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# Decoding Taj Mahal

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***Abstract-*** Taj Mahal was completed almost 350 years back by the Mughal emperor Shah Jahan to house the remains of his cherished wife. It is one of the world's wonders and depicts India's rich history.

As per today's evaluation very little we knew about how the building was conceptualized and executed. all we know the Taj Mahal is ordered by grids and is square in plan with chamfered corners, forming an unequal octagon

Author of this research would like to present a 1 part of 3 set of papers to trace back the evolution of **Taj Mahal Built form, Complex and elevation** from an equal sided **Octagon**. This discovery would redefine the concept called as The Hasht – Bihisht of Taj Mahal.

*Index Terms: Taj Mahal, architectural plan, octagon, decode, Hasht- Bihisht.*

*Fig 01: Taj Mahal isometric vew (source:author)*

## I. The Notion

The Taj Mahal was designated as a UNESCO World Heritage Site in 1983 for being “the jewel of Muslim art in India and one of the universally admired masterpieces of the world’s heritage”.

## II. Existing Theories

**Theory 1: 1989**

The Taj complex is ordered by grids. The complex was originally surveyed by J.A. Hodgson in 1825, [01] however the first detailed scholastic examination of how the various elements of the Taj might fit into a coordinating grid was not carried out until 1989 by Begley and Desai. Numerous 17th-century accounts detail the precise measurements of the complex in terms of the gaz or *zira*, the Mughal linear yard, equivalent to approximately 80–92 cm. Begley and Desai concluded a 400-gaz grid was used and then subdivided.[02] [03]

**Theory 2: 2006**

Research and measurement by Koch and Richard André Barraud in 2006 suggested a more complex method of ordering that relates better to the 17th century records. Koch and Barraud explain such apparently peculiar numbers as making more sense when seen as part of Mughal geometric understanding. Octagons and triangles, which feature extensively in the Taj, have particular properties in terms of the relationships of their sides. A right-angled triangle with two sides of 12 will have a hypotenuse of approximately 17 (16.97+); similarly if it has two sides of 17 its hypotenuse will be approximately 24 (24.04+). An octagon with a width of 17 will have sides of approximately 7 (7.04+), which is the basic grid upon which the mausoleum, mosque and Mihman Khana are planned.[02]

Discrepancies remain in Koch and Barraud's work which they attribute to numbers being rounded fractions, inaccuracies of reporting from third persons and errors in workmanship (most notable in the caravanserais areas further from the tomb itself).[02]

**Theory 3: 2009**

A 2009 paper by Prof R. Balasubramaniam of the Indian Institute of Technology found Barraud's explanation of the dimensional errors and the transition between the 23 and 17 gaz grid at the great gate unconvincing. Balasubramaniam conducted dimensional analysis of the complex based on Barraud's surveys. He concluded that the Taj was constructed using the ancient Aṅgula as the basic unit rather than the Mughal 'gaz', noted in the contemporary accounts. The Aṅgula, which equates to 1.763 cm and the Vistasti (12 Angulams) were first mentioned in the Arthashastra in c. 300 BC and may have been derived from the earlier Indus Valley Civilization. In this analysis the forecourt and caravanserai areas were set out with a 60 Vistasti grid, and the riverfront and garden sections with a 90-vistari grid. The transition between the grids is more easily accommodated, 90 being easily divisible by 60. The research suggests that older, pre-Mughal methods of proportion were employed as ordering principles in the Taj.[04]

