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Revealing the Parthenon's *logos optikos*

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Abstract

Ancient architects incorporated into their temples subtle adjustments of form, position, and proportion that have come to be known as optical corrections. Column shafts taper, although with a fine convex augmentation known as entasis. Peristyle columns and entablatures incline toward the middle, while virtually every horizontal surface from foundations to pediments bows up in the middle. The intercolumniations, the space between columns, widens out from base to top of shaft, along with the corner columns being enlarged relative to other columns. The adjustments of form correct the perceptual condition known as the irradiation effect, in which architectural elements appear attenuated when in silhouette. The adjustments of position produce a corrected image, although not in the strict sense of correcting an apparent illusion evident with the adjustments of form. The adjustments of proportion synthesize the architectonic and perceptual aspects of the previous two groups. Masons adjusted architectural elements' height, width, or both to insure apparent uniformity of size.

I will illustrate in this essay that Iktinos and Kallikrates, the architects of the Parthenon, conceived of these adjustments as optical corrections; however, their conception of an optical correction transcended the physiologically based definition of correcting an apparent illusion. The *architektones* conceived of these corrections as emulating Nature's illusionary hidden ordering – its *logos optikos*. Also, they conceived the corrections as apperceptions, as epistemological instruments that manifested architectonically the limits of vision. The architects allowed observers the opportunity to perceive architectural elements as different configurations and proportions that made observers aware of the thresholds of visual acuity and adverse effects of silhouetted contrast. Last, the architects conceived of the corrections as the nexus between realistic conditions and idealistic intent. They strove to present to all observers apparent

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uniformity, verticality, and linearity, which are all fundamental information features of visual perception and attributes achieved only in an ideal state.

> By common consent, the Parthenon is a great work of art. Yet, it has aesthetic standing as the work becomes experience for a human being. To understand the aesthetic in its ultimate and approved forms, one must begin with it the raw; in the events and scenes that hold the attentive eye and ear of man ...[7]

John Dewey charges the modern theorist judging the aesthetic experiences of the Athenian Acropolis with revealing the *logos*, the underlying principles of Nature and the political ambience of Periklean Athens, with the *optikos*, the perceptual experience. The means to comprehend these intentions of Nature resides in intellectually perturbing conditions that attract the "attentive eye," which have come to be known as optical corrections. They are the mutable situations of perception, the everyday, formal, and transcendent "events and scenes" to which natural philosophers devoted meticulous attention and which catalyzed Classical-period architects to invoke an acumen that has come to be associated with the Parthenon's aesthetic prominence [14].

I will illustrate in this essay that Iktinos and Kallikrates, the architects of the Parthenon, conceived of these adjustments of form, position, and proportion as optical corrections; however, their conception of an optical correction transcended the physiologically based definition of correcting an apparent illusion. The *architektones* conceived of these corrections as emulating Nature's illusionary hidden ordering – its *logos optikos*. They recognized that Nature is replete with illusionary conditions, for examples the fact that perception depends on viewing distance and that camouflaged objects and condition hide and reveal themselves. Also, they conceived of the corrections as apperceptions, the corrections functioned as epistemological instruments that manifested architectonically the limits of vision. The architects allowed observers the opportunity to perceive architectural elements as different configurations and proportions that made observers aware of the thresholds of visual acuity and adverse effects of silhouetted contrast. Last, the architects conceived of the corrections as the nexus between realistic conditions and idealistic intent. They strove to present to all observers apparent uniformity, verticality, and linearity, which are all fundamental information feature of visual perception and and attributes achieved only in an ideal state.

The essay will consist of three sections. In the first section, I will define *logos optikos*, the ancient perceptual paradigm that theoretically underpins the need for the optical corrections in architecture. In the second section, I will describe the function and particular correctional purposes for the adjustments of form, position, and proportion. In the third and final section, I will present a theory on construction viewing positions, which are geometrically and visually defined, as well as sacred, locations on the Acropolis, at which the architects

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stood to define the precise form, position, and proportion of architectural elements.

