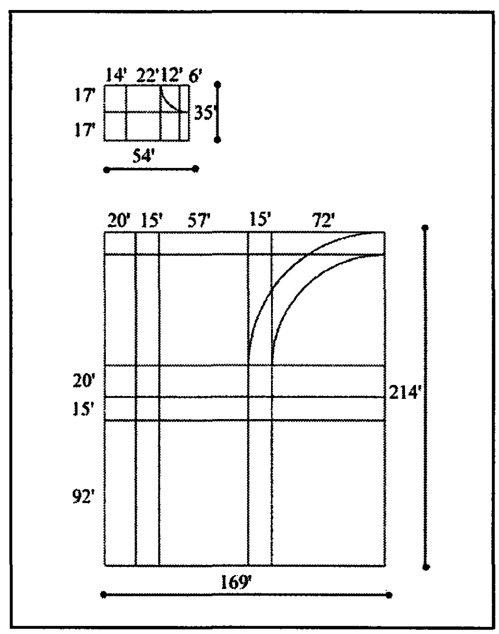

Fig. 8.4 Grids-a and grid-b

also sit along side of a thin waterway, specified in Palladio's description of the villa.[418]

8.1 THE RECONSTRUCTION

There is one fundamental problem with the Palladio's drawing. A side room is missing a dimension note needed to define the width of the room and the adjacent run of the stairs. Palladio provides the length (30ft.) but not the width. This dimension defines the overall size of the space, and it helps to define the shape and ordering of the stair. It is possible that the width of the space could be a ratio such as 2:1 (15'), or 3:5 that would make the missing dimension 18'. Both numbers are to small to create the adjacent flight of stairs that would clear the doors below. The proposal here calls for the space to be 22' wide, which should clear the door if there is a winding stair.

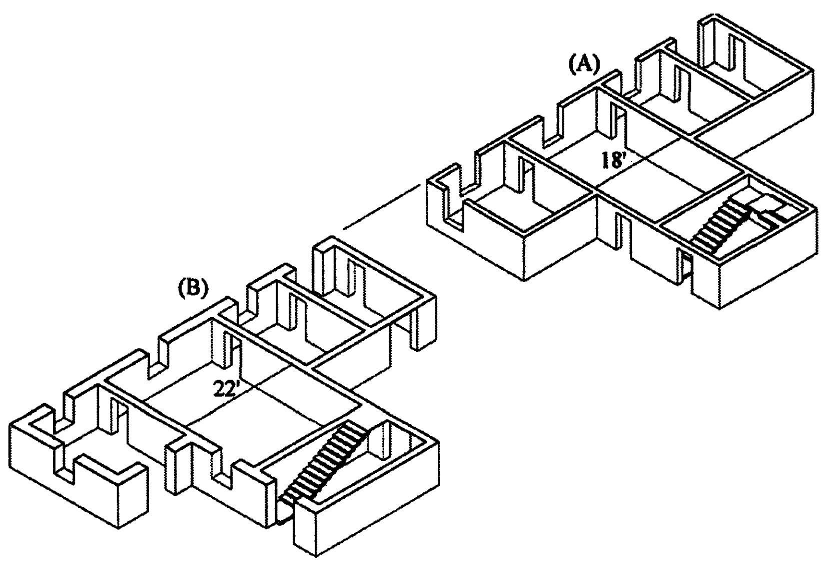

Fig. 8.5 Two solutions for the missing dimension. Scheme (A) offers a good ratio for the space 2:1 but there is not enough space in the stair to clear the 6'6" door. Scheme (B) offers space for door clearance but the number does not fit with Palladio's proportioning system. Any number greater than 22' dramatically breaks Palladio's rule for the maximum length of a stairs run (Palladio, A., p. 34).

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[417] Palladio, A. 1965 p.54
[418] Ibid.

8.1.1 Plan and Elevation Reconstruction

The plan was reconstructed from the dimensions listed on Palladio's drawing. It should be noted that Bertotti Scamozzi also did not include the missing dimensions in his plan drawing, instead he chose to guess at the size of the space. Once the basic layout for the wall grid along with dimensions was established (fig. 8.4), and the process of adding construction features were completed, the radius of the barns became quite obvious. It turns out that the center point for the radius of the circular barns is the edge of the large stair, in the center of the garden, leading to the lower barns. Reconstructing the plan drawing was quite uneventful. Palladio resolved many details in the plan through what seemed to a very simple order. The only area of conflict was in the connection between the house and the circular barn. It is unclear how the two were to connect in two-dimensions. In this solution, the attempt was made to join the barns to the outer wall of the main house.

The elevation did present some problems when defining the heights and variations between the two barns and the main house. Again Palladio's drawing is reminiscent of his sketch of the Temple of Fortune at Palestrina in that the elevation was composed of a stair stepping set of elements.[419] In addition to the variation in heights of the barns, the dome became as much of a construction issue as was a design issue. The dome is drawn in the *Quattro Libri* with a straight line at its the base, where the roof of the villa meets the dome, similar to the drawing of the Rotunda. There are no rules for the height of the dome, nor rules for its construction. Here again, another conjecture is made to define the height of the dome. In this case the guess is set at 72' to the top of the dome, the same dimension as the inside radius of the barns (fig. 8.4).

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[419] Lewis, D. 1981, p. 147

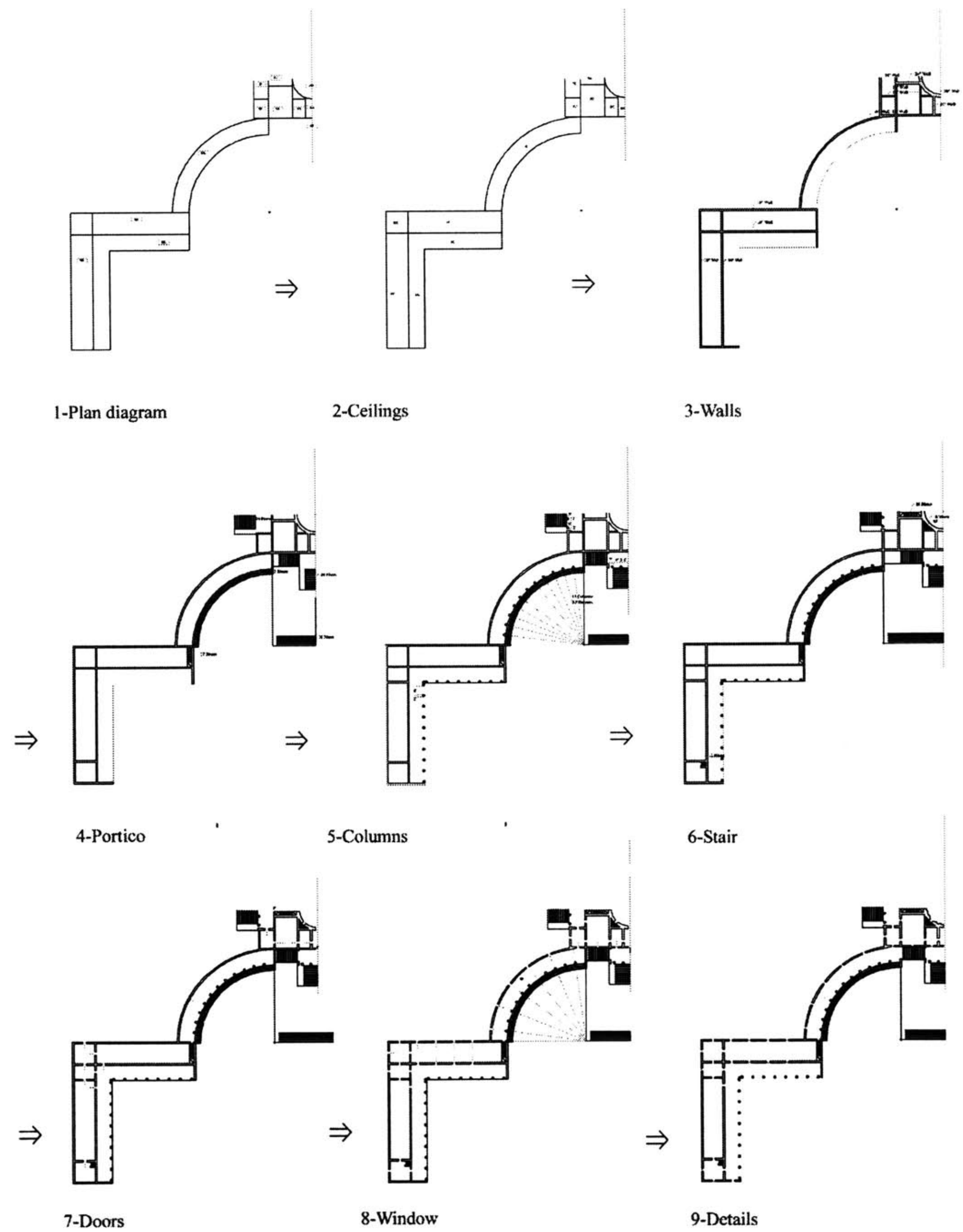


Fig. 8.6 Plan reconstruction derivation

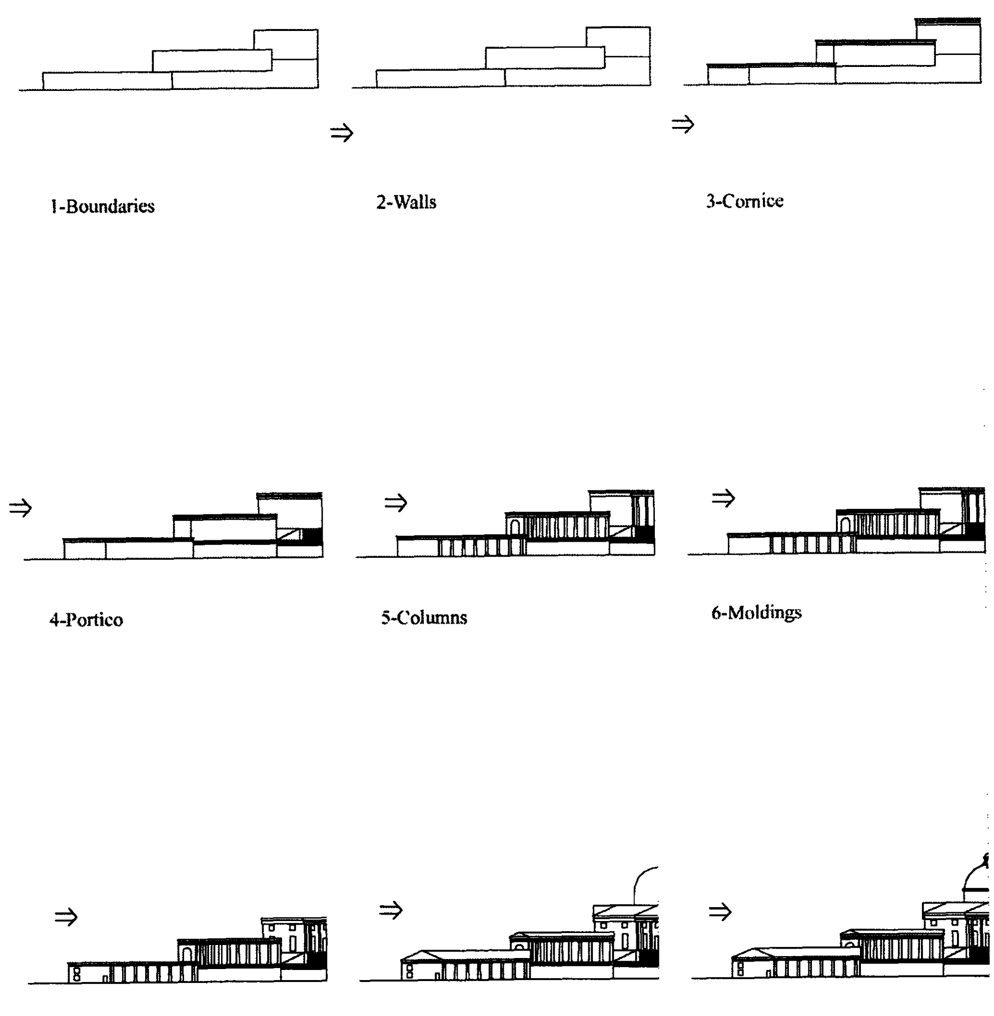


Fig. 8.7 Elevation reconstruction derivation

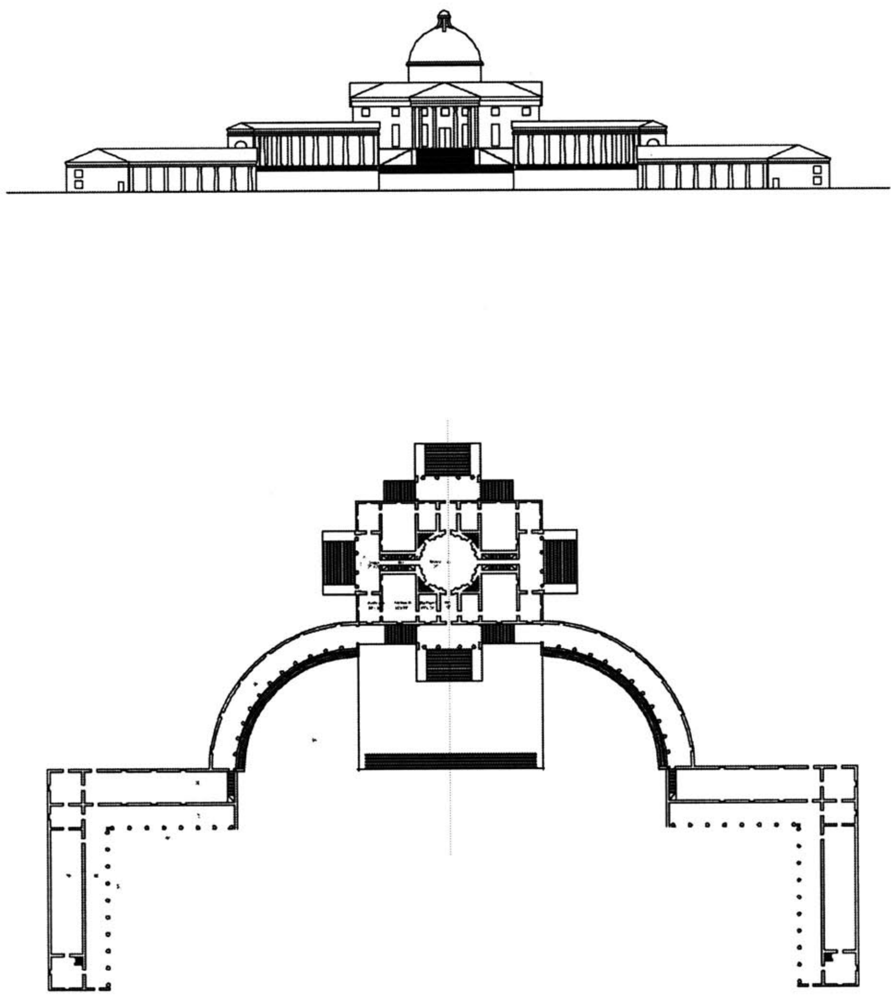


Fig. 8.8 Resulting plan and elevation drawing

8.1.2 Model Construction

The villa Trissino differs from the Villa Cornaro in that it has barns and a much larger site. The approach here will be the same as the villa Cornaro in that 12 steps will be used to and reconstruct the barns and the villa together, opposed to constructing the barns and villa separately.

8.1.2.1 Initial Plans

Although the first level of the plan shows the barns and the basement as one piece, the villa and its barns are constructed in three separate pieces: the basement, the upper barn and the lower barn. The walls at the basement of the villa follow the rules system for walls, which states that they are to be twice the thickness of the walls at the piano noble. However in this case the upper story walls do not follow Palladio's rules which calls for them to be half a brick thinner than the piano noble. Since the outer wall is flush and without moldings at the second level, I constructed them at the same thickness as the piano noble.

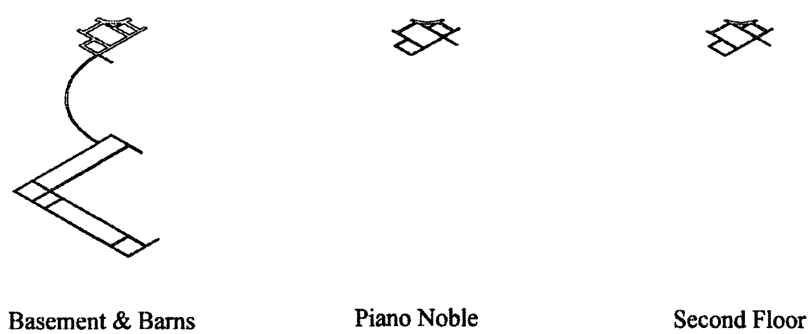


Fig. 8.9 Plan derivation

8.1.2.2 Walls

The floor to floor height is missing from the original Palladian drawing for the piano noble and the barns. However he does give dimensions for the height of the walls from the piano noble to the bottom of the roof cornice. Here 17' was given to the first floor, one to the floor thickness and 8'-0" was given to the upper story. In this case the conjecture for the basement wall height was taken from previous studies defining the basement at 11'-0" in height. The barns were given heights of 15' for the lower barn and 15' for the upper.

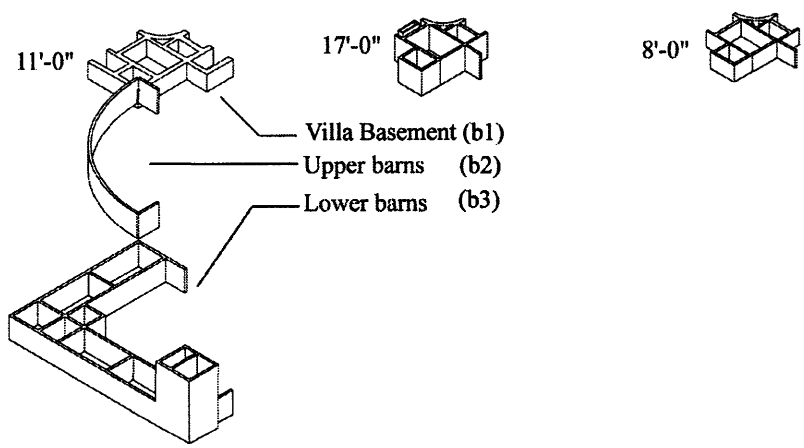


Fig. 8.10 Wall derivation

8.1.2.3 Ceilings, vaults and floors

The only ornate ceiling in the villa is perhaps a barrel vault at the entry hall. It turns out that there are two rooms with the possibility of supporting a vaulted ceiling the entry room and the small outer room, adjacent the connection to the barns. The middle space is a double height space similar to a large palace space with a flat ceiling. Basement vaults are semi elliptical vaults.

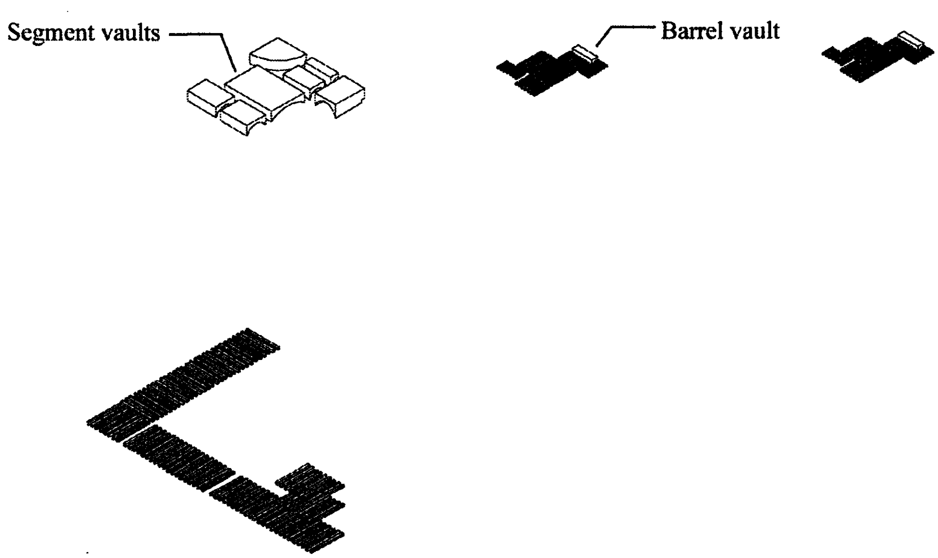


Fig. 8.11 Ceiling derivation

8.1.2.4 Cornice

The cornice is the most complicated part of the assembly. Each cornice type (c1, c2, etc.) is composed of three design conditions - an extrusion of the profile, a cap condition at the corners where two cornices meet and a reverse cap condition where two cornices meet in a corner. Composed of two parts, the Corinthian order is customized in four different ways. The first of the Corinthian orders is used for the balcony projection under the portico (c2); the second is used at the rotunda (c3), the third is the most ornate (c4), in this case placed under the pediment; the last is a flattened version with the least ornamentation, and it is used under the roof (c5). The most complicated connection or joint is at the portico. Here Palladio extends the ornate entablature (c4) over the columns away from the flattened cornice (c5) that surrounds the walls.

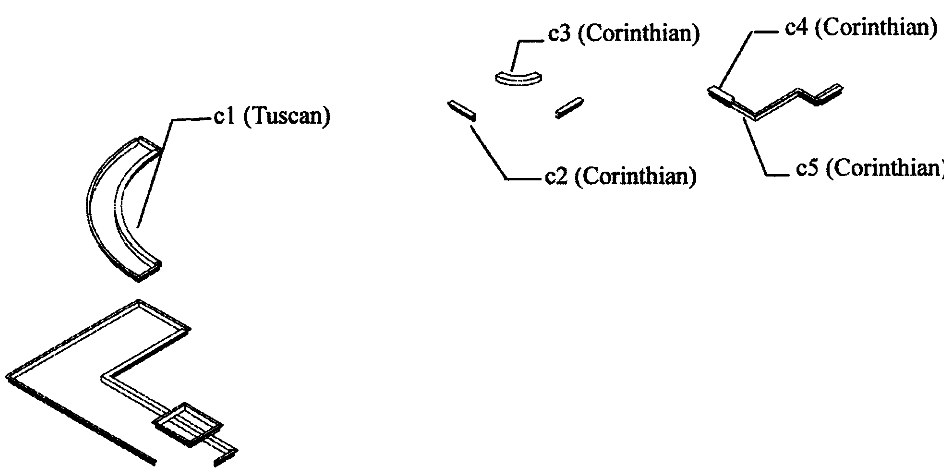


Fig. 8.12 Cornice types, refer to fig. for profiles

8.1.2.5 Portico and steps

There are three different portico stairs, each with its own function and layout. Types (s1) and (s2) are formal types leading to the porticos of the villa. Types (s3) and (s5) are service stairs leading to the upper and or lower barns. Type (s5) is a formal stair dividing the two gardens. The greatest conflict is in (s5) which is modeled differently than Palladio's original drawing. Palladio's drawings showed a set of stairs heading into the lower barns. This gave little room for a landing. The solution here calls for a switch back stair leading to the lower barn. The negative part of this is that it is uncovered.

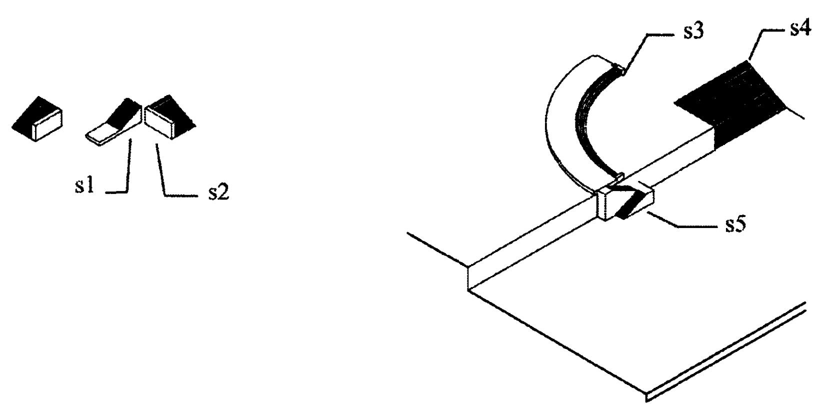
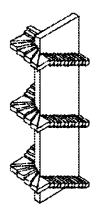


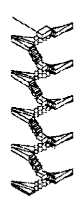
Fig. 8.13 Porticos and exterior stairs

8.1.2.6 Staircases

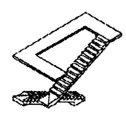
There are three types of stairs, each made of the standard brick supporting system, but there is question as to how the formal stair might have been constructed. Palladio shows the stair as a wrapping rectangular stair without an inner wall. It is not clear how it would support itself with out a wall so one was added in this study. The problem is that there is little room for the door and passageway shown in Palladio woodcut.