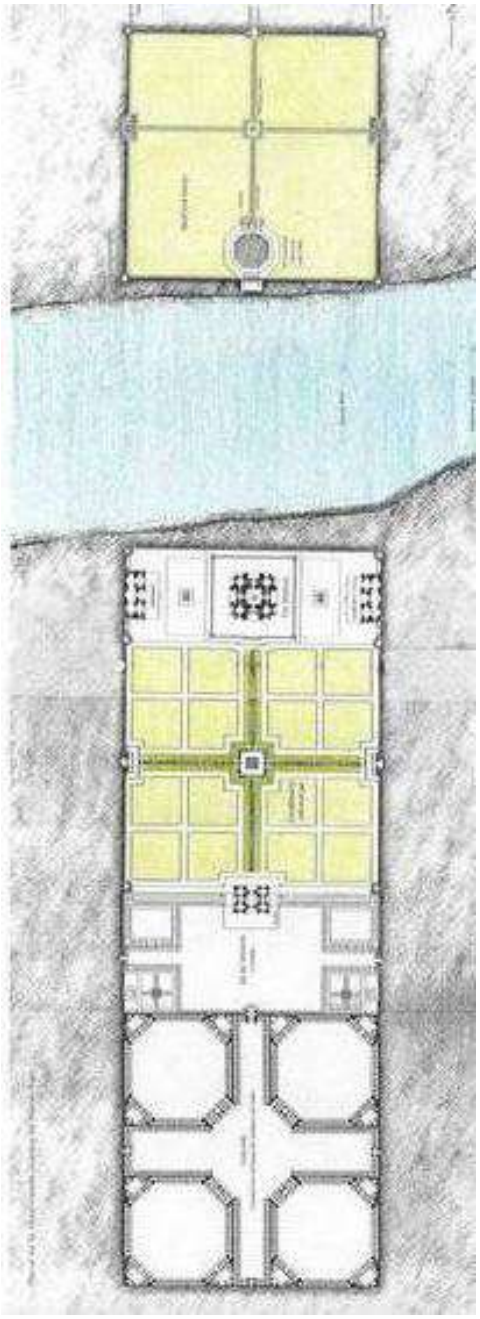

*Fig* 02: Taj Mahal complex site plan (source: http://www.the-south-asian.com/Jan2001/taj_complex.jpg)

## III. The Enquiry

The preceding theories give rise to an enquiry into "what is the correct dimensional organization of Taj Mahal and evolution of architectural concept.

**The Sacred**

The concept of after life is among the fundamental tenets of Islam. The Paradise (Jannah) and Hell (Jahannum) are significantly described in the Holy Quran and Hadiths (saying or traditions of Prophet Mohammad-pubh) [05].

It is mentioned that there are Seven Levels of paradise. The more good deeds one has performed the higher the level of paradise one is directed to, it has been said that the lowest level of paradise is one-hundred times better than the greatest life on earth. The highest level is the seventh called *jannat ul firdous*, in which God can be seen and where anything is possible). [06]

**The Metaphor**

The belief of afterlife or paradise in Islam is represented by the symbol *"Hasht- Bihisht"* is a Persian term literal for eight paradises. The symbolic representation of *Hasht – Bihisht* is derived by intersecting two square kept diagonally over one another resulting in the geometry of eight pointed star. [07]

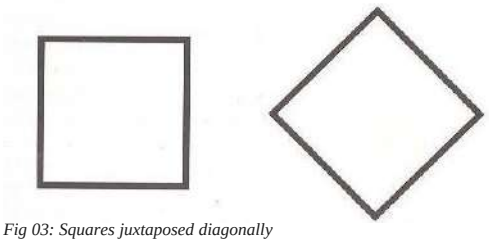

*Fig 03: Squares juxtaposed diagonally*

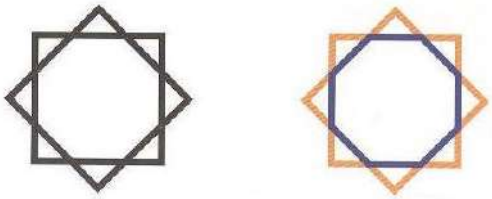

*Fig 04: Intersection of Squares*

This symbol of *Hasht- Bihisht* is deducted into two variations by the process of de-laminating the external and internal enclosures from the vertices; first is the eight pointed star also known as nine fold plan and as Al Quds star, second being the abstract version represented by the geometrical shape of a regular octagon. [08]