Logos Optikos

In his first book of *De Architectura*, the Roman architectural theorist, Vitruvius [21] introduces a central theme of his treatise, the "subject of vision," or in Greek, *logos optikos*. He references the subject as the common ground for astronomers, musicians, and geometricians and characterizes architects with knowledge in these areas, as men on whom Nature has bestowed "so much ingenuity, acuteness, and memory" that they transcend architecture to become pure mathematicians. Despite this lofty praise, *logos optikos* is an enigmatic conception. The *logos* of *optikos* juxtaposes rational systemization with psychological subjectivity. *Optikos* interacts dialectically with logic. Logic is reason; *optikos* is the perception; *logos* is ethereal truth; *optikos* is contingent and fallible.

The noun *logos* derives from the verb *legein*, which means to account for or describe something. For the earliest philosophers, the *logos* explained an event or physical object [3]. These logical explanations were the birth of modern science. No longer did myth adequately reveal reasons for the nature of things. In its earliest usage, *logos* referred to the description [11], however by the late sixth century BCE, it had become to mean "the formula or underlying principle common to all things" [13].

Logos had technical connotations with obvious architectural implications. It referred to measuring, reckoning, and proportioning. In this sense, *logos* was the ordering according to a common plan or measure [13]. An interest in symmetria, the measure, pervaded aesthetic thought at the time of the Parthenon's construction. The desire to establish an order behind the flux of experience was inherent in the Greek mind. Sanctuary planning, according to Constatin Doxiadis, involved corporeal units of coordinates. He suggests that ancient Greek sanctuaries were not designed on drawing boards but that each sanctuary developed on a site in an existing landscape. Architects used an anthropomorphic polar coordinate system, in which both orientation and distance were based on the human body. The architect's body defined the center point in this natural system; distances were paces, and orientations were to the left, right, in front of, behind, above and below [8].

For ancient Greeks, *optikos* referred to eyes, sight, and optics – the organ, the physiological process, and the geometric principles and psychological characteristics of vision. Discussions of light and visual processes are among the earliest known philosophical fragments of ancient Greece, with studies in these three areas developing concomitantly. Blindness and eye disease propagated study of the physiology of the eye. Artists' explorations of scenography and astronomers' observations of celestial movements caused the development of a mathematical theory of perspective.

Ancient Greek philosophers characterized sight with four theories. First, sight was an epistemological instrument; eyewitnesses provided the most truthful

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information [1, 12]. Second, and a bit contradictory, sight was fallible, evident by visual illusions in both nature and architecture [10]. Third, sight was tangible, conceived first as vectors [3] and later as particles [16]. Fourth, sight emanated from our eyes and traveled as a finite speed toward an object. It reflected from the object and returned to our eyes [3].

The philosophers conjoined these four theories of sight into a theory of visual perception that addressed the limits of sight. Illusions found in nature, created by man, or caused by physiological or psychological limitations of sight, reveal the limitations of the system, the *logos*, used to understand nature. Illusions, therefore, were not conceived as deceptive *(aphate)*, but as apperceptive: they are manifestations of the act of perception. Philosophers and artists conceived of perception as a conscious act, being constantly aware of their seeing and judging the world around them.

This cognizance of perception was illustrated in the architecture and sanctuary design of the period. Unlike contemporary architects, who disregard viewing distance by using abstract forms and regulating lines that derive from an attempt to please the mind, ancient architects endowed their architecture with the natural sequence for revealing information about itself based on viewing distance and orientation. Abstract architectural forms are representations of natural forms seen from afar, and the articulations of temples represents the details evident in nature when seen from close-up. From afar, an observer may discern its simplest forms, the triangular pediment, rectilinear frieze, the cylindrical columns, and planar steps. Upon closer viewing of the temple, its stylistic attributes, sculptural forms, and shadows layered onto the primary forms. The closer the observer approaches the temples, the more new information its presents, yet never becoming repetitive.

