Evolution of the Architectural Form Based on the Geometrical Concepts

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ABSTRACT

This study aims to reveal utilizes of basic geometrical elements in aspect to architectural form and space organization. In this consideration, architectural idea has been taken up within the framework of form, space, and geometrical concepts throughout the study.

Essentially, this work has three major objectives. The first is to look at the basic geometrical elements (point, line, plane, primary shapes, solid, etc.) which are based on the grammar of architectural form and then define the grammar that can be used to organize meaningful architectural compositions. The second objective is to relate these components of architectural form and to show how to organize them within the framework of geometrical rules. Through this organization the reader will develop to ability to consciously read a work of architecture and perhaps will even enhance his ability to design by using the grammar as a framework for logical self-criticism. The third is to look at the examples of building which have been designed according to geometrical concepts throughout the history of architecture. As a result of this overview it is aimed that architects still find some inspirations from earlier or current buildings while analyzing or designing them geometrically.

It is hoped that in the end the reader will have developed a greater understanding and enjoyment of architecture. And if he/she is and architect, his/her works may become more effective.

Key Words:

Basic Geometry, Pure Geometrical Forms, Geometrical Organizations, Formal Design, Abstract Geometrical Concepts, Design Fundamentals, Geometrical Design, Architectural Morphology.

ÖZ

Bu çalışma temel geometrik elemanların mimari form ve mekan organizasyonu oluşturmaya yönelik yararlı kullanımlarını ortaya çıkarmayı hedeflemektedir. Bu anlamda mimari fikir, form, mekan, ve geometrik kavramlar çerçevesinde ele alınmıştır.

Çalışmanın üç temel amacı vardır. Birinci amaç mimari formu oluşturan geometrik elemanların (nokta, çizgi, düzlem, hacim, temel geometrik şekiller vb...) ortaya çıkarılması ve anlamlı kompozisyonlar üretebilmek için kullanılan bu elemanların tanımlanması. İkinci amaç, bu temel geometrik elemanların kendi aralarındaki ilişkilerin ve biraraya geliş şekillerinin geometrik kurallar çerçevesinde gözler önüne serilmesi. Okuyucunun bu organizasyon ve düzenleme yöntemlerinden, daha önceden yapılmış bir binayı okuma yeteneklerini geliştirecek ipuçları almaları ve hatta bu organizasyon pensiplerinden kendi tasarımlarına katkıda bulunacak yararlı veriler elde etme olanakları bulacakları düşünülmüştür. Üçüncü olarakta, tarihte daha önceden yapılmış ve günümüzdede yapılmaya devam eden geometrik kavram esaslı çalışmalara gözatmak amaçlanmıştır. Bu şekilde mimarların bir binayı tasarlarken yada tasarlanmış binayı analiz ederken zengin bakış açısı kazanması arzulanmıştır.

Çalışmanın sonunda okuyucunun mimari zevk ve anlayışının gelişmesi beklenmektedir. Bu çalışmayı okuyan okuyucunun, eger mimarsa, daha etkin tasarımlar yapabileceği umulmaktadır.

Anahtar Kelimeler:

Temel Geometri, Saf Geometrik Formlar, Geometrik Düzenlemeler, Formal Tasarım, Soyut Geometrik Kavramlar, Tasarım Olguları, Geometrik Tasarım, Mimari Morfoloji.

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EVOLUTION OF THE ARCHITECTURAL FORM BASED ON THE GEOMETRICAL CONCEPTS

1 INTRODUCTION

1.1 DEFINITION OF THE PROBLEM

Geometry is a formative idea in architecture. It has been used as design tool since the very beginning of the architectural history. It is most common determinant of characteristic in building forms.

Geometry has been utilized on a broad range of spatial or formal levels in architectural design. In architecture, application of geometry includes the use of simple geometric shapes, solids, and varied form languages. Architects have been obtained more complex forms and spaces by using these geometrical elements and form languages.

Geometry basicly consist of point, line, plane basic shapes such as triangle, circle, square, etc, solids such as pyramid, cone, cube, etc by mathematical aspect. Those abstract elements have given a base to variety of geometries as conceptual through the history. Also we could see all use of those elements in architecture currently. Those are the elements which is directly effect forming of space and architectural form as in either constructional or conceptual meaning. In other words, those elements have added aesthetic, symbolic and conceptual richness to architectural design. For that reason, architects are widely used those elements especially in architectural space organization and relatively generation of architectural form in disciplin. Architects easily express the forms generated by them as conceptual by utilizing those geometrical elements.

Architects use those elements for replying different requirements (philosophic, aesthetic, or economic) in various steps of design such as plan, section or façade. Conceptual or constructional process of building form could only be explained by geometrical elements either pure or processed, or assembling with other elements in the way of principals of organization. In architecture those basic elements are enlargedly utilized both in two dimensional-planar elements and in three-dimensional-volumetric elements. Noticing of those geometrical elements and organization principals helps architects to utilize from geometry more effectively and adds the design much more reachness, and also gains a new design approach.

To sum up, those geometrical elements are used as an important determinant that signifies the character of composition of architectural form and space. Generation of form and space by utilizing basic geometrical elements makes them important inputs in architectural design. Generating the architectural form and space based on the geometrical rules and abstracting them within basic geometrical elements make the resulted form more understandable and recognizable.

1.2 THE AIM OF THE STUDY

Many architects throughout the history of architecture have always looked for ideas which will give form to their work and direction to their design. A geometrically determined definition of form and arrangements of parts made it possible for both architects to express architectural ideas clearly, and further, to allow for the development of sub-themes and variations which could be understood against the strong underlying formal order. Geometric ideas have became ground rules in the name of directing or making a complete understanding of previous studies for architectural design. With respect to that, basic geometrical elements are of utmost importance for generating of architectural form and space. One of the aim of the study is to define and clarify those elements as vocabulary of generating architectural form and space in conceptual meaning.

When we look at the history of architecture we see that there are many ways to organize architectural form based on utilizing of basic geometrical elements. These principles of organization of architectural form should be known by architects in order to design or analyze to their buildings. From this point of view, as a focus for study, one of the aim of this study is to show the effects of geometrical concepts on generation of architectural form and space, and establish a set of ground rules that guide architectural composition. In other words, the aim of the study is to make utilization of those elements in relation to form and space organization. Morphological relations of those either alone or conjuncting with other elements are targeted for transferring it in understanable and applicable format to architects or students. And these relations are abstracted and simplified to understand and employ by architects and students.

Using of those elements in architecture makes a way of placing different disciplines such as philosophy, religion, fundamentality, etc. in architecture easily. Also utilizing from those either as processed or pure add some symbolic, philosophical, fundamental and religious meanings to architecture. As a consequence, study are aimed to make entire definement for clarifiying relationships between different disciplines. In other words, study aims to achieve transferring theories being developed based on basic geometrical elements to readers.

1.3 THE METHOD OF THE STUDY

Study is constructed around three main parts. In the first stage, wishing is to make a research on geometry as a supporting element in architectural design. At the second stage, the study is attempted to define the characteristical structure and geometrization process of architectural form in general meaning. At the end, basic geometrical elements in conceptual meaning are researched for utilizing in space and form organization processsing. Through the overall study, logical structure between three main parts is efforted to explain around relations of cause and result.

In the first stage, primarily geometry was defined in mathematical discipline. After that using of geometry in architectural design with encircling different types of geometry was attempted to define. In this consideration, the questions of "why geometry is needed in architectural design and how it is used, what reasons for knowing geometry by designer, what contributions of geometry in space organization in conceptual meaning are", were tried to answer. As a result of answering them, it was gotten that it would be limited the study for become more clear. At this stage, in addition, basic geometrical elements were specified as vocabulary of design and searched the possibility of application them in various stages in architectural design.

At the second stage all doing was a definition of characteristical structure of architectural form. In the era from Vitruvius to Eisenman, different ideas on origin of architectural form and theories having been developed on architectural form were clarified. In respect to above, basic geometrical elements toward use of geometrization of architectural form were examined with a retrospective point of view and with foundation of major historical periods. The pure use of these elements as point, line, plane, shape and solid were clarified with spectrum of added examples on study.

At the last part, on basic geometrical elements having been clarified before were made a research on utilizing came from assembling and processing of them. Conceptually, those basic geometrical elements were worked for defining how they were combined, recombined, organized or regulated systematically by using methods as rotation, shifting, variation, inversion, and displacement. In this respect utilizing of those elements for architectural design are branched in two main groups. Firstly processed use of only one geometrical elements and secondly assembling operations of any number and types of elements were already researched.

2 GEOMETRICAL BACKGROUND OF ARCHITECTURAL DESIGN

2.1 HISTORICAL DEVELOPMENT OF GEOMETRY

Geometry is a mathematical system that is usually concerned with points, lines, surfaces, and solids. All mathematical systems are based on undefined elements, assumed relations, unproved statements, and proved statements. Different sets of assumptions give rise to different geometries. *(Grolier Encyclopedia)*

The word geometry is derived from the Greek words for earth and measure. Geometric figures first appeared over 15,000 years ago. These geometric figures used as shapes of buildings and decorations on pottery.

The study of geometry has flourished throughout the ages. In the ancient world civilizations in Egypt, Sumer, and Babylonia studied geometry. These civilizations studied the empirical side of geometry that was useful in their architecture. The Greeks then refined it into a more demonstrative geometry. The geometry of the Greeks dealt mainly with polygons, circles and three-dimensional shapes.

Thales developed the first general theorems for geometry. Pythagoras tried to explain all aspects of the universe in terms of counting numbers. These counting numbers of Pythagoras were represented by sets of objects arranged in geometric shapes. Plato was the another philosopher who was emphasized geometry in his academy. He used the five regular polyhedrons to explain the scientific phenomena of the universe. As a pupil of Plato, Aristotle developed the laws of logical reasoning. Euclid was structured the mathematics into a logical system. Even today, the geometry of Euclid's elements is assumed to be true geometry.

Modern geometry continues to deal with ancient problems, but it is not confined to Euclid's plane. There are new progressions in modern geometry, for example, in elliptic geometry all lines meet, and in hyperbolic geometry, there are infinitely many parallels to a line through each point. Another novelty in this period is that, the shortest distance between two points is not a straight line any more. Apart from that, in Modern Geometry, with fractals, different kinds of sciences come together. Some of them are Biology and Meteorology, Mathematics and Art.

2.2 RELATIONSHIP BETWEEN THE NATURE AND GEOMETRY

Humans abstracted to essential characteristics of natural elements throughout history. For example, the Sun and Moon were idealized in the circle. Circle also used at symbolizing the cosmic wholeness of the psyche. In the another example, the cardinal orientation points were idealized in the square. Beside this role, square symbolized the physical world of body and matter. As a result of the dialogue between forms found in nature, humans produce some geometric forms and figures such as circle, square, and so on.

The harmony inherent in geometry was a metaphysical pattern. It determined the physical nature of all things. Rationalization of natural system is obtained by interpretation of geometry within the terms of numeric relationships. Rationalization of natural system was necessary for division of space.

Geometrical laws exist within the natural world in order to express fundamental relationships. Natural world is operated according to certain geometrical laws. That does not mean that Nature obeys the geometrical laws. Geometry attempts to describe nature through symbolic notation. The concept of geometric form is rooted in subjective interpretations of nature. The logarithmic spiral of the golden section can be found in the fossilized remains of a nautilus shell. A square can be found, in the same way, in the cross-section of a pepper, cubes in crystals of pyrite.

In Vitruvian Man, Leonardo da Vinci placed the male figure within both circle and square. Man is represented as being at the center of creation, occupying both the irrational world of nature and the rational world of humanity.

Francesco di Giorgio Martini used the human torso at the center of the circle and square to generate a planning system for cathedral design. His drawing of "cathedral man" is fully congruent with Michelangelo's floor plan at St. Peter's in Rome, the ancient mandala centered on the heart of the church where the nave and transept cross.

2.3 TYPES OF GEOMETRY USED IN ARCHITECTURAL DESIGN

The most known geometries in mathematic are Euclidean geometry, projective geometry, analytic geometry, differential geometry, Non-Euclidean geometry, topology, fractal geometry, and descriptive geometry.

Projective geometry results from the application of the projection to geometry. Analytic geometry results from the application of calculus to geometry. It is the union of algebra and geometry. Descriptive geometry consists of the orthogonal projections of solid object onto a set of planes mutually perpendicular to each other to give plans and elevations. It facilitates the process of design or construction operations. Differential geometry uses calculus as a tool to investigate the properties of curves and surfaces. Non-Euclidean geometry is obtained by replacing Euclid's parallel postulate by one of its contradictory forms. Topology is the study of those properties of objects, which are not altered by stretching or bending. It has came to be regarded as a fourth division of mathematics, along with algebra, geometry, and analysis.

Among these geometries, ones most commonly used in architectural design will be mentioned below:

2.3.1 EUCLIDEAN GEOMETRY

Euclidean geometry is the study of points, lines, planes, and other geometric figures, using a modified version of the assumptions of Euclid. The development of Euclidean geometry extends at least from 10,000 BC to the 20th century. It was of great practical value to the ancient Greeks as they used it to design buildings and survey land. Even we still have used it today. *(Grolier Encyclopedia)*

The geometry in the Elements was a logical system based on ten assumptions. Five of the assumptions were called common notions, and the other five were called as postulates. The resulting logical system was taken as a model for deductive reasoning. This logical system had a profound effect on all branches of knowledge. Euclid's geometry is based in a plane or in the case of three-dimensional a space such as depicted in a normal axis system.

Set of proportions in geometry that can be derived by rigorous logical steps from the five postulates stated by Euclid in his elements. The five postulates are:

1. A straight line segment can be drawn, between any two points
2. Any straight line segment can be extended indefinitely
3. A circle of any radius can be drawn, about any point
4. All right angles are equal
5. If a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced infinitely, will meet on that side on which are the angles less than two right angles.

In addition to these postulates there are some definitions in the Elements of Euclid. The most known of these definitions are:

- A point is that which has no parts, or which has no magnitude
- A line is length without breadth
- The extremities of a line are points
- A straight line is that lies evenly between its extreme points
- A superficies is that has only length and breadth
- The extremities of a superficies are lines
- A plane superficies is that in which any two points being taken, the straight line between them lies wholly in that superficies
- A plane angle is the inclination of two lines to one another in a plane, which meet together, but are not in the same direction
- A plane rectilinear angle is the inclination of two straight lines to one another, which meet together, but are not in the same straight line (a graphic survey of perception and behavior for the design professions)

2.3.2 ANALYTIC GEOMETRY

Analytic Geometry is the branch of geometry in which points are represented with respect to a coordinate system, such as Cartesian coordinates. This geometry allows problems in algebra to be treated geometrically and geometric problems to be treated algebraically. The methods of analytic geometry have been generalized to four or more dimensions and have been combined with other branches of geometry. *(The Concise Columbia Electronic Encyclopedia, 1994)*

In 17th Century, Euclidean Geometry was incapable of providing some models. In mathematics, it was required more information on ellipses than Euclidean geometry supply. It was also required a more flexible method of manipulating these curves. Such needs of this time were eventually met by analytic geometry.

In Analytic geometry, pairs of numbers are represented by points in plane. Lines and curves are viewed as the locii of points moving according to specified equations. The x-axis is called as the abscissa, and the y-axis is called as the ordinate. All of Euclidean Geometry can be subsumed within analytic geometry. Fundamentally analytic geometry includes three-dimensional Cartesian system, in which the axes are labeled x, y, and z. Cartesian system facilitates to work with in the three-dimensional environment. Apart from that, analytic geometry includes many objects that are formed with curves and surfaces, which could not be described in Euclidean Geometry.

Three-dimensional conic forms and shells are the elements that are the most shared in architecture. In antique epoches, they were difficult to construct. Such elements of antiquity were made of blocks of stone that had to be cut to the right shape anyway, but modern structures are usually made of concrete that requires a framework. In assistance of the advantages of analytic geometry, such elements can be easily shaped after being moulded. Shells, ruled surfaces, doubly ruled surfaces are intensely used as structural elements in architecture by prodded of analytic geometry.

2.3.3 FRACTAL GEOMETRY

Fractal Geometry is a modern mathematical theory. It radically departs from traditional Euclidean Geometry. It is the formal study of mathematical shapes that display a progression of never-ending, self-similar, meandering detail from large to small scales. This means that when such objects are magnified, their parts are seen to bear an exact resemblance to the whole. In other words, the likeness continues with the parts of the parts and so on to infinity. Fractal geometry deals with shapes found in nature that have non-integer dimensions line-like rivers with a fractal dimension of about 1.2 and cone-like mountains with a fractal dimension between two and three. Natural shapes and rhythms, such as leaves, tree, mountain ridges, flood levels of a river, wave patterns, and nerve impulses, display this cascading behavior. These fractal concepts are found in any fields, from physics to musical composition. Architecture and design, concerned with control over rhythm, and with such fractal concepts as the progression of forms from distant view down to the intimate details, can benefit from the use of this relatively new mathematical tool. Fractal geometry is a rare example of a technology that reaches into the core of design composition, allowing the architect or designer to express a complex understanding of nature. *(Bovill, 1996)*

Mandebrot has stated that, all objects found in nature could not be defined by using Euclidean Geometry. From this point of view, he proved that it is possible to define all objects found in nature using Fractal Geometry. He claimed that, Modern Mathematics, Music, Painting, and Architecture seem to be related to one another. He showed also the roles of this geometry in architecture. A Mies van der Rohe building is described by Euclidean geometry while Beaux-Art building is rich in fractal aspects.

In architectural design, Peter Eisenman has used fractal algorithms as an inspiration source. One of these designs is Fin d'Ou T H ous project. The other one is Bio-Centrum Project in Frankfurt. He explained that his approach for this project is based on the Fractal Geometry. In this project Eisenman has departed from the traditional representation of architecture by abandoning the classical Euclidean Geometry.

Fractal geometry has been also used as planning grids, which are helpful in the coordination of layout of a building. Traditionally these grids are Euclidean. In the example of Villa Rotunda, building is designed with fractal planning grid using the fractal distribution. Grids of lines coordinate the layout of the building. The rhythms set up by the lines are symmetrical in two directions. In this example, fractal rhytms have been used to produce planning grids that utilize the rhytms of nature as a source of layout inspiration. (Fig 2.1)

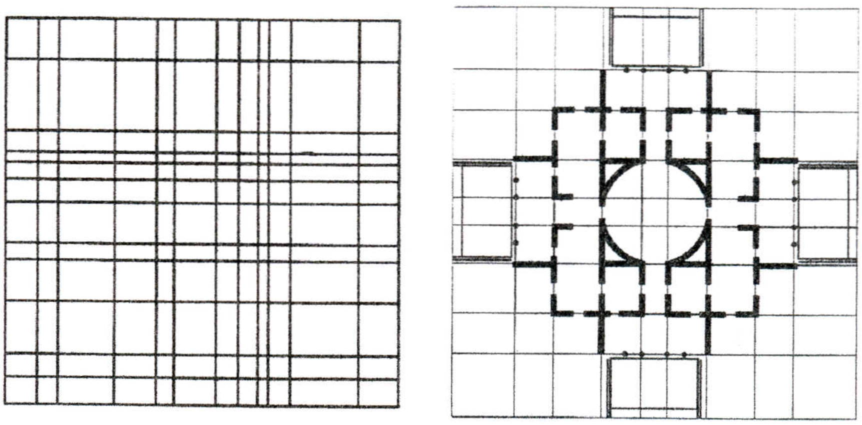


Fig 2.1 Fractal Planning grid based on the fractal rhythm for Villa Rotunda

2.3.4 NON-EUCLIDEAN GEOMETRY

It is hard to understand the Non-Euclidean Geometry for most people. People think it in an abstract way. In other words Non-Euclidean Geometry is an abstract part of mathematics. It takes the proof that two parallel lines never meet and shows how they can meet at a point. Within the range of this geometry, if two parallel lines are bent around a sphere, these lines meet at the top and bottom of the sphere. Non-Euclidean Geometry brought the invention of two types of geometry, Spherical and Hyperbolic Geometry. Geometry up to this point was mostly done on flat surfaces or plan geometry. With the thought of spherical and nonlinear geometry in mind once again math had created its uncertainties and challenges. Distances and sums of degrees in triangles that people once accepted as fact were now questionable; dependent upon what type of surface they were on. *(Carter, 1996)*

One of the most useful Non-Euclidean geometries is Hyperbolic Geometry, which was played an important role in Einstein's general theory of relativity. Apart from that Hyperbolic Geometry is very important in the field of Topology. It is a "curved" space. Hyperbolic Geometry helps us understand what an axiomatic system is proofs, theorems, postulates, and definitions. Hyperbolic Geometry has the property that lines starting in the same direction will get further and further away from each other. The other useful Non-Euclidean Geometry is Elliptic Geometry. Elliptic geometry has the property that lines starting out in the same direction get closer to each other and meet.

2.3.5 DESCRIPTIVE GEOMETRY

Descriptive Geometry was appeared first as a new mathematical discipline in the last decade of the 18th century. In this period of time, Gaspard Monge's Geometrie Descriptive reduced to the realm of algebraic analysis. This book studied by the students of the Ecole Polytechnique and it is the geometry of the new architects and engineers graduating from the Ecole Polytechnique. Descriptive Geometry was played an important role as an instrument in the genesis and development of industrialism and rational building during the 19th century. It subjected the arts and crafts of the goals of technology. Beside that, it represented the first possibility of a precise mathematical description of reality.

Monge's method was the first to provide a truly synthetic system that could be universally applied to all arts and crafts. Descriptive Geometry thus constituted a complete theory and practice of the operations that result from the combination of lines, planes, and surfaces in space. It concerned stonecutting, carpentry, fortification, and perspective. Apart from that it also concerned mathematics in which three-dimensional space figured. Descriptive Geometry is a mathematical discipline whose fundamental principles can be proven analytically. Beside that, it is also a tool for reducing three-dimensional objects into two-dimensional space.

In Journal Polytechnique, Gayverman asserted that only after having studied the application of descriptive geometry to the different arts and crafts could the architect be in a position to determine the exact form and composition of his buildings and their parts. In a different volume of the same journal, Monge pointed out that descriptive geometry provided a knowledge of forms of the different parts involved in all sorts of buildings, which were relative not only to the buildings stability but also to their decoration. *(Gomez, 1994)*

2.4 DEFINITION OF GEOMETRY BASED ON THE BASIC CONCEPTUAL ELEMENTS

Before the definition of the geometry in architecture, it should be defined what roles have the geometry in architectural design.

