Principles and Applications of Geometric Proportions in Architectural Design

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Abstract—*Roman Architect Vitruvius has state three conditions for good building i.e. commodity (usefulness), firmness (solidity or strength) and delight (beauty). Proportion plays very important role in all three as it provide guidelines for useful spaces, for creating good structural system and creating aesthetically pleasing environment. Since ages the humans have experimented the proportions of built mass by using mathematical principles. The Greece has used the geometric proportion in Parthenon by using the golden ratio in the façade of building, also used the correction of optical illusion by changing the proportion of building elements. The Roman Architect Vitruvius written that principles of proportion and symmetry used in architecture are in fact derived from symmetry found in shape of human body and he quoted "Therefore, since nature has designed the human body so that its members are duly proportioned to the frame as a whole, it appears that the ancients had good reason for their rule, that in perfect buildings, the different members must be in exact symmetrical relations to the whole general scheme".*

Le Corbusier has further evolved this system of proportion and given the name "Modulor" in modern context. Le Corbusier has explicitly used golden ration in his Modular system for architectural proportion and linked with anthropometric of Human Figure.

Geometric proportions were very important tool in design of building since ages and these have lost its significance in modern context. Most of architects in present generation have no idea of these proportion systems or involved in other complicated design issues, they forget to focus the design of buildings with proportional beauty. This paper will explore the relationship between geometry, nature and architecture; will define the golden ratio and fibbannoic series as basic elements for understanding geometric proportion. It will also explore the principles of geometric proportion exist since ages and application of these geometric proportion through library case studies.

Keywords: *Vitruvius, golden ratio, Modulor, Parthenon, Le Corbusier.*

1. INTRODUCTION:

Geometry has been used in buildings and other design forms across centuries. The first confirmed record of the use of geometry could be traced in Greeks period. Greeks have explored geometry in their public buildings such as Parthenon. However the prior to Greeks, many old civilizations have used the geometry for their structure e.g. prehistoric cave in Scotland.

There were many principles of geometry applied to designing of building such as form, space, shape, geometric proportion etc. Geometric ratio and proportions was very important tool used for aesthetic of building in ancient civilization. They have built structures with dimensions derived from mathematic constant and ratio such as golden mean, golden triangle, golden rectangle etc.

This proportion system has lost its significance due to many more multiple design issues in modern context. The architects are more concerned about space utilization, energy issues, sustainable principle, form oriented buildings, structural design etc. These architects used to forget the essence of architecture lies in its aesthetic, without it buildings are just machines .There is need to understand the importance of geometric proportion in architectural design process.

2. GEOMETRY , NATURE AND ARCHITECTURE :

"Look deep into nature, and then you will understand everything better." – Albert Einstein

The relationship between geometry, nature and architecture is very important to understand because human beings are closely observing nature since their existence. The human have started learning form nature and they have found that nature has geometric proportions in all her creation such as human, animals, and plants.

Roman Architect Vitruvius remarked that human body could be inspiring factor for creating perfect building and he write "Nature has designed the human body so that its members are duly proportioned to the frame as a whole." It is widely accepted that proportion of human body follow the principles of golden ratio. Later on Le Corbusier has developed theory of modular based on human body proportion and liking it to the building elements.

Nature has unique process; every object contains the simple geometric pattern within molecular seed which develop into complex structure forms for animals, plants and human being too. This cellular level geometric form in definite proportion could reflect the vibration quality and when these similar simple geometric patterns in definite proportions at cellular level are incorporated in architecture, it also reflects vibration exchange between building and its occupant.

3. THE CONCPET OF GOLDEN SECTION AND FIBBANNOIC SERIES :

The concept of golden section is theorized by Greek Philosopher Plato. He has establish the relationship between the two unequal segment of line, as per his theory that if ratio between the sum of two segment of line to larger part is same as ratio between large segment to small segment , the two part are in golden ration .This golden ratio is constant and its value is 1.6180339887.
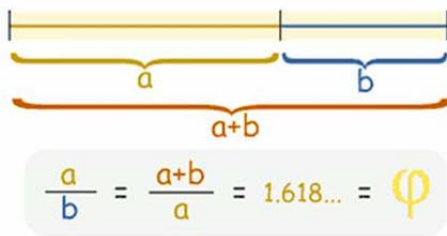

Fig. 1: Golden ratio through line segment

Golden ratio is recognized by different names such as The Golden Mean, Phi, the Divine Section, The Golden Cut, The Golden Proportion, The Divine Proportion, and tau(t).