Optical adjustments

Iktinos and Kallikrates incorporated into their temple subtle adjustments of form, position, and proportion. Column shafts taper, although with a fine convex augmentation known as entasis. Peristyle columns and entablatures incline toward the middle, while virtually every horizontal surface from foundations to pediments bows up in the middle. The intercolumniations, the space between columns, widens out from base to top of shaft, along with the corner columns being enlarged relative to other columns.

The adjustments of form, which include entasis, fluting of columns, upward curvature of horizontal surfaces, curvature in plans, and unleveled stylobate, the platform on which the perimeter columns set, correct the perceptual condition known as the irradiation effect, in which architectural elements appear attenuated when in silhouette. Entasis may be defined as the subtle augmentation to a column shaft profile with the purpose of insuring an apparently straight profile when the column is in silhouette. Its usage also occurs in antae (extension of walls), doorjambs, and pilasters, all elements where a high-contrast condition exists. (Fig 1) Fluting, in general, and the multiple centroid fluting of Doric columns and the elliptical fluting in Ionic columns, in particular, cast shadows

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back onto the column shaft to insure apparent rotundity. In other words, flutes prevent the column from appearing flat. (Fig 2) Upward curves are cambered horizontal surfaces incorporated into virtually every horizontal element from foundation stones up to the entablature. They counteract the apparent sagging caused by the visual weight of the peristyle columns or evident when viewing long lines. (Fig 3) Curvatures in plan are convex and concave profiles are found primary in cornice lines. The convex bowings in plan insure a straight profile when the cornice is in silhouette. (Fig 4) Unleveled stylobates slant lengthwise or diagonally, with higher points typically on the west. This inclination addresses the irradiation problem and insures an apparent levelness for the stylobate. (Fig 5)

Modern perceptual psychologists have conducted experiments in which they evaluated the influence that illumination and relative contrast have on the perception of illuminated and silhouetted objects. (Fig 6) Elworth's findings strongly substantiate not only the need for these augmentations of forms. He noted that the edges of black squares appear concave when strongly backlit. He attributed the apparent concavity to the physiological circumstance known as lateral inhibition [9]. Mather and Morgan substantiated the degree of augmentation that the Parthenon's architects and masons incorporated into their columns and stylobates. They determined that the irradiation's "blurring of the edges" could be as much as one minute of visual arc [17], which as I will explain later is the Parthenon's perceptual and construction tolerance. Moreover, it amounts to one half the amount of entasis incorporated into the columns, which suggests that the ancient not only perceived the need for entasis, but through possible experimentation determined the appropriate amount.

The adjustments of position produce a corrected image, although not in the strict sense of correcting an apparent illusion evident with the adjustments of form. Each of these adjustments, which include a transitional positioning of columns, and inward and outward leaning and asymmetrical refinements, assured either apparent uniformity or apparent verticality, or manifests the illusionary and naturalistic condition of camouflage. Transitional positioning is the systematic adjustment from a uniform placement of columns so that the intercolumniations appear uniform. Rarely are two adjacent columns exactly the same size, so masons to camouflage the disparity would shift their placements so that the space between the columns would appear uniform. (Fig 7) Inward leaning of peristyle columns responds to an apparent splayed effect that occurs when columns rest on flat or cambered surfaces. Columns along the perimeter of the temple leaned toward the center of the temple, with the corner columns leaning diagonally. (Fig 8) The frieze above the columns leaned outward, which was an architectural response to an ancient perceptual theory that sight is a vector traveling at a finite speed that reflected off an object and traveled back to the observer. The perception of distance was measured by an apparent length of time. As a result, for a wall or column to appear vertical, then it should lean forward. (Fig 9) The asymmetrical refinements are pervasive variations, either dimensionally from or in nonalignment with construction modules. They invoke the use of camouflage so to insure apparent uniformity. If the design of the

