International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 08 | August - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

GEOMERTY IN ARCHITECTURE

Vaishnavi Rishikesh Garud

vgarud99@gmail.com

M.V.P.S's College of Architecture, Nashik

Fourth Yr. B.Arch., 2021-22

Abstract: Geometry has an impact on our day-to-day lives. Geometry is one of the core factors or principles of design. Everything around us is a measurement. Architecture is a domain that majorly deals with geometry and visuals. In the history of architecture, proportions and symmetry along with basic shapes and forms, serves as basic tools for architectural design. From the pyramids in Egypt to the new World Trade Centre in New York City, great architecture uses the same essential building blocks as our body and all living things. Geometry not only plays role in the designing of the building but also becomes a part of the aesthetics of the building. The relationship between architectural design and geometry starts with the notion of harmony. Geometry contributes to the process of composition & designing in architecture. Elements in design & their interrelation introduce composition. Geometry is the science describing structures & spaces. Geometry influences the visual & structural aspects of design. Composition in architecture begins with space developing. Geometric figures, forms and transformations build the material of architectural design. This research is validated through various case studies and research papers. In the following paper we will analyse the role of geometry in the architectural design processes through several examples along with history of architecture.

Keywords: Geometric forms, history, mathematics, balance, proportion, symmetry

1. Introduction: The word Geometry deals with form, shape, and measurement and is the part of mathematics where visual thought is dominant. Since visual thought is a dominant part of architectural design, geometry is also an important part of architecture. Both design and construction in architecture deal with visualization, and architects constantly employ geometry. Architects use geometry in diverse ways while designing. The form of the igloo came from understanding of geometry and structure. Structures indicate general systems of order in various scientific disciplines, derived from the Latin notion "structura" which means join together in order. Mathematics can be seen as a general science of structures by considering systems of elements and their relations or operations. "Mathematics is the science of structure and pattern in general." In various architects' work, geometry is manifested in form & shape. The whole building is visualized in form of geometry and philosophies are attached to them. In the history of architecture geometric rules based on the ideas of proportions and symmetries formed fixed tools for architectural design.

The basic definition of geometry given in 'a visual dictionary of architecture" by Francis D.K.Ching states that ' a branch of mathematics that deals with the properties, measurement and relationship of points, lines and angles, end solids, deduced from the defining conditions by the means of certain assumed properties of space " .

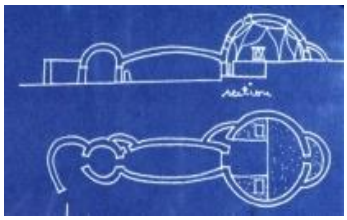

Fig.1- The Igloo. The dome shape of the igloo reduces the exposed surface area.

Aim: To study the importance and significance of geometry in architecture.

Objective: - To study the relevance of geometry in architecture.

- To understand how geometry & architecture are correlated.

- To learn about different principles of design there are related to geometry.

- To study reflection of geometry in historical & modern times.

Scope: This study majorly deals with the different types of geometry used in different typologies of buildings. Reference taken from different case studies and research papers.

The relationship between architectural design & geometry starts with the notion of harmony as the principle of all sciences. The concept of symmetry is combined with the idea of harmony & proportion. Geometry deals with figures & forms, elements, proportions, angles, transformations & relation between them.

2. Literature Review: When one thinks of geometry, images that come to the mind are of lines, points, squares, curves, circles, and other forms. The dome in medieval architecture assumed symbolic connotations; its shape symbolized heaven and was found to be appropriate for churches. Structural considerations prompted Renaissance architects to make its shape slightly elongated. Renaissance architects, like Alberti, emphasized proportions derived from perspective drawing, which were also found inmusical harmonies, to compose plans and elevations. In contrast, Le Corbusier emphasized modular proportions, using his modular, which was based on the Golden Ratio. As geometry developed in mathematics, the use of geometry in architecture also changed. Another use of geometry is in green building design where solar angles are used to determine the angles and spacing of shading devices. All these examples demonstrate that geometry plays an important role in architectural design and construction.

