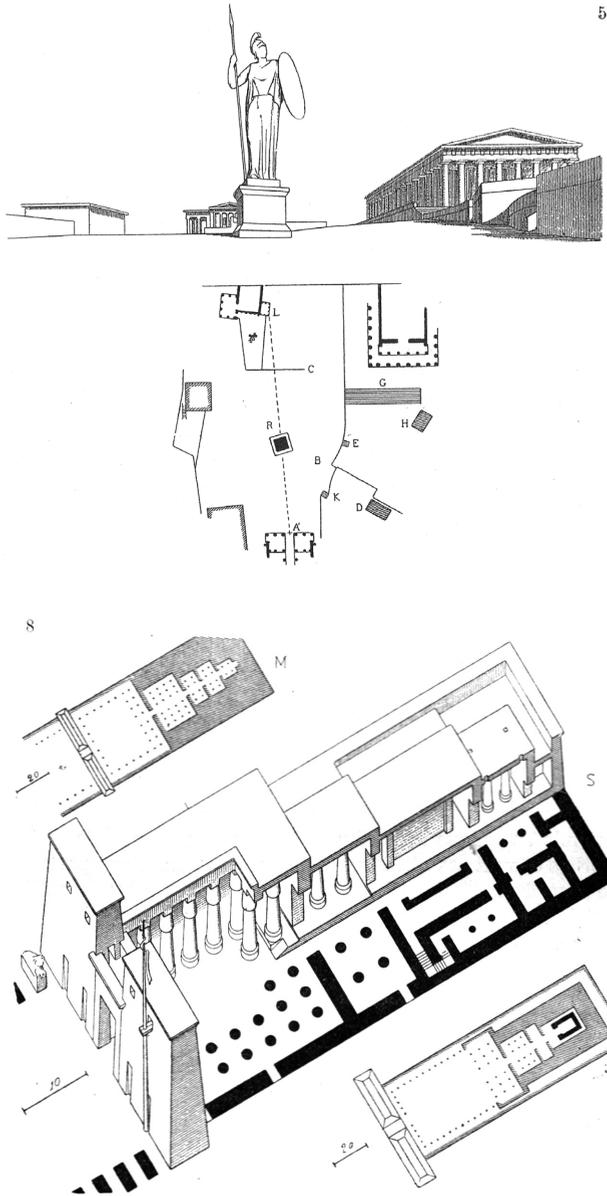


Auguste Choisy's Anatomy of Architecture

Richard A. Etlin

In his appreciation of Auguste Choisy, Maurice d'Ocagne of the Académie des Sciences called the man whom he knew so well «a humanist in the broadest and most complete sense of the term» (Ocagne 1930, 3).¹ This assessment provides the key to discerning the extraordinary accomplishments of a person who combined the skills of an imaginative engineer, a comprehensive architectural historian, a draftsman of great creative ingenuity, a learned Hellenist, and a creative philologist. To adopt a phrase from Roger Caillois, Choisy's writings cut «diagonally» across the grain of received ideas to offer fresh insights in unanticipated ways (Caillois 1960, 11–21).² They communicate with the force of self-evidence such that Le Corbusier, who was not wont to praise very readily, termed Choisy's *Histoire de l'architecture* (1899) «the most worthy book ever written on architecture» (Le Corbusier 1925, 116),³ after he had appropriated in a way that might be described as mental osmosis Choisy's main ideas about the lessons of Greek and Egyptian architecture (figures 1–2), which Le Corbusier saw as fundamental to creating a modern architecture; as well as the fundamental importance of the architectural promenade, which Le Corbusier considered the touchstone of a living architecture; and the aesthetic power in architecture of modeled surfaces, upon which Le Corbusier based his essay «Architecture, pure création de l'esprit», before preceding to devote an entire essay inspired by Choisy to the theme of *la modénature*; all this conveyed not only through words but also by using Choisy's perspectival drawings that showed the sequencing of buildings in space and Choisy's axonometric drawings that show buildings as organic entities (Etlin 1987, 266, passim; Etlin 1994, 112, passim). The very possibility that an avant-



Figures 1–2
Acropolis, Athens («First view of the Acropolis») and Egyptian temples with Temple of Khons, Karnak, in center (Choisy 1899, 1: 415, 64), three-dimensional illustrations reproduced later in Le Corbusier, *Vers une Architecture* (1923).

garde architect of the early twentieth century, intent on propagating a new and revolutionary architecture, would find such a range of sustenance in the historical writings of a nineteenth-century engineer and historian serves as eloquent testimony to the richness of Choisy's work.

Yet Choisy's importance to Le Corbusier should be taken only as illustrative of the depth of his work, which deserves an appreciation in its own right. To pursue this task, it is important to situate him within his own time. In effect, the extraordinary breadth of Choisy's prolific writings, including both text and illustrations, exhibits a unity expressed through the organic analogy so pervasive throughout

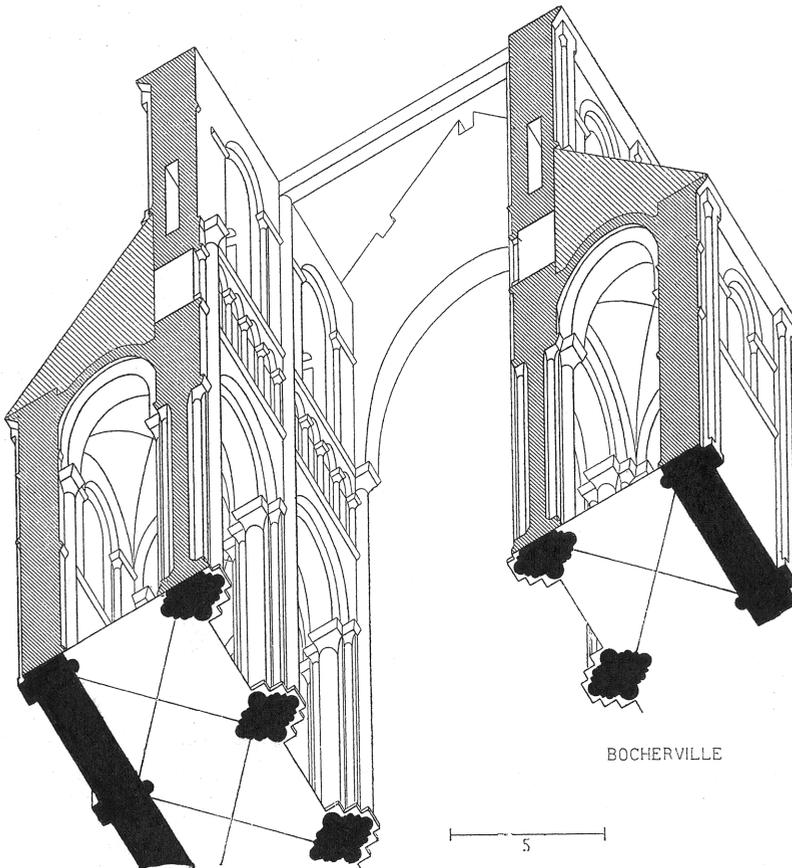


Figure 3
Saint-Georges de Boscherville. After Ruprich-Robert. Choisy 1899, 2: 193)

the nineteenth century.⁴ In that sense, Choisy's oeuvre takes its place as one additional building block of an intellectual edifice for which John Ruskin and Eugène-Emmanuel Viollet-le-Duc preceded him as the giants of the age.⁵ The writings of all three constitute an anatomy of architecture understood as a living organism capable of appreciation in its entirety, while also susceptible to a discerning dissection through drawing and through the identification of fundamental tenets, whose unity embraced the aesthetic and the structural through shared principles.

Choisy, of course, is famous for his cutaway, axonometric views into a building—sometimes from above, figure 2, other times from below, figure 3—drawings that convey the sense that he is a doctor of architectural anatomy, dissecting the architectural organism to reveal its skeletal structure, as if the stones, bricks and tiles, wood, and concrete were its bones, ligaments, and tendons, the exterior surfaces its flesh. In effect, Choisy described architectural structures in anatomic terminology. The thrust of the central vaults of the Basilica of Maxentius for example, is contained by internal buttresses, which «are, so to speak, interior buttressing organs» (Choisy 1899, 1: 528).⁶

Yet in all three cases, the anatomical drawings of architecture were also accompanied by aesthetic and poetic considerations. Ruskin's emphasis on aesthetic intentions and poetic effects needs no reminder. It should not be forgotten that Viollet-le-Duc extolled the poetry of the contrapuntal stance of the caryatids of the Erechtheum, as well as other aesthetic refinements in architecture (Etlin 1987, 271; Etlin 1994, 82–83, 94).⁷ Similarly, Choisy applied his characteristic axonometric drawing technique to illustrate not only structural forms but also the complex circulation of a building such as the Colosseum (Choisy 1899, 1: 576 fig. 7), as well as the aesthetic refinement of sculpted rings under the echinus of the Greek Doric capital.

