A STUDY ON THE USE OF GEOMETRIC PROPORTIONS USED TO DESIGN SINGLE UNIT MOSQUE PLANS IN THE OTTOMAN TURKISH EMPIRE

by

AZIZ V. BOOTWALA

B. Arch, L. S. Raheja School of Architecture.
Bombay, India, 1985.

A MASTER'S THESIS

submitted in partial fulfilment of the
requirements for the degree

MASTER OF ARCHITECTURE

College of Architecture and Design

KANSAS STATE UNIVERSITY

Manhattan, Kansas.

1988

Approved by :

Major Professor

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This research is seen as a result of many causes put together. It is difficult to account for all, but I do need to thank a few people who were closely linked with the study. I take this opportunity to thank my major advisor Dr. Eleftherios Pavlides and the other members on the advisory committee Prof. Bernd Foerster and Prof. Donald Watts. There were many times during the period of study that I reached a level of no progress and it was the encouragement and expertise of Dr. Pavlides that gave me a new start every time I needed one.

My gratitude goes to my parents and my family whose help and encouragement made it possible to complete this study far away from home. I hereby dedicate this study to my family for their continuous help and support.

Finally, I appreciate the help offered by by all other institutions linked with this study including the Wiegel and Farell libraries at Kansas State University which have been a source of great help.

PREFACE

In an attempt to develop design concepts based on the use of geometric proportions, this study is a fundamental step forward. The intent has been to examine these concepts using historical background and to translate the principles into a more comprehensive form. Chapter I describes the intent of research, its limitations and the methodology adapted.

In Chapter II the development of ancient geometry is traced and methods are developed for the purpose of analysis. A brief description of the use of geometric proportions in the Egyptian and Greek periods further emphasises the importance the use of proportions in design.

Chapter III discusses the use of geometric proportions in other forms of Islamic art like patterns and calligraphy.

Chapter IV provides a brief history of the Ottoman Turkish Empire, the period adopted for study and further discusses the development of Mosque designs.

A step by step analysis of the use of geometric proportions in the design of single unit mosque plans is provided as part of Chapter V with the findings and recommendations in Chapter VI.

LIST OF FIGURES

CHAPTER I

INTRODUCTION

i. Intent of Research

The contemporary Muslim world is presently facing a challenge in determining its future physical environment. Many Muslim countries are undergoing or will undergo in the near future a large scale transformation of the urban physical fabric. Changes are taking place not only in the economic or political field but in the physical built environment as well (AKA seminar papers, 1978: pg xii). The influence of foreign technology on the built environment has created an impact which is far from Islamic concepts.
Architectural rhythm which generate a sense of unity are forgotten. Form has lost its symbolic value and material substance simply refers to the Newtonian physics, far removed from the traditional concepts of form and matter in Islamic cosmology (pg. 2). The question that needs to be answered is how can future architectural development be stopped from further disintegrating the Islamic cultural identity.

The specific elements and sensibility which make Islamic architecture both beautiful and functional need to be researched and defined so that the underlying principles can be derived and applied to the design approach, thereby creating an architecture in the spirit of Islam. There is growing concern as to how Islamic architecture should be developed for the muslims of today. It defintely cannot be done by copying or mimicking the past, rather it should be done by analysis of basic principles used in the past, and by developing concepts based upon these principles. The basic principles that were traditionally used included the use of light and color, form and matter (pg.2). Just as Islam is based on unity (Tawhid) and is the means towards integration of human life and in fact all multiplicity into unity, so also the architecture in the spirit of Islam integrates all principles and reflects unity. The use of geometric proportions in designing buildings is closely linked with Islamic architecture, as much as it is with Egyptian, Greek or Roman (El- Said, 1976: pg.115 ff.). For further reference read Geometric Concepts in Islamic Art by Issam El-Said and Ayse Parman.

With the spread of Islam and subsequent development of an architecture in the spirit of Islam, the "mimar" or "muhandis" (geometer, builder) (pg.1) further improved the utilisation of the principles of proportions and adapted this method to best serve their beliefs and practices. The system of proportions creates a sense of unity and everything is related to or emanates from that unity. This defines the fundamental principle of "tawhid" (unity), on which is based the entire religion of Islam (For further reference read Ideals and Realities of Islam by Sayed Hussein Nasr). By experiencing this outer sensible form and understanding it man is in a position to progress from the whole to the essence or from the "zahir" (apparent) to the "batin" (inner reality) of a form. "The triangle, the square and the circle are not merely shapes, essentially they incorporate a reality the understanding of which through "tawil" (intellect) leads man to the world of similitudes and ultimately to the truth. (Ardalan, 1973: pg xiii).

It will be an interesting study to analyse the principles of form generation in the design of mosque plans as there are likely to be common factors which would help develop design concepts. Research on the use of geometric proportions in Islamic architecture would help define its applications to design future mosques. An analysis of the method used in designing mosque plans based on the principles of proportion will help derive common factors which would generate general concepts for design solutions.

Mosque buildings in the Islamic world have great significance and importance attached to them. As written in the Holy Koran "And when We made the House (at Mecca) a resort for mankind and a sanctuary, (saying): Take as your place of worship the place where Abraham stood (to pray). And We imposed a duty upon Abraham and Ishmael (saying): Purify My house for those who go around and meditate therein and those who bow down and prostrate themselves (in worship)" (Koran II : 125). The mosque is the house of God, a place for worship which provides man the freshness, peace and harmony of nature in the imperfect environment he has built for himself. The mosque is refered to as the handicraft of God and reminds man of the creator (Ardalan, 1973: pg.xii). Being the house of God, throughout the history of Islamic architecture all Islamic dynasties contributed greatly to the development of Mosques.

The purpose of this research is to analyse the plan forms of mosque designs and to determine the methodology used to design mosques based on the principles of geometric proportions. The research will specifically test the hypothesis mentioned below, based on the patterns analysed in Chapter V.

HYPOTHESIS

Patterns based on geometric proportions were utilised as a tool of measurement and form generation in Islamic architecture to generate the design of mosque plans.

ii. Research Focus.

The mosque or "masjid" in reality is not only a place of worship or prostration but also the political and social center of muslim life. Hence, in addition to its main function as a place for prayer, within its limits the mosque has provided space for social functions such as education, community gatherings, shelter for travellers, etc. However in later periods of Islamic history individual buildings were developed for the various functions once associated with the mosque. This gave rise to the foundation of large religious complexes developed by Mamluks, Timurids, Ottomans and Mughals (Ref. to Appendix A for chronology of Islamic periods).

Since the mosque has such a dominating impact on the life of a muslim, the physical form of the building and its immediate environment is a source of great influence to every Muslim. Despite the lack of surviving monuments from the first two generations of Islamic history, there is evidence that certain mosques which evolved then gave Islamic architecture some of its most characteristic and enduring forms (Hoag, 1977: pg 13). Throughout the history of Islamic periods it is seen that every period made significant contributions to the development of mosque architecture (Ref. Kuban, 1974, 1985). It is beyond the scope of this research to study development of mosque design in all periods of Islamic history and so the study is restricted to Mosque buildings in the Ottoman Turkish Empire. The Ottoman Empire was the last ruling Islamic power and had contributed extensively to the development of architecture. Among the various types of mosques developed this study will focus mainly on the single unit mosques (ref. Chapter IV). Being the smallest unit the single unit mosque is being used for the purposes of analysis and any conclusions drawn from the analysis may then be recommended to be tested for multi unit mosques and larger complexes.

iii. Research Methodology.

The methodology to be employed for conducting this study will consist of literature review, development of analysis patterns and analysis of plan forms mosques proposed for analysis (ref. Appendix B) with the help of annotated diagrams to test for the use of geometric proportions.

The literature that will be critically evaluated in relation to the methodology to be developed mainly consists of books and articles dealing with ancient geometry, geometric proportions, and the development of architecture in the Ottoman empire. A brief description of the use of geometry in other architectural styles will be provided as part of the theory and analysis methodology. For the analysis of plan designs of mosque buildings each plan will be dealt with individually and primarily analysed on the principles described in Chapter II. The method of validating the plans is described in Chapter V which is followed by the analysis of individual plans.

CHAPTER II

DEVELOPMENT OF THE USE OF GEOMETRIC PROPORTIONS

i. Development of ancient geometry

Geometry can be seen to exist in every form of living being and non-living existence. The analysis of something as small as a molecule to that of a human form will reveal geometric models and proportions. The field of geometry is considered to be one of the earliest manifestations of previous civilizations which developed from period to period based on the experiences of mankind. Knowledge of geometry has been used as a culture creating tool since ancient times and is responsible for having radically influenced the cultural development of major ancient civilizations for many thousand years (Brunes, 1967: pg9).

For man in the early ages, magic, science and religion were all inseparable and so were a part of the corpus of skills possessed by the priesthood. Since geometry was linked with the ability to measure, (literally meaning "the measuring of the earth"), it was always considered to be a branch of magic (Pennick, 1980: pg7). The entire system of geometry which Brunes terms as "ancient geometry" was secret knowledge kept only by those residing in a temple. Knowledge of geometry spread over a tremendous area and can be traced from Europe to Egypt to Near and Far Eastern countries. As the knowledge was only the prerogative of the temple brethren or the "initiated one", the accepted procedure was that a brother from one temple would travel to various temples in other countries and return to his home temple with the treasures of knowledge he had attained (Brunes, 1967: vol.I, pg10). Egyptian temples were considered the best and enjoyed the reputation of storing the richest knowledge. This knowledge was never put into print, but was always communicated by mouth until such time that it was felt necessary to give it a written form else it may be forgotten. The result was a number of geometric shapes which contained a distinct significance to the knowledgable and for the ignorant it seemed to be some mystic sign. Thus like every other society of craftsmen or industry which has its own trade secrets, knowledge of geometry survived through time under the cloak of secrecy (pg 12).

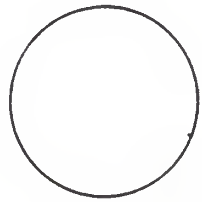
Geometry has been used in art and has also been a source of great influence on architecture since early Egyptian times. The principles of geometry which gave rise to the concept of proportions have a direct bearing on architecture from early times. Long before numbers came into existence, the Mesopotamian and Egyptian civilizations were known to have used proportions in generating their architecture. From the Egyptian civilization it is seen that proportions were derived by dividing the circumference of a circle into desired parts as that was the easiest method that could be adapted on site with the use of only a peg and rope. The Greek genius transformed this geometry into a reasoning device. Thales in early 6th century B. C. developed a more precise and academic form which over a period of time became more and more sophisticated (El-Said, 1976: pg3). Most architectural shapes that have been used through the ages are inseparable from geometric proportions and are closely related to either the empirical rules of thumb or the later geometry developed by the Greeks. Besides being technical devices trying to fulfill an architectural function, the geometric shapes that have been used throughout traditional architecture also bear an inherent denotative aspect which is the hidden meaning of classical architecture seen in the Egyptian, Greek, Roman, Islamic and other periods (Ardalan, 1973: xii).

The use of geometric proportions is seen extensively in the design of religious buildings. The harmony contained within these principles of proportions was recognized to be the most cogent expression of a divine plan which underlies the world, a metaphysical pattern which determines the physical. Pennick refers to this as sacred geometry and links it with various mystical tenets based on "that which is in the lesser world (microcosm) reflects that of the greater world or universe (the macrocosm)." There are a few geometric forms and proportions which can be termed fundamental from which all the diverse structures in the universe are composed. Each form bears its own unique property and carries an esoteric symbolism which has remained the same since dawn (Pennick, 1980: pg8-9). Similarly, every proportional quantity has its own philosophy but it is beyond the scope of this research to discuss it in the present context.

Various authors have discussed this aspect of geometry and have given it different names. Brunes refers to it as ancient geometry while Pennick refers to it as sacred geometry and Hambidge refers to it as

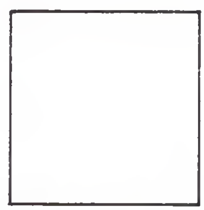
Dynamic Symmetry. They all have an inherent relation and strongly support the intent of this research. While Brunes discussed the square and the circle, Pennick discusses its symbolism from religion's point of view and Hambidge discusses the rectangle and its components.

A Study of the Basic Forms:



The Circle:

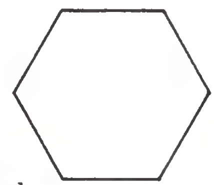
Research indicates that the circle was the earliest form known to mankind (Pennick, 1980: pg17). It is a form which is visible in everyday life as seen in nature. The application of the circle as a symbol of time and passage of seasons made it an extremely important form for man in the early ages. The circle represents completeness and attaches divinity to its form. Often it is referred to as the mother figure from which all other geometrical figures are generated (pg 17).



The Square:

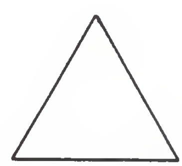
Compared to the circle which represents the macrocosm, the square is a representation of the microcosm and hence represents the world. It is unique in the sense that a cross within the square would represent the cardinal points and the diagonals would divide it into eight triangles commonly known as the eightfold divison of space. A square can be considered to be an externalised form of a circle, a more comprehensible form to work with. The "squaring of the circle" means a lot to geometric proportions as will be seen later in the chapter. Combinations of the circle and the square reveal proportions that were used in ancient days and would be an excellent approach for anyone considering the use of proportions even today (Pennick, 1980: pg 18-19).

The Hexagon:



Representing the six powers of motion, namely up, down, front, back, left and right, the hexagon is a natural geometrical figure produced by the division of the circumference of a circle by its radius. It is noted that under conditions of equilibrium, the patterns of cells which make up organic life are perfect hexagons (Pennick, 1980 : pg 20). A honeycomb is the best known natural hexagon, and is attributed to a certain geometrical forethought that the bees possess with economy as the guiding principle (Pennick, 1980: pg20). The hexagram which is achieved by joining the alternate vertices of the hexagon produces interpenetrating equilateral triangles which symbolise the fusion of opposing principles namely hot and cold, fire and water, earth and air, etc...(pg 20-21).

The Triangle:

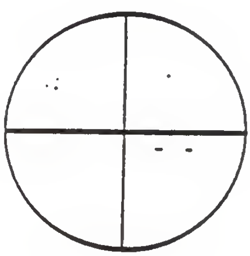


In addition to the square and the hexagon the triangle is the only figure which can fill up space around a point without leaving empty space. The tip of the triangle is considered by Ardalan to be the active zone, hence, with its point downward, it symbolizes a form active towards the earth and passive towards heaven and with its point upward it symbolizes active towards heaven and passive towards earth (Ardalan, 1973: pg26). It is a fundamentsl to many geometrical figures and in fact is a primary source for generating three of the five platonic solids (pg 23).

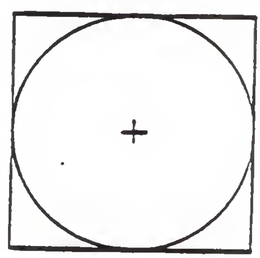
Having analysed the basic forms thus far it is appropriate to discuss the fundamental geometric symbols developed by Brunes and Hambidge which will form the major source of analysis of various plan forms in Chapter V.

ii. Method of generating proportional system through subdivision of the square and the circle (adapted from Secrets of Ancient Geometry Vol.I by Tons Brunes).

A.



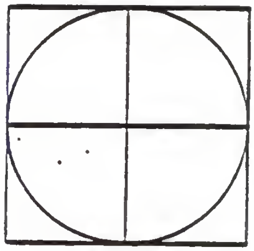
B.



A. This diagram was the first and the the point at which all mathematical speculation began, namely the circle and the cross.

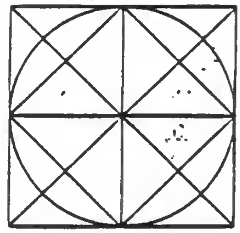
B. In this man produced his first geometric construction by drawing two vertical and two horizontal lines outside the circle.

C.



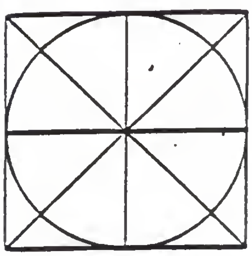
C. The same diagram with the addition of the vertical cross dividing the square into four smaller squares.

E.



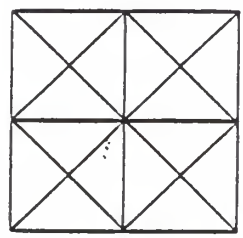
E. The half size square is entered from tip to tip of the vertical cross, and the quadratic area is divided in this way into 16 small triangles.

D.



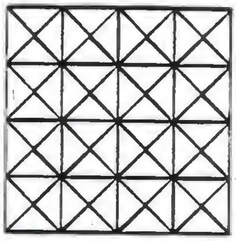
D. Entering the diagonal cross splits the square into four large triangles and when the vertical cross is reintroduced the square is divided into eight triangles.

F.



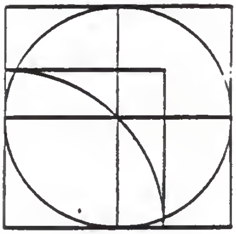
F. Previous experience is applied to dividing the square into triangles in the order 2, 4, 8, 16, and 32.

G.



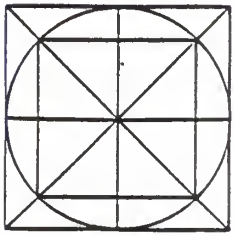
G. This shows the division into 64.

I.



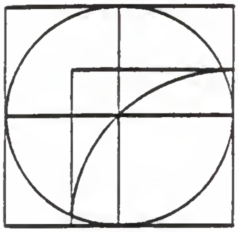
I. The half sized square is constructed in the lower left corner of the square. This construction indicates the upper horizontal and the right hand vertical sacred cuts.

H.



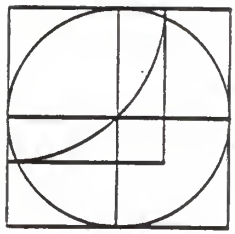
H. Shows how the half size square can be constructed on the points at which the diagonal cross intersects the circumference of the circle, and the first step towards calculating the length of the circumference is taken.

J.



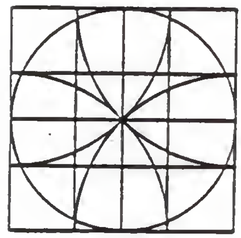
J. The same construction executed in the lower right of the main square, showing the left hand vertical and the upper horizontal cuts.

K.



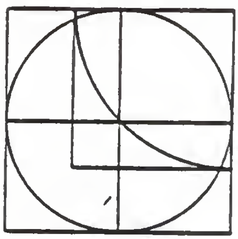
K. Shows the lower horizontal sacred cut and the same vertical as I.

M.



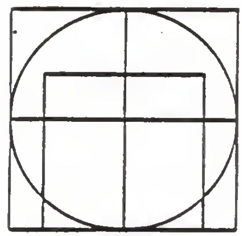
M. This is the combination of the four previously indicated sacred cuts, two vertical and two horizontal.

L.