- Geometry affords us the power to realize geometrically conceived forms with ease.
- It gives us the ability to describe form with precision.
- It can make every person enjoy a sense of divinity by the mere existence of the undeniability and perfection of the geometric shapes.
- It has solved the problems inherent in the geometry of shapes, thus giving us sets of ready-made forms that can be manipulated in a variety of ways. *(Antoniades, 1992)*

Geometry is interested in the subjects of point, line, plane, basic geometric shapes (circles, triangles, squares), angles, solids (cones, spheres, cube), and so on. These elements play an important role in architectural design in order to generate architectural form. Using these basic elements within the framework of organizational principles, architects produced objects and generated building forms. These elements which have been mentioned above are also pure and abstract geometric figures in the geometry. They are sometimes thought to have an aesthetic or symbolic power in design. These elements can be described as a vocabulary, which is used to generate more complex architectural forms. Architects have used these basic elements within the discipline of geometrical principles. In the forward chapters it will be showed how to use the elements in architectural design in order to generate architectural form.

All through the history of architecture, geometric shapes and solids have been used. These simplest geometric elements, with help of proportions, make architecture pleasing to the eye. By advancing the basic geometric shapes the structure capabilities are also enhanced. The most elementary shapes, either singly or in combination are the regular polygons. They are the basis for prisms, pyramids, patterns, and many other parts of architecture. Regular polygons are symmetrical, equilateral, and equiangular. Those of side three, four, five, and their fist truncations are most commonly used. Truncation is the means of changing a shape by cutting the corners back. All regular polygons have right triangles, isosceles triangles and rectangles present. The right triangle is the primary element of the triangles. The height of the right triangle is the radius of the polygons. When height and thickness is added to the regular polygon it has the possibility of becoming a prism.

The patterns can be rotated, transposed, overlapped, interlaced, and interlocked with other forms to create another geometric forms. The use of primary shapes creatively, as a formative generator is the one of the most frequently used method in the architectural design. More complex configurations are possibble through manipulation of forms derived from several primary geometrical shapes. For example, grids are methods most frequently used in architectural design. Architects have used square, rectangular, triangular or circular modular grids extending them to three-dimensions. Combination and manipulation of grids like basic geometric figures by rotation; translation and overlapping can be utilized to create more complex architectural forms.

In the ancient period of time, the Egyptian pyramids and tombs were built using geometric figure of triangles, rectangles and squares. Apart from those cones, prisms, pyramids and other shapes were used for constructing the roofs of the cathedrals and palaces. Beside these, circles and semicircles were used to construct amphitheaters, stone monuments, and arches. In the following applications, the circles are mixed with rectangles to produce a curve.

Greek architects developed a system of proportions based on the low diameter of the temple columns. Multiplication and division derived the spatial intervals and measurement of masses. Medieval architects used it based on the measurements of areas in the cathedrals. In Gothic period, architects used equilateral triangle and the square to design buildings.

During the pioneer time of America, houses and barns were made out of Squares, triangles and circles. When two of theses shapes are placed together to form a building, the lines between the shapes disappeared. The two shapes become one. Most buildings were made from squares and triangles. To change the shape and look of the buildings, the builders add or subtract squares and triangles. For example, to make a shed attached to a barn, they would add another square and then top it with a triangle. A porch could be added to a house by subtracting a square from the existing building. All buildings were made up of either open space or shapes. The open space becomes the windows and doors, while the shapes were the frameworks.

The Indian tepees look like right circular cones. The tepee is in fact a pyramid with a polygonal base of eighteen or more sides. The shape of the ground is more of an oval shape then a circle. As the number of sides increase the pyramid looks more and more like a right circular cone.

2.4.1 DIFFERENT USAGES OF CONCEPTUAL ELEMENTS IN ARCHITECTURAL DESIGN

Basic geomerical elements and geometrical rules are used so wide spectrum of purposes in architectural discipline. For example such basic geometrical elements can be used conceptually in either two or three-dimensional organization of form and space. Apart from that it had a role of designing the different constructive elements that in the spectrum from biggest scale to the narrest one. In other words, in architectural design, these geometrical elements are used at full scale of building. Accomodation of the building on site, construction of the staircase in section using three-four-five triangle, giving shape to the windows in elevation are some of the relevant examples how these geometrical elements are used for different purposes. Some of these methods are:

Constructing the window of the Gothic churches:

One of the most typical elements of Gothic architecture is the tracery. It founds in windows and on walls in Gothic churches. It is constructed from circular arcs and straight line segments. Gothic window based on the equilateral triangle. The theme of the windows is geometry itself. (Fig 2.2)

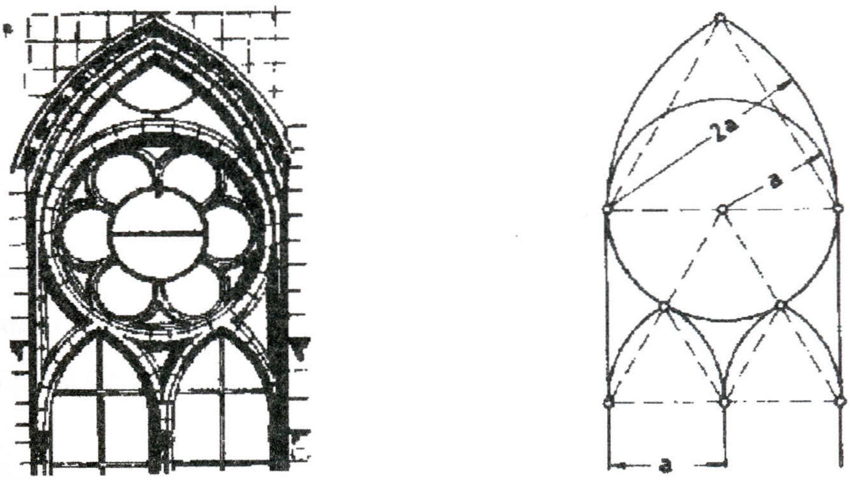


Fig 2.2 Construction of the window based on the equilateral triangle

As a plan generator using transformational Geometry:

One of the effects of the new geometrical ideas on architecture was a gradual transformation of space from pure, static, and isolated to composite, dynamic, and interpenetrating. Transformational operations were geometrical methods, which could be used for plan generators. (Fig 2.3) These operations were including area, rotation, reflection, translation, and coordinate transformation. There are many examples of these transformational operations in architecture.

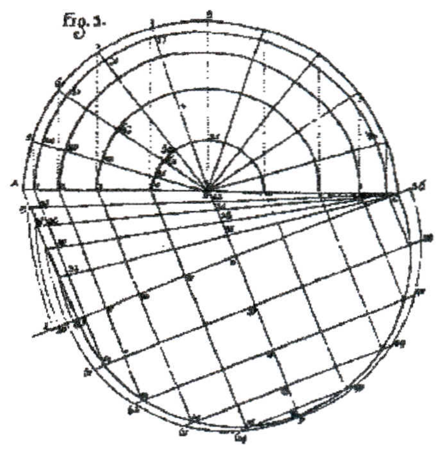


Fig 2.3 Diagram of the transformational geometry by Guarini

Use for design and decoration of the building:

The Domus was one of Romans earliest building types. It embodies the basic characteristics of Roman design. Analysis of houses suggests that two simple geometric systems underlie the design of these houses at all scales.

One geometric system used in the Domus is the ad quadratum. In this series of squares the side of each square is equal to the diagonal of the next smaller square. This progression can be constructed by joining the midpoint of the sides of a square. (Fig 2.4.a) Other geometric system is the sacred cut. Starting with a given square and its diagonals, arcs are drawn with a compass centered at each corner of the square, with a radius equal to half the diagonal, going through the center point of the square. Each of these arcs intersects two adjoining sides of the square, dividing each side into three segments, with the center larger than the side segments. Connecting the points where the sides are cut by the arcs gives the nine-port grid. The large central square of the grid will be referred to as the sacred cut square of the original square in the corners of the grid have sides equal to half the diagonal of the sacred cut square. (Fig 2.4.b) *(Williams, 1996)*

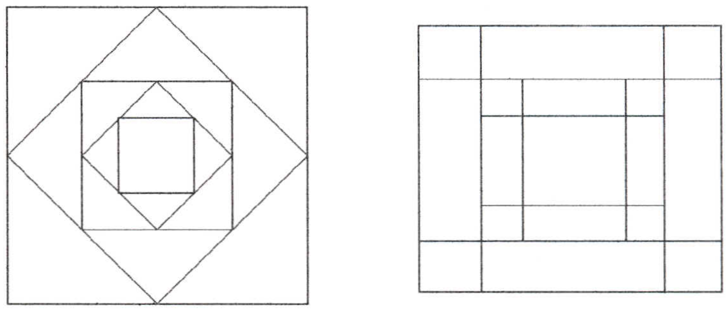


Fig 2.4 Geometric schemas of ad quadratum and sacred cut

The two geometric systems, both based on the square. They can be constructed using only compass and straight edge. The square and circle are closely related in this geometry. These systems emphasize a center through concentric reiterations of the same geometric operation. Concentric reiteration is used in variety of scales in house, for example, in the central atrium space or central floor mosaics. (Fig 2.5)

These geometric systems explain the proportional relationships between the shape of house site and its organization and subdivision. Apart from that, they are used to determine the proportions of volumes of space throughout the house.

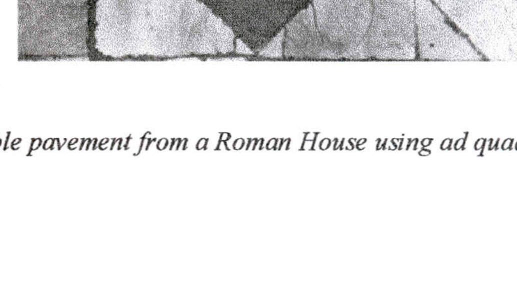


Fig 2.5 Marble pavement from a Roman House using ad quadratum geometry

Use of datum frame as geometrical Ordering techniques:

Throughout the history, geometric properties have been utilized in the architectural applications as part of design and construction process. The Watts house is an important example of geometrical design process in architectural design. In this example, geometric properties have been used while setting out the design upon the site using datum frame. (Fig 2.6) This directness of application extends to the actual construction process where some of the geometrical design processes are also done at full scale. In addition, it provides a ready feedback and verification of the design in the field. In doing so, the process allows for improving the fit between the original design intention and its final implementation. *(Williams, 1996)*

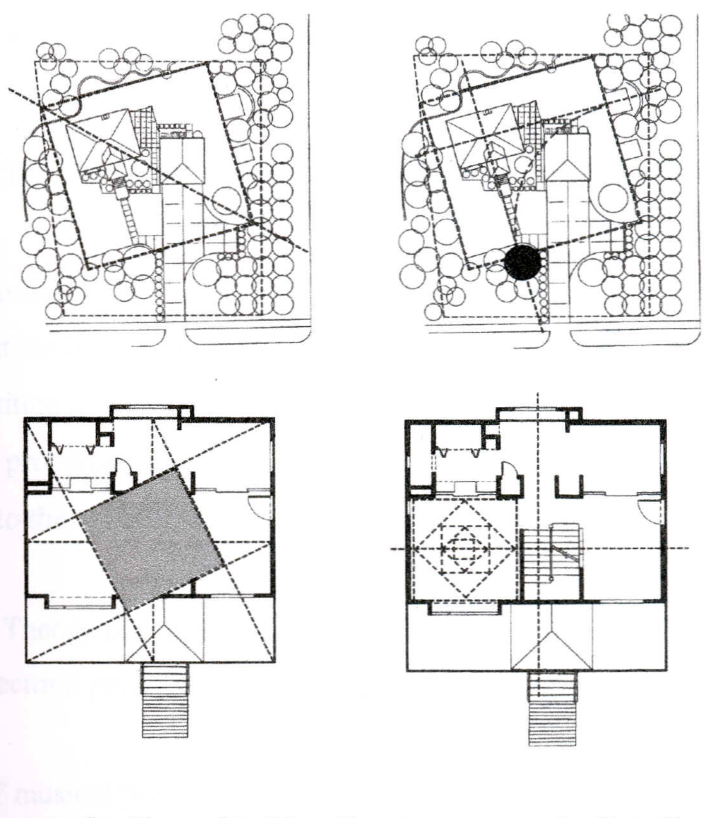


Fig 2.6 Site Plan and Building Plan datum squares for Watts House

Interpretation of the minimal surface of J. Plateau:

The surface generated with dipping the three-dimensional model of curve into soapy water by Joseph Plateau, has become a factor affecting the forming of cities and buildings after a while. It represents the least exterior surface of all surfaces containing the same volume of air. As an isoperimetric property, its circumference encloses the largest surface area. The people of ancient times were aware of this isoperimetric property founding a town. A town wall of the least possible length containing the largest area had to be circular. C.N. Ledoux presented a circular plan for a town, the form as "pure as the one the Sun describes in its movement." Like the circle, the sphere also appears in architecture. Ledoux planned a spherical house. Apart from that, Boullee used the sphere in the cenotaph of Newton. The hemispherical igloos of the Eskimos solve the problem of a structure based on a plane with the greatest possible volume for the same external surface.

2.4.2 GEOMETRIC SYSTEM OF PROPORTIONS IN ARCHITECTURAL DESIGN

Systems of proportions have facilitated the technical and aesthetic requirements of a design throughout the history of architecture. These systems of proportions have to:

- ensure a repetition of a few key ratios throughout the design
- have additive properties that enable the whole to equal the sum of its parts
- be adaptable to the architect's technical means

In his book The Theory of Proportion in Architecture, P.H. Scholfield discusses three systems of architectural proportion:

1- the system of musical proportions used during the Renaissance developed by Leon Battista Alberti,
2- a system used during Roman times,
3- the Modulor of the twentieth-century architect, Le Corbusier,

While the Roman system is based on the irrational numbers, the Modulor is based on the Golden Mean. Both of these systems can also be approximated arbitrarily closely by integer series, and these integer series can be used to implement the system with negligible error.

In the Alberti's architecture, there was intimate relationship between number and architecture. Alberti's architecture reflected a supreme harmony and musicality because the divine numbers of Pythagorean and Neoplatonic thought correspond to architectonic measures. Nature, the Universe, and God are reflected through a total musicality. (Audible music, and crystallized music in architecture). According to Alberti mathematical order is not only the order of the divine, but also the basis for any order that can be achieved in reality. Apart from that, for him, all values of the principle dimensions of the building may be encompassed in a system of a few mathematical relationships.

3 CHARACTERISTICS OF ARCHITECTURAL FORM

3.1 DEFINITION OF ARCHITECTURAL FORM

Form in architecture is not merely related to space and the activity occurring within this space. Form is also a vehicle for meaning or a sign. Apart from that architectural form is also related to the elements themselves; their arrangements, and combination with each other (syntax); the meaning (semiotics); and the effects on people (pragmatics). Form can not therefore simplify be reduced to the single of choice of elements and their arrangement. Neither can form be seen purely as a vehicle of meaning.

For that reason it is possible to appraise the architectural form within the framework of three categories:

- Space-defining element (related to use)
- A sign (related to arrangement, significance and effect)
- Structure (dependent on the laws of static and the strength of materials)

3.1.1 SOME NOTIONS ON ORIGIN OF THE ARCHITECTURAL FORM

Every theorist, who has been concerned with the issue of the origins of architectural form, has assigned to the primitive form a different meaning, in accordance with the conceptual framework within which he operated. Some of these notions are mentioned below.

Vitruvius:

Vitruvius' conception of the source of form emerges in his account of how primitive men created the first shelters. The first men improved first experiments by observing the *shelters of others and adding new details to their own inceptions, and by modifying constructional forms and details, which failed in winter storms. The original source of form, then, was found first in experiments with building materials, then in adaptation and refinement as climate and use tested and the shelters, and also in imitation of successful shelters elsewhere. The source of form is thoroughly embedded in the physical world itself and owes nothing to an extra-sensory divine overseer. (Gelernter, 1995, pp62)*

Vitruvius, in his De architectura libri decem, had considered the structural framework as a precondition of architectural form. Vitruvius described two primitive constructions. (Fig 3.1) The first is the Colchians in Pontus. The second model of primitive house described by Vitruvius is the one of the Phrygians, who lived in an open country where timber was scarce. In both models of primitive construction, Vitruvius implies that the geometric forms are the consequence of direct operation with physical objects rather than abstractions that pre-existed in the mind of the builder.

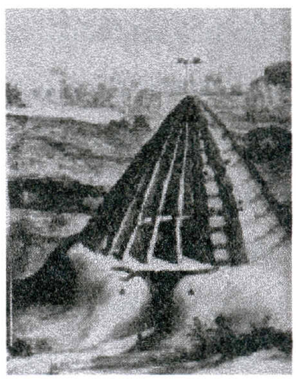


Fig 3.1 The Primitive houses of the Colchians and Phrygians

From these primitive structures, according to Vitruvius, the architectural orders developed later. It can be contended that the skeletons of Vitruvius' primitive houses were a materialistic version of the Platonic Idea: they stood for the image-idea that guides the artist-architect in his creation.

Marc-Antoine Laugier: structure as perceived form:

The structural form of the primitive house was also a key issue in the theory proposed by Marc-Antoine Laugier in the 17th-century. As Vitruvius, Laugier also places the origins of architectural forms in nature: the first dwelling was built in the forest, with branches and trees. In spite of these materialistic connotations, Laugier's cabane differs from the previous theories of Vitruvius in one important aspect: the cabane is an abstract concept as much as it is a material construction. For Laugier, the architect derived the idea of the building from the primitive house. Thus, the primitive house is the basic structural skeleton, represents the first architectural idea.

Viollet-le Duc: the rationality of construction as generator of architectural form:

In Histoire de l'habitation humaine, Viollet-le-Duc offered his particular view of the origins of the first house in the form of a legend.

Viollet-le-Duc's account of the origins of the first house cannot remind of the primitive dwellings described by Vitruvius. There are significant differences between the descriptions of the primitive house provided by Vitruvius and Viollet-le-Duc. These differences reveal the different conception of architecture that both authors had. For Vitruvius, the primitive house was more a creation of nature than of man. Viollet-le-Duc, on the other hand, emphasizes the rationality of the men who built the first house. Furthermore, Viollet-le-Duc assumes that the construction system itself has its own logic, and that this logic determines the architectural forms. Hence, the conical form was the result of a technique consisting in fastening the trees in their upper part. The form of the hut, therefore, was not an idea first conceived in the mind, but the consequence of the logical construction technique. Furthermore, the idea of the first house is associated with the structural form, which for Viollet-le-Duc constitutes the essence of architectural form.

In the transition from the nineteenth to the twentieth century, Le Corbusier came up with an interpretation of the origins of architecture that emphasized the mentalistic nature of the first architectural invention. For Le Corbusier the first house was a primitive thought, rather than a primitive construction. Finally, in this century, the field of cybernetics and computing has provided the framework within which notions like design process emerged. Architects and theoreticians, like Alexander and Eisenman, rejected the idea that a design starts with a preconceived image or type. Instead, they proposed the consideration of design as a `patterned design process, in which the initial image or type plays no significant role.

Each one of the different interpretations of the origins of architecture stresses a different aspect of architectural form. For Vitruvius, and for the Renaissance theorists, architecture was basically imitative. Viollet-le-Duc was interested in finding out the causes that gave rise to architectural forms. He thought that the positive rules from which form derive should be found in the construction techniques and in the materials employed. For Le Corbusier, architecture was basically a creation of the mind. *(Madrazo, 1995)*

3.1.2 THE GEOMETRIZATION OF ARCHITECTURAL FORM

Transition from the classical vocabulary to subsequent vocabulary consisting of geometric forms first appeared in the Greek temple. This is the most intriguing aspect of the historical development of architectural form. In the development of architectural form identity of conception and perception has been a constant driving force. According to this, the geometrization of architectural form would have arisen from the desire to achieve this identity between conceived form and perceived form.

Pantheon:

The Pantheon is the perfect example of a line of thought that sees the foundations of all architecture in simple, basic geometric forms. The form of this building is determined by circle, cylinder and hemisphere. (Fig 3.2) The use of simple geometric forms in the design of buildings goes back to the beginning of architecture.

The building is symmetrical on plan. It was laid out about a longitudinal axis. It consists of two basic elements, the columned portico and the rotunda. Although the interior is a pure, centrally planned space, emphasis is placed on the longitudinal line of access along the axis. The dimensions of the building are governed by harmonic proportions. The overall height of the spherical space and the diameter have a proportion of 1:1. The height of the cylinder to that of the overall height is 1:2.

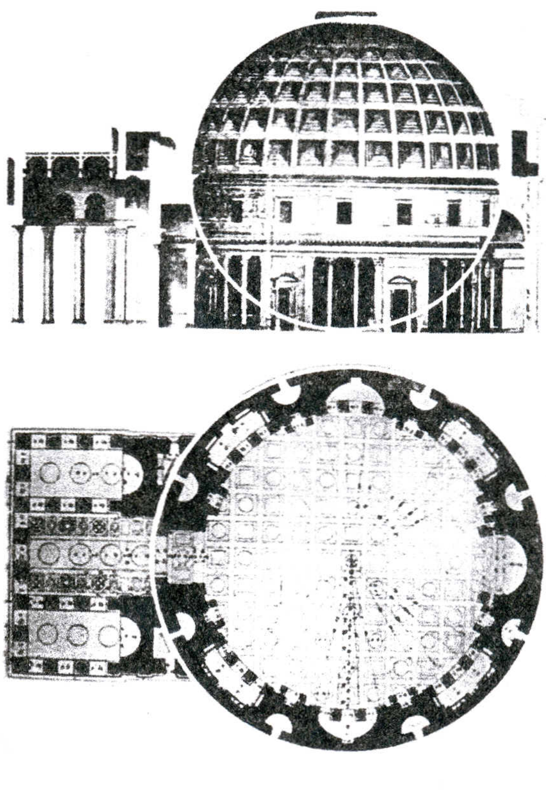


Fig 3.2 Plan and section of the Pantheon

In the Renaissance, theories of Alberti and ideas of Palladio were supported by the preoccupation with form perception. The villas of Palladio are distinguished by a harmonic integration of parts within the whole. In Palladio's villas, this harmony is achieved in spite of the strong contrast that exists between two different conceptions of architectural form: the classical forms of the temple front, and the geometric volume to which this is attached. Besides the visible forms, in the Palladian villa there is an invisible geometric framework that holds together the distinct parts that make the building. This invisible framework is the expression of the symbolic and perceptual natures of architectural form in the Renaissance.

