

Architecture Development and Golden Ratio

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Abstract: This study discusses golden ratio and its architecture applications, through identifying the mathematical dimension of golden ratio and its geometric shapes, applications, architecture dimension, by analyzing historical architectural models that has different dimensions of golden ratio, in order to come out with theoretical findings that define golden ratio as a basis for architectural development and recommendations that support its applications.

Keywords: Architecture, Golden Ratio

1. Introduction

The mathematical dimensions of golden ratio does not teach design, does not suggest the architecture idea, and do not bring fancy thoughts. It just organize the building structure mathematical dimensions as a definition of specific architectural formation based on same configuration requirements, it also achieve structural balances as an-acceptable beauty value shown. Also, due to golden ratio the architectural ideas can generate a variety of different ideas through times, allowing civilizations to get magnificent various architecture styles.

1.1 Target of research

- Visualization of golden ratio dimensions on architecture.
- Confirming golden ratio as basic element on architectural formation.
- Assuring that architecture development is related to golden ratio.
- Defining the importance of golden ratio and its right application on architecture.

1.2 The research needs

Architecture reduction that caused by opinions that doesn't recognize the importance of golden ratio.

1.3 The research problem

Lack of available study sources.

2. The Research Method

The researcher has adopted the descriptive and analytical method for this research paper:

Through identifying the mathematical dimension of golden ratio and its geometric shapes, applications, architecture dimension, by analyzing historical architectural models that has different dimensions of golden ratio, in order to get out with theoretical findings that define golden ratio as a basis for architectural development and recommendations that support its applications.

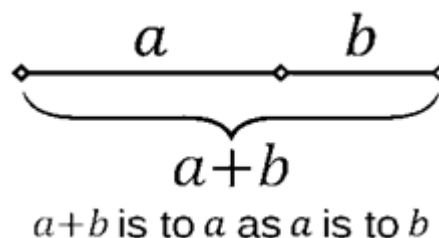
2.1 The expected results

- Identifying new side of golden ratio.
- Reaching a modern concept of golden ratio that contributes on architecture development and architecture integration with local areas.

3. Theoretical background

3.1 Defining golden ratio mathematically

It is a sum of two numbers divided by the largest, equal the ratio between the largest number and smallest. The Golden Ratio conception is simple: imagine that you have a line divided into two parts, (A) the longest part and (B) the short one. So the total line is $A + B$, and the result of division will be $A / B = A + B / A$, as follows



The same idea in the next drawing: Supposing that point (C) divides (AB) by same ratio



Otherwise:

If you have a surface length value is equal to (100%) divided into two parts, the large part value equal (62%) and the small part value is equal to (38%) - Which means the smaller part will be (1) and the large will be (1.62), as approximately 3 to 5. shown in following drawing



On other words:

A line with (8m) length, divided into two parts, (5m) and (3m). The division of the large part on the small one $5/3$ is equal to 1.666, specifically equal (1.6180339887). And this value is equal to golden number.

A -The golden number equal

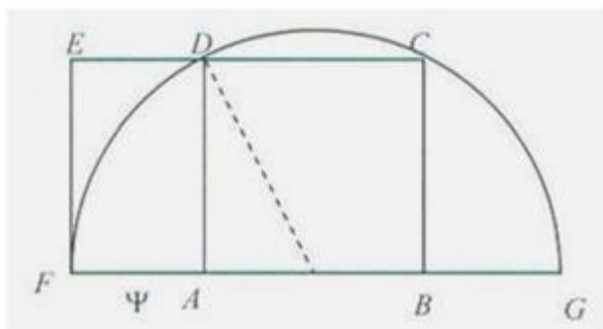
1.618

The golden ratio geometric number is repeated frequently on old mathematicians calculations as a magical number and the golden number has many names as (the Golden Ratio, the Holy Ratio, the Golden Section and the Divine Number), also it presents the structural base of nature formation.