Balance

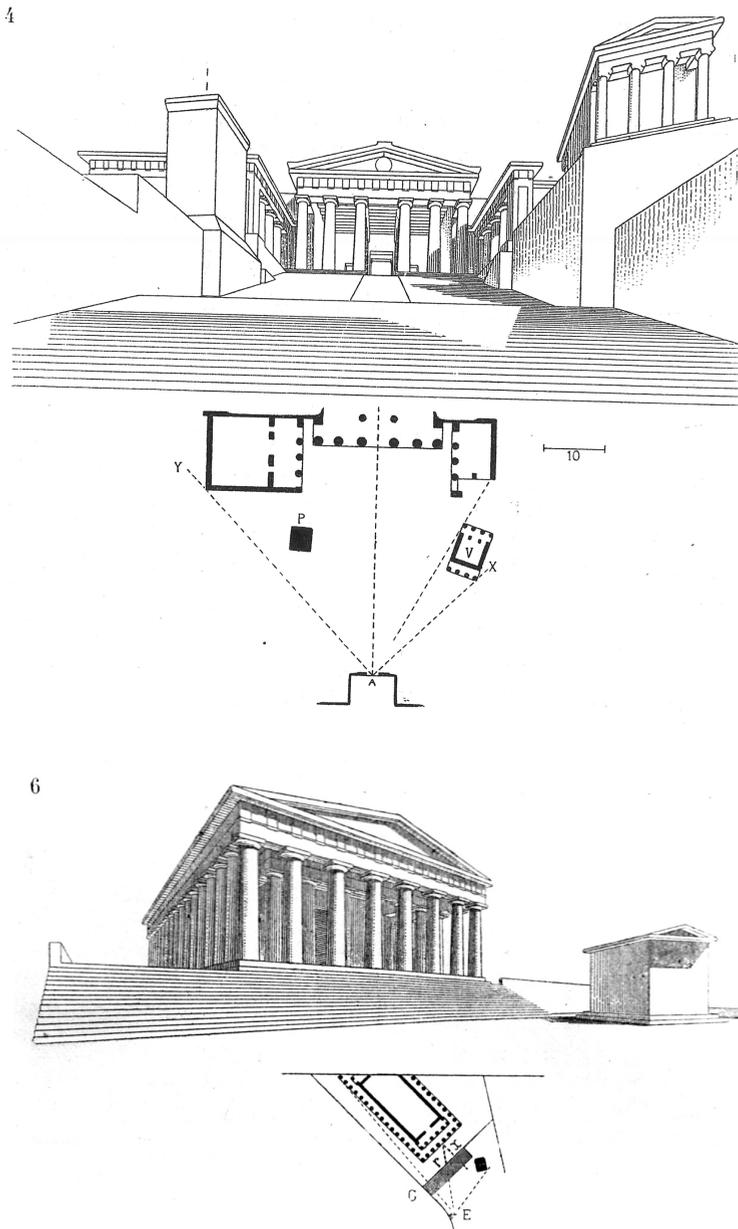
One of the most important concepts that pervade Choisy's writings is the idea of balance, which Choisy discerns both as an aesthetic principle and as a structural strategy. Whereas at first glance, Choisy's perspectival views of each scene on the Athenian Acropolis and his cutaway axonometric drawings of buildings that show their structure may appear to have nothing in common, both reflect his fascination with balance in architectural design. It is instructive that Choisy first addressed the issue of balance as an aesthetic attribute before proceeding to apply the concept to structural form.

In earlier studies, I traced the history of the application of the concept of picturesque order to the Greek architecture of the Acropolis in the 1830s and 1840s

after the liberation of Greece from the Ottoman Turks and the welcoming of Western architects and classical scholars to what had been a military fortress but what was now being transformed into an archaeological site (Etlin 1987, Etlin 1994, Etlin 2005). The twenty-four-year old Choisy, still an engineering student, visited the Acropolis in the summer or early fall of 1865, where he discerned a purposeful order to the arrangement of the temples in contradistinction to the previous assertion in 1845 by the Prix-de-Rome architect Alexis Paccard, who had maintained that «one can . . . certify that there never was a general aesthetic arrangement either to relate the buildings together or to arrive in a worthy manner to the different levels on which the temples are built» (Paccard [1845] 1982, 351).⁸

In contrast, Choisy postulated a carefully arranged sequence of scenes in which the theme of victory over the Persians was repeatedly celebrated by Pericles through his rebuilding of the Acropolis after the defeat of this enemy, which had destroyed the previous ensemble of temples within this sacred precinct. First came the symmetrically balanced scene viewed from the entrance to the forecourt to the Propylaea, Figure 4, with the temple dedicated to Athena, goddess of Athens, as the victory goddess, i.e., the Temple of Athena Nike, given the privileged position of an elevated oblique orientation within an otherwise orthogonal composition. This was followed by the asymmetrically balanced scene that appears as one emerges from the Propylaea, Figure 1, which is dominated by the towering statue of Athena as the warrior goddess, Athena Promachus, also presented on the oblique. The third scene presents the main temple of Athena, the Parthenon, Figure 5, on the oblique, and is followed by the fourth and final scene, which focuses on the caryatid tribune of the Erechtheum, also viewed on the oblique.

Choisy presented this analysis first in 1865 in his paper «Note on the Asymmetrical Curvature of the Steps along the Western Side of the Platform of the Parthenon» and then in his *Histoire de l'architecture* (1899) as part of a broader discussion of Greek architecture, which he entitled «The Picturesque in Greek Art: Assymetrical *Partis*, the Ponderation of Masses» (Choisy 1899, 409–422).⁹ The title of his first paper, which he was invited to read both to the Académie des Beaux-Arts and the Académie des Inscriptions et Belles-Lettres, refers to the controversy over the discovery of convexly curved horizontal lines throughout the Parthenon, including its stylobate and even the steps carved into the bedrock along the western edge of the platform on which the stylobate and temple sat. Were they intentional or merely the result of settling? If intentional, was their purpose to obviate the appearance of drooping lines or, as others observed, to impart a feeling of muscular life to the building? After all, the asymmetries of the Propylaea and of the Erechtheum were now widely understood as embodying the picturesque principle of showing life, as was the oblique view.



Figures 4-5
Acropolis, Athens: «View of the Propylaea» and «First View of the Parthenon» (Choisy
1899, 1: 414, 416)

The German architect and archaeologist Carl Boetticher, who had discovered the convex curvature of the platform steps in 1862, believed that this demonstrated the lack of intentionality because these steps never carried a building (Boetticher 1863). Choisy, though, cognizant of the importance of oblique views, Figure 5, demonstrated geometrically that in order for all the horizontal lines in the scene to recede harmoniously in a perspectival recession, the summit of curvature of the steps carved into the bedrock had to be shifted 7.5 meters to the left of the temple's centerline—as shown by point «r»—thereby confirming the intentionality not only of these curvatures but also of all the others, while also teaching the twin guiding principles of the site plan: asymmetry and displacement of axes. The equal angles that Choisy found in the first scene in front of the Propylaea, Figure 4, between the centerline and AY and AX respectively, as well as the truncation of the right pavilion of the Propylaea at the point that the sight line along the inner side of the Temple of Athena Nike touches that pavilion were further geometric demonstrations of intentionally ordered picturesque design.

The term that Choisy used to explain the balance between the asymmetrical forms in each scene—*la pondération*—is significant. It appears to be a term from mechanics, which refers to a balancing of weights to either side of a fulcrum.¹⁰ Applied by Choisy not in his essay of 1865 but rather in his book of 1899, ponderation was a word that Viollet-le-Duc had employed in the first volume of his *Entretiens sur l'architecture* (1863) to describe visual balance (Viollet-le-Duc 1863, 255). The Prix-de-Rome architect Louis-François Boitte would use this term in 1864 to describe the semblance of symmetry within actual asymmetry at the Propylaea (Etlin 1987, 273 n. 47).

In his description of the Acropolis, Choisy explained, for example, how the large pavilion preceded by the pedestal for a statue at the left side of the Propylaea was visually balanced by the masses of the obliquely positioned Temple of Athena Nike and the truncated pavilion behind it on the right side: «Nothing appears more irregular than this plan; yet it presents a balanced ensemble, where the symmetry of the masses is associated with the most original variety of details» (Choisy 1899, 1: 414).¹¹ Through an ingenious balancing of asymmetrical masses, placed at different distances, given different forms and heights, some orthogonal, others oblique, the successive scenes at the Acropolis present a visual balance that Choisy termed «une dissymétrie géométrique» (Choisy 1865, 415). Ponderation, explained Choisy when he returned to the theme in 1899 with a review also of the most important Greek temple sites, was characteristic of Greek architecture, which reached its culminating achievement in the rebuilt Athenian Acropolis where «the apparent asymmetries are only a means of imparting a picturesque character to the most skillfully ponderated group of buildings that ever was» (Choisy 1899, 1: 413).¹²

The importance of Choisy's discoveries to one of the central archaeological and aesthetic issues of his time should not be underestimated, not only for the age and then for Le Corbusier, but also for Choisy's own subsequent work in the history of architecture, where he applied his learning and insights as an engineer. Knowing the importance of ponderation as an aesthetic concept, grounded in an

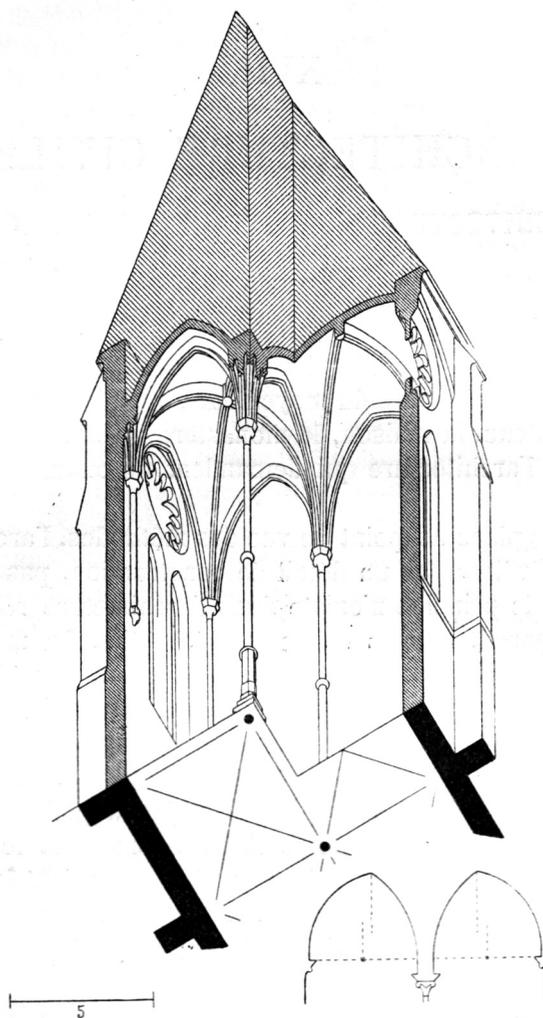


Figure 6
Refectory, Saint-Martin des Champs, Paris. After Lassus. (Choisy 1899, 2: 528)

inner feeling of balance based on the perception of physical weight to either side of the fulcrum, it is easy to see Choisy's cutaway axonometric drawings, which show the structural anatomy of buildings, as an application of this outlook to the world of structural design. Choisy's famous drawings show balanced volumes and masses, structural equivalents to the visually ponderated asymmetrical symmetries at the Acropolis.