Fig.2- The dome of St. Peter's Cathedral. The shape symbolized heaven and due to structural considerations it was slightly elongated.

a) Elements of Geometry

1) Volume: A plane extended in a direction other than its intrinsic direction becomes a volume.
Conceptually, a volume has three dimensions: length, width and depth. All volumes can be analysed and consists of:

- Points or vertices where several planes come together

- Lines or edges where the planes meet

- Planes or surfaces which define two limits or boundaries of a volume

2) Form: Form is an inclusive term that has several meanings. In this study, form suggests reference to both internal structure and external outline and the principle that gives unity to the whole. While form often includes a sense of three-dimensional mass or volume, shape refers more specifically to the essential aspect of form that governs its appearance—the configuration or relative disposition of the lines or contours that delimit a figure or form.

2. i) Proportion: Proportion is an ordered relationship between two comparable entities, visible or invisible. Certain proportions have been found to be generally satisfying to the human senses. Proportional system is evolved out of geometrical principles. It helps in achieving ordered relationship in design. It is a system used to relate parts in an overall composition. Proportion is a means by which elements are composed to achieve the qualities of unity, balance, rhythm etc.

2. ii) Organization: The spatial organization primarily indicates the pattern of arrangement of various biotic and abiotic elements arranged in a non-randomly orientation in any space around any dimension.

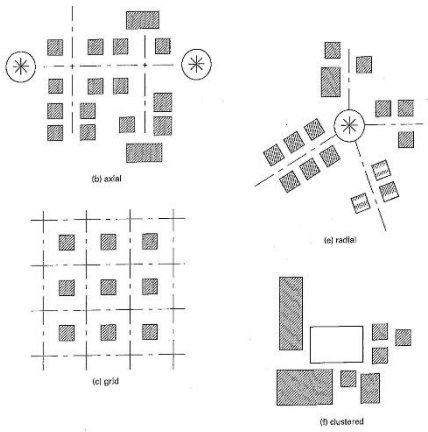

Fig.3- Spatial Organizations in Architecture

A centralized organization has an area of highlight in the centre of the structure with other smaller spaces arranged around a stable or concentrated manner. The secondary spaces can be equal in sizes or different, depending on the purpose that they are meant to serve in order to have a balanced composition.

Linear organization can be defined for a single unifying element about which other objects can be added depending on their function, size and requirements. They are linear as they are arranged along an axis rather than a random arrangement, without any element of visual hierarchy or special articulation as a result of which there linear volume is dominant.

The radial organization is a combination of both centralized and linear organizations having a central focal point from which the radial linear spaces seem to emerge, however, it in radial organization every unit seems to expand towards the surroundings while incase of centralized organization it seems to be inward.

The clustered organization typically relies on the proximity of the relative spaces and has repetitive cellular spaces having certain visual qualities in common.

Grid organization has a three-dimensional appearance to a liner structure, arranged perpendicular to each other, giving the composition a sense of stability uniting the forms of various sizes and shapes. This allows a particular area to stand out and acts as a hierarchy.

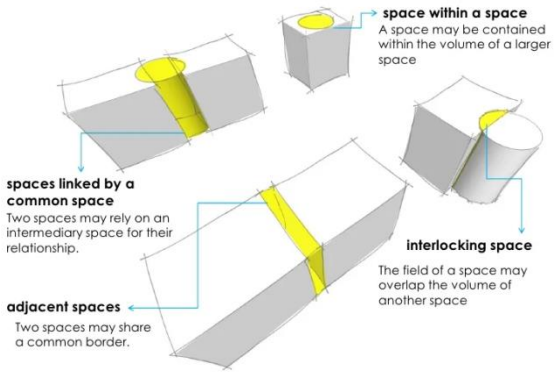

Fig.4- Spaces in Architecture

Space within a Space is a like a large canvas having a lot of smaller spaces, where the larger space acts to create a visual boundary, hence the smaller space depends on the larger one, which eventually defines the environment along with the relationship. Also the smaller space could define itself by having a different orientation or could indicate a functional difference adding onto the entire building envelope.