B-The golden ratio named (PHI) relative to (Phidias). And its symbol ϕ

Not only that, there is also different geometrical forms define golden ratio, as follows

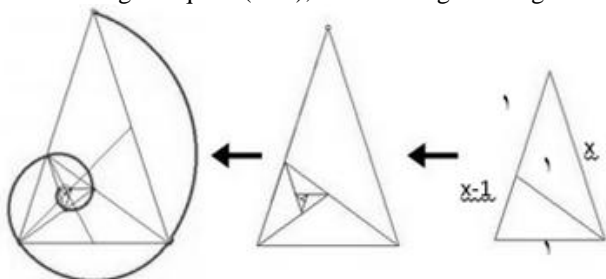
1) The Golden Rectangle



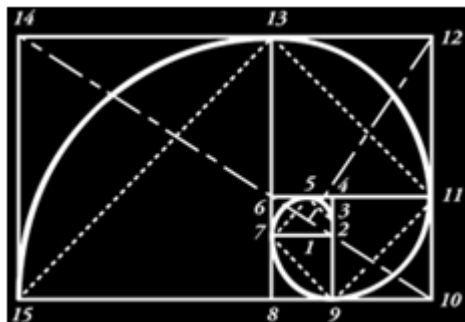
It is a complex geometric shape of a square and a small rectangle. The result of dividing big rib in the small rectangle (EF) on its Opposite rib (FA) equal to the sum of the big rib in the big rectangle (EC)on its Opposite rib (EF). And this value is equal or close to(1.618).

2) The Golden Triangle

Is the isosceles triangle, its head angle equal to (36 °), and its two base angles equals (72 °), as following drawing shows

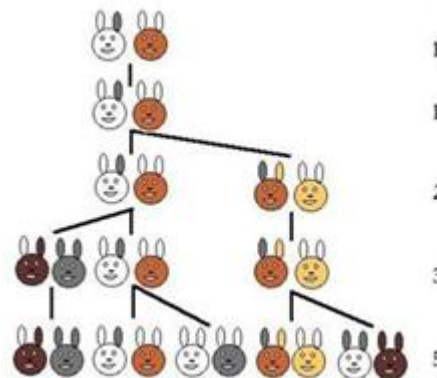


3) Fibonacci shell



It's a golden shell drawing, has been drawn depending on golden rectangle and it can be noticed on sunflower blossom, and beach shellfish.

Dealing with this ratio can make a beautiful joyful vision to individuals as Fibonacci sequence illustrate. The Fibonacci sequence emerged before 300 years of birthing Leonardo Davinci. But, this sequence was attributed to him later because he discovered its existence during studying rabbits reproduction, and since then until now this sequence is one of the most famous geometric sequences on the world (e.g. using Fibonacci sequence frequently on exchange foreign market (Forex).



The Fibonacci sequence idea is simple and easy to understand as following explain shown

The Fibonacci sequence start with these numbers (0, 1, 1, 2, 3, 5, 8, 13, 21, 34....), and these numbers ordering according to series concept as { each number value equal to previous two numbers sum value}, also, the Fibonacci sequence numbers advantage with values approaching golden number progressively as a result of every divide between any value to its previous, as following

1		1/1	1,000000
1		2/1	2,000000
2	=1+1	3/1	1,500000
3	=1+2	5/3	1,666666
5	=2+3	8/5	1,600000
8	=3+5	13/8	1,625000
13	=5+8	21/13	1,615385
21	=8+13	34/21	1,619048
34	=13+21	55/34	1,617647
55	=21+34	89/55	1,618182
89	=34+55	144/89	1,617978
144	=55+89	233/144	1,618056
...		377/233	1,618026
		610/377	1,618037
		987/610	1,618033

B - Golden ratio in architecture

The mathematical dimension of golden ratio has different architecture applications according to different design formations, as

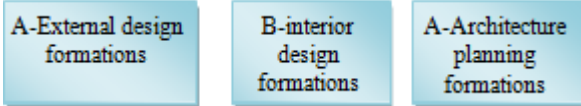


Figure 1: The golden ratio architecture dimensions
Source: add by other

The golden ratio mathematical dimension subject to previous design formations that based on following points;

- 1) The historical ages.
- 2) Architectural styles that basically depend on architectural schools.
- 3) The architect ideas, imagination, design drawing, and building applications must based on certain architecture style.