And Choisy brought the same keen perception and subtle intuition to describing the structural balancing of architectural forms as he had to the ponderated designs of the Acropolis, especially with an eye for identifying asymmetrical symmetries in structural design. For example, presenting the refectory of Saint-Martin des Champs, Figure 6, dating from the Gothic equivalent to Periclean Greek architecture in that «the first half of the thirteenth century» was «the most beautiful period of Gothic art», Choisy first marveled at the elegant thinness of the central column that is «so light that one would have thought it metal». Then he noted that the «stability» of the composition has been «assured by an ingenious artifice» whereby the transverse arches are asymmetrical (Choisy 1899, 2: 528–529).¹³ Choisy's sketch of the section shows a double asymmetry: a sharper descent to the vault toward the thin central column that results from the displacement of the axis of the vault toward the center of the room. This is achieved through mirror asymmetries for the paired vaults. Hence, there is lesser thrust toward the delicate central shaft and more toward the wall with its exterior buttress.

Let us remember that Choisy was using the word «artifice» as had Philibert Delorme to designate a clever and skillful stratagem (Delorme 1567, fol. 91, *passim*).¹⁴ The poetry of the arrangement derives not only from its visual appearance but also from the ingenuity of the creative solution. Choisy had applied the same sensitivity first at the Acropolis and then in his history of structural design to identify ingenious design solutions in asymmetrical compositions that yield perfectly satisfying architectural forms whose harmony and cleverness are highly praiseworthy.

Self-Bracing

Although Choisy did not articulate a theory of structural forms, he repeatedly identified clever examples of architectural design whereby the balancing of masses to stabilize the thrusts involved some manner of self-bracing. The importance of this phenomenon cannot be overestimated. First, it shows how the concept of ponderation, first used by Choisy to explain the visual balance in Greek architectural site planning, was then applied to structural analysis, where it was often found in self-bracing structures. Second, it identifies self-bracing as an im-

portant leitmotif of Choisy's writings. Third, it teaches us today the importance of this concept, which is not commonly found in the literature on structural design and behavior. Fourth, it helps to familiarize us with the usefulness of the term «structural form», used so felicitously by Curt Siegel in his book, *Strukturformen der modernen Architektur* (1960).

Commenting in *L'Art de btir des Romains* on the need to brace concrete vaults during the long period of curing, Choisy pointed out that rather than merely use buttresses, the Romans had ingeniously arranged vaulted rooms so that they would be self-bracing by mutually shouldering each other, Figure 7: «and one enters into the customary practice where the various parts of a building are mutually self-buttressing without need for extraneous consolidation»

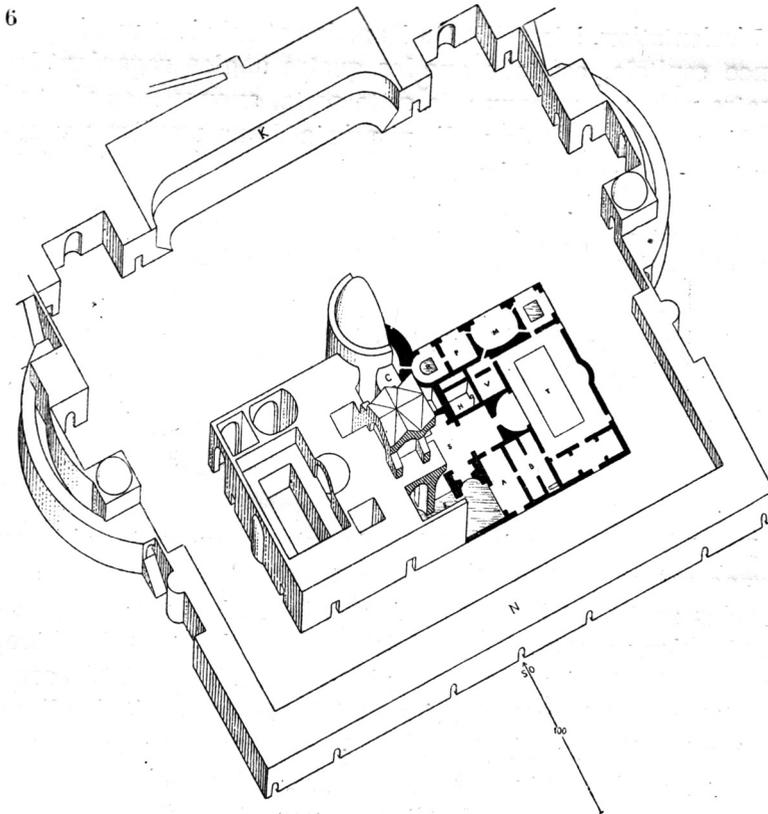


Figure 7
Baths of Caracalla, Rome. After Blouet. (Choisy 1899, 1: 572)

(Choisy 1873, 92–95).¹⁵ Choisy's appreciation of self-bracing extended to all levels of structural forms. In the *Histoire*, he illustrated a late Gothic form of flying buttress as found in the Cathedral of Alençon, Figure 8, and used also in the rebuilding of the choir buttresses of Amiens Cathedral, as well as other late Gothic buildings, whereby the combination of paired arches, each reversed with respect to the other «conjoins the advantage of an absolute rigidity with that of bracing the entire height of the shoulders» of the vault (Choisy 1899, 2: 305).¹⁶ Choisy's abbreviated style does not enter into lengthy explanations about many of his assertions. Hence the reader is left to figure out that this «absolute rigidity» derives from the self-bracing action of each arch that arrests the possible deformation of the other and reinforces the consolidation through compression of each arch.

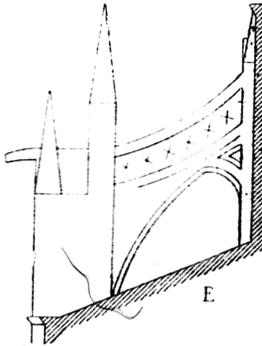
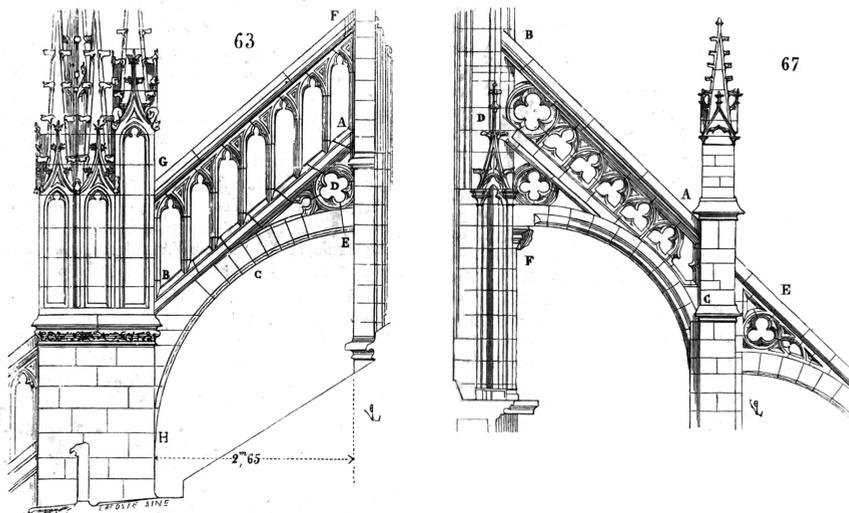


Figure 8
Flying buttress, Cathedral of Alençon. (Choisy 1899, 2: 305)

Choisy's explanation of the self-bracing action of the buttress in Alençon takes its place as a late solution in a series of designs that Viollet-le-Duc had previously considered according to this theme of self-bracing. Toward 1260 in the straight section of the choir of Amiens Cathedral, the separation of the arched flyer and the top diagonal strut, customarily in close proximity but now distanced by the introduction of a light tracery between the two, deprived the buttress of a needed self-bracing against the combined thrust of the vault and the transverse arch, causing the buttress to lift out of place. This deficiency in design was remedied in the fifteenth-century redesign of the buttresses for the choir of the church of Eu, Figure 9, where a thick diagonal stone strut in the form of a reversed flat arch was built directly upon the arched flyer «so as to oppose a powerful resis-



Figures 9–10

Flying buttress, Church in Eu and of Cathedral of Troyes. (Viollet-le-Duc 1854–1868, 1: 73, 77)

tance to the lifting of the arch at point C caused by the thrust of the vault». ¹⁷ Viollet-le-Duc praised the flying buttress of Troyes Cathedral, Figure 10, where the stonework of the double stone strut with open tracery — whose bottom chord was tangent to the arch — was arranged perpendicular to the arch, so as to «brace them more effectively» than the vertically disposed tracery at Amiens and Eu (Viollet-le-Duc 1854–1868, 1: 72–78). ¹⁸ Choisy continued this line of thinking by repeating Viollet-le-Duc's analysis of the flying buttress at Eu and then adducing for a second time the example of Alençon, where the reversed arch works even more effectively: «Any lifting [of the arched flyer] is henceforth impossible» (Choisy 1899, 2: 309–310). ¹⁹