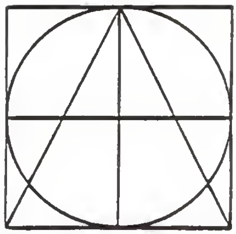
L. Also shows the same horizontal cut and the same vertical as J.

N.



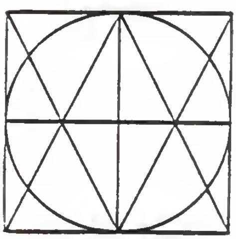
N. Shows an arrangement with the half size square in which it occupies the center of the baseline on the original sqaure.

O.



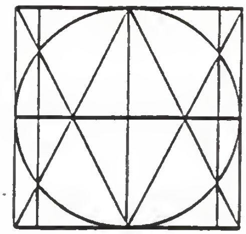
O. This shows the important acute angled triangle which is to prove the first step towards calculating the area of the circle.

P.



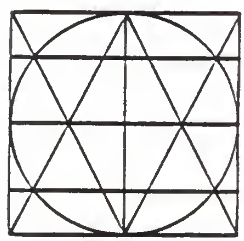
P. Its opposite partner is entered, their intersections with the circumference marking off the circle's rectangle.

Q.



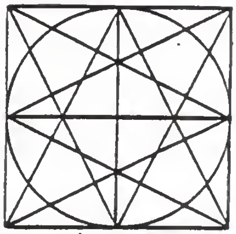
Q. This is the same diagram as in P, only with the circle's rectangle entered.

R.



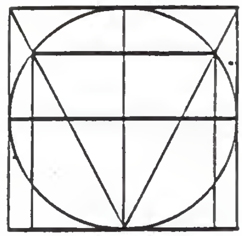
R. The same as Q, but showing the two horizontal lines which indicate the circle's rectangle horizontally at the foor and at the top of the original square.

S.



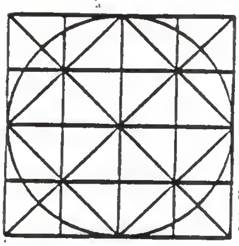
S. Diagram with the four acute angled triangles, showing the eight pointed star.

U.



U. This diagram is in effect part of R, the square on the circles rectangle appearing more as an independent unit.

T.



T. The diagram which provided us with a number of accurate divisions of the circles circumference.

iii. Method of generating proportional system using root rectangles (Adapted from the Elements of Dynamic Symmetry by Jay Hambidge).

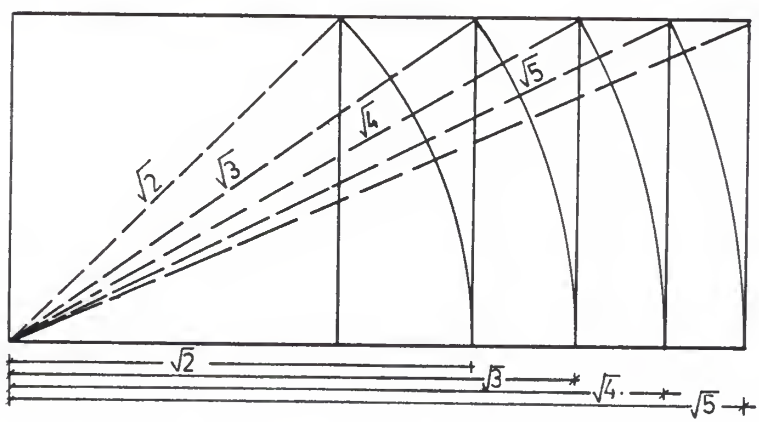
Root Rectangles

Incommensurable literally means unmeasurable and it is this unmeasurable quality of the length of a line that gave rise to root rectangles. The root rectangle is derived from a square and its diagonal. It is based on the theory "the square on the hypotenuse of a right- angle triangle is equal in area to the sum of the squares on the other two sides". The following illustrations will clearly define the concept of root rectangles. (For further reference, read Practical Applications of Dynamic Symmetry by Jay Hambidge).

A simple method of constructing all root rectangles is described in the following two figures.

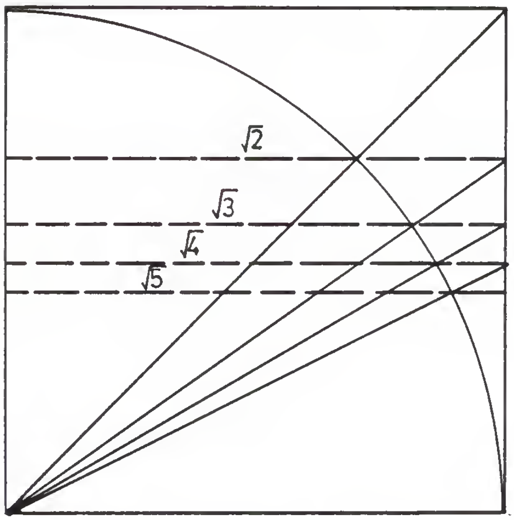
Root rectangles constructed by extending the unity square.

Fig. 2.2.a



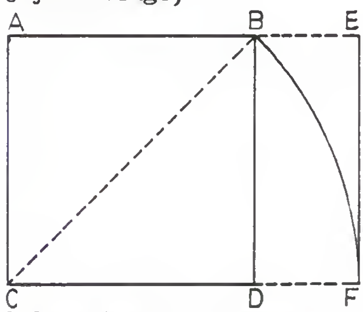
Root rectangles constructed within a square.

Fig. 2.2.b

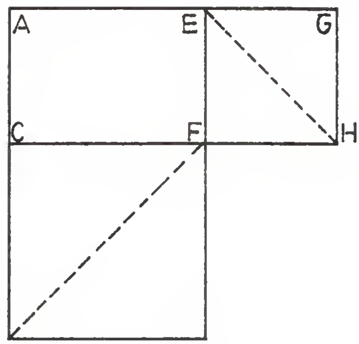


Following is a concise explanation of the fundamental steps that may be used while using the root rectangles.

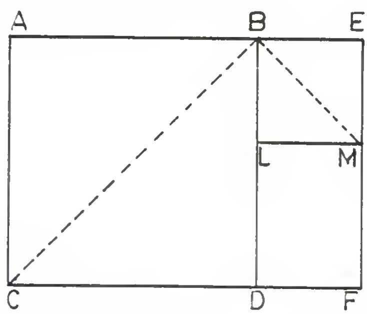
The Root Two Rectangle (Adapted from Elements of Dynamic Symmetry by Jay Hambidge)



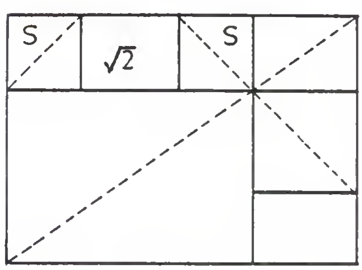
2.3.a. ABCD is a square of side= unity. Insert diagonal BC = $\sqrt{2}$. With C as center and BC as radius draw arc BF such that CF = BC = $\sqrt{2}$. ABEF is a root two rectangle.



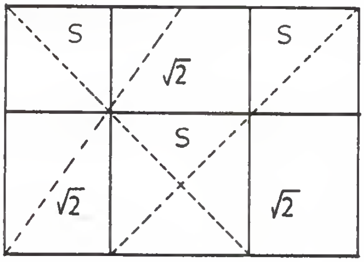
2.3.b. The area of the square EFGH described on the end EF of the rectangle = 1/2 the area of the square described on the side CF of the root two rectangle.



2.3.c. If a square ABCD is applied to one end of the root two rectangle the excess area consists of a smaller square BELM and a root two rectangle LMDF.

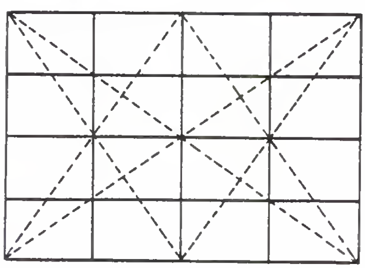


2.3.d. The diagonal of a root two rectangle intersects the applied square and divides the area into two smaller squares (s) and a root two rectangle (/2).

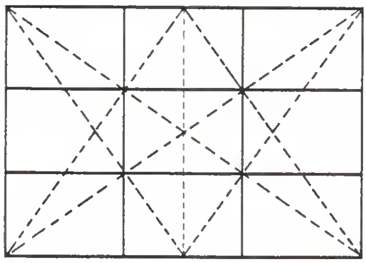


2.3.e. The diagonals of the squares applied on either side of the root two rectangle divide the entire space into three squares and three root two rectangles.

In a root two rectangle the diagonals of the whole and the diagonals of the reciprocals divide the area into a never ending series of root two rectangles (the reciprocal of a rectangle is a figure similar in sahpe to the major rectangle but proportionately smaller in size. Rectangle BEDF is a reciprocal of rectangle AECF).



2.3.f. sub - division of a root two rectangle into smaller figures with a ratio of 2.



2.3.g. subdivision of a root two rectangle into smaller figures with a ratio of three.

iv. Use of Geometric Proportions in Egyptian Architecture

Numerous attempts have been made to reveal the design secrets which formed the basis of the splendid buildings of ancient periods and that of the middle ages. Amidst all the diversity and variation in design, there always seemed to be a mutual relationship that existed due to a consistent harmony which reflected from building to building (Brunes, 1967: pg 121). This common denominator which created this harmony was nothing but basic geometric principles and proportions.

Due to the annual overflowing of the river Nile which destroyed all its boundaries, the Egyptians had developed an empirical scheme using simple knowledge of the so called "pythagorean" triangle with the help of which they could re- establish boundaries after each inundation (Pennick, 1980: pg 43). This method was then adapted for tomb and temple construction and was termed the "chording of the temple". Later it was developed to lay out rectangles and other more complex forms.

Early Egyptian architecture is known to be linear and orthogonal (right angled). The temples in particular were long, narrow, horizontal and directional through pylon, court and hall to sanctuary (Davies, 1982: pg 10). It is possible to examine the design of temples and see how the original nucleus has been expanded using the principle of addition through juxtaposition. The principle of symmetry about the longitudinal axis was preferred to bilateral symmetry to achieve balance. Accentuation was done by ensuring that everything grew in size according to rules of proportions common to all parts. Normally a grid was used with preference given to rectangles built up from squares in the ratio 2 : 1 or triangle with ratio 8 : 5 which is a close approximation of the Golden Section (Davies, 1982: pg 11), (For further reference on the use of geometric proportions in Egyptian architecture, refer to Secrets of Ancient Geometry, Vol. I & II by Ton Brunes).

v. Use of Geometric Proportions in Greek Architecture.

Fundamental principles of geometry and geometric proportions were taught to the Greeks by Pythagoras and later by Plato (ref. to Timaeus). A formal development was done by Euclid which was termed Euclidian Geometry. Practical geometry was directly related to whole number ratios which eliminated any necessity to measure angles or fractions.

The means adapted by Greek architects was to formulate rules of proportions such that every element could be derived from a dimension already decided. It was possible to predict the appearance of a building before it was built based on the rules of proportions of another already existing Temple. Using this as a guildline it was possible to alter the building by changing a specific rule (Coulton, 1977: pg 64ff). The difference between the Egyptians and Greeks was that the Egyptians built from what they knew and the Greeks built as they wanted to build.

Having adapted the post and beam system, the Greeks devoted much time to the refinement of the column and lintel so as to achieve the greatest aesthetic effect in terms of beauty of line and of form. Motivated by a desire to discover an order that could explain existence, thereby relieving the burden of life, they developed classical "orders" which were called Doric order and Ionic order, and later the Corinthian order (Davies, 1982: pg47). The Greeks also examined constituent elements thereby trying to achieve unity through multiplicity, ie.using the principle of composition through adding either by superimposition or by juxtaposition.

Almost every temple was formed on the basis of traditional geometric pattern and despite differences in the designs, each showed the use of a common principle of composition and shared similar ingredients like proportions, rhythm, symmetry, etc. The famous Greek Parthenon, built on the Athenian Acropolis provides a good study of the use of geometric proportions. (For further reference on the use of geometric proportions in Greek architecture refer to Secrets of Ancient Geometry, Vol.I & II by Ton Brunes).

CHAPTER III

USE OF GEOMETRIC PROPORTIONS IN ISLAMIC ART

i. Use of geometric proportions to develop basic patterns.

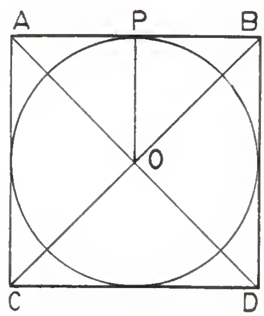
Geometric patterns are an integral part of Islamic art. The fundamental system adopted in creating these patterns is the systematic arrangement of the repeat unit which produces the overall design of the pattern. Depending on the size, shape and relative position of the surface area under consideration the patterns possesed either bilateral, lateral or radial symmetry.

The religious consciousness in Islamic art has been the most important factor. Due to this, geometric patterns reached the highest degree of development in the decoration of religious architecture. The widespread usage of these patterns clearly indicates the development of geometric proportions used for decoration and other art forms. The interlaced patterns signify the indivisibility of the "unity" that is "God", which is the fundamental principle of Islam. The complexity of patterns developed is a reflection of the One God whose presence is an all pervasive force throughout the creation (Wade, 1976: pg.7 ff).

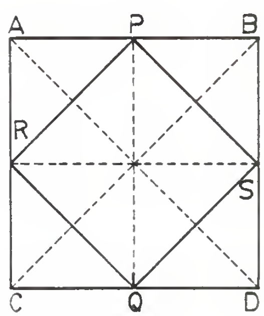
The patterns developed were a major source of design for tile decoration, wood engraving and carving, carpet designs, calligraphy and various other forms of art in addition to architecture. A few patterns that have been used commonly
are discussed in the next few pages.

The Square and the Root Two method of designing patterns.

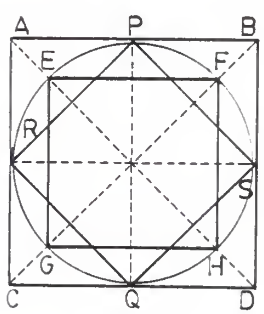
(Refer to Geometric Concepts in Islamic Art by Issam El-Said and Ayse Parman)



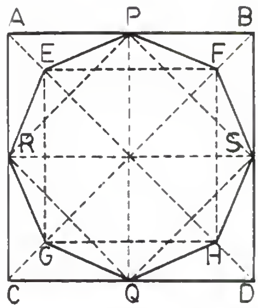
3.1.1. With O as center and radius = OP draw a circle and the circumscribed square ABCD.



3.1.2. Insert the horizontal and vertical axis PQ and RS and complete the square PQRS. Let the sides of the square PQRS = unity, therefore using Pythagoras theorem PQ = AC = $\sqrt{2}$ PR or $\sqrt{2}$ QR. Hence the inner and outer square are in the proportion 1: $\sqrt{2}$.



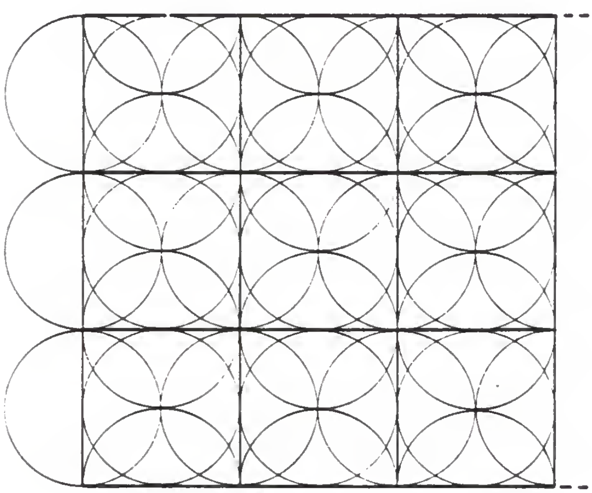
3.1.3. By joining the points of intersection of the cicle and the diagonals of the circumbscribed square ABCD, complete the square EFGH. By geometry PQRS = EFGH.



3.1.4. The squares PQRS and EFGH thus create the octagon and the octagon star. This is the unit pattern based on the square and root two which is then used to create various patterns.

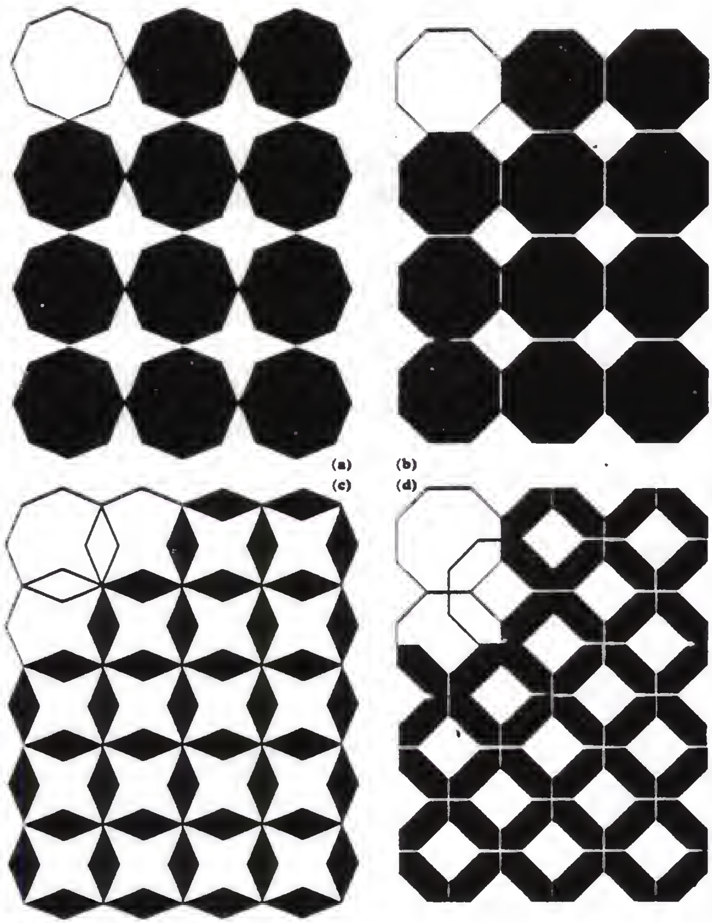
A few patterns using the basic unit pattern based on the square and root two are shown on the following pages. For purposes of designing surface areas, the entire surface under consideration is divided into equal parts using the circle. Once this has been done the surface can now be filled with the unit pattern in desired combinations. (Ref. fig. 3.1.5).

Fig. 3.1.5



The Octagon and its variations
(Adapted from Pattern in Islamic Art by David Wade)

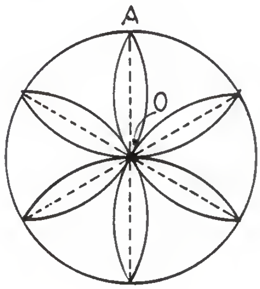
Fig. 3.2



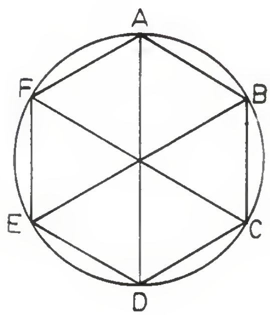
a. In contact at corners. b. In contact at sides, giving a second semi- regular tesselation. c. Overlapping by two sides. d. Derived from the formations at (b) overlaid on itself

The Hexagon and the Root Three method of designing patterns.

