# HARMONIC DESIGN IN MINOAN ARCHITECTURE

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During 1964-66 a study was undertaken of the remains of Bronze Age construction in the Aegean Basin in an attempt to establish certain underlying principles of Minoan, Mycenaean and other Aegean architectural design. Some 330 structures at 90 sites were examined and measured; evidence for planning and layout procedures, and for modular and proportional design canons were sought. The results of the project, presented (June 1968) in partial fulfillment of the requirements for a doctoral degree at Harvard, are outlined below. [1]

Between ±2000 BC and ±1500/1400 BC, Minoan Crete generated the first large-scale, complex townscapes in Europe and a sophisticated architecture comparable to the contemporary architectures of Egypt and the Lewant. During this period a number of large structures, known conventionally as "palaces," were constructed at Knosses, Phaistos and Mallia, and (slightly later) at Kato Zakro, Gournia and Plati (Fig. 1). The largest of these, at Knossos, may be enclosed within a square roughly 150 meters on a side. The palaces are generally similar in groundplan; each consists of a solid mass of construction pierced by a central courtyard and elsewhere by smaller courts and light-wells. The outer trace is not uniplanar but consists of a series of recesses and projections of varying size. The buildings are in most cases two stories in elevation (in certain sections perhaps taller); one palace, at Phaist s, spreads over some seven terraces of varying height. The first three palaces named also have extensive paved courtyards bordering their western facades; in all cases building material is stone, frequently in the form of finely squared masonry blocks, particularly on the outer facades.

The remains have come to light only since the turn of the century;[2] since that time Crete has become one of the most thoroughly explored areas of Greece;

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[1]All measurements here are metric; Bronze Age in Greece: Early: ±2700-

[2]Beginning with the excavations at Knossos by Sir Arthur Evans in 1899; final publication: A. Evans, The Palace of Minos at Knoss , 4 vols., 1921-1936; In 1900 the palace at Phaistos began to be uncovered: L. Pernier and L. Banti, Il Palazzo Mincico di Festos, 2 vols., 1935 and 1951.

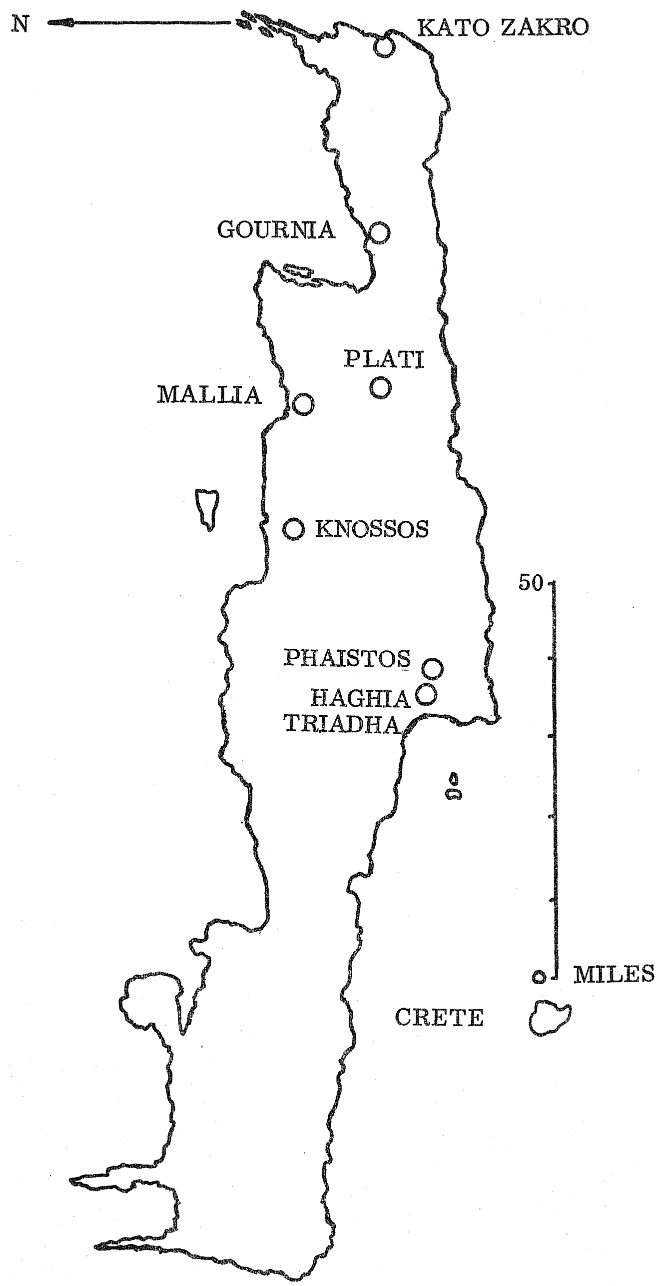


Fig. 1 Minoan Palatial Complexes

scores of settlements, large and small, have come to light on this island not much larger than Long Island. Surprises still come forth; one of the six palaces mentioned above (Kato Zakro) was discovered in 1963, and last Summer (1967) a new town belonging to the Early Bronze Age (±2700 — ±2000 BC) was uncovered on the South coast.