Adjacent spaces allow each of the individually independent spaces to clearly define them and still serve their individual needs, however, the continuity that exists between the two spaces

depends on the characteristics of the plane that they are separated and bridged by at the same time. It can either appear as a standalone plane in a volume of space or it might exist as a row of columns and allows a better visual continuity.

Interlocking space indicates the relationship between two such spaces having their volumes overlapping giving an identity to space and the common space is hence the area of mutual sharing. Although the interlocking area can be shared equally by each space, it can also converge with one of the spaces and become an inherent part of its volume, and it might serve as the link between two original spaces.

Spaces linked by a common space, which is that two separate spaces can be joined by a third intermediate space and the attributes of the two spaces are defined by their relationship with the third space. However, the intermediate space can differ in orientation or shape from the other two spaces or can be of the same size and of the same material.

2. i) Form and Space: Geometry is related to form and space. Form is inclusive term that has several meanings, which may refer to an external appearance that can be recognized. An approach to architecture is based on an individual understanding of an architect. The idea of form and space is always as the starting point and at the centre while beginning any new project. It suggests reference to both internal structure and external outline and the principle that gives unity to whole. But most of the projects are concentrated on external configuration of form. In addition to spaces, shape and forms have visual properties of size, color, texture. It also has relational properties which govern the pattern and composition of elements, position, orientation, etc.

b) Evolution of Geometry

Geometry is the foundation; Geometry brings with it the noble joy of mathematics. Geometry is being related to different mythological theories of a form. As man developed geometry, they attached various theories to geometrical forms. Different symbols have different meanings according to Hindu philosophy: the 'square' represents the 'earth' in compliance with the cardinal points. The ‘Triangle' symbolizes the Indian ‘Trinity' and is the principal governing element. Based on natural form, people developed basic geometric forms. In Islamic architecture, the 'circle' is thought as a symbol of eternity, a form without a beginning or an and. It is the most perfect and an expression of justice. The 'Dome', a highly geometric element has become' an increasingly a characteristic feature of Islamic buildings. It is thought of as an 'image of heaven'. The development of mosque was done with combination of square and circles.

The Romans wished to create a symbolic form of a new kind of systematic world order, which embraced a unified religion, a unified body of laws, and a unified civilization. This organizational spirit is revealed in their manner or grouping buildings as done in the forums, in the organization of business activities in common centres, in combination of three orders on the exterior of the building as in the Colloseum (Doric on first, Ionic on second and Corinthian on third and fourth); in the combination of Ionic and Corinthian to form the composite order. Romans are supposed to be main Inventors of geometry', ancient civilization. Its geometry is based on the union of a cylinder (rotunda) and a hemisphere (dome) over a circular ground plan. The design of Pantheon displays a harmonious disposition of a circle and a rectangle. The Pantheon with its utter simplicity laid the foundation of the idea of the centralized building.

Greeks were able to find some of use of geometrical forms. Greek took first step to the conception of independents forms detached from any unitary word view.

In medieval and Gothic architecture, basic form was syntheses of rectangular planes with conical domical roof over it. During the medieval ages, centric form and linear form were developed together and had been juxtaposed on each other to develop the interior spaces and the exterior forms of Turkish Mosque, Gothic and renaissance Cathedrals. From here, the aspect of 'Third Dimension' distinguishes Byzantine architecture from Early Christian architecture. From here the basic principles remained constant with development in the third dimension. The skeletal structure and an additional tower are main character of Romanesque architecture.