Barn Stair



Rotunda Stair



Formal Stair

Fig. 8.14 Interior stairs

8.1.2.7 Columns and arches

It is unclear as to what orders Palladio might have used for the barns, and the main villa. Palladio specifies that the loggias are to be of the Corinthian order and that the barns are Tuscan. Bertotti Scamozzi challenges this by saying that the upper barns were designed by Palladio to be of the Ionic order and that the lower barns were meant to be of the Tuscan. It is most likely that the real challenge of the orders is in the dome. Palladio does not assign an order to the half columns in the dome. In the Four Books he says "*There are some half columns in the hall, that support a gallery, into which one goes from the rooms above; which by reason they are but seven feet high, serve for mezzati.*[420]" Bertotti Scamozzi lists the order under the dome to be Corinthian. I have also listed the order to be Corinthian in the documentation, but this will be challenged in the visualization.

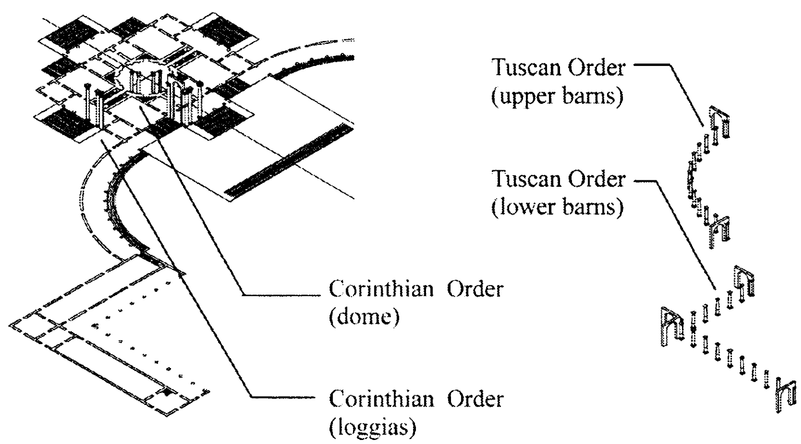


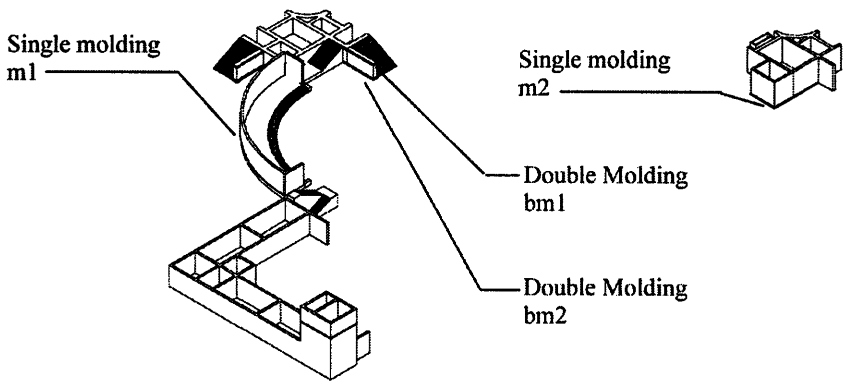
Fig. 8.15 Columns and arches

[420] Palladio, A., 1965, p. 51

Fig. 8.16 Moldings

8.1.2.8 Moldings

There are two molding types (double and single) surrounding the lower levels of the villa and barn.



8.1.2.9 Doors

Room doors worked fine when installed by Palladio's rules. The formula for the principle doors did not work at the second story. The height of the opening and archway at the colonnade had to be altered to compensate for the large entablature.

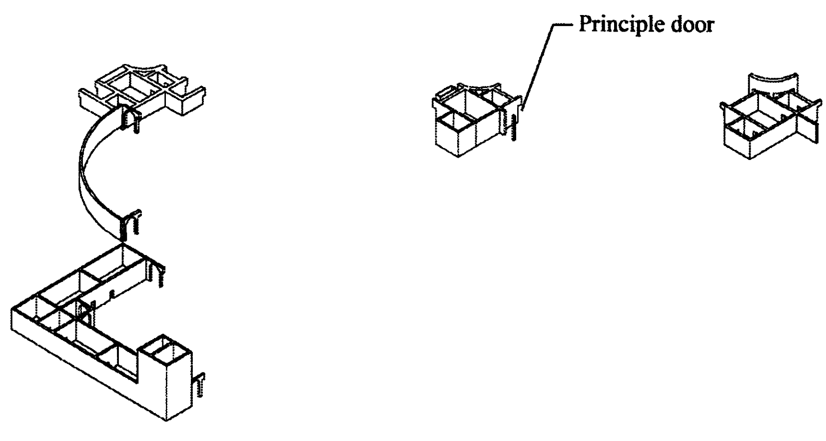


Fig. 8.17 Doors

8.1.2.10 Windows

The generic window size formulated for the villa was also used in the upper and lower barns.

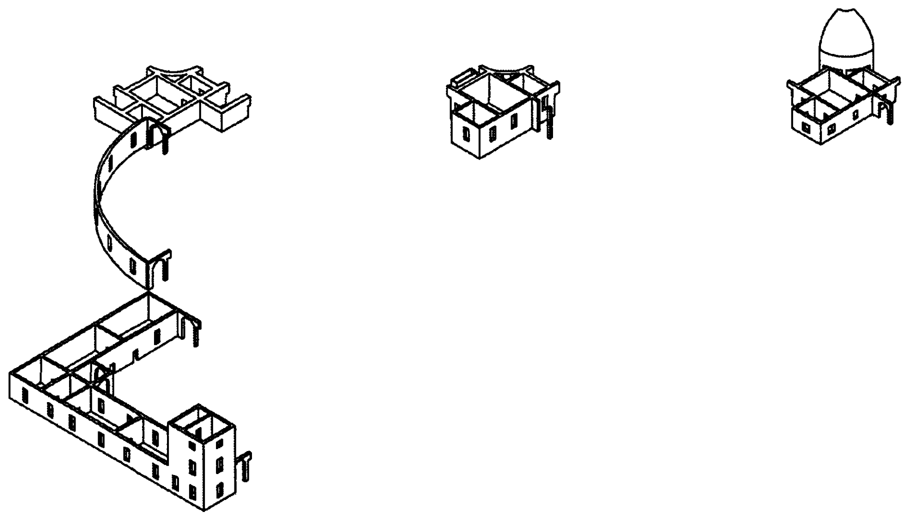


Fig. 8.18 Doors

8.1.2.11 Details

Here, two principal door types are used, the scroll being the most formal of the two. Balustrades and newel post are used at the balcony level.

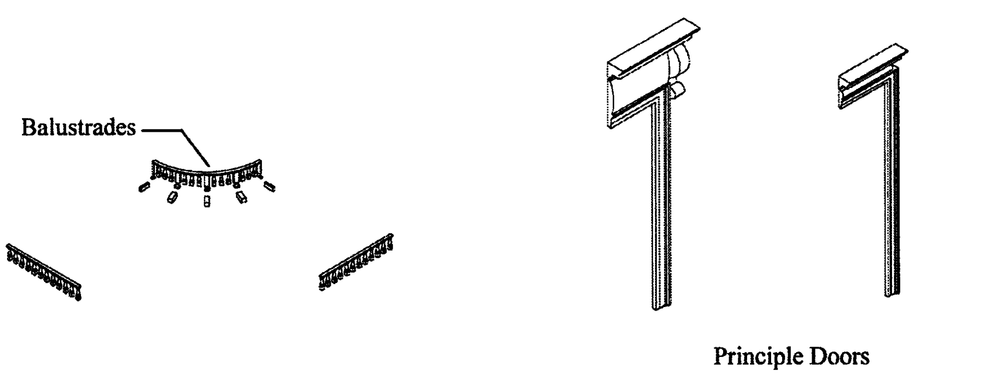


Fig. 8.19 Details

8.1.2.12 Roof and pediment

The pediment is of the Corinthian type angled at 23.2 degrees, supported by minor and major types.

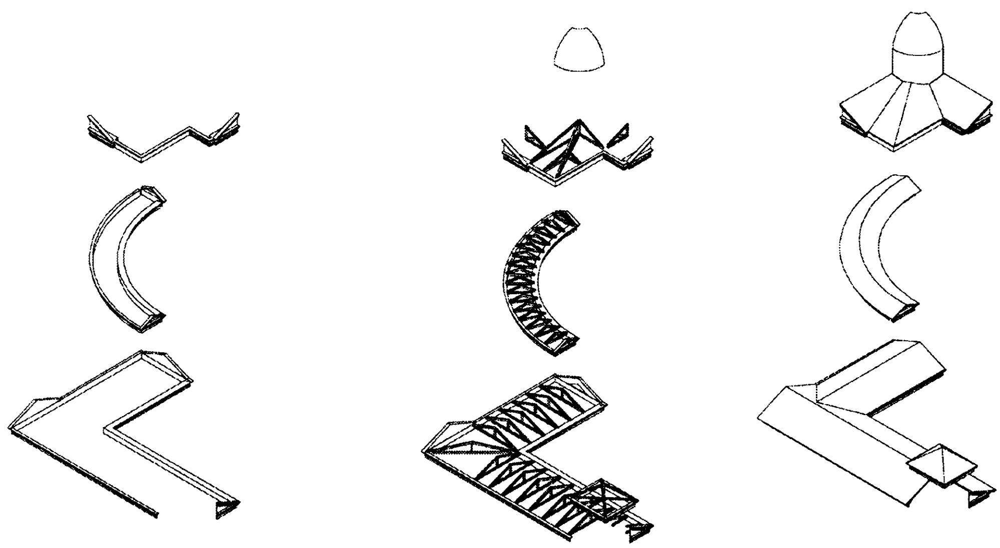


Fig. 8.20 Cornice, roof truss and roof

8.2 RECONSTRUCTION RESULTS AND CONFLICTS

As with any reconstruction, there are many conflicts and contradictions. I will outline the most significant two. First is the conflict over the height and construction of the dome. There are no rules for defining the height of the dome. Although the villa Rotunda is rendered with a similar dome, the two cannot be compared on similar terms. The Villa Rotunda's dome is drawn almost as if it were a metal dome with very little wall space between the base of the dome and the top of the villa roof. The Villa Trissino has walls extended far above the roof-line of the villa, and the dome has a radius lower than that of the Rotunda. Palladio's drawing shows the Villa Trissino dome with moldings and details around the upper portion of the dome, which could mean that the dome was composed of brick.

List of conflicts in the model construction:

1. How does the connection between the house and the barns work?
2. What are the orders of the columns at the barns?
3. What is the height of the dome?
4. The slope of roof does not adhere to the rules
5. What are the heights of the barns in relation to the house?
6. What is the elevation height of the base of the lower and upper barn?
7. What are the molding types for the dome?
8. What solution will accommodate the steps from the upper barn to the lower barn?
9. Are there any windows in the basement?
10. What are the true proportions of the tall slender columns at the porticos?

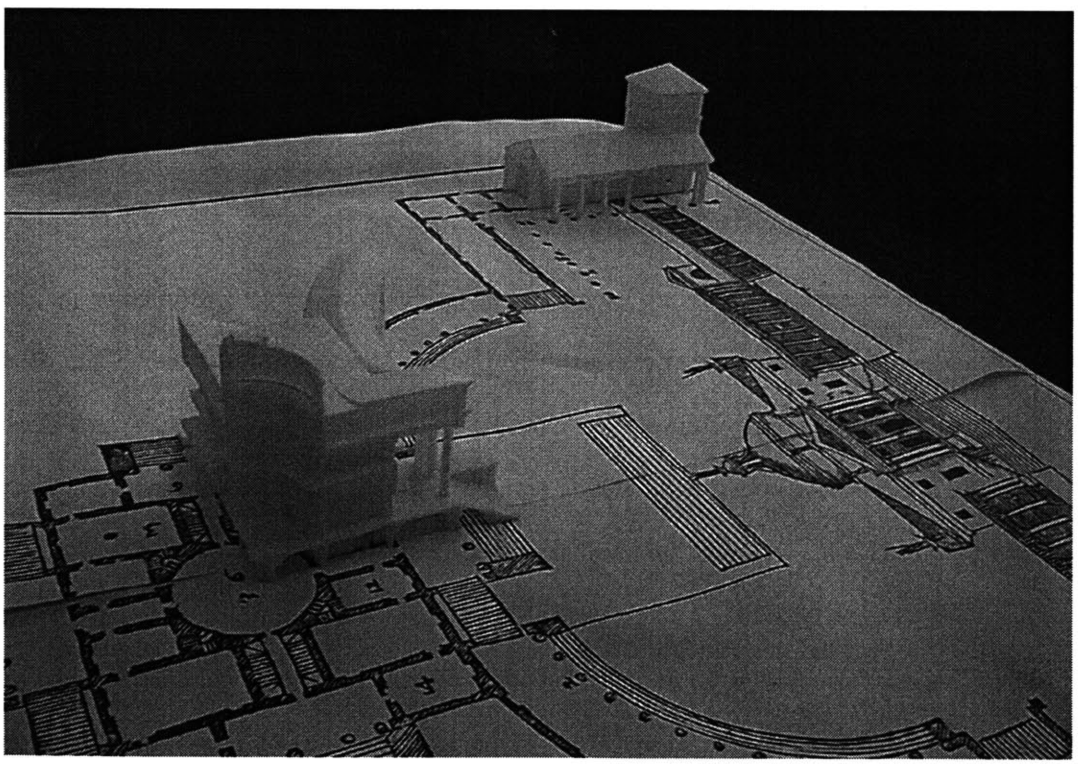
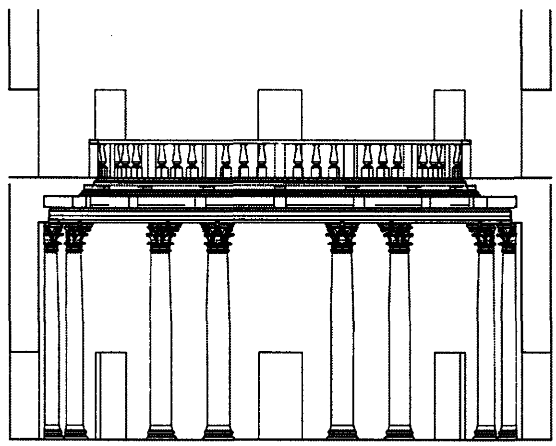


Fig. 8.21 Three-dimensional print from the cad-model

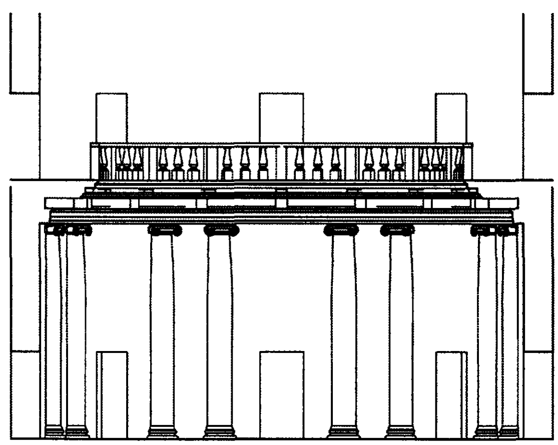
The second conflict is over the half columns in the central space. Palladio does not specify which order to use, but the two possible orders , Ionic and Corinthian are tested in this next section.

8.3 INTERIOR STUDIES

Overall interior conflicts were minimal. Most of the spaces constructed from the rules resulted in similar sized spaces as those found in Bertotti Scamozzi's drawings. The complications arose from the proposed ordering of the columns in the central domed space. Palladio outlines the spatial composition in his text. The question here is what was the order of the half columns? The possibilities include the Ionic and the Corinthian orders. There are two references that can be taken from other dome spaces similar in composition to this villa. The first is the Tempietto Barbaro at Maser, which happens to also have a portico of the Corinthian order and a domed space articulated with half columns in the Corinthian order. These half columns support a balcony of thin balustrades, above with no supporting newel post. The second space similar to the design of the Villa Rotunda, which is of the Ionic order on the outside and frescos with columns of no particular order on the inside. The inner wall below supports the balcony, lined with balustrades and newel posts.



Solution - A



Solution - B

Fig. 8.22 Proposals for the Corinthian and Ionic orders at the dome

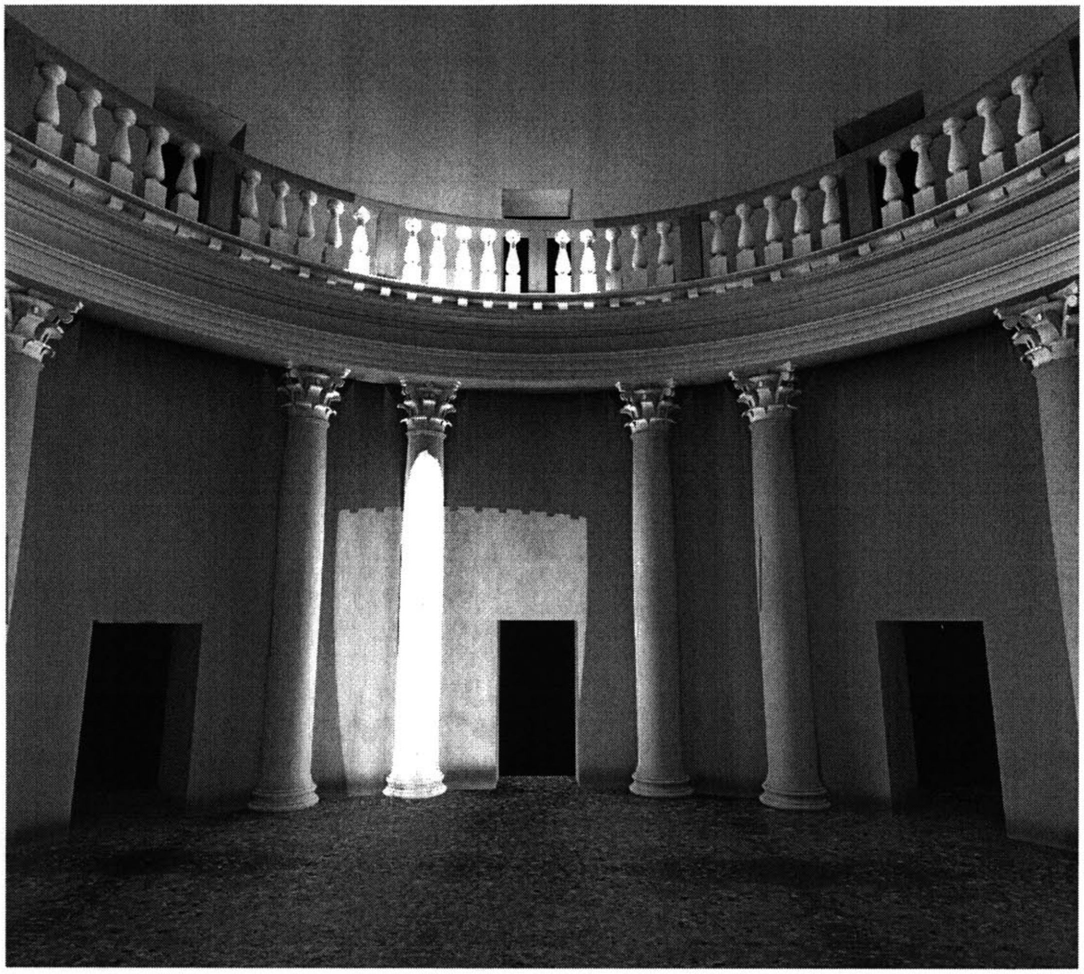


Fig. 8.23 Rendering of the central hall with half columns in the Corinthian Order

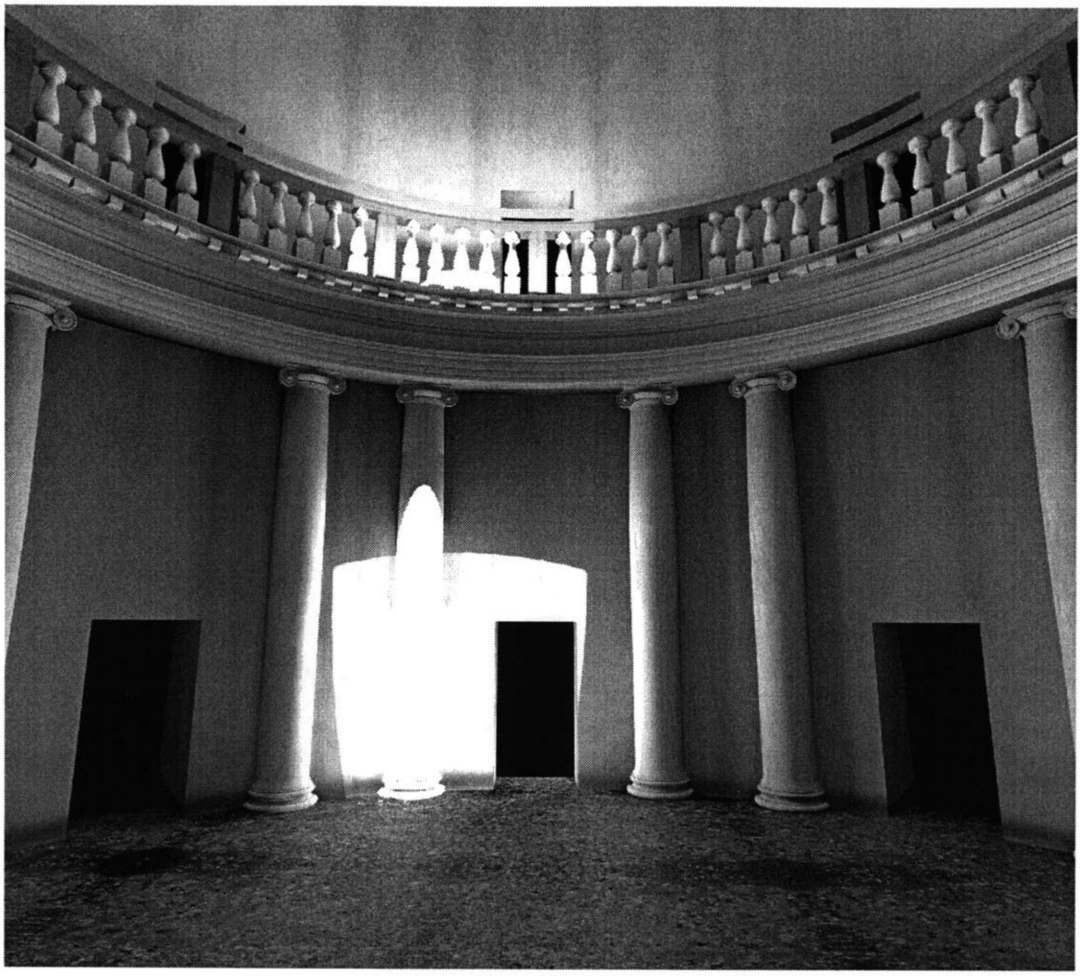


Fig. 8.24 Rendering of the central hall with half columns in the Ionic Order

8.4 SUMMARY OF FINDINGS

This study is an example of a visual test without a clear method of resolution or mechanical method of evaluation. There is not a systemized method for evaluating qualitative materials. In this chapter both solutions are tested in the space using a single light source at the top of the space. The source is simple daylight cased through and opening in the ceiling. It is unlikely that Palladio would have used Doric, so the speculation is narrowed to two types - The Ionic and the Corinthian. The selection is based exclusively on choice, which is also based on experience. An advancement of this reconstruction process could seek to eliminate the issue of choice based on experience and use choices based on rules.