Choisy's understanding of self-bracing enabled him to ascertain the reason for the seemingly curious undulating forms of unbaked brick walls in ancient Egyptian architecture, Figure 11, (Choisy 1904, 21–42). Employed only in humid but not dry zones and hence in areas where the infiltration of water into the soil could cause a sliding of the mud-brick wall, as well as disruptive pressures within the bricks from water absorption, the undulating shape of the walls create a dual self-bracing action, one for the wall itself in its entirety with respect to the soil and another within the wall between the individual segments: «The wall engages, it bites into the soil somewhat like teeth; and, within the

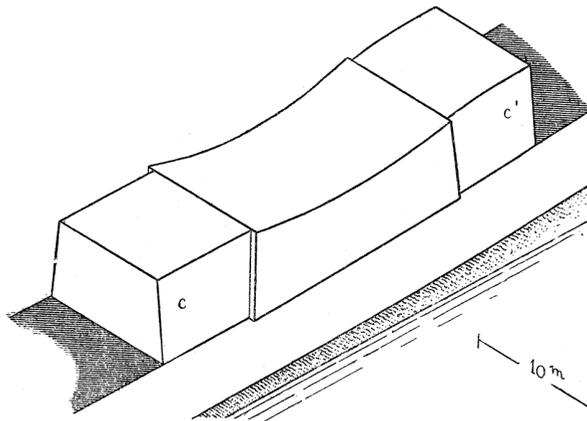


Figure 11
Undulating unbaked brick wall, Karnak. (Choisy 1904, 24)

body of the wall, one segment bites into the other» (Choisy 1904, 35).²⁰ Choisy also appreciated how the segments of gently convex profile, Figure 12, not only reduced the thrust by half with respect to flat segments but also established an internal self-bracing action between every two convex segments: «Thrust F is replaced by thrust f , which is about half as strong. Not only is the thrust attenuated, but a symmetrical thrust f' develops, which effectively counterbalances the thrust f » (Choisy 1904, 36).²¹

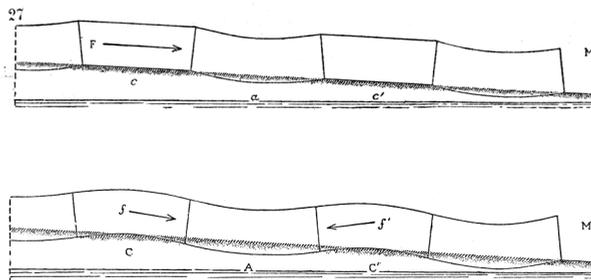


Figure 12
(A) Unbaked brick wall without convex segments; (B) with convex segments. (Choisy 1904, 36)

Choisy also admired the self-bracing found in Moorish architecture through the superimposition of arches in the Great Mosque of Cordoba, Figure 13, A. Lateral stability was assured for the stacked piers by adding a second level of bracing arches, a technique that was then repeated with enhanced decorative effect, Figure 13, B, as well as enhanced rigidity, by an interlocking pattern that linked the lower columns with arches reaching across two bays with an upper range of arches that spanned one bay each: «This new arrangement had the advantage of assuring a supplementary rigidity» (Choisy 1899, 2: 92–93).²²

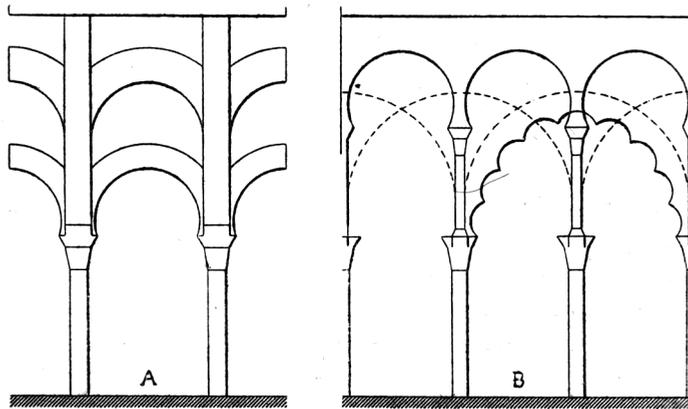


Figure 13
Great Mosque, Cordoba. (Choisy 1899, 2: 92)

Choisy, like Viollet-le-Duc before him, does not appear to have recognized the double wall as a structural form.²³ Robert Mark and his co-authors—following upon Jean Bony's and Robert Branner's studies of the double wall as an aesthetic form in Romanesque architecture—discuss double walls, which they term «walls-with-voids», and comment on the strength afforded for bracing thrusting vaults (Bonde 1993, 106–107). Yet Choisy would identify double walls as self-bracing forms through analogy to timber braces when he found comparable forms in stone.

Choisy, for example, focused on the remodeling of the Romanesque church of Saint-Hilaire in Poitiers, Figure 14, where the replacement of a timber roof with stone vaults over an exceptionally wide nave prompted a series of design decisions first to mitigate thrust and then to brace against it. As Choisy observed, the

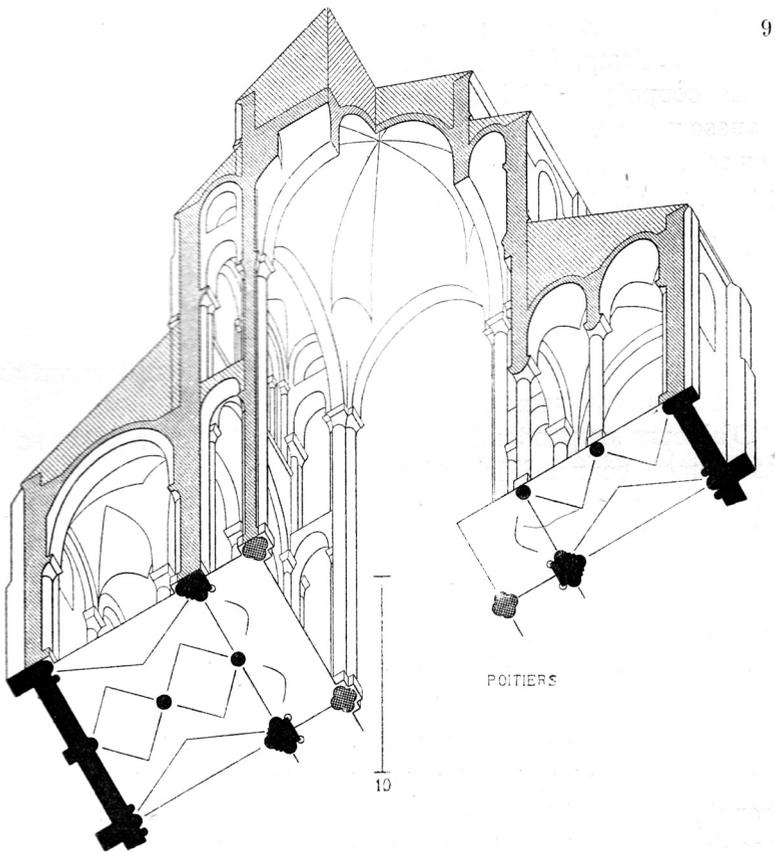
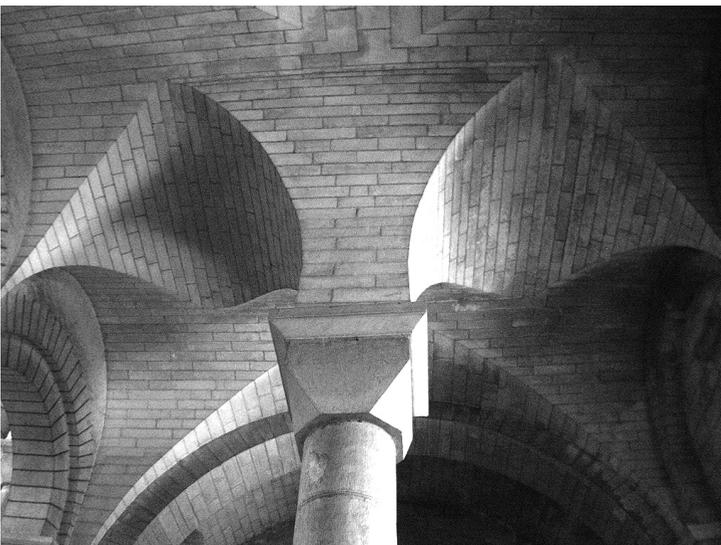


Figure 14
Saint-Hilaire, Poitiers. (Choisy 1899, 2: 199)

choice of «polygonal cupola that thrust only slightly» was accompanied by the construction of an airy internal line of piers that were linked to the walls with three levels of miniature barrel vaults —precisely the feature that Mark and his co-authors (Bonde 1993, 106–107) would identify as the best way to tie a double wall together in order to avoid shear and to render it an effective structural form. In this way, explained Choisy, «the walls were engaged in contributing to the equilibrium; and this artifice of interior bracing elegantly reduced in thickness gave birth to one of the most original decorative effects ever found in Romanesque art» (Choisy 1899, 2: 198–200).²⁴



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Figures 15–16
Saint-Hilaire, Poitiers. (Photos: author)

It is curious that although Choisy recognized the principle of enhanced rigidity in the two-dimensional pattern of interlocking arches at Cordoba he did not comment on the analogous three-dimensional pattern of interlocking groin vaults that alternated one large vault with two smaller vaults in the side aisles of Saint-Hilaire, Figure 15, as well as in the vaults over the double walls, Figure 16.²⁵ As Philibert Delorme had explained in *Les Nouvelles inventions pour bien bastir et  petits fraiz* (1561), the addition of more curves in a vault strengthened it: «You can add still more curves, as many as you wish. The more there are, the stronger the form» (Delorme 1561, fol. 26v).²⁶ These curves against curves are also self-bracing.