After Byzantine, Gothic architecture was characterized by use of pointed arch, the rational system of vaulting & buttressing. In Renaissance architecture, geometry played a key role. The spatial geometry was determined by functions. Larger organizations were achieved by adding different geometric units retaining an identity, yet responding to the entire configuration. The building that marks development of the renaissance is St. Peters in Vatican.

In 1919, the Bauhaus was founded on the remains of the Arts and Crafts Movement in Germany. It resulted in an extraordinary success in influencing architectural education all over the world. Bauhaus initiated the study of architecture by manipulating abstract shapes without any reference to building functions or the ultimate strength of materials.

In Holland in 1917, the 'De Stijl' moment developed. The use of vertical and horizontal lines at right angles offered a balanced relationship of unequal parts. Le Corbusier developed a vocabulary of Purist aesthetics. His idealization of platonic solids with idea of mechanization and modernity was highly influential.

3. Methodology: The study of an individual architect's works is used as a case study to explain approaches to geometry in architecture within a particular historical period. Texts, drawings and photographs are used to outline the various kinds of geometries that have developed in mathematics and the way geometry has been employed by architects.

The Italian Renaissance (1400 to 1600), Modern (1750 – 1950) and Post-Modern (1950- to present) phases saw significant changes in form and shape in architecture. Therefore, the works of Andrea Palladio (1508-1580), Frank Lloyd Wright (1867-1959), and Frank Gehry (1929-present) as case studies respectively for the Italian Renaissance, Modern and Post-Modern periods are discussed.

Concepts of Geometry
Euclidean Plane Geometry
Projective Geometry (Including Perspective And Descriptive Geometry)
Cartesian Geometry
Differential Geometry
Non-Euclidean Geometry
Fractal Geometry

Phase	Case Study
Italian Renaissance (1400 To 1600)	Andrea Palladio (1508-1580)
Modern (1750 – 1950)	Frank Lloyd Wright (1867-1959)
Post-Modern (1950- To Current)	Frank Gehry (1929)

3. i) Andrea Palladio:

Andrea Palladio followed the tradition of earlier Italian Renaissance architects by reiterating the principles of classical architecture that his predecessors had revived. His works are often associated with symmetrical fronts and columns of classical orders topped with a pediment. He achieved the Renaissance ideals of beauty and harmony through a rigorous application of proportion and geometry.

While planning his Villas, Palladio established some planning principles from which he never deviated.

The more public rooms were on the central axis while the left and right sides had symmetrical suites of rooms, which went from rectangular chambers, via square middle sized rooms, to small rectangular ones. The Villas usually had a cubic exterior with minimal ornamentation.

Villa Rotonda, Italy

The Villa Rotonda might be considered a 'Villa-temple' as the form reflects an idealized idea of order and harmony. The Villa is a made of simple composition of a cube and the hemi-sphere. The most significant characteristic of the villa is it's centralized organization.

In the Villa Rotunda, Palladio inserted a circle within the square. Palladio resolved the problem of combining the curve and the straight line. He repeated the portico on all the four sides of the square plan to make the building symmetric on all four sides, which resulted in a perfectly centralized building.

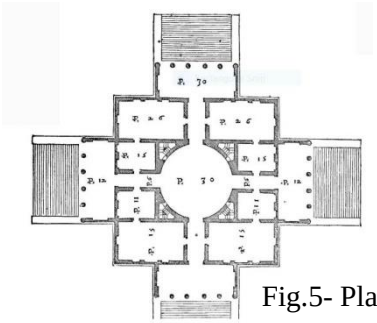

Fig.5- Plan of Villa Rotanda

3. ii) Frank Lloyd Wright:

His architecture eventually developed with pure, independent geometric shapes that were fused into larger compositions. According to Wright, design was an abstraction of nature in purely geometric terms. Wright's architecture was composed of pure abstract horizontal and vertical planes, where the horizontal plane was more prominent. Thus, he gave an original expression to modern architecture.