Summary of Findings

Resolved

- The Villa Trissino can be constructed by the construction rules in chapter 4
- The orders at the porticos
- Dome size
- Roof construction at the villa and the barns
- Dome height
- Spacing of windows and doors in the barns
- The construction of the building fits together as per the *Four Books*
- Missing room dimension at 22' from wall to wall

Unresolved

- Dome construction
- Connection between the upper barns the house or villa
- Stairs from the upper barns leading to the lower barns
- Orders in the dome
- Sizes and proportioning of the barns

8.5 CHAPTER SUMMARY

This chapter was the first of two case studies using methods described in chapters 4 - 7. Each part of the study presented previous unexplored information leading to new questions. This chapter presented a reconstruction of a partially constructed villa set atop a hill, along side a beautiful creek. The results of the reconstruction present a palatial villa of a massive order, assembled by rule with few conflicts. The reconstruction also demonstrated the possibility for a new set of rules based on the construction of the dome.

LIST OF FIGURES

8.23 Rendering - Rendering of the central hall with half columns in the Ionic order

APPENDIX - A

VILLA TRISSINO, MELEDO

LIST OF TABLES

Table 8.1 Site and Floor Plan Data

rules	element	function	variables & equations	fig.
0-Site Plan				
4.2.8.ls	site	assignment (farming villa)	-	-
4.2.1.pa	site	assignment (general villa)	-	-
5.3.3.ls	site	assignment (street)	-	8.2
5.3.2	site	assignment (hill)	-	8.2
4.2.2.pa	grid-a & grid-b	assignment (middle of site)	-	8.2
4.2.8.ls	grid-a & grid-b	assign grid -a & grid-b	-	8.2
4.3.1.pa	grid-b (barns)	may not impede house	-	-
4.3.7.ls	grid-b (barns)	straight of circular	-	-
4.3.8.ls	grid-b (barns)	dovecotes at ends	-	-
1-Plan				
5.5.1.1.ls	rectangle	assign main hall	36' diameter	5.11
5.5.1.2.ls	rectangle	assign inset portico	14' x 17'	5.11
5.5.1.3.ls	rectangle	assign extended portico	-	5.11
5.5.1.4.ls	rectangle	assign side hall	19'x6'	
5.5.1.5.ls	rectangle	side rooms	varies	5.11
5.5.1.6.ls	rectangle	assign stair	16' x 12'	5.11
5.5.1.8.ls	rectangle	assign barns	varies	5.11
5.5.1.9.ls	rectangle	assign barn loggia	varies	5.11
4.4.4.1.pa	rooms	mirrored	-	-
4.4.6.2.pa	stair	placement	-	-
4.4.11.ls	lines	initial wall thickness		
2-Ceilings			-	4.8
5.5.2.1.ls	symbol - flat ceiling	assignment	-	4.10
5.5.2.6.ls	symbol - dome	assignment	-	4.23
3-Walls				
5.5.3.1.ls	wall thickness	assignment	18"	5.13
5.5.3.2.ls	wall thickness	assignment	24"	5.13
5.5.3.3.ls	wall thickness	assignment	30"	5.13
4.5.10.ls	wall thickness	assignment	-	
4.5.11.ls	wall thickness	assignment	-	4.4
4-Portico				
5.5.4.1.ls	stair (front portico)		a=15' b=19' c=5' d=10'	5.14
5.5.4.1.ls	stair (side portico)		a=15' b=19' c=5' d=13'	5.14
5.5.4.4.ls	stair (side of front portico)		x= 19' y=12'	5.14

rules	element	function	variables & equations	fig.
5.5.4.4.ls	stair (barn portico)		a=14' b= 5' c=1'6"	5.14
4.4.2.1.pa	loggia	assignment	-	
4.8.14.ls	riser & tread (broken rule)	size	portico < 20'	
5-Column				
5.5.5.1.ls	column (portico)	assignment	2'dia	5.15
5.5.5.1.ls	column (barns)	assignment	2'dia	5.15
5.5.5.5.ls	pilaster	assignment	2'wide	4.13
4.9.10.1.pa	column	even number of columns	-	4.35
4.9.10.2.pa	column	middle column space larger	-	4.31
6-Stairs				
5.5.6.1.ls	rectangular stair	assignment	x=20' y=4'	5.16
5.5.6.2.ls	triangular stair	assignment	x=8'8" y=8'8"	5.16
4.8.1.pa	stair	location	-	-
4.8.2.1.pa	stair	location	-	-
4.8.3.1.pa	stair	openings	-	-
4.8.13.ls	stair	span walls	-	4.27
4.8.4.pa	stair	width of stair	-	-
4.8.14.ls	riser size		ri=6" tr=12"	4.25
7-Doors				
5.5.7.1.ls	principle door	assignment	-	5.17
5.5.7.2.ls	room door	assignment	-	5.17
4.15.3.pa	principle door	location	-	
4.15.4.pa	room door	size	e=22' a=6'1"	4.45
4.15.5.ls	principle door	size	e/3.5=a 12/3.5=3'3"	4.45
4.15.8.ls	room door	size	c=3'0"	4.45
8-Windows				
5.5.8.1.ls	window center	assignment	-	5.18
5.5.8.2.ls	window double	assignment	-	5.18
5.5.8.3.ls	window double hall	assignment	-	5.18
4.16.5.ls	window location	assignment	-	
4.16.6.ls 4.16.9.ls	window variables (width)	size	d1=4'6" d2=4'6" b =20'6"	4.50
4.16.7.ls	window typical	size	b/4.5 = d1 20'6"/4.5 = 4'6"	
9-Details				5.19
5.5.9.3.ls	window seat	assignment	-	

Table 8.2 Elevation Data

rules	element	function	variables & equations	fig.
1-Bound.				
5.6.1.ls	initial shape (main house)	assignment	x = 54'9" y = 25'6" k = 24'6"	5.20
5.6.1.ls	initial shape (upper barn)	assignment	x = 102'6" y = 18' k = 15'	5.20
5.6.1.ls	initial shape (lower barn)	assignment	x = 111'2" y = 15'	5.20
2-Walls				
4.5.2.pa	walls - piano noble	sizing	-	4.6
4.5.3.pa	walls - second story	sizing	d = 0"	4.6
4.5.7.pa	walls foundation	sizing	c = 9"	4.6
3-Cornice				
5.6.3.1.ls	cornice -second story	assignment & size	y = 5'	5.22
5.6.3.3.ls	cornice -barn (upper)	assignment & size	y = 4'"	5.22
5.6.3.3.ls	cornice -barn (lower)	assignment & size	y = 1'6"	5.22
4-Portico				
5.6.4.1.ls	pedestal & step (front)	assignment & size	k = 3" l = 14'6" d = 9'6'	5.23
5.6.4.1.ls	pedestal & step (upper barn)	assignment & size	k = 1'6" l = d = 3'	5.23
4.8.13.ls	stairs	span walls		4.31
5-Columns				
5.6.5.1.ls	Tuscan column (upper barn)	assignment & size	d = 18' x = 2'2"	5.24
5.6.5.1.ls	Tuscan column (lower barn)	assignment & size	d = 22' x = 2'8"	5.24
5.6.5.4.ls	Corinthian column	assignment & size	d = 25'6' x = 2'	5.24
5.6.5.5.ls	Arch at barn	assignment & size	d = 15' x = 7'6"	
4.9.1.2.pa	column	location	-	
6-Molding				
5.6.6.1.ls	molding piano noble	assignment & size	x = 6" y = 9"	5.25
			-	

7-Windows & Doors				
5.6.7.1.ls	rectangle	assignment	-	5.26
4.15.5.ls	rectangle (principle door)	variables	a=6.1 y= b=12'	4.45
4.15.7.ls	rectangle (principle door) Formula returns strange numbers	size	y=2a b=a-y/12 12.1=2(6.3) =6.3-12.1/12	
4.16.4.1.pa	window	location	-	
4.16.4.2.pa	window	size	-	
4.16.6.ls	window (height)	variables	h1=12'2" b=22'6" d1=4'4" h2=10'	4.46
4.16.7.ls& 4.16.10.ls	window	equation	h1=(2(d1))+b/6 13'=(2(4.6))+22.5/6 h2=h1-h1\6 10.0=12.1-12.1/6	4.46
8-Roof				
5.6.2.ls	roof (gable-pediment)	assignment & size	x = 20'10" y =9'	5.27
5.6.3.ls	roof (hipped-upper barn)	assignment & size	x =16'8" y =3'7"	5.27
5.6.3.ls	roof (hipped-lower barn)	assignment & size	x =37'5" y =8'"	5.27
5.6.8.ls	Dome	assignment & size	x=20'6 y=32'6	
4.19.7.pa	roof	slope	t =23.2 w/9 x 2 w = 40' 109.5/9x2 = 24'	4.59
9-Details				
9.1.ls	dome cupola	assignment	-	8.3
5.5.6.2.ls	dome moldings	assignment	-	5.28

Table 8.3 Model data

rule	element	function	variables & equations	fig.
1-Plans				
4.5.7.pa	foundation walls (house)	Double wall thickness of piano noble	-	8.1
2-Walls				
4.5.2.pa	walls diminish			8.2
4.5.7.pa	foundation walls	extrusion of basement plan by extrusion of upper barn by extrusion of lower barn by	b1-11'-0" b2-18'-0" b3-15'-0"	8.2
4.5.3.pa	second story walls	extrusion of halls and side room by '-3" extrusion of side room by 12'-0"	-	8.2
4.5.15.ls	wall variables		0f=36"-60" 1f=18"-30" 2f=18"	8.2 4.3
3-Ceilings				
4.6.2.3.pa	ceiling thickness	creation of rafters creation of flooring over rafters	f=18" j =12"x12" j2=18"	4.7
4.7.11.ls	segmented vault	creation of segmented vaults in basement	f = 18" v = 3'-6" r = varies	4.23
4.7.8.2.ls	barrel vault	creation of barrel vault	f = 1'-0" r = 5'-0"	4.15
4-Cornice				
4.20.8.ls	cornice variables	extrusion of cornice profile c1 (barns) extrusion of cornice profile c2 (balcony of house) extrusion of cornice profile c3 (balcony of house at rotunda) extrusion of cornice profile c4 (portico) extrusion of cornice profile c5 (under roof)	Tuscan cornice (c1) z = 3'-6" y = NA Corinthian cornice (c2) z = 3'-0" y = NA Corinthian cornice (c3) z = 3'-8" y = NA Corinthian cornice (c4&c5) z = 5'-0" y = NA	4.54
5-Portico				

rule	element	function	variables & equations	fig.
4.8.13.ls	tread and riser size	22 steps at main entry 5 steps at barn 30 steps at garden 30 steps at barns pedestal	12" x 6"	4.29
5.5.6.1.ls	stair	addition of new stair	-	5.16
4.8.8.2.pa	stair		-	
4.5.10.ls	wall	new wall	-	
6-Staircases				
4.8.2.pa	staircase	hide stairs		
4.8.3.1.la	staircase	three openings		
4.8.4.pa	staircase			
4.8.9.1.pa	staircase	oval or round		
4.8.13.ls	stair	span walls		4.31
4.8.14.ls	step	tread and riser	12" x 6"	
4.8.12.ls	stair	variables	rectangular stair w =3'-0" k = 10'-0" d = 12" ff = 30' w1= 14' w2= 4'-0" ri = 6" tr = 12" triangular stair w =1'-6" b = open d = 12" ri = 6" tr = varies	4.27 4.28
7-Columns				
4.9.10.1.pa	column	even numb of col.		
4.9.10.2.pa	column	larger space in mid.		4.31
4.9.13.2.pa	column	pilaster at end		4.31
4.9.15.ls	loggia & rotunda variables	insert Corinthian columns at porticos insert Corinthian columns at rotunda insert Tuscan columns at barns	p = 2'-6" s = 6'-0 d = 1'-6" c = 2'-6" m = 10'-4"	4.31
4.14.1.ls	Arch variables		House x = 6'-4" z1 = 23'-6" Barns x = 8'-7" z1 =9'-9"	4.44
8-Moldings				

rule	element	function	variables & equations	fig.
4.5.6.pa	moldings noted			
6.1.8.ls	molding variables	basement-bottom molding-bm1 basement-top molding -bm2 first floor- bottom molding p1 barn molding-bn	bm1=6"x12" bm2=6"x12 p1 = 6" x 9" bn = 6"x 9"	8.3
9-Doors				
4.14.1.ls	door openings	basement-10-door openings barns-13-door openings (including all levels of the dovecotes piano noble-9 door openings (2 principle doors) second floor-8 door openings (2 principle-doors)		4.45
4.14.5.ls	door variables (piano noble)		a = 5'-1" b = 9'-4" c = 3'-0" d = 6'-6" e = 18'-0"	4.45
10-Windows				
4.15.4.1.pa	window			
4.15.6.ls	window		4'-4"	4.49
4.15.7.ls	window		12'-2"	
6.1.10.1.ls	basement window	1 basement windows 27 barn window 5 large wind. @ piano noble 5 small wind @ second floor	basement x = 1'-6" y = 3'-6" barn x = 3'-4" y = 7'-6"	8.4
4.18.3.ls	balustrade	insertion of balustrade	r1 = 6" r2 = NA by = 20" bx = 1'-6"	4.49
4.16.12.ls	ornamentation	door profile	x = 2'-0" y = 5"	4.47 7.13
12-Roof				
4.19.2.pa	roof	cover building		
4.19.3.pa	roof	bear on walls		
4.19.4.pa		divide into 9 parts		
4.19.5.pa		slope equals 2 parts		
4.19.7.pa	roof variables	pediment cornice rafter main roof	d1 = 9" d2 = 10" z=23.2 degree	4.53