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Parthenon was completely based on a module, then, ideally, a vertical axis should extend up through the centers of the columns and align with the joint of two beams that rest on the columns. However, in the Parthenon, this situation does not exist. Minute yet systematic discrepancies occur, which illustrates an intentional desire to camouflage. This intent to camouflage is ingeniously achieved by positioning the flute faces and not the arrises, the sharp formed by adjoining flutes, at the column centerlines. An observer must impose an imaginary line down the middle of the shaft with which to compare to the architrave joint. The centerline is an actually an ever changing shadow line. This dynamic line reflects a particular attitude toward the metrical unit; only in its rational conception is it precisely immutable. [15] (Fig 10)

The adjustments of proportion synthesize the architectonic and perceptual aspects of the previous two groups. Masons adjusted architectural elements' height, width, or both to insure apparent uniformity of size. The three adjustments – column tapering, a temperamental refinement, and enlarged corner columns – require observers to compare several architectural elements or features either simultaneously or sequentially. Tapering of column shaft diameters perspectivally increase columns' apparent height, while conversely, if the observer focuses on the intercolumniations, tapering counters the perspectival foreshortening by producing intercolumniations of apparently uniform width. (Fig 11) From my investigation of over forty classical-period temples, I determined that from a distance twice the height of the columns would the space between the columns at the top of the shaft appears the same as the space between the columns at their base. This desire for apparent uniformity in a vertical orientation also occurred. Masons proportionally increased the size of words on higher lines than those inscribed below. From a particular viewing position visual uniformity is assured. (Fig 12) Corner columns are usually several centimeters larger in diameter than adjacent columns to counter the attenuated effect evident in silhouetted forms, which brings the presentation of the optical corrections full circle. (Fig 13) These adjustments of form, position, and proportion were not only systematically incorporated in to the Parthenon, but evidence of one of more of them can be found through out Classical-period architecture, which substantiates that a *logos*, a system, conceptually based in a perceptual need, an *optikos*, existed.

Construction viewing position

During the investigation of the Parthenon's upward curvature, I discovered the presence of construction viewing positions, locations from where ancient architects may have defined the form, position, and proportion of architectural elements. It was inspired by Doxiadis' planning vantage point theory, in which he suggests ancient architects positioned themselves in a particular spot to lay out visually the sanctuary [8]. The theory of a construction viewing position (CVP) focuses on the refining of architectural elements and reveals how architects interrelated sanctuary planning and articulation of architectural elements. The CVPs illustrate also how architects conceived of geometry as the

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liaison between the *logos*, the intentionality of the design, and the *optikos*, the appearance of the design. The CVPs for the Parthenon's two fronts and two flanks stylobates, the platform on which the outer columns rest, are determined by simple geometric operations and it is from these positions that ancient architects defined the height of the upward curvature.

According to the archaeologist, J. J. Coulton, ancient architects employed one or more measurement systems in the design and construction of temples: arithmetic, geometric, and visual [6]. In the arithmetic system, architects proportioned and mason laid out temples using a foot or a module as its symmetrical unit. Both individual elements and the complete temple supposedly derived from either multiplying or dividing the unit. Using the foot or module reflected a favoring of a consensus over personal taste, in the sense that an aesthetic decision might be precisely duplicated from one temple to another [19]. Coulton also asserts that ancient architects and masons relied on geometric associations to define heights, widths, and dispositions of architectural elements [6]. Ancient architects did not produce comprehensive sets of construction documents as commonly practiced today. As a result, design and construction occurred simultaneously, with preconceived design concerns continually modified by construction.