Despite the archaeological familiarity of Minoan remains, a thorough study of the architecture has yet to be published, which fact is partly responsible for a good deal of misinformation about its nature. Another contributing cause is the great contrast Minoan architecture makes with Greek temple design of a millenium later; the great complexity and seeming irregularity of the former have provided more than one Classical scholar, trained to appreciate the apparent clarity and simplicity of the Greek temple, with nearly insuperable obstacles to understanding.[1]

There are other factors contributing to the general misunderstanding, the most relevant here being that the palaces (and most notably Knossos) underwent periodic rebuilding and remodelling during the centuries of their use. This has tended to obscure the fact that each large complex was designed initially as a coherent whole. Archaeological research has shown that in some cases (e. g., Phaistos)[2] different sections of a palace were constructed at different times: necessarily, construction of such enormous structures would have been phased for varying reasons. The view of Arthur Evans that the palace of Knossos "became" a single structure as a result of the coalescence of separate buildings bordering a central piazza is today not widely held.

Unlike the later Greek temple, the Minoan palace was not designed with bilateral symmetry as its overriding principle; the organizing principles are somewhat more complex and are only now beginning to be understood. That one of the keys to the solution involves the ratios of a Fibonacci Series will

[1]As late as 1957, the author of one of the major textbooks on Greek architecture could write "It appears that the Minoans did not object to disorderly planning as such; they obviously saw no advantage in symmetry and may have been lovers of the picturesque at all costs; in fact their architecture resembles their other arts in showing no sense of form." A. W. Lawrence, Greek Architecture (Penguin, 1957), 34.

[2]The earlier palace at Phaistos was built in at least four separate phases, beginning on the south and working north, E. Fiandra, "I periodi struttivi del primo palazzo di Festos," Kritika Khronika 15/16 (1961-62) 112 ff. Nevertheless, the entire plan is a unity, as demonstrated by a study of the measurements.

become apparent below. Within the last decade the researches of Prof. Graham of Toronto have provided a number of initial insights into the nature of Minoan metrology.[1] He postulated the existence of a builders' modules (which he called the "Minoan Foot") used in the layout of the palaces; the value was set at .3036.[2]

That Graham's conclusions were premature was shown by the results of the aforementioned project, in which some 12,000 measurements were made on structures both on Crete and elsewhere in the Aegean and Greece: evidence of four modules was found. Of the 330 structures examined, 217 revealed clear evidence of modular usage (or at least were sufficiently well-preserved to admit of careful measurement):

| MODULE | A | B | C | D | other[3] |
|---|---|---|---|---|---|
| value: | .2704 | .3380 | .4330 | .3036 | |
| times found: | 104 | 67 | 17 | 20 | 9 |

An immediate curiosity was that the distinction in usage revealed no consistent geographical or chronological pattern; i. e., A was not found in area X to the exclusion of B, C, and D, nor was its use limited to one chronological period within the Bronze Age, etc. Indeed, the impression was gained that a builder was more or less free to choose any of the four in laying out his structure.[4]

A comparison was then made of the scales based on each module (Fig. 2); it was noted that there were certain consistent points of contact among the scales of a single unit of measurement. The relationship may be expressed geometrically (Fig. 4); if a rectangle is constructed with the short side equal to .5408, and the long side .676 (= 2 x .338), then the diagonal = 2 x .434. The relationship is 10:16 or 5:8. It is of interest also that the diagonal bisecting

[1]J. W. Graham, The Palaces of Crete (Princeton, 1962) ch. XIII, w. refs.

[2]Graham's study involved a sample of measurements of palace sections similar in design at various places; a by-product of a study of window-recesses, the author did not have as his purpose a comprehensive metrological examination of architectural remains of the Bronze Age in Greece.

[3]Six structures yielded evidence of a module of .40, three of .45.

[4]As if (to use a New Haven example) Brockett's street grid of 1643 employed rods and each of the Yale colleges was laid out on a different system (meters, feet, fathoms, etc.). Examples may be found in World Weights and Measures, UN Handbook M/21/rev. 1. (1966), for simultaneous usage of several systems in a given country.