APPENDIX -B

VILLA TRISSINO, MELEDO

LIST OF FIGURES

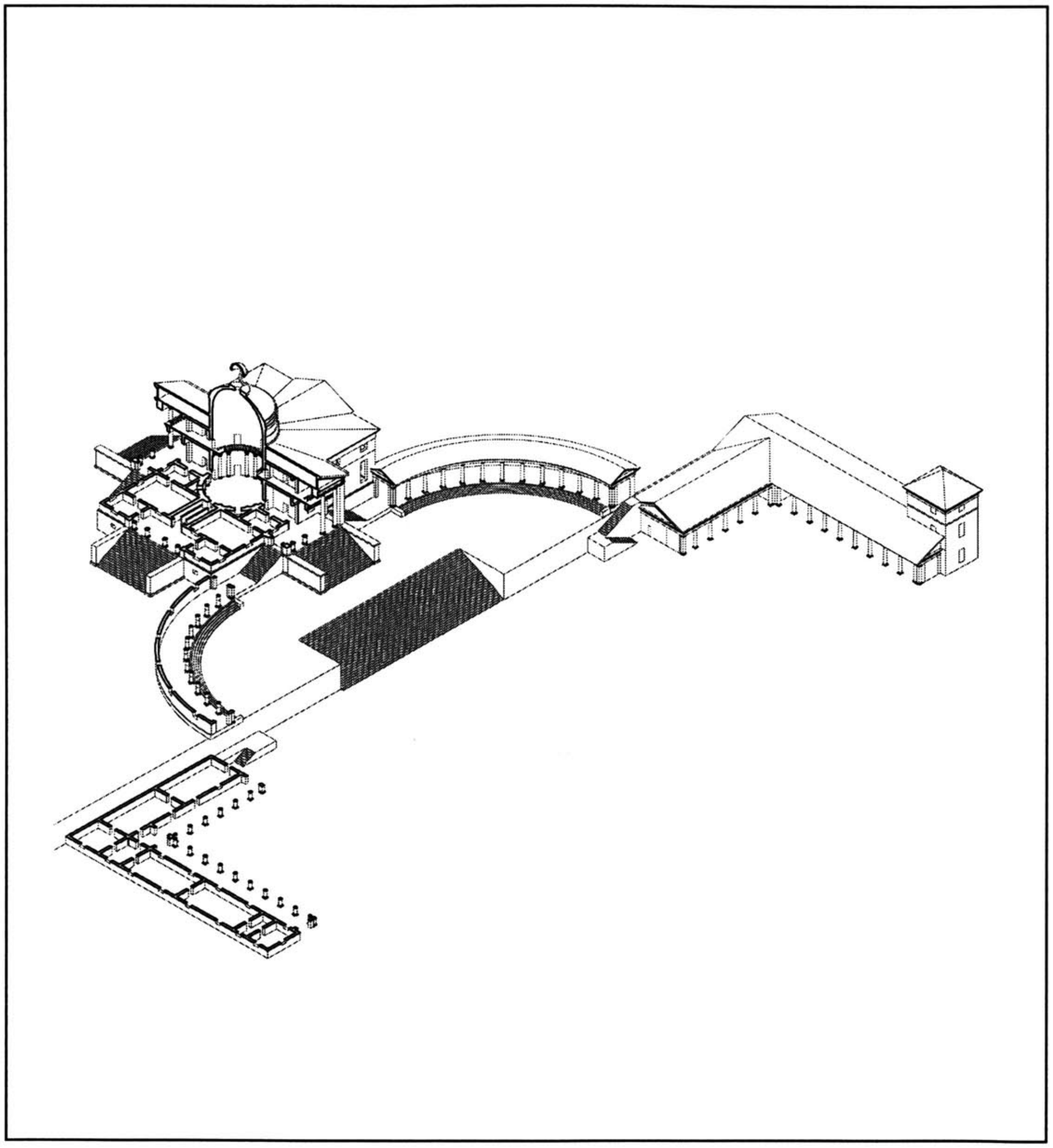


Fig. 8.24 Isometric projection of villa model

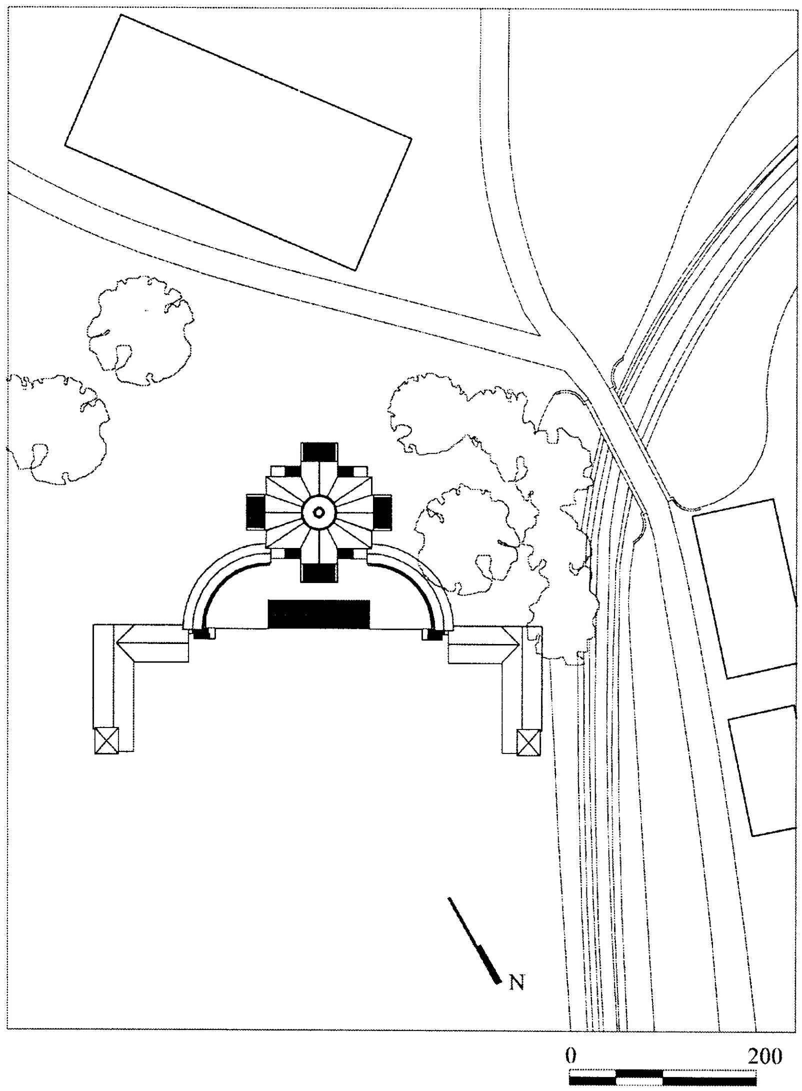


Fig. 8.25 Site plan

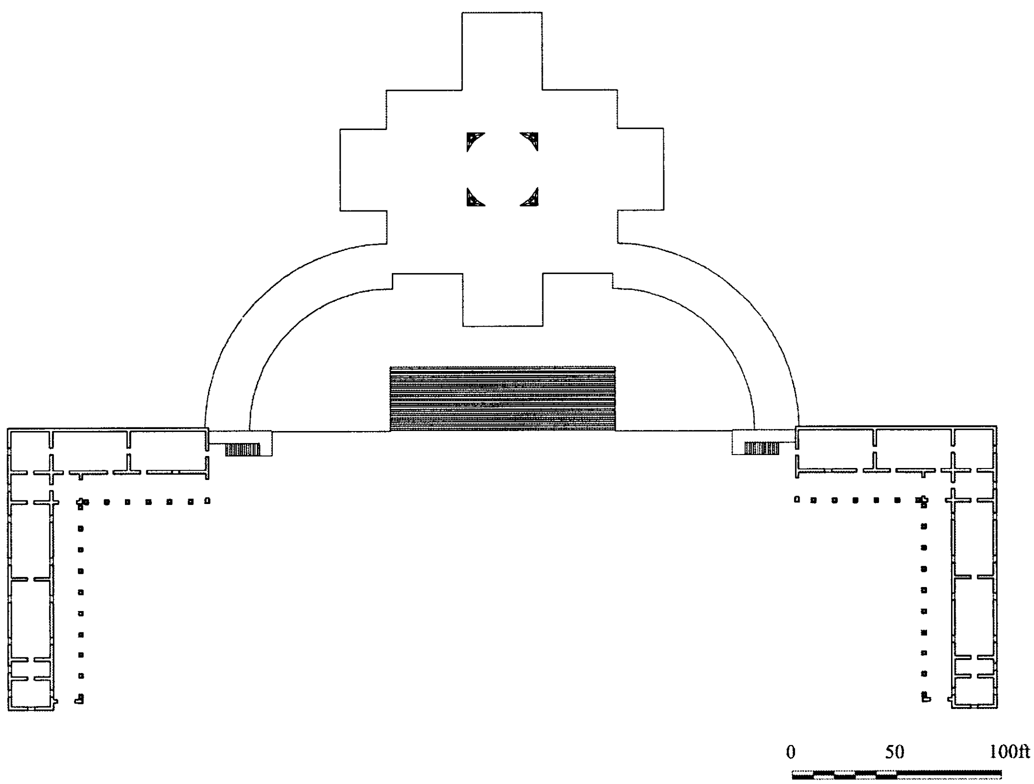


Fig. 8.26 Floor plan - Basement

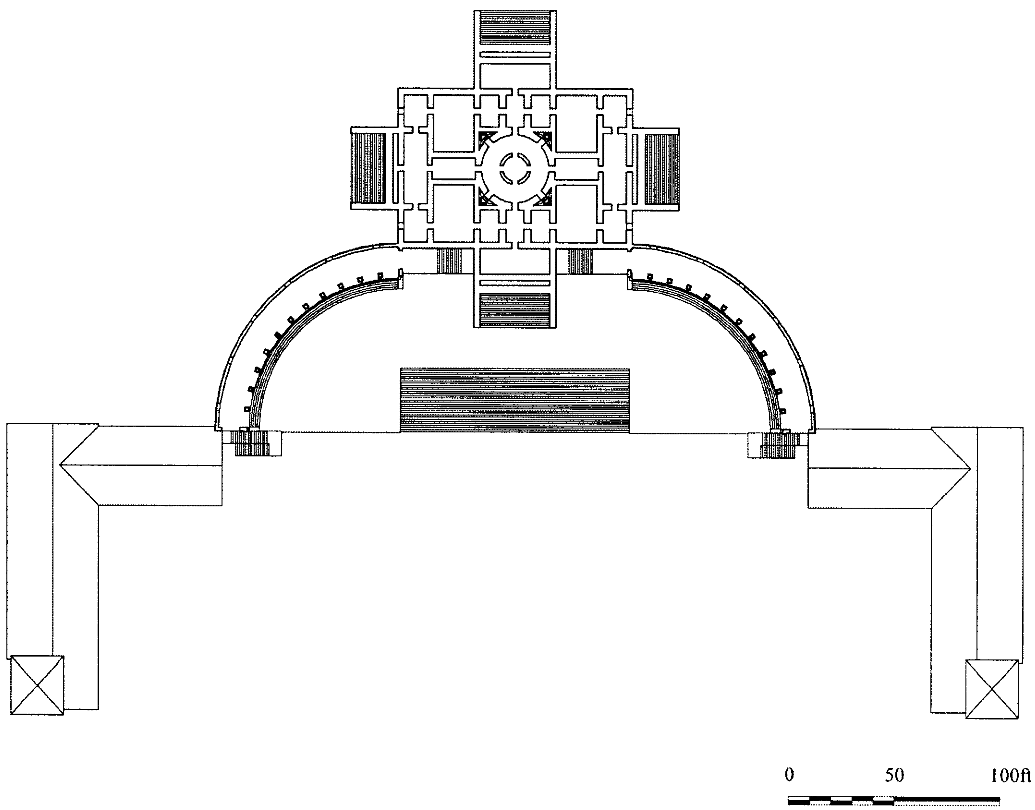


Fig. 8.27 Floor plan - Piano noble

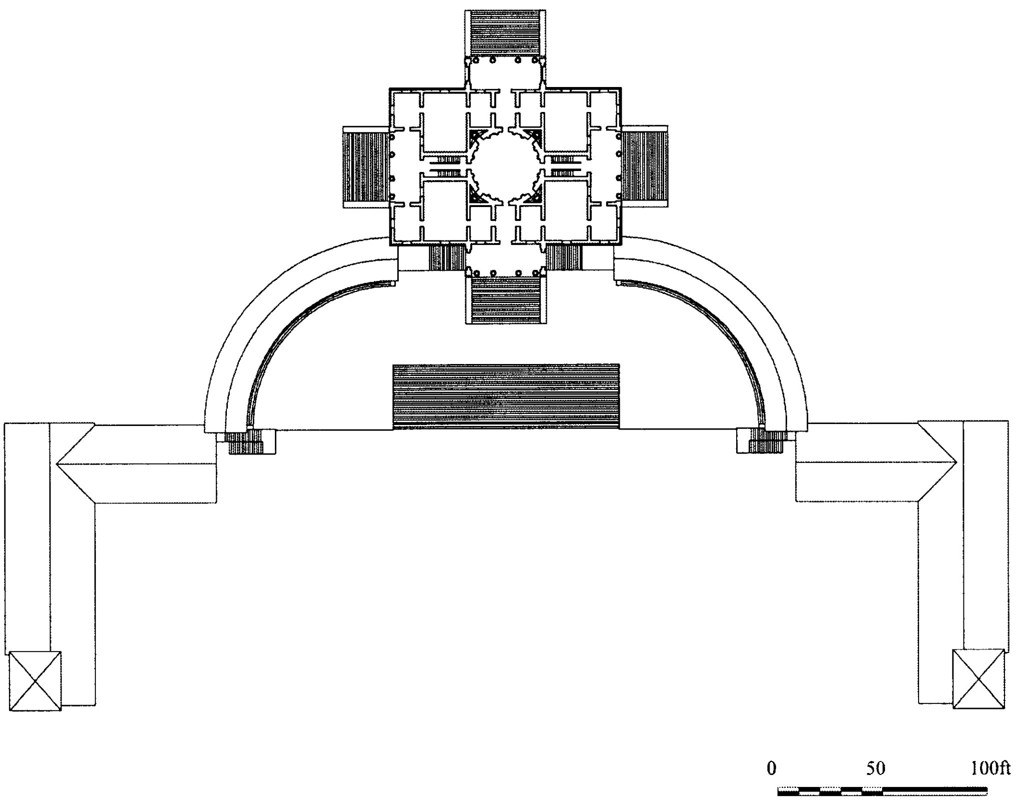


Fig. 8.28 Floor plan - Second floor

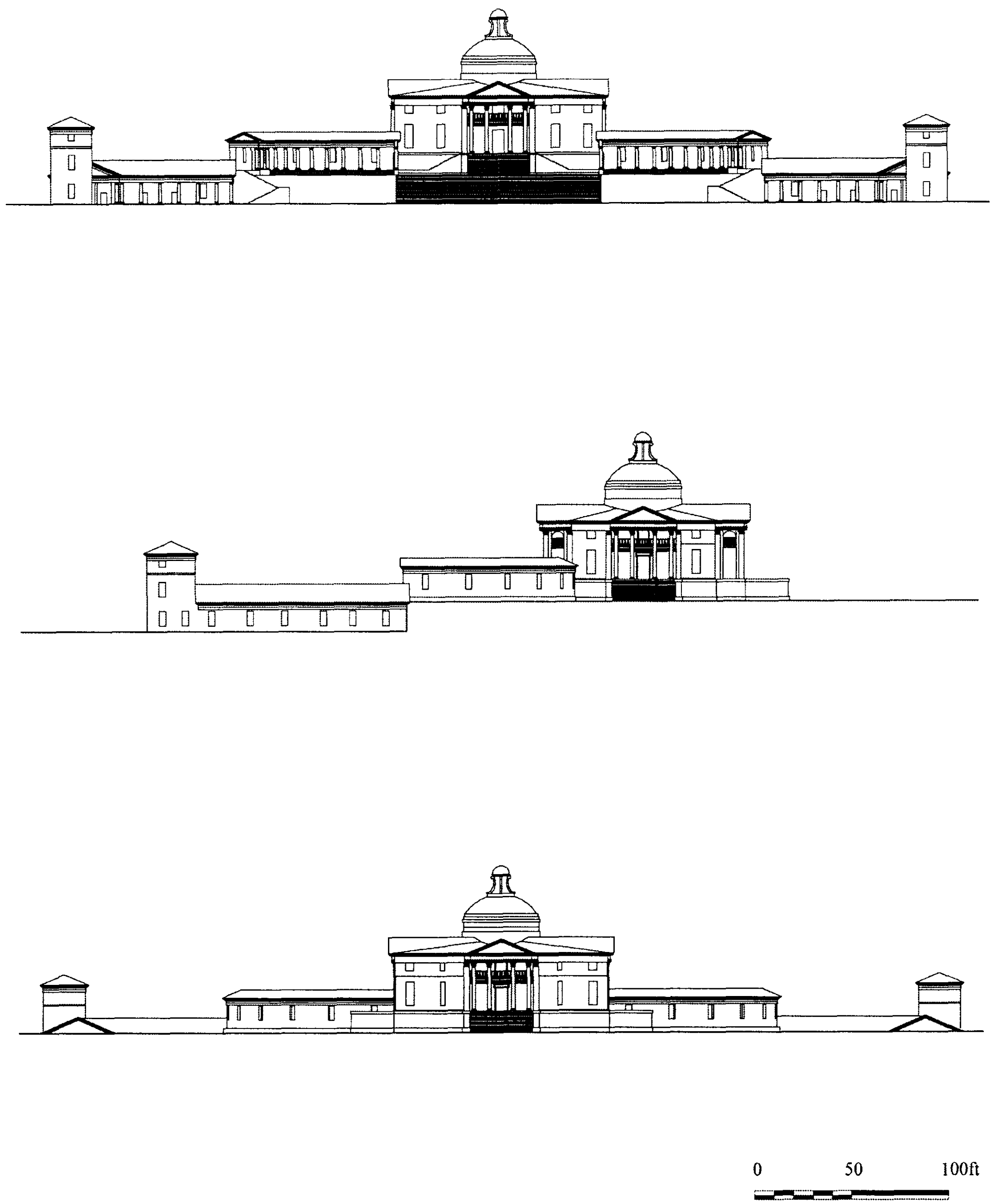


Fig. 8.29 Elevation - Front, Side and Rear

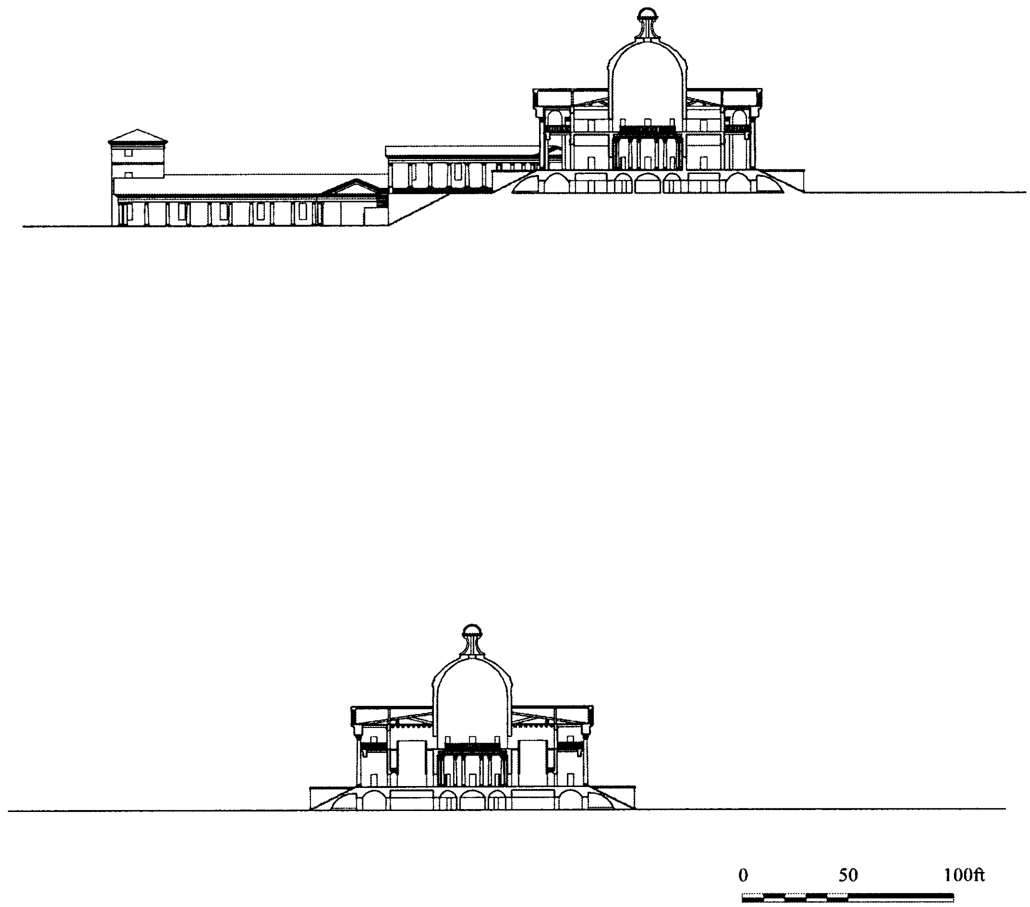


Fig. 8.30 Section - Longitude and Transversal

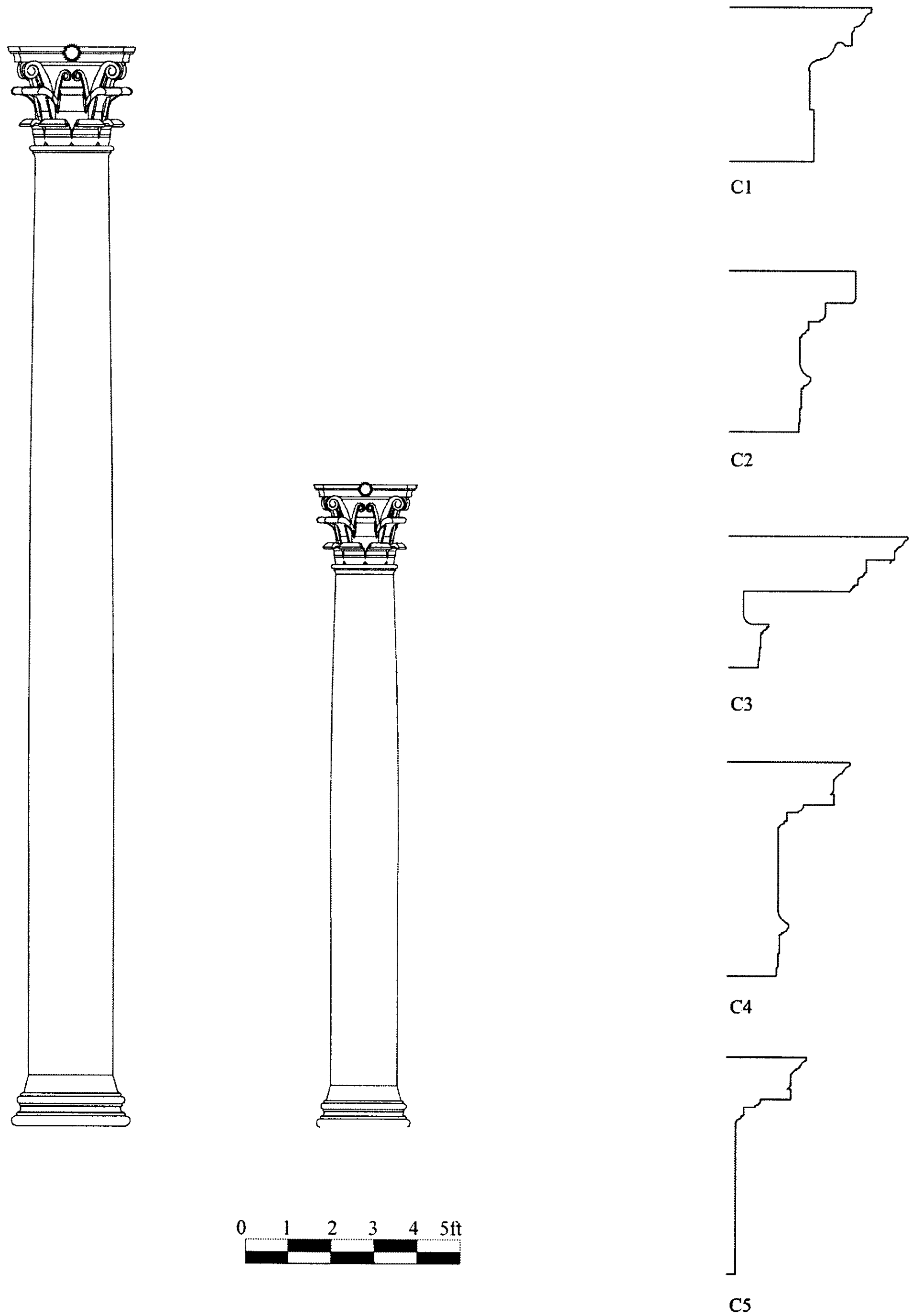


Fig. 8.31 Column and cornice profile

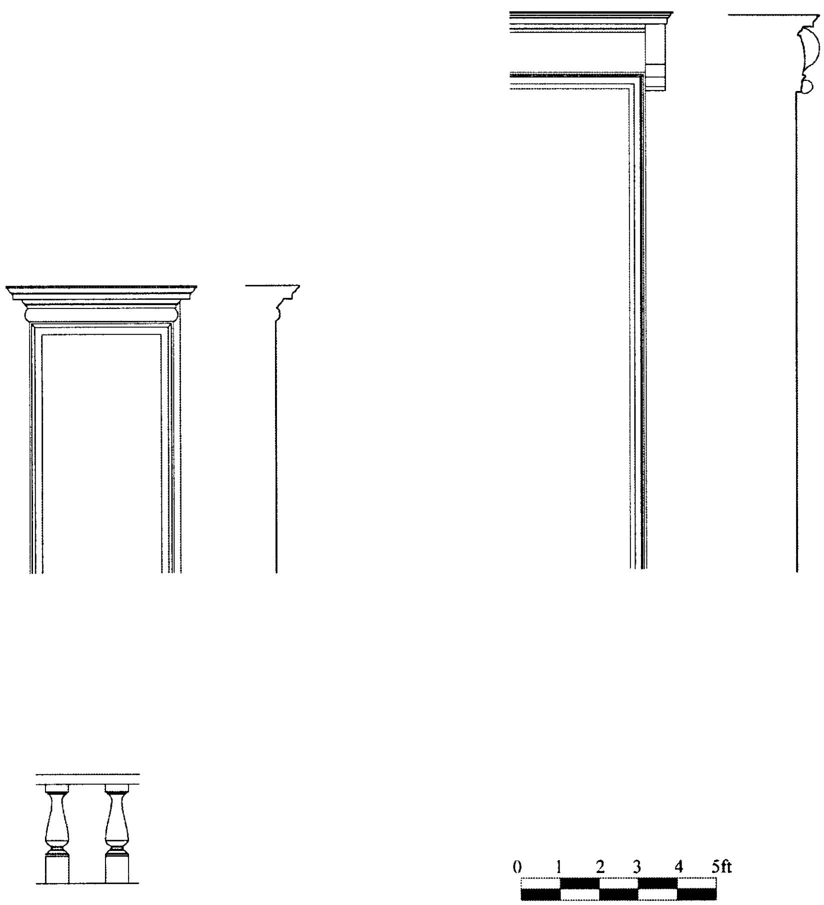


Fig. 8.32 Detail - Door profiles and balustrade profile

CHAPTER NINE

THE VILLA MOCENIGO, ON THE BRENTA

Case Study B

9.0 THE COUNTRY PALACE

The Villa Mocenigo on the Brenta River was Palladio's last design entry in the *Four Books*.[421] The Villa is Palladio's largest and most ornate, composed of many columns, spaces and details. It has also been argued that part of the villa was built but the rest never completed. One view is that Palladio never had plans to build this villa, and that it was intended to serve as an ideal villa.[422] In support of Puppi's point that the Villa Mocenigo served as a representation of an ideal villa is the fact that the villa appears to be a combination of a palace and villa. The body of Mocenigo is similar in composition to the inner courtyard of the palazzo Thiene and Porto. Where it differs from the traditional palace is in its height which is only two stories like that of a typical villa. Villas of similar designs and proportions range from the villa Thiene, Cicogna which has a similar loggia to the villa Badoer which as a similar barn type, although not identical. Due to the fact that it is completely unexecuted and there is a lack of records of any kind the reconstruction will be quite difficult.

The only reconstructions published are those of Palladio & Bertotti Scamozzi. A field study of a site for this villa defined by maps and documents of the area, show that the villa would has to be located in the area of Dolo. The site is placed between a road and a small river way approximately 3/4 mile from the Brenta River (fig. 9.3). It was assumed that the water channel adjacent to the site

[421] Burns, H. data provided, summer 1997

was used to carry goods upstream to the villa from Venice. The site is flat, surrounded by two walls at its perimeter, similar to the property wall of the Villa Barbaro in the town of Maser. It measures 100 paces in length or approximately 350 feet - the same distance across as Palladio's plan. Finally, there are many discrepancies in the villa proportions first presented by Bertotti Scamozzi in terms of the columns in the atrium and rooms. Puppi defines these proportions as a problem in the design due to a quick rush to print.

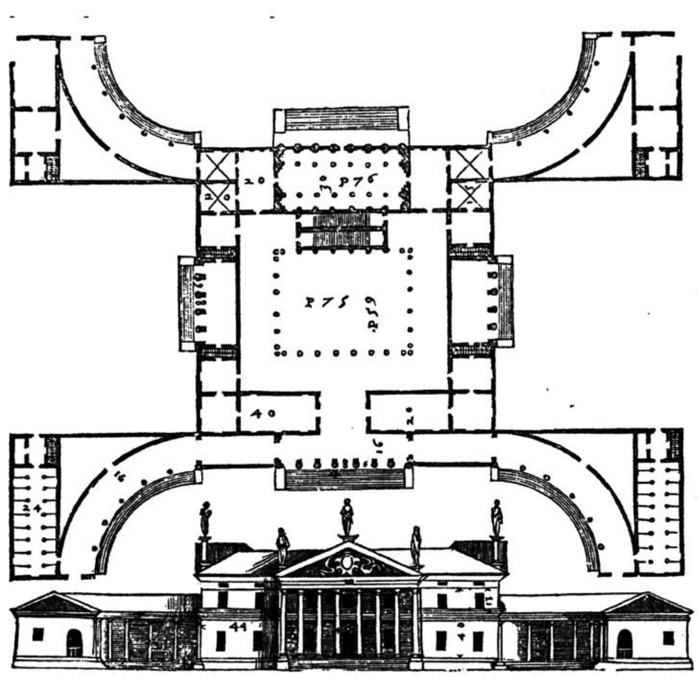


Fig. 9.1 Palladio's drawing of the villa Mocenigo

[422] Puppi, L. 1973, p.358

In spite of the fact that the design appears to be complete, there are many areas of indecision not resolved by Palladio or Bertotti Scamozzi.[423] The connection between the circular and the straight portion of the barns are the same detail as the barns in the Villa Badoer, but the physical execution of the design is totally different from Badoer in the drawings. Palladio's intentions for the intersection of the two barns are not clear. They were meant to terminate at their intersection with a pediment or were they intended to be two separate barns like that of Badoer.

Fig. 9.2 View of site from river way; note the center of the site is marked by a large white pole in the center of the photograph

[423] Bertotti Scamozzi, B., 1776

Another issue is the ceilings, for which the drawing notes only having two vaults. The rest are assumed to be flat, except for the back hall that is lined with full and half columns along the walls. Bertotti Scamozzi represents this space with vaulted ceilings and not a flat ceiling - the columns and beams of the type found in the hall of the Villa Cornaro (fig. 7.21). A possible reason behind the lack of vaulted ceilings could be cost. Vaulted ceilings are quite expensive, and it is possible that most of the cost was put into the walls, columns and column capitals. The reconstruction of the Villa Mocenigo is enormous, requiring a variety of model shapes and rules, both existing and new.

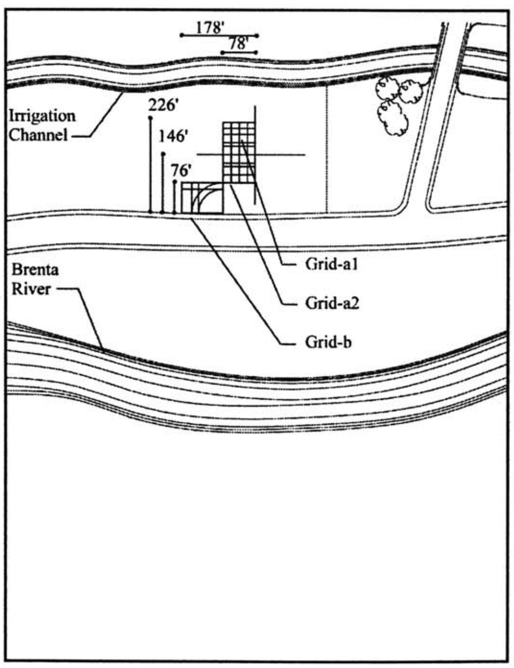


Fig. 9.3 Site plan with grid-a1, a2 and grid-b

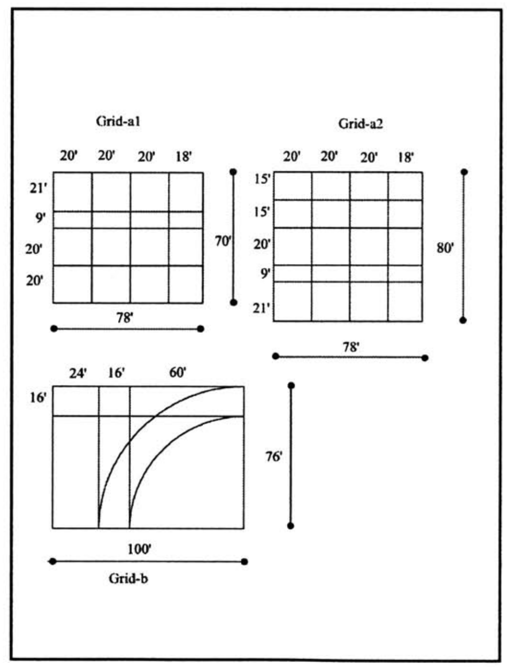


Fig. 9.4 Grids-a and grid-b in detail; dimensions reflect the sizes listed in Palladio drawing for the house and barn grids

9.1 THE RECONSTRUCTION

As simple as the design appears, the reconstruction process was extremely complicated. Details such as cornice connections, arcs from the barns, roofs and multiple column insertions made for a laborious study of objects and connections. Examples of this are the loggias that bring together columns, column capitals, the entablature, the roof and pediment, balconies, walls and floors. Each has its own fitness requirement based on rules found in section 4.9. The loggias also call for many offset objects from other objects. For example, the pediment at the front the portico requires a detail separate from the entablature below, and from the cornice that surrounds the upper outer wall (fig. 10.1). Here the challenge is finding a rule that would fit the pediment to the entablature or the cornice. Many conditional states are needed to satisfy all situations.