The visual method, or "designing by eye" according to Coulton produces a network of inconsistent proportionalities that does not reflect the prevailing regularity in the architecture of fifth century BCE Greece [5]. He, and others, suggests that consensus proportions governed designs, thereby recognizing a respect for archetype over a desire for invention [18]. A visual method is, however, as sophisticated as the arithmetic and geometric methods and allows architects to achieve the same precision of measure. Humans are quite capable of discerning minute visual differences. Under normal viewing conditions, such as those on the Acropolis, an observer can perceive one minute difference in visual arc—one sixtieth of one degree [2]. This distinction is equivalent to only one centimeter from approximately thirty-five meters away. If this perceptual tolerance is translated into ancient Greek terminology, it is the equivalent of one-half of one dactyl (their subdivision of one foot equivalent to an inch) viewed from a distance equal to one half the length of the Parthenon's stylobate. Coulton contends that one half of a dactyl is the typical construction tolerance for ancient temples [5]. In addition to its high degree of accuracy, the visual method is experiential. It acknowledges viewing distances and orientation of view, which the other two systems disregard.

Architects and masons must have developed both a sensitive eye, not only to spot construction error and poor technical virtuosity, but also to emulate the way Nature composes and reveals itself; and a creative eye to camouflage the ever-occurring construction error and to model the natural order using architecture. They did not have "supernatural" vision; however, they trained themselves through experience and observation to become cognizant of finer and finer details. They focused their sight into very narrow cones of vision to define the dimensional characteristics of the adjustments. Entasis in the Parthenon's northwest corner columns is first noticeable from a point halfway between the

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Parthenon and Propylaia. From the bottom of the steps on the Parthenon's west side, the amount of inward leaning and taper incorporated into the Parthenon's west front corner columns creates a commensurable visual ratio of three to four between the distance across the façade at the top of the column shaft and the distance across the façade at the base of the of the columns. These adjustments exemplify a mastery of perception and craft, while simultaneously representing a willingness and desire to experiment.

What propagated the inquiry into the optical characteristics of upward curvature was the simple question: If the intended purpose of the upward curvature was to produce an apparent level surface from one end of the temple to the other, then should it not be possible to locate a position from where the apparent height of the curve appears uniform from one end to the other? Perceptually, this location would be defined as the spot from where a person could not distinguish a change in height from a base line up to top surface of the stylobate at given points along the stylobate. This condition can be verified optically by determining whether from this location the subtended visual angles are either consistent or their differences are to minute to perceive.

The first step in the inquiry was to determine the height of the curve at each column centerline. The centerlines were chosen for two reasons. Precise measurements are known and because they demarcated by tangible and easily recognizable points, the joints in paving stones. The height of the upward curvature was defined at each column centerline because it is easily demarcated during construction and easily camouflaged after construction. The two top corners of the stylobate are not in the same plane; the east corner is approximately three centimeters higher than its western counterpart. The base line for measuring the height of the curve is not level, however it respects precedent and construction logic. Archaeologists believe that workers stretched a taut cord between the two corners, which in the case of the Parthenon mediates the elevation difference and produces a more symmetrical curve than if the base line were level. This procedure for measuring the curve's height produced significant optical characteristics.

My first discovery was that from a distance equal to one half the length of the Parthenon's north stylobate, 34.8 m, the height of the curve at its maximum point subtends a visual angle of ten minutes, which contemporary perceptual psychologists suggest is the largest undistorted visual angle [2]. We are capable of perceiving much larger images, however our brain must assimilate the myriad of smaller images into a coherent whole, which is when "mistakes" or ambiguity occurs.

The procedure used to determine the construction viewing position involved several criteria, along with the simple observation: the curve is shorter at the corners, therefore an observer stands closer to the corners so the visual angles are optically similar. The three criteria are: first, the viewing position should respect known classical knowledge of geometry and surveying. Second, the viewing position should respect the nature of architectural construction specifications of the Classical period. Third, the visual angles subtended from the viewing position of the curve at the column centerlines should all be on the order of ten

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minutes of visual arc. If not all ten minutes, then the difference between various angles should not be greater than one minute of visual arc, the smallest discernable visual angle under normal viewing conditions. By using the ten minute visual angle as the perceptual unit of measure and the one minute visual angle as the perceptual tolerance, I suggest that the ancient architects scrutinized the construction with great precision, which is corroborated by the unbelievable construction tolerances by today's standards found in the Parthenon. (Table 1)

The location respecting all criteria is the simplest to describe and define. It is the bisector of a ninety degree arc whose radius is one-half the length of the stylobate. This description requires two construction viewing positions for the north and south flanks. For the east and west fronts of the Parthenon, there are single viewing positions that are again one half the length of the stylobate away but in line with the temple's center axis. From these six positions, the height of the curve at each of the column centerlines subtends a visual angle on the order of ten minutes of visual arc, which means that the upward curving appears level.