Villa Rotunda by Leon Alberti Battistita:

The Villa is derived from a common geometrical rules. The ground plan is based on a square. The external form is dominated by the porticos set in front of all four sides of the main cube of the building. (Fig 3.3) In this building, the four horizontal directions are gathered into a centre. The hearth of the plan is the circular hall. The plan of building is not just one square, but a concentric series of five. The size of each one is determined by the radious of a circle circumbscribed about next smallest. The cross-section through the Villa Rotunda is also a composition of circles and squares.

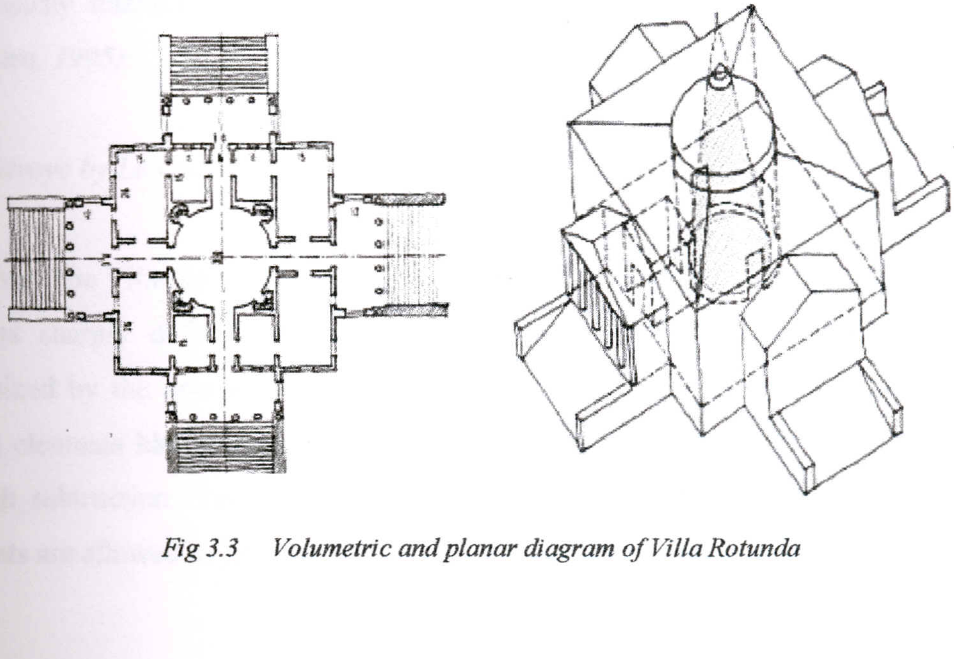


Fig 3.3 Volumetric and planar diagram of Villa Rotunda

In later artistic periods (Mannerism, Baroque, Rococo), the invisible framework of geometry was lost. The self-contained classical forms gave place to more expressive forms, no longer so easily perceivable. There is no invisible geometric framework that can hold together the uncontrollable forms of the buildings of the Baroque or the Rococo. Later, the architecture of the seventeenth century represented a return to the classical ideal. According to this classical ideal, the idea of the building form should be easily apprehended by the mind's eye. In that time, the important issue was to perceive form in the epistemological sense rather than the aesthetic sense. This emphasis on the epistemological meaning of form is one of the reasons why architectural forms became visibly geometric during the eighteenth century. In effect, geometric forms lend themselves to that ease of apprehension. According to some architects like Boullee, architectural form should be apprehended easily. This is a requisite of a true work of architecture for him. In Boullée's designs, the classical forms were relegated to a secondary role, and the geometric solids became the visible expression of the symbolic and perceptual natures of architectural form.

The identity of perception and conception was finally achieved in the buildings of Le Corbusier. A building like the villa Savoye is an example of the beholder to reproduce, in his mind, the creative process of the architect. In effect, the building is perceived in much the same way as it has been conceived: as a system made out of sub-systems, continuously interacting among them, without ever reaching a state of equilibrium. *(Madrazo, 1995)*

Villa Savoye by Le Corbusier:

As a form, the Villa Savoye is almost a perfect white rectangular prism, a platonic solid with its sharply defined geometry. While the perimeter of the Villa is strongly determined by the geometry of the box, the interior is not. (Fig 3.4) Rather than the adding elements like porches or terraces, the elemental box of the Villa is elaborated through subtruction. Terraces and scooped out of the mass of the box and figural elements are allowed to emerge only within its taut frame. It is a morphological exercise in the manipulation of pure form. In the planar organization, it begins with a square, which is then subdivided by a square grid. The enclosing square is extended along one axis.

Fig 3.4 Villa Savoye by Le Corbusier

3.2 THEORIES OF ARCHITECTURAL FORM

The theories of Architectural form first appeared in the ancient period of time. In that time, Plato played important role on development of theories of form. According to him, the concept of form encompassed, among others, metaphysical, aesthetic, epistemological, logical and ethical meanings. In Plato's philosophical system, the concept of form had all of these connotations at once. Similarly, the architectural forms of the Greek temple also had a multiplicity of meanings.

In the Renaissance, the architectural form also reflected the form paradigm that was peculiar to the time. Unlike the Platonic Idea, the Renaissance Idea is not an essence existing in its own separate world, but an idea in the mind of the artist. This emphasis on the mind, which stresses the epistemological and aesthetic meanings of form, began to separate the different meanings of form that were unified under the Platonic Idea.

In the centuries after the Renaissance, the epistemological meaning of form becomes more important than the aesthetic one. In the seventeenth century, the perception of form in the aesthetic sense had already been equated to the perception of form in the epistemological sense. As the aesthetic experience requires, the idea had to be perceived instantly, at a single glance. The forms that can be more easily apprehended are geometric figures, like cubes and cylinders. Hence, architectural form became more geometric. In the designs of Boullée, architectural forms had been created so as to grasp easily. For Boullée, geometric forms were beautiful because they were understandable, that is to say, easily apprehensible. Therefore architectural form had mostly an epistemological meaning.

In the transition from the eighteenth to the nineteenth centuries, Type replaced Idea as the prevalent form paradigm. Then, the remaining aesthetic connotations of form were definitely lost. Type stood, almost exclusively, for the epistemological meaning of Form. Laugier's cabane is the expression of a basic form that the beholder can derive from those buildings that bear a visual similarity to the Greek temple. The distinction between an inner form and an outer form springs naturally from Laugier's cabane. In this regard, Laugier's conception of architectural form announces the eclecticism of the following century. In the nineteenth century, architectural form was thought in terms of an inner form that was clothed with ornament.

At the beginning of the twentieth century, the psychology of form was postulating a connection between the object's actual form and an objective form (constructs in the mind). The term Gestalt was used to refer to these two kinds of form. After the advent of Gestalt psychology, the traditional inductive view of perception gave place to another view. According to this view, seeing and conceiving were considered two inseparable moments of the act of perception. The ideas and buildings of Le Corbusier equally reflect this identity of perception and conception. Le Corbusier did not only perceive the columns of the Greek temple as cylinders; he also conceived his buildings as if they were made of the same geometric solids.

In the twentieth century, form began to abandon the realm of the mind. The meaning of form that the notion of structure conveys is more methodological than epistemological. In this period of time, as a design methodologist, Alexander suggested a mathematically based design process. Eisenman also attempted to get rid of form and type (the preconceived image). From this point of view, he proposed a view of design as a transformation process derived from the generative grammar of Chomsky. The intention of Eisenman's theories is more aesthetic than scientific. The forms of his buildings evoke the aesthetic of the Modern Movement.

Following the advent of the computer, artificial models can be created through the design process. A form, represented in a computer, becomes the expression of a universal from which an infinite number of instances or variations can be generated.

3.3 GEOMETRIC OPERATIONS ON ARCHITECTURAL FORM THROUGHOUT THE HISTORY OF ARCHITECTURE

Geometry has been part of architectural design since ancient period of times. The angle of inclination of the Great pyramid was determined by a geometric construction in that times. This geometric construction involved then fashionable problem of squaring the circle. (Fig 3.5)

During the Middle ages, the great churches and cathedrals were designed on intricate geometrical lines. The house of God must be designed according to the mathematical principles because mathematic was a link to the divinity.

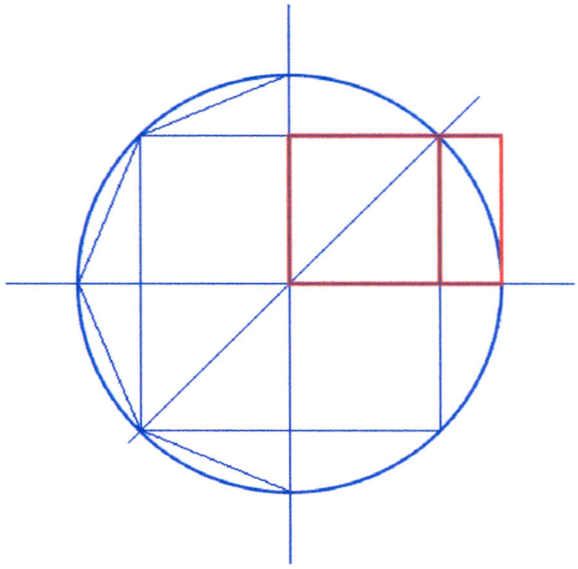


Fig 3.5 A Diagram for squaring the circle

During the Renaissance this idea was developed in other ways. Beautiful buildings must be designed with geometrical vocabulary because mathematic was held everything behind all that was beautiful in the world. Mathematical concepts supplied the essence of our understanding of the world. During the Renaissance it provided a theory of proposition to design buildings. Apart from that it also supplied the theory which artists could build a perspective.

The aesthetic rules of the Greek, Roman and Renaissance architects were based on various geometric ratios. Geometric constructions, based on direct sightlines and reflections were the basis of Greek and Roman acoustic design.

Until the seventeenth century, geometry was used as a architectural mathematics in architectural design.

By the late nineteenth century, buildings became bigger, more numerious and more complex. Therefore, there was a science of structural design, using ever more geometric operations in this period of time.

To sum up since Greek times, it has seemed that the fundamental principles of architectural form must be mathematical. Sometimes these principles have been numerical ones, sometimes geometrical. Order in architecture arises from the regularities in which numerical ratios can be combined. They lead to proportional and modular systems. These systems are synthetic in that they provide ways of generating forms. Architecture must emulate the underlying geometric order of nature. Apart from that architecture must tend to produce schemes for the analysis of finished forms.

3.3.1 THE ANCIENT PERIOD OF TIME

Greek architects searched for rules to generate divinitely determined forms. They found these rules in geometry and proportion. They started to design with a basic module found within the building itself. This basic module could be the width of a triglyph in a Doric temple or the lower diameter of a column. All of the other dimensions in the building derived from this basic module. By this basic module, it is specified the number of columns and their locations; the ratios of plan width to length and column diameter to height.

For many architects in ancient Greek and Egyptians, the rules which generate the form came from geometry. Perhaps based on the belief that orderly geometry reflected the order of the divine world, precise geometrical systems with which to generate forms. The ancient Egyptians took one major dimensions of an important room in the proposed design as the basic module, and then employed regular multiples and fractions of that module to determine the dimensions of everything else in the scheme. In addition, they derived the relative proportions of elements in plan and elevation from simple geometrical figures, most notably the square and a few triangles with specified ratios of base to height. Along with the organizational concept of symmetry, this helped create buildings with clear rational order. According to the ancient Egyptian mind geometry represented a precious revealed truth about the divinity's timeless and universally valid design requirements. Here is the beginning of several ideas that will later appear throughout the history of western design theory. Some of these ideas are: good design is based on timeless principless of form; these principles originate in a divinity; and geometrical systems can capture these principles.

Phythagoreas:

Pythagoreas developed a distinction between matter and form. This distinction later influenced most Western philosophy and design theory. He noted that geometrical figures like triangles possess certain unchanging formal chatacteristics. According to him this formal characteristics are independent of the figure's physical material. For example, the angles of a triangle add up to 180 degree whether the triangle is made of wood or bronze. Apart from that, every other object in the world must also posses an underlying form that exist independently of its physical matter. Although the material world is changing, these object's underlying form remains the same.

Plato:

The Greeks developed such theories for discovering ideal form. One of these theories is derived from Plato. Plato established two different proportioning systems. One is the numerical system derived from Pythagorean harmonic ratios; the other is a geometric system derived from the platonic solids. (Fig 3.6)

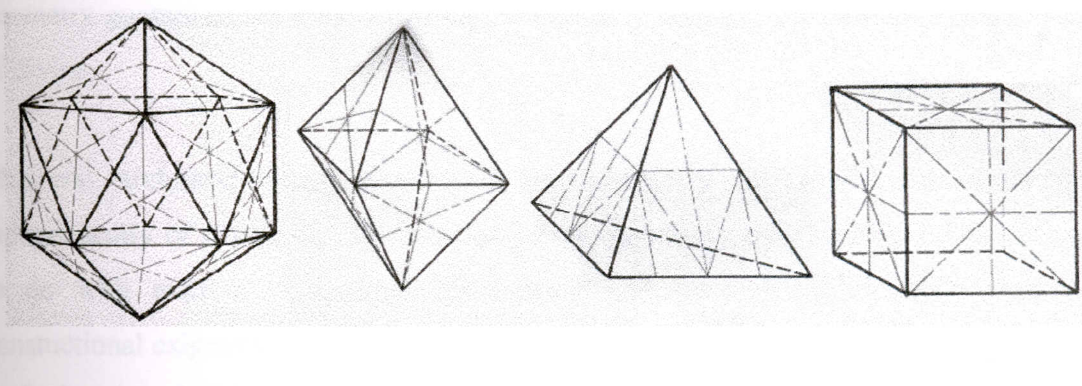


Fig 3.6 The regular geometric solids of Plato (Water, Air, Fire, Earth particles)

In the Timaeus, Plato observes the geometric fact that only five regular geometric solids are possible. He goes on to allocate to four of these solids the four theoretical elements:

air: Plato proposed was made from particles taking the shape of the octahedron,
fire: from the tetrahedron,
earth: particles of earth took the shape of the cube,
water: he ascribed the icosahedron,
the fifth regular solid: the dodecahedron, Plato allocates the structure of the cosmos.

These geometric solids later became known as the Platonic Solids. Curiously architects much later changed these into the sphere, the cylinder, the cone, the pyramid, and the cube, presumably because these are more suitable building blocks for architectural forms.

3.3.2 THE GOTHIC

Medieval architects started to design with simple geometrical figures, like circles, equilateral triangles, and squares. Through a series of prescribed steps, architects generated complex geometrical forms that organized the building both in section and in plan. This geometry assured the structural fitness of the building. Apart from that this geometry guaranted the building would necessarily embody the essential characteristic of divine.

Medieval architects often determined the geometry in Gothic cathedrals quite independently of structure. The selection of one geometry over another often had more to do with matters of internal consistency and geometrical elegance than with constuctional exigency. For example, the foundations of cathedrals were laid well before basic decisions had been made about the design of the piers or the height of the overall building section. Equilateral triangle was proposed as the ordering principle of the section, even though the exact height of such a triangle is incommensurate and physically difficult to built.

There were two design schemes which directed the designs of buildings in these period of time: Ad Quadratum and Ad Triangulum.

Medieval architects used Ad Quadrature for proportioning building plans and facades. Apart from that this scheme was used for locating and proportioning some architectural elements throughout a building. Quadrature involved in 45-degree rotation of nesting squares to produce a series of like-proportioned figures. These figures have some important roles:

- to determine and position the relative sizes of building parts such as nave piers of a church
- to regulate the composition of constituent elements such as a spire or pinnacle
- to generate repetitive carved stone ornament

These geometries were seen as the key to building design long before the systematic codification of such geometries by architects of the Renaissance.

Use of the Ad Triangulum scheme was achieved the same objectives in a similar way. The only difference was that the lattice was hexagonal and composed of closely packed equilateral triangles.

3.3.3 THE RENEISSANCE

In the Renaissance, architecture derived from the measure of human beings and was their external projection. Leonardo's Vitruvian Man established a connection between the lineaments of the human figure and abstract geometry. As a result of that, the Renaissance design is characterized by experimentation with ideal forms, ideal geometries and ideal proportions.

The architects of the Renaissance believed that their buildings had to belong to a higher order. In order to achieve this they returned to the Greek mathematical system of proportions. According to Renaissance architects architecture was mathematics translated into spatial units. Applying Pythagoras' theory of means to the ratios of the intervals of the Greek musical scale, they developed on unbroken progression of ratios that formed the basis for the proportions of their architecture. These series of ratios manifested themselves not only in the dimensions of a room or a façade, but also in the interlocking proportions of a sequence of spaces or an entire plan. From this point of view it is possibble to say that architects took their interest in ideal geometry and central planning. In other words, architects organized the building facades plans according to idealized geometry. For example Alberti and Bramante used the four-square schemas mostly organizing the building facades. In addition to this, the building plans also conceived and organized by architects according to nine-square grid or another idealized geometric method.

At St. Peter's Church in Rome, Bramante takes his interest in ideal geometry and central planning. His proposals for the Church plan includes nine-square-grid, rotated grids, a vast centralized domes surrounded by an elaborate ambulatory, and so on. (Fig 3.7)

Geometrical figures and mathematically derived ratios were believed to hold universal truth about the order of the cosmos. Proportional systems drawn from the ancients were rationalized and systematized. Musical theory and architectural theory were bound together and governed by the same harmonic ratios.

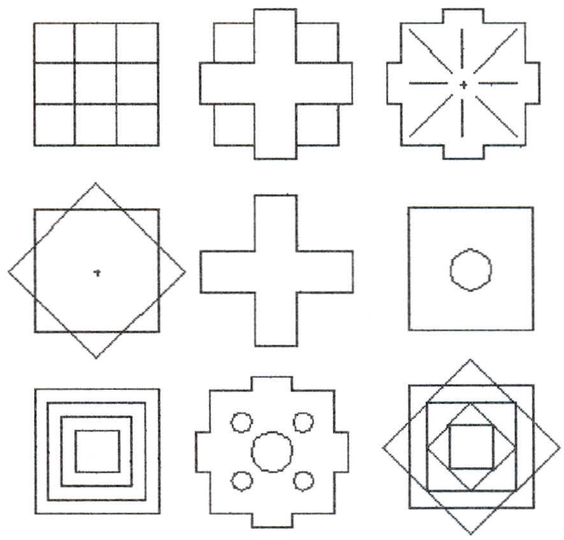


Fig 3.7 Diagrams of St. Peter Church by Bramante

Although it was not an explicit requirement of Reneaissance architectural theory, most building plans were symmetrical. Symmetry plays an important part in architectural work. Many building plans or elevations are symmetrical in plan or in elevation.

Leon Battista Alberti:

Music and geometry are fundamentally one and the same for Alberti. Music is geometry translated into sound, and that in music the very same harmonies are audible which inform the geometry of the building. He used idealized geometrical elements frequently in his designs as an organizational element. For example, the façade of San Andrea and Santa Maria Novella organized according to the for-square geometrical schema.

Alberti recommends nine basic geometrical figures in all for churches: apart from the circle, he lists the square, the hexagon, the octagon, the decagon and the dodecagon. All these figures are determined by the circle. In addition to these six figures he mentions three developments from the square, namely the square plus one-half, the square plus one-third and the square doubled.

Andreas Palladio:

Andreas Palladio brings the theory of Renaissance proportioning to its most sophisticated state. He turns the idea of subdividing a plan into harmonious parts around by starting with rooms in harmonious ratios and joining them together to produce the entire building.

Circular

Square 1:1

The diagonal of the square......1:1.414

A square plus a third 3:4

A square plus a half.................2:3

A square plus two-thirds...........3:5

Double square.........................1:2

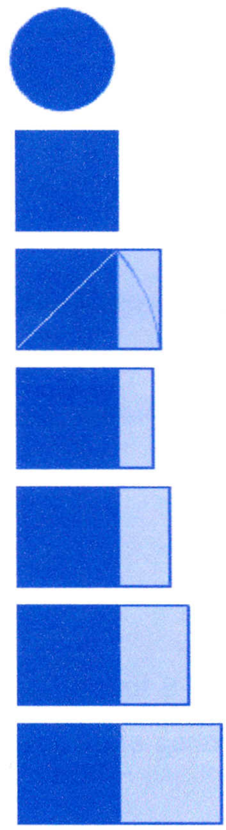


Fig 3.8 Palladio's seven sets of Proportions used in the construction of rooms

Palladio supplies general rules for the proportions of the height of rooms to their width and length that is for the relationship of the three dimensions which constituting the shape of a room. He recommends seven shapes of rooms in the following sequence: (1) circular, (2) square, (3) the diagonal of the square for the length of the room, (4) a square and a third, (5) a square and a half, (6) a square and two-thirds, (7) two squares. (Fig 3.8)

3.3.4 THE BAROQUE

Baroque architecture emphatically utilized geometrical operations to determine forms and spaces. Geometry became a metaphysic transforming the world of man into a symbolic universe. The clear geometry of Renaissance forms and rational precision of Renaissance space was supplanted by an architecture suffused with dynamic play among masses. In this period, buildings were no longer conceived as isolated objects, but rather as part of an urban continuum. For that reason, in the Baroque architecture, space is rhytmic. Complex plans were generated from the superimposition of clear, simple geometrical figures. The multiple geometries can be synthesized into a single, undulating line.

Accepting the essential symbolic dimension of geometrical operations in architecture within the epistemological framework of the seventeenth century, it is possibble to discern the coherence of Baroque architectural intentions, containing both rational and sensuous dimensions.

Guarino Guarini:

In Guarini's work, geometry symbolized the highest values, but it was not opposed to nature. Geometrical form guaranteed the truth of theory, while geometrical operations were used as a tool for the transformation of the world.

According to Guarini, architecture had to be governed by a rational geometry capable of providing stability to the building. Apart from that, geometry could had to generate symbolic form and space by combinations of figures and figural transformations. In this way, the ultimate meaning and beauty of architecture depended on the implementation of geometrical operations.

The principles of geometry provided by Guarini were strictly Euclidean. His geometry was never an abstract mathematical discipline, but depended on an intimate relation with the figures such as the square, the triangle, the pentagon, and so forth.

Geometry was used by Guarini was a precise technical tool. It was an instrument in order to achieve a reconciliation between spiritual values and the world of man. In his geometry, the basic geometrical figures of Euclidean were combined and transformed to design extremely complex and seductive buildings.

3.3.5 THE ENLIGHTENMENT

One of the syptoms characterize the Enlightenment is the arbitrary use of architectural forms borrowed from the styles of the past. In this period of time, architecture had depended upon the geometry in order to vouchsafe its role as an immediate form of reconciliation between man and world, between microcosm and macrocosm. Some theorists, like Laugier went back to the primitive hut to rediscover the true and natural elements of architecture. On the other hand some theorists like de Fournay approached the same problem from another angle, demanding that architecture ought to regenerate through geometry. According to him, in contemporary projects cube, pyramid, cone, cylinder and sphere were legion.