The fibbannoic series is 0,0,1,2,3,5,8,13,21………. and in this series the next no is sum of two previous no and the ratio of next no to previous no is constant called golden ratio. In nature the Fibbannoic series found in animals, plants etc This series has very great significance in almost all field because the ratio of two no is in golden ratio.
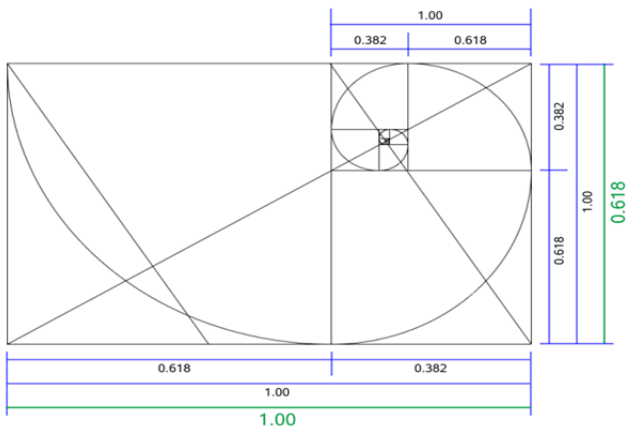

Fig. 2: Golden spiral

4. PRINCPLES OF GEOMETRIC PROPORTION IN ARCHITECTURAL DESIGN :

The system of proportion exists everywhere in nature such as human body, shapes, artwork, music, painting and even in cosmic design of the universe. In architecture, the proportion is defined as relationship between one part of design to other or to the whole design that may create harmonious and aesthetical.

Proportion denotes as ratio between two numbers. This ration could have quantitative and qualitative meaning attached to it. Mathematician might be interested in quantitative aspect more but architects are more interested in qualitative aspect of this ratio. The quantitative aspect could be called as "Proportion as ratio"and qualitative aspect as "Proportion as beauty".

System of proportion has been used to fulfill the technical and aesthetic requirement of design throughout history of architecture. There were key principles for this proportion system as follows:

a) Ensure the repetition of key ratio throughout design
b) have additive properties so that the whole could be divided into different parts easily
c) be adaptable to architect's technical means

There were many pioneer architects who has developed the system of proportion in history of architecture such Vitruvius in Roman period , Leon Battista Alberti in Renaissance period , Le Corbusier in twenty century.

A. Vitruvius Proportion system :

According to Roman Architect Vitruvius, an architect should consider the three central aspects of design for building: *firmitas* (strength), *utilitas* (functionality), and *venustas* (beauty).

Theory of venustas is very complicated and as per these principles timeless notion of beauty could be learnt from "truth of nature", nature's designs are based on universal laws of proportion and symmetry. He has believed that human body's proportions are perfect created by nature and these could be used by an architect for designing of building.

Leonardo da Vinci in Renaissance has drawn Figure based on work of Vitruvius and He has made the an ideal human body fitted precisely into both circle and square and through this illustration he has told to link geometric forms of building to human body's proportion.
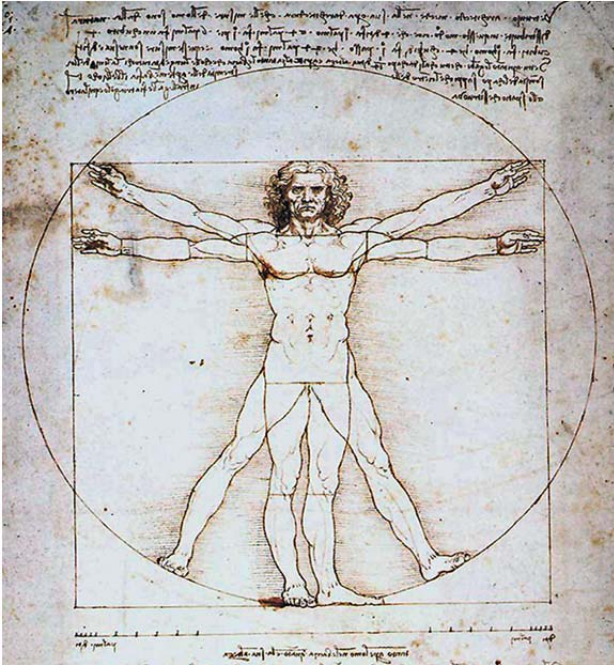
Fig. 3: Vitruvius Man drawn by Leonardo da Vinci