9.1.1 Plan and Elevation Reconstruction

The greatest point of controversy for Bertotti Bertotti Scamozzi is that Palladio disregarded many details on this project in particular dimensioning used to measure the atrium. The three top conflicting areas of the plan are the front of the plan in relation to the elevation, the location of doors at the small villa stairs and the dimensioning of the columns and spacing at the front loggia. Some dimensions such as the general height of the building on the elevation, and most room sizes work fine. Lastly there is the conflicting detail over the entry to the building that does not have a supporting wall. The span is over 36' in length. Bertotti Scamozzi solves this by adding walls to the missing space.

In spite of a few conflicting dimensions, most rooms fit precisely within the outer boundaries of the plan-in other words there were few left over spaces. Because of the small number of vaulted spaces, most walls were 18" in thickness; due to the fact that the building did not have a basement service, spaces were on the same level as entertainment. Because of the marshy conditions, the piano noble is raised almost 5' off of the ground plane. Intercolumniation was close to the dimensions listed on Palladio's drawing, except that Palladio did not make clear the different orders at the lower level or the need to use half columns at the back wall of the atrium. Here I followed Bertotti Scamozzi's speculations and put Ionic columns on the first level of the atrium and Corinthian at the top. Doors and windows were simple openings with few conflicts in terms of stairs or low ceilings. The elevation reconstruction was also uneventful except for the windows at the barns that had no fitness requirements. Palladio does not have a rule for windows outside the scope of the main villa. The sloping of the roof was a bit difficult to define merely because it has and odd way of terminating when it intersected with other parts of the same roof.

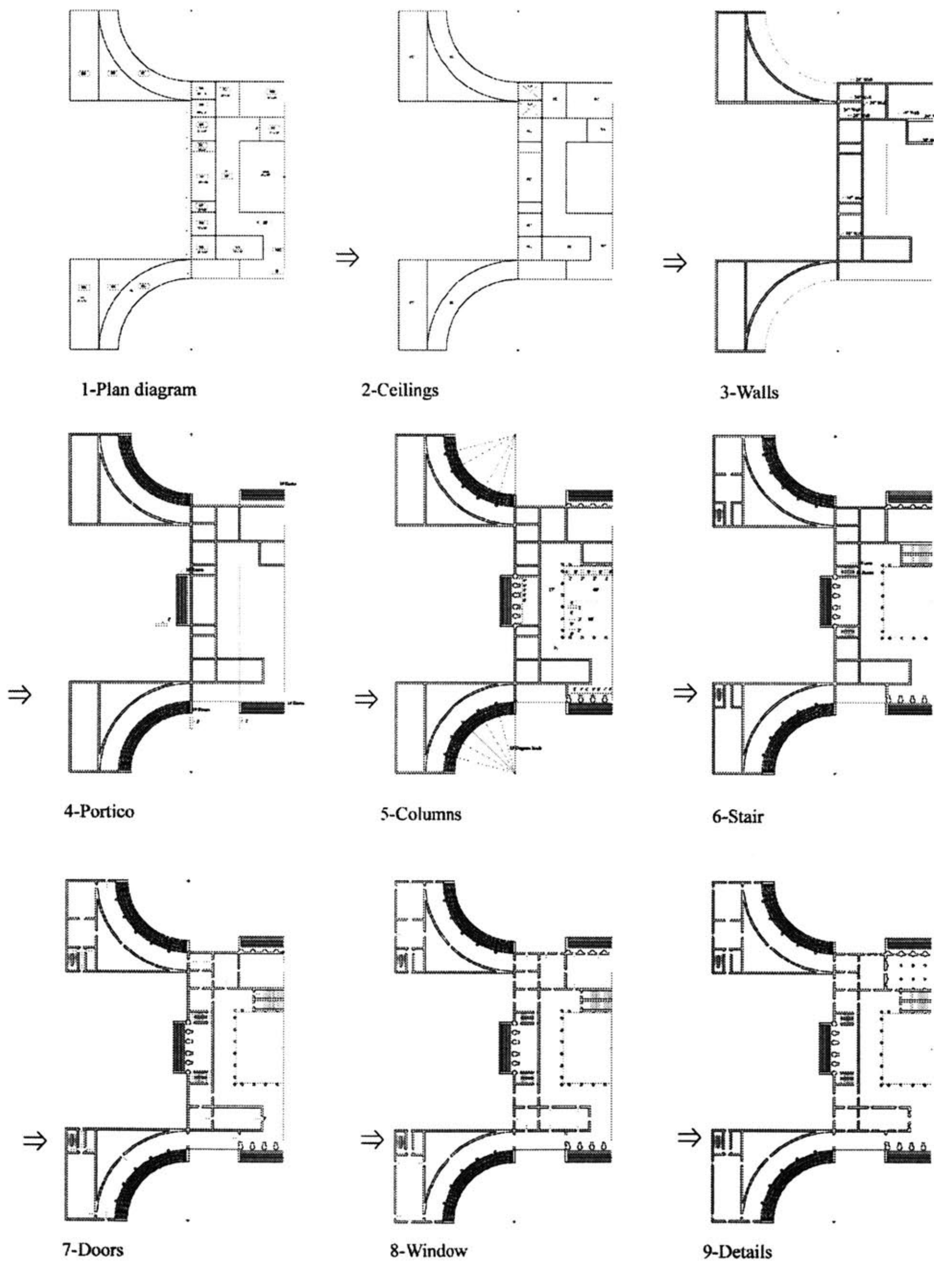


Fig. 9.5 Plan reconstruction derivation

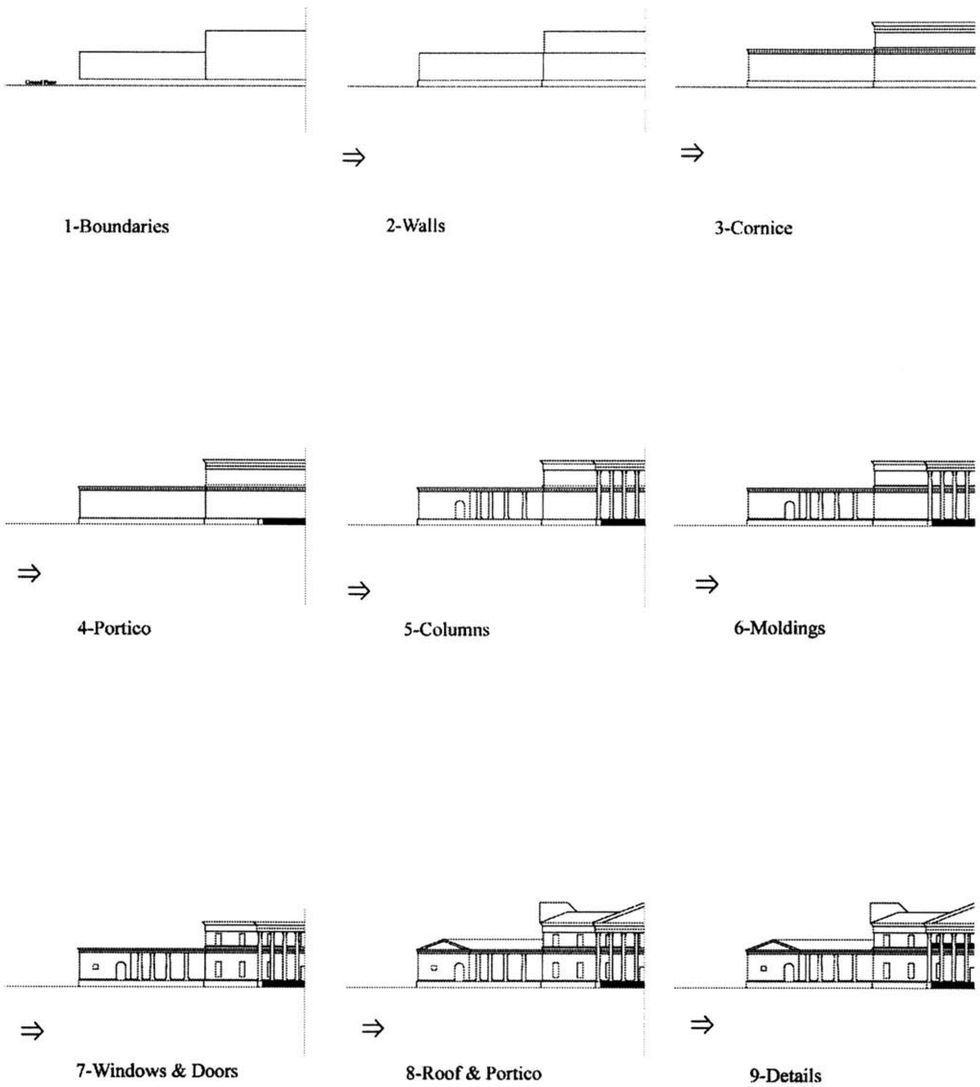


Fig. 9.6 Elevation reconstruction derivation

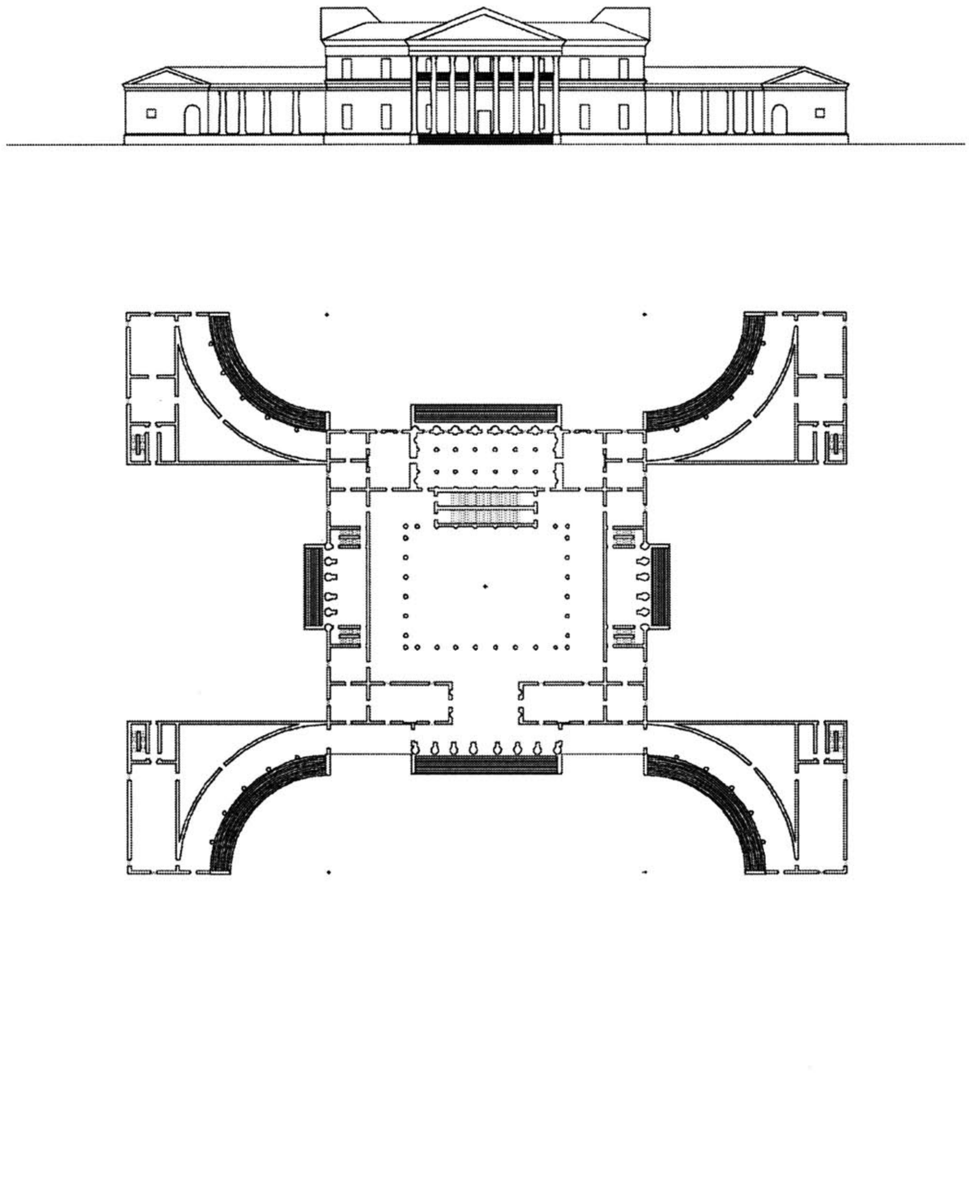


Fig. 9.7 Finish plan and elevation

9.1.2 Model Construction

This villa required the most computing power of any model I have ever constructed. The model contains 112 columns -Corinthian and Ionic. The villa model for Trissino contains 80 columns and of that, only 32 are Corinthian. The remaining are 48 are of the more simpler Tuscan order. Computational operations performed on the completed model were slow and difficult due to the complicated column capitals. In the end, the main assembly of the model was as simple as the floor plans. There were few complications or contradictions between the design rules and the physical construction rules.

9.1.2.1 Initial Plans

Since there are few vaults at the first or second levels, all but two rooms are constructed of 18" thick walls. The two vaulted spaces in the back of the villa are 24" in thickness. The villa also has no basement, removing basement wall issues from this equation. However, for visual purposes the foundation contour was made 9" wider than the walls at the base. This makes the piano noble appear to rise from a wider base. The walls at the second floor are of the half a brick thinner than those at the piano noble, making all of the walls at that level 12" in thickness.

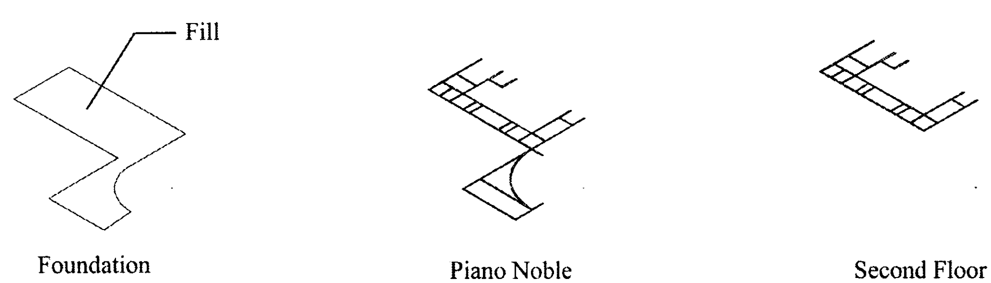


Fig. 9.8 Plan derivation

9.1.2.2 Walls

Due to the variations in dimensions listed on the drawings, walls are the first articles to cause confusion. Palladio provides a distance of 40' on the face of his elevations. This is in reference to the height of the façade from the floor of the piano noble to the underside of an 8' cornice and entablature. The second floor lined up with the top of the cornice for the barns, which by his dimensions (22-1/2'-column + 4-1/2' cornice) is at 27' in elevation. By Palladio's calculations, the piano noble measures 17' from the first to the second floors. If the numbers were used there would be a major discrepancy in the proportions of the façade. The cornice at the piano noble would be 10' lower than the barns. The top of the barn roof would appear to be in line with the roof of the entire villa. Here I chose the larger of the two numbers (22'), adding 4-1/2' for the entablature, giving a final dimension of 27' for the piano noble. The walls for the second floor are a combination of the 13' noted on Palladio's drawing and the 8' entablature (21'-0").

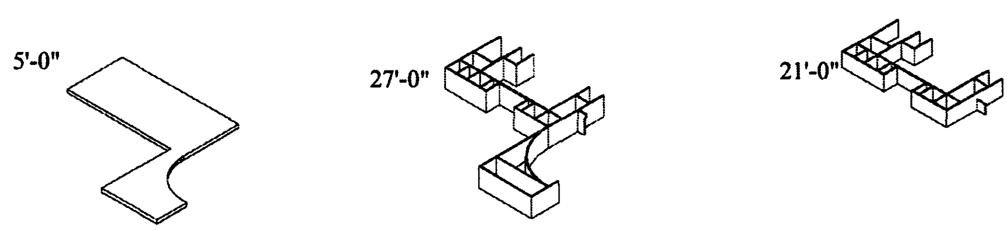


Fig. 9.9 Wall derivation

9.1.2.3 Ceilings, vaults and floors

The back two rooms contain cross vaults, constructed under conditions outlined in chapter 4, section 6. The remainder of the villa and barns contains joists.

Fig. 9.10 Ceiling derivation

9.1.2.4 Cornice

There are three cornice types made of two orders, Ionic and Corinthian. The Ionic order wraps the piano noble and the barns on all sides. The 8' Corinthian cornice and entablature wraps the upper portion of the second story wall, terminating at the entablatures of the loggias. The Entablatures are of the same order with a differing profile.

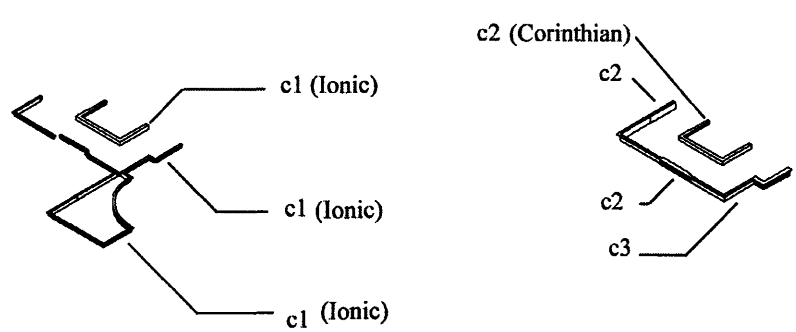


Fig. 9.11 Cornice types, refer to fig. for profiles and size

9.1.2.5 Portico and steps

There are three portico stairs, all of the same type, using the same rules. The barns are of the same level as the piano noble.

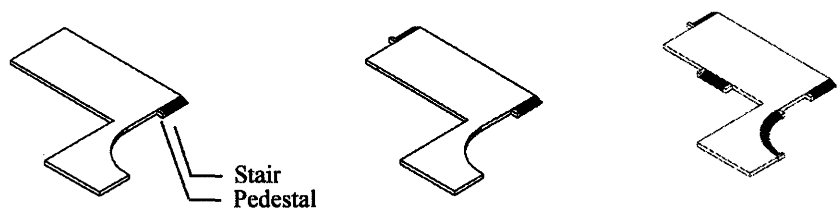


Fig. 9.12 Porticos and exterior stairs

9.1.2.6 Staircases

As with the Villa Trissino Meledo there are three staircases. The first is the barn's stair, used to access the barn attics. The second is a slightly more formal stair probably used by service people to access the attic of the villa and the second floor. And the last is a formal scissors stair that is used to only access the second floor.

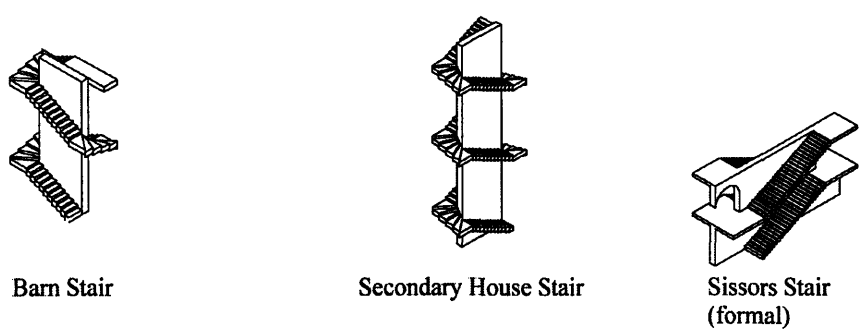


Fig. 9.13 Interior stairs

9.1.2.7 Columns and arches

There are two orders, each with a similar number of columns in the villa, except for the rear hall which has twelve full Ionic columns and 16 half columns. The atrium is arranged of 26 Ionic and 26 full Corinthian columns, and 6 half columns on the wall of the formal stair. The front loggia is arranged with eight full columns, while the rear façade is arranged with 8 half columns. The side loggias are arranged with four full columns and two pilasters that are inserted into the corners of the outer wall.

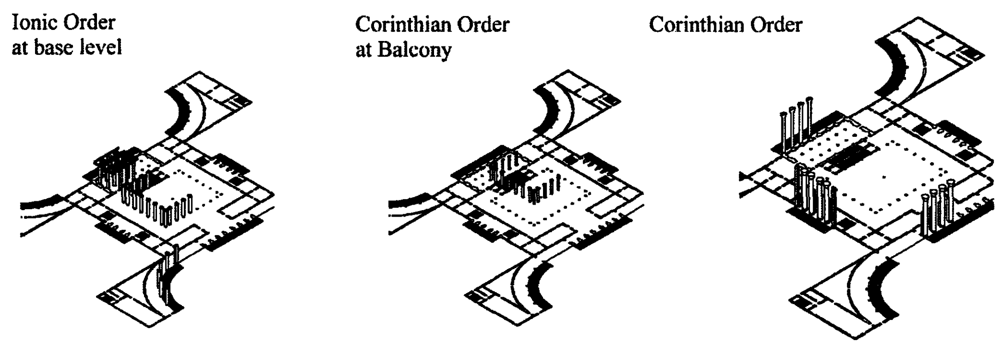


Fig. 9.14 Columns

9.1.2.8 Moldings

There are two molding types (double and single) surrounding the lower levels of the villa and barn and the lower level of the second floor.

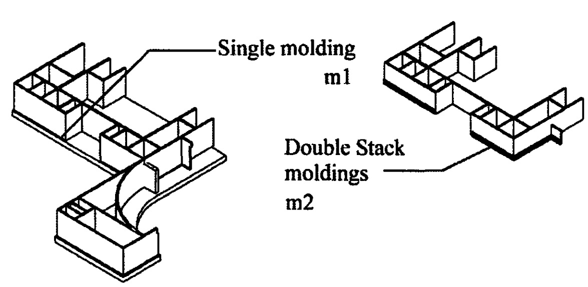


Fig. 9.15 Moldings

9.1.2.9 Doors

Palladio drew the entrance of the villa without walls in the location of the principle door. Here, a wall similar to Bertotti Scamozzi's reconstruction was constructed. The span of the space where the opening is noted on Palladio's drawing (fig. 9.1) is approximately 40' in length.

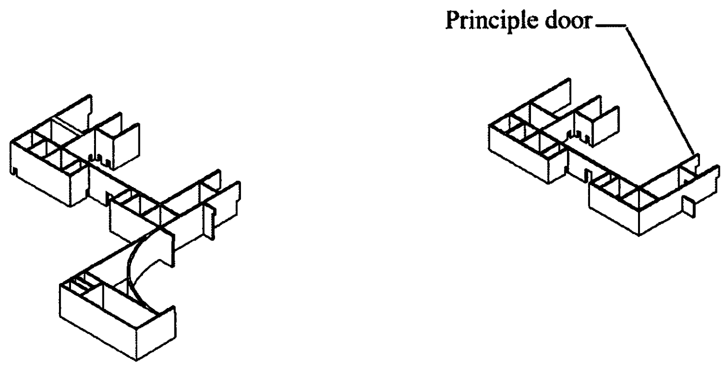


Fig. 9.16 Doors

9.1.2.10 Windows

There are four window types. The formula given in the Four Books can only be used for the main windows on the first level. The remaining windows are based on assumptions listed in table 9.3. These window types include smaller windows at the barn, the second story window and the attic windows.