Etienne-Louis Boullee:

Boullee believed that the emotional response in architecture depended on the effect of the composition of bodies in their totality. The general volumetric composition of architecture was to be determined by the regular bodies. These rational and perfect forms were necessarily found in nature. His geometrical bodies are Euclidean, that is, transcendental. The geometrical solids were postulated as symbol of a transcendent order, representing ethical, aesthetic, and religious values, revealing the preestablished harmony between man and the world.

Boullee's theoretical projects invariably included centralized plans, and their massing was determined by cubes, pyramids, truncated cones, cylinders, and spheres. Their formal expression was characterized by large, smooth surfaces. According to Boullee the plan of the universe formed by the Creator. Symmetry was the foundation of the constutive principles of architecture. Geometrical solids were explicit symbols of a cosmic order. Sphere is one of the elemental bodies. Boullee defined sphere as the essential polyhedron, incorporating the properties of all the other bodies. Its contour is the sweetest and most fluid. Furthermore it is the image of perfection. Apart from the sphere, the pyramid was one of his most important prototypes. According to him, the pyramid is the sad image of barren mountains and immutability. The pyramid was conceived by Boullee as a quassi-natural model. *(Gomez, 1994)*

Claude-Nicholas-Ledoux:

Ledoux maintained that there was a problem in the architectural design. The problem was the devaluation of architectural meaning. He believed the existence of primordial forms had been ill represented and distorted through history. He propounded that these original forms could be recovered by architects

Ledoux believed that all forms derived from nature. The elemental forms were inspired by the geometrical purity of natural phenomena. These elemental forms can be accesed through perception. These are also letters of the architectural alphabet: the sphere, pyramid, circle, square and so on. And for him, the geometrical elements used in architecture could become symbols of human values.

In order to create a symbolic order, Ledoux recommended that architects use simple geometrical solids and figures. He accepted the importance of proportion as a source of beauty and for convenience and economy. For him, the geometrical figures and bodies epitomized ideal beauty and they were the elemental notes of architectural composition.

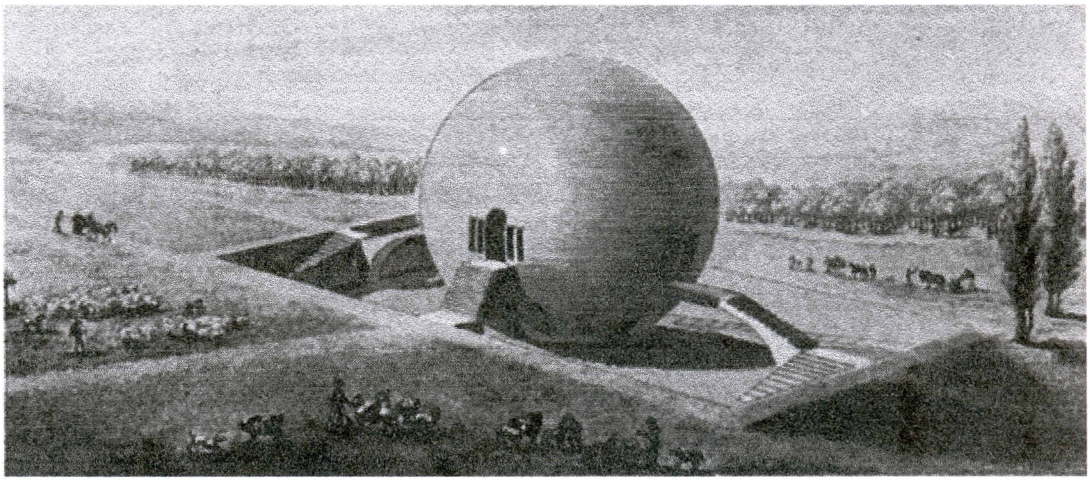


Fig 3.9 Project for an agricultural lodge by C.N.Ledoux

Eventually, the classical orders and proportion were replaced by the Euclidean solid's, which possessed mainly qualities of scale and symmetry. The use of these solids was motivated by a symbolic intention. The geometrical bodies were considered to be the most appropriate vehicle for reconciling man and his institutions with an external nature. This geometry was not a method or operation. The figures were used because they were believed to be the fundamental constitutive and visible elements of nature. (Fig 3.9)

Jacques Nicholas-Louis Durand:

According to Durand simple and symmetrical geometrical forms should be used in architectural design. From this point of view, Durand recommends the use of a circular instead of a square or rectangular plan, for the simple reason that its perimeter is less. The more symmetrical, regular, and simple a building is, the less costly it will be. Economy thus prescribed the manner and means of buildings, forbidding all that which was not strictly necessary.

The simple geometrical solids used as prototypes in architectural projects lost their symbolic connotations; they became signs of the new values, the formal language of technology. Durand was conceived that simple forms that were easy to perceive produced some pleasure in the observer (but this was not the crucial issue). Such forms were to be used because they corresponded to those conceptions already shaped by the rules of economy.

Durand used the methodology of descriptive geometry in order to simplify the expression of architectural ideas and to make relation between the objects and physical reality of the building.

In Durand's theory, number and geometry, finally discarded their symbolic connotations. Proportional systems would have the technical instruments. The geometry applied to design would act merely as a vehicle for ensuring its efficiency. Geometrical forms lost their cosmological reverberations; they were uprooted from the Lebenswelt and their traditional symbolic horizon, they became instead signs of technological values. This in turn led to the geometry of the Bauhous, the International style, and the Modern Movement, which was essentially the undifferentiated product of a technological world view. As part of a theory that cast off metaphysical speculation, the simple and anonymous geometry of most contemporary architecture speaks only to a technological process, not to the world of man.

3.3.6 THE MODERN PERIOD OF TIME

Many twentieth-century architects have used ideal geometry to lend rationality or integrity to their plans, sections and elevations. Some, seemengly bored with simple relationships, have experimented with complex arrangements in which one geometry is overlaid on another.

In this period of time, direct relations have been postulated between the pure geometrical solids in Ledoux projects and the work of Le Corbusier or the piecess of a chess set produced in the Bauhous. Such characteristics as austere simplicity, the absence of the classical orders, and the use of platonic solids and simple geometrical figures in plans and elevations are seen as precedents of Twentieth Century architecture.

Louis Kahn even wrote a poem in which Boullee and Ledoux have the same importance for architecture as Bach for music or the sun for the universe.

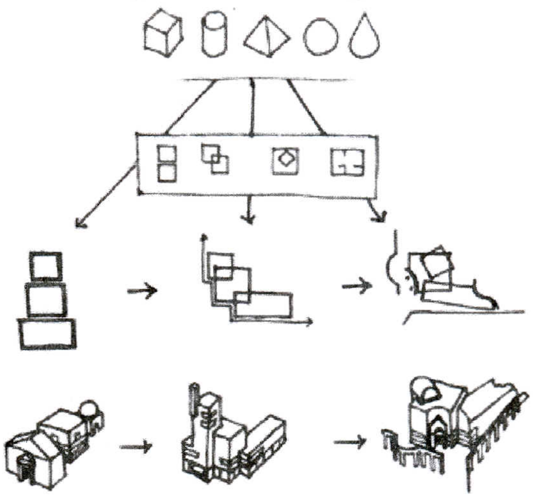


Fig 3.10 The major periods comprising the modern tradition. (Neo-Classicism, Functionalism, and Postmodernism) Periods have a common vocabulary made up of geometric volumes (cylinders, pyramids, cubes, etc) but the interpretition of these volumes varies according to the dissimilar philosophies each period.

The majority of architects of the Modern, as well as the Post modern Movements, generally ascribed to Euclidean geometry and geometric principles as a means of creating and further articulating form. Le Corbusier, Mies Van der Rohe, and architects of the De Stijl, Russian Suprematist, and Russian Constructivist schools ascribed to abstractions as generators of building components, two dimensional abstractions, and abstract solid. A minority of artists and architects aspired to a conception of space that had the principles of experimental psychology as its fundamental generating framework. F. L. Wright was also an architect who managed to create space by integrating the geometric conception with the experimental.

All the architects of the Modern Movement, from Mies to Corbusier and Wright, approached space as a logical condition in which geometry, generic volumes, and accomodated functions occurred through integral interrelationships, by complementing and respecting the integrity of each other. Solids were respecting solids, functional areas were respecting functional areas, and none were intruding into another without following the rules suggested by the geometric order that is the rules of the game.

3.4 GENERATION OF ARCHITECTURAL FORM

In the formal design, there are two sets of elements:

- the conceptual elements (point, line, plane, and volume)
- the visual elements (shape size, color, texture, etc.)

Conceptual elements do not exist physically, but are perceived as being present. Visual elements can be seen, and constitute the final appearance of a design.

3.4.1 CONCEPTUAL ELEMENTS OF ARCHITECTURAL FORM

Architectural forms and spaces can be broken down into four element types: points, lines, planes, and volumes. In architecture, the elements are generally three- dimensional volumes defined by vertex (points), edges (lines), segments (planes). The four element types have intrinsic characteristics in an architectural context. Lines denote direction (along the line), significant end points (at the end of the line), and boundary (from end to end or side to side). Intersections of lines identify a third point with more content than the end points. This content can be described as the resulting reference point (the intersection) from which relative judgements of distance and angle of intersection can be made.

A three-dimensional design can be conceived in the mind before it takes on physical shape. The design is thus defined by the following conceptual elements:

3.4.1.1 POINT

In geometry, a point is the prime generator of form and the prime element in the vocabulary of form. There is no dimension of a point. Conceptually it has no length, width or depth. It has a static, directionless, and centralized characteristic. Points indicate a position in space. They are used to mark a position in space or on the ground plane. In architecture, we can see a vertical linear element (columnar element) on plan as a point. In other words a point can be projected into a vertical linear element such as a column, obelisk or tower. A columnar element is seen in plan as a point.

In geometry, point has some important roles as a prime generator of form. We can think of a line as a conjunctive element which connects to different two points. Therefore, points serve to mark the two ends a line and two points establish two directions, through their centers or between them. Apart from that the point can serve to mark the intersection of two lines or the meeting of lines at the corner of plane or volume. (Fig 3.11)

Although it is not visible, point has an marker role at the center of a field. They are establish centers for groups of form. The primary task of points is the definition of center. Characteristically points are finite and bounded. In discussing the role of geometry in architecture we shall begin with a point equal in their relationship to all surrounding directions. *(Gurer, 1990)*

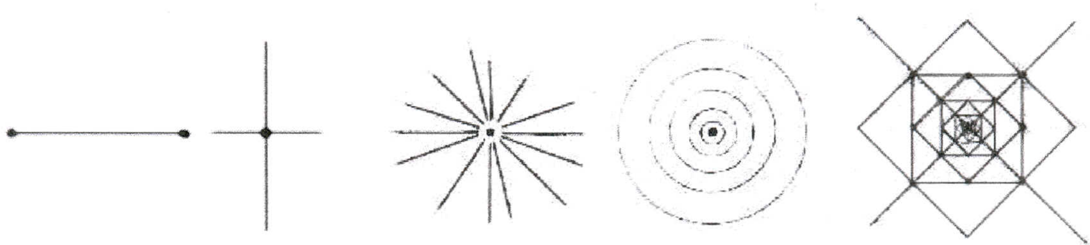


Fig 3.11 Different positions of point as prime element in the vocabulary of form

3.4.1.2 LINE

Line is the second generator of form in geometry. The line, geometrically defined, is a one dimensional entity which can be infinity extended in two directions. It can be imagined as a transformational relationship which links the two points. In other words, a line can be understood as a point which has been dragged or translated in space. Conceptually, a line, in geometry has one dimension only, length, but no width or depth. A line has an important role in the formation of visual constructions. For example, lines make the edges of solids, the edges of planes, and the joining of these elements. Such lines also have an important role as compositional elements regulating the forms and patterns in a composition. Apart from that they contribute to the expressive qualities of the form. If the linear extension predominates over width and depth, the form will read as a plastic line in space. One of the visual properties of line is to be primary expression of defining space. In other words, they effectively bound areas and volumes.

In architecture, linear elements is rarely used by themselves. They usually function with solids and planes as structural elements in the pattern. We can see such linear elements joining, supporting, surrounding the other visual elements in the space. Apart from that these lines serve to describe the edges of, and give shape to planes. Consequently the primary task of lines is the definition of edge or perimeter. They are defined both by extension and by their ability to set up distinctions between one side and the other.

3.4.1.3 PLANE

Plane is the third element to generate the form in geometry. It can be said that two lines describe a plane which connects them in staight and only one dimension. In other words, plane is a line is extended in a direction other than its intrinsic dimension. (Fig 3.12) Geometrically any two points on plane surface can be joined by a straight line which lies wholly on that surface. In geometry, a plane has only two dimensions, length and breadth, but no depth. From this point of view, the plane can be described as a two-dimensional and unbounded surface which extends infinitely in all directions. *(Gurer, 1990)*

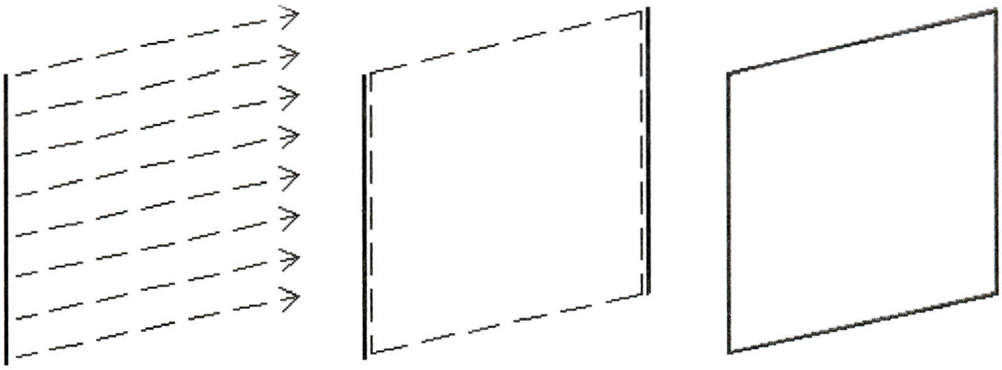


Fig 3.12 Generation of Plane by extending a line

Shape is a plane's primary identifying characteristic. It is determined by the contour of the line forming the edges of the plane. Since our perception of a plane's shape is distorted by perspective, we see the true shape of a plane only when we view it frontally.

In the formation of a visual construction, a plane serves to define the limits or boundaries of a volume. Since architecture, as a visual art, deals specifically with the formation of three-dimensional volumes of form and space, the plane becomes a key element in the vocabulary of architectural design.

A flat plane in itself is neutral in spatial activity. It has neither an exterior nor an interrior aspect. It is just a plane. When it is curved, though, it gives different solution. The plane has a definite exterior expression on the convex side. The concave side has a strong interrior expression. It defines a space volume of positive shape and size. If we use an S-curved plane, the two expressions are combined. Both sides have elements of exterior and interior spatial activity.

It can not be expressed a plane in space without thickness as well. It has to exist as material. The difference between a solid and a plane is relative. If the length and breadth dominate over the thickness, the form is perceived as a plane.

Fig 3.13 Schoreder House by Gerrit Rietvelt

Architecturally, planes have an important role to define three-dimensional volumes of form. They represent the surface of and object and mostly they are in a position which is vertical, horizontal, or inclined. (Fig 3.13) The types of plane which is used in architectural design are: the overhead plane, the wall plane, and the base plane. The configuration of these planes together in architectural design will describe the building's overall form and massing.

3.4.1.4 SOLID

Solid is the forth element to generate form in geometry. Conceptually, a solid has three dimensions: length, width, and depth. If a plane is dragged through space, the resulting form is a cube or some other rectangular prism. As with all other architectural elements of geometry, the solid occupies a space. In geometry, characteristically, a solid consists of points (vertices), lines (edges), planes (surfaces). In solids, there are points where several planes come together; lines where two planes meet; and planes which are the limits of boundaries of solid. Solid is a something with bulk; something that express itself by projection in all the three dimensions of space. It may be solid all the way through like a block of stone. It may be hollow like terra cotta, or like a building. Its visual quality is the same.

Cone:

The cone is a curved surface which is generated by revolving a straight line, one point of which is fixed, about one closed curved base line. Additionally, it is possible to describe cone as a solid which is generated by the revolution of a right triangle about one of its sides.

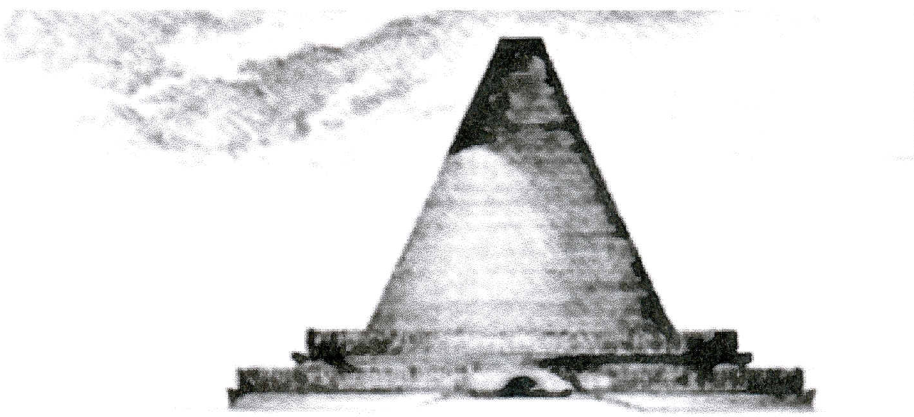


Fig 3.14 Conical Cenotaph Project by Etienne Louis Boullee

Sphere:

The sphere is a special form of solid in which every point on its surface is equidistant from a common center. The result is a continuous curved surface on which there are no edges. A great circle on the sphere is formed by the intersection of the sphere with a plane which passes through its center. A small circle is formed by the intersection of the sphere with a plane which does not pass through its center. Sphere can also be generated by the revolution of a semicircle about its diameter, whose surface is at all points equidistant from the center. Characteristically, a sphere is a centralized and concentrated form. It is self-centering and normally stable in its environment.

Fig 3.15 Geode in La Villette by Adrien Fainsilber

Cylinder:

The cylinder is a curved surface which is generated by moving a straight line about two closed curves as base lines. All positions of this line are parallel to the axis of the cylinder, to each other. From other point of view, it can be described as a solid which is generated by the revolution of a rectangle about one of its sides. It is centralized about the axis passing through the centers of its two circular faces.

Fig 3.16 Casa Rotonda by Mario Botta in Stabio

Pyramid:

The pyramid is a geometrical solid having a triangular, square, or polygonal base and triangular sides which meet in a point. The number of sides depend on the number of edges on the base. If the axis is perpendicular to the base, and if the base is a regular polygon, the figure is a right pyramid and the sides are congruent triangles. Between the solids, the properties of pyramid is similar to those of the cone. Except that having a flat planes on the lateral surfaces. So, the cone is a soft form while the pyramid is relatively hard and angular.

Fig 3.17 The Pyramids of Cheops, Chephren an Mykerinos at Giza, Egypt

Cube:

The cube is the simplest of the rectangular solids. It has six surfaces, and each of these is a square which is equal in size to the other five. The angle between any two adjacent faces is a right angle. Because of the equality of its dimensions, the cube is static form.

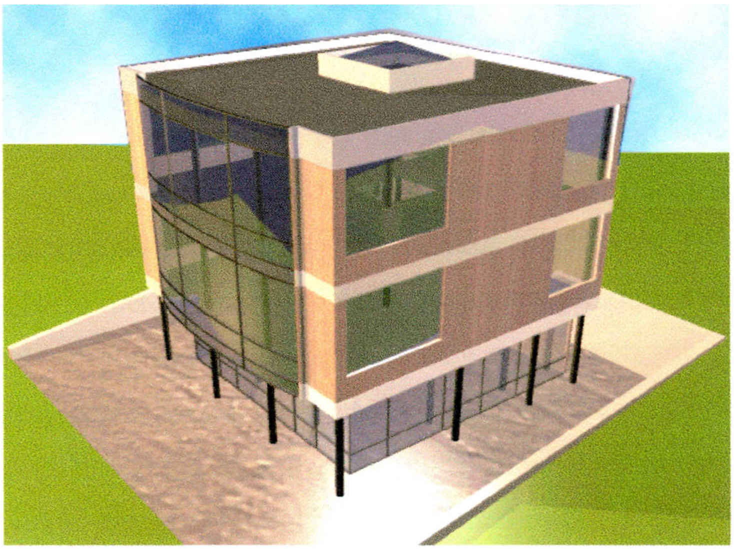


Fig 3.18 A student Project

3.4.2 VISUAL ELEMENTS OF ARCHITECTURAL FORM

Three-dimensional forms are seen differently from different angles and distances, under different lighting conditions and in different color or texture. It can be considered that the following elements to be independent of such variable situations:

3.4.2.1 SHAPE

Shape refers to the characteristic outline of a plane figure or the surface configuration of a volumetric form. It can be the outward appearance of a three-dimensional form and the main identification of its type. For that reason, a three-dimensional form can be rendered on a flat surface by multiple two-dimensional shapes. In geometry regular shapes are the circle, and the infinite series of regular polygons that can be inscribed within it. Of these the most significant are the primary shapes: the circle, the triangle, the square and the rectangle.

The circle:

The simplest of the two dimensional shapes that are used is the circle. The circle is also the easiest shape to draw both on paper and on the ground. It is the most compact geometric shape. It only has one dimension, the radius or diameter, and is located only at its center. In a circle there are no corners, no beginning, and no end. It is also non-directional. A circle may also be considered to be a regular polygon with many sides. The more sides the polygon has the more accurate the characteristics of a polygon are to a circle. The circle is the strongest of the two dimensional shapes. For the same reason semicircles are used in arches. The semicircle is found in the design of amphitheaters, arches, and in the front of buildings. It produces a vanishing appearance to the buildings from a distance. The circle, while the square and the rectangle can be subdivided in a variety of ways, can only be divided in one or two ways. This limits the use of the circle. However, a circle can be subdivided into twelve equal parts. This gives the circle great adaptability for architecture. This allows the architects ways to use the strength of the circle, while changing the appearance of the circle.