B. Alberti Proportion system :

Alberti explain the harmony of proportion could be achieved in such a manner "nothing could be added, diminished or altered expect for the worse". It simply means that one should go for perfection in the system of proportion; one should explore many options before finalizing the best one. He created a system of architecture based on the ratios 2:1 and 3:1 suggested by the Timaeus of Plato in ancient Greece and based on musical scale. He reasoned that "what is pleasing to the ear should be pleasing to the eye." He has applied the system of proportion for designing of the two buildings namely Santa Maria Novella in Florence and San Sebastiani in Mantua, Italy.
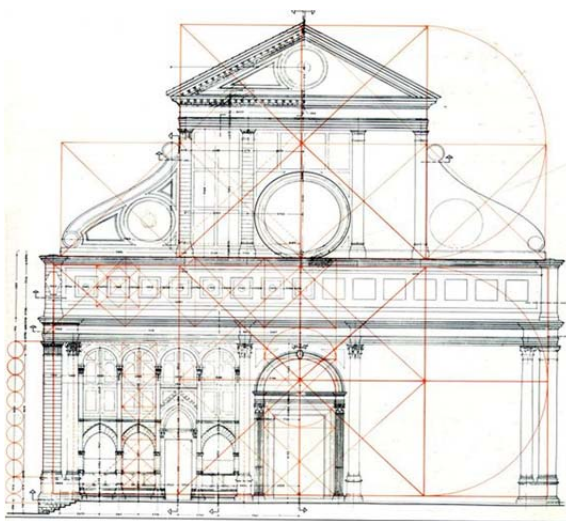
C. Le Corbusier Modulor System :

Le Corbusier has taken the advantage of knowledge given by Vitrivus, Vitruvius, Leonardo da Vinci's Vitruvian Man, Leone Battista Alberti and interpreted this knowledge in new way called " Modulor".

Le Corbusier has created Le Modular six-foot (about 183-centimeter) Man, somewhat resembling the familiar logo of the "Michelin man," with his arm upraised (to a height of 226 cm; 7'5"), was inserted into a square. The ratio of the height of the man (feet to head 183 cm; 6') to the height of his navel (at the mid-point of 113 cm; 3'8.5") was taken precisely in a Golden Ratio. He has further divided the height of man (from feet to the raised arm) in golden ration (140 cm and 86 cm) at the level of wrist of downward –hanging arm. These two ratios (113 /70) and (140/86) were further divided into smaller dimensions according to Fibonacci series. According to the quantities of 113 and 226, Le Corbusier developed two vertical measurements, the red series and the blue series, which are descending scales related to the height of the human figure. The basic plot of human figure is 113 (feet to naval), 70 (naval to head) and 43 (head to raised arm) have been shown on left side of human figure. The all anthropometrics of human activities could be worked out by Modulor man .
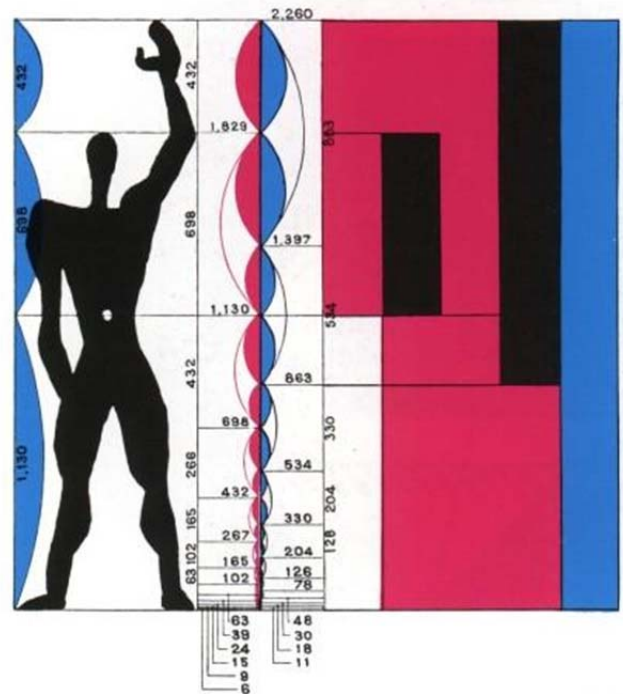