The Golden ratio dialectic ruled by required design and its different architectural design frame as {Rhythm, diversity, repetition and symmetry...etc}. Also, it is not surprising that some designers indicate to absence of golden ratio in architecture design, they just know about individual's mentality that doesn't recognize the formation of golden ratio in architecture buildings unless the usual buildings vision, but the architect is a perfection design. The researcher recognizes the golden ratio in each building, whether it's built on golden ratio or not. Because he knows that golden ratio is a perfect integral architecture work, as following restrictions shows

A- The Golden Ratio application restrictions

- 1) Structural frames of plants, animals, geometric shapes and environment - for exterior design formation: The golden ratio require to integrate the exterior design structure with surrounding local environment as follows
 - a) Through ages: The golden ratio requires the existence of contemporary architecture formation.
 - b) Geometrically: the golden ratio require to reflect individuals social demands on architectural building design content and integrate it with the surrounding local environment.
 - c) Socially: the golden ratio requires the consistency of building structure formation with individual's awareness and the people's desire needs.

All this must be done in a way that shows buildings future expansion as a sound architecture vision.

- 2) Open spaces - for interior design formation: The interior design formation golden ratio expresses an open plan spaces that provide the visual communication between individuals And optimal space function. Large open spaces always mean existence of optimal space function that express individuals stability, and on this restriction we can realize that maximum and minimum interior divided designs are not more than individuals Innovative frames, denies the exceeding supposed limits between interior spaces as a mental limitation that redact designers creativity.
- 3) Organic style- for architecture planning formations: Golden ratio on external planning formation expressed by nature environment as God Almighty created it in a

most beautiful form, and the organic planning style reflects the divinity of golden ratio that demand integration and harmony between local environment and building structures optimally as referred to by architecture history, through different civilizations as (pharaohs civilization, Babylon civilization, Greek civilization and secular civilization, not only that, but also the architecture modern school has classified organic planning as a contemporary and future planning).

Analyzing historical architectural models that has different dimensions of golden ratio

In this paragraph, analyzing historical architectural models that have different dimensions of golden ratio, in order to come out with theoretical findings that defines golden ratio as a basis for architectural development, and recommendations that support its applications.

1) Study and Analysis pyramid Khufu model

The pyramid Khufu was built in 2560 BC. M, to be the largest pyramid in Giza, Cairo. Also the pyramid Khufu has been considered as a first construction that shows the golden ratio



Photo 1: Pyramid Khufu elevation
Source: elbalad/3640745/

The mathematical dimension of Golden ratio in Khufu Pyramid, shows as follows



Photo 2: The mathematical dimension of Golden ratio in Khufu Pyramid

Source: mo7itona.com/2015/05/blog-post_32

The architectural dimension of golden ratio in Khufu pyramid is represented by

2) The pyramid form

The old Egyptian architects had a sharp intelligence, they had an optimal knowledge about geometric forms and mathematical sciences like no one had, and designed their buildings depending on immortality methodology: that encourages architects to design according to architectural elements that identify human time in balance with God's time, and that was the best expression of old Egyptian architects reference to Rifaat al-Jadraji refers in his book (Beauty in Human Conscious) about human and God's time, in the following phrase:

The time of God is a disabling of human through freedom innovative ability, causing damage in human imagination of the relation between production and productive cycle time, that the salvation doctrine including unification concept is transformed in the imagination into a semi-frozen state in cycle waiting for transition to another world).

The Egyptian architecture has summarized this perception in "immortality and pride" and chose to make geometric architecture formations to express the Egyptian kings' pride, grandeur, distinction and immortality in life and after death, and the pyramid form was the chosen geometric formation to express this architecture civilization, because of its advantages of:

- Pyramid form is a symbol of pride, strength, hardness and loftiness.
- Pyramid form was characterized by its ability to save its content from being damaged and destroyed.



Photo 3: Shown Parthenon Temple on the Acropolis Plateau

Source: ancient-greek-wallpaper/10074970.html

The Parthenon Temple is an-optimal example of Greeks ingenuity in architecture and golden ratio through times, also it's considered as one of the best ancient Greek models that built on the Acropolis hill of Athens.

The mathematical dimension of Golden ratio in Parthenon Temple:

Ancient Greek architects have used the golden ratio to make architectural beauty in human consciousness a shared reference memory between individuals contribute on buildings application, as follows

- Pyramid form was featured with four- surfaces that allows light to flow inside the Pyramid in a smooth way that create a healthy, comfortable environment.