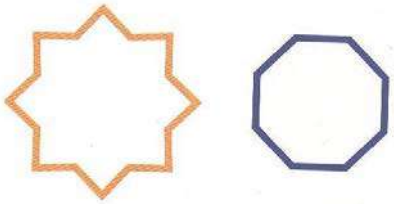

Fig 05: The variation of eight pointed star and the octagon

The geometry of the two variant is then assembled into numerous geometric patterns. These patterns extensively employed in the buildings as lattice screens, inlay work, landscaping patterns etc. [09]

**The Significance of number 12**

Starting out life as an immensely useful number for counting and dividing things, the number 12 became a number revered by mathematicians and early astronomers. So the skies were divided into 12 portions as were the months of year, reflecting the annual movement of heavenly bodies. Superstitions and religion beliefs were piled on top of respect for the number 12 and were adopted by multiple early civilisations.

The number 12 is a highly respected and practical number. It has many factors for such a low number, so it is one of the lowest easily-divisible numbers. Number 12, however, divides into 6, 4, 3 and 2, giving it a large number of practical uses where things have to be divided up into whole numbers, from calendars to clocks. As a result of all these factors, mathematicians get excited about the number 12 and apparently, they *always* have done! For example, Pythagoras, the classical mathematics genius, teacher, and leader of a pagan religious movement, taught that the number 12 had divine, profound mystical meaning. [10]

## IV. The Analogy

While inquiring into the layout and building plans of Taj Mahal and correlating it with the existing theories and dimensional survey conducted, the author came across the mention of *"Hasht-Bihisht* and rectangular grid used in the construction of Taj Mahal.

Author would like to impart a new correlation with the eight sides of symbol of the *Hasht-Bihisht*, number 12 and Taj Mahal complex to decode the concept and evolution of building plans and elevations.

## V. Basis of Study

Research and measurement by Koch and Richard André Barraud in 2006 concluded the mausoleum is set at the northern end of the main axis of a vast oblong walled-in complex that measures 896.10 x 300.84 m (fig. 5), which works out to 1112.5 x 374 Shahjahani *gaz*. Of this complex, the
Tomb garden and its forecourt are fully preserved; we measured it as 561.20 x 300.84 (300) m, that is, 696 x 374 (373) *gaz* (fig. 6). The Shahjahani linear yard, called *gaz* or *zir*, {, corresponds to about 81–82cm, or 32 inches; our field studies have shown that it was not an exact unit but a relative, proportionally used one, the length of which could vary slightly, even within one and the same building complex. For the overall length of the Taj complex, the average *gaz* figure comes to 80.55 cm. [11]

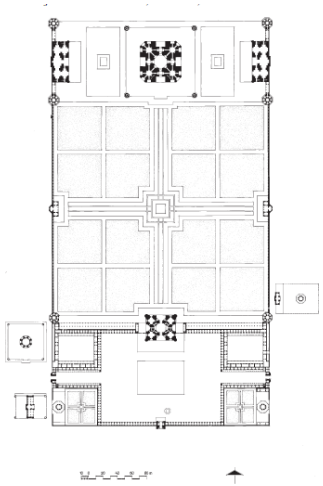

*Fig 06: Plan of preserved Taj Mahal complex (Drawing Richard A Barraud and Ebba Koch)*

| ELEMENT | METRES | | | GAZ | | |
|---|---|---|---|---|---|---|
| | Length | Breadth | Height | Length | Breadth | Height |
| **Overall Complex** | **896.10** | **300.84** | | **112.50** | **374** | |
| **Overall preserved Complex** | **561.20** | **300.84** | | **696** | **374** | |
| **Taj Ganji** | **334.90** | **300.84** | | **416.50** | **374** | |
| **Jilaukhana** | **165.1 – 165.23** | **123.51** | | **204** | **153** | |
| **Great Gate** | **41.20** | **34** | **23.07** | **51** | **42** | **28.5** |
| **Charbagh** | **296.31** | **296.31** | | **368** | **368** | |
| **Riverfront Terrace** | **300** | **111.89** | **8.7** | **373** | **138** | |
| **Maosoleum** | **56.90** | **56.90** | **67.97** | **70** | **70** | **84** |
| **Minarets** | **5.65** | | **43.02** | **7** | | **53.5** |
| **Mosque** | **56.60** | **23.38** | **20.30** | **70** | **29** | **25-29** |

*Fig 07: All dimensions from Koch, p. 258-259 credited to Richard André*

## VI. The Solution

Analyzing these dimensions which were based upon the measure drawings by Indian architect Richard Andre Barraud, a co author with Ebba Koch, high resolution images and model by the Google Earth and personal site visit to complex.