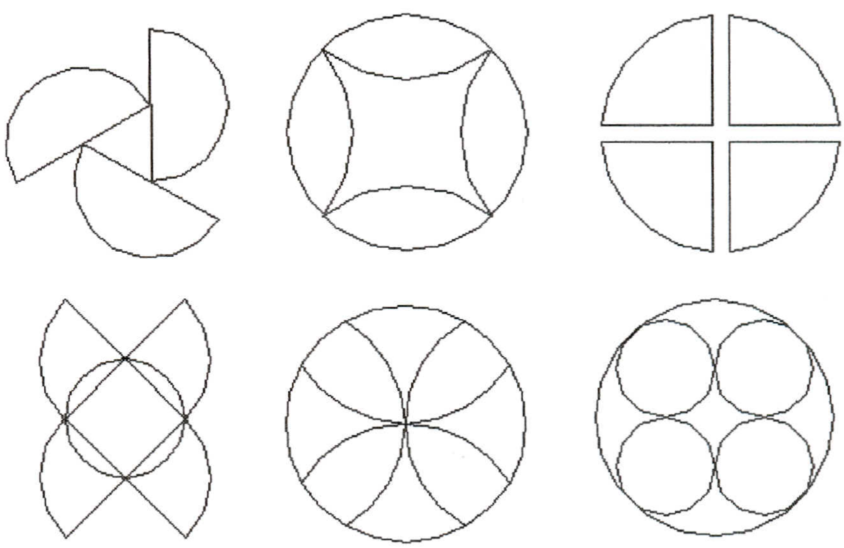


Fig 3.19 Compositions of Circles and Circular segments

The triangle:

The isosceles triangles have been used for roof slopes and frame dwellings. The equilateral triangle is the most frequently used and versatile isosceles triangle. They are rigid shapes. This rigidity helps to let rotation and flexibility is among the buildings, when they are put in a grid. Another important shape in both geometry and architecture is the right triangle. It is used for patterns and design. These patterns and designs cause illusions of depth. Because of the right triangles, corners of the buildings are square. Right triangles help to support buildings. All of the regular and irregular polygons, prisms, pyramids, and solids are dependent on right triangles. Architects for staircases and for roof slopes use the three-four-five right triangle most often. This triangle provides the maximum slope that is possible under the building codes. The right triangles can also be used to make patterns of interest in the constructions as well as for support. Through truncation of equilateral triangles the architects can design a hexagon structure. Using this knowledge of truncation of triangles, new buildings can be formed from the progressions of threes.

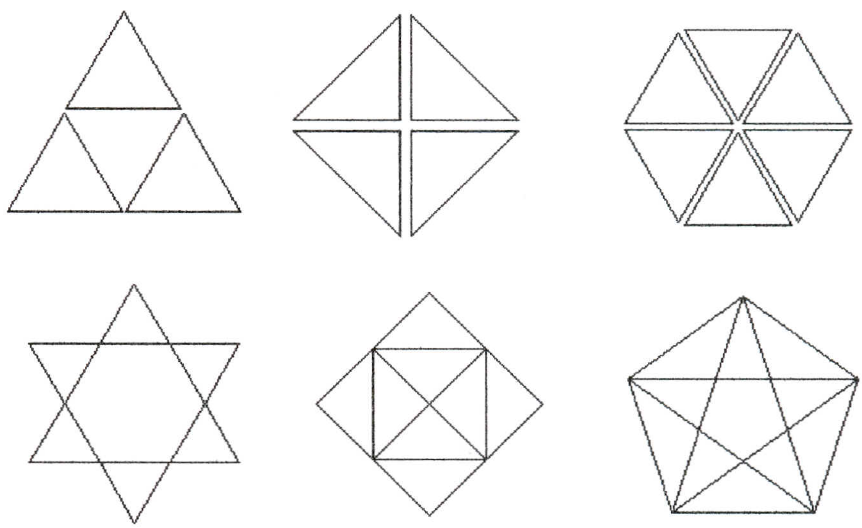


Fig 3.20 Compositions of triangles and triangular segments

The Square:

The other primary shape is the square. It is probably the most used shape in architecture. Most buildings are made from squares with other shapes added or subtracted from the square. Squares form several bases for architecture. They are the walls of prisms, surfaces of cubes, and the bases for pyramids. Squares appear on seven of the thirteen semi-regular solids, and their sides are parallel. The square is the center for rectangles. Although the perimeter is probably the most efficient in a square, it is proportionless. Therefore, it is not usually the best rectangle for architecture. In architecture rectangles are flat squares. Using the truncation of the square, architects get a pattern of octagons with small squares in the open spaces. All the regular polygons whose number of sides divides evenly by four are suitable for architecture. This series is called the progression of the fourths. For example, squares octagons and dodecagons. These shapes, when combined in-groups of four will have lines in common with an enclosing square. The shape in the center is continuously changing as the number of side increases. This sequence holds a parallel relation to the square.

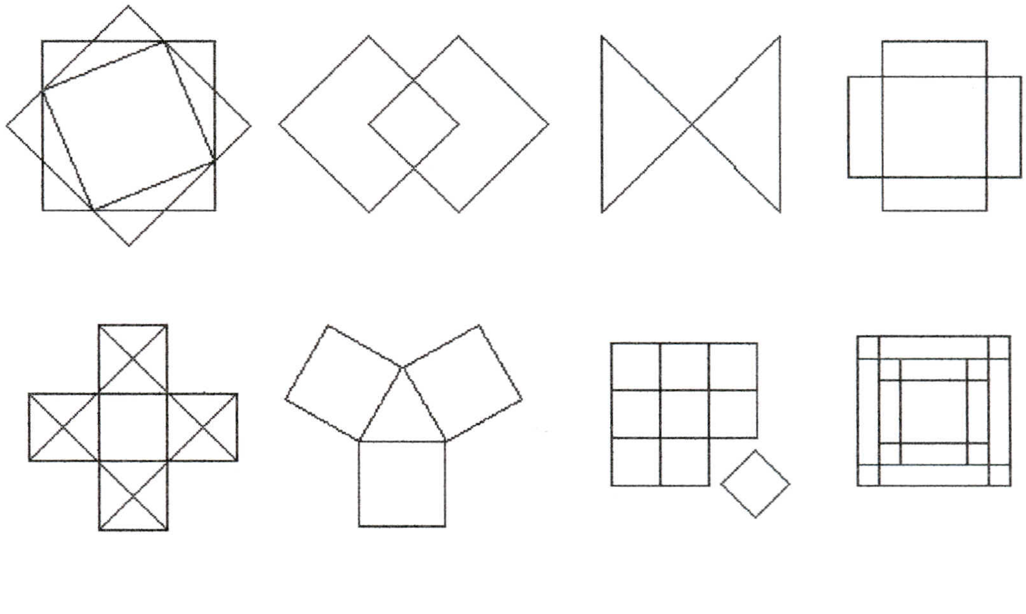


Fig 3.21 Compositions of squares and square segments

Rectangle:

Another very important shape is the rectangle. It has been used in most situations in architecture. Architects like it because it is easy to adapt for human needs. In one building rectangle are used in windows, doors, rooms, and the entire construction of the building. A rectangle depends on the right angles at the corners. The length and width depend on the eye of the architect. There is not one rectangle that will satisfy all architectural needs. Many rectangles can be said to be important in Architecture. Rectangles that are either off square or can be divided into even squares can be used in a variety of ways. A rectangle building with the smallest perimeter surface is the most economical for the architects to build. The greater the length of the perimeter the more varieties of shapes are available to be used.

3.4.2.2 TEXTURE

Texture is the size and organization of the particles constituting of surfaces. In other words, it is the visual and especially tactile quality given to a surface by the size, shape, arrangement, and proportions of the parts. It determines the degree to which the surfaces of a form reflect or absorb incident light. Therefore texture refers to the surface characteristics of the material used in the design. It may be naturally unadorned or specially treated.

The words, which describe characteristic visual texture is taken from the experience of touch-rough-smooth, hard-soft, dull-shiny, opaque-transparent, metallic, iridescent. As a result of these, it may be small-scale texture that accents two-dimensional surface decoration or bolder texture that accents three-dimensional tactility. The color white is itself an example of visual texture. The white appearance is due to the way in which they disperse the light. Contrast in any of the tonal or visual texture qualities give a visual field that is not all the same. It can be accepted that this is the basic condition for perceiving form.

Texture is one of the most important elements a designer can use in establishing scale in buildings because of its multiplicity of form and its great potential for direct human response. Texture has a great effect on visual weight, as well as being an important contributor to architectural experience in its own right. For example, objects or planes, which have smooth surfaces, are commonly perceived as being less heavy than these have rough surfaces.

3.4.2.3 LIGHT

Light plays an important part in emphasizing the nature of form. The play of light also has a great effect on the perception of texture. In addition, it is important in influencing the perception of interior space.

Building forms are often adapted to some regional variations. Where the sun is high and the sky glaring, hard-edged forms tend to predominate. Where the sun tends to be a weak and low, shape appear softer, and forceful colours are needed to give strong definition.

To bring light to the interior space is one of the fundamental architectural facts. There are many examples of buildings in which light was used as design concept throughout the history of architecture.

Light is accepted as a factor, which directly effects creating of forms and spaces in architecture. For example, in the centralized spaces, it could be used for accumulating the human beings on centrepiece part of that space (centerpoint). Additionally, in longitudinal spaces, it could be used as the way of direction of human transitions or focusing their perceptiveness towards end of architectural space. That kind of conceptual use of light highly causes the space organizations in architecture.

3.4.2.4 COLOR

The color is the attribute that most clearly distinguishes a form from its environment. It can be natural or artificial. When it is natural, the original color of the material is presented. When it is artificial, the original color of the material is covered up by a coat of paint, or transformed by treating with some other method.

A phenomenon of light and visual perception that may be described in terms of an individual's perception of hue, saturation, and tonal value. In the perceptual bases, the boxes painted in dark colours are judged heavier than identical boxes painted in light colours. Thus colour may be an important contributor to visual weight. In other words, it affects the visual weight of a form.

The psychology of color is a complex and highly subjective field. Our mechanical perception of it is influenced by the size of the sample, the presence of other colors in the vicinity, and the color of the incident light. Most designers consider the color wheel a sure guide to matching colors, but some find it restrictive.

Since past, concept of color, is utmost importance to the human being that have had a reams of study, with having an importance on many branches such as psychology, phsychology, art, architecture, etc. Starting with an example a space as room which consisting of nude walls could be much enthusiastic with color usage. Hot colors give the feelings putting themselves a little bit be emphasized in proportion to location in space. On the contrary, cold colors become latter, and it is percepted as if they were much more distances away than they were.

3.4.2.5 SIZE AND SCALE

Size is the physical dimensions of length, width, and depth of a form. While these dimensions determine the proportions of a form, its scale is determined by its size relative to other forms in its context. Size is not just greatness or smallness, length or brevity, which can only be established by way of comparison. Size is also concrete measurement, and can be measured on any three-dimensional form of length, breadth, and depth from which its volume can be calculated.

The size of a building, and of its elements such as entrances, windows, and interior spaces, has an important direct influence on our emotional response. It also affects our estimate of visual weight, which is important in terms of aesthetic evaluation and of emotional response to perceptions of harmony and balance.

Concept "scale" is a proportion, which comes from the evoluation of human. It is need to build the forms considering human's physical measures and human's all needs. If not, it causes some physical damages on human. It could be mentioned between building and its surroundings just as between building and human. The comparation of building with either an another or an objects aside take or gives a clue on scaling of buildings and their components.

Scale depends on the perception of the size relationship of one thing to another. Human body can be used as the measure in determining whether something else is large or small. In other words, measure of a building is in relationship to the human body whether considering the outside of the building or the inside space.

3.5 CONCEPTUAL DESIGN STRATEGIES USED IN ARCHITECTURAL DESIGN

On every stage of design, design strategies play an important role for a better improvement of the concept of "whole". It helps in arranging elements one by one or one to one as well as considering their relations with whole. It also gives a contribution on arrangements of basic geometrical elements, which encompass the use of space and form. Those design strategies are applicable both two-dimensional-pictorial plane and three-dimensional architectural works.

1.Unity: all of the elements on the visual plane appear to be one cohesive unit.

2.Balance: when visual weight is distributed evenly

3.Contrast: the opposite of unity, contrast is achieved through differences in elements

4. Harmony: the blend of unity and contrast, resulting in a pleasing visual whole

5. Rhythm: the tempo of a visual piece

6.Proportion: one element in relation to another

3.5.1 UNITY

Unity is an essential element in a composition. It has often been equated directly with beauty. Described simply, it is the quality possessed by a building or group of buildings in which the elements are seen to be bounded together for some reason. In a symmetrical composition this occurs because each element has a partner in its mirror image across the centerline. In an asymmetrical composition it is derived in a more complex way from the visual forces of attraction and compatibility, and from the sense of balance. A grouping appears to have unity when the visual centers of gravity of the individual elements are clustered close to the center of gravity of the whole. Lines or forms connect the elements obviously assisting in trying the grouping together. Unity can be achieved through similarities in texture, color, and detailing of elements. In whole and integrated architectural design, unity is a highly desirable goal.

3.5.2 BALANCE

Balance is the impression of equilibrium in a pictorial or sculptural composition. In order to achieve it, the forms are generally arranged about an axis. But it depends on forms and color. Balance and proportion usually go hand-in-hand. Equilibrium is defined as a balance of elements in a composition. Equilibrium thus can be considered a part of the unity between balance and proportion. A work that lacks equilibrium may be one-sided or without coherence. A composition, in which most of the prominent shapes and masses are on one side, for example, would seem to be lopsided unless the other side had interest-spatial, linear, or color-to balance it.

There are two basic notions about balance. The first, often termed symmetrical balance, describes a situation in which two halves of an object divided visually by a perpendicular plane is perfect of near-perfect mirror images of each other. The second, sometimes called dynamic balance, describes an approximately equal summing up of the elements on either side of a readily perceived visual fulcrum in a building's composition.

By Symmetry:

Symmetry is the property of geometrical figures to repeat their parts. This is the definition of the geometry according to geometrical meaning. Beyond the geometrical definitions there is broader meaning to symmetry that is related to harmony, proportion and beauty. In general meaning, Symmetry is the correspondence in size, shape and position of parts on opposite sides of a dividing line or axis. If a line is drawn on the axis, either in plan or in elevation, one half of the building could be reproduced as a mirror image of the other half. Use of symmetry is one method for creating balance. There are various methods in order to generate symmetry in architectural design. Some of them will be ordered below. (Fig 3.22)

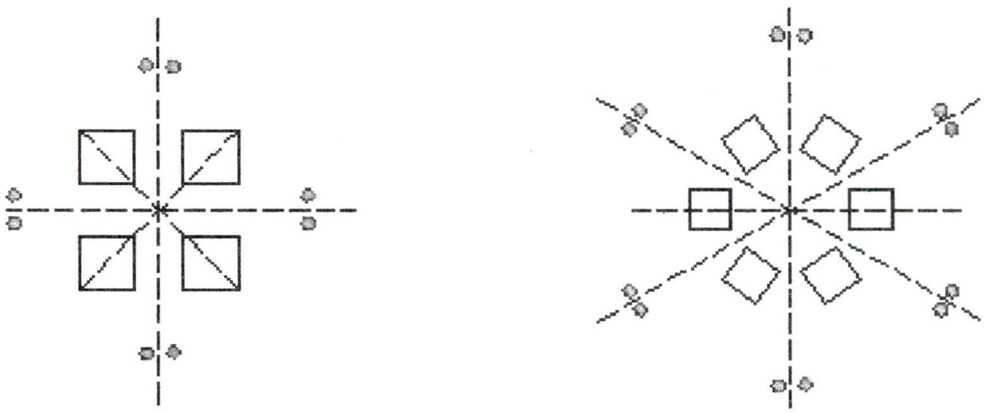


Fig 3.22 Diagrams for symmetrical balance

Reflectional symmetry: There is at least one special point in the object or pattern that differs from all the others. In this type symmetry, two halves of the whole is each other's mirror image.

Rotational symmetry: rotating an object around its axis forms this type of symmetry. It appears in the same position two or more times during a full revolution. It can be two-fold, three-fold, etc. It is common that reflection and rotation appear together in the applications. The regular polygons in the geometry are basic elements of architectural form as a design vocabulary. These elements have also both rotational and reflectional symmetry.

Translational symmetry: In these group symmetries, a pattern is generated by repeating a motif at equal intervals. The resulting pattern shows periodicity in one direction. Repetition can be achieved by a simple shift in one direction. Furthermore, repetition can also be achieved by reflection and rotation.

By asymmetry:

The underlying rules of asymmetrical balance are more difficult to understand and convey than those of symmetry. The horizontal and vertical play essential roles. Our upright position, top and bottom, horizontal or vertical line, the right angle between the two, are immediately understood and we are able to discern the slightest deviations. These phenomena are easier to perceive with precision than are proportions.

3.5.3 CONTRAST

Contrast is the element for sounding the variousness. Contradictions have impressed humans, and also add a livening up property on composition of the forms about to design. If the rates of variety reduce in designs, it barely causes monotony. Also the way of getting the wanted contradictions on architectural forms is to use color, texture, at variance with shapes. Contrast should be composed by using those elements either forlonely alone or their various mixing.

In its meaning, contrast could also be reflected as a mean for regulating environment. That is so, any form gets its meanining by an opposite one. The interdependence of the elements is achieved by tension resulting from their opposing characteristics. Either existing or absence of contrast highly effects composition of architectural forms. It serves to give an unambiguous identity to two fundamental systems and it enables the designer to establish a hierarchy of meaning in the composition. As a result, contrast has importance that due to the elements highly be wanted to emphasize which becomes more dominant and more attractive. There is many expression of opposition in nature such as solid-void, convex-concave, curved-straight, horizontal-vertical, etc.

Consequently, contrast in composition involves the juxtaposition of elements that are strongly different from one another. Contrast can be built into any of the physical attributes of elements or surrounding spaces: shape, color, weight, texture, size, etc.

3.5.4 RHYTHM

The term rhythm is borrowed from the related art of music. It is a time-based expression of balanced movement in a processional sense. The simplest example would be a regular series of shapes with the same interval between them. A colonnade, with the repeated beats of solids and voids, represents such a pattern that it creates a rhythm. It becomes perceptible as the viewer physically moves by through, or around a building or space.

Rhythm is often established by the use of regular repetition. One way to achieve repetition is to replicate whole forms without regard to their spacing, interval, or placement on or in a building. Another way to achieve repetition is by the interval between simple forms (whether these are formally or functionally similar) serves as the thing repeated, and this introduces rhythm. *(Orr, 1985)*

In addition to introducing by this way, rhythm can be formed by increasing the height or width of the units. This idea can be applied to any of the visual dimensions, such as shape, size, tone, or texture. Consequently, instead of the same form, it can be used alternatively repeating two or more contrast forms, colors, or intervals.

3.5.5 PROPORTION

Proportion is the ratio of one part of a building to another. Proportion generally refers to a relation between various parts of a building due to analogous ratios. Proportion theories attempt to describe nature in terms of mathematically ordered magnitudes. These are used to construct systems of rules governing relationships between constituents in a configuration, and between constituents and a whole. There are three types of progression: geometric, arithmetic and harmonic. Throughout history, architects have sought to create pleasing compositions by inventing proportional systems. Following are three examples of these systems.

Ancient Greek proportional systems:

Ancient Greek proportional systems were based on mathematical ratios. These ratios were seen as evidence of a perfect universe that could be demonstrated in mathematics, music, and in the human body. The dimensions of a Greek temple are based on the radius of the module. One could construct an entire temple based on one part and the ratio. The most perfect proportion was the Golden Section. The Golden Section is the mathematical system of proportion originates from the Pythagorean concept of "all is number" and the belief that certain numerical relationships manifest the harmonic structure of the universe. The Golden Section is derived with simple geometric constructions. (Fig 3.23)

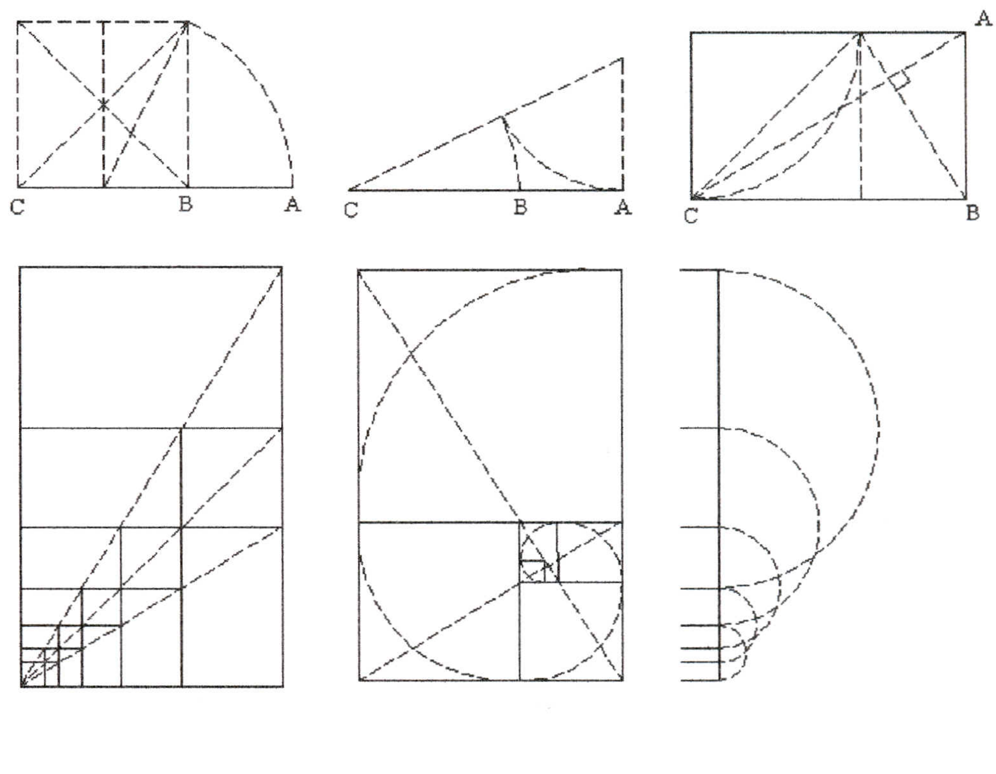


Fig 3.23 Generation of the Golden Section through geometric operations

Renaissance proportional systems:

Renaissance proportional systems were based on ancient Greek and Roman systems. Many Renaissance architects drew their own illustrations for the text of the Ten Books of Architecture by the Roman architect Vitruvius. The two most influential illustrations were those of the human body, legs and arms outstretched in a perfect circle and square and of the orders. The orders included the three Greek orders; Doric, Ionic and Corinthian, and the two Roman orders; Tuscan and Composite.

La Modulor by Le Corbusier:

The Modulor is the proportioning system developed by Le Corbusier. He based his measuring tool on both mathematics and the proportions of the human body. He believed these proportions are evident in the human body. The purpose of the modulor was to maintain the human scale everywhere.