These advantages as a knowledge base direct the Egyptian architect to work during Pyramids design and application, in spite of the absence of required technology at that age, and the exhaustion of great energy in Pyramids application, but it can be said that the Pyramid productive is equal to Pyramid composition consumption energy and sometimes encroaches it.

Khufu pyramid model summarizes:

- The golden ratio contributes in achieving engineering balance and beauty on a standard proportionality way.
- The golden ratio applications is a result of architects acumen, and requires architect to be aware of society and social demands because the cultural thought of society is the governing thought of architecture design, also architect must be aware about quality of building materials, in order to solve the dialectical social demands transformation into building materials if the appropriate technology is not available, in order to create a new architectural language appropriate to age looking forward to the future in different words of the ancient architecture with potential for future expansion.

Study and Analysis of Parthenon temple model:

The Parthenon temple is located on the Acropolis, in the city of Athens, Greece. Was built in between 447-432BC, and designed by Greek architects (Ektinos and Calicratas) with sculptor Vidias as a supervisor of designing Greek sculptures.



Photo 4: The golden ratio of Parthenon Temple elevation

Source: Parthenon –golden-section

The architectural dimension of Golden ratio in Parthenon Temple is represented in:

- 1) The geometric proportions in the Parthenon Temple, which express the harmony between human body dimensions and the temple sacred architecture style.
- 2) The temple design style and construction, along with Vidiyas's impressive collection of art sculptures, which made the temple building an advantage with beauty and function optimally. As the temple design is a result of spirituality faithful human Greek decision, represented through the three design restrictions from (aesthetic restriction, mathematical restriction, and rational restriction).
- 3) The temple columns with a central bulge formation, as the designer format the temple column with a contradiction of structure diameters from the bottom to the top causing a bulge in the center of the column as an innovative ideology manage to achieve:
 - a) An- aesthetic value from correcting the straight column visual error that make the column appear weak in the middle.
 - b) Development of golden third rule into individuals mentality so they could identify the Intuitive perception between Parthenon temple columns distances such [the ability to identify the distance between the columns in the angles and the columns in the adjacent side as it is less than the separating distance of two columns between the other columns in the temple center or elevation, so as the distance between the column in the angle and the next column doesn't seem greater than the distance between the rest columns' only then the temple vision becomes very simple to perception, as the following photos shows:



Photo 5: Shows Parthenon Temple columns design
Source: how-Greek-temples-correct- visual- distortion



Photo 6: Shows Parthenon Temple perspective

Source: Parthenon -in-acropolis-landmark- architecture

Parthenon Temple model analyzes summary:

- 1) The golden ratio depends on applying aesthetic, rational and mathematical restriction in building construction in order to get an-optimal architecture.
- 2) The golden ratio depends on adopting the visual error theory in building construction contribute on formatting building functional features on elevations.

Study and Analysis of King's Church model:

King's College Church located in England and linked to Cambridge University, also it's considered one of the most remarkable examples of late Gothic architecture that is characterized by magnificent structural prominence in inner outside elevations.



Photo 7: King's College Church perspective view
Source: King's - College - Chapel

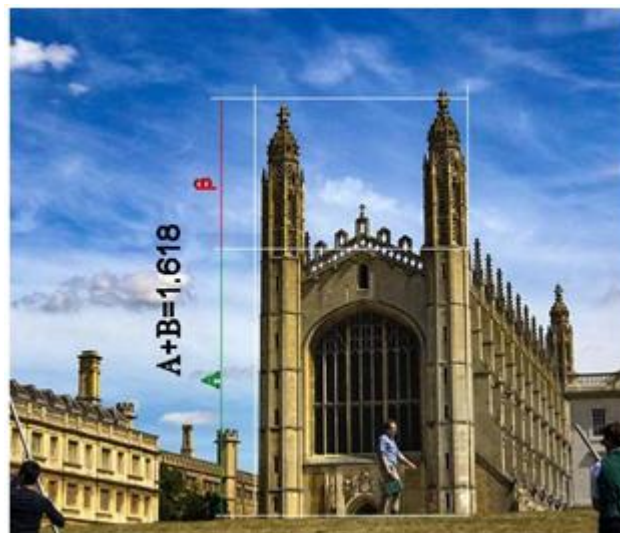


Photo 8: The golden ratio of King's College Church front elevation
Source: the researcher

The architectural dimension of Golden ratio in King's College Church model is represented in:

Where the Church of King's College contains of the largest fan vault structure that express the Gothic style in the world. Vault with same curved spaced equidistantly rids like a fan, as the following photos shows



Photo 9: Shows ribs formation in King's College Church van vault roof structure
Source: King's-College-Chapel-Cambridge-23486



Photo 10: Shows King's College Church van vault roof structure
Source: King's-College-Chapel-Cambridge-23486

King's College Church model analyzed summary:

- 1) The golden ratio springs from an clear structural expression of architectural function and springs on it to get a beautiful and consistent architecture formation.
- 2) 2-The golden ratio depends on social demands to format building structure and functional architecture features.

Study and Analysis Villa Rotunda model

Villa Rotunda is located on a small hill in Vento, Italy, and is designed by Andrea Palladio in 1592.



Photo 11: Villa Rotunda front elevation
Source: Villa- Rotunda-front.jpg

Villa Rotunda is considered one of the architectural distinguished Milestones of the Renaissance era.

The Renaissance era has formed the beginnings of industrial and machine revolution where the designers used the machine to distribute a similar structure and architecture formation to different regions and countries in order to achieve more economical surplus, and that lead to turn attention from architectural details to abstract architectural models and adjust diversity origins on the classical design principles that was prevailing then.

Villa Rotunda is based strongly on symmetry, perspective and proportionality values of old Greek architecture, as the following photos shows:

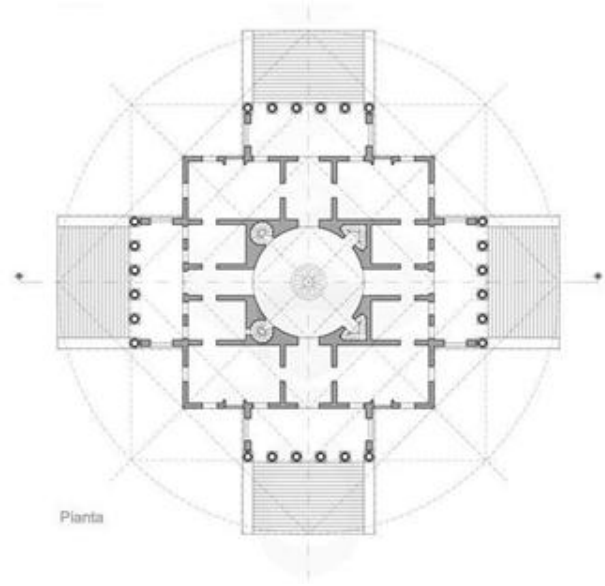


Photo 12: Villa Rotunda ground plan drawing
Source: A. Palladio - Villa Capra detta La Rotunda

Villa Rotunda was built on Greek style and Greek cross shape as the above plan drawing shows. Palladio also depends on the four elevations similarity principle in his building application non-affected by the local surrounding area, and this design method has been known later as "Palladio design style" and became very common at the begging of the industrial age.

*The mathematical dimension of Golden ratio in Villa Rotunda model:

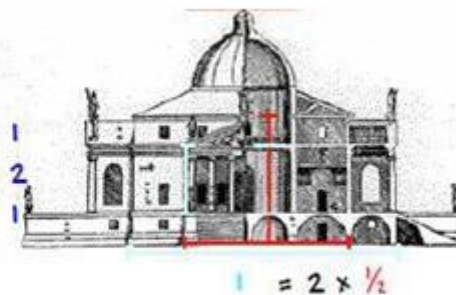
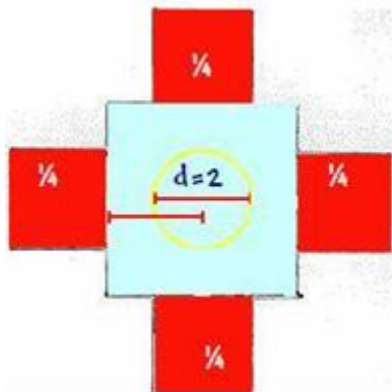


Photo 13: Villa Rotunda golden ratio
Source: by the researcher

The architectural dimension of Golden ratio in Villa Rotunda model is represented in:

- 1) We can get the golden ratio from applying “Palladio design style” or the four elevations similarity principle mentioned above, on building elevations. Where Palladio creates an invisible deviations in building construction to allow individuals to enjoy elevation natural visions as a panoramic vision.
- 2) The Greek cross building structure that have a central hall covered by circular dome in the cross and express golden ratio.
- 3) The old wall drawing as a expressive openness artistic paintings in buildings interior surfaces express the building features and the golden ratio, as the following shows

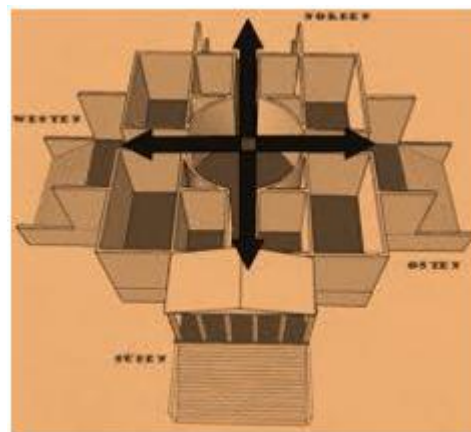


Photo 16: Shows Villa Rotunda site plan
Source:co.uk/product/ Villa- rotonda



Photo 14: Shows Villa Rotunda interior Wall Drawing
Source:pt.wikipedia.org/wiki/ Villa-Capra



Photo 17: Villa Rotunda perspective shows the four elevations similarity principle.
Source: org/vd / dawshagya215982



Photo 15: Shows Villa Rotunda cross Greek plan structure
Source: add by researcher

Villa Rotunda model analysis Summary:

- 1) The golden ratio is based on the geometric structures featured with Symmetry and geometric proportionality.
- 2) The golden ratio relies on making directed similar copies of building elevations fit with the surrounding local area.
- 3) The golden ratio depends on the visual error theory to express building function.
- 4) The golden ratio is based on wall drawings that express the social needs form the (benefit need, symbolic need and the need for pleasure).

Study and Analyzsis of Neuterd de Roschamp church model

The Catholic Church of Neuterd de Roschamp is located in the small town of Ronschamp, near the south-east of Paris. In 1950, the reformist church's bishop wanted to erase the ancient churches architecture style from decorations and ornaments, because they felt it was the reasons behind the people's ignore to pray. And they hired LuCorbusier to redesign their churches according to Christian sacred architecture restrictions and for that LuCorbusier has adopted the modern art and architecture as an absolute solution for redesigning church's and achieving bishop's demands.

- 4) Using of white walls in painting church in order to reflect the positive impact on worshipers such as(worship mood-peace of mind and happiness).
- 5) Formatting the church structural elements as functional elements, especially the outside eastern wall which reflects the out sound from the external pulpit, and the different windows frames that are responsible of lighting Church interior spaces.



Photo 18: Side perspective Neuterd de Roschampchurch
Source:le-corbusier-notre-dame-du-haut/



Photo 20: Neuterd de Roschamp church interior perspective
Source: archdaily.com/84988

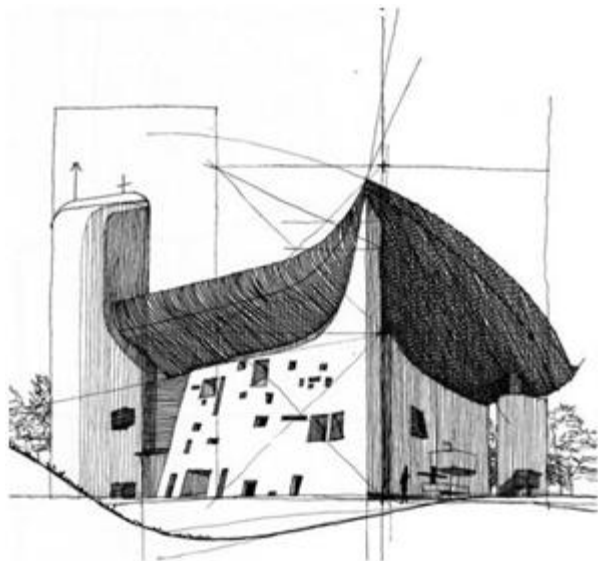


Photo 19: The mathematical dimension of Golden ratio in Neuterd de Roschampchurch
Source: mahmoudqahtan.com-golden-ratio



Photo 21: Neuterd de Roschamp church side perspective shows it's the curved walls
Source: archdaily.com/84988

The architectural dimension of Golden ratio in Neuterd de Roschamp church represented in:

- 1) The irregular sculptural formation which LuCorbusier had expressed on through the walls, ceiling and floor tiles.
- 2) The aggregative architecture style which LuCorbusier had expressed on through the different architectural formation such(surreal formations-organic formations-functional formation) and collected them in an optimal form that express the functional content.
- 3) The church open plan space that based on thick concrete walls.