| MODULE | A | B | C | D |
|---|---|---|---|---|
| 1 | .2704 | .3380 | .4330 | .3036 |
| 2 | .5408 | .6760 | .8660 | .6072 |
| 3 | .8112 | 1.0140 | 1.2990 | .9108 |
| 4 | 1.0816 | 1.3520 | 1.7320 | 1.2144 |
| 5 | 1.3520 | 1.6900 | 2.1650 | 1.5180 |
| 6 | 1.6224 | 2.0280 | 2.5980 | 1.8216 |
| 7 | 1.8928 | 2.3660 | 3.0310 | 2.1252 |
| 8 | 2.1632 | 2.7040 | 3.4640 | 2.4288 |
| 9 | 2.4336 | 3.0420 | 3.8970 | 2.7324 |
| 10 | 2.7040 | 3.3800 | 4.3300 | 3.0360 |
| 11 | 2.9744 | 3.7180 | 4.7630 | 3.3396 |
| 12 | 3.2448 | 4.0560 | 5.1960 | 3.6432 |
| 13 | 3.5152 | 4.3940 | 5.6290 | 3.9468 |
| 14 | 3.7856 | 4.7320 | 6.0620 | 4.2504 |
| 15 | 4.0560 | 5.0700 | 6.4950 | 4.5540 |
| 16 | 4.3264 | 5.4080 | 6.9280 | 4.8576 |
| 17 | 4.5968 | 5.7460 | 7.3610 | 5.1612 |
| 18 | 4.8678 | 6.0840 | 7.7940 | 5.4648 |
| 19 | 5.1376 | 6.4220 | 8.2270 | 5.7684 |
| 20 | 5.4080 | 6.7600 | 8.6600 | 6.0720 |
| 25 | 6.7600 | 8.4500 | 10.8250 | 7.5900 |
| 30 | 8.1120 | 10.1400 | 12.9900 | 9.1080 |
| 35 | 9.4640 | 11.8300 | 15.1550 | 10.6260 |
| 40 | 10.8160 | 13.5200 | 17.3200 | 12.1440 |
| 45 | 12.1680 | 15.2100 | 19.4850 | 13.6620 |
| 50 | 13.5200 | 16.9000 | 21.6500 | 15.1800 |
| 55 | 14.8720 | 18.5900 | 23.8150 | 16.6980 |
| 60 | 16.2240 | 20.2800 | 25.9800 | 18.2160 |
| 65 | 17.5760 | 21.9700 | 28.1450 | 19.7340 |
| 70 | 18.9280 | 23.6600 | 30.3100 | 21.2520 |
| 75 | 20.2800 | 25.3500 | 32.4750 | 22.7700 |
| 80 | 21.6320 | 27.0400 | 34.6400 | 24.2880 |
| 85 | 22.9840 | 28.7300 | 36.8050 | 25.8060 |
| 90 | 24.3360 | 30.4200 | 38.9700 | 27.3240 |
| 95 | 25.6880 | 32.1100 | 41.1350 | 28.8420 |
| 100 | 27.0400 | 33.8000 | 43.3000 | 30.3600 |
| note also: | | | | |
| 21 | 5.6784 | 7.0980 | 9.0930 | 6.3756 |
| 34 | 9.1936 | 11.4920 | 14.7220 | 10.3224 |
| 55 | 14.8720 | 18.5900 | 23.8150 | 16.6980 |
| 89 | 24.0656 | 30.0820 | 38.5370 | 27.0204 |
| 144 | 38.9376 | 48.6720 | 62.3520 | 43.7184 |
| 233 | 63.0032 | 78.7540 | 100.8890 | 70.7388 |
| 377 | 101.9408 | 127.4260 | 143.2410 | 114.4572 |
| 610 | 164.9440 | 206.1800 | 244.1300 | 185.1960 |

Fig. 2 Partial Scale of Values of the Four Modules

| METRIC | .2704 | .3380 | .4330 | .3036 |
|---|---|---|---|---|
| .676 | 2.5 | 2 | | |
| 1.08 | 4 | | 2.5 | |
| 1.352 | 5 | 4 | | 4.5 |
| 1.52 | | | 3.5 | 5 |
| 2.02 | 7.5 | 6 | | |
| 2.16 | 8 | | 5 | |
| 2.704 | 10 | 8 | | 9 |
| 3.04 | | 9 | 7 | 10 |
| 3.38 | | 10 | | 11 |
| 4.056 | 15 | 12 | | |
| 4.33 | 16 | 13 | 10 | |
| 5.408 | 20 | 16 | | 18 |
| 6.07 | | 18 | 14 | 20 |
| 6.76 | 25 | 20 | | |
| 8.112 | 30 | 24 | | |
| 9.10 | | 27 | 21 | 30 |
| 9.464 | 35 | 28 | | |
| 9.72 | 36 | | | 32 |
| 10.82 | 40 | 32 | 25 | 36 |
| 11.24 | | | 26 | 37 |
| 12.16 | 45 | 36 | 28 | 40 |
| 13.52 | 50 | 40 | | 45 |
| 14.872 | 55 | 44 | | |
| 15.21 | | 45 | 35 | 50 |
| 16.224 | 60 | 48 | | |
| 18.20 | | | 42 | 60 |
| 20.28 | 75 | 60 | | |
| 21.22 | | | 49 | 70 |
| 21.64 | 80 | | 50 | |
| 27.04 | 100 | 80 | | 90 |
| 30.36 | | 90 | 70 | 100 |
| 33.80 | 125 | 100 | | |
| 40.56 | 150 | 120 | | |
| 47.32 | 175 | 140 | | |
| 54.08 | 200 | 160 | 125 | 180 |
| 60.72 | | 180 | 140 | 200 |
| 67.60 | 250 | 200 | | |
| 75.80 | | (approximate) | 175 | 250 |