Fig. 5: Le Modular Man by Le Corbusier

**Fig. 4: Geometric proportion in elevation of
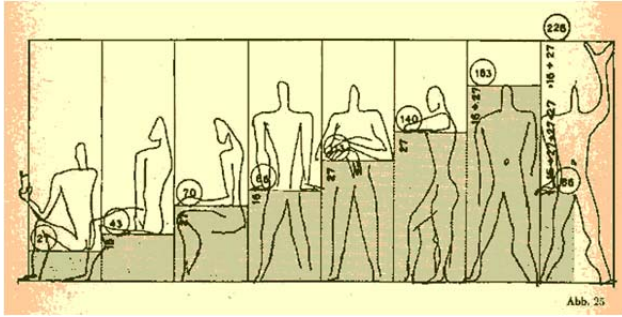Santa Maria Novella in Florence**

Fig. 6: Anthropometrics through Le Modulor Man

He has used this Modulor principles in designing of Villa Savoye,Poissy- France,Mill Owners Association Building Ahemdabad ,Unite D'habitation Marseilles, France , planning and designing of Capitol complex ,Chandigarh .

5. CASE STUDIES OF GEOMETRIC PROPORTIONS

A. PARTHENON ,ROME :

The Parthenon has been designed in Greek period and its façade is based on golden ratio. There were three types of column used in Greek period, Doric columns represent the male human figure, Ionic column represent the female human figure. The third type of column is called Corinthian column. The height and entablature of Doric column is eight and two times to its base respectively. There was more height and entablature in ionic column. The Doric column looks much thicker then ionic column.
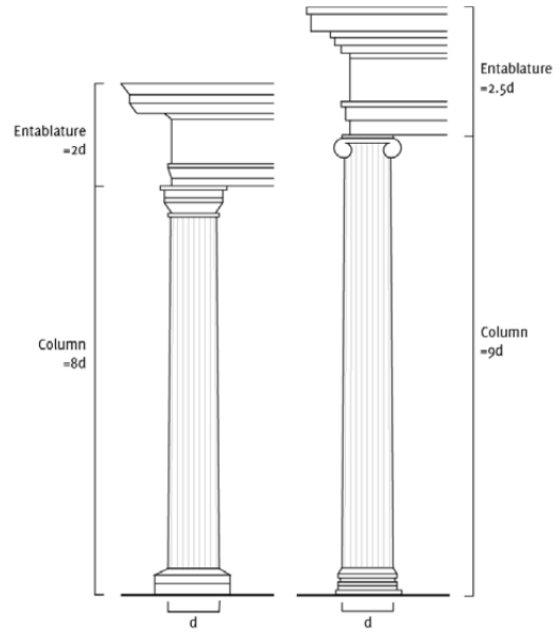

Fig. 7: Golden ratio in façade of Parthenon.

Fig. 8: Proportion of Doric and Ionic column in Greek

B. PYRAMIDS OF GIZZA, EGYPT :

The great Pyramid of Giza is one of the earliest examples to use golden ration and it is built around 2560 B.C. Its height is the radius of a circle whose circumference equals the base perimeter, and its height is the side of a square whose area equals that of each of the four sides.

The earth and moon's dimensions could be calculated through dimension of Great Pyramid of Gizza. You have to draw an inscribed circle inside the square (the Earth) and a small circle centered at the apex and tangent with the preceding one (the Moon). It is to be pointed out that cosmic proportion has been incorporated in buildings.
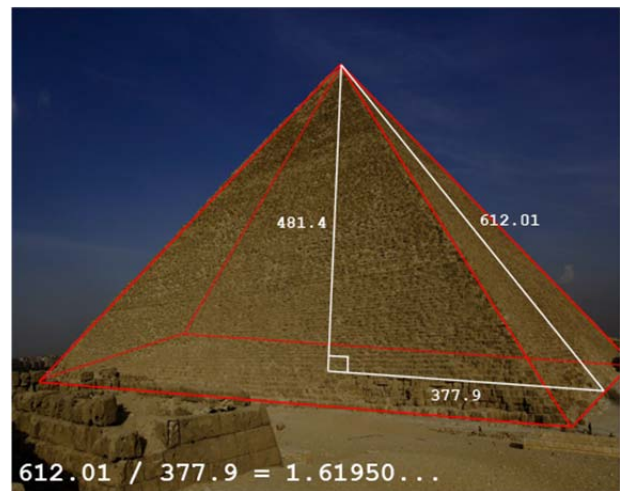