4 FORM-GIVING AND FORM-FINDING GEOMETRIC OPERATIONS

Abstract and geometric formal operations are exist in any conception of physical space. These formal operations are universal in the sense that such formal concepts as solid and void, centroidal and longitudinal, planar and volumetric. They are primitive notions which can not be reduced and which exist in most conception. The transformations of these regularities necessary to produce a specific environment. Transformations may be described by such formal actions as superimposition, juxtaposition, and rotation to produce a new level of formal information in any specific physical environment. The physical environment can be seen not only in its functional and iconographic dimensions but also in its formal one -as being generated from a series of abstract formal operations.

At this stage of the study, basic geometrical elements having been defined that were entirely encompassed throughout the former chapters will be redefening as design vocabulary within terms of utilizing of form and space organization. Utilizing the elements can be distributed into two main groups. In the first group, it will be attempted to define the approaches based on the recognizable transformation of one pure geometrical element (pre-existent geometrical element). In the second group, the approach is based on the way of accumulating any number and various types of basic geometrical elements. In this scope, firstly architectural concepts using for generating of architectural form or space will be defined. And then, it will be mentioned that could be basic geometrical elements for utilizing in form and space organization.

4.1 CONCEPTUALIZATION OF ARCHITECTURAL FORM

The concepts are ideas that integrate various elements into a whole. These elements can be ideas, notions, thoughts, and observations. In architecture, a concept suggests a specific way that programmatic requirements, context, and beliefs can be brought together. Thus, concepts are important part of architectural design.

Architectural concepts are ideas that have been reduced to a formal architectonic concern like daylight, space, sequences of spaces, integration of structure and form, and siting in the landscape. Each can influence the general design of a building.

4.1.1 DEFINITION OF THE TERMS USING FOR CONCEPTS

The following four synonyms have been used by various designers to describe their search for concepts: themes, ideas, parti, and notions.

Theme:

A theme is a specific pattern or idea that recurs throughout the design of a project. It can be narrow in intention, like a specific geometric theme that appears throughout the project, or it can be more general.

Idea:

Ideas are specific, concrete thoughts. They are appeared as the result of an understanding, insight, or observation. In architecture, there are many ideas including ways to orient a building, the placement of building, transitions between forms, the best way to develop a spatial sequence, and the like. Building design are composed of many small decisions like these.

Notion:

Notions are very similar to ideas except that there is a connotation of randomness. Notions are ideas that are presumed to be insubstantial, unsubstantiated, or often trival when tested against other ideas.

Parti:

The concept of the parti is used to simplified our understanding of formal organizations. Deriving from the French word partir (to depart), a parti is a point of departure for an architectural idea. A parti is a clear, strong, abstract diagram which is used as the organizational armature for a more complicated arrangement of form. Partis can be drawn from elemental geometry: for example, organizations can be cubic, linear, or circular. Partis can make use of a datum or a neutral ground against which variations can be understood. Transformations of simple formal organizations often serve as the major idea of a design scheme. Actions like rotation, reflection, shifting, shearing, translation, displacement, repetition, variation, reversal, scaling, inversion, recursion, etc., are often applied to an initial organization to create more complex arrangements of parts which nonetheless are logical connected to one another. *(Synder, 1979)*

Anthony Antoniades, in his book, "Architecture and Allied Design" defines the types of the concepts used in architectural design as

- *Analogies*: looking at other things,
- *Metaphors*: looking at the abstractions,
- *Essences*: looking beyond the programmatic needs,
- *Programmatic concepts*: looking at the stated requirements,
- *Ideals*: looking at universal values.

4.1.2 ARCHITECTURAL ORDERING SYSTEMS

The meaning of ordering system is here related to the geometrical structure of the buildings or urban groupings. Ordering systems are a kind of fundamental and permanent rules which govern the interdependence of the elements of architectural form.

In order to live against nature, it is necessary to construct buildings. Ordering systems facilitate to construct buildings, prepare the site and finally fit it all together. Repetition, alignment, and juxaposition are some of the methods which are used for most frequently ordering the buildings. All these methods have been achieved by using fairly simple geometry. Architects have designed buildings according to some ordering systems. Some of them will be mentioned below:

Hierarchical systems:

In the hierarchical systems, the composition of elements are in relation to a scale of importance. Hierarchy is a powerful unifying factor. It makes it possible to combine elements in bigger, simpler and more recognizable entities. Elements of the hierarchy do not have to be similar each other. There are mostly two kinds of elements that constitutes the hierarchy: primary and secondary elements. Between these elements there is a dependent relationship. In the hierarchy depending on the relationships between the elements, one or several elements can become clear and dominate the others.the discovery of dominant and subordinate elements in a group of buildings is applicaple not only to masses or facades but equally so to architectural space. In order to create an hierarchical system, it should be obtained some conditions. Variations of relative sizes is one of these conditions. The other one is the disposition and singularity of form in relation to a context (for example: centrality, axiality, orientation, geometric operations, etc.) In addition to this, an architect should know the implicit hierarchy of certain geometric configurations in order to design an hierarchical system.

Repetitional systems:

Repetition in the form of rhythm is an extremely simple principle of composition. Repetition of the all forms can be obtained by addition, by division of a whole, by simply constitute a series without a clearly identifiable overall form. The simplest form of repetition is a linear pattern of redundant elements. Elements need to be grouped in a repetitive character. These elements moreover share a common trait allowing each element to be individually unique but belong to the same family.

Axial systems:

The specific property of the axial systems is to organize the elements along a line. Because of its linear character axes gives to organization a direction. Forms and spaces arranged along this line can be regular or irregular in form. As an design strategy, the axis have played a key role on organizing forms and spaces since ancient times. It is a a powerful, dominating, regulating device for architectural organization. Originally axes has formed the basis of monumental architecture. In the modern usage, axes consist of bi-lateral symmetry with a hierarchical volumetric arrangement. In other words, axial systems implies symmetry and required the balance of elements that form the organization itself.

4.2 ASSEMBLING OPERATIONS OF BASIC GEOMETRICAL ELEMENTS

In the creation of an architectural form, besides pure or processed uses of a basic form, it is also possible to create a new whole by using several basic forms. It can be necessary to use more one basic form in some cases where there is an intention of using fragmental order of masses. This intention is caused by such situation as different functions taking place in the building with different necessities of space form, environmental conditions, aesthetic goals, etc.

In this part of the study, basic geometrical elements will be examined by around the criteria of basic geometrical rules as the way of creating of livable spaces. In this kind of assembling of that either the same kind of elements or different ones are used. Depending on the relationships between togethering elements, usually each one could keep its properties and sometimes could completely lost its pre-existent properties.

The possible relationships are:

- *Elements are seperated*
- *Elements are linked*
- *Elements are adjacent*
- *Elements are Interrelated (interlocking and interpenetrating)*

4.2.1 ORGANIZATION OF THE COMPLETELY INDEPENDENT ELEMENTS

In these kind of organizations, gathering elements conserve their physical properties. In other words, basic geometrical elements are independent and they can be perceived individually. Assembling of these basic geometrical elements could have been examined into two groups: togethering the completely seperated elements and linking the elements with another intermediate elements.

4.2.1.1 SEPERATED ELEMENTS

Elements are seperated by distance and there is no connection between the elements of the composition. Elements are relatively close to each other or share a common visual trait such as shape, material or color.

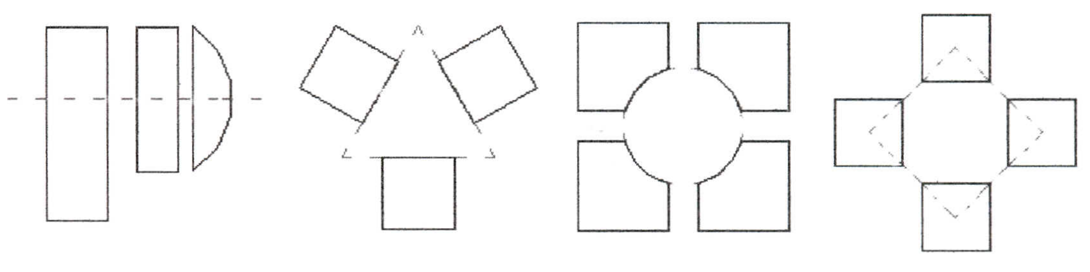


Fig 4.1 Togethering the completely seperated elements

Seperated elements could create a common central space by encircling or arraying around a central point. (Fig 4.1) Those are the seperated elements could be togethered by any cover structure for the sake of its wholeness. Except that, those elements could be adjusted as linear. Visual wholeness of these elements could be done by ordering them on a conceptual linear wall sequencely.

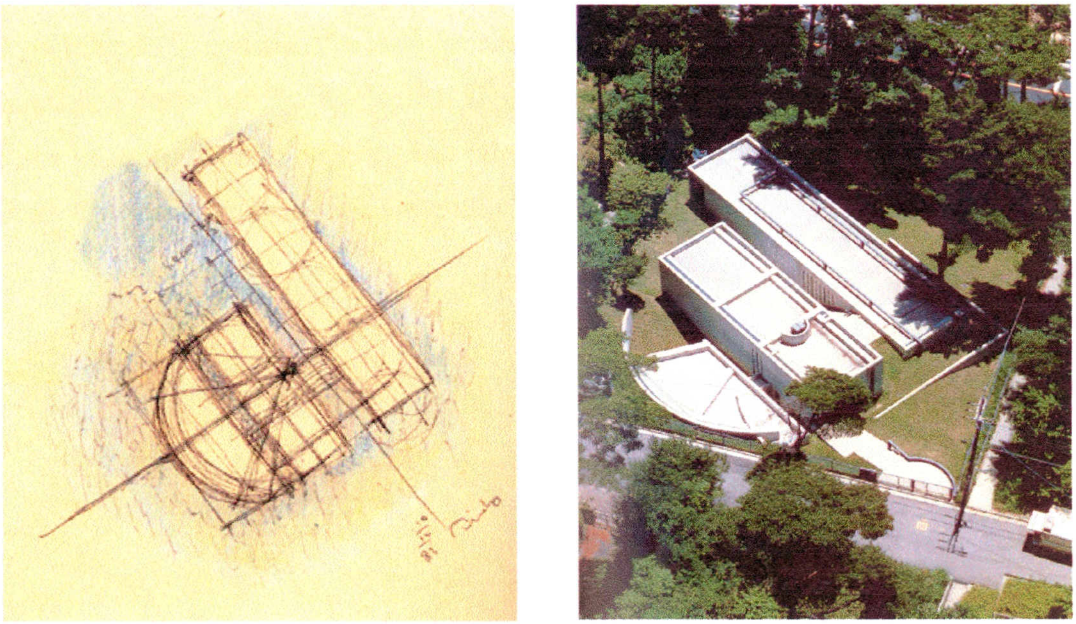


Fig 4.2 Koshino House and extension by Tadao Ando

It is the one thing that only be achieved by shape, material, color usages. That preserves perceptiveness of elements that are physically seperated from each other. In the project, Koshino House by Tadao Ando, visual wholeness between the cylindrical element and prismatic elements, which are perceived as seperated, has been achieved. And functional interrelations between those elements have been gotten up by utilizing the land in a tennable way. Architect has successed in compounding seperated geometrical elements with use of material and color. Also, relevant organizations of elements give overall composition a harmonic wholeness. (Fig 4.2)

4.2.1.2 LINKED ELEMENTS

Two or more seperated forms are linked or related to each other by a another, intermediate form. Forms are seperated by distance and they are connected with a third intermediate form. (Fig 4.3) This intermediate form is also supplied the visual and spatial relationship between the two forms. The form and orientation of the intermediate form can be differentiated depending on the functional requirements. For example, the intermediate form can be equivalent in size and shape to the other forms or it can become linear in form in order to link other two forms. Even, the intermediate form can become the dominant space in relationhip.

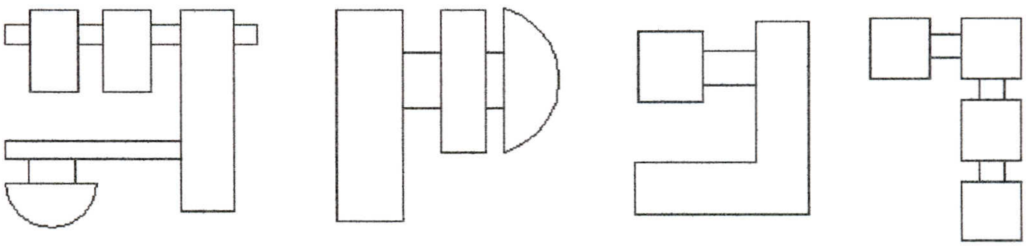


Fig 4.3 Linking basic forms with a intermediate or common space

Connective element in some cases may be major and dominate space. And elements could create a new composition either by groupping out around this concrete dominant space. In such situation as here, unifiying and major concrete space has the properties of enoughly sized volume and enough perimeter for a requiremnt of assembling other geometrical elements. In this kind of organization, the element as mentioned dominant concrete space before, which is task of unifiying is usually one of basic geometrical elements.

The conjunction of each elements to each one could diverse either through order of linear composition, or as mentioned above, could be around a central concrete dominant space being stooded to it. In linear organization, elements that are bonded in sequencely either forlornly or in various types at the composition a linear property. This organization express a direction and signify a movement, extensions the form is organized so that it extends a long continuous line. Characteristcally, this line can be straight, curved, broken, regular, or irregular in form.

Consequently, in the linking process, forms are linked to each other through intermediary forms or elements. These intermediary elements can be arranged by the use of basic forms or covering elements such as eave, arbor, vault, etc.

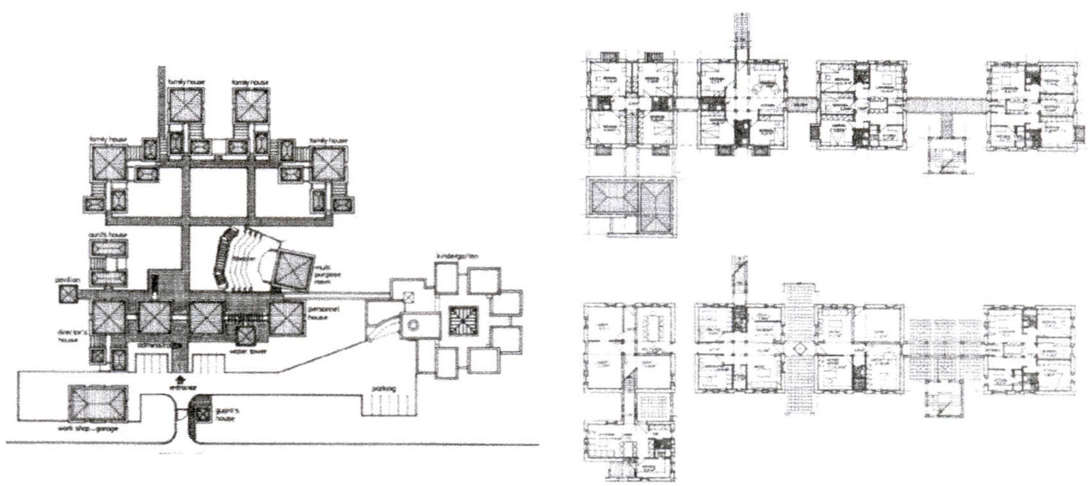


Fig 4.4 SOS Children's Village in Lefkose by Cem Türün

In this consideration, Y.K.K Guest House designed by Fumihiko Maki is a relevant example of linked organizations. Building is organized about a geometric idea. Composition is governed by an overall and regular geometric pattern. At this building, square grid is constantly disrupted by changes of angle, oblique approaches, extensions, and curved elements. Grids and axes serve to organize a visual and sequential perception of space. In this building, the center is continually shifting, creating a fluid and dynamic ordering of space rather than a static and measured one. The interior space dissolves into a complex of superimposed of grids, subtly articulated and subdivided by squares. (Fig 4.5)

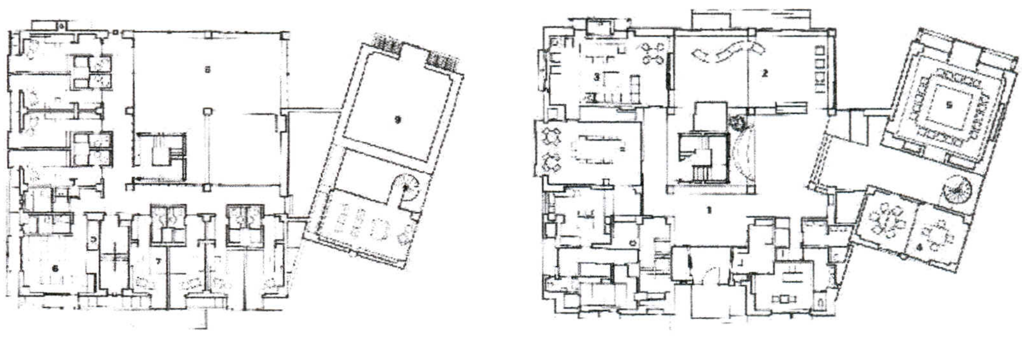


Fig 4.5 Plans of the Y.K.K Guest House by Fumihiko Maki

4.2.2 ATTACHED ELEMENTS

This technique is applied by adding a basic form to another laterally. However, the effect of addition also decreases as the dominance of the basic forms to each other decreases. In order to make the attachment, the surfaces to be attached must be harmonious. (Fig 4.6) As a result of continuous attachment of the same basic forms having the same dimensions, there appears a modulor integration and growth. By modular attachment of the selected unit forms, a regular form can be obtained, as well as an irregular one.

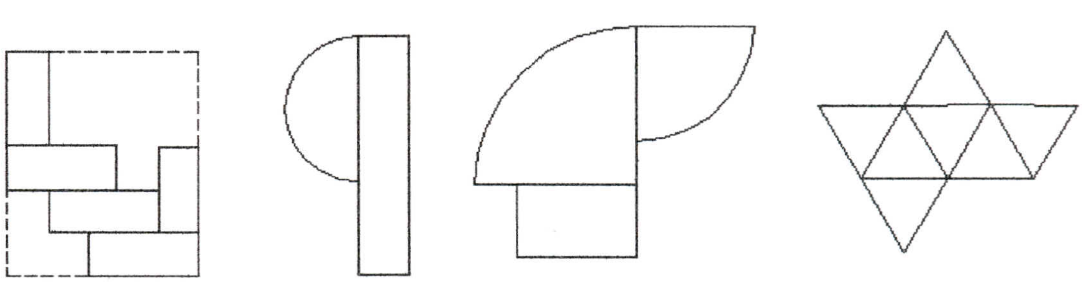


Fig 4.6 Attachment of the basic geometrical forms

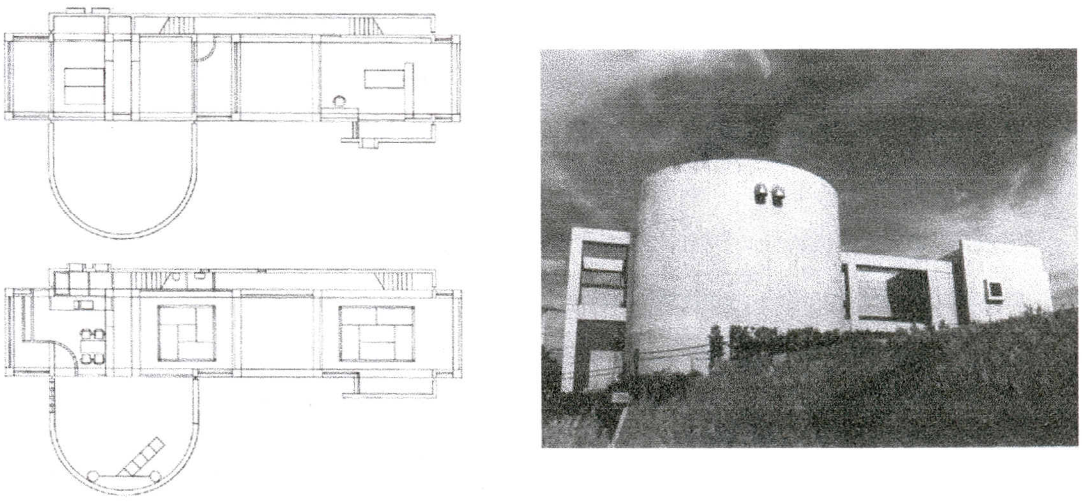


Fig 4.7 Hirabayashi House by Tadao Ando

Elements could be attached each other in edge-to-edge, edge-to-corner or corner-to-corner positions, it is the most widely used conjunction method, is edge-to-edge contact. Because the most effective assembling occur between those kinds of joinment elements. In Hirabayashi House by Tadao Ando, two basic geometrical elements as semi-cylindrical mass and prismatic mass were assembled in the way of contacting each other edge-to-edge position. There is surface assembling between elements and because of that two elements couls easily be discerned outside. (Fig 4.7)

4.2.3 INTERRELATIONSHIPS OF THE ELEMENTS

In this type relationships, the basic elements are integrated partially or completely depending on the functional, environmental or aesthetical requirements. As a result of these requirements, togethering the interrelated elements have been examined under the two main title:

4.2.3.1 INTERLOCKING RELATIONSHIPS

Interlocking formal relationship is generated with the overlapping of two forms. In other words, interlocking is the integration of two or more basic forms by partially inserting them into each other. In the process of generation, some factors effect the creation of interlocking effects. Some of these effects are: characteristic aspects of the forms, their dimensional differences, the number of surfaces affected from interlocking.