Fig. 3 Similar Metric Dimensions with Disparate Modular Values

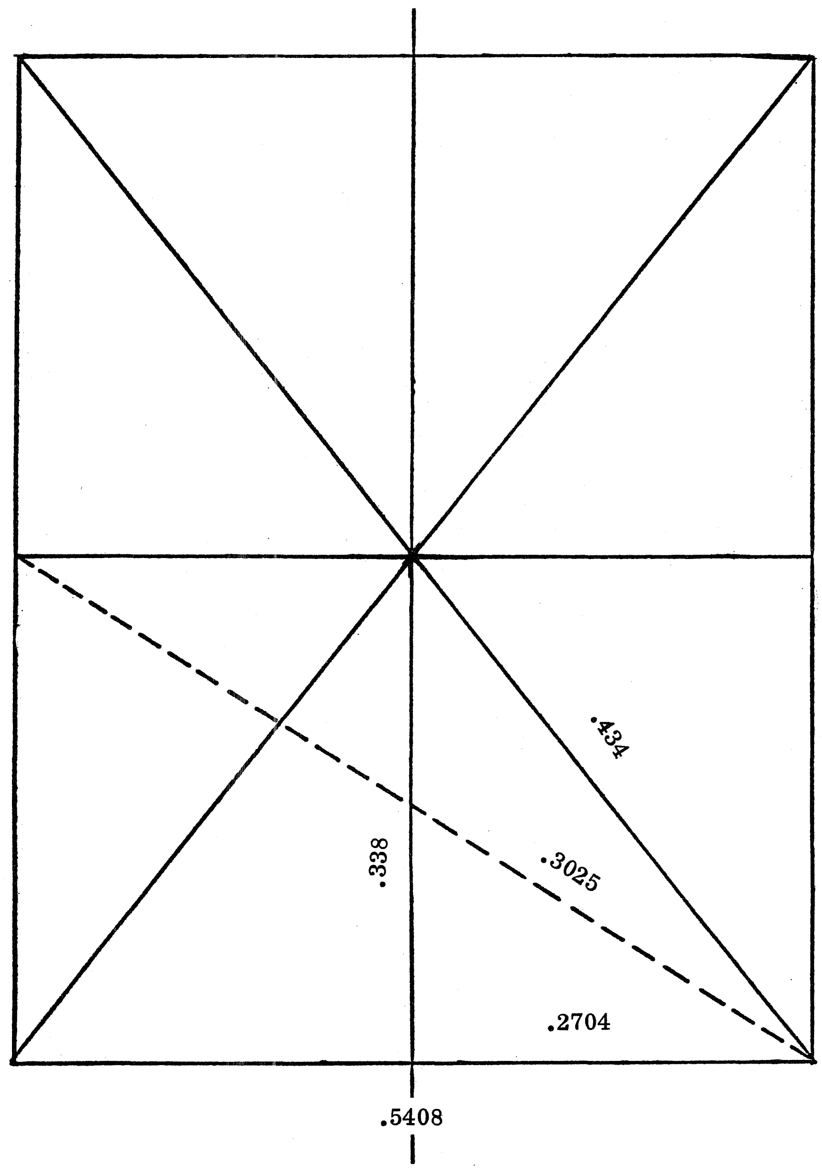


Fig. 4 Geometric Interrelationships of the Four Modules

the central axis is .3025 (.3036 = D). Using .3380 as base integer, a Fibonacci Series may be generated in which all four modules appear:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| .3380 | .6760 | 1.014 | 1.690 | 2.704 | 4.394 | 7.098 | 11.49 | 18.60 | 30.1 |
| 1 | 2 | 3 | 5 | 8 | 13 | 21 | 34 | 55 | 89 |
| (vs. .3380 (actual found values) | | | | 2.704 | 4.33 | | | | 30.36) |

The value of the first integer, .3380, was tentatively taken as the base unit of measurement on which the three variations depend.

This quadripartite system forms the basis of the harmonic system of Minoan architectural design, and brings into focus the complicated system of relative proportions of various subsections of a structure. An excellent example is the western-facade section of the palace at Mallia (Fig. 5).

The section with which we are concerned consists of three subsections further articulated into three wall-planes, two projections and one recess per subsection. The designer gave the wall-planes the proportions shown in Fig. 6, A = 8, B = 5 + 5 + 5, C = 8. The Fibonacci integers (base = 2 x .338 = .676) are also indicated:

| SECTION: | A | B | C |
|---|---|---|---|
| SUBSECTION: | 1. 2. 3 | 4, 5, 6 | 7, 8, 9 |
| (actual) | 3.31/3.13/3.31 | 6.03/6.06/6.09 | 3.72/2.82/3.65 |
| (ideal) | 3.38/ r /3.38 | 6.02/6.02/6.02 | 3.72/ r /3.72 |
| INTEGER NO.: | 4 / r /4(= • 10) | 10 / 10 / 10 | 9 / r / 9 , |

where r = remainder (i. e., A1, A3, C7, C9 were staked out from outer edges inward; r having a metrological value of null). Note also that both A and C approximate in toto the 11th Fibonacci Integer of this series (9.75 vs. 9.75 (A) and 10.19 (C)); the latter is in error by .44, or one unit of Module C (.433), the module generally used in the layout of the palace.

The system of proportions employed by the Minoan architect in the detailed articulation of the perimetral walls extends also to the underlying grid of a palace's groundplan. While space prohibits detailed examination of the procedures in a palace's layout, the following general points may be noted.[1]

The palaces of Knossos, Phaistos and Mallia share the following design-characteristics. Each plan may be generated by a series of steps involving a

[1]Factors such as solar orientation of buildings, as well as alignment of certain building axes on prominent landscape features, play a role in design also, as yet not fully understood. Cf. V. Scully, The Earth, the Temple and the Gods (Yale 1962 and 1968) ch. 2; and below, n. 11.