These construction viewing positions are not just abstract, geometrically defined locations; they coincide with sacred and historically significant locations on the Acropolis. For the north elevation stylobate, the CVPs are demarcated by the Great Altar to Athena, the most sacred spot on the Acropolis, and the south edge of the foundation stones of the first temple to Athena. For the west elevation, the CVP is on axis the center of the Parthenon and situated at the bottom of the steps leading down to the Chalkotheke. To demarcate the CVP with existing architectural features illustrates how thoroughly architects planned their sanctuaries. (Fig 14)

To conclude this discussion of construction viewing positions as locations from which to perceive the ideal state of apparently level would present only half of the story. Any tourist who has visited the Parthenon knows quite well that standing at the northeast corner and looking down the north side of the temple, the upward curvature is obvious. However, as the person walks westward the steps and stylobate appear level. The question arises: which of these two images was the intended perception of the steps and stylobate? I suggest both. To conclude that the straight image was the correct one suggests that the sole purpose was to correct for an apparent illusion. However, to allow a person ready access to a spot from where the upward curvature is obvious, suggests that the upward curvature was intended as a epistemological instrument—a tool with which to inform people of the limitation of vision and of the limitations of their conceptions, their *logos*, of vision. Similar ambiguous perceptions exist for other adjustments. Column profiles can be perceived as both straight and convex. To postulate deception on the part of the architects advocates a rational paradigm rather than an experiential paradigm. Experience is inherently ambiguous; we constantly assimilate disparate images into an apparent coherent whole. These optical corrections, as a system, and the construction viewing positions, in particular, exemplify a perceptual paradigm wherein the observers are made consciously aware of the relationship of where they are standing and at what they are looking.

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Conclusion

Jerome Pollitt notes that "the Classical period was not an age in which pure abstraction, divorced from the real world of human life and action, was of all-consuming interest. Man was the measurer, and things had to be measured in the light of his experience" [20]. In regard to the Parthenon, he submits that the "new world Protagoras is brought into balance with the older world of Pythagoreans—the foremost of several fusions of opposites which make the Parthenon the most vivid and comprehensive embodiment in the visual arts of Classical thought and experience" [20].

This study of Parthenon's *logos optikos* serves as a critique of modern world view where observer is separated from object. The ancient architects did not conceive of architecture as an entity. The aesthetic experience of the optical corrections is most aptly described as ambiguous, not in the sense of being vague but to enrich. The architects did not present single, correct images; they introduced a palette of revealing experiences consciously acknowledging viewing position, orientation of view, and time of day. Individually and in their sum, experiencing the adjustments of form, position, and proportion impart a reciprocating relationship between observer, architecture, and Nature.

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[22]

Table and Figures

Table 1. Heights and Visual Angles for the Parthenon's North Stylobate

Column	Curve Height	Visual Angle	Column	Curve Height	Visual Angle
NE	.0025m	0.3 MVA	10	.100	10.75
2	.0275	3.74	11	.0946	11.04
3	.045	6.26	12	.084	10.55
4	.06	8.28	13	.075	10
5	.0775	10.33	14	.06	8.28
6	.0842	10.7	15	.042	6.24
7	.0932	10.88	16	.02	2.72
8	.101	10.85	NW	0	0
9	.102	10.1			