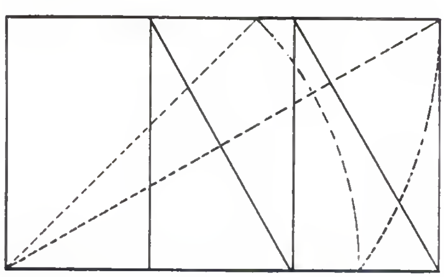
(Refer to Geometric Concepts in Islamic Art by Issam El-Said and Asyde Parman).



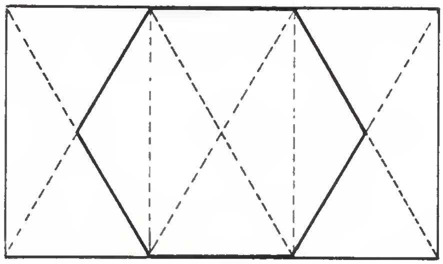
3.3.1. Describe the circle OA. The radius of the circle cuts the circumference into six equal parts forming the hexagon ABCDEF.



3.3.2. Draw the hexagon ABCDEF and insert its diagonals. This can now be considered to be the basic unit pattern for designing larger surfaces.



3.3.3. The hexagon can also be drawn using the root three rectangle and its reciprocals.

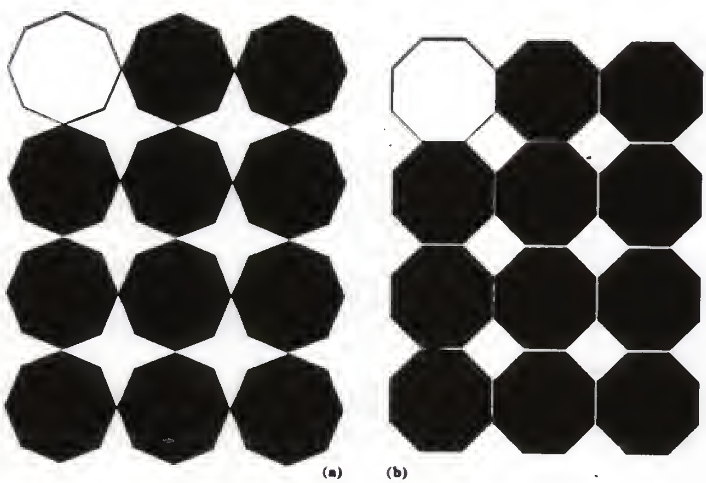


3.3.4. The diagonals of the reciprocals of a root three rectangle form a hexagon which can be used to create various patterns.

The Hexagon and its variations.

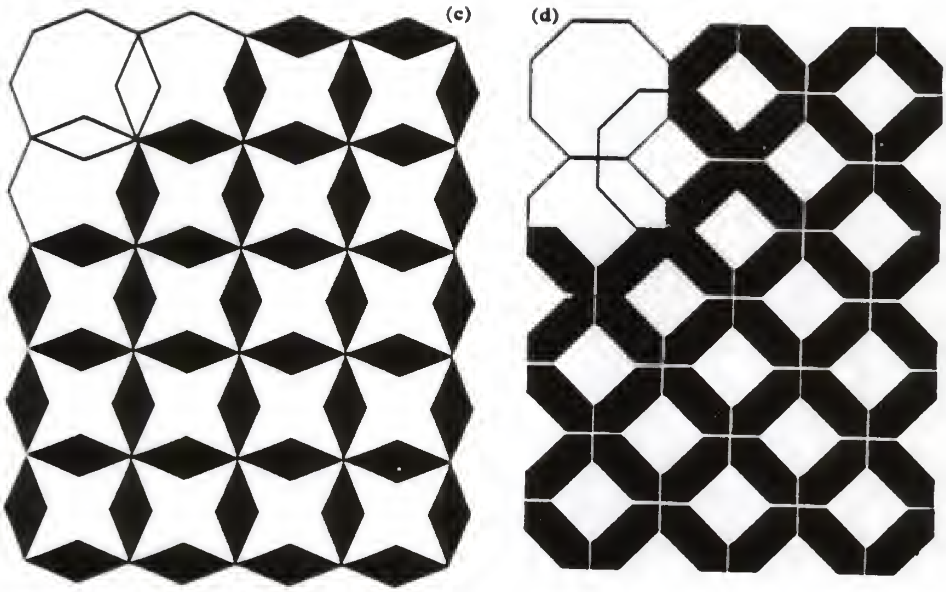
(Adapted from Pattern in Islamic Art by David Wade)

Fig. 3.4



a. The hexagons derivation from the isometric tesselation (grid or pattern).

b. In contact at corners forming the first of the semi- regular tesellations.

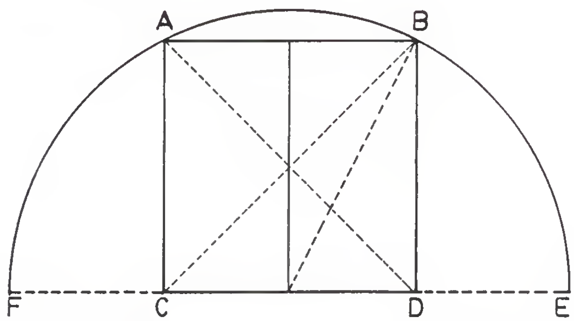


c. A variation of the previous arrangement.

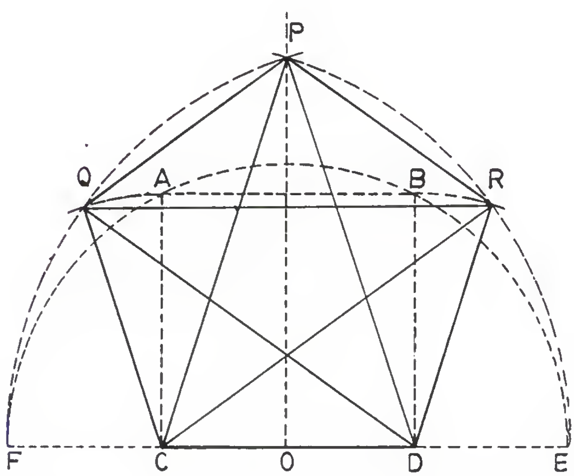
d. A combination of the two previous arrangements.

The Pentagon and the Golden Ratio method of designing patterns.

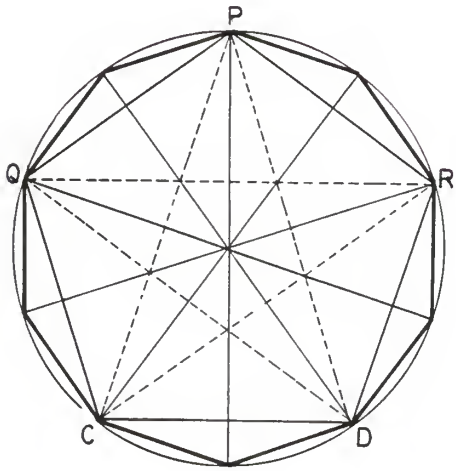
(Refer to Geometric Concepts in Islamic Art by Issam El-Said and Ayse Parman).



3.5.1. Draw the square ABCD with side = unity. Bisect at O the side of the square ABCD. Draw the diagonal OB and with O as center and radius = OB cut CD extended at E. This side CE is proportional to the golden ratio $\phi = (\sqrt{5} + 1)/2$. Similarly extend on the other side of CE at F.



3.5.2. With O as center and radius= OF draw arcs from E&F to meet at P. With C as center and radius = CA draw an arc to intersect FP at Q. Similarly intersect EP at R. Join PQCDR to complete the pentagon. Draw the diagonals by joining the alternate points. Note each side of the star is in the ratio ϕ.



3.5.3. Bisect each side of the pentagon to intersect the circle Join the points on the circle to draw the decagon. The pentagon and the decagon can now be used a s single unit patterns for larger surfaces.

Similar methods as specified earlier can be used to design the entire surface area under consideration. Patterns developed using this method are shown on the following pages.

The Pentagon and its variations
(Adapted from Geometric Concepts in Islamic Art by
Isam El- Said).

Fig. 3.6

a : b = 2 sides of pentagon : 2 sides of the star decagon.

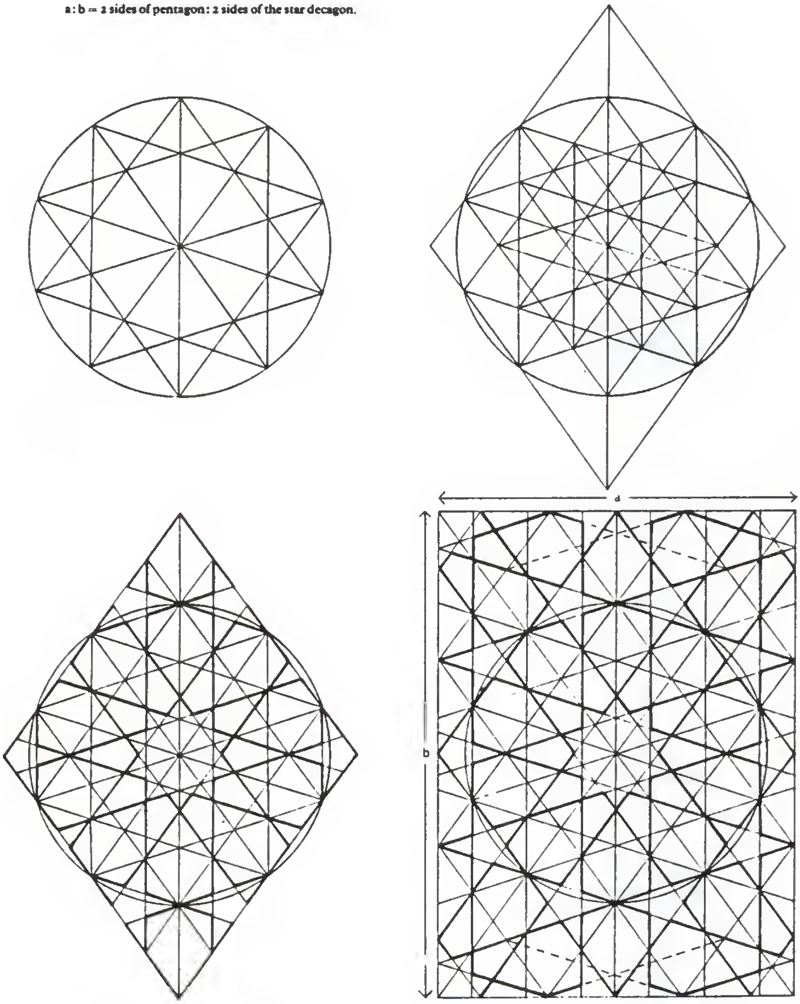
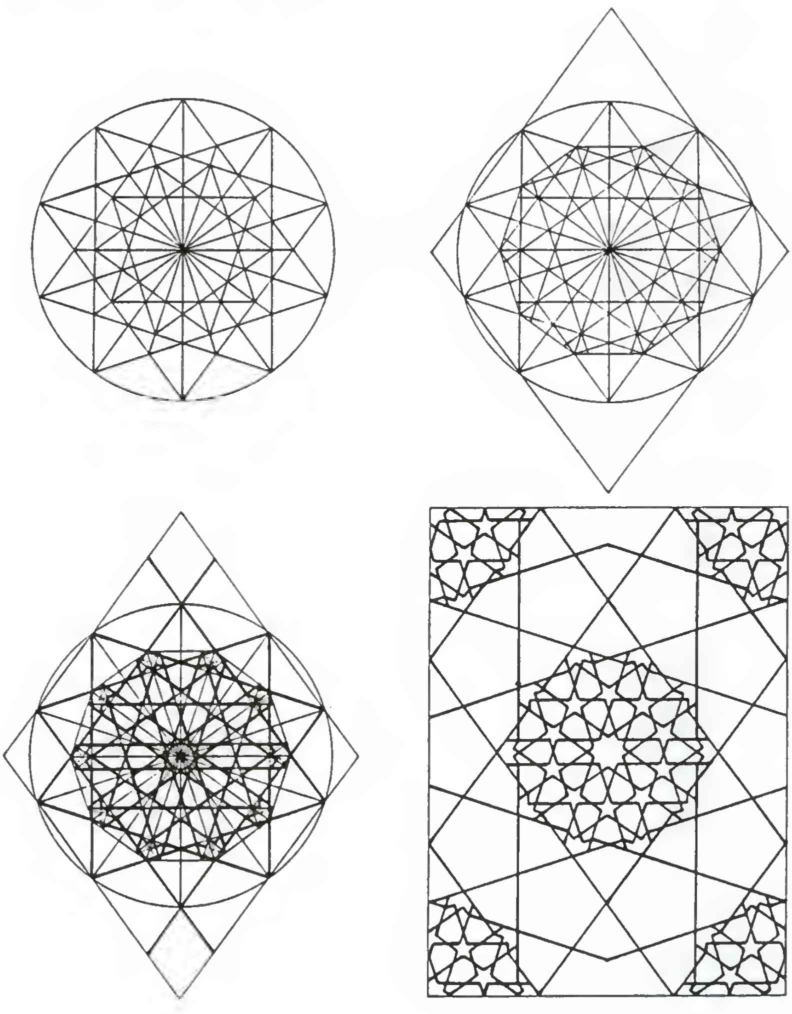


Fig. 3.7

The repeat pattern of this design is derived similarly to that of the previous design but ellaborated by the addition of more grid lines within the master grid.



ii.Use of geometric proportions in Calligraphy design.

Calligraphy in the Islamic world is considered to be very important as it records the word of God in the Holy Quran. Of the various calligraphic styles known to have developed, the Kufic and Cursive scripts are the most predominant ones. (For further reference on Calligraphy ref. to Islamic Calligraphy by Annemarie Shimmel). Calligraphy like all other Islamic art, architecture and decoration is closely related to geometry. It is refered to as "the geometry of line" implying that all letters are governed by certain rules of proportions (Burckhardt, 1976: pg48,9). The Cursive script developed by Ibn Muqlah (a wazir (minister) in the court of the Abbasid Caliph) is based on the use of certain proportions. The proportions used were not similar to the ones discussed thus far, nonetheless it is considered important to document the methodology developed. However it must be noted that the unit patterns of the hexagon and hexagonal star, the octagon and the octagonal star were used many a time to describe the calligraphy (El- Said, 1976: pg 130).

Since it is beyond the scope of this research to conduct any study in the field of calligraphy, the following material has been adapted from "Geometric Concepts in Islam" (El-Said, 1976: pg130-2) which will help support the idea of proportions used in calligraphy.

"The thickness of the pen employed was the unit measure for the size of the letters, and was refered to as the "Nuqtah" (point). The proportion of the thickness to the length of the letter "alif" (the

first letter of the Arabic alphabet, and written as a vertical straight line) determined the basis of construction of the script. When a circle was drawn with the alif as diameter, the shape and the proportional sizes of all the other letters of the alphabet could be derived from this circle, as will be shown later. The system of "nisbah fadilah" (noble proportion) of calligraphy, based on the method of Ibn Muqlah was outlined in one of the fifty two epistles written in Basra at the end of the tenth century AD. by the Ikhwan al-Safam (brethren of purity- who aimed at integrating Islamic and Greek philosophies). The proportion of the thickness to the length of the alif was 1:8 points (see fig.3.8.a). The letters "ba" "ta" and "tha" which differ only in the number and position of indication dots, were equal to the alif, ie., eight points long (fig.3.8.c). Letters with rounded forms were equal to one half or one quarter of the circumference of the circle drawn with alif as the diameter. Therefore for convenience of explanation, the circumference of this cirlce is equalled to 24 points although mathematically it is equal to 25 points. The upper stroke of the letters "jim", "ha" or "kha", which also differ with respect to the indication dots, was four points (one half length of the alif), and the lower arc was one half of the circumference of the circle or twelve points (ref. fig.3.8.d).
The letters "ra" or "za", without and with an indication dot, respectively, were each one quarter of the circumference of the circle, ie., six points long (fig.3.8.e). The other letters of the alphabet were constructed with similar reference to the alif and the

circle.

All Cursive scripts which have developed since Ibn Muqlah have been constructed by this same geometric method based on the alif and the circle; they differ in length of the alif, and the relative proportions of the other letters to the alif or its circle".

Fig. 3.8

(Adopted from Geometric Concepts in Islamic Art by Issam El-Said and Ayse Parman).

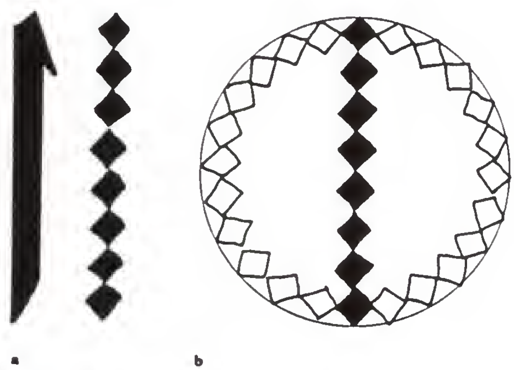
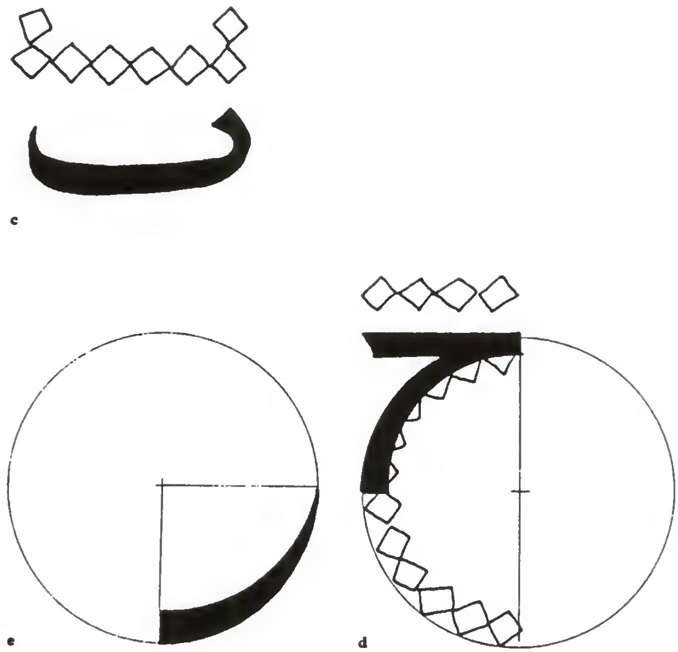


Fig. 3.8



Use of Patterns in Calligraphy Design.

Fig. 3.9

Vault in mausoleum of Oljeitu, Sultanniya, Iran.