I started my study by focusing on the Taj mahal and its dimension, as this look like the starting point of whole complex. The measured dimension previously done by researchers suggest it to perfect chamfered square of side 56.90 m which converts to 70 gaz as approved upon.

56.90m = 70 gaz

1m = 70/56.90 = 1.23 gaz

1m = 1.23 gaz or

1gaz = 0.812 m**12 gaz = 9.75 m**

Closely analyzing the building plan of Taj Mahal one could see the underlay of octagon embedded in the composition which could be the starting point of the design. So our assumption made as believe to start with the octagon as the basis of design evolution. The pattern which evolved is very typical of Mughal architecture in India.

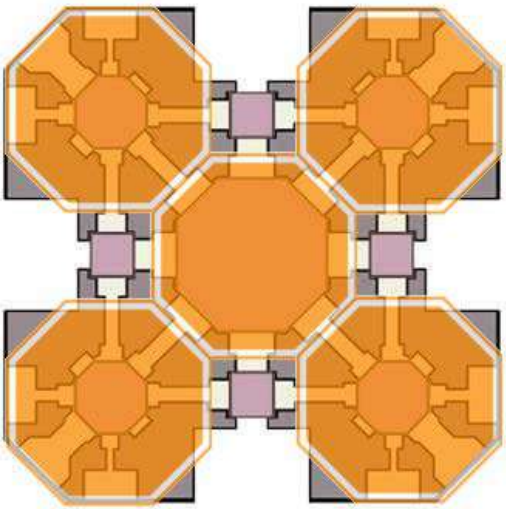

*Fig 08:Ooverlaping of octagon on Taj mahal plan*

I believe this plan is evolved out of sacred octagonal geometry of *Hasht-Bihisht,* which is repeated all over in Taj Mahal complex.

Many Islamic designs are built on squares and circles, typically repeated, overlapped and interlaced to form intricate and complex patterns. A recurring motif is the 8-pointed star, often seen in Islamic tile work; it is made of two squares, one rotated 45 degrees with respect to the other. The fourth basic shape is the polygon, including pentagons and octagons. All of these can be combined and reworked to form complicated patterns with a variety of symmetries including reflections and rotations. Such patterns can be seen as mathematical tessellations, which can extend indefinitely and thus suggest infinity. They are constructed on grids that require only ruler and compass to draw.

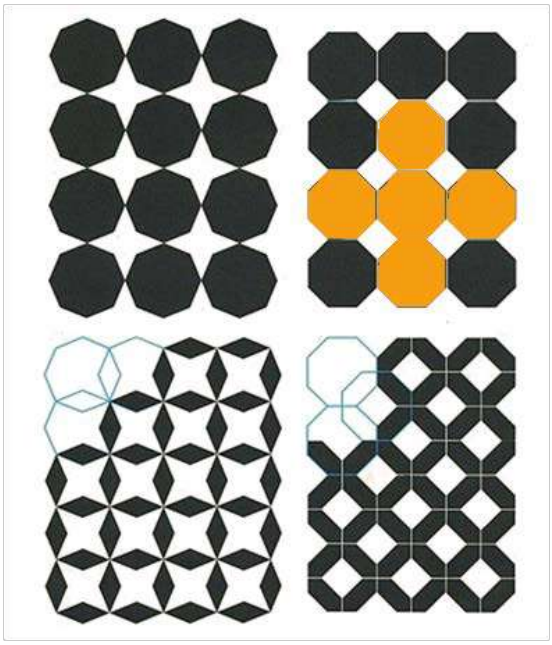

*Fig 09: Various octagonal patterns in mughal architecture*

We would be recreating the evolution process statring from a single octagon to generate the plan of Taj Mahal and challenge the existing theories