Once again, although Choisy did not develop a general theory of double-shell construction in vaults and domes, he did comment on the 25-meter diameter brick dome of the early fourteenth-century Mausoleum of Oljaitu at Sultanieh, Figure 17, whose structure, as explained by Choisy, consists of two thin surfaces of bricks joined with horizontal brick struts and provided with arches (or thin

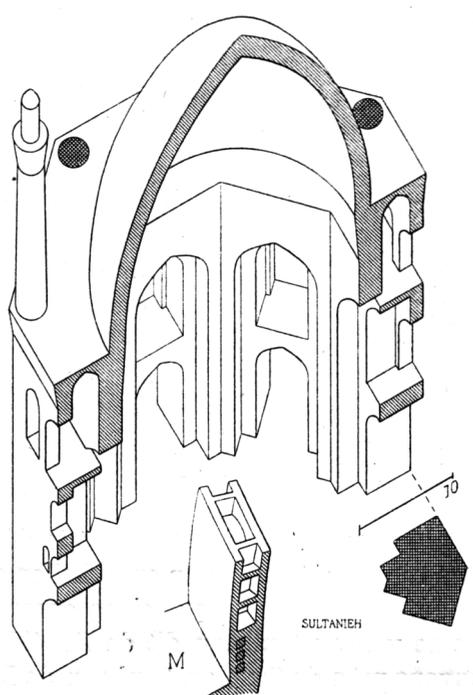


Figure 17
Mausoleum of Oljaitu, Sultanieh, Iran. After Dieulefoy. (Choisy 1899, 2: 101)

barrel vaults) that lie parallel and adjacent to these inner and outer brick surfaces. «With this configuration», explains Choisy, «one obtains a vault as rigid as a solid one but lighter and with less lateral thrust» (Choisy 1899, 2: 101).²⁷ It appears that the explicit articulation of the idea that a double-shell vault provides enhanced rigidity had to await a later date and can be found most explicitly in Michele Melaragno's *An Introduction to Shell Structures: The Art and Science of Vaulting* (1991) in his discussion of Brunelleschi's dome over the crossing of Santa Maria del Fiore (Melaragno 1991, 58).²⁸

Ingenuity and the Poetry of Reason

In his essay on Choisy, D'Ocagne expressed especial appreciation of Choisy's account of the self-bracing action in undulating Egyptian brick walls. D'Ocagne introduced this example by referring to Choisy's «divinatory gift», his uncanny ability to divine the working of seemingly strange architectural forms, this particular case being «the most singular» of a host of «ingenious» structural forms in Egyptian architecture (Ocagne 1930, 16–17).²⁹ In effect, D'Ocagne's encomium to Choisy is filled with repeated references to human ingenuity, whether to an ingenious method of construction or an ingenious structural form, both to the ingenuity of the builder or designer and to Choisy for discerning the method or meaning. To Choisy, such ingenuity was evidence of rationality, a rationality that was a creative response to a need and often poetic in effect. Thus, when explaining the intellectual elegance of the solution of the interlocking pattern of arches in the great Mosque of Cordoba, whose result was also highly decorative, Choisy seems to be anticipating a reader's negative reaction that would dismiss the form as whimsical, for he comments, «in any case it was rational» (Choisy 1899, 2: 93).³⁰

The ingenious aspect of rational forms and procedures in architecture must always be kept in mind when reading Choisy, as also with Viollet-le-Duc. In effect, Viollet-le-Duc's assessment of Greek architecture, expressed early in his *Entretiens sur l'architecture*, offers a definition of reason that might be taken as emblematic of Choisy's understanding of human creativity in the architecture of all times:

If we consider one by one all the parts of a Greek temple, if we study them by themselves and in their immediate relationship to the whole, we can always find the influence of those judicious and delicate observations which signal the presence of art, that exquisite sentiment that submits all forms to reason, not to the dry and pedantic reason of the geometrician, but to reason directed by the senses and by the observation of natural laws (Viollet-le-Duc 1863, 55).³¹

Because of the range of possible meanings contained within the word «rational», it is easy to forget the complex and subtle approach of both these thinkers with their emphasis on ingenious thinking and poetic effect and the natural link between the two phenomena. Henri Bergson distinguished between reasoning «geometrically» whereby the mind works in a «diagrammatic and rigid» manner and an alternative form of reasoning that «follows the sinuous and mobile contours of reality» (Bergson 1920, 3). When Viollet-le-Duc and Choisy spoke of reason and rationality they meant the latter rather than the former.

Yet, like all of us, both Viollet-le-Duc and Choisy could not escape from the prejudices of their time. Their response to the daring *trompes* of the fifteenth century onward was typical of the age. Today we sympathize with appreciative assessment of *trompes* in the sixteenth and seventeenth centuries, with praise for their structural ingenuity and difficulty as well as their unaccustomed and rare form. Viollet-le-Duc and Choisy, though, adhered to the eighteenth-century condemnation of the *trompe* for its willful difficulty (Pérouse de Montclos 1982, 219–222), the former disdainfully dismissing the idle quest of «finding pleasure» in solving «useless problems» (Viollet-le-Duc 1854–1868, 9: 314),³² the latter repeating the often heard criticism about creating «an effect of anxiety» by a form that hovers in space without apparent means of support.

Faulting the fan vaults of the Henry VII Chapel at Westminster Abbey, Figure 18, which, Choisy argued, spring from a pendant that forms part of a supporting arch essentially hidden from view but that appears to hover in space over the head of the viewer, thereby threatening to come crashing down, Choisy condemned this artifice as the «mannered» effort of a «decadent age». The terms of Choisy's condemnation are significant, for he writes that here science has displaced art: «la science envahit l'art» (Choisy 1899, 2: 283–284).³³ In other words, good architecture cannot rely on science only but requires judgment that engages an appropriate aesthetic effect. Rationality, understood as merely adhering to the laws of physics to create a structural form, does not suffice.

As Viollet-le-Duc had argued, reason had to be guided by the senses as well as the observation of natural laws. Good architecture was a union of ingenuity with these two other factors. As the example of the *trompe* reveals, people will differ as to what the senses teach. Hence, for Viollet-le-Duc and Choisy, the builders of such *trompes* pushed their ingenious use of artifice too far. This is where the aspect of ruse or subterfuge enters into the meaning of the word artifice and is condemned.

When ingenuity and artifice are employed appropriately and most completely, they yield in their totality a true architectural organism, such as Gothic architecture. Choisy presents the Gothic as an organism and as such, the result of artifice, which he contrasts with Romanesque architecture that he understands as

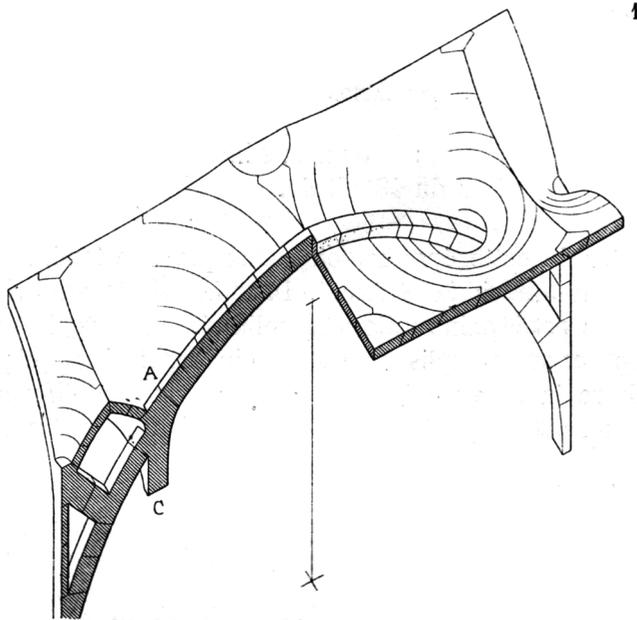


Figure 18
Henry VII Chapel, Westminster Abbey. After Willis. (Choisy 1899, 2: 283)

lacking this trait: «Gothic architecture is that of a society with limited resources that applied itself ingeniously to produce great works: it is all comprised of artifices, the opposite of Romanesque art». These artifices had one single unifying component, i.e., the rib:

Such, then, is the economy of our great Gothic buildings with respect to the general system of equilibrium: the entire structural mechanism with respect to statics is reduced to the ribs that permit the direction of the thrusts and the flying buttresses that permit them to be opposed from afar. Thanks to this double means, the builder can master the thrusts that the use of vaults involves. Eliminating all inert mass, he is able to reduce the building to its active parts. Deprived of powerful means [as found in mass], he substitutes combinations [of active structural forms] . . . One might regret that so skillful an organism is at the same time so complex and especially that a member so essential as the flying buttress is directly exposed to the causes of destruction: but this was the price to pay for equilibrium.

Choisy then proceeds to praise the «daring» of these buildings, «unknown in antiquity» and concludes with an appreciation that conjoins once again the achievements of aesthetics with the ingenuity of structural form: «The soaring forms impart to our cathedrals an aspect belonging only to them and the structural idea that makes them possible constitute together one of the most fecund that architecture has ever attained» (Choisy 1899, 2: 320–321).³⁴

Here Choisy was following Viollet-le-Duc who had insisted on the fundamental distinction between «the inertia of Roman structure» and the «active» principle of Gothic structure (Viollet-le-Duc 1863, 270).³⁵ Although, as modern scholarship has shown, both Roman and Romanesque structure were far from passive (Armi 2000; Lancaster 2005; Etlin 2009), Viollet-le-Duc and Choisy were offering a crucial distinction between two fundamentally different approaches to structure that Felix Candela would articulate more completely in the next century: «*passive structures* conduct loads directly without changing their course, like bearing walls and columns which are merely elements interposed between the loads and the ground; *active structures* are those capable of changing the direction of loads and forcing them throughout the structure enclosing a certain space» (Candela 1954, 84).