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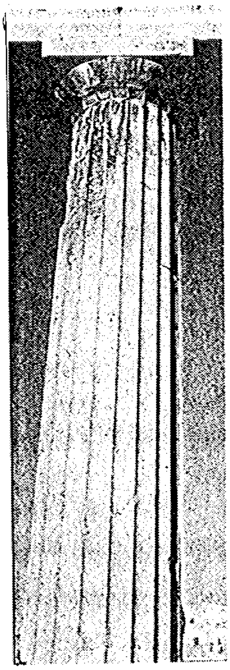

Figure 1: Entasis

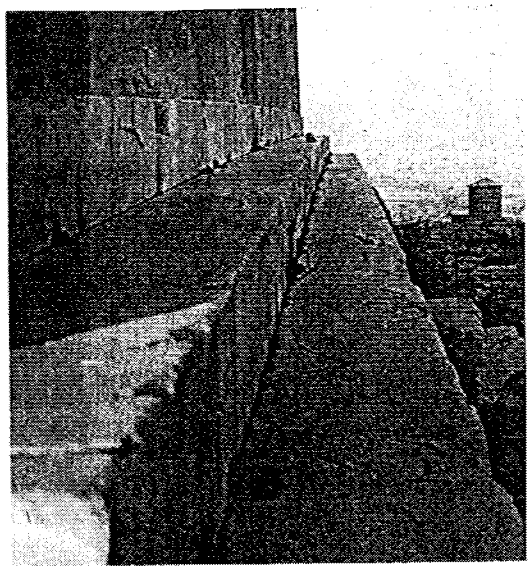

Figure 2: Upward Curvature

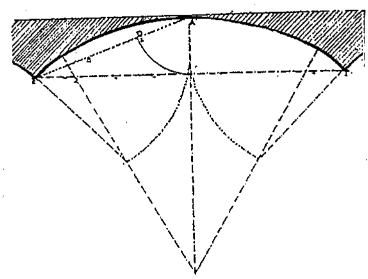

Figure 3: Fluting

Figure 4: Curvature in Plan

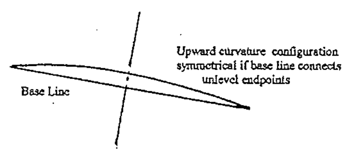

Figure 5: Unleveled Stylobate

Figure 6: Irradiation Effect

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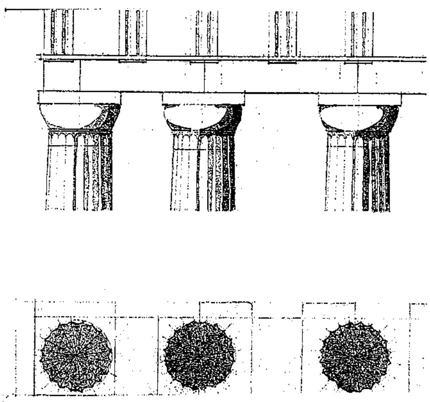