## VII. The Study

**Step 01**

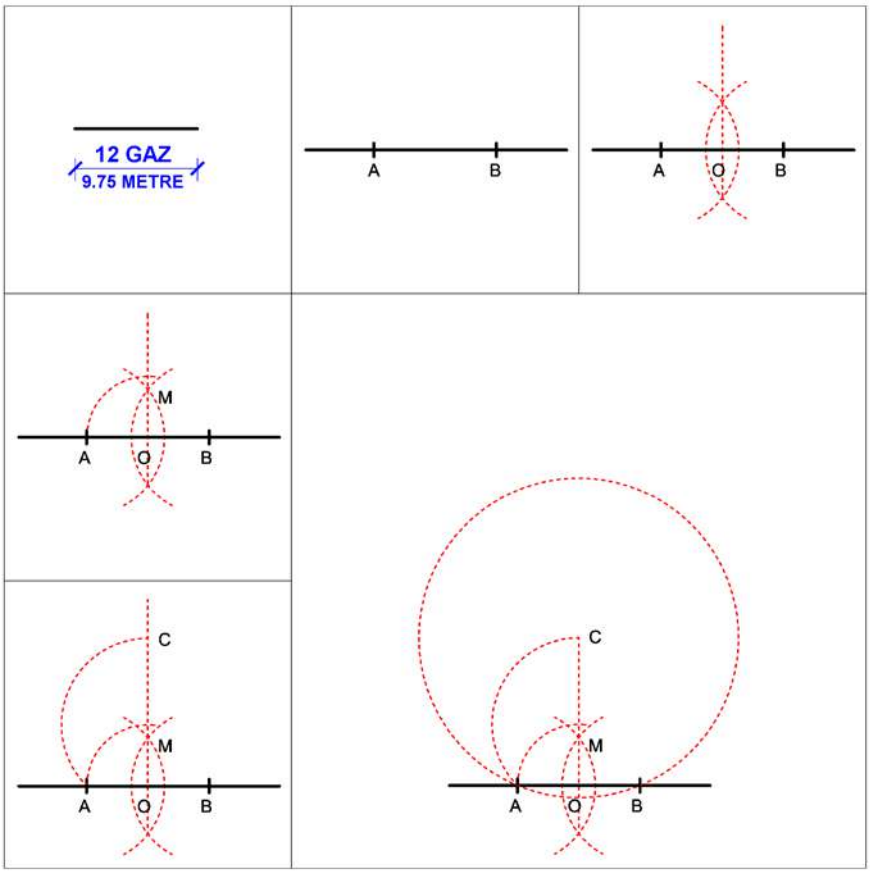


Fig 10: Source Author

First step is to draw a horizontal straight line as shown in the diagram. On this line we will mark a point A which would be the first vertex of octagon. Now we will transport the given length (L = 12 gaz) onto our previously drawn horizontal line with a compass set on point A where it cuts the line we will call it vertex **B** of the octagon.

Next is to draw the perpendicular bisector of the line **AB,** to do this draw 2 arcs of same radius from vertex **A** and **B** these radiuses must be longer than half of line **AB**. Perpendicular bisector is the line that passes through these intersection of arcs and cut the line segment **AB** which will be called as **O.**

With the compass centred at **O** and radii **OA** draw an arc until it cut the perpendicular bisector at point **M.** Now with the compass centred at point **M** and radii **AM** draw an arc until it cut the perpendicular bisector at point **C.**

Point **C** is the centre of circle which will inscribe an octagon as it will be passing through the point **A** and **B.**