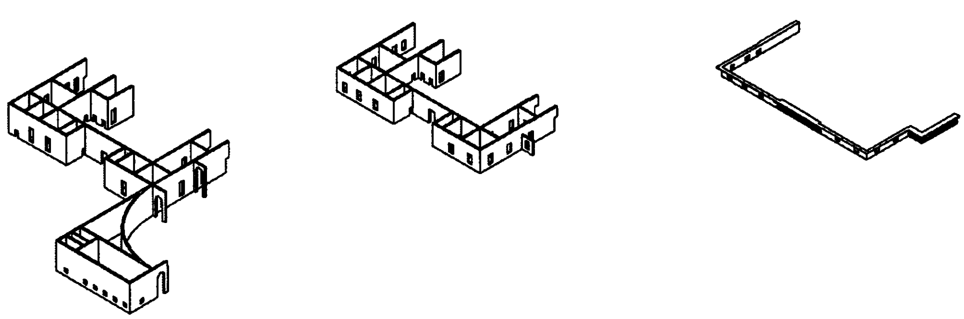


Fig. 9.16 Doors

9.1.2.11 Details

There are two principal door types, the scroll being the most formal. This villa model also includes fireplaces with mantels. The size of the mantel and its type are speculated.

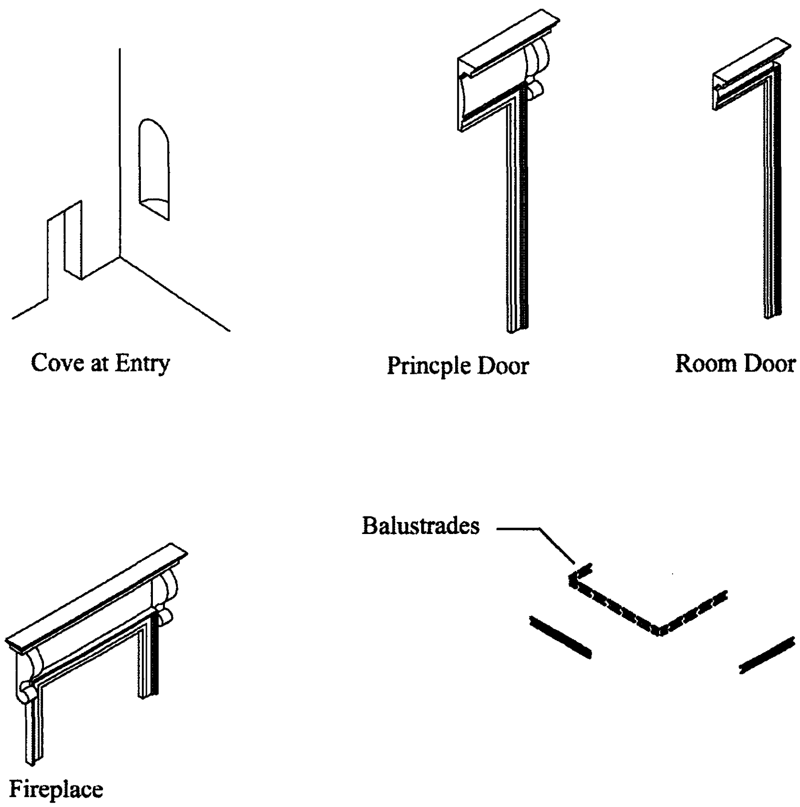


Fig. 9.17 Details

9.1.2.12 Roof and pediment

Here the challenge is to define the roof type for the barns as well as to define the angles of the slope. The barn roofs are composed of two shapes, rectangular and circular. Each meet at the front façade of the barn and share the same roof pediment. In a section drawing, Bertotti Scamozzi draws the two barns meeting at the front façade of the barn, sharing a larger roof structure. Here the barns are modeled as two separate units meeting under one unit. The issue is to resolve what lies under the larger roof unit where the two barns meet. Roof rafters do not align smoothly with the two smaller roof rafters. The main villa roof also contains a few unresolved areas. The most obvious is the open condition at the back of the roof pediment. At this point the roof is supported by wooden joist. It is possible that the opening could be enclosed with a wooden pediment.

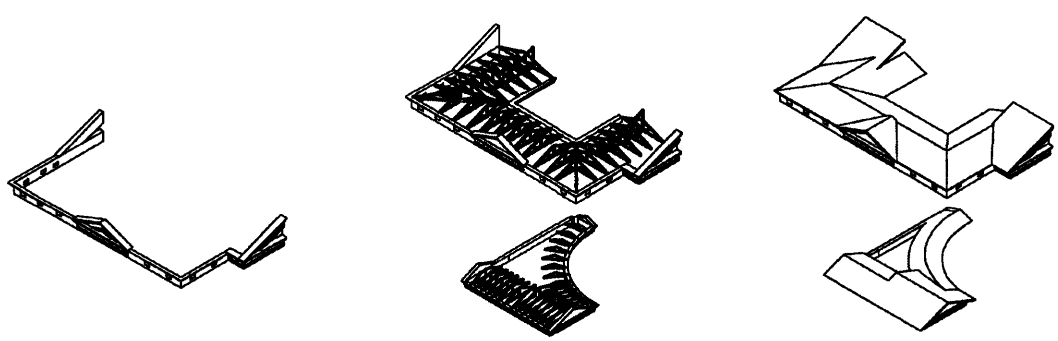


Fig. 9.18 Cornice, truss and roof

9.2 RECONSTRUCTION RESULTS AND CONFLICTS

There were many areas of conflict in the design as well as the construction, mostly within the details. As mentioned earlier, the basic outline of the design fits with most of Palladio's design rules. As per Palladio's rules the villa is symmetrical, it is placed in the center of a flat site and the patron moves through the most beautiful room first (atrium) before moving to the back of the villa. Also the barns define the outer edges of the site and the nicest sitting rooms face a view of a small water channel and not the street. The greatest area of conflict here was the contradictions in the construction. For example, what is the connection of the barns to the pediment at the front façade expected to be?

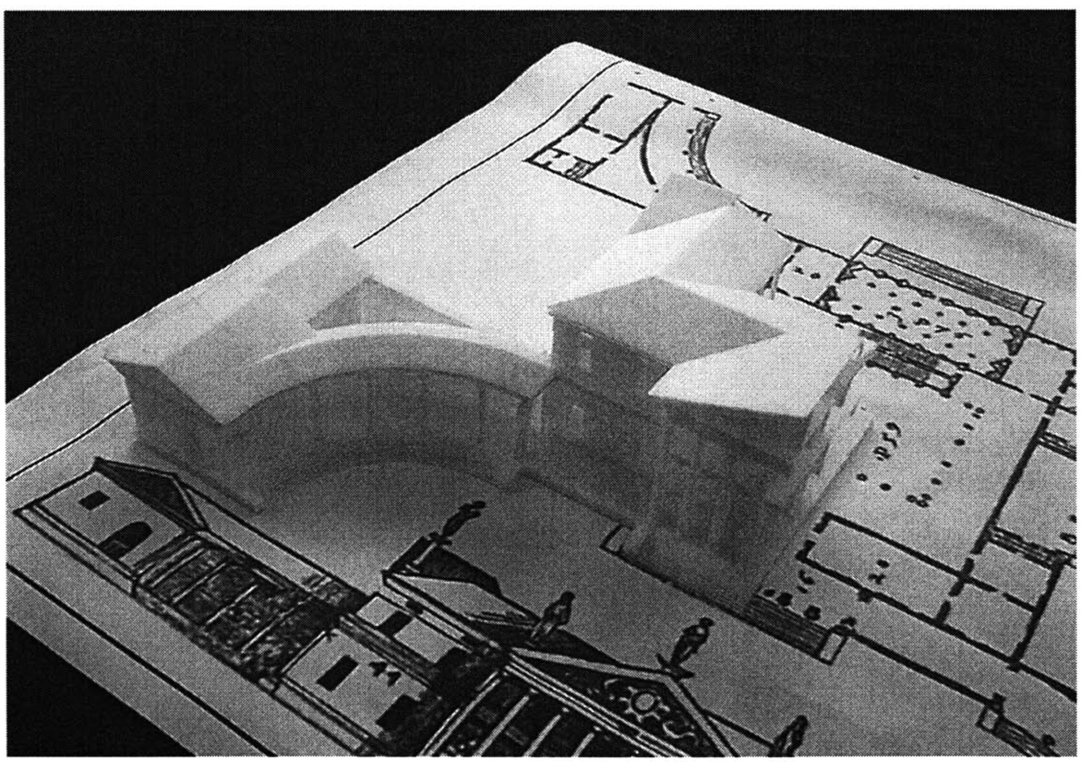


Fig. 8.19 Three-dimensional print from the cad-model

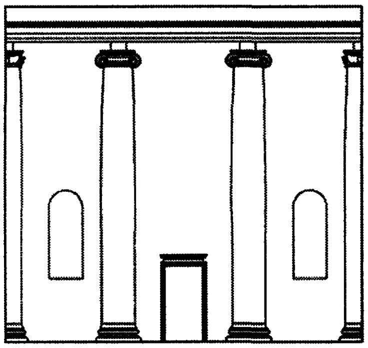
List of conflicts in the model construction:

1. Are the ceilings vaulted or flat?
2. What is the ceiling condition of the rear hall?
3. What is the order of the back room?
4. Is the entry hall enclosed or open as in Palladio's drawing?
5. What are the real proportions of the columns at the loggias?
6. Roofs do not follow slope rules
7. What are the proportions of the atrium columns?
8. What is the size of the windows at the upper story?
9. Roof connection at the front end of the barns is problematic
10.

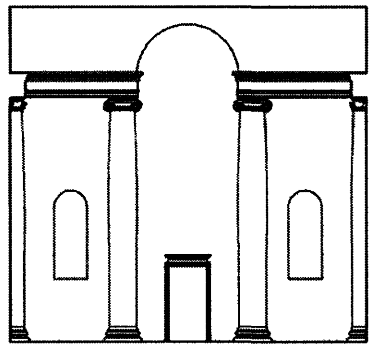
9.3 INTERIOR STUDIES

Of all the undefined spaces in the Villa Mocenigo, the rear hall stands out as a framework for many design ideas. Palladio does not indicate on his drawing whether the space is a series of columns supporting a flat ceiling, or a series of vaults. From the ceiling to the selection of the column type, Palladio's proposal for the performance of this space is unclear. Bertotti Scamozzi renders his section cut with Ionic columns supporting an arched ceiling. Here I have tested four solutions and found the final to be the most compatible in the space. Each solution was inspired from Palladio's built work and modeled to fit the space.

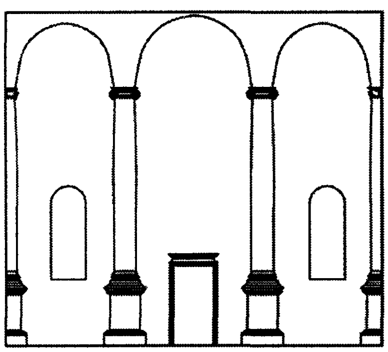
The first proposal (Solution-A) is a column and beam assembly with slightly oversized columns supporting an intermediate beam and floor joist (fig. 9.21). The space is similar in design to that of the Villa Cornaro in that it is a column and beam assembly supporting a flat ceiling. Solution-B contains a series of cross vaults over scaled down columns. (fig. 9.22) This proposal is similar to the cross vaulting found in the entry hall of the Palazzo Barbaran and the vestibule of the Palazzo Thiene. The third scheme is also a series of cross vaults with end vaults and columns on pedestals (fig. 9.23). The inspiration for this design comes from the oratory of San Cristoforo in Vicenza (not designed by Palladio), except that the scheme for the columns and pedestal in San Cristoforo has very narrow columns atop a very narrow pedestal. In my proposal the columns and pedestals are much too wide to make for a successful space. The fourth and final solution is the one I find most successful (fig. 9.24) mostly because of its spatial potential. The slender columns leaves ample room on the floor for entertaining large crowds. It is composed of a cross-vaulted ceiling of the type found in San Cristoforo, which is supported by long narrow columns and base. I would imagine Palladio would consider this to be a new design based on the fact that no palace or villa is composed of a similar combination of vaults, columns and half columns. Each solution suffers from the fact that the columns are placed evenly across the space, and typically the central row would be a bit wider than these proposals. It is still unclear why Palladio chose not to include the cross markings on his plan drawing.



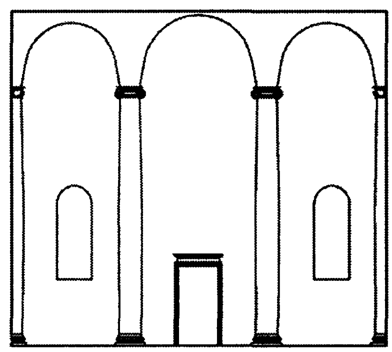
Solution - A



Solution - B



Solution - C



Solution - D

Fig. 9.20 Design Proposals for Main hall

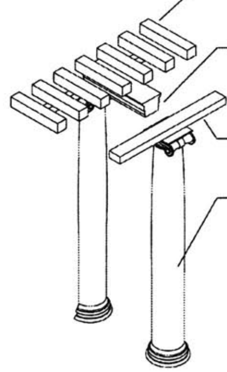


Fig. 9.21 Design Solution A

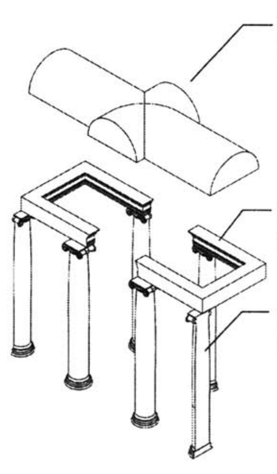


Fig. 9.22 Design Solution B - Arch [illegible]

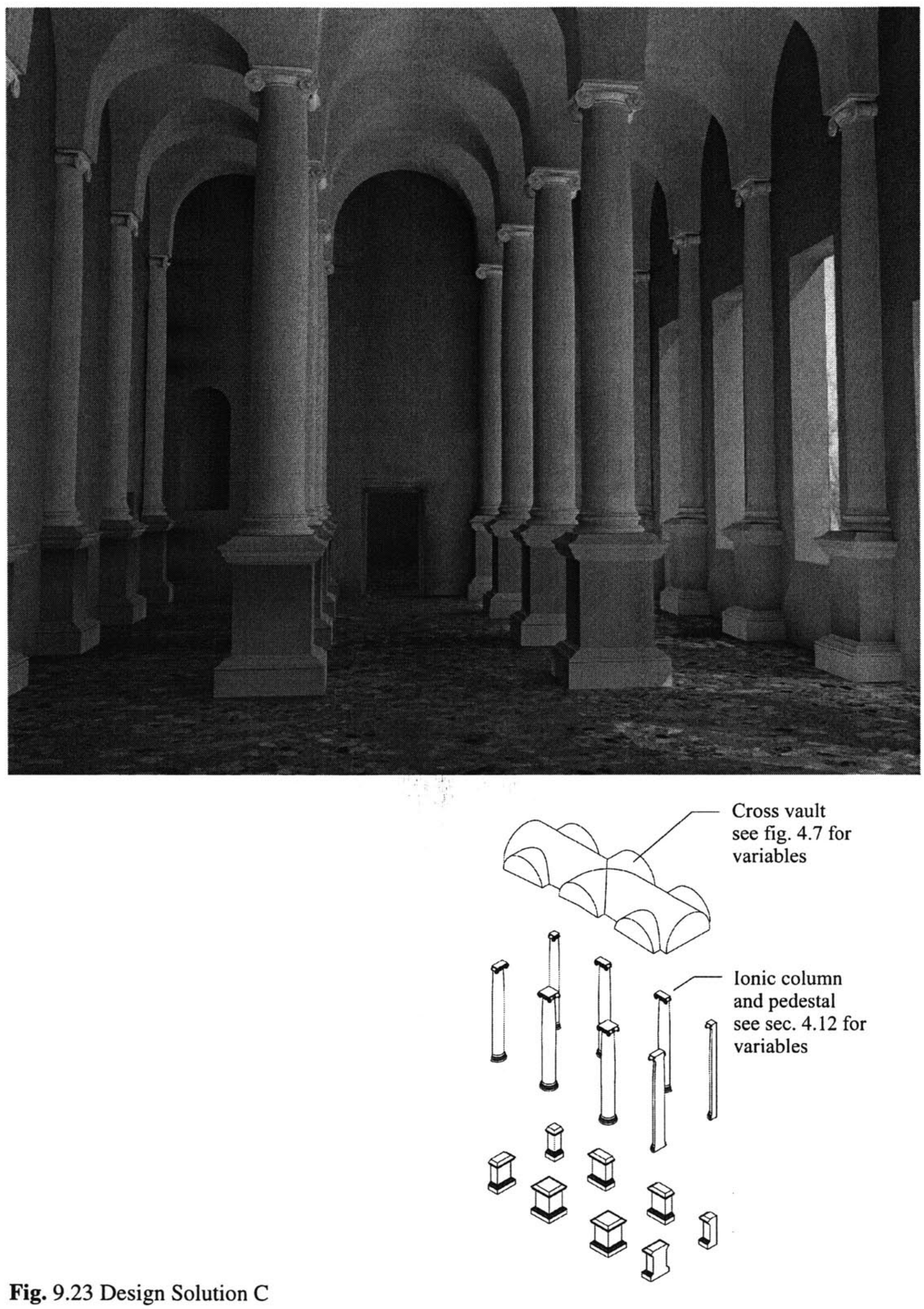


Fig. 9.23 Design Solution C

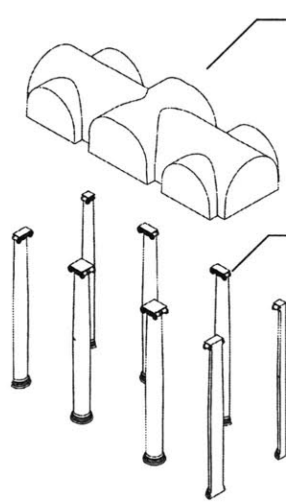


Fig. 9.24 Design Solution D

9.4 DISCUSSION OF FINDINGS

Of the four schemes, the one that would work technically is Solution-A, the flat ceiling. This scheme disregards issues of ceiling height and column spacing. All of the remaining schemes vary in their outcome based on the spacing of the columns. In other words, the spacing determines the sizing of the vaults and the relationship of one vault to another. The scheme I would choose visually would be Solution-D, the cross vault solution, based on the amount of space on the floor granted by the slender columns, the level of details in the ceilings, and intense levels of illumination from the bouncing of light off of the circular ceiling. Either way the solutions given here have one major flaw, and that is they do not take into account spacing of the central bay of columns for which Palladio notes on his drawing. Although he does not provide dimensions for the spacing one drawings, the large gap between the center bay of columns in relationship with the outer bay demonstrates the intension to create a larger bay in the center. It can be assumed that the size of the space is 30' overall, and that the space between the columns at the center bay was 20', leaving 5' on either side for the spacing of the columns from the walls. If the space had a wider center bay, the vaults would not align at their apex. Most solutions would have to favor some type of barrel vault condition instead of cross vaults as my proposals demonstrate. In this case, if I were to create a method of evaluating the final renderings, it would have to include an understanding of the construction or design principles. In fact, the change in construct would give cause to visual changes in the space. To conclude the next step in the design study would be to reconstruct new vaults based on a wider center space between the columns. The reconstruction process used here is not flexible enough to deal with dramatic changes in model. The building parts such as the ceiling would have to be remodeled to meet the changes.

Summary of Findings

Resolved

- The hall is constructed of the Ionic order with a central bay twice the width of the outer bays
- The hall is constructed of vaults with columns that have a plinth and an entasis
- The front entry space is an enclosed space, not an open space as is in Palladio's drawing
- Sizes of rooms
- Sizes of stairs and stair runs
- General space proportions for the columns and the orders in the atrium
- Structural methods for the walls, ceilings and roof
- Entry hall's missing walls
- General roof supports
- Orders throughout the villa
- Design solutions for the rear hall
- Porticos are resolved

Unresolved

- The barns are of the Ionic order; window locations and sizes are not found
- The barn roofs are unresolved
- Pediments at the rear of the roof of the main villa are unresolved
- Spacing of columns in the atrium is unresolved
- Ceiling types in rooms are unresolved
- Cornice molding details and measurements are unresolved
- Sizes of external moldings are unresolved
- Window sizes at the upper story are unresolved

9.5 CHAPTER SUMMARY

The drawing of the villa Mocenigo published in the *Quattro Libri* (fig. 9.1) was the final version of a series of unpublished designs (drawings) with a similar program. Documentation on the project began in 1554, with an inspirational sketch of the plan of the Roman theatre at Venice that was composed of a semicircular floor plan with many rooms extending from the center. It was said that Palladio constructed a series of sketches of plans for this villa while traveling along the Brenta river on route to visit Daniele Barbaro, his mentor. His sketches represented the villa with a main body similar to the version published in the *Four Books,* and barns in a rectilinear plan shape. The difference was in the shapes of the barns that started off in a square configuration, later changing to the circular configuration, inspired by the circular form of the plan of Roman Theater in Vicenza.

This reconstructed model is a representation of a combination of a working villa and palace. The details as seen in the renderings of the rear hall are taken from both, yet the general appearance at the façade is exclusively that of a villa. This combination of building types defines two issues. One, the formal direction of Palladio's buildings in that it could have been possible for Palladio to create a building that is a combination of other building types, church, villa, and palace. Second, Palladio’s vision for the ideal villa was one that offered the grand presence of a palace and the utility of a farm, the two spaces being distinct in form and function.