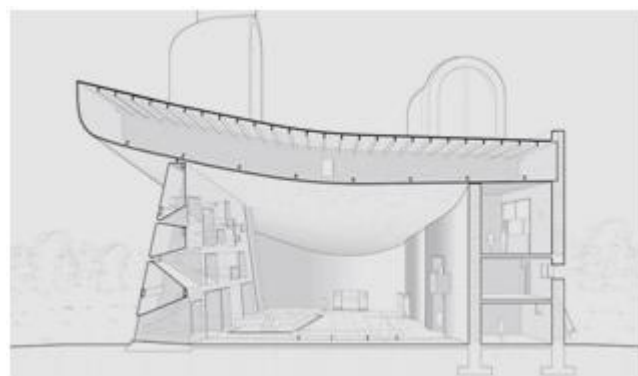


Photo 22: Neuterd de Roschamp church section drawing
Source: notre-dame-du-haut-le-corbusier-/ronchamp-chapel



Photo 23: Neuterd de Roschamp church perspective (A)
Source: notre-dame-du-haut-le-corbusier elevations



Photo 24: Neuterd de Roschamp church perspective (A)
Source: notre-dame-du-haut-le-corbusier elevations

Neuterd de Roschamp church model analyzed Summary:

- 1) The golden ratio depends on sense, imagination and innovation as a tool to control building restriction optimally.
- 2) The golden ratio expressed by the open horizontal plans in interior design.
- 3) The golden ratio stems from the genius solutions of buildings structural functions, and relies on it to get an integrated building with the surrounding local area.

4. Findings

- 1) The golden ratio contributes in achieving engineering balance and beauty on a standard proportionality way.
- 2) The golden ratio applications is a result of architects acumen, and requires architect to be aware of society and social demands because the cultural thought of society is the governing thought of architecture design, also architect must be aware about quality of building materials, in order to solve the dialectical social demands transformation into building materials if the appropriate technology is not available, in order to create a new architectural language appropriate to age looking forward to the future in different words of the ancient architecture with potential for future expansion.
- 3) The golden ratio springs from an clear structural expression of architectural function and springs on it to get a beautiful and consistent architecture formation.
- 4) The golden ratio depends on social demands to format building structure and
- 5) The golden ratio is based on the geometric structures featured with Symmetry and geometric proportionality.

- 6) The golden ratio relies on making a directed similar copies of building elevations fit with the surrounding local area.
- 7) The golden ratio depends on the visual error theory to express building function.
- 8) The golden ratio is based on wall drawings that express the social needs form the (benefit need, symbolic need and the need for pleasure).
- 9) The golden ratio depends on sense, imagination and innovation as a tool to control building restriction optimally.
- 10) The golden ratio expressed by the open horizontal plans in interior design.
- 11) The golden ratio stems from the genius solutions of buildings structural functions, and relies on it to get an integrated building with the surrounding local area.

5. Recommendations

- 1) Make lectures and cultural courses to identify architects about:
 - a) The golden ratio and it's evolution over ages.
 - b) The importance of golden ratio as a basic architecture element that achieve the optimal architectural formation.
 - c) The necessity of golden ratio of different dimensions visualization over ages and emphasizing it as a shared intellectual reference between individuals, consists of a different contemporary architecture formation that would contribute in creating ancient conserved restriction.
 - d) How to apply the proper golden ratio mathematically and architecturally.
 - e) The golden ratio contradicts the dialectical between (content and form) leads to architectural reduction, and calls to integration of functional content with architectural formation , where the golden ratio designs are considered :
- 2) The humans need desire such as(benefit needs, symbolic needs and the need for pleasure).
- 3) Depending on the optimal degree in architectural design and applications.
- 4) Social ideologies as basic restriction to format the building interior content and external elevations so as to make a comfortable vision for the local community.

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