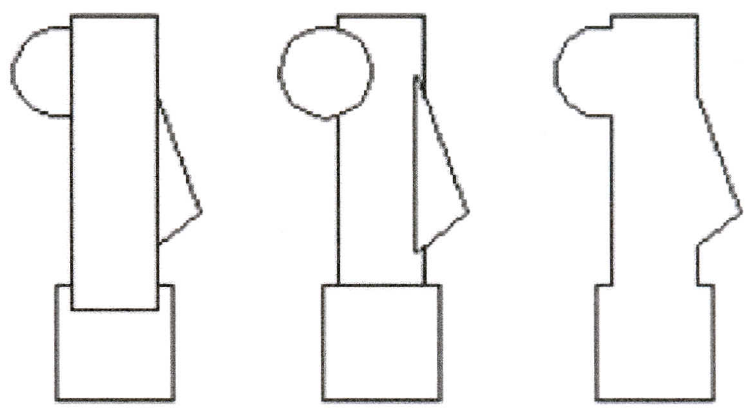


Fig 4.8 Two-dimensional organization schemas of intersecting basic forms

When two forms interlock, generally each interlocking portion of organization conserves its identity. Assembledge of these portions can be done through several ways. The position of interlocking portions determine the characteristic of the organization. For example interlocking portion can be shared equally by each form or merged with one of the forms. Even the interlocking portion can be developed its own integrity as a space that serves to link to two original space. In this type of assembledge, a zone of shared space is created between the elements. (Fig 4.8)

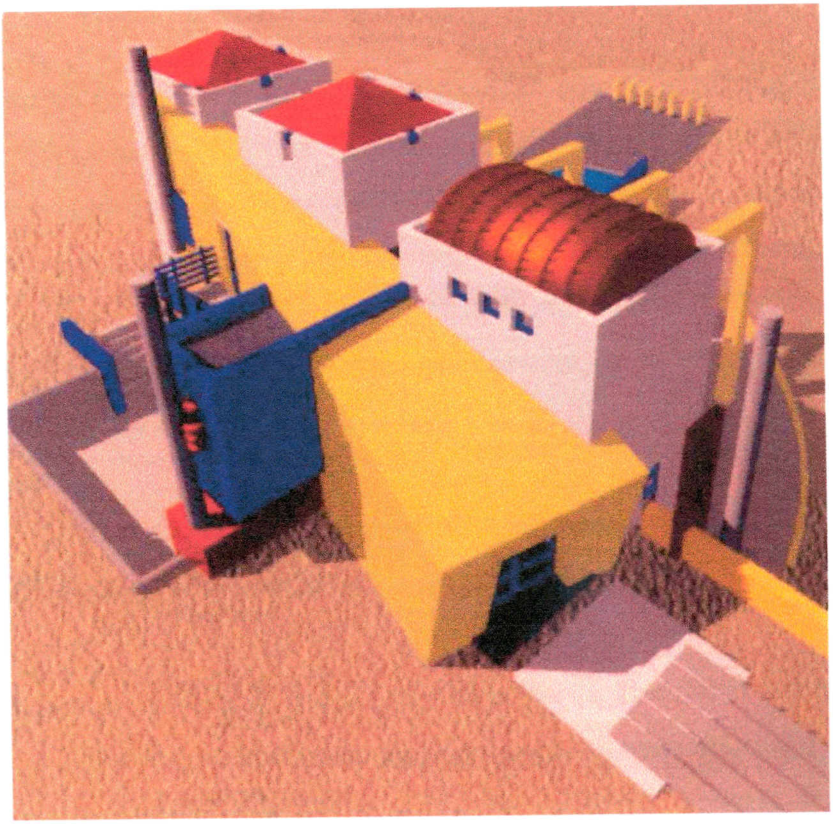
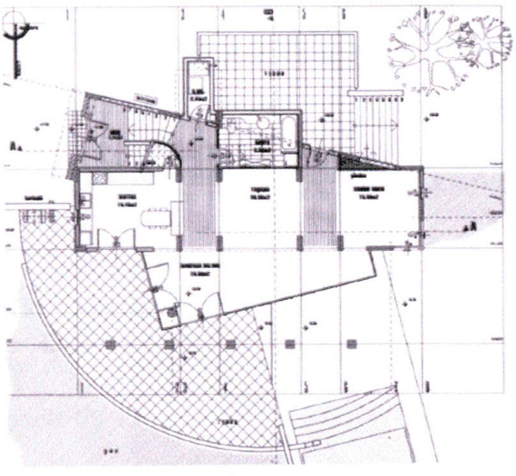


Fig 4.9 A House by Çınar Bilgin inİzmir



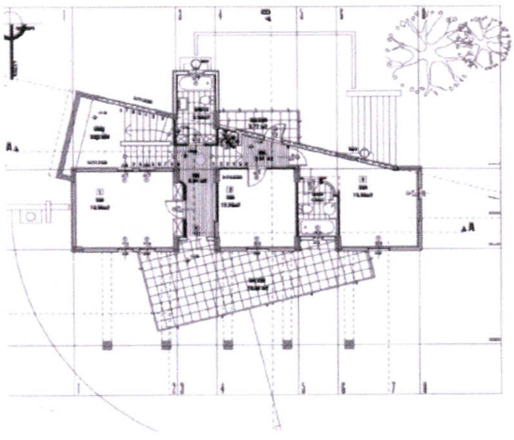


Fig 4.10 Plans of the House Designed by Çınar Bilgin

In the house project of Çınar Bilgin in İzmir, overall composition consists of units of two elements with square plan, one element rectangle in plan and prismatic elements completely overlapped in different angles. There are an interrelationship between elements bot interpenetrating (wholly overlapped) and interlocking (partially overlapped). Spatial differentiations are occured and spatial richness obtained in perceptiveness, on the points of junctions of elements being overlapped in different angles. (Fig 4.9 and Fig 4.10)

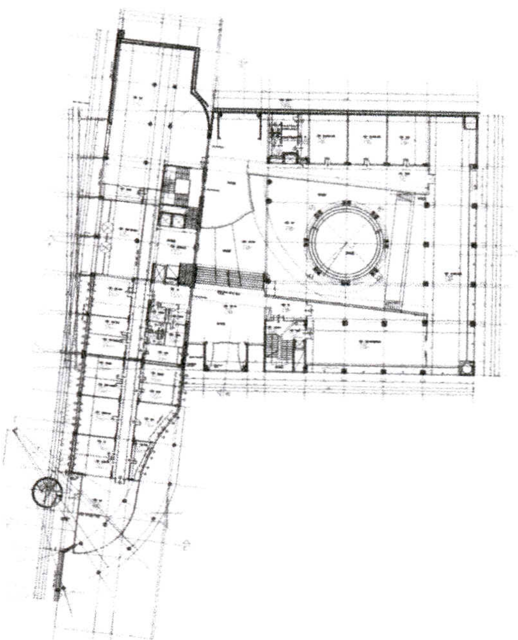
To sum up, there are three major ways while organising the spaces within the framework of interlocking relationships:

- Two or more several spaces of different geometrical form overlap and merge into a new shape. In this process one space, or even both, will be deformed, i.e. their formal seperation would be senseless, because it would yield fragments.
- Two spaces being overlapped retain their independence, remain recognisable, and together create a new spatial quality.
- When two spaces overlap in a way that one includes the other, this gives rise to space within space.

4.2.3.2 INTERPENETRATING RELATIONSHIPS

In the interpenetration relationship, hierarchy between the forms is based on first on their difference in scale. Secondly, it is based on the relative strength of the gestalts formed by the dynamic characteristic of the forms. The domination of smaller forms by larger ones is typically reinforced by the dynamic quality of the smaller form. (Fig 4.11)

However, contrast can be used effectively in such circumstances to strengthen the sense of sequence. While maintaining the dominance of the larger form. If the intersecting forms are of similar size, the one exhibiting the stronger sense of closure or penetration will dominate.



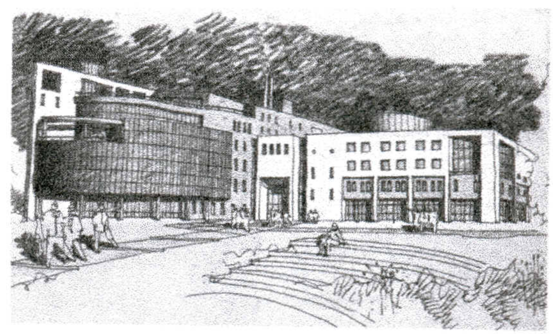


Fig 4.11 ITU Presidency Building in İstanbul by Necati Inceoglu

In the Hoffman House designed by Richard Meier, the building form is generated based on the interpenetrating relationship. The idea for the plan seems to have been generated from the shape of the site, which is an almost perfect square. The diagonal across the square determines the angle of one of the elevations of one of the two main rectangles on which the plan of the house is based. Each of these two rectangles is a double square. One is set on the diagonal of the site; the other is parallel to the sides of the site. They share one corner. Their geometric interrelationship determines the position of almost everything in the plan. (Fig 4.12)

Some spaces are defined by the interaction of the overlaid geometric operations. The positions of basic elements such as walls and columns are determined in accord with the complex armature of lines that is created with the geometry of the rectangles. The squares are sometimes subdivided to make the geometry even more complex.

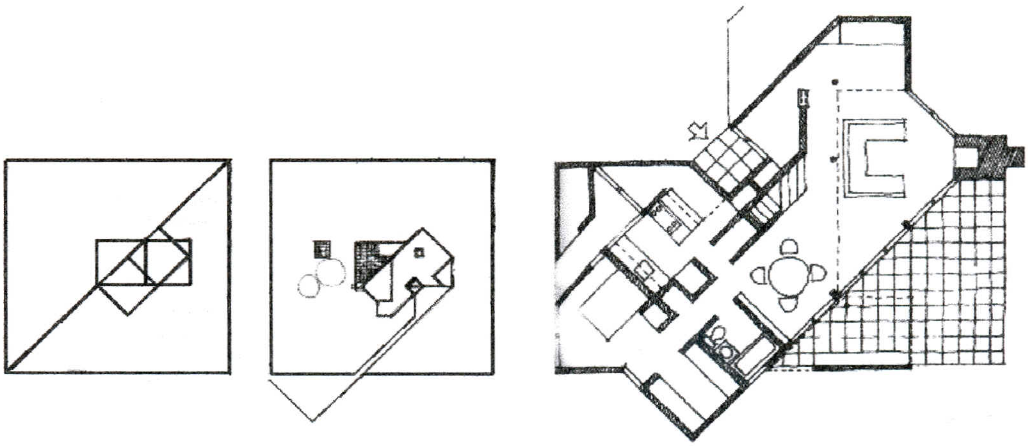


Fig 4.12 Abstraction of the interlocking geometries

4.2.4 GRIDAL REGULARITIES

Conceptual theme for generation of gridal organization is the repetition of the basic geometries, which represent the modulor units of spaces. A gridal organization is a kind of the method of articulating lines, shapes, and intersections. In other words, organization can be done both by repeating a basic form that can be used as a module and by repeating several forms in a certain system. Briefly, there is a dependence upon a geometrical order in the formation of gridal organization. The repetition of basic geometries is supported with multiplication, combination, subdivision and manipulation processes in order to generate overall composition. In these organizations, the positions of forms and spaces are regulated by two or three-dimensional grid pattern or field. Bringing the modules together is obtained by some principles of organization such as subtruction, addition and layering processes. These processes do not effect the identity of overall composition as a grid.

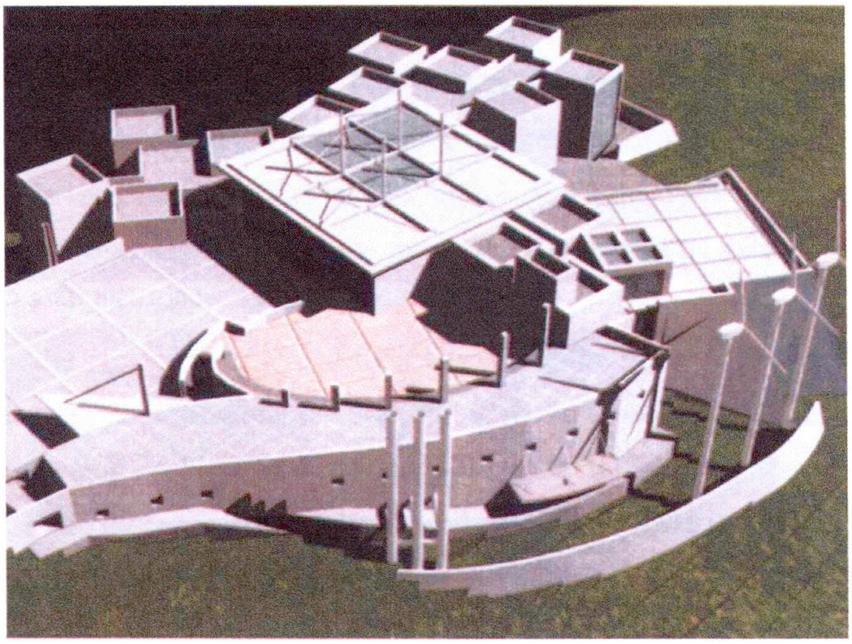


Fig 4.13 ITU Natuk Birkan Primary School in Istanbul by Selim Velioglu

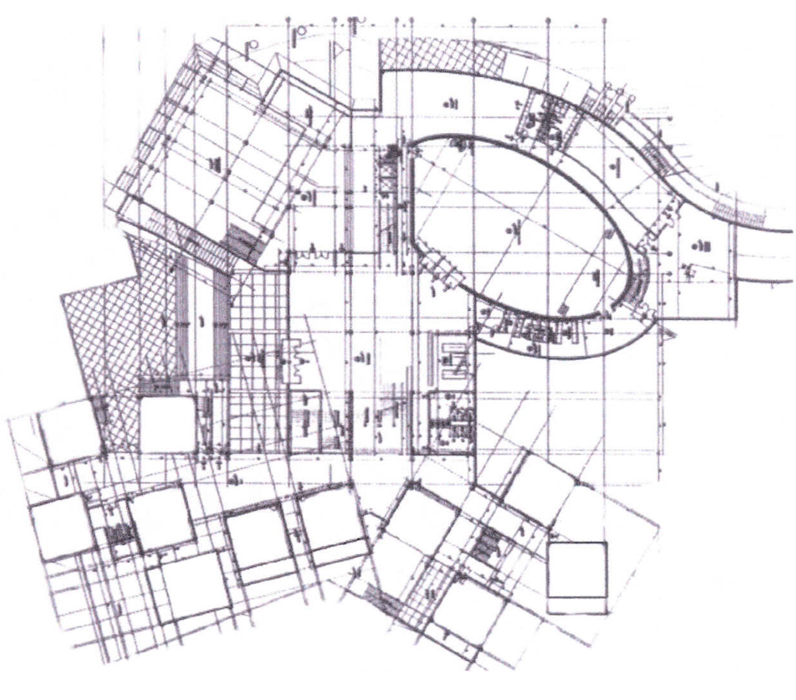


Fig 4.14 Plan of the ITU Natuk Birkan Primary School

Like basic geometric figures, grids can be combined or manipulated through the process of rotation, shifting, and overlapping. From this point of view, it is possible to design a gridal organization by rotating or dislocating the portion of grid about a point in the basic pattern. In the example of the "ITU Natuk Birkan Primary School", basic units of the plan and its generator is the square modules. The geometric schema consists of a system of overlaid squares. Those modules are minted up in a new composition for accumulating the project on land and fully answering the neediness by rotating as well as overlapping. In some regions on the project, having been rotated different square grids by overlapping each other, a new complex composition are gotten. Shortly, here basic unit itself is hierarchically arranged, and capable of local modifications wiyhout the destruction of its principle. (Fig 4.13 and Fig 4.14)

Arrangements of series of lines or basic geometric shapes constitute the overall composition. So the relationship between these lines and shapes are important for generation of the organization. Gridal organizations can become more complex by decreasing the intervals between the lines or by increasing the number of lines and geometric shapes that occur within the organization. Elements of the grid might or might not be orthogonal to each other. There are various ways to organize these elements to give shape the overall composition. For example, if the relationship is orthogonal, with all intervals in both series equal, a square grid result. Two orthogonal series, each with more than one equal interval, create a rectangular and plaid grid. Two non-orthogonal series of lines constitute a parallelogram grid. In other example, a triangular grid can be formed by three intersecting series of lines which have common points of intersection.

The most widely used pattern is the rectangular grid. In its simplest form, its characteristics include edge similarity, constant space size, and constant space shape, and some significance given to the edge intersections. One of the reasons for which this pattern is used so widely is its flexibility. It can be strecthed along its axes to give direction to the composition. In addition to this, within the pattern, sequences can be developed by varying the element sizes. Nesting and interlocking forms can be developed by deforming the grid. Apart from rectangular grids, there are other regular grid systems that have been used by architects to plan spaces. These include triangular grids, hexagonal grids, octogonal grids, etc. These grids are not as flexible as the rectangular grid. Beside that they have some very rigid implied hierarchies that are appropriate to some situational needs. The hexagonal grid, for example, has better continuation along its sides than the rectangular grid, giving the space more inward focus. The octagonal grid is even more centrally focused; and where it has to nest with a rectangular grid, a spatial hierarchy of scale produced in which the octagon is dominant.

Any cross lines in the series creates intersection point within the grid. Although these intersections alone do not give enough information to describe a grid, they are critical construct in the organization. For example intersections can be arranged in what is apparently a square grid, but connecting these intersections differently, it is possible to create parallelogram or triangular grids.

Architects have used geometrical grids since ancient times. They posses fascinating possibilities for order, achievement of unity and rhythm. For example, in the Casa Andreis, Paolo Porthegesi give a clear demonstration of the actual field concept in architecture. Building shows a free and continuous space, with a strong contact between inside and outside. Spatial continuity is organized by five foci which define concentric series of circles. The circles interferece inside the house where space becomes like a dynamic stream. (Fig 4.15)

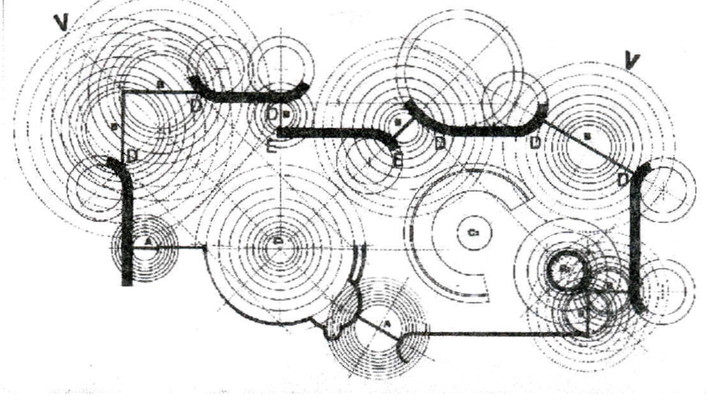


Fig 4.15 Geometric conceptual schema of Casa Papanice by P. Porthoghezi,Rome, 1969

Some recent architects who have been used geometrical grids are Louis Kahn, Moshe Safdie, Aldo Van Eyck, Mario Botta, Alfred Neuman and Bruce Goff. Bruce Goff has been a master in the use of combinatorial geometrical grids. Goff was able to adjust and combine geometric systems appropriately in order to integrate them with functions. Another example of combinatorial geometrical grid is the personal residence of John Portman. It is a grid combining squares, circles, and connecting rectangles. Louis Kahn used triangles and combination grids only in the plan of the Government Center in Dacca. He used the difficult combination of the "two", and and assigned broad functional destinations to the elements of his grid. (serviced and servant elements of the plan) All these architects have used geometry ang geometrical grids with the traditional Euclidean attidute.

4.3 PROCESSED USES OF ONE BASIC GEOMETRICAL ELEMENT

In those kinds of utilization of geometrical elements, the main thing is to make the changes on one geometrical element considering its formal wholeness not to be changed perceptively. The aim of this change is to answer the building form to the functional, aesthetic, and environmental requirements. Those changes could be on either two-dimensional-planar objects such as square, triangle, circle, etc. or three-dimensional-volumetric objects as pyramid, cube, cylinder, etc. All these processes put the design a new innovation as formal beauty with aesthetic proportions. At the end of those processings, building form keeps the properties of its origin. Approaching the design in the concept of wholeness (that use only one geometric form solving all spatial problems in its wholeness) could seem to limit at first sight. Whereas, if those elements are considered as seperately, it is clearly, it has always an immense variation. By using geometrical knowledgements as well as interventing to whole, a designer could easily obtain the chance of solving design problems. All utilizes towards whole has already ben taken up in four categories. These are transformation of whole, additions to whole, diminution from whole, and division of whole.

4.3.1 TRANSFORMATION OF THE WHOLE

The process of changing in form through a series of discrete permutations and manipulations in response to a specific context or set of conditions without a loss of identity or concept. It is such a progression that changes in form take place within the boundary of the object itself. (Fig 4.16) Effects of these changes can be occurred either the two or three dimensional form. Characteristically before these changes applied on the basic forms, they have simple reference frames. Changes from reference frame to other schemes should become perceptible. Understanding of the design concept depends on the perception of the ordering system. Through the series of finite permutations, the model is strenghtened and built upon. In other words, in transformational systems, it is essential that a designer understand the fundamental nature and the structure of the concept. Consequently, transformation is a principle for formal organization. In transformational systems, there is a prototypical architectural model and this model is transformed through a series of discrete manipulations in order to respond to specific conditions.