LIST OF FIGURES

APPENDIX - A

VILLA MOCENIGO, ON THE BRENTA RIVER

LIST OF TABLES

Table 9.1 Site and Floor Plan Rules

rules	element	function	variables & equations	fig.
0-Site Plan				
4.2.1.pa	site	assignment (general villa)	-	-
5.3.3.ls	site	assignment (street)	-	10.2
4.2.2.pa	grid-a & grid-b	assignment (middle of site)	-	10.2
4.2.4.pa	grid-a & grid-b	site location	-	-
4.2.8.ls	grid-a & grid-b	assign grid -a & grid-b	-	10.2
4.3.1.pa	grid-b (barns)	may not impede house	-	-
4.3.7.ls	grid-b (barns)	straight of circular	-	-
4.2.6.ls	grid-a & grid-b	rotation of shape (align with street)	-	10.2
1-Plan				
5.5.1.1.ls	rectangle	assign main hall	18' x 27'	5.11
5.5.1.2.ls	rectangle	assign inset portico	18' x 10'	5.11
5.5.1.5.ls	rectangle	side rooms	varies	5.11
5.5.1.6.ls	rectangle	assign stair	16' x 12'	5.11
5.5.1.8.ls	rectangle	assign barns	varies	5.11
5.5.1.9.ls	rectangle	assign barn loggia	varies	5.11
10.1.ls	rectangle	assign atrium	38' x 60'	NR
4.4.4.1.pa	rooms	mirrored	-	-
4.4.6.2.pa	stair	placement	-	-
4.4.11.ls	lines	initial wall thickness		
2-Ceilings			-	4.8
5.5.2.1.ls	symbol - flat ceiling	assignment	-	4.10
5.5.2.5.ls	symbol - cross vault	assignment	-	4.23
3-Walls				
5.5.3.1.ls	wall thickness	assignment	18"	5.13
5.5.3.2.ls	wall thickness	assignment	24"	5.13
4.5.10.ls	wall thickness	assignment		
4.5.11.ls	wall thickness	assignment		4.4
4-Portico				
5.5.4.1.ls	stair (front portico)		a=15'3"" b=10' c=2' d=36'	5.14
5.5.4.1.ls	stair (side portico)		a=2'6 b=10' c=2' d=19'	5.14
4.4.2.1.pa	loggia	assignment	ri =6" ti =12"	4.25
4.8.14.ls	riser & tread (broken rule)	size	portico < 20'	
4.4.2.2.pa	portico	size		

rules	element	function	variables & equations	fig.
5-Column				
5.5.5.1.ls	column (portico)	assignment	4'dia	5.15
5.5.5.1.ls	column (inner court)	assignment	2'dia	5.15
5.5.5.1.ls	column (barns)	assignment	2'dia	5.15
5.5.5.5.ls	column and pilaster	assignment	2'dia	4.13
4.9.10.1.pa	column	even number of columns	-	4.35
4.9.10.2.pa	column	middle column space larger		4.31
6-Stairs				
5.5.6.1.ls	rectangular stair	assignment	-	5.16
5.5.6.6.ls	scissors stair	assignment	-	5.16
4.8.1.pa	stair	location	-	-
4.8.2.1.pa	stair	location	-	-
4.8.3.1.pa	stair	openings	-	-
4.8.13.ls	stair	span walls	-	4.27
4.8.4.pa	stair	width of stair	-	-
4.8.14.ls	riser size		ri=6" tr=12"	4.25
7-Doors				
5.5.7.1.ls	principle door	assignment		5.17
5.5.7.2.ls	room door	assignment		5.17
4.15.2.1.pa	principle door	size		
4.15.3.pa	principle door	location		
4.15.4.pa	room door	size	e=22' a=6'1"	4.45
4.15.5.ls	principle door	size	e/3.5=a 22/3.5=6'3"	4.45
4.15.8.ls	room door	size	c=3'0"	4.45
8-Windows				
4.4.2.1.pa	loggia	assignment	ri =6" ti =12"	4.25
4.8.14.ls	riser & tread (broken rule)	size	portico < 20'	
4.4.2.2.pa	portico	size		
5.5.8.1.ls	window center	assignment	-	5.18
5.5.8.2.ls	window double	assignment	-	5.18
5.5.8.3.ls	window double hall	assignment	-	5.18
4.16.5.ls	window location	assignment	-	
4.16.6.ls 4.16.9.ls	window variables (width)	size	d1=4'5" d2=4'5" b =20'	4.50
4.16.7.ls	window typical	size	b/4.5 = d1 20'/4.5 = 4'5"	
9-Details				

rules	element	function	variables & equations	fig.
5.5.9.1.ls	fireplace	assignment	-	5.18
5.5.9.2.ls	cove	assignment	-	5.18
5.5.9.3.ls	window seat	assignment	-	
4.19.1.ls	fireplace	location	-	
4.19.2.ls	fireplace	location	l = 5' d =18"	4.50
4.19.4.ls	fireplace	size		

Table 9.2 Elevation Rules

rules	element	function	variables & equations	fig.
1-Bound.				
5.6.1.ls	initial shape (main house)	assignment	x = 78' y = 40' (27' &13') k = 5'0"	5.20
5.6.1.ls	initial shape (barn)	assignment	x = 10' y = 22'6" k = 5'0"	5.20
2-Walls				
4.5.2.pa	walls - piano noble	sizing		4.6
4.5.3.pa	walls - second story	sizing	d = 6"	4.6
4.5.7.pa	walls foundation	sizing	c = 12"	4.6
5.6.2	wall	assignment		5.21
3-Cornice				
5.6.3.1.ls	cornice -second story	assignment & size	y = 8'	5.22
5.6.3.2.ls	cornice -first story	assignment & size	y = 5'0"	5.22
5.6.3.3.ls	cornice -barn	assignment & size	y = 3'2"	5.22
4-Portico				
5.6.4.1.ls	pedestal & step	assignment & size	k = 4' l = 34' d = 5'	5.23
4.8.13.ls	stairs	span walls		4.31
5-Columns				
5.6.5.1.ls	Tuscan column	assignment & size	d = 22' x = 2'	5.24
5.6.5.4.ls	Corinthian column	assignment & size	d = 40' x = 4'	5.24
5.6.5.5.ls	Arch at barn	assignment & size	d = 15' x = 7'6"	
4.9.1.2.pa	column	location		
6-Molding				
5.6.6.1.ls	molding piano noble & second floor	assignment & size	x = 6" y = 9"	5.25
7-Wind & Door				
5.6.7.1.ls	rectangle	assignment		5.26
4.15.5.ls	rectangle (principle door)	variables	a=6.3 b=11.5'	4.45
4.15.7.ls	rectangle (principle door)	size	y=2a b=a-y/12	

rules	element	function	variables & equations	fig.
	Formula returns strange numbers		12.6=2(6.3) 9.35=12.6-12.6/12	
4.16.4.1.pa	window	location		
4.16.4.2.pa	window	size		
4.16.6.ls	window (height)	variables	h1=12'2" b=20' d1=4.4" h2=10'	4.46
4.16.7.ls& 4.16.10.ls	window	equation	h1=(2(d1))+b/6 12.1=(2(4.4))+20/6 h2=h1-h1\6 10.0=12.1-12.1/6	4.46
8-Roof				
5.6.2.ls	roof (hipped)	assignment & size	x = 40'9" y =9'	5.27
5.6.3.ls	roof (gable)	assignment & size	x =24'4" y =6'3"	5.27
4.19.7.pa	roof	slope	t =21.6 w/9 x 2 w = 40' 40.8/9x2 = 9'	4.59
9-Details				
5.6.9.ls	balustrade	assignment		5.28

Table 9.3 Modeling Rules

rule	element	function	variables & equations	fig.
1-Plans				
4.5.7.pa	foundation walls	Double wall thickness of piano noble		9.1
4.5.5.3.pa	first and second floor	flush		
2-Walls				
4.5.2.pa	walls diminish			9.2
4.5.7.pa	foundation walls	extrusion of basement	-5'	9.2 4.6
			27'	
4.5.5.3.pa	second story walls	extrusion of halls and side room	13'	9.2
4.5.15.ls	wall variables		1f=18"-24" 2f= 12"-18"	9.2 4.3
3-Ceilings				
4.6.2.3.pa	ceiling thickness	creation of rafters creation of flooring over rafters	f=18" j =12"x12" j2=18"	4.7
4.7.10.2.ls	cross vault		f = 18" r1= 5'2" r2= 5'2"	4.17
4-Cornice				
4.20.8.ls	cornice variables	extrusion of cornice profile c1 (Corinthian) extrusion of cornice profile c2 (Ionic-balcony) extrusion of cornice profile c3 (Ionic-barn)	c1 z = 4'-7" y = NA c2 z = 3'-6" y = NA c3 z = 3'-6" y = NA	4.54
5-Portico				
4.8.13.ls	tread and riser size	10 steps pedestal	12" x 6"	4.29
4.8.8.2.pa	stair type		-	
4.5.10.ls	wall	creation of new wall	-	
6-Staircases			-	
4.8.2.pa	hide stairs			
4.8.3.1.la	three openings			
4.8.4.pa	staircase > four feet			
4.8.9.1.pa	oval or round stair			
4.8.13.ls	stair span walls			4.31
4.8.14.ls	tread and riser		12" x 6"	

rule	element	function	variables & equations	fig.
4.8.12.ls	stair variables		rectangular stair w =3'-0" k = 10'-0" d = 12" ff = 30' w1= 14' w2= 4'-0" ri = 6" tr = 12"	4.27 4.28
7-Columns				
4.9.1.1.pa	upper col. over bottom			
4.9.1.2.pa	Ionic over Corinthian			
4.9.10.1.pa	even numb of col.			
4.9.10.2.pa	larger space in mid.			4.31
4.9.13.2.pa	pilaster at end			4.31
4.9.15.ls	loggia variables	insertion of one Ionic column scale Ionic column insert Corinthian column scale Corinthian column	p = 2'-6" s = 6'-0 d = 1'-6" c = 2'-6" m = 10'-4"	4.31
4.14.1.ls	Arch variables		House x = 6'-4" z1 = 23'-6" Barns x = 8'-7" z1 =9'-9"	4.44
8-Moldings				
4.5.6.pa	moldings noted			
6.1.8.ls	molding variables	first floor- bottom molding base molding second story- bottom molding top molding	bm1=6"x12" bm2=6"x12 p1 = 6" x 9" bn = 6"x 9"	
9-Doors				
4.14.1.ls	door openings	13 piano noble doors second floor- 18 subtraction	a = 5'-1" b = 9'-4" c = 3'-0" d = 6'-6" e = 18'-0"	4.45
4.14.4.pa	room door height			
4.14.6.ls	principle door width		4'-4"	
4.14.7.ls	principle door height		12'-2"	

rule	element	function	variables & equations	fig.
4.14.8.ls	room door width			
4.14.9.ls	room door height			
4.14.5.ls	door variables			
10-Windows				
4.15.4.1.pa	window		barn x = 3'-4" y = 7'-6"	4.49
4.15.6.ls	window			
4.15.7.ls	window			
6.1.9.2.ls	service stair window		x = 3'-4" y = 7'-6"	
11-Details				
4.19.2.ls	fireplace			
4.19.4.ls	fireplace	subtraction of fireplace from wall		
4.18.3.ls	balustrade	insertion of balustrade scale of balustrade copy balustrade 9 times creation of railing copy upper railing to lower railing	r1 = 6" r2 = NA by = 20" bx = 1'-6"	
6.1.11.1.ls	cove	subtraction of cove from wall		
4.16.12.ls	ornamentation	insertion of door profile scale of door profile extrusion of door profile	x = 2'-0" y = 5"	4.47
12-Roof				
4.19.2.pa	roof	cover building		
4.19.3.pa	roof	bear on walls		
4.19.4.pa	roof	divide into 9 parts		
4.19.5.pa	roof	slope equals 2 parts		
4.19.7.pa	roof variables	pediment cornice rafter main roof	d1 = 9" d2 = 10" z=23.2 degree	4.53