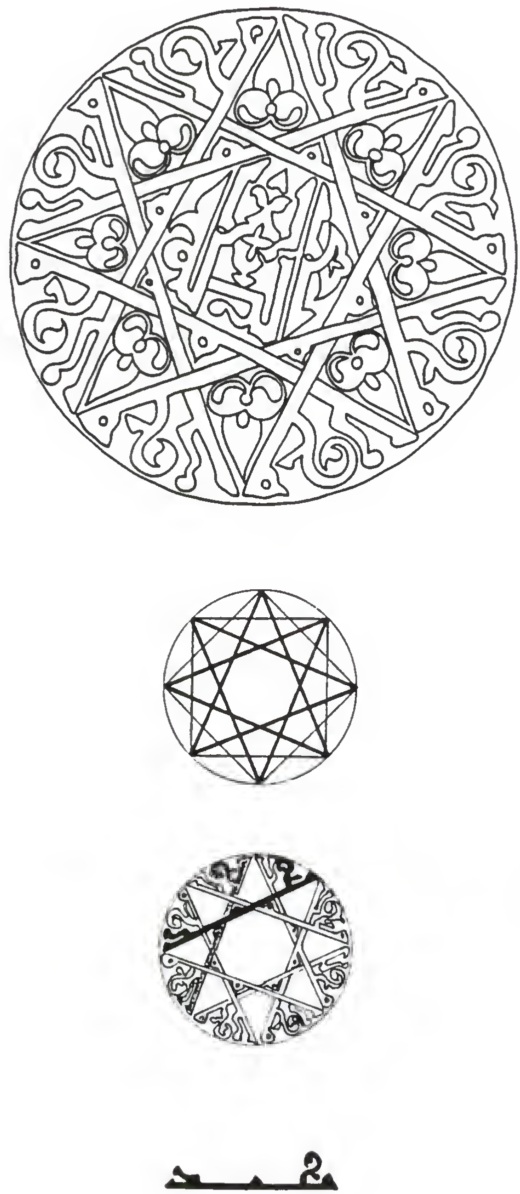
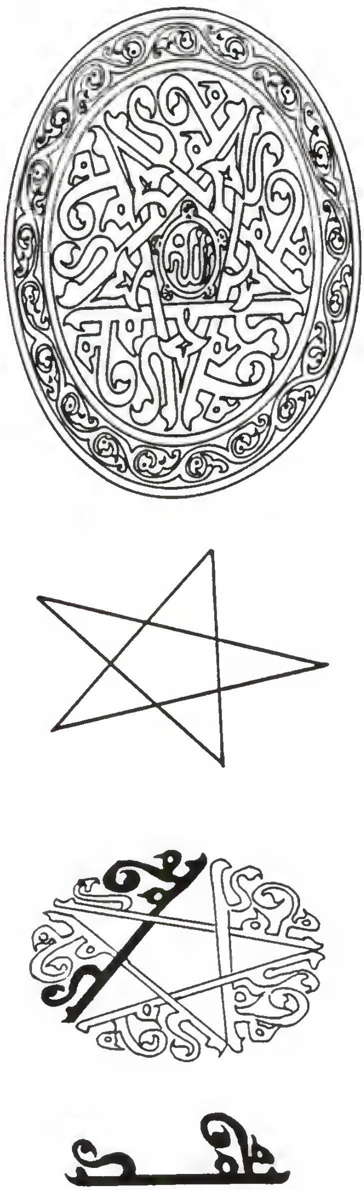


Fig. 3.10

Vault in mausoleum of Oljeitu, Sultanniya, Iran.



CHAPTER IV.

HISTORICAL BACKGROUND

i. Development of the Ottoman Empire.

The Ottomans or the "osmalis" (Osman from whom they derived the name Ottomans) can be traced back to a tribe called "kayi" or the Oguz family of Turks. As soon as the Anatolian Seljuk empire collapsed the Ottomans began to rise in Turkey and Osman the first Ottoman ruler started to expand the territory in early 14th. century (Refer to Appendix C for map of the Ottoman Empire).

The Ottomans set up their first stable capital at Bursa which was captured in 1326. The Ottoman state suffered a great setback a century later when it lost a large part of the Anatolian territories to the Timurids (Refer Appendix A). However they retained the parts in Europe and quickly reorganised the state. In 1453 the Ottomans captured Constantinople which since then came to be called Istanbul (Scerrato, 1976: pg 153).

The Ottomans were the heads of the Oguz Turkish family and according to the Turkish law and tradition the state was owned by a member of the ruling family. However after the death of Murad I, the third ruler, the election of the new ruler was restricted to the immediate family. The rulers were called "Sultans" and they enjoyed absolute power over their subjects and this relationship continued throughout their history although with gradually diminishing force (Kuran, 1968:

pg 13).

The period from the victory over Constantinople till the death of Suleiman the Magnificient (the tenth in the row of rulers) is considered as the Golden Age of the Ottoman Turkish empire. It is then that the Ottomans reigned over a major part of Europe, Middle East and North Africa.

Administrative Organisation: Remaining within the frame of Islam, the Ottoman empire was the most lasting and complex empire of the entire Turkish world. It possessed a well organised army, a set pattern of administration and a well devised social system. The Islamic religious law (the shariah) was accompanied by a secular code (qanun) which particularly helped in maintaining law and order in the state. The chief administrative body was the "divan" (the council of state) which was held under the chairmanship of the Sultan of the time. The Sultan was assisted by "vazirs" (ministers) in making decisions. The vazirs positions were held either by intellectual scholars or military commanders. The hierarchy of positions in the administration was 1. vazir (minister), 2. beylerbeyi (governor general), 3. sancak (governor). These positions were not only responsible for military but also for civil administration and security.

Social Setup: In living with the ancient Islamic institution of "dhimma" (protection afforded to defeated people) (Scerrato, 1976: pg 153), the Ottomans did not favor religious intolerance. The non-muslims enjoyed judicial, educational and cultural non- interference.

They were organized into "millets" that assured regular tax revenue and whose fundamental obligation was allegiance to the sovereign. The society was divided into two fundamental classes, the rulers and the subjects or the protected flock. However there was no specific barrier between the two which guaranteed considerable social mobility (Kuran, 1968: pg.14).

Soon after the capture of Constantinople, Istanbul became the capital city. A major cultural development was that the doors of "madrassas" (centers of learning) were opened to all the subjects of the state. Istanbul became one of Islams major centers of knowledge with great libraries and it was not long before Turkish became the third Islamic literary language in addition to Arabic and Persian (Scerrato, 1976: pg 158).

Ottoman Architecture: New neighborhoods were founded by building large complexes called "Kulliye", generally located outside the city walls. Initially they started building simple complexes and reached the peak after the fall of Constantinople, when buildings became more monumental. The complexes normally consisted of mosques, madrassas, imaret(public kitchen), hamam (public bath) and other various public welfare activity buildings. Often a commercial building was erected to meet the expenses of the mosque and madrassa. In addition to the commercial building there was the han (caravanserai). It consisted of a two storey structure with rooms arranged around a courtyard. The rooms on the ground floor were offices of the inn keeper and store rooms to keep the luggage that was brought in with the caravans. Also there was the "arasta" or the markets which acted as a source of income. The markets were a simple row of one storey shops arranged on either side of the street which in some cases may be open to the sky. In addition to these markets there were special markets for cloth dealers called "bezistan" (Kuran, 1968: pg 17).

The Ottomans were creative and inventive. Being liberal with traditions and having an open minded attitude there is evidence of Byzantine, Armenian and Seljuk influence on their architecture. Primary attention was given to the mosque and madrassas. The individual buildings of early Ottoman complexes were symmetrical and orderly in design, however the general composition was not. The buildings followed the topology and were grouped arbitrarily (Kuran,1968: pg18).

Following is an outline of Mosque architecture, its development and state in the Ottoman empire.

ii. Elements of a Mosque and Development of Mosque architecture and its state in the Ottoman period.

Elements of a Mosque.

The ritual of prayer is a well defined activity for which people gathered in a mosque at various hours of the day. The act of salah (prayer) culminates in prostration (sujud), from which comes the word masjid, the place to prostrate before God. The act of prayer is performed in parallel rows to follow the movements of the imam (leader) and this indicated the spatial direction to which the prayer hall should correspond. Over a period of time basic requirements connected with the prayer gave rise to essential elements of a mosque.

The "mihrab" (niche) was introduced to signify the place from which the imam would lead the prayer and also to indicate the direction in which to face (towards Mecca) while in the act of prayer. The wall which had the mihrab came to be called the "qibla" wall. It was a normal practice for the imam to deliver a "khutba" (sermon), which was signified by the "mimbar" (raised platform) on which the imam could raise himself and deliver the sermon. The mimbar was normally placed to the right of the mihrab, but often it was on wheels so it could be moved to convenient locations. The "minaret" (tower) was introduced to call the muslim brethren together at an appointed time for prayer. "Tahara" (physical purification of the body is required before the start of every prayer which gave rise to a place for "ghusl" or ablution (Kuban, 1974: partI, pg4-6).

Besides these basic requirements, depending on the size of the mosque, there would be a large "haram" (sanctuary) on the qibla wall and a "sahn" (courtyard) to which the haram opened. "Riwaqs" (arcades) appeared on the three sides of the sahn. The haram gives shelter to various secondary elements and contains mostly the "hujra" (cells) for religion education, screened enclosures for female worshippers, etc. Over a period of time depending on the size of mosque that was built many of these services took the form of individual buildings which gave rise to large building complexes in the latter stages of development (Kuban, 1970: partI, pg6-7).

Development of Mosque architecture.

Prophet Mohammad's house is considered as the first mosque from which the Islamic mosque tradition was developed. During the lifetime of the prophet many mosques were built based on the concept of an almost square room and a courtyard. The Ummayads were the first Islamic dynasty to come to power and they developed architecture to express worldly power. The basic concept of the mosque remained the same, however the ceiling heights increased to express magnanimity and the courtyards adapted a more formal approach. The Great Mosque of Damascus built in AD706-714 is a strong example of the Ummayad architecture (Scerrato, 1976: pg20-22; Kuban,1970: partI, pg14-17).

The Abbasids continued building on the same principles. With the spread of power to Egypt, North Africa and Spain the mosque architecture varied considerably, but remained faithful to the concept of the mosque being a multi- support sanctuary combined with a courtyard and a minaret (Scerrato, 1976: pg 31-36; Kuban, 1970: partI, pg18-22). As soon as the Fatimids came to Egypt from North Africa they built the mosque of Al- Azhar, which today stands as a great center of learning. Certain elements were introduced which later became typical of Egyptian mosques. A dome was introduced over the bay before the mihrab and over both the end aisles before the qibla wall. The Al-Hakim mosque which was built in the image of Al- Azhar introduced a gateway projecting from the main facade with minarets on either side (Scerrato, 1976: pg 53-55; Kuban,1985: partII pg1-2).

The Seljuk, Ghaznavid, Ilkhanid, Timurid and Safavid dynasties have a major role in influencing mosque arhcitecture in Iran, Afghanistan and Central Asia. The ready availability of mud brick or baked brick permitted the building of large size structures and at the same time facilitated decoration, from simple geometric relief to intricate patterns of glazed and colored brick. The Seljuks developed on the basis of the courtyard and the four iwans which formed the core of the design. The Ilkhanids followed the Seljuk tradition with minor modification. Minarets were placed symmetrically on either side of the gateway or iwan instead of the single towering Seljuk mosques. The Safavids brought along with them a period of monumental architecture. They maintained the basic concept in planning and stressed mainly refinement of finish and intricacy of design. Mosques in these areas represent an almost homgenous style concentrating more on elegance and technical achievement (Kuban, 1985: partII, pg7-14).

Long before the Moguls had reached India, the sub- continent was already influenced by the Sultanates in early thirteenth century. Mosques built in India were largely influenced by Turkish and the already existing Hindu architecture. The use of marble developed in the decoration of the facade. Most mosques developed the open courtyard scheme with projecting gateways, however many mosques built in the provincial style did not have courtyards. The Moguls developed mosque architecture into a mature classical style. An excellent example would be the Jami- Masjid at Fathepur Sikhri which has a large courtyard surrounded by arcades and cells on either sides along the walls. The famous gateway or the "Buland Darwaza" was built as a victory tower commemorating the Moguls military triumphs. Among characteristic elements seen in the Mogul architecture was the use of domed and flat roofs, clerestories and balconies, decorative grills and above all the unorthodox approach to planning (Scerrato,1976: pg 135-152; Kuban,1985: partII,pg14-18)

Mosque architecture in the Ottoman Turkish Empire.

The architecture developed by the Ottomans in Turkey was not only Islamic but also had late Roman and Byzantine influence (Kuban,1985: partII, pg 18-19). The Ottomans concentrated on the organisation of space under one dome and tried to merge the mosque tradition with the already existing Anatolian buildings. The mosque designs were more standardized and can be broadly categorized into i. single unit mosque, ii. multi- unit mosque (Kuran, 1968: pg23-26).

A multi- unit mosque has a large interior space which is divided into various compartments, in which one or more of the compartments may be domed based its importance.

A typical single unit mosque, which is the area of study, consists of a square room, a two or three bay porch and a minaret. The prayer room is generally surmounted by a dome and the porch is covered by a dome or vault or both. The geometric form of the exterior defined by basic geometric shapes of the square and the circle is reflected in the interiors. The central dome tends to draw the entire interior space towards the center. This type of single unit mosque was developed throughout the the six centuries of the Ottoman rule and became more sophisticated in decoration towards the end (Kuran,1968: pg 27). Architectural decoration mainly consisted of arabesque and calligraphy patterns. The arabesque which includes ornamentation was restricted to geometric forms as described in Chapter III. Calligraphy which is frequently linked with arabsque was very rich in design and did not differ much from the Eastern Arabic calligraphy (ref. chapter III). However it was composed of graphic elements achieved by symmetric reduplication, a method established by Mongol artists (Burckhardt, 1976: pg 51-8).

CHAPTER V

GEOMETRIC ANALYSIS OF SINGLE UNIT MOSQUE PLANS

For the purpose of analysis, single unit mosque plans were identified from various sources and compared for accuracy of dimensions and other relevant factors. However since the method of analysis demands accuracy, the problem of relying on the sources was analysed as follows. A properly executed analysis of the square single unit plan reveals with accuracy the slightest difference between the plan and the geometric diagram used as overlay. If the basic square is drawn even a millimeter small or large none of the geometric forms from Chapter II would fit the plan.

As Brunes mentions, the chance of fitting the analysis to a building that has not been built according to geometric forms is just as small as solving a large crossword puzzle with other words than those intended, and yet end up with some kind of an answer.

Some of the examples used are in ruins or in a state of collapse and the drawings in the present sources are traced from books which largely depend on previous measurements and reconstruction. Also often while drawing plans the persons concerned make notes on site and prepare final plans in offices which are far away from the site leaving little or no choice for verification. Often builders of a later date while restoring or rebuilding classics of a former time do not confirm to the proportions used giving rise to discrepancies in all post- repair drawings. Finally there is the inaccuracy to be accounted due to the printing and xeroxing which stretch the paper and introduce minor fluctuations in the original drawings.

The comments made above must therefore be considered as an explanation for imperfection at certain levels of analysis . However every effort has been made to check for accuracy and consistency. The following pages describe the analysis of every plan individually.

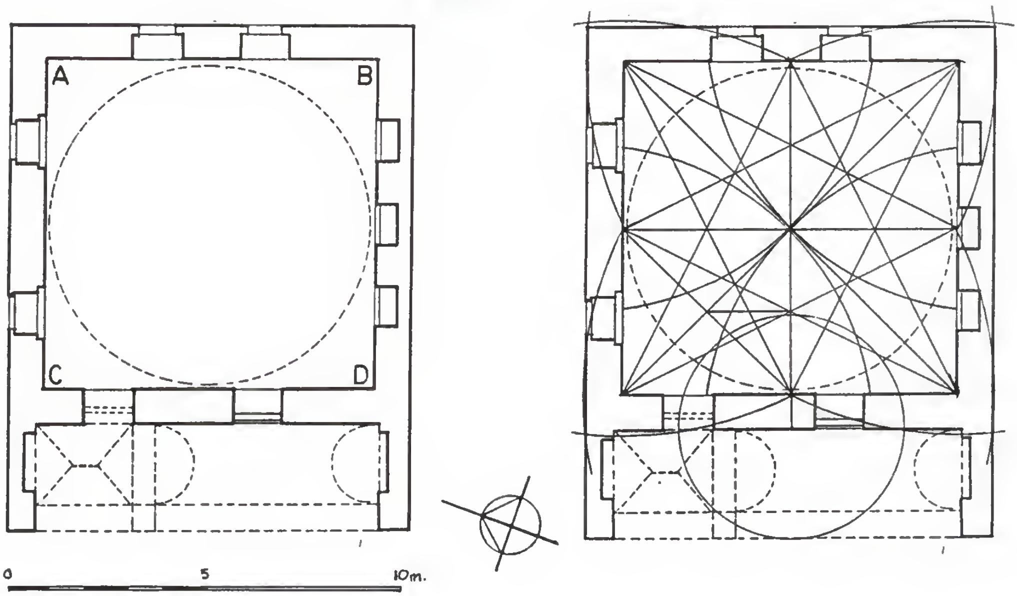


Fig. 5.1.a
(Adapted from The Mosque in Early Ottoman Architecture by Aptullah Kuran)

MOSQUE OF HACI OZBEK IN IZNIK

Also known as the "Carsi Mescidi" (Market Mosque), the mosque of Haci Ozbek was built in 1333 and is one of the oldest Ottoman buildings. It consists of a square prayer room and originally had a three bay porch.

On the exterior the hemispheric dome, the dodecagonal drum and the base walls are all separated from one another by means of saw toothed cornices. The original porch was torn down due to a street widening program and was replaced by a vestibule located opposite the mihrab. This is one of the few single unit mosques which never possessed a minaret.

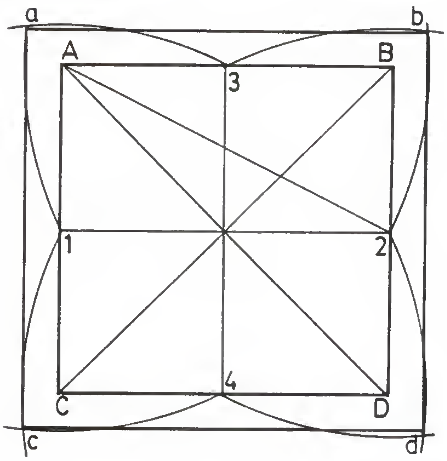


Fig. 5.1.b

Method of determining the wall thickness.

Notes to the analysis of fig. 5.1.b

1. Draw the interior square ABCD as shown in plan (ref.fig.5.1.a).
2. Insert the horizontal (1,2) and vertical (3,4) aixs and the two diagonals AD and BC.
3. Insert the diagonal A2 to the half square A1B2.
4. With A as center and radius = A2 draw arcs to intersect diagonal BC at "b" and "c".
5. Repeat the step with points B, C and D as center to locate points "a" and "d".
6. Join the points of intersection (a,b,c,d) of the arcs to determine the outer square abcd. This determines the wall thickness.