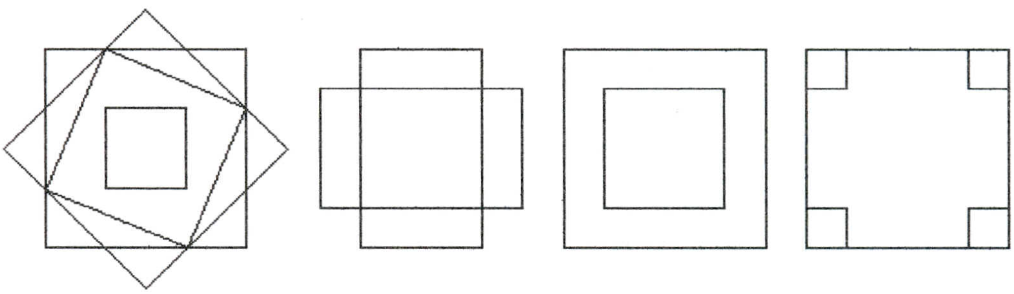


Fig 4.16 Transformation of square in two dimension

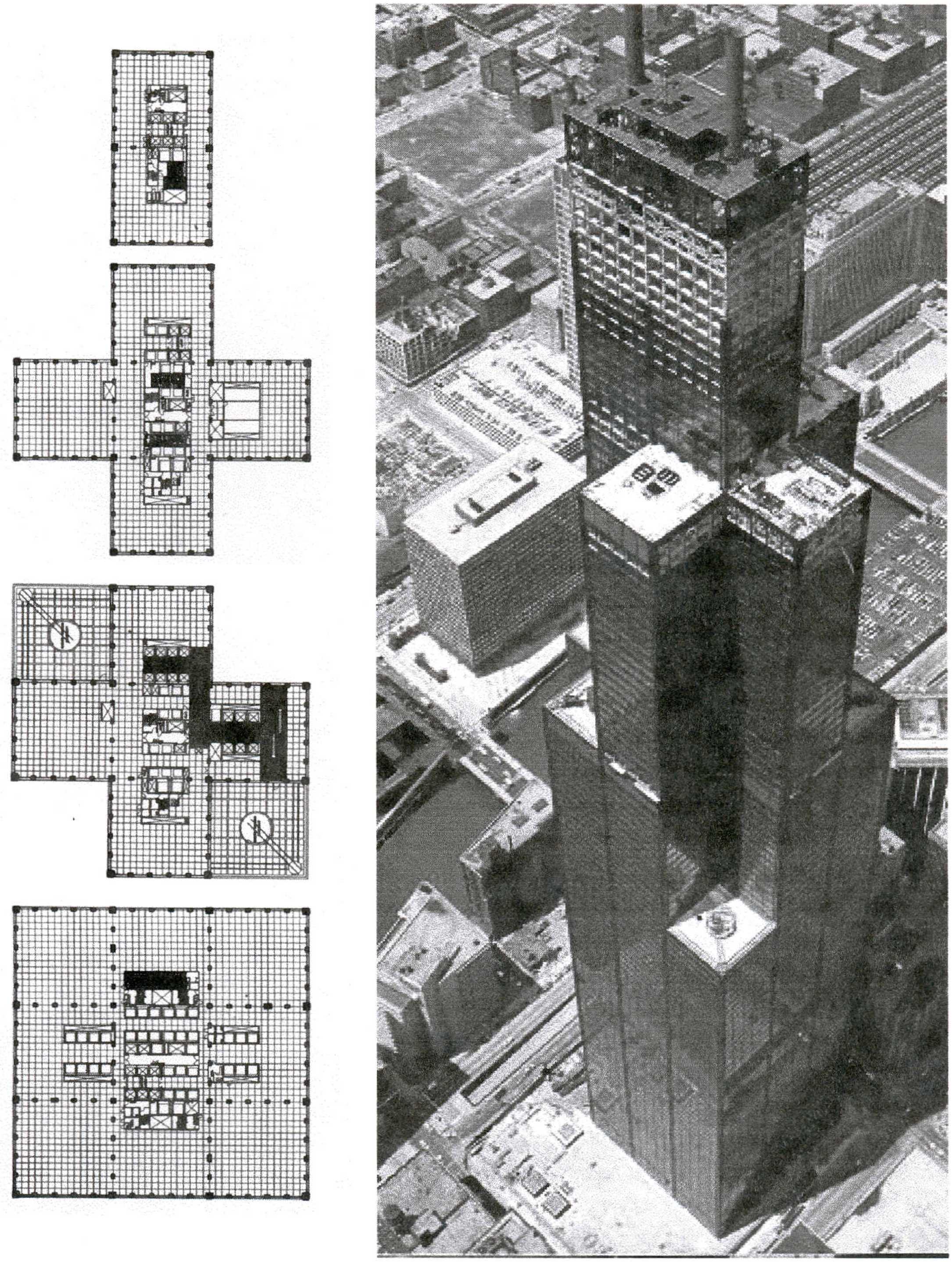


Fig 4.17 Transformation of square as the building rises in height

(Sears Tower by Skidmore Owings and Merril Architects)

Sears Tower building by Skidmore Owings and Merril architects is the best example for the transformation of square in plan. Its architects are used the pure square at various types on locating at each floor. Using a transformated square elevated in third dimension got a different form. The Tower containing a square form in plan at the lowest part of the building rises with different plan types, which are gotten from transformation of square. To come to conclusion, seemly the building has the effect of giving a compact form. (Fig 4.17)

The another example of the transformation of square is the project "Kare Ev" by Gungor Kaftanci. In this project space organization, in plan, processes towards diagonals of the square. The conjunction of square diagonals, stairs, and fireplace are exist. Architect for the sake of creating a livable spaces made a truncation around the basic form. Especially, by subtracting the corner of square, is made main entrance, and terrace. The resulting composition is geometrically regular, stable, and concentrated. (Fig 4.18)

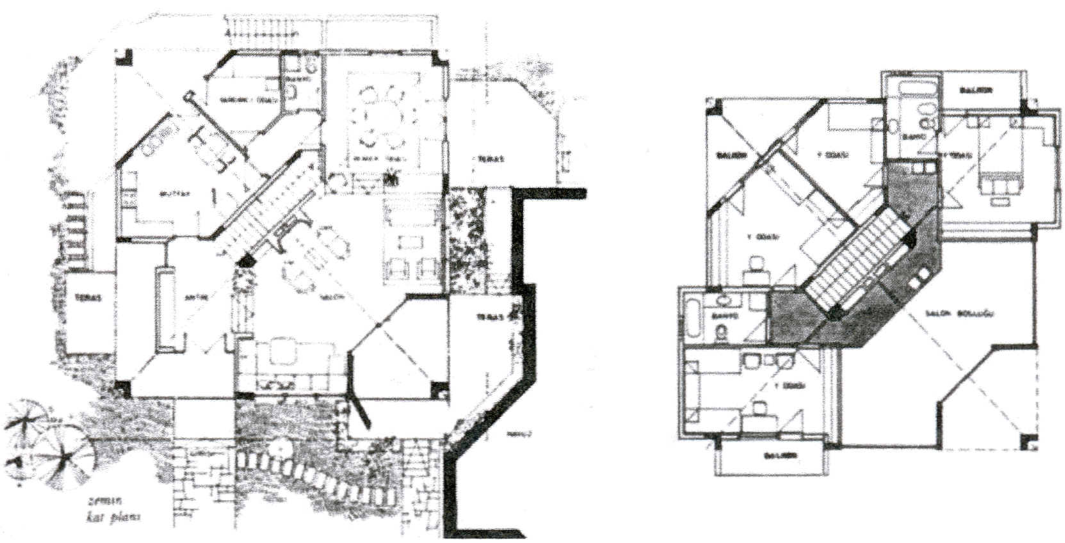


Fig 4.18 Sarda House by Gungor Kaftanci in Izmir

4.3.2 ADDITIONS TO THE WHOLE

The addition process is progressed by adding another pure or processed basic form to main form. There are several factors while realizing the addition process. The most effective factor is the size of the added part in comparison to the main form and its partial effect. In other words, the aggregation of idetifiable units or parts is the most important factor which has to be in this operation. Although it is generated from the identifiable individual elements. Addition process renders the parts of the building as dominant.

All additions can be done in a different types. Additions the elements to where and how are defined according to functional, aesthetic, and environmental requirements. As stated about, elements could be added either the side of main form, or the top surface, or both. The additions on side surfaces are generally emerged as vertical circulation elements such as stairs, lifts, etc. (Fig 4.19) Also it is possible to express the additions on side surfaces as two dimensional. In some cases of addition, differentiation between the top surfaces and lateral surface can not be made.

On the other hand, the elements added to the top of the main form are inclined roof forms, hemispherical or conical lightening and vaults, etc. Among these added elements, inclined roof has special properties because of covering the top surface totally. Addition elements to the top surface of basic element can be done for several purposes. For example, they can be added to main form so as to take natural light appropriately from the top surface. These added elements are shaped and placed according to the functional requirements. These elements mostly are the staircases, elevators, and chimneys. The geometric forms of these elements can be differentiated according to their purpose of the usage in the building. *(Onat, 1991)*

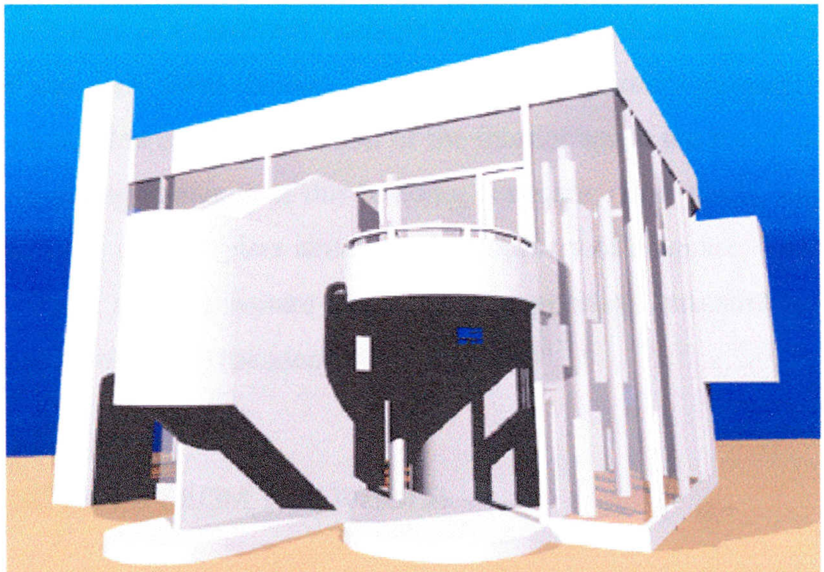


Fig 4.19 Wunder House

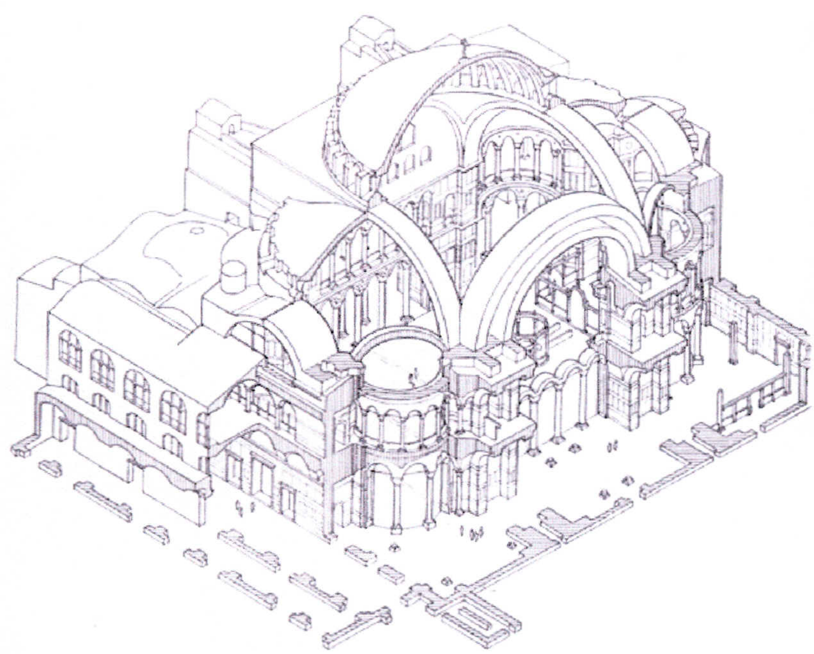


Fig 4.20 Aksonometric view of the Hagia Sophia

Hagia Sophia Mosque is an relevant example of the applications that added parts to the top surface of the main form. Design is determined by primary geometric forms. The form of the ground plan and the elevation of the interior space are based on geometrical rules. The form-giving elements of this building is square, cube, circle, and sphere. The spherical dome rests on four piers situated at the corners of a square. The link between the spherical dome and the square plan of the supporting structure is provided by spherical triangular elements (pendentives). (Fig 4.20)

4.3.3 DIMINUTIONS FROM THE WHOLE

As a result of designing with dimunition method, overall form is perceived as whole is dominant. In other words, although the piecess have been subtructed, we have perceived the overall composition as whole is dominant. The dimunition process can be progressed by removing a single portion or several portions from the solid body of the basic form. Within the framework of dimunition process, the piecess of form may be subtructed from the lateral surfaces, the top surfaces or both surfaces of the basic form. (Fig 4.21)

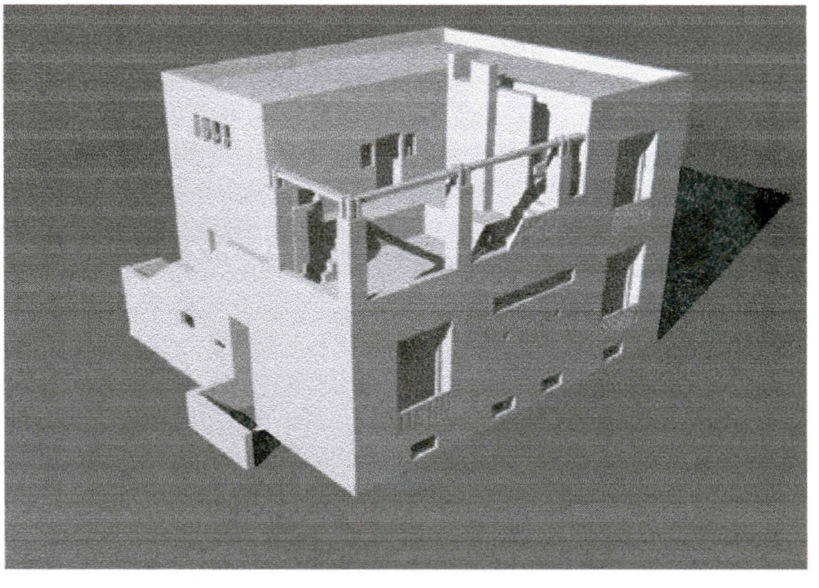


Fig 4.21 Lido House by Adolf Loos

While dimunition from the lateral surfaces, desired parts of the main form is removed from the lateral surfaces, and top surface of the building is not effected. In other words, the top surface preserves its basic shape which is dependent upon the basic form. Dimunition can be seen in different number of lateral surfaces in continuity. Preserving the identity of basic form, in this application, depends upon the maintaining the vertical edges of the basic form. In other words, maintaining the vertical edges throughout the subtraction process will give to the overall form a visual wholeness. (Fig 4.22)

On the other hand, dimunition from the top surfaces effects merely the top surface of the main form, lateral surfaces are not changed and stay within the boundaries of form. In other words, like the previous application (the process of dimunition from the lateral surface) dimunition of the parts from the basic form does not change the visual wholeness of the overall form. For this reason fundamental exterior effect of the basic form does not changed. In most examples of this application, the overall form has an introverted character. Determinants of this character for architectural form is the inner use of the building or the exterior conditions such as wind, sun, or noise.

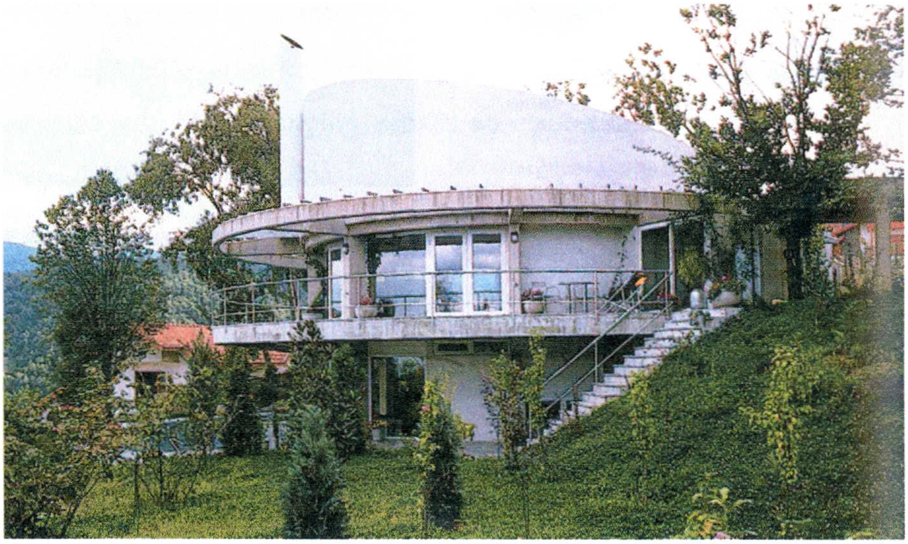


Fig 4.22 Gurel House by Radi Birol in Sapanca

In the Gurel House, building form was obtained by overlapping same central circular plans diminishing nearly about two meters in radious on each floor. The building has a circular plan organization, on base floor, six meters in radious, on first floor, eight meters in radious, and in terrace, ten meters in radious. Because of that building could be seen as cylindrical in form being subtracted from lateral surfaces. (Fig 4.22)

4.3.4 DIVISION OF THE WHOLE

In these applications, as a whole, basic geometric form is divided more parts. In other words, at the end of the division, two or more partial forms come into being. (Fig 4.37) The process of division of the basic geometrical forms is done according to functional requirement of the building. Depending on the usage, the parts can be independent from each other or linked to each other to ensure continuity of the inner circulation. Operations, which are applied on the basic form (after the division of the form), should be done without destroying the effect of the division. In such divisions, partial forms remain within the boundaries of the basic form and continue to define those boundaries. In addition to this type of organization, it is also possible to make an angular change in the position of a part. As aresult of this angular change, the boundaries of the basic form can also be changed. This changing causes an opposing effect of the part against the order of the basic form.

Fig 4.23 Marriage Office Building of Çankaya Municipality by Nesrin-Affan Yatman

5 CONCLUSION

When we look at the historical development of geometry as a form-generator tool, it can be seen that the determination of architectural form according to geometrical principles is a subtle tool in the hands of an architect. And this one can not equate with formal rigidity.

In the past, geometry and architecture had much in common and the practical problems encountered by early builders led them to geometrical discoveries. Today, however, there is not just one kind of geometry, but many. The advent of mathematics brought the possibility of alternative new geometries from which architects choose the most convenient one. These modern geometric concepts have given architect new ideas of architectural form and spatial organization in relation to new mathematical methodologies in design. The concept of modern geometry has potential value in describing and helping us to understood some of the geometrical relationships within buildings. While traditional geometry offers a fixed system to describe everything in nature, in the modern geometry there is a gradual transformation of space from pure, static to composite and dynamic.

Geometry, overall study, was taken place as design tool from which architects frequently utilize in their works. And geometry was directed in order to use in architecture enoughly, by taking over its mathematical meaning. For that reason, primarily, geometrical concepts that are used both architectural and mathematical discipline are defined and specified. After that process of geometrization of architectural form was attempted to explain by using those basic geometrical concepts. In other words, two or three-dimensional basic geometrical elements, considering architectural discipline, were examined their assembling operations theoretically and pratically by using various number of principals of organization. Those elements could be used both as two-dimensional-planar elements for space organization on plan and section, and be used as volumetric elements in architecture (just the same as in the building Villa Savoye by subtracting inner part of a massive cube). Overall study, the form and space organizations as if they were so wide, were explained in a logical discipline. By doing that the most used geometrical operations on a space and form organization were labelled.

When workings designed based on the geometrical concepts are examined through the history, it could be clearly seen that geometry has the capability of being able to be used in both practically and theoretically for adding new thing on form generation. For example, in antique eras, geometry had the divine meaning. Because of that, in that era, God's Home had should been constructed considering the geometrical rules and basic geometrical elements. Such that pure elements like pyramid presenting an exalted position had been used as architectural form. Also applicationsin Gothic period, geometrical rules had the same usage just as antique period of time. In Renaissance, beauty and aesthetical concepts had been equated with geometry and pure use of geometrical elements. In this era, beauty of building (aesthetical proportions) had been explained in relation with geometrical concepts. In Baroque period, geometry had gained a methaphysical meaning in the architectural discipline. In Enlighteenment period, many theoreticians and architects especially Boullee and Ledoux had given geometry a philosophic meaning. Basic geometrical forms in the same era had been loaded with symbolic, religious, and fundamental meanings such as purity and excellence. At the beginning of modern period since economical obligations, those elements had also been used for functional requirements and rationalization. In recent applications, some groups of architects (Louis I Kahn, etc.) used the pure geometrical elements of past decades and some of others such as Le Corbusier choosed the way of using basic geometrical forms by them.

Consequently, as a result of geometrical operations being done by using basic geometrical elements, architectural form and space turned from the situations of pure, static, and isolated to composite, dynamic and interpenetrating. Primarily, architectural forms and spaces having been organized by strict geometrical rules turned more flexible form and space organizations in parallel to developments of architects' abilities of using geometrical elements.

Two different approaches were clarified by utilizing those conceptual elements of geometry in architectural form and space processing. In the first, elements keep their identifications as a result of geometrical operations. In that approach, we could gain the knowledgement about kernel of design concept on the resulted form. In second, basic geometrical elements using for identifiying of building form conceptually could not be perceived on resulted form. In those kinds of examples, it is hard to find the kernel of design concept on a completed building form.

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APPENDIX

GLOSSARY

Abstraction: A distilation of a basic idea or parti into its most significant or telling parts.

Additive Forms: Characterized by a basic progress which involves adding simple solids together to make a more complex whole.

Axiality: Relationship or organization along a conceptual connecting or dividing line.

Balance: The pleasing or harmonious arrangement or proportion of parts or elements in a design or composition.

Cartesian Space: Based on th X, Y, Z coordinate system of Rene' Descartes, an infinitely expandeble and homogeneous space defined by a square grid.

Centralized Plan: A building plan which is organized around a central point.

Composition: The arranging of parts or elements into proper proportion or relation so as to form a unified whole.

Concept: A mental image or formulation of what something is or ought to be, esp. an idea generalized from particular characteristics or instances.

Dome: A hemi-spherical vault or capula supported by a circular wall or drum or by corner supports.

Form: The shape and structure of something as distinguished from its substance or material.

Geometry: The mathematical discipline which deals with measurements, relationships and properties of points, lines, planes, angles, and figures in space.

Golden Rectangle: A rectangle whose proportions embody the relationships of the golden section. A golden Rectangle can be infinitely decomposed into a square and another golden rectangle.

Grid: A framework of crossed lines; common architectural grids are four-square and nine-square.

Hemicycle: A semi-circular form.

Hierarchy: A system of things, spaces, or areas ranked one above the other in series.

Idea: A thought or notion resulting from mental awareness, understanding, or activity.

Juxtaposition: The close placement of elements which may have no relationship other than their adjacency.

Line: The edge or contour of a shape.

Morphology: Literally a branch of biology which examines the forms and structures of plants and animals, used in architecture to discuss the study of form.

Order: A condition of logical, harmonious, or comprehensible arragement in which each element of a group is properly disposed with reference to other elements and to its purpose.

Organization: The systematic arranging of interdependent or coordinated parts into a coherent unity or functioning whole.

Parti: From the French verb 'partir' meaning 'to leave' or a point of departure, used in architecture to designate the basic organization of a design.

Platonic Solid: Based on the theories of the Greek philosopher Plato, Platonic or primary shapes are rooted or extended to generate primary volume which are the sphere, cylinder, cone, pyramid, and cube.

Point: The major idea, essential part or salient feature of a narrative or concept.

Proportion: The comparative relations between dimensions or sizes.

Quadrature: A Gothic method of design and proportion which relies on the interrelationship of square figures.

Radial: Disposed about a central point.

Rhythm: Repetition or system with uniform pattern or beat recurrence.

Rotation: The act of turning around a central point or axis.

Shape: The outline or surface configuration of a particular form or figure.

Subtractive form: Shape which is understood to have been created by a process of subtraction from a whole, i.e. by the removal of pieces or the carving out of a void from a solid.

Superimpositions: The simultaneous presence of two or more forms, one atop the other.

Triangulation: A Gothic method of design and proportion based on the interrelationship of triangles.