APPENDIX - B

VILLA MOCENIGO, ON THE BRENTA RIVER

LIST OF FIGURES

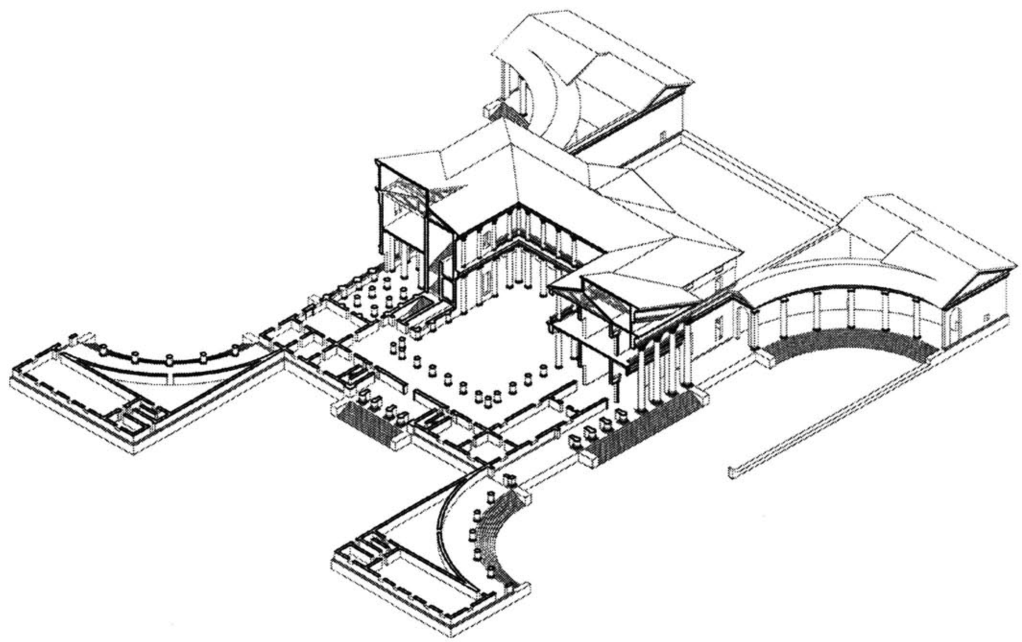


Fig. 9.24 Isometric projection of villa and site

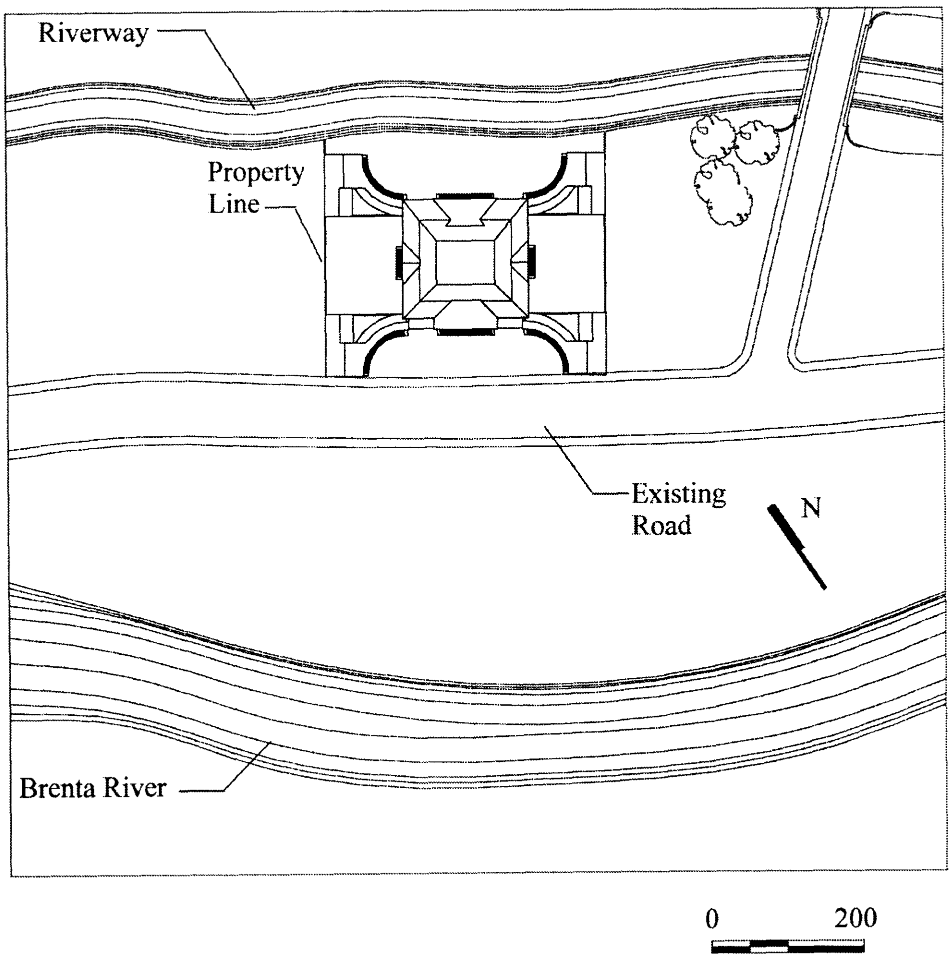


Fig. 9.25 Site plan

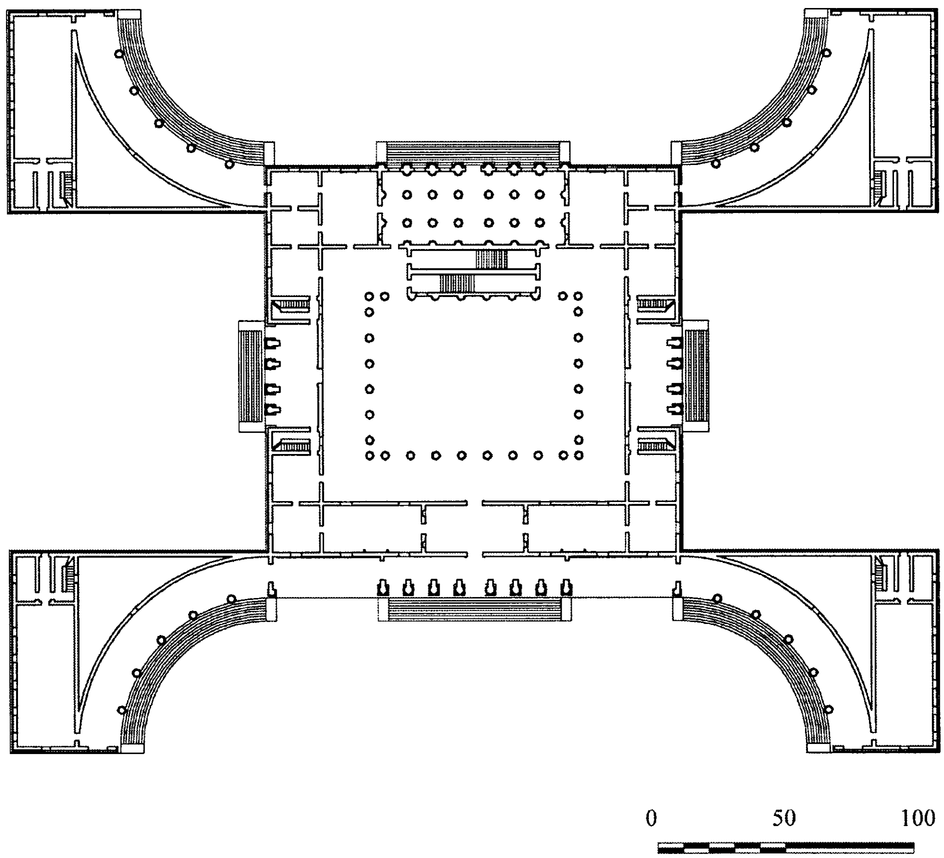


Fig. 9.26 Piano noble plan

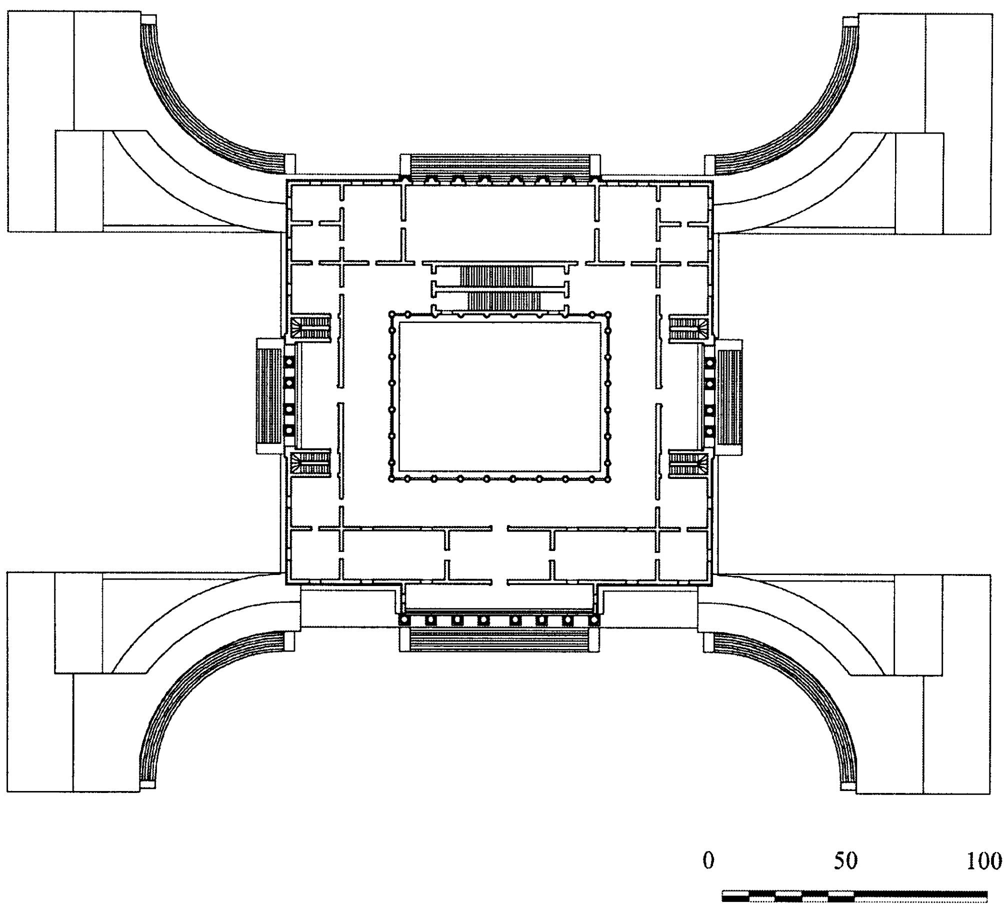


Fig. 9.27 Second floor plan

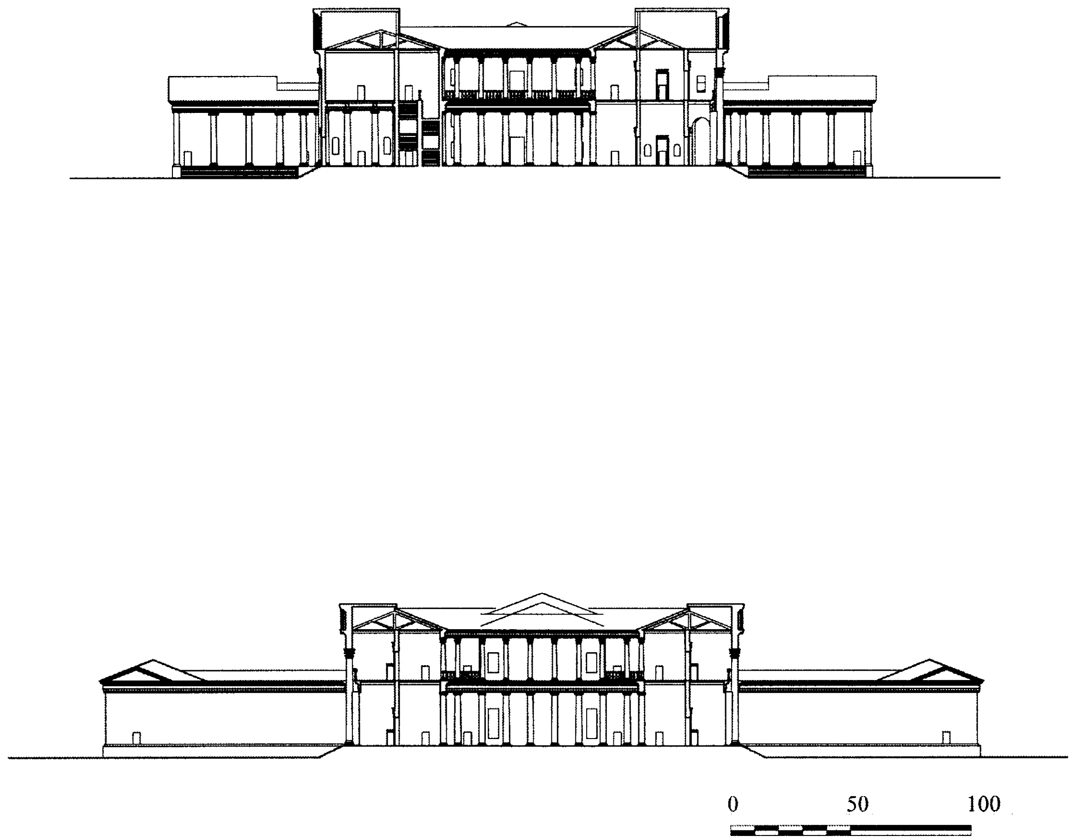


Fig. 9.28 Sections through central axis

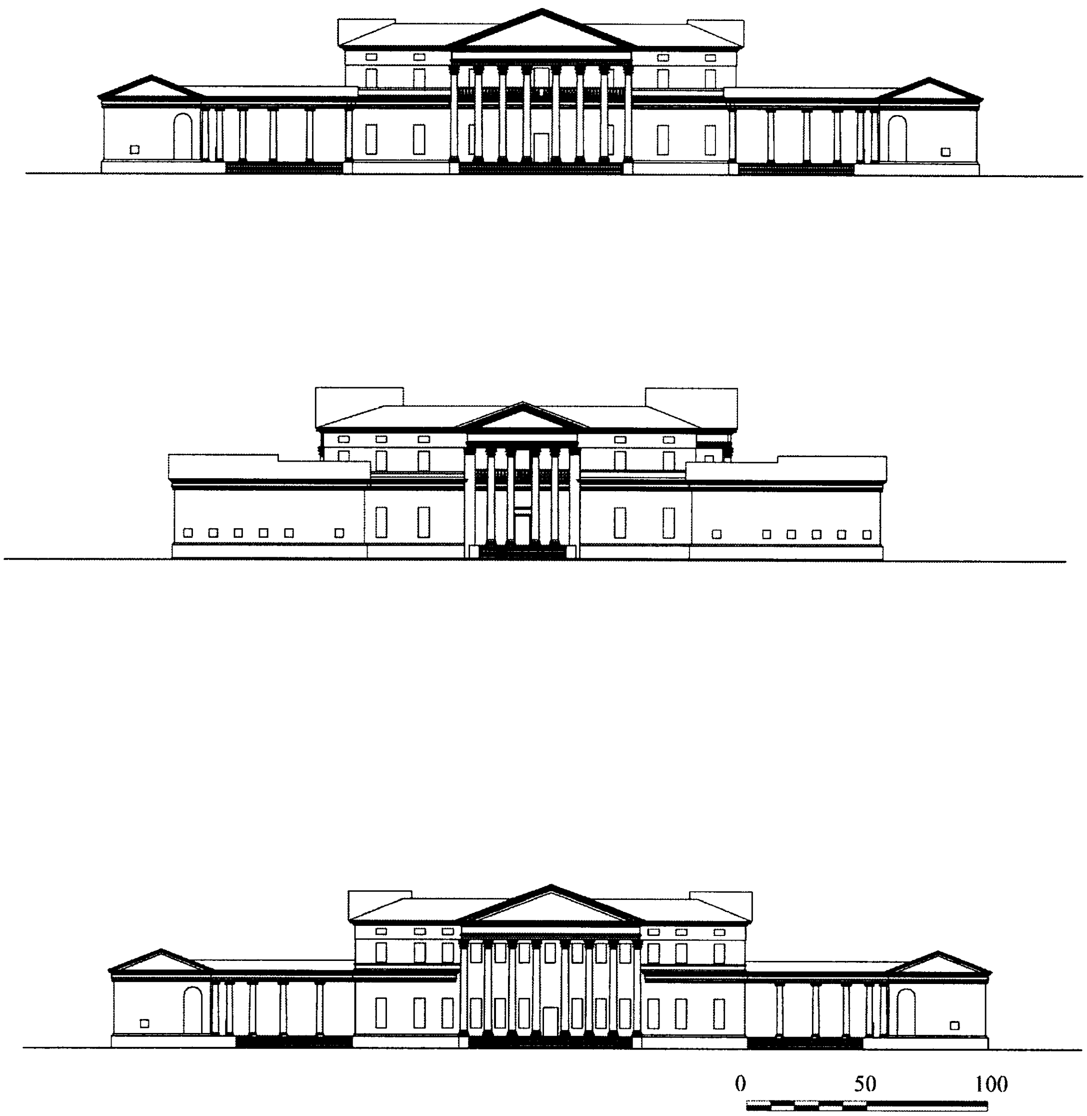


Fig. 9.29 Elevations

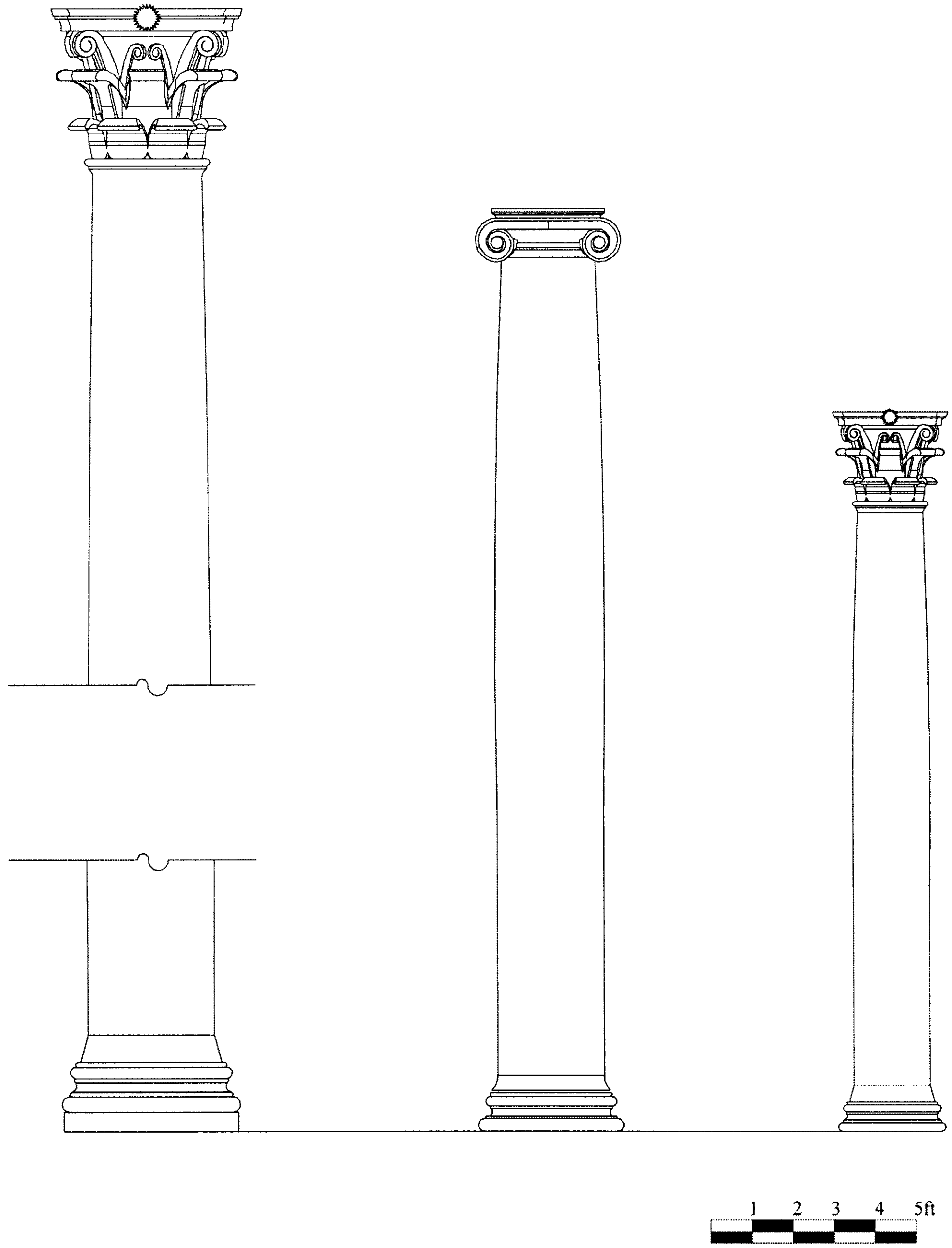


Fig. 9.30 Column Details

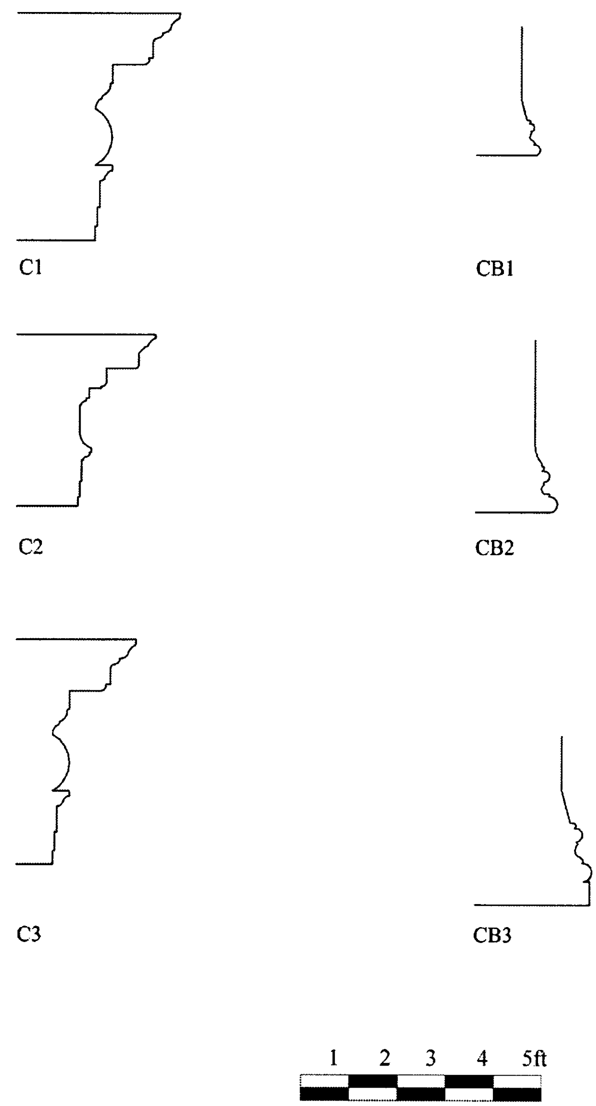


Fig. 9.31 Column profiles

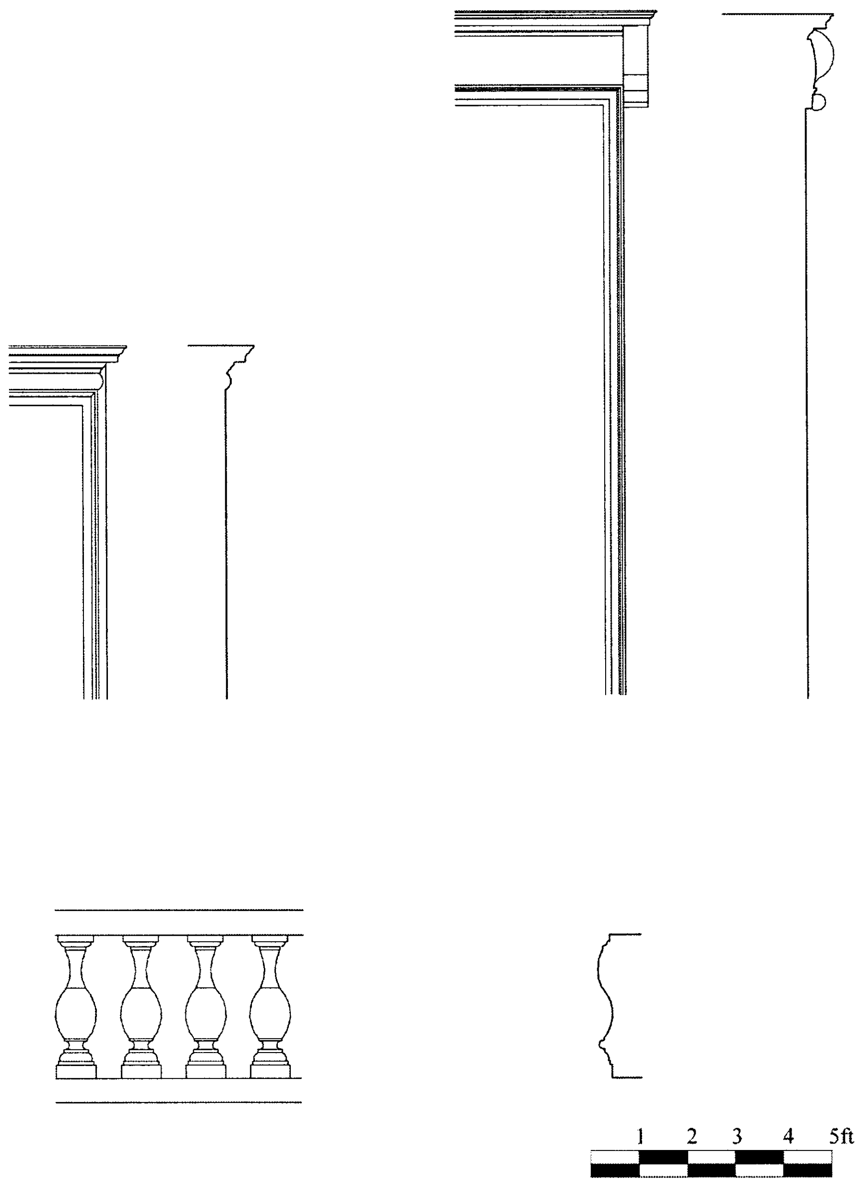


Fig. 9.32 Door and balustrade details

CHAPTER TEN

TOWARDS A NEW PALLADIAN GRAMMAR

10.0 THE TWO DIMENSIONS OF PALLADIAN DESIGN

Palladio designed in two dimensions, while the masons built in three dimensions. He applied design rules to lines to create shapes, and masons applied construction rules to shapes to create building parts adding up to the whole. A similar process was used to reconstruct Palladio's buildings. The conflict in the computation surfaced at the joining of lines or objects. From this, details are resolved, the style is captured[424] and new inventions arise from objects that meet in strange ways. The joining of objects always gives rise to complications in the procedure. Multiple conditional statements or new inventions are the only way to manage the computation.[425]

In this study, the Villas Mocenigo and Trissino are seen for the first time in one, two and three dimensions. This reconstruction process offers an opportunity to challenge the results in the forms of text rules, shapes, and documentation. Most important is that these representations offer the opportunity to see the unseen. During the day, the rotunda space of the Villa Trissino is bathed in beautiful diffuse light, while the main hall of the Villa Mocenigo is showered direct light most of the day. Who could have imagined these spaces appearing the as they do in the renderings? Who would have imagined the size and nature of the Villa Mocenigo with its enormous atrium space? The renderings in this study provide a vehicle for appreciating the beauty of these unbuilt spaces.

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[424] Stiny, G., 1981, p.258 The rules here are meant to capture the description of the shape. I am certain that rules are also meant to be applied in three dimensions. In this text I am only referring to the rule for descriptions in terms of their two dimensional qualities.

[425] Flemming, U., 1986 p. 349

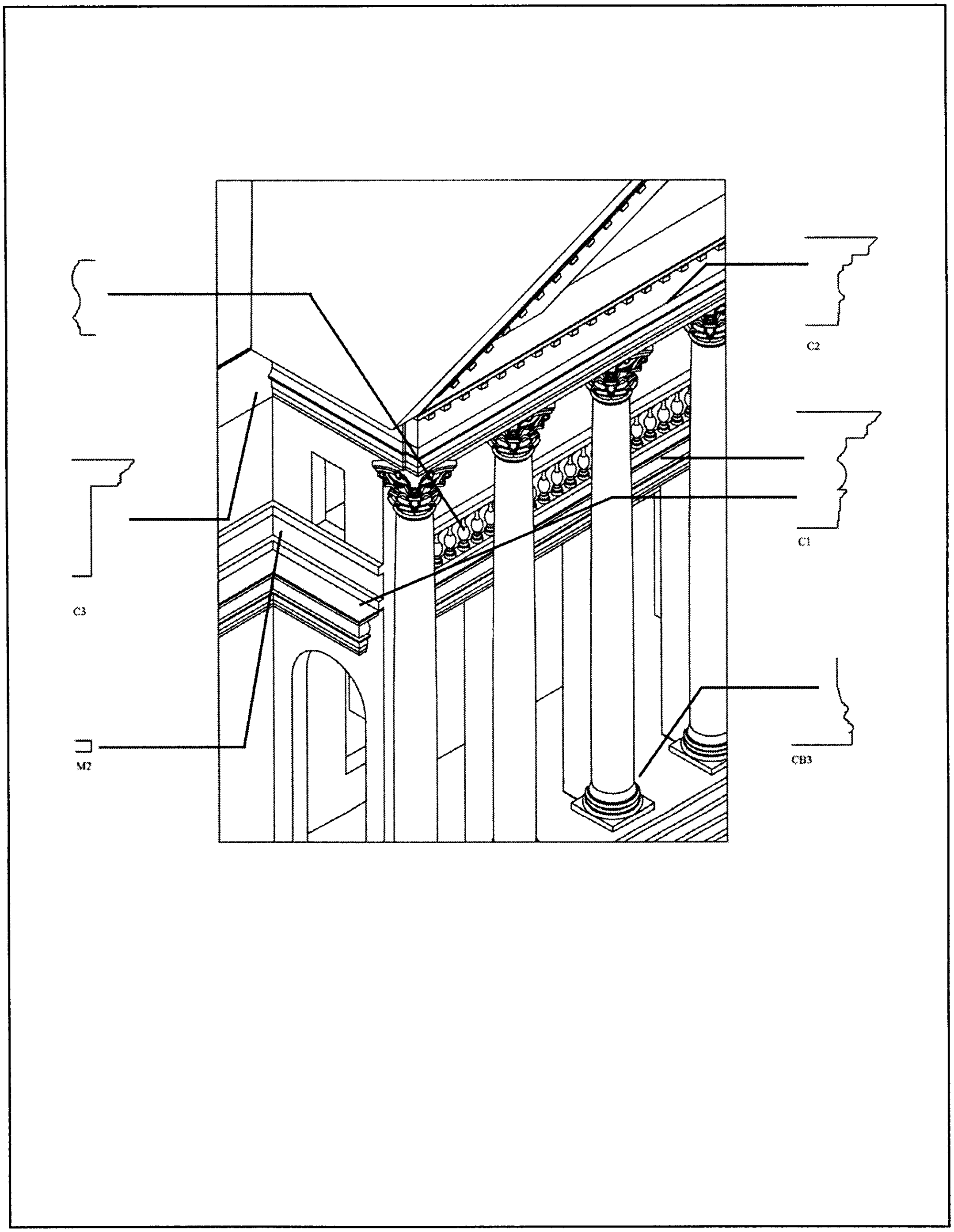

Fig. 10.1 Isometric view of the Villa Mocenigo loggia showing profile information

In summary, the process used to reconstruct the villas in this study requires two forms of input (two-dimensional drawings and one-dimensional rules applied to the drawing and five forms of output (text rule derivation, graphical derivation, three-dimensional print, two-dimensional documentation and renderings). Each form of input or output adds a greater level of detail and understanding of the villa than the other. Here accuracy is the goal. The pilot study demonstrated that a lack of accuracy leads to objects or files with little depth or potential for deep and meaningful study. The first models were articles of sculpture, not scholarship. Good scholarship should offer a means of checking the resulting material against the work of others.

10.2 THESIS CONCLUSIONS

The thesis is a presentation of two unbuilt case studies and the rules used to create the villa model file. Three conclusions can be made from this study; (1) that Palladio's design and construction methods are linked, (2) in order to discuss resulting materials they must be presented and evaluated under qualitative and quantitative terms and (3) there is always more than one solution to any given design problem. The original points of the thesis were to reconstruct two of Palladio's unbuilt villas and to do so using a method that would furnish a reconstruction and evaluation in more than one dimension.

First, the analysis presented many rules written and unwritten by Palladio, in a state from which algorithms can be written. Within the analysis I found the basic shapes of unknown objects such as vaults, cornice moldings, entablature construction and walls. The study also clarified Palladio's numbering and measurement systems, while outlining the procedure for constructing a column from Palladio's original rules. Here the rules are presented in such a way that missing dimensions can be checked against built buildings, and three-dimensional rules can be translated into a computer program. Starting with the reconstruction of the plan and elevation, shape rules can be easily written to handle a three dimensional reconstruction.

Second, the reconstruction process says that there are many ways to view visual proposals, and as Tufte explains, one method of seeing could lead to a possible disaster. The discussion of the design begins with its representation. Here I have presented spaces, forms and details in many formats, knowing that one photograph cannot describe all. Each method of representation has its own audience for whom the two case studies can be challenged. For example, designers focus on renderings, historians focus on the data found in the spreadsheets, and shape grammarians focus on the graphic derivation of the model.

There are multiple design solutions to any reconstruction problem. Palladio was famous not only for his buildings, but also for the fact that he offered many design schemes for any given project. There are at least six catalogued schemes for the design of the Villa Mocenigo. Palladio learned more about the site and the client by drawing and testing different designs. Reconstruction must follow a similar process of discovery by trial and error. It is through the incorrect plans generated by the Palladian Grammar that we learn about Palladio's rules on room layout and proportioning.

10.3 THE PALLADIAN GRAMMAR PART-TWO

This study should demonstrate that Palladio's designs are three-dimensional objects derived from a two-dimensional shape, such as a plan or a profile that could be formed from shape rules similar to those in section 5.3 of this text. The next step in this process would be to define shape rules for processing of the ten profiles listed in section 5.1. Each profile would require one rule or transformation to convert its shape into a three dimensional object. The corner detail in figure 10.1

is composed of many profile and objects, each in need of a transformation rule in order to create a three-dimensional object. For example, in order to reconstruct the Ionic cornice within this figure, the profile (c1) would require one extrusion rule and three conditional statements (fig. 10.2).

1) Rule 1 - Extrusion rule

2) Rule 2 - Conditional statement - Corner condition

3) Rule 3 - Conditional statement - End condition

4) Rule 4 - Conditional statement - Edge condition

The initial profiles are generated at the beginning each step listed in section 6.1. Above is a list of rules for just the cornice. Similarly, visual shape rules can be written for wall construction, window openings and stairs once the variables are defined (chapter 4). The shape grammar designed to

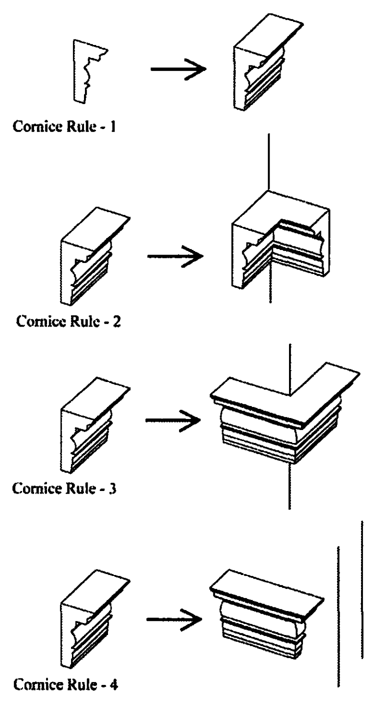

Fig. 10.2 3D shape rules for the transformation of an Ionic cornice reconstruct parts of the villas based on construction materials must also be able to resolve conflicts in the rules. Grammars can be written so that conflicts can be handled by creating a conflicting grammar or design grammar. In summary, the New Palladian Grammar would be created from four sub grammar systems within the new grammar. The process starts with a profile drawings or 2D grammar (1) that can be scaled, and transformed using through a (2) proportional grammar system. 3D rules (3) are applied to the profile shape to create a three dimensional product of the kind found in figure 10.2. This 3D grammar component would also locate the object accurately in relation to other parts in the model. Next, design grammars (4) could resolve any rule conflicts or at best design new rules for new Palladian parts or villa designs. The final grammar would focused on creating 3D shapes of any size, locating the shape in its place in relation to previous parts and will resolve rule conflicts by creating new rules or a new design. The final villa would be created exclusively from shapes.

A lesson to be taken from this study is that evaluation materials should be taken just as seriously as shape grammars. Within this text I presented four forms of for visualizing a reconstruction: spread sheet, 2D drawings, 3D prints and renderings. Each article of reflective material initiates ideas for more new material. The issue here is to sort visual material computationally in a manner that is as simple as the sorting of shape rules. The next step is to create a *Palladian Evaluator*. Stiny's evaluator works by sorts floor plans in order to narrow the choices based on the number and spatial relationship of rooms.[426] Here the goal is to sort in other dimensions, searching for the ideal shape in a 2D or 3D drawing or model, or to sort by lighting values or surface textural values in the case of a rendering. The final method of sorting can be based on measurements and data given in the spreadsheets.

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[426] Stiny, Gibs., 1978 ©

The *Next Palladian Grammar* and the *Palladian Evaluator* will be two programs used to create shapes and villas and one that can evaluate the output media by sorting assigned values such as light intensity, texture, size, or shape recognition.

LIST OF FIGURES

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