**Step 02**

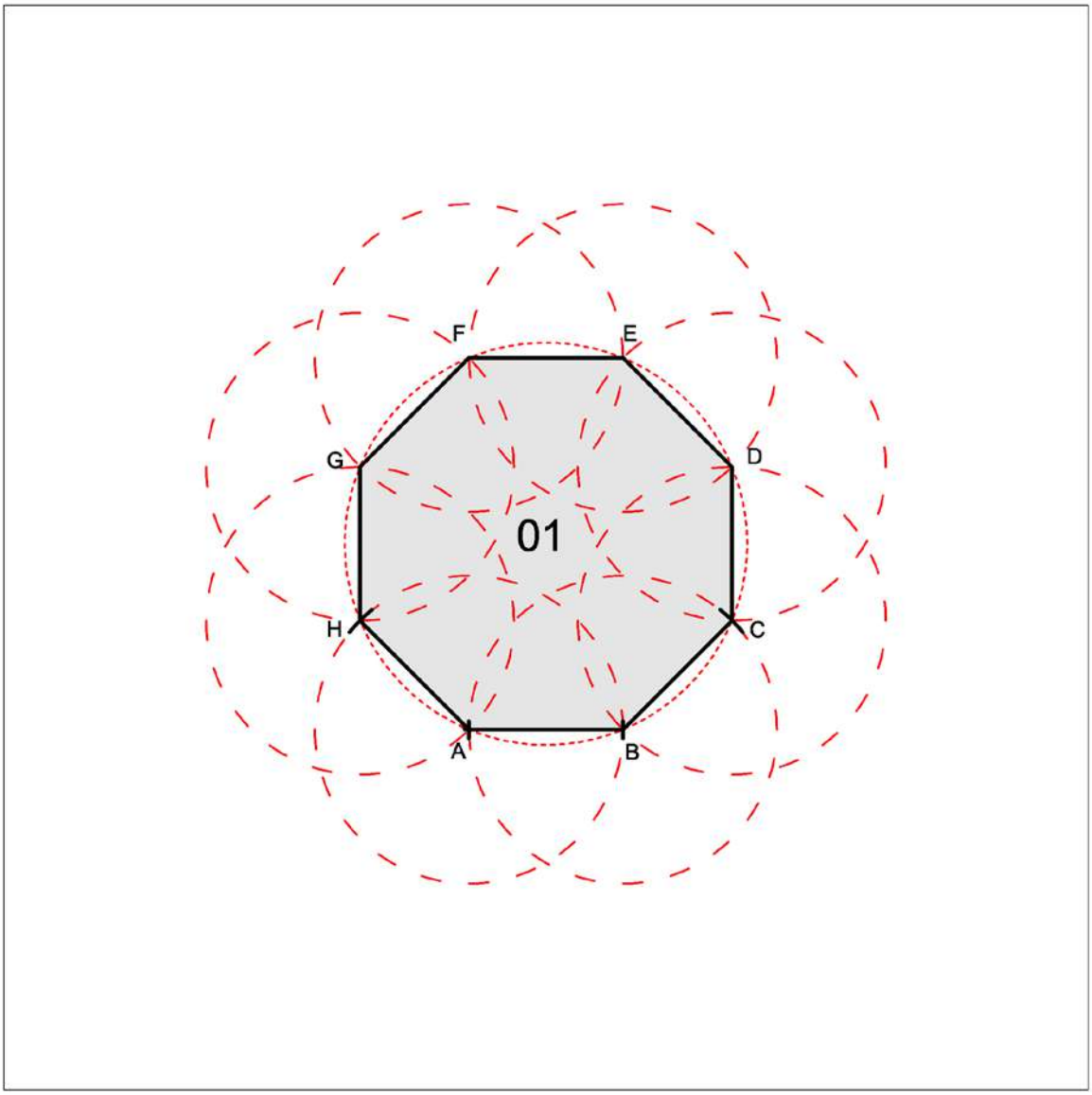


Fig 11: Source Author

On the given circle with the compass centred at vertex A and radii AB draw a circle which will intersect at point H on the circle. Draw a line connecting from point A to H which will be the next side of the octagon.

Repeat this step with vertex H as centre and radii HA to get point G on the circle and on until it will finish at the vertex B on the circle.