We study historical figures for numerous reasons: to understand a different age both on its own terms and to provide perspective to our own, to render homage to great minds and souls, and to find the intellectual tools that we need for our own times. Choisy's assessment of Gothic architecture as an organism, considered from the perspective of Candela's notion of active structure, as opposed to Choisy's belief that Romanesque architecture functioned primarily through what Candela would term passive structure, provides us with an intellectual tool at least as useful as Curt Siegel's term *Strukturformen*. Choisy's writings contain, as if in watermark, a pedagogical strategy whereby structure and the history of structure are presented according to the notion of structural forms, which in turn are explained as active structure that directs forces where desired and that can also be given self-bracing configurations which enable them to counter more effectively disruptive forces.

Architecture and Society

I began this essay with Maurice d'Ocagne's encomium of Choisy as the consummate humanist and briefly reviewed Le Corbusier's appreciation of several of the multifarious aspects of Choisy's intellectual achievement. I return to this theme for my conclusion. Because Choisy was an engineer; because he wrote books on the art of construction in various historical societies; and because so much of his two-volume history of world architecture, as well as his commentary on Vitru-

vius's treatise, is devoted to the clever and ingenious use of materials, methods of construction, and creation of effective structural forms and systems, it is easy to forget the breadth of his accomplishments that include these understandings at their core but do not reduce architecture to the limits of this purview.

We have seen Le Corbusier's appreciation of Choisy's writings about the sequencing of spaces, what Le Corbusier would term the architecture promenade. Choisy was certainly not the first writer to address this subject, but he may have been the most complete. The British architects Thomas Leverton Donaldson and Charles Robert Cockerell had briefly considered the effect of successive views in various ancient cultures. And Viollet-le-Duc had briefly considered this phenomenon, which he had termed the *mise-en-scène*, by which he had stressed in a general way that Egyptian, Greek, Roman, and Asian societies had carefully prepared the approach to a temple so as to create a sense of anticipation and climax through «skillfully managed transitions» (Viollet-le-Duc 1863, 253–257).³⁶ Yet Choisy went further. Taking up the contemporary notion of the representative building type that characterized a culture by embodying essential aspects of its values and mores, Choisy identified the architectural promenade as an essential feature of these representative building types and showed how the specific features of each society's architectural promenade contributed to the meaning of that building. This insight he applied to Egyptian, Assyrian, Hindu, Mycenaean, Greek, Roman, and eighteenth-century French cultures (Etlin 1994, 97–106).

We have also seen how Choisy repeatedly found poetry and beauty within many of the most ingenious structural forms that he identified. Let us review aspects of his discussion of the Greek Doric order to see how carefully he observed the relationship between structure and aesthetic expression. Here Choisy was following the example of Carl Bötticher's treatment of *Juncturen* (astragals, thori, abaci, plinths, guttae, etc.) in *Die Tektonik der Hellenen* (1844, rev. ed. 1874), where Boetticher had argued that the only basis for aesthetic expression in the making of objects of any scale, from utensils to buildings, was the «visualizing of the material static achievement» of the «tectonic body» (Boetticher 1874, 1: 19–27, 182, 185; Etlin 1994, 6; Eck 1994, 167, 170).³⁷

Looking then, to the *Juncturen* of the Doric order, Figure 19, Choisy explained that in the archaic period (T), the curved form of the echinus offered a visual expression of weight being carried upon the projecting cantilever of the stone with a loading concentrated toward the edge. As the contour of the echinus was adjusted into a tauter profile, the altered shape offered the image of a loading distributed over the entire projection.

Addressing the way the way in which the columns and capital meet, Figure 20, Choisy explained that before the fifth century (C) there was a concave neck placed between the two (G), a structural arrangement that weakened the form

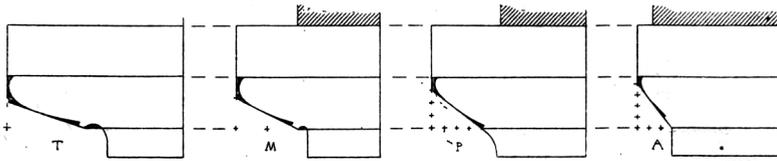


Figure 19
Evolution of the Doric capital. (Choisy 1899, 1: 315)

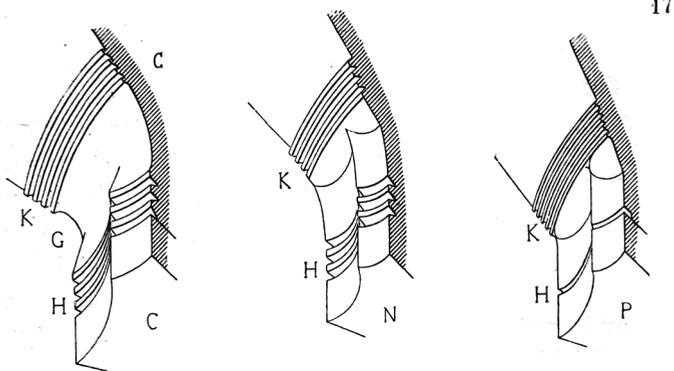


Figure 20
Evolution of the Doric order. (Choisy 1899, 1: 317)

while allowing the sunlight to spread out without a sharp profile. This dual fault was alleviated with the removal of the neck. While this neck existed, the channeling either stopped below it or penetrated into its concavity (C). With the disappearance of the neck the channeling was continued to the point of spreading of the echinus (N, P). Yet (N), the continued use of multiple rings (H) that cast deep shadows was soon recognized as aesthetically inferior to a simple indentation (P), like a saw cut, to mark the end of the shaft and the beginning of the capital, as found in the Temple of Theseus and in the Doric buildings at the Acropolis. This example serves to show how through Choisy's attentive eye, the multiple goals of constructive rigor, expressive logic, and poetic effect are gradually perfected in a given society (Choisy 1899, 1: 315–318).

Choisy, like all the Hellenists of his century before him, considered the Parthenon the supreme realization of beauty in architecture. His words echo those of numerous architects, historians, and classical scholars who preceded

him: «the Parthenon presents itself to us as the supreme effort of genius in the pursuit of the beautiful (Choisy 1899, 1: 467)». ³⁸ By the time Choisy had arrived at the Acropolis, nearly all the subtleties had been discovered: the entasis of the columns, the parabolic section of their channeling, the convex parabolic curvature of all the horizontal lines, the gentle inclination of all the columns and of the walls of the cella, and the irregular spacing of the end columns—all refinements to make the building seem regular where optical illusions would have vitiated the effect, to seem strong where optical illusions would have suggested weakness, and to seem alive with a muscular energy, an embodied life force, while being firmly grounded into the bedrock, such that centuries later Le Crobusier would imagine it growing from the bedrock like a natural outcrop (Etlin 1987, 274). We have seen how Choisy was able to contribute to this portrait of an extraordinary building.

Yet Choisy went even further. After praising the Parthenon, he proceeded to affirm: «it is the ideal itself of the century of Pericles and Phidias: the authors of this masterpiece, Ictinus and Callicrates, must be counted among the most illustrative representatives of art during its greatest period» (Choisy 1899, 1: 467). ³⁹ Taken by itself, this last sentence might seem merely like one more reiteration of the principle articulated by Hippolyte Taine, which electrified an entire generation, that the art in any age is a reflection of the values of the society at that time (Etlin 1994, 166). Yet Choisy was able to give precision to such an assertion through an imaginative interpretation of ancient Greek contract and accounting documents to demonstrate the societal values and procedures that made a building like the Parthenon possible. This skill, which Choisy, according to D'Ocagne, had developed to a rare level of expertise even for a Hellenist, enabled him to publish «those admirable *Etudes épigraphiques sur l'architecture grecque*»: «Nobody before Choisy was able to explain the meaning of certain inscriptions through the lack of the dual competency as epigraphist and architect which he so fully possessed» (Ocagne 1930, 14). ⁴⁰

Deciphering the contract to extend the pavement around a temple in a remote site, Choisy was able to demonstrate from this humble legal document the «extreme precision of workmanship that the Greeks imposed on all things», thereby providing an empirical confirmation of the Greek attentiveness to the «minutia of details» (Choisy 1884, 201). ⁴¹ By studying the inscription ordering the restoration of the walls of Athens, Choisy discovered still another aspect of Greek society that created the context in which masterpieces such as the Parthenon could be envisaged and executed. Greek society accorded public honors to a contractor who exceeded the stipulated requirements of a contract, whether through the substitution of better materials or the application of better methods of construction. In this case, the choice was between a rough or finished exterior surface and a

terra cotta or stone cornice. «The undertaking of public works», concluded Choisy, «consequently was less of a lucrative profession than an honorable but often burdensome charge: arming ships, equipping troops; everything, down to set design for theater, was the subject of ruinous undertakings; and one felt himself amply compensated in hearing at the Pnyx or the Theater the proclamation of a decree recording the completed sacrifice» (Choisy 1884, 80).⁴²

The contract for the construction of the Arsenal of Piraeus listed the dimensions of the building, the size and shape of the stones, and the thickness of the wood. With this list of materials, Choisy reconstructed on paper the building as an elegant timber structure with large central nave and two side aisles. Not only did it serve the utilitarian purpose of an arsenal, concluded Choisy, it also afforded a «public promenade» on the way between the agora and the harbor. As for the timber edifice, Choisy found it to be a «daring» structure in which the thickness of the walls and pillars were reduced to a minimum while still allowing for a «monumental appearance». The dimensions, moreover, revealed the quest for «order», «harmony», and «unity» even in so modest a utilitarian construction (Choisy 1884, v, 15, 19). If the Parthenon, as the British architect Francis Cranmer Penrose —the person who had related to the world through precise measurements the mathematical adjustments to the lines of this edifice— was «humanly speaking, perfect» (Penrose 1851, 82), then Choisy's *Études épigraphiques* illuminated the cultural context in which such a building was possible.