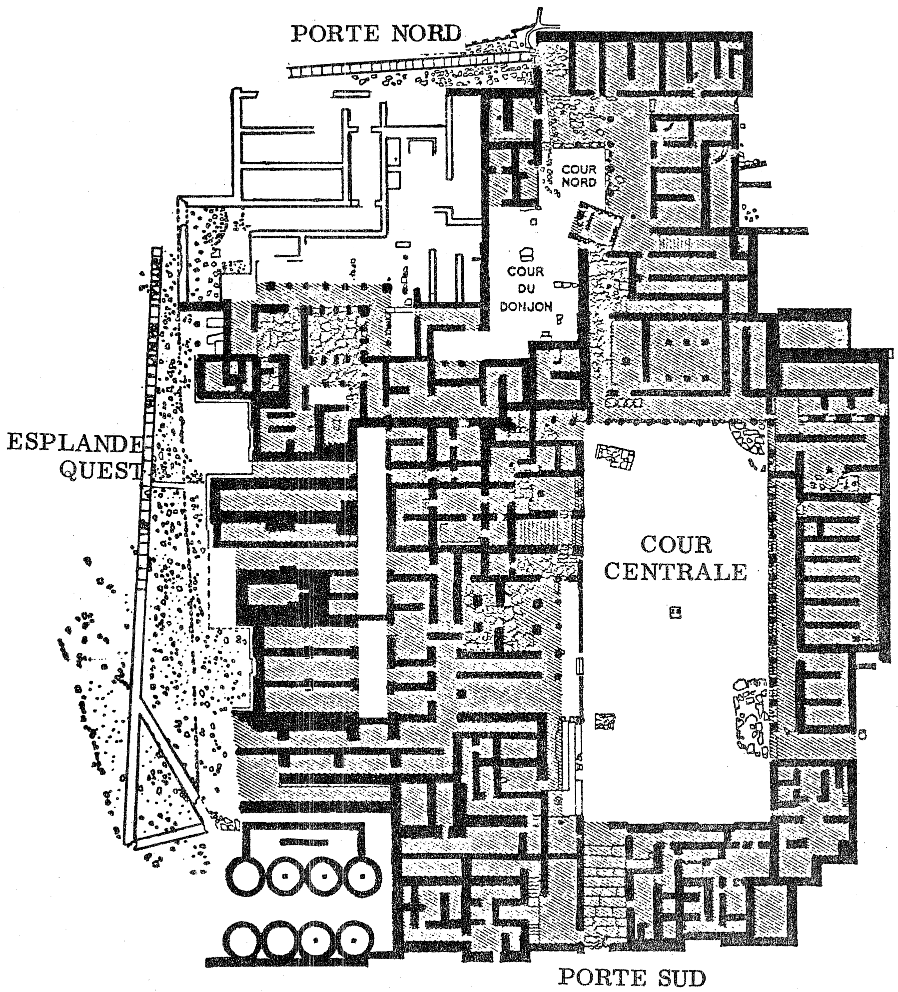


Fig. 5 Mallia Palace

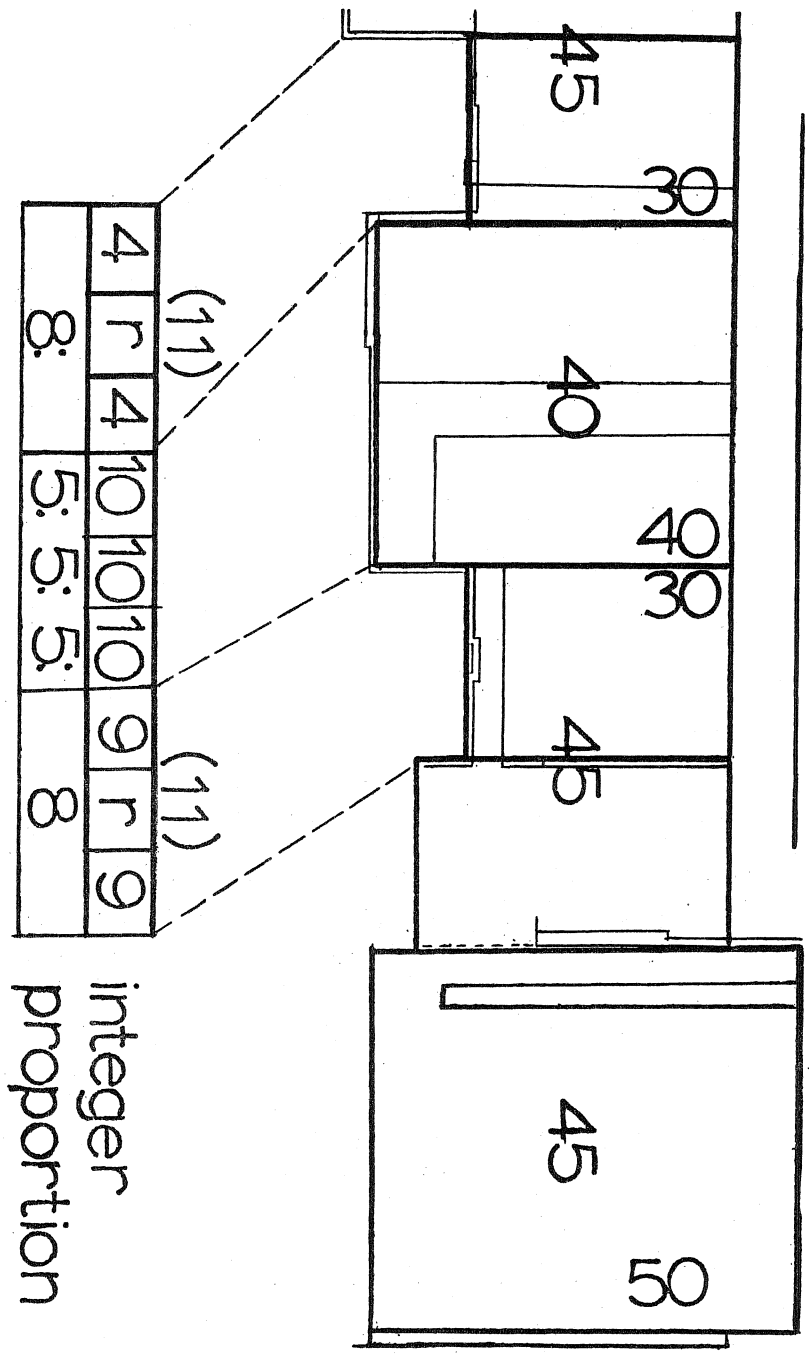


Fig. 6 Analysis of Mallia West Facade

grid based on a rectangle with the proportion 5:8 (160B x 200 B). The basic rectangle was presumably laid out with pegs and ropes of fixed length. The center point was found (by means of diagonals or rope, which would have to be 200 C in length[1]), and four quadrants were further indicated. The two eastern quadrants will delimit the central court, the two western the west-central block of the palace. At the center of the overall rectangle (or along an EW axis passing through that point) was constructed a room of (presumably) some ritual significance, the so-called Pillar Crypt.

The entire palace may be generated by subdivisions or additions of fixed modular size to the central grid-rectangle; the procedures vary in detail among the palaces. It is noteworthy that the subdivisions of a grid coincide generally with the functional subdivisions of a palace.

A Palace may be described as a grid of squares of varying size, the sizes determined by a sequence of interrelationships based on proportions such as 3:5, 5:8, 8:13, etc., as well as 1:2, and 1:1. Figure 7 gives an indication of the manner in which the designer generated his plan. Square 2 of this west facade of Knossos is related to 3 as 3:5: square 5 is to square 4 as 2:3. It is also notable that the number of long storage magazines in each grid-block is directly related to the modular size of each square; thus, squares of 30 units have three magazines, those of 50 have 5, etc.

The use of Fibonacci numbers also pervades the design of non-architectural items made by the Minoans. A simple example is shown in Fig. 8, the famous Sarcophagos of Haghia Triadha near Phiastos, whose painted sides are an important source of information on Minoan funerary ritual. The various parts of this limestone coffin reveal the relationship 1, 2, 3, 5.

A more complex example is the design of a large gaming board found in the Knossos palace. The nature of the game is not yet understood; pieces resembling chess pawns have been found, whose bases in size match the diameters of the circles of the inlaid board. The design may be analyzed as indicated in the diagram; the sequence of six integers with .067 as base is found in various subsections of the board; overall proportion is 8:13 (Fig. 9).

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[1]The Egyptians occasionally used as a module the <u>remen</u> or diagonal of a square laid out in normal cubits (W. M. F. Petrie, <u>Ancient Weights and Measures</u> (London 1926) 41 and <u>passim</u>.