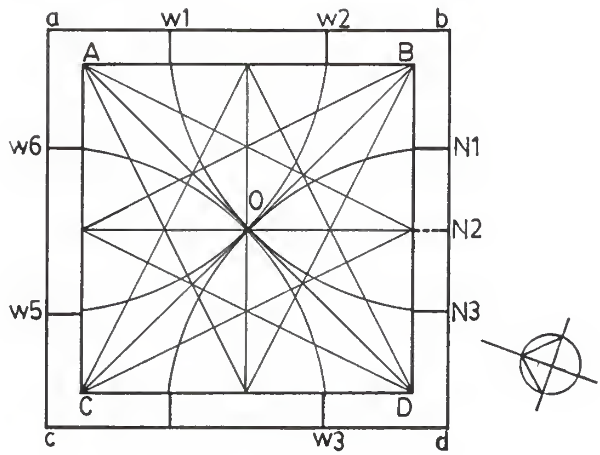


Fig. 5.1.c

Method of locating wall openings traditional niches.

Notes to the analysis of fig. 5.1.c

1. With point A as center and radius = AO(O being the center of the square ABCD) draw an arc intersecting "ab" at (w2) and "ac" at (w5).
2. Repeat the step with B,C and D as centers to determine the window positions on the north east (w1, w2),north west (w5, w6) and south west (w3) walls.
3. The same procedure also locates the two niches (N1, N3) on the south east wall. However the traditional mihrab N2 is placed symmetrically about the horizontal axis (1,2).

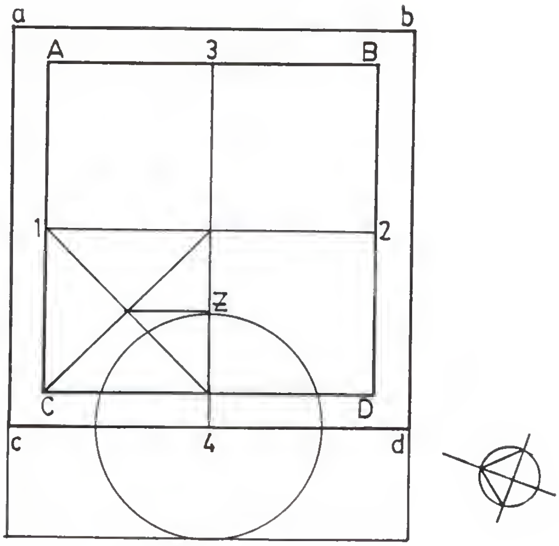


Fig. 5.1.d

Method of determining the porch width.

Notes to the analysis of fig.5.1.d

1. Draw the diagonals of the 1/4 square of the inner square ABCD.
2. Extend the point of intersection of the diagonals to the vertical axis 3,4 to intersect at Z.
3. With point 4 as center and radius = 4Z draw a circle.
4. Extend the walls from points c and d.
5. Draw a tangent to the bottom of the circle till it intersects the walls to determine the porch width.

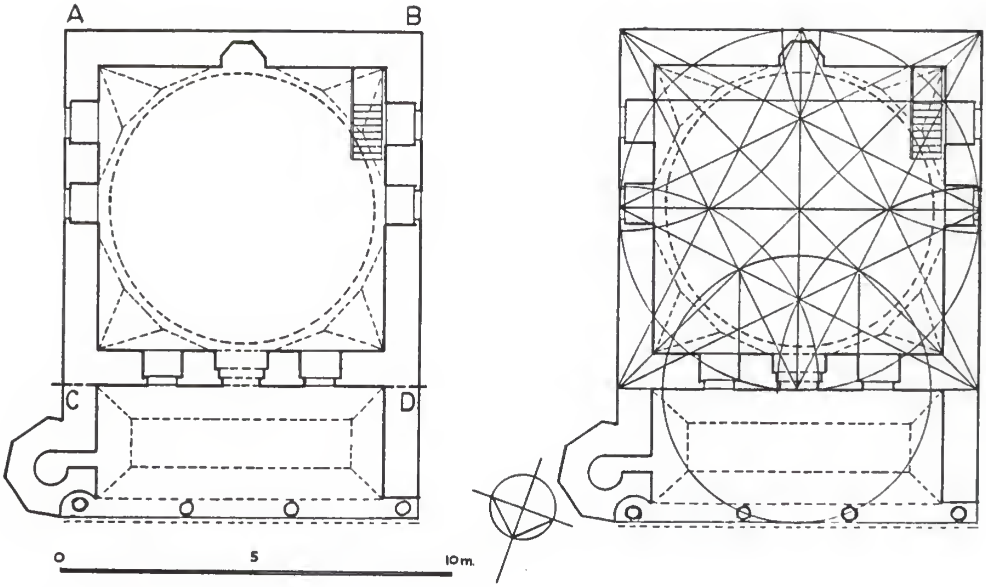


Fig. 5.2.a
(Adopted from The Mosque in Early Ottoman Architecture by Aptullah Kuran)

MOSQUE OF ALLAEDDIN BEY IN BURSA

This is a single unit mosque built by Allaeddin Bey . An inscription plate above the entrance provides the information that it was built in 1335 and underwent a major restoration in 1862.

The interior comprises of a square room surmounted by a hemispherical dome. The structure is very much symmetrical and minor displacements can be attributed to the fact that the plan was drawn after the stucture underwent major
restoration work.

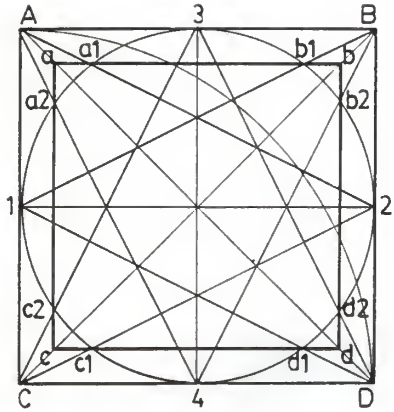


Fig. 5.2.b

Method of determining the wall thickness.

Notes to analysis in fig. 5.2.b

1. Draw exterior square ABCD as shown in plan (fig. 5.2.a).
2. Inscribe circle tangent to ABCD.
3. Insert the horizontal (1,2) and vertical (3,4) axis and the two diagonals AD and BC.
4. Insert the diagonals of the rectangles AB21, AC34, DB34, DC21 which are half squares (or the inscribed acute angles) A-2, A-4, B-1, B-4, C-2, C-3, D-1, D-3 to intersect the circle at a1, a2, b1, b2, c1, c2, d1, d2.
5. Join the points of intersection of the inscribed circle and the diagonals of the halves (from 4. above) intersecting at points a, b, c, d to determine the wall thickness.

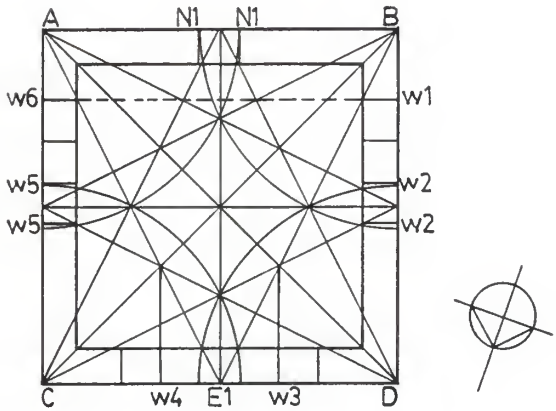


Fig. 5.2.c

Method of locating wall openings and traditional niches.

Notes to analysis in fig. 5.2.c

1. With point A as center and radius = AO, (O being the point of intersection of the horizontal axis and the diagonal to vertical half A3C4) draw an arc to intersect AB at (N1) and AC at (w5).

2. Repeat the same process with points B, C, and D as centers to determine the windows on the north east (w5) and south west (w2) walls, the entrance (E1) on the north west wall and the mihrab (N1) on the south east or qibla wall.
3. Extend the lines passing through mutual points of intersection of the component lines of the diagram to determine the other windows on the north east (w6), south west (w1) and north west (w3, w4) walls.

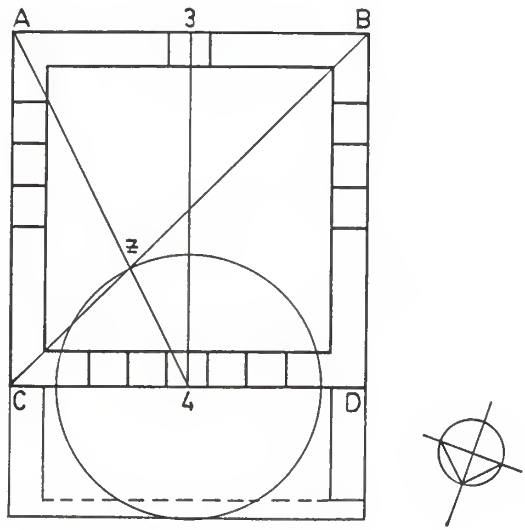


Fig. 5.2.d

Method of determining the porch width.

Notes on the analysis of fig. 5.2.d

1. With point 4 as center and radius = 4-z (z being the intersection of BC and A4 (the 1/3 dimension line) draw a circle (which is equal in diameter to the central dome).
2. Extend the walls from C and D.
3. Draw a line tangent to the bottom of this circle till it intersects the walls to determine the porch width.

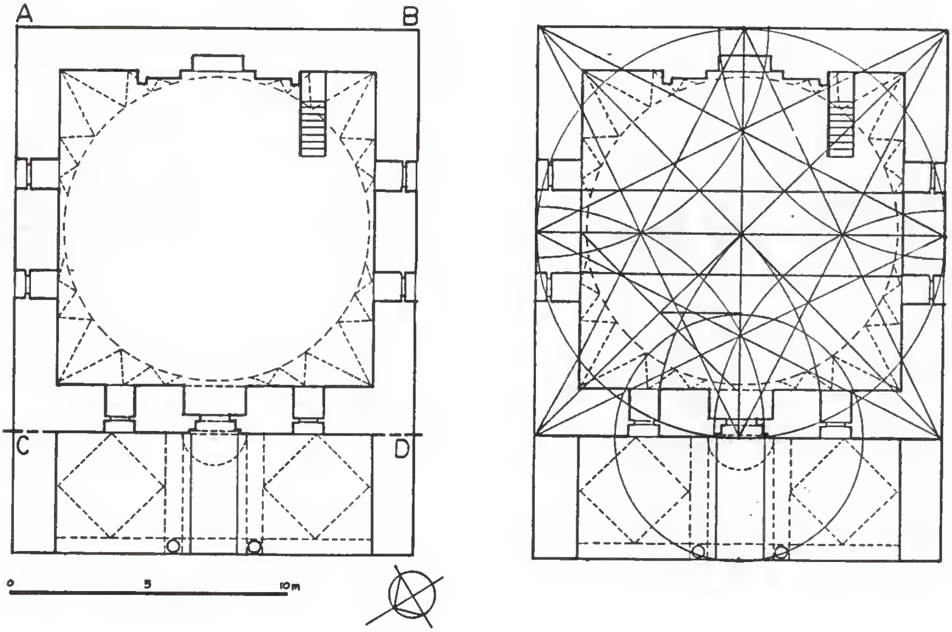


Fig. 5.3.a
(Adapted from The Mosque in Early Ottoman Architecture by Aptullah Kuran)

MOSQUE OF HUDAVENDIGAR IN BEHRAMKALE

This small mosque built on the slope of the acropolis of the ancient Greek city of Assos, is another typical example of the single unit mosque. Built by Murad I (the Hudavendigar) it has no inscription plate but various authors claim it to be built in the mid 14th. century.

The mosque building mainly consists of a domed square prayer room and a three bay porch. At present the porch is in ruins and devoid of any elements. The other elements in the mosque are strongly influenced by

Greek and Byzantine styles, largely due to its geographic location. The openings in the walls are placed symmetrically as can be seen in the plan and its analysis.

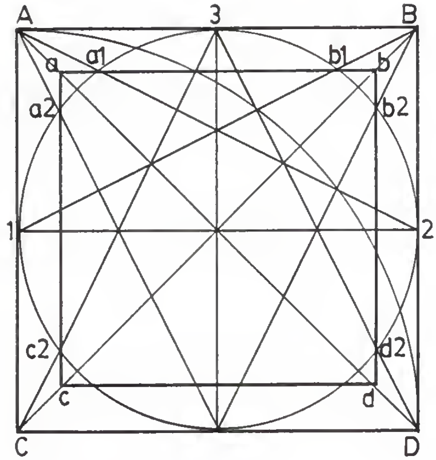
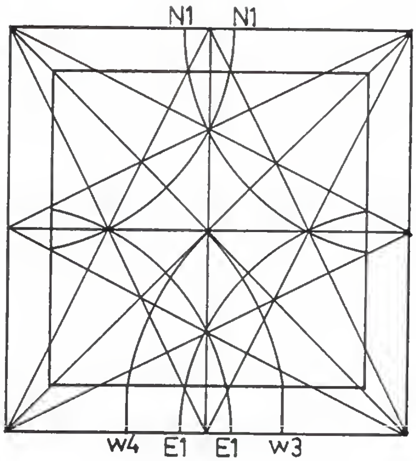


Fig. 5.3.b

Method of determining the wall thickness.

Notes to analysis in fig. 5.3.b

1. Draw exterior square ABCD as shown in plan (fig. 5.3.a).
2. Inscribe circle tangent to ABCD.
3. Insert the horizontal (1,2) and vertical (3,4) axis and the two diagonals AD and BC.
4. Insert the diagonals of the rectangles AB21, AC34, DB34, DC21 which are half squares (or the inscribed acute angles) A-2, A-4, B-1, B-4, C-2, C-3, D-1, D-3 to intersect the circle at a1,a2, b1,b2, c1,c2, d1,d2.
5. Join the points of intersection of the inscribed circle and the diagonals of the halves (from 4. above) intersecting at a, b, c, d to determine the wall thickness.



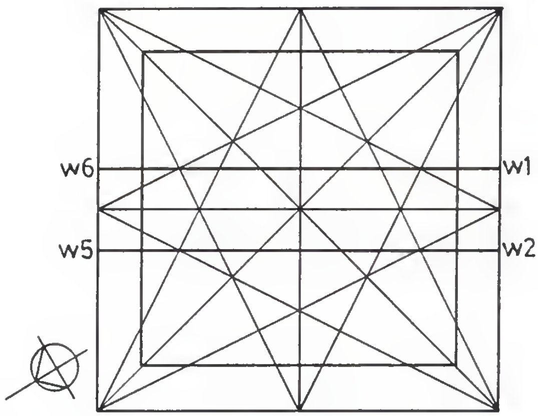


Fig. 5.3.c and Fig. 5.3.d

Method of locating wall openings and traditional niches.

Notes on the analysis of fig. 5.3.c and 5.3.d

1. With C as center and radius = CO (O being the center of square ABCD) draw an arc from O to intersect CD at w3 (ref. fig. 5.3.c)
2. Repeat the process with point D as center to locate point w4. The points of intersection determine the window openings in the north west wall.
3. With point A as center and radius = AP (P being the point of intersection of the horizontal axis and the diagonal to the vertical half A3C4), draw an arc to intersect AB at N1.
4. Repeat the same process with points B, C, and D as centers to determine the the entrance (E1) on the north west wall and the

mihrab (N1) on the south east wall.

5. Extend the mutual points of intersection of the component lines of the diagram to determine the other window positions on the north east (w5, w6) and south west (w1,w2) walls (ref. fig. 5.3.d)

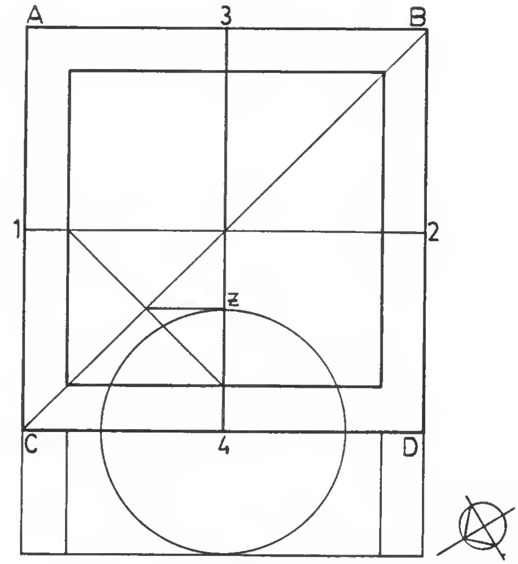


Fig. 5.3.e

Method of determining the porch width.

Notes on the analysis of fig. 5.3.e

1. Draw the diagonals of the 1/4 square of the inner square abcd.
2. Extend the point of intersection of the diagonals to intersect the vertical axis 3,4 at z.
3. With point 4 as center and radius = 4-z draw a circle.
4. Extend the walls from points C and D.
5. Draw a line tangent to the bottom of the circle till it intersects the walls to determine the porch width.

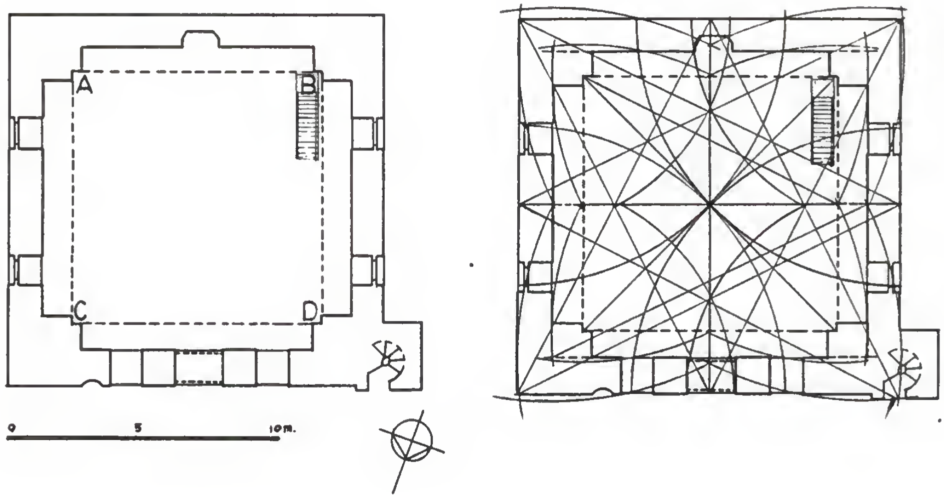


Fig. 5.4.a
(Adapted from The Mosque in Early Ottoman Architecture by Aptullah Kuran)

MOSQUE OF HOCA YADIGAR IN INONU

The mosque of Hoca Yadigar was built in the period of Murad I in 1374. The interior of this mosque is more symmetrical than other similar types of mosques and is more orderly and better proportioned.

The walls are of rubble stone and end at the top in a saw- toothed cornice. The dome is not exposed on the exterior but remains hidden under an octahedral cap covered by terra- cotta roof tiles. The building does not have a porch. It however has a minaret on the north west side which is atypical of other typical single unit mosques.