Choisy's anatomy of architecture then, ranged through the entire gamut of concerns —the dissection of structure through cutaway axonometrics and other types of analytical drawings; the elucidation of ingenious structural design, economical methods of construction, and optimal use of appropriate materials; the explanation of the logic of self-bracing structural forms; the presence aesthetic refinements; the importance of the sequencing of spaces as inherent to the nature of architecture, with a consideration to the siting of buildings; the relationship of building types to social values; the precision of technical, administrative, and financial documents related to building; and the existence of a public realm that promoted service and sacrifice through emulation and public honors. In 1930, Maurice d'Ocagne opened his appreciation of Choisy's career by observing: «Auguste Choisy... This name has hardly penetrated into the public's consciousness? (Ocagne 1930, 3).⁴³ One hopes that the current availability of Choisy's works online as a free service, along with the new Spanish translation of his *Histoire de l'architecture*, in conjunction with the papers of this congress, as well as other studies past and future, will enhance the public's awareness of the extraordinary range and depth of accomplishments of this consummate humanist and will serve as a model for future generations of engineers and architectural historians.

Notes

1. «Humaniste dans la plus large, la plus complete acception du terme» (Ocagne 1930, 3).
2. «Le progrès de la connaissance consiste pour une part à écarter les analogies superficielles et à découvrir des parentés profondes, moins visibles peut-être, mais plus importantes et significatives . . . Il est temps d'essayer la chance des *sciences diagonales*» (Caillois 1960, 11–21).
3. «Auguste Choisy, cet admirable inspecteur général des Ponts et chaussées en retraite, auteur du plus digne ouvrage qui fût sur l'architecture» («La Modénature». Le Corbusier 1925, 116).
4. On the importance of the organic analogy to nineteenth-century architectural thought, see Eck 1994.
5. In *Grammaire des arts du dessin* (1867) Charles Blanc refers to Viollet-le-Duc's drawings of Gothic architecture as presenting «the detailed anatomy of this great body» (Girón 2006, 62). An apt example of Ruskin's anatomical approach to architecture can be found in what Stephen Kite has termed the «evolutionary taxonomy» of the shapes of windows in Venetian Gothic architecture, a classification that Edoardo Arslan had deemed still valid more than a century later (Kite 2009, 108; Arslan 1972, 26). Javier Girón refers both to Viollet-le-Duc's own reference to comparative anatomy in explaining the evolution of architectural forms and to Choisy's anatomically based architectural drawings: «especially his use of axonometric from below or his particular way of making a building's anatomy» (Girón 2003, 1007). Girón's subsequent distinction between Viollet-le-Duc's anatomical and Choisy's geological approaches to analytical drawings can be seen as variants on a theme. As Girón observes, Viollet-le-Duc also at times utilized contemporary geological vocabulary (Girón 2006).
6. «ce sont pour ainsi dire des organes intérieurs de buté».
7. I intend to develop this theme further in my paper, «La Poésie de l'invention et l'invention poétique chez Viollet-le-Duc», to be delivered at the international colloquium, «Viollet-le-Duc à Pierrefonds et dans l'Oise», Pierrefonds, September 24–25, 2010.
8. «on peut toutefois, d'après les faits que je viens d'énoncer, certifier qu'il n'a jamais existé une disposition générale dans l'ensemble dans la décoration, soit pour lier les édifices entr'eux, soit pour arriver d'une manière digne aux différents sols sur lesquels les temples sont construits».
9. «Le Pittoresque dans l'art grec: Partis dissymétriques, pondération des masses».
10. In his study of curvature and other refinements on the Acropolis, Lothar Haselberger associates both the newly developed contrapuntal statues in the realm of sculpture and «precision-engineering theories of machine-builders» with new developments in architecture, while noting that «the surviving treatise on catapult-building by the third-century B.C. engineer Philon of Byzantion» quotes from the lost *Canon* by Polykleitos, sculptor of the contrapuntal *Doryphoros* (Spearbearer, c. 450 B.C.) (Haselberger 2005, 106–107, 112–113).
11. «Rien n'est en apparence plus irrégulier que ce plan; en fait c'est un ensemble équilibré, où la symétrie des masses s'associe à la plus originale variété de détails». See also Choisy 1865, 414–415): «Rien n'est dissymétrique comme la disposition géométrale des Propylées: la masse toutefois, de part et d'autre, s'équilibre, et le contour apparent est limité à droite et à gauche par deux lignes issues de la base des degrés, et également inclinées sur leur axe».

12. «et dans cette nouvelle Acropole les apparentes dissymétries ne sont qu'un moyen de donner le pittoresque au groupe d'architecture le plus savamment pondéré qui fut jamais».
13. «la plus belle période de l'art gothique, la première moitié du 13e siècle . . . le quilage est d'une telle légèreté qu'on le croirait métallique; et la stabilité est assurée par un ingénieux artifice . . . : l'emploi d'arcs-doubleaux à profil dissymétrique».
14. «l'en trouuay le trazit et inuentay l'artifice en ladicte année mil cinq cens trentesix, par le moyen et ayde de Geometrie, et grand trauail d'eseprit: lesquel ie n'ay plainct depuis, ainsi plustot louë Dieu gradnement, de ce que d'un seul traict, et seule façon de trompe, on les peult faire toutes». Delorme is discussing the *trompes* that he had invented and built in Lyon, Paris, and Anet, emphasizing his pride in their daring structure, difficulty of execution, and wondrous strangeness of appearance, especially the *trompe* to the right in the courtyard of the Hôtel Bullioud (Lyon) and the *trompe* for the king's *cbabinet* at the Château d'Anet.
15. «et l'on rentrait dans le cas ordinaire où les diverses parties d'un monument se contrebutent mutuellement sans exiger de consolidation étrangère».
16. «Cette combinaison joint à l'avantage d'une raideur absolue celui de répartir la butée sur toute la hauteur des reins».
17. «Cet étai est appareillé comme une plate-bande retournée, de façon à opposer une résistance puissante au relèvement de l'arc produit au point C par la poussée de la voûte» (Viollet-le-Duc 1854–1868, 1: 73).
18. «Les pieds-droits de l'arcature à jour sont perpendiculaires à la direction des deux buttées, et les étré sillonnent ainsi beaucoup mieux que s'ils étaient verticaux, comme dans les arcs-boutants des choeurs de la cathédrale d'Amiens et de l'église d'Eu» (Viollet-le-Duc 1854–1868, 1: 78).
19. «Tout relèvement est désormais impossible».
20. «Un mur ondulé n'est autre chose qu'une courtine interrompue à des intervalles plus ou moins rapprochés par des travées plongeante, paliers invariables où vient s'amortir l'effort de descente des travées droites. Le mur engrène, mord en quelque sorte à dents de scie sur le sol; et, dans le corps du mur, une assise mord sur l'autre».
21. «La poussée F se trouve remplacée par un effort f , à peu près moitié moindre. Non seulement la poussée s'attenuée, mais un effort symétrique f' se développe, qui contrebalance sensiblement l'effort f ».
22. «Ce mode nouveau avait l'avantage d'assurer un surcroît de rigidité; à tous égards il était rationnel».
23. In his discussion of the section through St.-Étienne in Caen, Viollet-le-Duc was puzzled by the placement of the half-barrel vault over the side gallery below the springing of the nave vaults and hence too low for effective bracing: «Mais ce demi-berceau n'arrive pas au point de la poussée de ces voûtes». Had he recognized the structural function of the wall-with-voids, he would have understood that the nave vaults are braced by the double wall, which in turn is braced toward its base by the half-barrel vault (Viollet-le-Duc 1854-1868, 1: 61, fig. 49). Choisy shows a comparable section of St.-Étienne, as well one of Saint-Georges de Boscherville, Figure 3, without comment on the wall-with-voids (Choisy 1899, 2: 193 fig. 5, 303 fig. C).
24. «des coupoles polygonales qui poussent très peu» (198). «Grâce aux arcs d'entretoisement, les murs se trouvaient intéressés à l'équilibre; et cet artifice d'éperons in-

térieurs élégamment élégis a donné lieu à un des effets décoratifs les plus originaux que l'art romain ait rencontrés» (199–200).

25. The original groin vaults of one bay that is still in place, slightly irregular in form and covered with plaster, suggest that these aisle vaults were constructed in *moellons*, a type of stone apparent in the walls of this church. (There is also the possibility of a rubble construction or a combination of rubble and *moellons*.) The *parti* combines one partial large groin vault with two partial smaller groin vaults in alternating fashion, the former spanning the entire bay, while the later spring from an intermediary free-standing column. This arrangement of intersecting larger and smaller groins has been repeated in the vault that connects the two parts of the double wall, what Choisy termed «cet artifice d'éperons intérieurs élégamment élégis». The beautiful ashlar stereotomic vaults seen today are a nineteenth-century restoration that, from the evidence of the one original bay, seems to be a faithful repair of the original forms, albeit in a more sophisticated stone technique. The existence of walls constructed of *moellons* leads one to hypothesize that the decision to create a double wall by inserting a new structural element within the nave was prompted not only by what Choisy cites as the excessive width of the nave relative to the customary span of the cupola but also by a recognition that the walls could not brace the thrust of the new stone vaults that were going to replace the older timber roof. These arrangements are part of an overall strategy to minimize thrust and to brace it as effectively as possible, hence the choice of the polygonal cupola with its lesser thrust after the example of Notre-Dame du Puy en Velay, along with a variation in the treatment of the corners, so that the groins do not align with this weaker point.
26. «Vous y pouvez encore mettre plusieurs courbes, ie dy tant que voudrez. Et tant plus y en aura, plus l'oeuvre sera forte».
27. «on obtient ainsi une voûte tout aussi rigide qu'une voûte pleine, mais plus légère et de moindre poussée».
28. «Another structural feature of this Brunelleschi dome was its adoption of a double-shell system. Two domes are rigidly connected along the eight ribs and as well at the bottom and top rings. The external shell, the lighter one, was considered to be an exterior protective skin easily repairable from outside when necessary. The inner shell, which is less accessible for repairs, is stronger and thicker. The two combine into a single structure that is much more rigid but lighter than a similar single-shell dome would be».
29. «le don divinatoire de Choisy» (16)
30. See note 22 above.
31. «Si nous prenons un à un tous les membres d'un temple grec, si nous les étudions en eux-mêmes et dans leurs rapports directs avec l'ensemble, nous trouverons toujours l'influence de ces observations judicieuses, délicates, qui font reconnaître la présence de l'art, ce sentiment exquis qui soumet toutes les formes à la raison, non point la raison sèche et pédante du géomètre, mais à la raison dirigée par les sens et par l'observation des lois naturelles» («Deuxième Entretien»).
32. «Ce sont là des artifices de stéréotomie qui n'ont rien à voir avec l'art sérieux du constructeur, et qui sont faits pour amuser les esprits curieux de problèmes inutiles».
33. «la science envahit l'art, et l'on sent à ces dispositions cherchées l'effort d'un âge de décadence». (284)