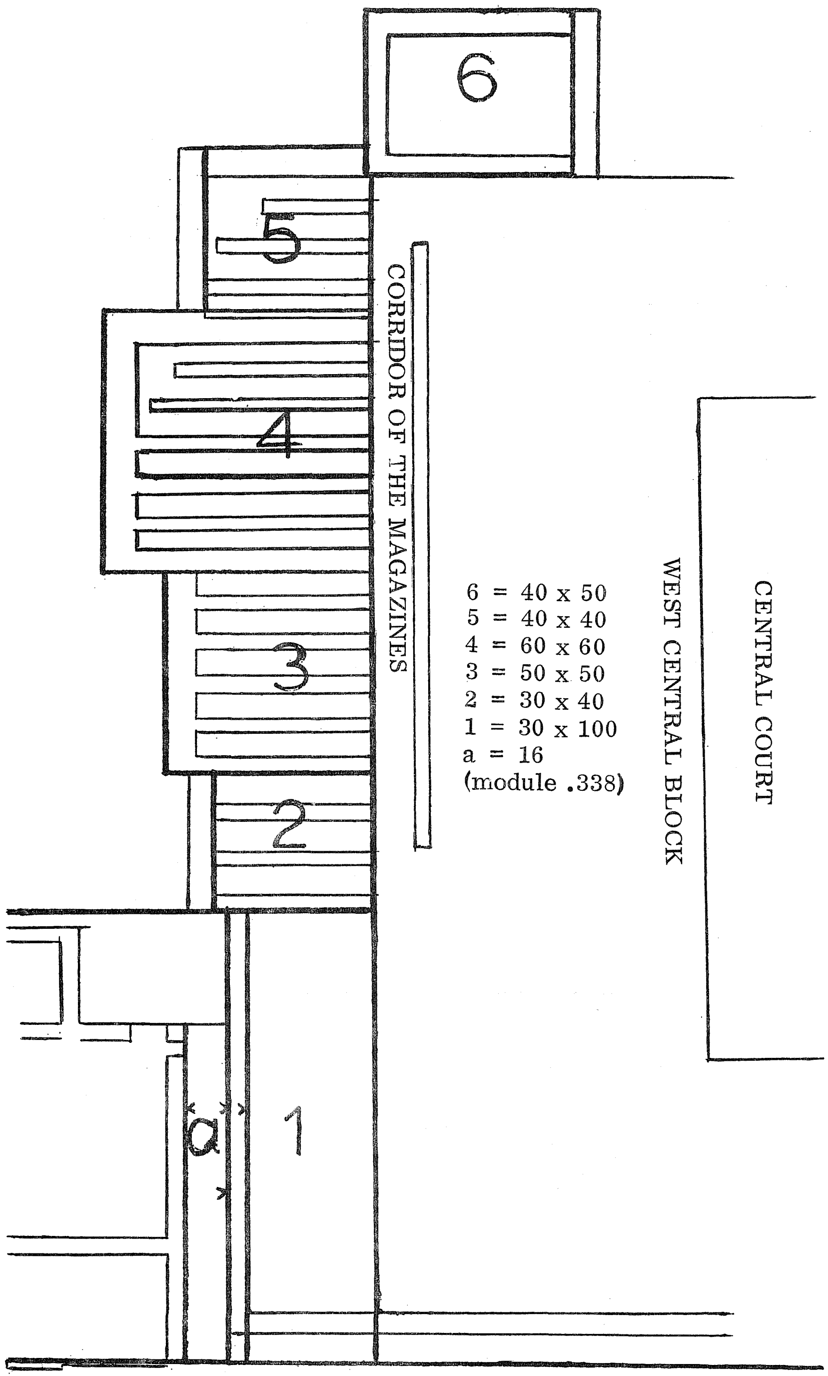


Fig. 7 Analysis of Knossos West Facade

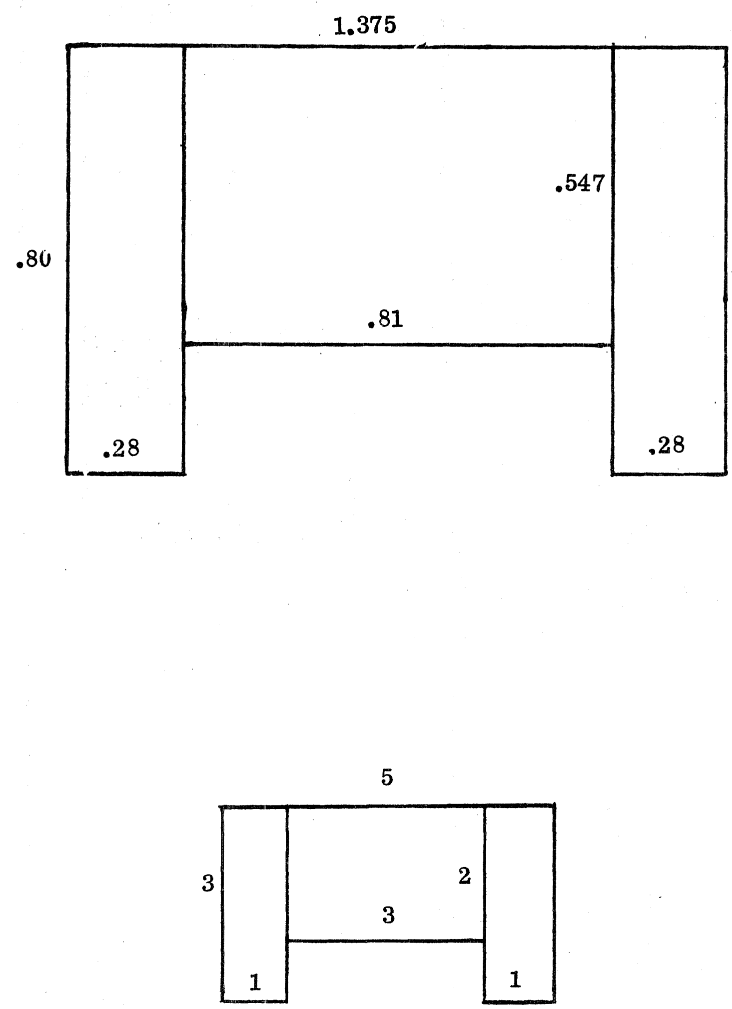


Fig. 8 Analysis of Flank of Haghia Triadha Sarcophagos

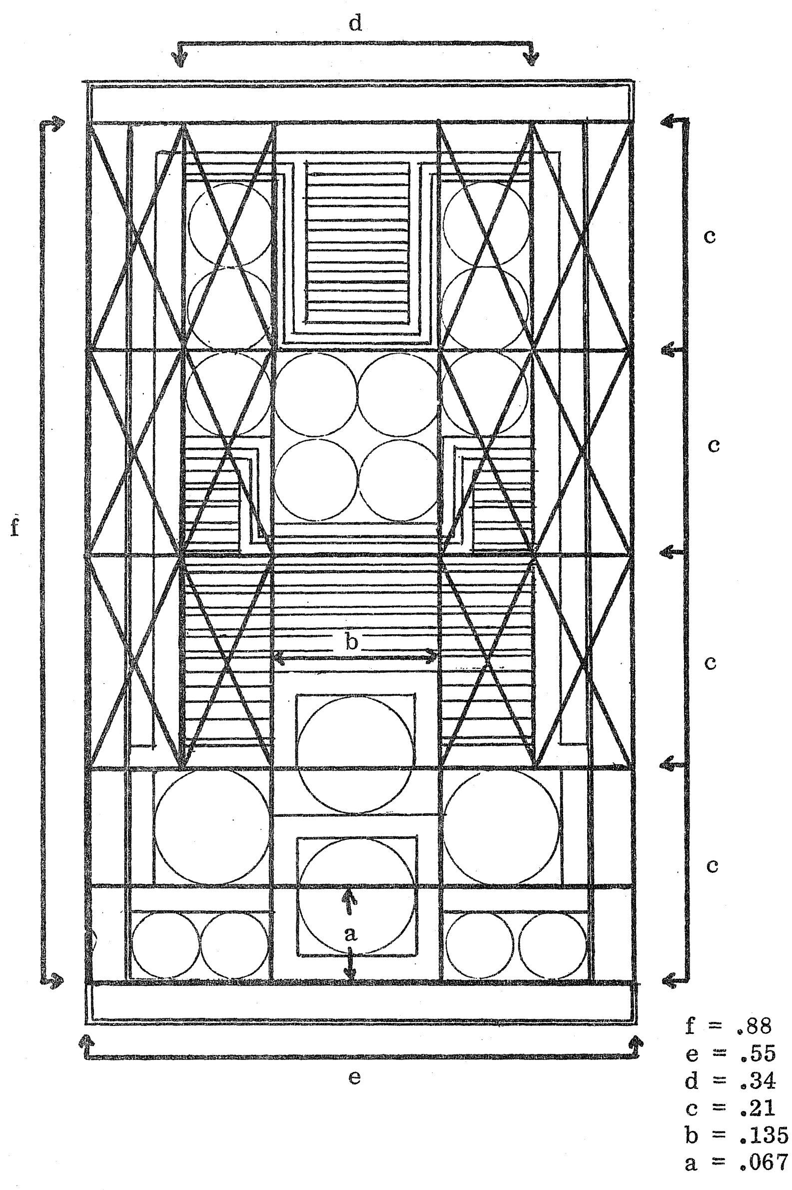


Fig. 9 Analysis of Knossos Gaming Board: Fibonacci Proportions

This brief consideration of various aspects of Minoan design and its relation to the Fibonacci system[1] would best be concluded with the following observation. We are not now in a position to understand the full significance of the harmonic system of Minoan design. The principles of the Fibonacci system were certainly understood, as evidenced by the monuments themselves. Whether these principles were a trade secret of a small class of artisans or more widely understood is not known.[2] Of several scripts used by the Minoans during their history, only one, the last one to be employed, has been deciphered; it is a primitive form of Greek, and it was employed for bureaucratic purposes (listing of commodities, produce, etc.) only; no literature survives, and we certainly have no mathematical treatises.[3]

It is now known that contemporary Egyptian architecture reveals design principles based in part on the Fibonacci system;[4] it has been known for some time that early in the palatial period Minoan craftsmen were employed in the construction of at least one major Egyptian monument.