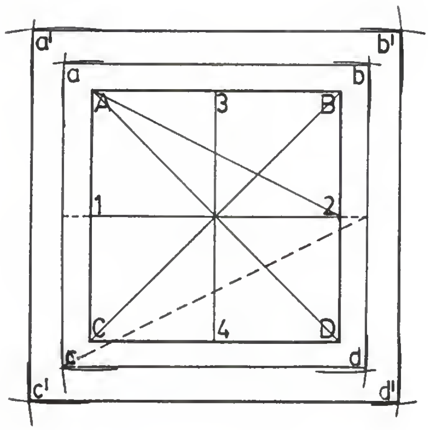


Fig. 5.4.b

Method of determining the wall thickness.

Notes to the analysis of fig. 5.4.b

1. Draw the interior square ABCD as shown in plan (fig.5.4.a).
2. Insert the horizontal (1,2) and vertical (3,4) axis and the two diagonals AD and BC.
3. Insert the diagonal A2 to the half square A1B2.
4. With A as center and radius = A2 draw arcs to intersect diagonal BC at "b" and "c".
5. Repeat the step with points B, C and D as center to locate points "a" and "d".
6. Join the points of intersection (a,b,c,d) of the arcs to determine the outer square abcd.
7. Repeat the entire process, step 2-6 with square abcd as the base

square to determine the wall thickness, by completing the square a'b'c'd' .

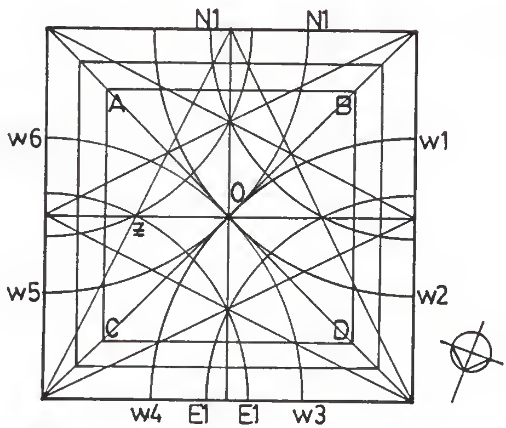


Fig. 5.4.c

Method of locating wall openings and traditional niches.

Notes to the analysis of fig. 5.4.c

1. With point A as center and radius = AO (O being the center of the square ABCD) draw an arc intersecting ab and ac at w5.
2. Repeat the step with B,C and D as centers to determine the location of windows on the north east (w5,w6), north west (w3,w4) and south west (w1,w2) walls.
3. With point A as center and radius = AZ (Z being the point of intersection of the horizontal axis and the diagonal to the

vertical half draw an arc intersecting ab at N1.

4. Repeat the step with points B, C and D as centers to determine the mihrab N1 on the south east wall and the entrance E1 on the north east wall.

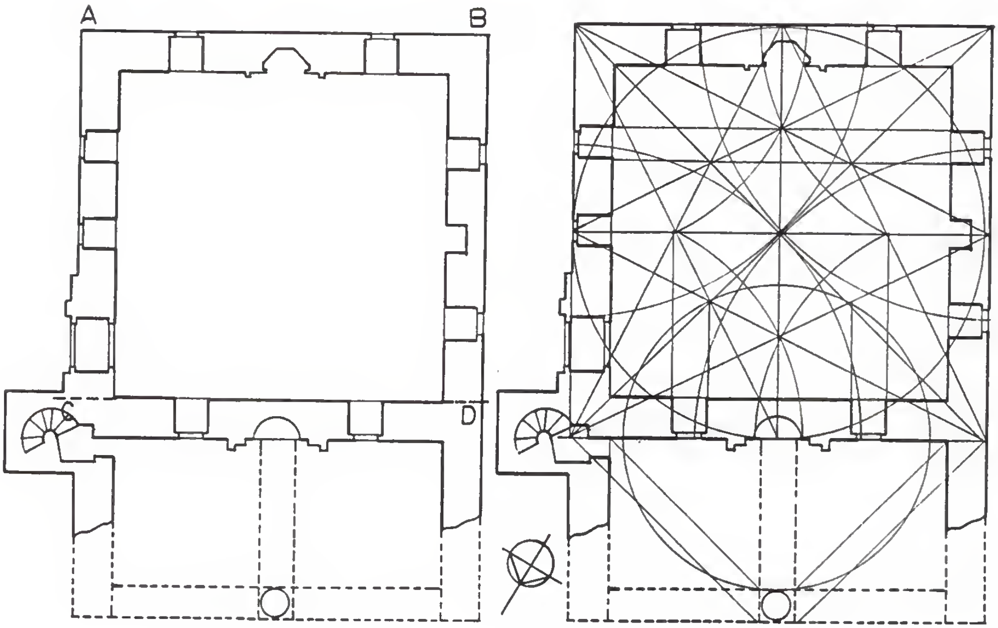


Fig. 5.5.a
(Adapted from The Mosque in Early Ottoman Architecture by Aptullah Kuran)

MOSQUE OF HACI SAHABEDDIN PASA IN EDIRNE

This mosque which is also known as "Kirazali Cami" (Cherry Mosque) was built in 1436 by Haci Sahabeddin Pasa and is the oldest existing mosque in the city of Edirne. Built on the same principles of the 14th. century mosques it has a square prayer room and a porch which is very much of a prototype of a single unit mosque.

Three of the outer walls were faced with cut stones where as the north west wall was plastered. A typical feature is the presence of a mihrab on the porch placed at the center of the wall. Due to this feature the entrance to the mosque is not from the porch but from the side walls as can be seen in plan. This mosque was amongst the first few mosques to be built with a two bay porch.

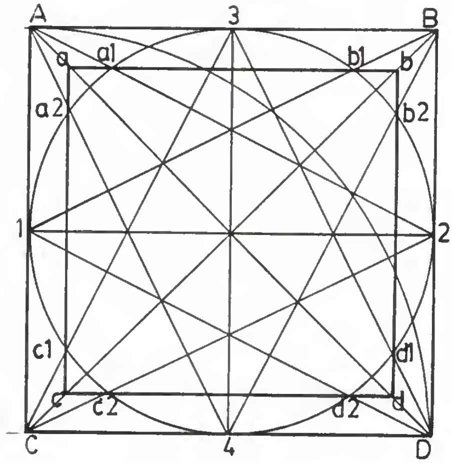


Fig. 5.5.b

Method of determining the wall thickness.

Notes to analysis in fig. 5.5.b

1. Draw exterior square ABCD as shown in plan (fig.5.5.a).
2. Inscribe circle tangent to ABCD.
3. Insert the horizontal (1,2) and vertical (3,4) axis and the two diagonals AD and BC.
4. Insert the diagonals of the rectangles AB21, AC34, DB34, DC21 which are half squares (or the inscribed acute angles) A-2, A-4, B-1, B-4, C-2, C-3, D-1, D-3 to intersect the circle at a1,a2, b1,b2, c1,c2, d1,d2.
5. Join the points of intersection of the inscribed circle and the diagonals of the halves (from 4. above) intersecting at points a,b,c,d to determine the wall thickness.

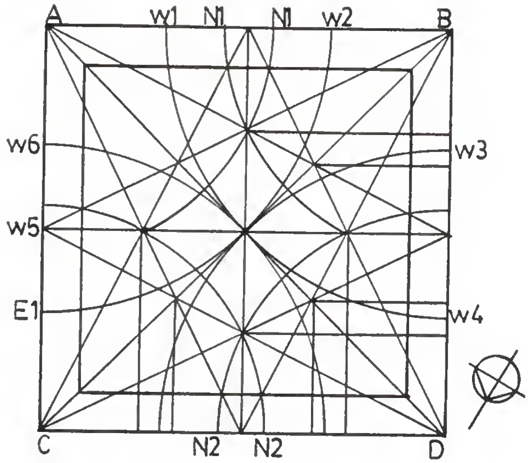


Fig. 5.5.c

Method of locating wall openings and traditional niches.

Notes to analysis in fig. 5.5.c

1. With point A as center and radius = AP, (P being the point of intersection of the horizontal axis and the diagonal to vertical half A3C4) draw an arc to intersect AB at N1.
2. Repeat the same process with points B, C, and D as centers to determine the niche on the front facade N2 and the traditional mihrab N1 on the south east or qibla wall.
3. With point A as center and radius = AO, (O being the point of intersection of the horizontal and the vertical axis) draw an arc to intersect AB and AC at w2 and E1.
4. Repeat the same process with points B, C, and D as centers

to determine the window positions in the south east (w1,w2) and south west (w3,w4) walls and the entrance E1 on the north east wall.

5. Extend the lines passing through mutual points of intersection of the component lines of the diagram to determine the other window positions on the north west (w5,w6) and south west (w3,w4) walls.

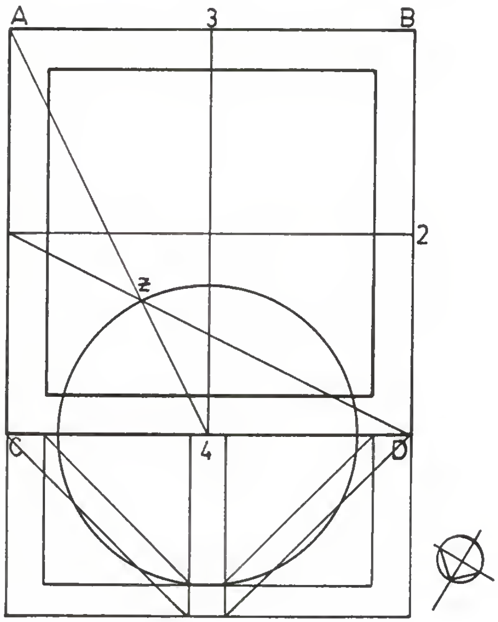


Fig. 5.5.d

Method of determining the porch width.

Notes on the analysis of fig. 5.5.d

1. With point 4 as center and radius = 4-z (z being the point of intersection of the diagonals A4 and D1 draw a circle.
2. Extend the wall thickness from C and D.
3. Draw the diagonals from the inside of the wall to intersect the circle. This divides the porch into two halves and a central column space.

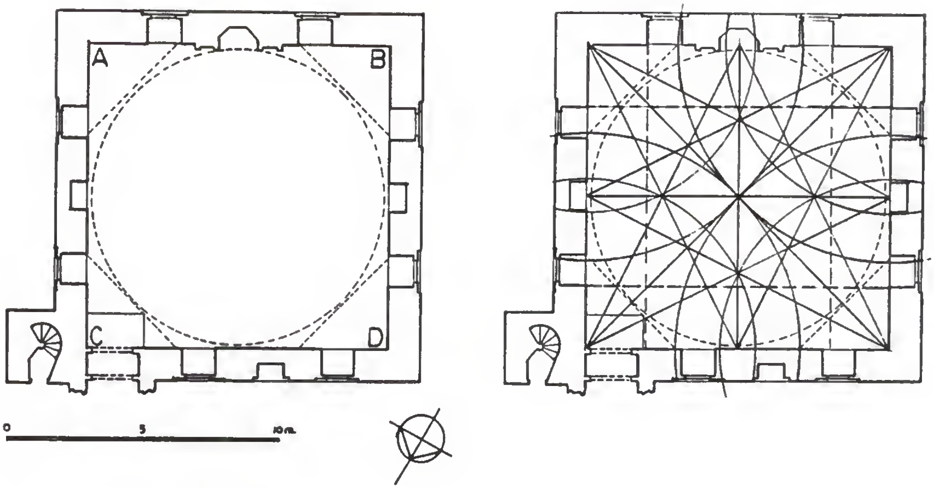


Fig. 5.6.a
(Adapted from The Mosque in Early Ottoman Architecture by Aptullah Kuran)

MOSQUE OF KASIM PASA IN EDIRNE

Situated on the eastern shore of the river Tunca in Edirne, this single unit mosque was built in AD 1478 and was partially restored as late as 1964. It was built by Kasim Pasa, a minister in the court of Mehmed II.

The exterior is finished in dressed stone. The windows and most of the other elements were arranged in a definite order. The central dome rests on squiches which are expressed on the exterior by a pitched roof triangular projection. The mosque does not have a permanent porch, however there once existed a timber structure in front of the building.

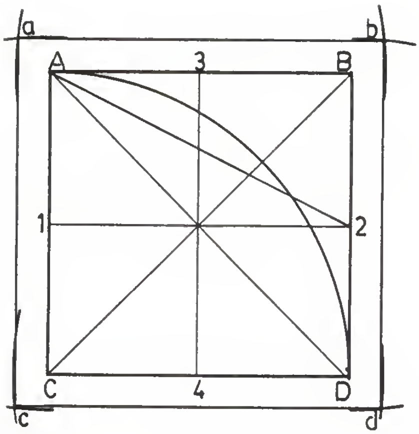


Fig. 5.6.b

Method of determining the wall thickness.

Notes to the analysis of fig. 5.6.b

1. Draw the interior square ABCD as shown in plan (fig.5.6.a).
2. Insert the horizontal (1,2) and vertical (3,4) aixs and the two diagonals AD and BC.
3. Insert the diagonal A2 to the half square A1B2.
4. With A as center and radius =A2 draw arcs to intersect diagonal BC at "b" and "c".
5. Repeat the step with points B, C and D as center to locate points "a" and "d".
6. Join the points of intersection of the arcs (a,b,c,d) to determine the outer square abcd. This determines the wall thickness.

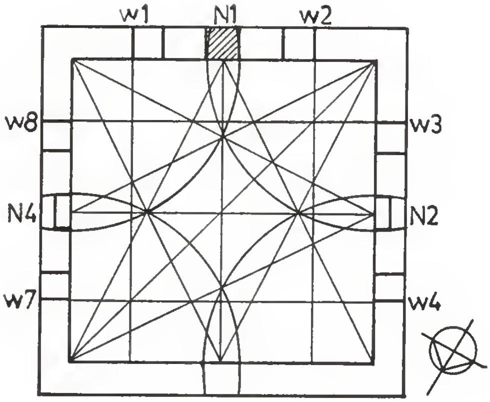


Fig. 5.6.c

Method of locating the wall openings.

Notes to the analysis of fig. 5.6.c

1. With point A as center and radius = AZ, (Z being the point of intersection of the horizontal axis and the diagonal to vertical half A3C4) draw an arc to intersect AB at N1 and AC at N4.
2. Repeat the same process with points B, C, and D as centers to determine the mihrab N1 on the south east or qibla wall and the niches on the south west (N2) and north east (N4) wall.
3. Extend the lines passing through mutual points of intersection of the component lines of the diagram to determine the other windows on the north east (w7,w8) and south east (w1,w2) and south west (w3,w4) walls.

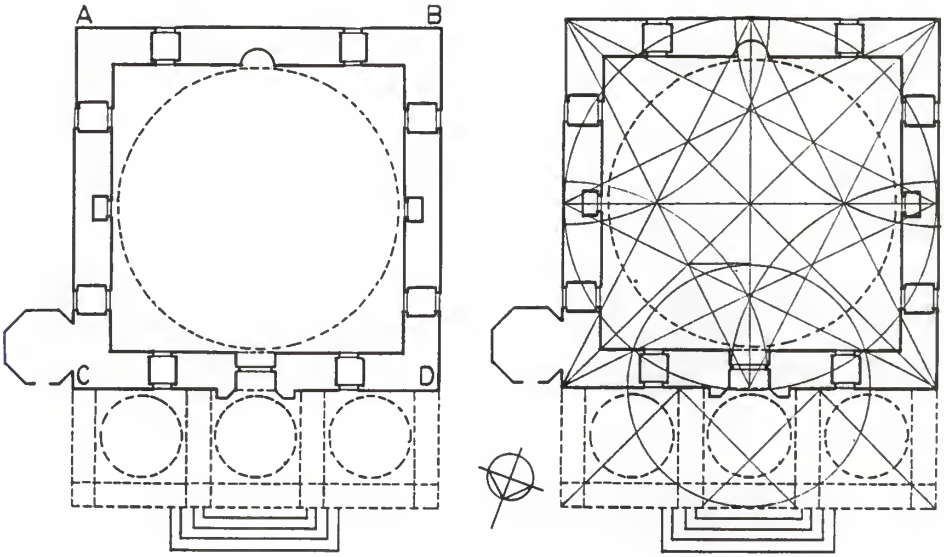


Fig. 5.7.a
(Adapted from The Mosque in Early Ottoman Architecture by Aptullah Kuran)

MOSQUE OF FIRUZ AGA IN ISTANBUL

The mosque of Firuz Aga was built by Sultan Bayezid II in 1490. Since it is built in the last decade of the 15th. century it is considered to be a very matured example of a single unit mosque.

The interior of the domed structure is a perfect square and is built symmetrically across the axis. The three bay porch is open at both ends and is supported by four columns. The whole building is faced with hard, white stone of which most of Istanbul's Ottoman buildings were constructed.

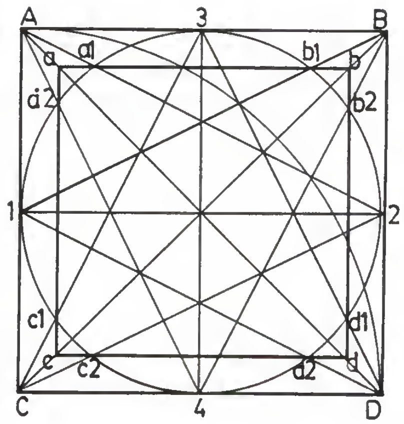


Fig. 5.7.b

Method of determining the wall thickness

Notes to analysis in fig. 5.7.b

1. Draw exterior square ABCD as shown in plan (fig.5.7.a).
2. Inscribe circle tangent to ABCD.
3. Insert the horizontal (1,2) and vertical (3,4) axis and the two diagonals AD and BC.
4. Insert the diagonals of the rectangles AB21, AC34, DB34, DC21 which are half squares (or the inscribed acute angles) A-2, A-4, B-1, B-4, C-2, C-3, D-1, D-3 to intersect the circle at a1,a2, b1,b2, c1,c2, d1,d2.
5. Join the points of intersection of the inscribed circle and the diagonals of the halves (from 4. above) intersecting at a,b,c,d to determine the wall thickness.

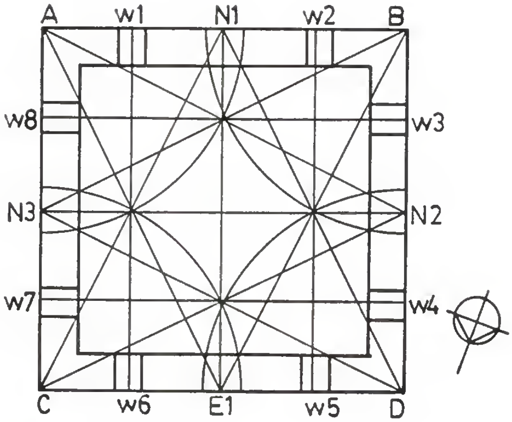


Fig. 5.7.c

Method of locating wall openings and traditional niches.