Unity Temple, US

Frank Lloyd Wright was not concerned with the traditional symbolic aspects of geometry; he was concerned with the logic or the rationale behind the shape (geometry) of the form. In the Unity Temple a centralized organization is realized without the use of a circle. The main theme of the plan is a square intersected with a cross. The plan is symmetric along the main axis, but similar to his other works, circulation is not along the main axis; one enters the building perpendicular to the main axis. Wright evokes the power of geometry and symmetry to achieve spirituality and harmony.

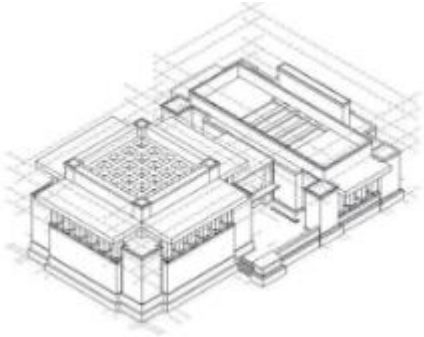

Fig.6- Three dimensional view of Unity Temple

3. iii) Frank Gehry:

One of the critical points of Gehry's explorations has been to capture the dynamism of surroundings. He used the grid and principles like axis and symmetry in plan, but usually distort them or breaks them when they translate to three-dimensional form. He constantly tries to juxtapose rectangular geometry with curves or distorted forms. His building forms are sculptural, iconic and often imitate forms in nature. Frank Gehry's work is characterized by unconventional shapes and forms. His buildings have distorted forms that either collide to form a single sculptural object, or are arranged individually in a seemingly random manner within a landscape.

The Disney Hall, California

In this building, he merged differences between roof wall, inside surface and outside surface by creating shapes that twist and curve in more than one direction. It is quite impossible to attribute any shape to the

exterior of the building. The metallic surface acts as a skin that is layered around the rectilinear auditorium to define volumes for the lobby and other auxiliary functions of the Disney Hall. In plan, the auditorium is a symmetrical rectangular space with spaces organized in a random manner around it.

Fig.7- The Disney hall

4. Conclusion: Geometry contributes to the process of composition & designing in architecture.

Geometric figures, forms & transformations build the material of architectural design. Nature has been a source of inspiration for many architects. Different perspectives of nature have led to varied formal expressions in architecture. Indirectly this has led to different approaches to geometry in architecture. Geometry plays vital role in design as well as construction. Geometry, in combining forms and space in to a single essence, not only facilitates purpose but communicates meaningful organization of elements can be achieved with conscious use of geometrical ordering principles. Geometry is understood to be a constitutive part of architecture, indispensable to it, but not dependent on it in any way. Looking at the development throughout history we can conclude, that the abstract nature of geometry is not so much the expression of pure logic as it is an attempt to make human perception and experience more conceptually precise and transform them into geometric in the sense of creating orientation in space through the act of measurement.

5. References:

https://www.researchgate.net/publication/342538094_Role_of_Geometry_on_Architecture

https://www.researchgate.net/publication/237544451_GEOMETRY_CONCEPTS_IN_ARCHITECTURAL_DESIGN

https://core.ac.uk/download/pdf/4276134.pdf

http://www.geometrie.tugraz.at/wallner/matharch.pdf

https://www.schwartz.arch.ethz.ch/Publikationen/Dokumente/geoinarch.pdf

https://blarrow.tech/spatial-organization-in-architecture/

http://rsd2-alert-durden-reading-room.weebly.com/uploads/6/7/1/6/6716949/ching-architecture_form_space_order.pdf

https://link.springer.com/article/10.1007/s00004-017-0332-1

https://www.academia.edu/21489200/Mathematics_and_Architecture_Importance_of_Geometry

https://www.re-thinkingthefuture.com/rtf-fresh-perspectives/a1202-importance-of-geometry-in-architecture/