[5] It would seem reasonable to assume that such a situation would provide an opportunity for the diffusion to Crete of the principles of this system. If this was the case,[6] it should be borne in mind that it was only the principles which were diffused, for the Minoan system is grounded in a Minoan metrological system, and the Egyptian is based on a native cubit-measure system.

Whatever the case, the essential point remains: in laying the foundations of architecture in Europe, the Minoan architect designed his structures

[1]Discussed in detail as it applies to some 50 structures in the author's dissertation, "Minoan Palace Planning and its Origins" (Harvard 1968) Chapter III (unpublished).

[2]One of the primary ritual symbols of Minoan Crete, the "double-axe" sign, incised on walls within the palaces, may be an ideogram of the 5:8 triangle of Fig. 4; for a similar situation, cf. A. Badawy, Ancient Egyptian Architectural Design (UCLA 1965) 40-46.

[3]Cf. J. Chadwick, The Decipherment of Linear B (New York 1958); M. Ventris and J. Chadwick, Documents in Mycenaean Greek (Cambridge 1959) 117.

[4]A. Badawy, op. cit., part IV.

[5]W. M. F. Petrie, Illahun, Kahun and Gurob (London 1891) ch. 3.

[6]Ibid., 14. A measuring rod of .676± was found at Kahun ($\frac{1}{2}$ = .338) which (not being an Egyptian measure) might be connected with the Minoan workmen employed in the construction of the pyramid of Sesostris II. On the other hand, Levantine workmen were also employed there; there is no firm basis for deciding to whom the rod should be attributed.

[Continued on p. 317.]