Notes to analysis in fig. 5.7.c

1. With point A as center and radius = AO, (O being the point of intersection of the horizontal axis and the diagonal to vertical half A3C4) draw an arc to intersect AB at N1 and AC at N3.
2. Repeat the same process with points B, C, and D as centers to determine the entrance E1 on the north west wall, the mihrab N1 on the south east or qibla wall and the niches N3 and N2 on the north east and south west walls.
3. Extend the lines passing through mutual points of intersection of the component lines of the diagram to determine the other window positions on the north east (w7,w8), norht west (w5,w6), south east (w1,w2) and sout west walls (w3,w4).

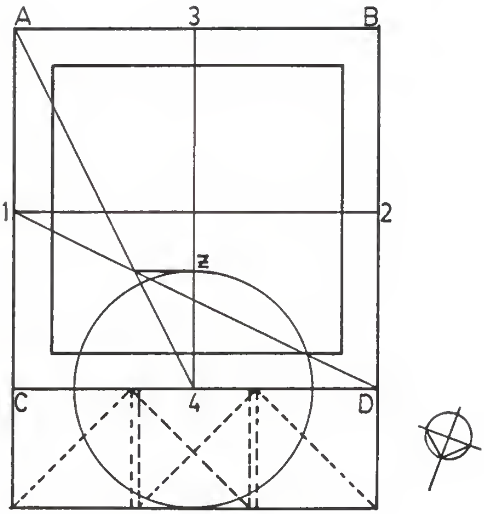


Fig. 5.7.d

Method of determining the porch width.

Notes on the analysis of fig. 5.7.d

1. Draw the diagonals of the 1/4 square of the inner square abcd.
2. Extend the point of intersection of the diagonals to the vertical axis 3,4 to intersect at z.
3. With point 4 as center and radius = 4-z draw a circle.
4. Extend the external wall line from points C and D.
5. Draw a line tangent to the bottom of the circle till it intersects the wall line to determine the porch width.
6. The side two bays are squares and the area left over forms the central bay.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS.

i.Conclusions

In Chapter V geometric principles used in the development of single unit mosque plans were analysed. The proportions used for design are all based on the unit factor (ref. Chapter I, pg.2)thus creating an entire scheme which reflects unity. As mentioned earlier the fundamental concept of Islam is "Tawhid" (unity) and every thing that exists is in relation to the unit factor. Islam does not accept the theory of ex-nihilo, rather it claims that the creation or the universe is the art of the creator (Nasr, 1975: chp.1)

The notion of "through the creation reach the creator" is strong in Islamic context. The creation is considered as that which is apparent and the creator as that which is transcendent (ref. Nasr, 1975: chp.1). This is reflected in the design of building. There is evidence from the analysis in Chapter V that plans were made from the perimeter to the inside. This again reflects the aspect of unity, as every space designed within is in relation to the perimeter which is the unit base.

From the analysis in Chapter V there is evidence of recurrent patterns which were used to determine various elements in plan. The elements included wall thickness, porch width and location of windows, entrances and mihrabs. The results are reported in the form of a matrix (ref. Appendix E) to indicate the similarities and differences found in the variious plans used as study samples.

Irrespective of the period or time during which the mosque was constructed there is strong evidence of two well defined recurrent patterns. Both recurring patterns as discussed in the following pages help in determining the elements mentioned earlier. Since there is no developed explanation defining the use of the two methods it is evident that it was the knowledge possessed by the craftsmen and builders and the use of either method depended on the sole discretion of the builder/ craftsman. This can be supported by the fact that there is evidence of mosques being built using both methods (ref. Appendix E). Hence it may be concluded that there was no particular regulation or law which governed the use of the two different recurring patterns.

However it must be noted that the use of geometric proportions is only a tool that may be used as part of the design process. It is not a complete system and does possess insufficiencies. The point that needs consideration is the fact that it is an important method that can be adapted to create an integrated design. Also it must be noted that the methods identified cannot be termed Islamic as such. There is evidence of the use of these methods in earlier styles, but as mentioned in Chapter I, these methods were adapted and modified to best suit the needs of Islamic identity. Such possible integrated schemes well reflect the spirit of Islamic unity. Following is a conclusion of the recurring patterns found to be used in the development of single unit Ottoman mosques.

Method of determining the wall thickness

There is recurring evidence of two methods which were used to develop the wall thickness. Method "A" is based on the principle of determining the circle's rectangle. The major difference between method "A" and method "B" is that in "A" the exterior wall dimension is given whereas in "B" the interior wall dimensions are given.

Method A

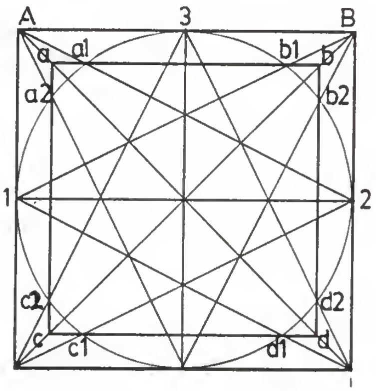


Fig. 6.1

1. Draw the exterior square ABCD as shown.
2. Inscribe circle tangent to ABCD.
3. Insert the horizontal (1,2) and vertical (3,4) axis and the two diagonals AD and BC.
4. Insert the diagonals to the rectangles AB21, AC34, DB34, DC21 which

are half squares (or the inscribed acute angles) A-2, A-4, B-1, B-4, C-2, C-3, D-1 and D-3 to intersect the circle at a1,a2, b1,b2, c1,c2, d1,d2.

5. Join the points of intersection of the inscribed circle and the diagonals to the halves to determine the wall thickness.

Method B

Having determined the interior wall dimension this method then proceeds to determine the wall thickness by establishing the exterior wall dimensions. It must be noted however that method A and B are applicable only to square plans.

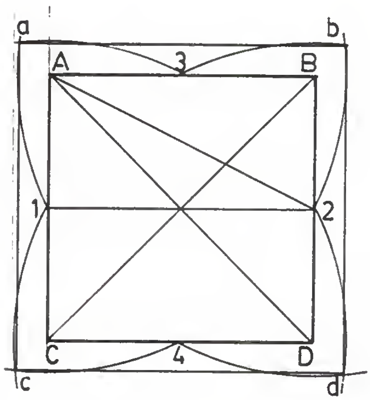


Fig. 6.2

1. Draw the interior square ABCD as shown .
2. Insert the horizontal (1,2) and vertical (3,4) axis and the two diagonals AD and BC.
3. Insert the diagonal A2 to the half square A1B2.

4. With A as center and radius = A2 draw arcs to intersect diagonal BC at b and c.
5. Repeat the step with points B, C and D as centers to locate poins a and d.
6. Join points abcd to determine the exterior wall dimension.

Comments

The methods identified for determining wall thickness are true only for square plans. However there are cases (ref. fig. 5.3.b) when all the walls are not of the same thickness. This may be due to the fact the monument has undergone restoration and was not rebuilt consciously.

There is sufficient numerical difference in the thickness achieved due to both methods, which implies that indeed there were more than one method employed. Method A works from the outside to the inside whereas Method B works from the inside to the outside. However both methods deal with the perimeter which is seen to be the first step in designing single unit mosques.

Both methods use a unit square and all other operations are carried out in relation to the reference square.

Method of locating the Entrances

For all entrances which are located in the center of the wall opposite the traditional mihrab, there is evidence of only one pattern. However it may be explained using two different techniques which are explained below.

For exceptional cases (A1 in the matrix), where the entrance is not opposite the mihrab but is off center or on the side walls, the method used is the same as that used to locate window openings.

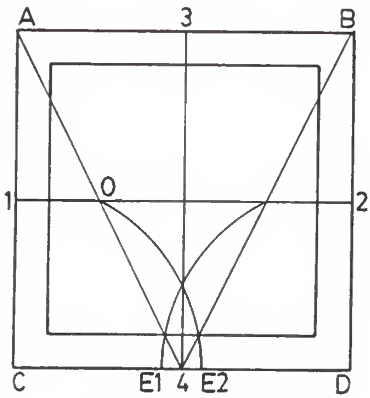


Fig. 6.3

1. With point C as center and radius = CO (O, being the point of intersection of the horizontal axis and the diagonal to the vertical half A3C4), draw an arc to intersect CD at E1.
2. Repeat the process with point D as center to locate the point E2 on CD. This determines the width of the entrance on the front wall.

Note: The location of the entrance can also be explained as placed symmetrically about the vertical axis (3,4).

Comments

In general it may be concluded that the entrance is positioned directly opposite the traditional mihrab. Also in most cases the entrance is approached through the porch.

However due to reasons specified earlier in Chapter V the entrance may have been moved from its original position and relocated in the side walls. There is also a case where the entrance is replaced by a mihrab on the exterior front wall and the entrance is not from the porch but from the side wall.

The arc which defines either edge of the entrance is actually constructing a root three rectangle in the unit square (ref. fig. 2.2.b). The other method which is used simple whereby the entrance is located symmetrically about the vertical axis.

Method of locating the niches

The traditional mihrab is located on similar principles as that of the entrance. However there are cases where there is a mihrab on the porch wall instead of an entrance. The analysis method in this case still remains the same. Occasionally there are niches on the side walls developed for decoration or aesthetic purposes. In this case the analysis method adapted is the same as that used for locating windows.

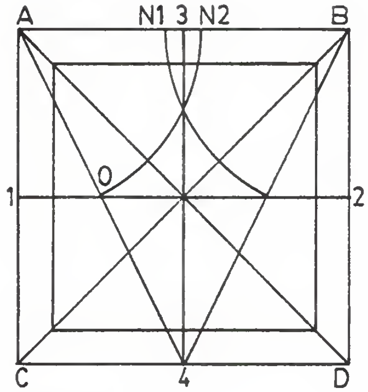


Fig. 6.4

1. With point A as center and radius = AO (O, being the point of intersection of the horizontal axis and the diagonal to the vertical half A3C4), draw an arc to intersect AB at N1.
2. Repeat the process with point B as center to locate the point N2 on AB. This determines the width of the niche on the rear wall.

Note: The location of the niche can also be explained as placed symmetrically about the vertical axis (3,4).

Method of locating windows

There are basically two methods noted which were used for locating window openings. Method "A" used the end points of the plan and a specific radius to draw arcs and intersect the walls to locate the windows, whereas method "B" used the principle of extending the mutual points of intersection of the component lines of the diagram.

Method "A"

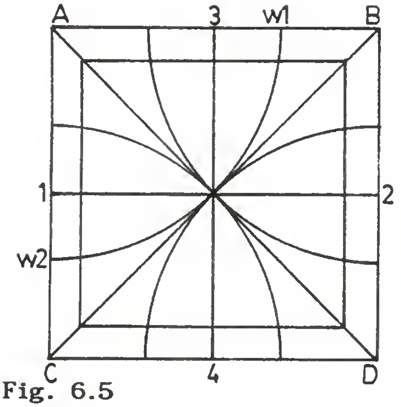


Fig. 6.5

1. With point A as center and radius = AO (O, being the center of square ABCD draw an arc to intersect AB at w1 and AC at w2.
2. Repeat the process with points B, C and D as centers to locate window positions on all other side walls.

Method "B"

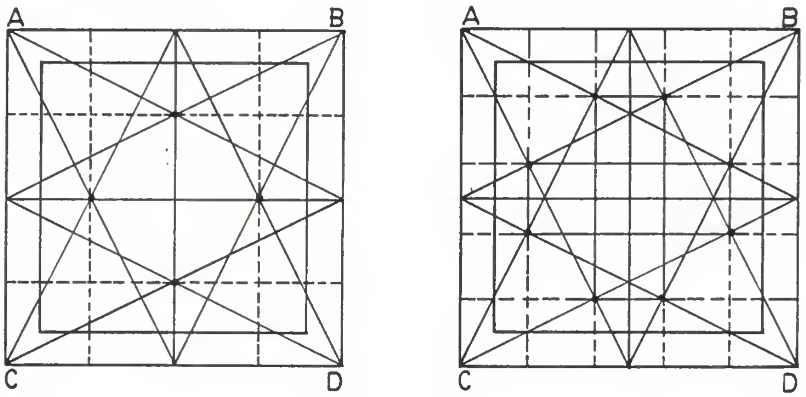


Fig. 6.6

1. Insert the horizontal (1,2) and vertical (3,4) axis.
2. Insert the diagonals AD and BC.
3. Insert the diagonals to the half squares (or the inscribed acute angles).
4. Extend the mutual points of intersection of the component lines of the diagram to intersect the walls AB, AC, DC and DB to locate the window positions.

Comments

There is substantial evidence of recurring patterns to prove that both methods were employed to locate window openings. Based on the analysis Method A uses the sacred cut (ref. fig. M, pg.16,17), and Method B uses the mutual points of intersection of the component lines.

The sacred cut creates an alternating proportion and also helps in locating points which otherwise would be difficult to locate numerically. Same holds true for the location of windows using mutual points of intersection. A grid can be developed using the points which would help the builder locate the points graphically rather than using accurate numbers.

Method of determinig the porch spans

There is evidence of two methods that were used to determine the porch width. Method "A" used the diagonals to the 1/4 square to determine the porch , whereas method "B" used the diagonals to the vertical and horizontal halves to determine the the porch span.

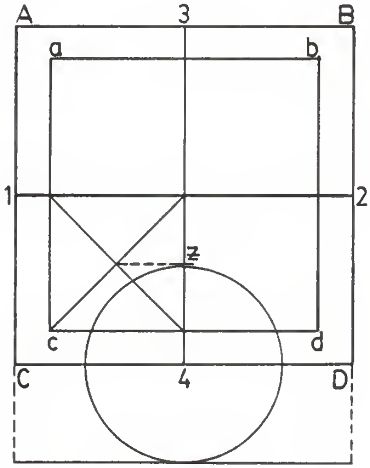


Fig. 6.7

1. Draw the diagonals of the 1/4 square of the inner square abcd.
2. Extend the points of intersection of the diagonals to intersect the vertical axis (3,4) at z.
3. With point 4 as center and radius = 4–z draw a circle.
4. Extend the wall lines from points Cand D.
5. Draw a line tangent to the bottom of the circle till it intersects the walls to determine the porch width.

Method "B"

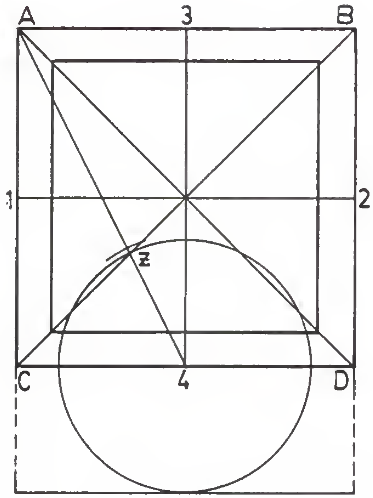


Fig. 6.8

1. With point 4 as center and radius = 4-z (z, being the point of intersection of BC and A4 (the 1/3 dimension line) draw a circle
2. Extend the walls from points Cand D.
3. Draw a line tangent to the bottom of this circle till it intersects the walls to determine the porch span.

Comments

Due to the fact that all single unit mosques do not have a porch it can be established that the porch was not a primary element of the single unit mosque. From the analysis pattern it is apparent that the porch is an addition to the mosque and not an extension of the same. The number of bays vary from one porch to the other depending upon the style and period during which it was constructed.

Recommendations

The geometric analysis of single unit mosque plans has opened many doors for further research. Since this study was restricted only to plan forms, it is recommended to analyse and trace possible recurring patterns used in the development of sections. A successful analysis of the section will not only support this study but will also strengthen the hypothesis. In trying to analyse the section certain issues need to be considered so as to carry forward the results of this study. Emphasis needs to be given to the height of wall openings that is entrance doors, windows and niches. A study of the dome section may reveal the proportion of either the radius or diameter to the height in section. The overall height to width ratio may also be proportionate to the ratios studied earlier in the study. The height of the minaret compared to the base or the overall height of the building may be an interesting proportion to analyse.

Being a pilot study of this nature a major problem faced was the accuracy of plans. It is recommended that before conducting any such research, time should be invested in preparing measure drawings of the building under study. A field study of this type will not only help in acquiring accuracy but will also identify errors in other plans of the same building. Also a comparison of the plans of the same building will help identify elements which have been changed or destroyed over the past years.

The results of this study are based primarily on geometric analysis.

It is recommended to study the proportions using numerical values and mathematical formulae. There is evidence of the fibonacci series being used to develop the logarithmic curve and subsequent numerical patterns which are converted to geometry. A comparison of the numerical and geometric patterns may reveal facts which could serve as a major contribution to the field of design. The numerical proportions underlying the geometric derivation can then be used by present day architects and designers.

The study of geometric patterns in single unit mosques has surfaced certain recurrent patterns as mentioned earlier in the Chapter. Based on the results it is recommended that the analysis be carried further to test its applications for the development of multi unit mosques and larger complexes. Being a basic square unit the single unit mosque plans have helped in establishing fundamental principles for the use of geometric proportions. By using the principles of sub-division or juxtaposition, multi unit mosques and larger complexes can be developed. Incorporating these fundamental principles will help maintain the sense of unity due to its relation to the basic form.

The results of this study are not a complete set of guidelines or principles but are definitely an eye opener. Use of these principles and other modifications to them will help create a much more conscious approach to design in the muslim world. As mentioned in the introduction "architectural rhythm has been forgotten and form has lost its symbolism". A sincere application of the results may not recreate all lost concepts but will certainly serve as a step forward in recreating an architecture in the spirit of Islam.

Finally it needs to be mentioned that any restoration work being done on such buildings should be done consciously. If there is evidence of geometric patterns in the architecture, then while restoring due respect must be given to the system and the use of proportions must be maintained. Failure to do so only creates a disturbance in the eye of the viewer and confusion in the mind of the scholar.

APPENDIX A

CHRONOLOGICAL LIST OF ISLAMIC PERIODS.