Figure 7: Transitional Positioning

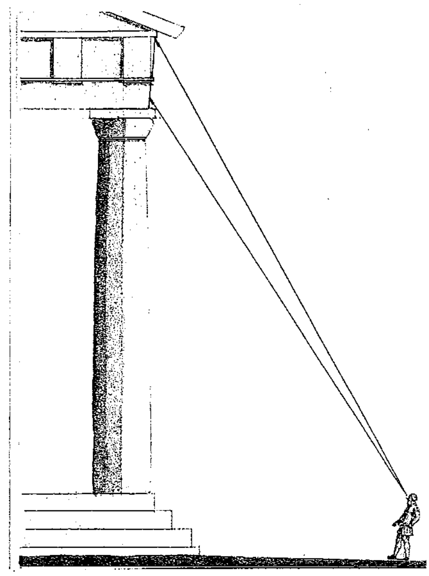

Figure 9: Outward Leaning

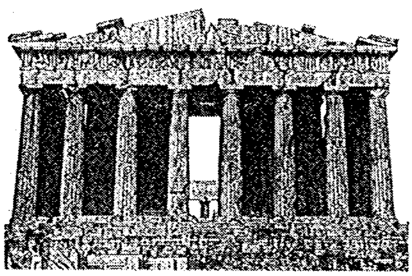

Figure 8: Inward Leaning

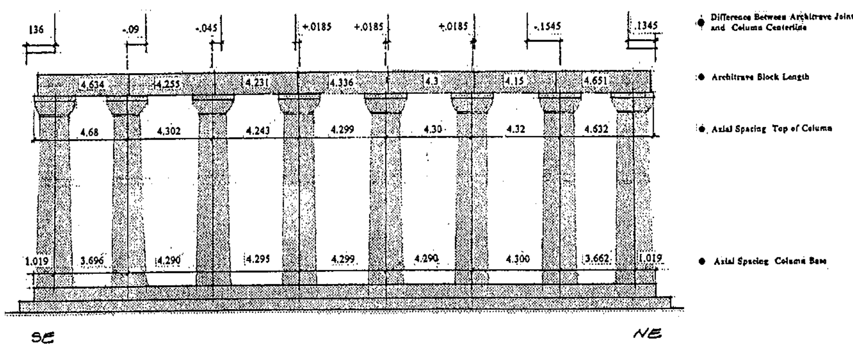

Figure 10: Asymmetrical Dimensioning

Paper from: *Design and Nature,* CA Brebbia, L Sucharov & P Pascola (Editors).
ISBN 1-85312-901-1

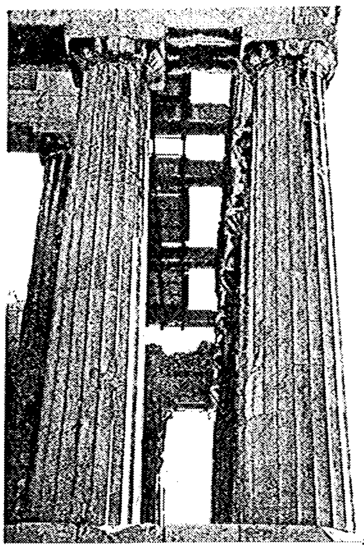

Figure 11: Column Tapering

Figure 13: Enlarged Corner Column

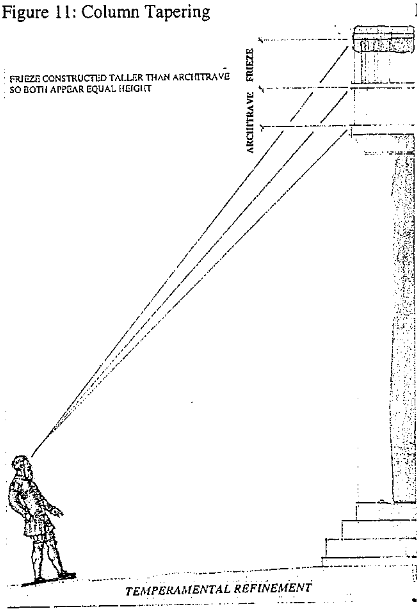

Figure 12: Temperamental Refinement

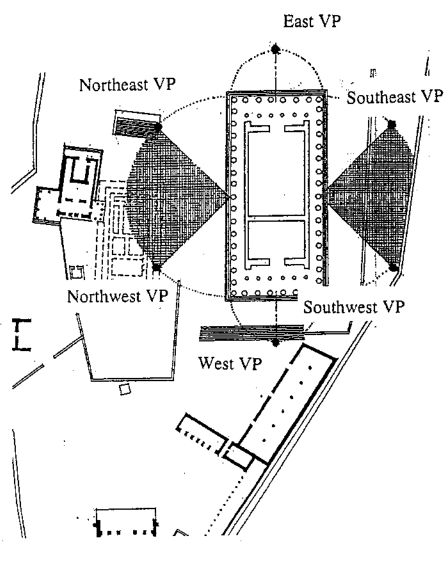

Figure 14: Construction Viewing Positions