34. «L'architecture gothique est celle d'une société à ressources limitées qui s'ingénie à produire de grandes oeuvres: elle est toute d'artifices, l'inverse de l'art roman. On peut regretter que son organisme si savant soit en même temps si complexe, et surtout qu'un membre aussi essentiel que l'arc-boutant soit directement exposé aux causes de destruction: mais l'équilibre était à ce prix. Les édifices du moyen âge sont de frêles constructions si on les compare aux monuments antiques; en revanche, quelle hardiesse inconnue à l'antiquité!»
35. «de buttées actives opposées à des poussées...l'inertie de la structure romaine» (Septième Entretien).
36. «par des transitions habilement ménagées» (253)
37. My and Caroline van Eck's treatments of Boetticher appeared independently of each other in the same year. Van Eck postulates a «radical break» with previous architectural treatises whereby Boetticher «demonstrated . . . an intrinsic connection between structure and ornament» while showing how ornamental forms could be «the analogical representation of the static task» (Eck 1994, 170).
38. «le Parthénon se présente à nous comme le suprême effort du génie à la poursuite du beau».
39. «c'est l'idéal même du siècle de Périclès et de Phidias: les auteurs de ce chef d'œuvre, Ictinus et Callicarte doivent compter parmi les plus illustres représentants de l'art à sa plus grande époque».
40. «ces belles *Études épigraphiques sur l'architecture grecques*... Des inscriptions existaient dont nul avant Choisy n'était parvenu à préciser le sens, faute de cette double compétence de l'épigraphiste et de l'architecte qu'il possédait si pleinement».
41. «L'entreprise à laquelle se rapporte ce long devis est fort simple en elle-même: un élargissement de trottoir; l'extrême précision de travail que les Grecs s'imposaient en toutes choses explique seule la minutie des détails». The essay ends: «Telles sont les principales indications techniques qui ressortent du texte de Livadie: texte verbeux, diffus, semé d'incidents et de digressions de tout genre, et dont la prolixité exactitudes contraste avec la concision élégante des textes attiques. Mais la seule étendue de ce devis a sa signification: elle atteste l'importance que les Grecs attachaient, même dans des contrées moins heureusement douées pour les œuvres de l'art, à cette exécution parfaite du travail qui semble être pour eux un besoin aussi impérieux que l'harmonie des formes ou la justesse des proportions» (207–208).
42. «L'entreprise des travaux publics était donc moins une profession lucrative qu'une charge honorable mais parfois assez lourde: l'armement des vaisseaux, l'équipement des troupes, tout, jusqu'aux représentations scéniques, faisait l'objet de ces ruineuses entreprises; et l'on se regardait comme amplement récompensé lorsqu'on entendait proclamer au Pnyx ou au Théâtre un décret enregistrant le sacrifice accompli».
43. «Auguste Choisy... Ce nom n'a guère pénétré dans le public». Ellipsis in original.

Reference list

- Armi, C. Edson. 2000. «The Cobel Table». *Gesta*. 39, no. 2: 89–116.
- Arslan, Edoardo. 1972. *Gothic Architecture in Venice*, translated by A. Engel. New York: Phaidon.

- Bergson, Henri. 1920. «Life and Consciousness» (May 1911). In *Mind-Energy: Lecture and Essays*, translated by H. Wildon Carr. London: Mammilla.
- Boetticher, Carl, 1863. «Meine Untersuchungen auf der Akropolis von Athen im Frühjahr 1862». *Zeitschrift für Bauwesen*. 3. 1863: cols. 195–224, 405–470, 557–608.
- Boetticher, Carl, 1874. *Die Tektonik der Hellenen. 1. Die Lehre der tektonischen Kunstformen: dorische, ionische und korinthische Bauweise*. 2nd rev. ed. Berlin: Ernst and Korn.
- Bonde, S.; R. Mark, E. C. Robison, 1993. «Walls and Other Vertical Elements». In *Architectural Technology up to the Scientific Revolution: The Art and Structure of Large-Scale Buildings*, edited by R. Mark. Cambridge, Mass.: MIT Press, 52–137.
- Caillouis, Roger. 1960. «Sciences diagonals», in *Méduse et C^e*. Paris: Gallimard, 11–21.
- Candela, Felix. 1954. «Stereo-Structures». *Progressive Architecture*. 35. June: 84–93.
- Choisy, Auguste, 1865. «Note sur la courbure dissymétrique des degrés qui limitent au couchant la plate-forme du Parthénon». In *Académie des Inscriptions et Belles-Lettres. Comptes rendus des séances de l'année 1865*. Nouvelle série. Paris. 1: 413–417.
- Choisy, Auguste, 1873. *L'Art de bâtir chez les Romains*. Paris: Ducher et Cie.
- Choisy, Auguste, 1884. *Études épigraphiques sur l'architecture grecque*. Paris, Librairie de la Société anonyme de publications périodiques.
- Choisy, Auguste, 1899. *Histoire de l'architecture*. 2 vols. Paris: Gauthier-Villars.
- Choisy, Auguste, 1904. *L'Art de bâtir chez les Égyptiens*. Paris: Édouard Rouveyre.
- Delorme, Philibert. 1561. *Les Nouvelles inventions pour bien bastir et à petits fraiz*.
- Delorme, Philibert. 1567. *Le premier Tome de l'architecture de Philibert de l'Orme conseiller et aumosnier ordinaire du Roy, et Abbé de S. Serge les Angiers*. Paris: Federic Morel.
- Eck, Caroline van. 1994. *Organicism in Nineteenth-Century Architecture: An Inquiry into Its Theoretical and Philosophical Background*. Amsterdam: Architectura and Natura Press.
- Etlin, Richard. 1987. «Le Corbusier, Choisy, and French Hellenism: The Search for a New Architecture». *Art Bulletin*. 69. June: 264–278.
- Etlin, Richard. 1994. *Frank Lloyd Wright and Le Corbusier: The Romantic Legacy*. Manchester: Manchester University Press.
- Etlin, Richard. 2005. «The Parthenon in the Modern Era». In *The Parthenon from Antiquity to the Present*, edited by J. Neils. New York and Cambridge: Cambridge University Press, 362–395.
- Etlin, Richard. 2009. «Serial Barrel Vaults, Inverted Arches, and Rings: A Neglected Family of Structural Forms». In *Proceedings of the Third International Congress on Construction History*, edited by K.-E. Kurrer et al. Cottbus: Brandenburg University of Technology, 543–551.
- Girón, Javier. 2003. «Drawing, Reasoning and Prejudice in Choisy's *Histoire de l'architecture*». In *Proceedings of the First International Congress on Construction History*, edited by S. Huerta. Madrid: I. Juan de Herrera, SEdHC, A. E. Benvenuto, COAM, F. Dragados, 1007–1022.
- Girón, Javier. 2006. «Drawing and Construction Analysis: From Piranesi to Choisy». In *Proceedings of the Second International Congress on Construction History*, edited by M. Dunkeld et al. Cambridge: Construction History Society, 61–87.
- Haselberger, Lothar, 2005. «Bending the Truth: Curvature and Other Refinements of the

- Parthenon». In *The Parthenon from Antiquity to the Present*, edited by J. Neils. New York and Cambridge: Cambridge University Press, 100–157.
- Kite, Stephen, 2009. «Watchful Wandering.' John Ruskin's Strayings in Venice». *Journal of Architectural Education*. 62 no. 4. May: 106–114.
- Lancaster, Lynne C. 2005. *Concrete Vaulted Construction in Imperial Rome*. New York and Cambridge: Cambridge University Press.
- Le Corbusier. 1925. *Almanach d'architecture moderne*. Paris: G. Crès et cie.
- Melaragno, Michele, 1991. *An Introduction to Shell Structures: The Art and Science of Vaulting*. New York: Van Nostrand Reinhold.
- Ocagne, Maurice d'. 1930. *Auguste Choisy et l'Art de bâtir chez les anciens*. Vannes: Imp. Lafolye and J. de Lamarzelle.
- Paccard, Alexis, [1845] 1982. «Mémoire explicatif de la restauration du Panthéon». In *Paris-Rome-Athènes. Le Voyage en Grèce des architectes français au XIXe et XXe siècles*. Exhibition catalog. École nationale supérieure des Beaux-Arts; École française d'Athènes; Museum of Fine Arts, Houston. Paris: École nationale supérieure des Beaux-Arts, 351–368.
- Penrose, Francis Cranmer, 1851. *An Investigation of the Principles of Athenian Architecture*. London: Longman.
- Pérouse de Montclos, Jean-Marie de. 1982. *L'Architecture à la française, XVe, XVIIe, XVI-IIe siècles*. Paris: Picard.
- Siegel, Curt, 1960. *Strukturformen der modernen Architektur*. Munich: Callwey.
- Viollet-le-Duc, Eugène-Emmanuel. 1854–1868. *Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle*. Paris: B. Bance, A. Morel.
- Viollet-le-Duc, Eugène-Emmanuel. 1863. *Entretiens sur l'architecture*. Vol. 1.