DATES	ISLAMIC DYNASTIES & CAPITALS	EVENTS IN ISLAMIC WORLD	WORLD ARCHITECTURE
622		Hegira of Prophet Muhammad	532–63: Ayat Sophia at Constantinople
632–661	The Four Orthodox Caliphs Capital at Mecca	Period of rapid conquest: 632, Syria and Iraq; 636–40, Persia; 641, Egypt	625–75: Mamallapuram Temples, India
661–750	Umayyad Caliphs Capital at Damascus	669 (–800): Caliphs appoint governors of North Africa; 710–12, conquest of Spain; 711, conquest of Pakistan	685–705: Dome of the Rock, Jerusalem 706–715: Umayyad Mosque at Damascus
750–1258	Abbasid Caliphs Capital moved to Baghdad (760); then to Samarra (836)	786: Harun al-Rashid	785–987: Great Mosque at Cordova
756–1031	Umayyad Caliphate rules Spain from Cordova		
800–909	Aghlabid Dynasty in Ifriqiya (Tunisia), Algiers, Sicily		c. 822: Barabudur Temple, Java
819–1005	Samanid Dynasty in Transoxiana and Khurasan: principal centers, Nishapur and Samarkand		
868–904	Tulunid Dynasty in Egypt Capital at Cairo		876–79: Ibn Tulin Mosque at Cairo
909–1171	Fatimid Dynasty	Based in Ifriqiya in 972: rule Sicily to 1071: rule Egypt from 960 to 1171	814: First Cluny Abbey Church, France 950: Pagoda of Daigo-ji, Kyoto
932–1056	Buid Dynasty in Persia and Iraq		967: Banteay Srei, Cambodia
972–1148	Zirid Dynasty rule Ifriqiya		990–1012: al-Hakim Mosque at Cairo
977–1186	Ghaznavid Dynasty in Afghanistan, Khurasan, N.E. India Capital at Ghazni		
992–1211	Qarakhanid Dynasty in Transoxiana and E. Turkestan		
1016–1086	*Reyes de Taifas* in Spain		1017–37: St. Sophia, Kiev (first Russian stone church)
1038–1194	Seljuks of Iran Capital at Rayy and Isfahan		1052–65: Westminster Abbey, London
1056–1147	Almoravid Dynasty in North Africa and Spain	1071: Defeat of Byzantines at Manzikert	1063–94: San Marco in Venice
1077–1327	Seljuks of Rum in Turkey		1113–50: Angkor Wat, Cambodia
1100–1215	Ghorid Dynasty in Afghanistan and Hindustan		Many Gothic cathedrals being built throughout Europe
1102–1408	Artuchid Dynasty in Upper Mesopotamia		
1127–1262	Zenghid Dynasty in Mesopotamia and Syria		
1130–1250	Almohad Dynasty in North Africa and Spain (1269)		1165: Notre Dame, Paris, begun
1169–1250	Ayyubid Dynasty in Egypt and Syria (1271)		1174: Campanile (Leaning Tower), Pisa
1196–1269	Merinid and Wattasid Dynasties in Morocco		1194–1260: Chartres Cathedral, France c. 1200: The Bayon, Cambodia
1206–1222	Sultanates of Delhi ruling northern India Mamluks (1206–1290) Khalji (1290–1320) Tughluq (1320–1414) Sayyid (1414–1451) Lodi (1451–1526) Suri (1526–1555)	1206–27: Genghis Khan leads Mongols into Islamic world	1200: Begin Quwwat al-Islam Mosque and Qutb Minar in Delhi
1228–1534	Hafsid Dynasty in Tunisia and E. Algeria		
1236–1492	Nasrid Dynasty in Spain Capital at Granada		1246–58: La Sainte Chapelle, Paris
1250–1517	Mamluks in Egypt Bahrites (1250–1382) Burjites (1382–1517)		
1256–1222	Ilkhanid Dynasty in Iran Capitals at Tabriz and Sultaniya		
1271–1218	Mamluks (of Egypt) rule Syria		1296–1434: Florence Cathedral
1300–1924	Ottoman Turks Capitals at Bursa, Edirne, and Istanbul		
1314–1292	Muzaffarid Dynasty in Iran and Kirman		
1336–1422	Jalairid Dynasty in Iraq, Kurdistan, and Azerbaijan		1353–91: Alhambra, Granada
1370–1200	Timurid Dynasty in Iran Capitals at Samarkand and Herat	1370–1404: Tamerlane's rule	
1380–1468	Turkoman Qara Qoyunlu in Azerbaijan and Iraq Capital at Tabriz	1453: Conquest of Constantinople	1394–1415: Ulu Cami at Bursa
1428–1599	Shaibanid Dynasty in Iran and Transoxiana	1492: Granada falls to Ferdinand and Isabella of Castile	1420–34: Dome of Florence Cathedral 1440: Pitti Palace, Florence 1485–1523: Jami Masjid, Champanir
1502–1736	Safavid Dynasty in Iran Capitals at Tabriz, Qasvin and Isfahan	1520–66: Suleiman the Magnificent, Ottoman ruler	1547–61: Dome of St. Peter's, Rome 1550–56: Mosque of Suleiman the Magnificent, Istanbul
1517–1502	Ottoman Turks gain control of Egypt and Syria		
1526–1858	Mogul Dynasty in India Capitals at Delhi, Fathepur Sikri, and Lahore	1556–1605: Akbar, Mogul ruler of India	1550: Villa Rotunda of Palladio, Vicenza 1565: Humayun's Mausoleum, Delhi

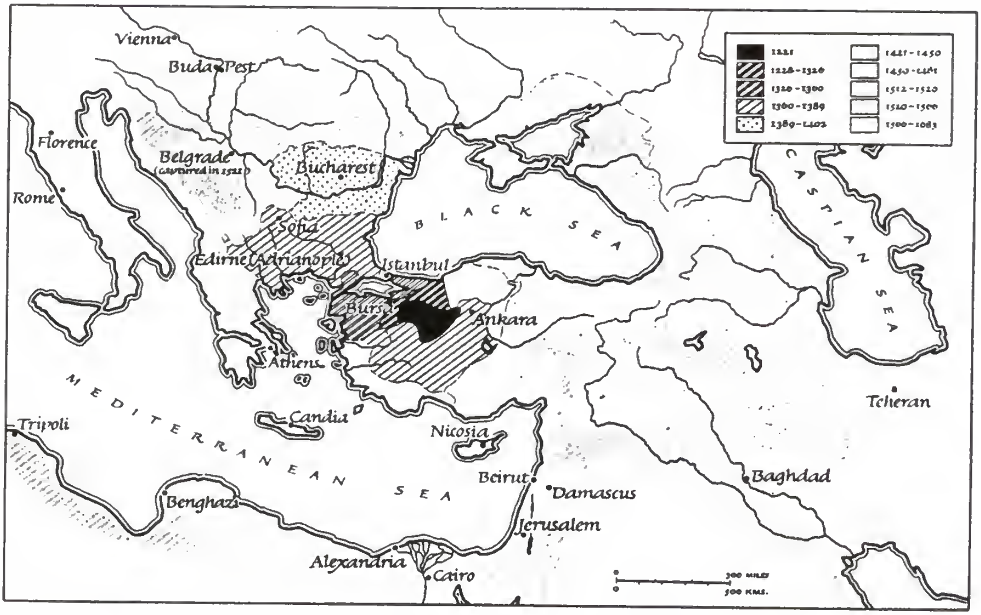
APPENDIX B

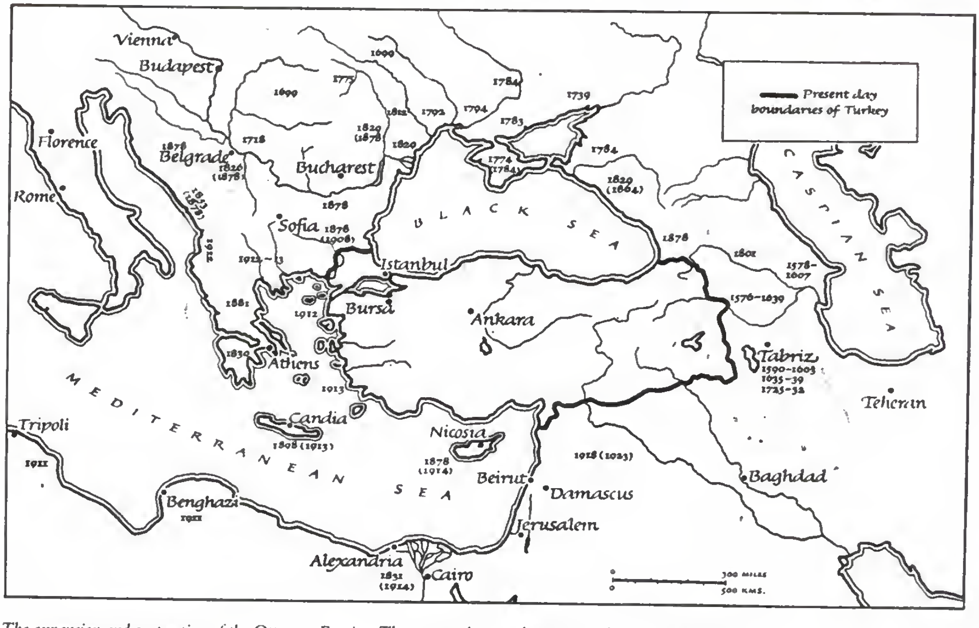
MOSQUES PROPOSED FOR ANALYSIS.

1. MOSQUE OF HACI OZBEK	IZNIK	1333
2. MOSQUE OF ALLAEDDIN BEY	BURSA	1335
3. MOSQUE OF HUDAVENDIGAR	BEHRAMKALE	MID. 14th.cent.
4. MOSQUE OF HOCA YADIGAR	INONU	1374
5. MOSQUE OF SAHABEDDIN PASA	EDIRNE	1436
6. MOSQUE OF KASIM PASA	EDIRNE	1478
7. MOSQUE OF FIRUZ AGA	ISTANBUL	1490

APPENDIX C

MAP OF OTTOMAN EMPIRE.





The expansion and contraction of the Ottoman Empire. These maps do not take account of minor fluctuations

APPENDIX D

LIST OF RULERS IN THE OTTOMAN EMPIRE.

OTTOMAN SULTANS		POLITICAL EVENTS		ARCHITECTURE
Osman Bey, 1281–1320(?) Orhan Bey, took title of Sultan, 1324(?)–62 Murat I (Hudavendigâr, or The Ruler), 1362–89 Beyazit I (Yıldırım or Lightning Beyazit), 1389–1402	1308 1321 1326 1349 1361 1371 1378–85 1389 1390 1397	Break-up of Selçuk Empire Ottomans reach Sea of Marmara Orhan Gazi takes Bursa Ottomans cross into Europe Murat I captures Edirne Ottomans reach the Adriatic Ottomans occupy Anatolia from Kütahya to Amasya Murat I's victory at Kosova Ottomans establish a navy in the Aegean Yıldırım Beyazit enters Athens	1331 1333 1334 1339 1365 1370 1376 1390 1396	Süleyman Pasha Medrese, Iznik Haci Özbek Cami, Iznik Orhan Cami, Iznik Orhan Cami, Bursa, begun Hudavendigâr Cami, Bursa, begun İsa Bey Cami, Selçuk Ulu Cami, Manisa Yıldırım Complex, Bursa, begun Ulu Cami, Bursa, begun
Süleyman, İsa, Musa, Mehmet dispute the throne until Mehmet I prevails, 1413–21 Murat II, 1421–44 and 1445–51 Mehmet II (Fatih or The Conqueror), 1444–5; 1451–81 Beyazit II, 1481–1512	1402 1448 1453 1481	Beyazit defeated at Ankara by Timur who overruns Ottoman Anatolia Murat II with the second victory at Kosova consolidates Ottoman power in the Balkans Ottomans take Constantinople Revolt of Beyazit's brother, Cem	1419 1437 1452 1463–70 1472 1484 1486	Yeşil Complex, Bursa, begun Üç Şerefeli Cami, Edirne, begun Rumeli Hisar, Bosphorus Fatih Complex, Istanbul Çinili Kiosk, Istanbul Beyazit Complex, Edirne, begun Beyazit Cami, Amasya
Selim I (Yavuz the Inexorable; in Europe known as Selim the Grim), 1512–20 Süleyman I (known in Europe as the Magnificent), 1520–66 Selim II (known in Europe as the Sot), 1566–74 Murat III, 1574–95 Mehmet III, 1595–1603	1509 1517 1521 1529 1537 1555 1570 1577 1589	Great earthquake in Istanbul Conquest of Syria and Egypt Süleyman I takes Belgrade The first siege of Vienna Raids on Puglia and Corfu Peace of Amasya (with Persia) Capture of Cyprus War with Persia renewed Mutiny of the Janissaries	1501–6 1518–20 1536 1543–8 1550–6 1562–5 1567–74 1586 1597	Beyazit Cami, Istanbul Fatih Pasha Cami, Diyarbakır Hüsrev Pasha Cami, Aleppo Şehzade Cami, Istanbul Süleymaniye Complex, Istanbul Mihrimah, Istanbul Selimiye, Edirne Muradiye, Manisa Yeni Cami, Istanbul, begun
Ahmet I, 1603–17 Mustafa I, 1617–18 Osman II, 1618–22 Murat IV, 1623–40 Ibrahim I, 1640–8 Mehmet IV, 1648–87 Süleyman II, 1687–91 Ahmet II, 1691–5 Mustafa II, 1695–1703	1622 1623–40 1648 1683	Janissaries depose Osman II Murat IV restores order and captures Erivan and Baghdad Janissaries depose Ibrahim I Second siege of Vienna	1609–16 1639 1663	Sultan Ahmet Cami, Istanbul Baghdad Kiosk, Topkapısaray Completion of Yeni Cami, Istanbul
Ahmet III, 1703–30 Mahmut I, 1730–54 Osman III, 1754–7 Mustafa III, 1757–74 Abdülhamit I, 1774–89 Selim III, 1789–1807	1730 1766	Murder of Sadrazam Damat Nevşehirli Ibrahim Pasha and deposition of Ahmet III, after popular uprising against taxes and Western ideas Great earthquake in Istanbul	1728 1748–55 1759–63	Ahmet III Fountain, Istanbul Nuruosmaniye Cami, Istanbul Laleli Cami, Istanbul
Mustafa IV, 1807–8 Mahmut II, 1808–39 Abdülmecit, 1839–61 Abdülâziz, 1861–76 Murat V, 1876 Abdülhamit II, 1876–1909 Mehmet V, Reşat, 1909–18 Mehmet VI, Vahdettin, 1918–22	1824 1894 1922	Massacre of the Janissaries by Mahmut II Severe earthquake in Istanbul Deposition of the last Sultan	1800 1826 1853 1918	Rebuilding of Eyüp Sultan Cami Nusretiye Cami, Istanbul Dolmabahçe Saray, Bosphorus Türbe of Mehmet V Reşat, Eyüp

APPENDIX E

MATRIX OF ANALYSIS RESULTS.

FINDINGS		1	2	3	4	5	6	7
WALL Thickness	Method "A"	-	A	A	-	A	-	A
	Method "B"	B	-	-	B	-	B	-
Entrance	Method "A"	-	A	A	A	A1	A	A
	Method "B"	-	-	-	-	-	-	-
Niche (MIHRAB)	Method "A"	A	A	A	A	A	A	A
	Method "B"	-	-	-	-	-	-	-
Windows	Method "A"	A	A	A	A	A	-	-
	Method "B"	-	B	B	-	B	B	B
Porch Span	Method "A"	A	-	A	-	-	-	-
	Method "B"	-	B	-	-	B	-	B

BIBLIOGRAPHY

Ardalan, Nader and Bakhtiar, Laleh. The Sense of Unity. Chicago : The University of Chicago Press, 1973.

Brunes, Tons. The Secrets of Ancient Geometry. Vol I & II. Copenhagen : Rhodes International Science Publication, 1967.

Bruckhardt, Titus. The Art of Islam. London : World of Islam Festival Pub. Co. Ltd., 1976.

Davies, G J. Temples, Churches and Mosques. A Guide to the Appreciation of Religious Architecture. Oxford. England : Basil Blackwell Pub. Ltd., 1982.

El-Said, Issam and Parman, Ayse. Geometric Concepts in Islamic Art. London : World of Islam Festival Pub. Co. Ltd., 1976.

Goodwin, Godfrey. A History of OTTOMAN ARCHITECTURE. London: Thames and Hudson, 1971.

Goodwin, Godfrey. Islamic Architecture- OTTOMAN TURKEY. London : Scorpion Pub. Ltd., 1977.

Gyorgi, Doczi. The Power of Limits, Proportional Harmonies in Nature, Art and Architecture. Colorado : Shambala Pub, Inc., 1981.

Hambidge, Jay. The Elements of Dynamic Symmetry. New Haven : Yale University Press, 1920.

Hambidge, Jay. Practical Applications of Dynamic Symmetry. New Haven : Yale University Press, 1932.

Hoag, John D. Islamic Architecture. New York: Harry N. Abrams, Inc. Publishers, 1977.

Kuban, Dogan. Muslim Religious Architecture. Part I. The Mosque and its Early Development. Netherlands : Inst. of Religious Iconography State University Groningen, 1974.

Kuban, Dogan. Muslim Religious Architecture. Part II. Development of Religious Architecture in Later Periods. Netherlands : Inst. of Religious Iconography State University Groningen, 1985.

Kuran, Aptullah. The Mosque in Early Ottoman Architecture. Chicago: University of Chicago Press, 1968.

Kuhnel, Ernst. Islamic Artr and Architecture. Chicago : The University of Chicago Press, 1968.

Michelle, George,ed. Architecture of the Islamic World. London : Thames and Hudson, 1978.

Pennick, Nigel. Sacred Geometry. Symbolism and Purpose in Religious Structures. Northamptonshire : Turnstone Press Ltd., 1980.

Schimmel, Annemarie. Islamic Calligraphy. E.J. Brill, 1970.

Scerrato, Umberto. Monuments of Civilization - ISLAM. New York : Crosset and Dunlap Pub., 1976.

Wade, David. Pattern in Islamic Art. New York : Macmillan Publishers Co. Inc., 1976.

Vogt- Goknil, Ulya. Living Architecture OTTOMAN. New York :Grosset and Dunlap, 1966.

A STUDY ON THE USE OF GEOMETRIC PROPORTIONS USED TO DESIGN SINGLE UNIT MOSQUE PLANS IN THE OTTOMAN TURKISH EMPIRE

by

AZIZ V. BOOTWALA

B. Arch, L. S. Raheja School of Architecture.
Bombay, India, 1985.

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfilment of the
requirements for the degree

MASTER OF ARCHITECTURE

College of Architecture and Design

KANSAS STATE UNIVERSITY

Manhattan, Kansas.

1988

ABSTRACT

The term geometric proportions has been closely related to the history of architecture, with special reference to religious buildings. In Islamic architecture there is seen to be extensive use of geometric proportions in designing mosque plans. The purpose of this research is to analyse the plan forms of mosque designs and to determine the methodology used to design mosques based on the principles of geometric proportions. Since it is beyond the scope of this research to study the development of mosque designs in all periods of Islamic history, the study is restricted to single unit mosque buildings in the Ottoman Turkish Empire.

The Ottomans contributed tremendously towards the development of mosque designs. They concentrated mainly on the organisation of space. Single unit mosques consisting of a square prayer room, a porch and a minaret were developed throughout the Ottoman rule. The form of the plan is based on the use of geometric proportions. Analysis of these plan forms is the main subject of study. The methods used for analysis are based on the analysis patterns developed by Tons Brunes and Jay Hambidge.

The analysis indicated the methods based on geometric proportions that can be used for developing single unit mosque plans. Based on the analysis there is evidence of two well defined methods that were used to design mosque plans. Primarily the methods help in determining the perimeter, the wall thicknesses,

the location of windows, entrances and niches and the width of the porch. A matrix developed at the end indicates the similarities and differences found in the various plans used as study samples.