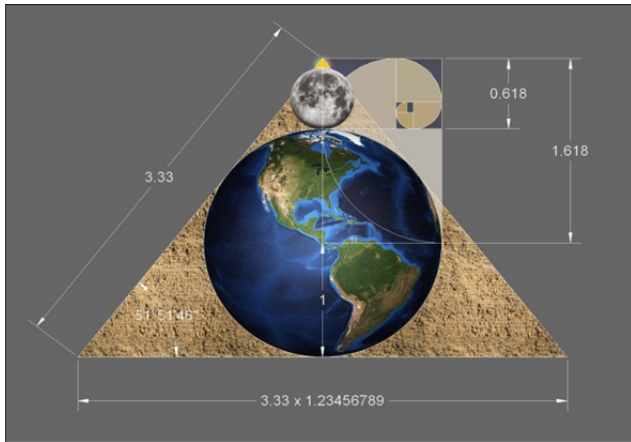**Fig. 9: Golden ratio in Great Pyramid of Gizza.**

Fig. 10: Earth and Moon's dimensions through Great Pyramids of Gizza.

C. UNITE D'HABITATION BY LE CORBUSIER :

This is one of the largest housing projects completed after World War II in Marseille, France around 1952 and the concept of this housing was based on "Vertical garden city". Le Corbusier has implemented his Le Modulor concept in this housing.

The building has standard module of 2.26m (Modulor man's dimension). The façade of this building is carefully designed orchestrated pattern of single and double stories height balconies generated from 15 different types of living spaces and public, communal spaces in which dimensions are determined by Modulor system.

He has used the system of golden ratio in plan, section, the front elevation, section of apartment, in woodwork, wall, roof and some prefabricate furniture.
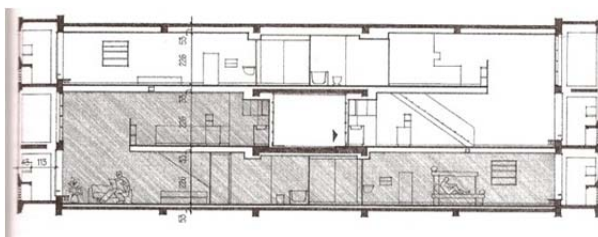

Fig. 11: Golden ratio in front elevation

Fig. 12: Golden ratio in section of apartment block

D. U.N. SECRETARIAT BUILDING BY LE CORBUSIER :

Fig. 13: UN Secretariat Building West 3, Golden Ratios with PhiMatrix

The United Nations Secretariat building is tall skyscraper of 154 m(505 ft) located in Manhattan New York. The building is design on the basis of golden ratio.The building is considered as 41 storeyed including mechanical top floors, so he has divide 41/1.618 =15.7 floor, He has made first non reflective band in between 15 and 16th floor. The other non reflective band also been made on the basis of golden ratio only.

E. CALIFORNIA POLYTECHNIC STATE UNIVERSITY :

The College of Engineering at California Polytechnic State University is design on the basis of Fibbannoic Series and golden mean. The landscape architect Jeffrey Gordon Smith describe in his own word "As guiding element, We selected the Fibbannoic Series spiral , or golden mean , as representation of engineering college "

Fig. 14: Golden spiral in the plan of College of Engg.

6. CONCLUSION

It has been discussed that geometry plays very important role in architectural design since ages. There is strong relationship between geometry, nature and architecture. Architects through history were interested in human body proportion and tried to link these proportions to the building design in various ways. Le Corbusier has given new theory of Modulor based on golden mean, anthropometrics of human body and Fibbannoic series. Le Corbusier has applied this theory in his architecture and his buildings are known all over world for aesthetic.

The present generation of architects are very less interested in geometric proportion of building or do not have enough knowledge about it. The modern architects are more interested in evolving form but to forget to detail out these forms in good proportion. It has been learned from the case studies that geometric proportion could be used in various ways in design of building such as planning, façade, sections, form, space, detail of various elements of building such as column etc

Geometric proportion should not act as constraints for architect's creativity but this knowledge should be used in its right context of design.

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