Connecting all the point as shown in the figure will give you an octagon 01 (A,B,C,D,E,F,G,H )

**Step 03**

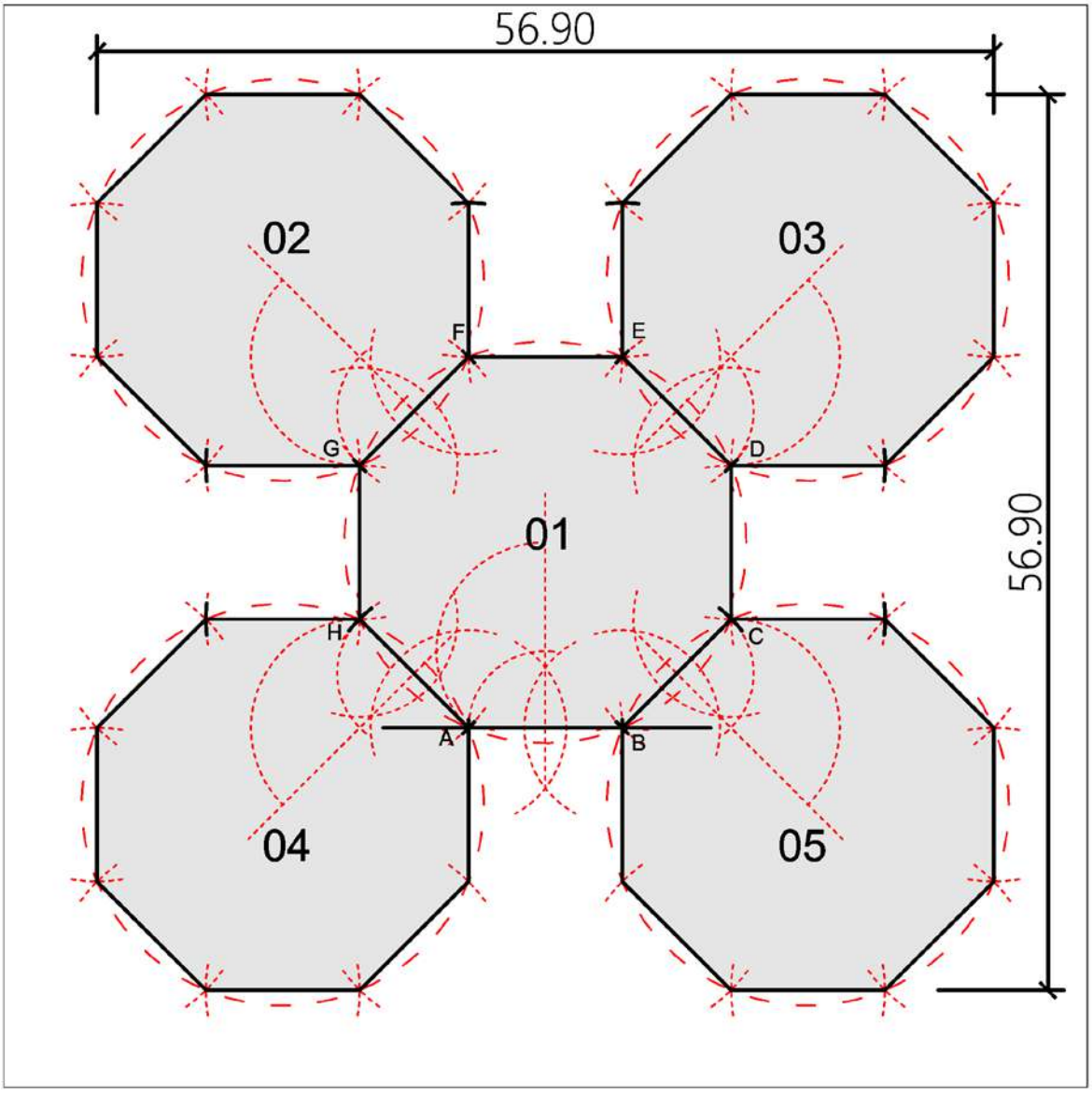


*Fig 12: Source Author*

Now with octagon 01 in place whole process can be repeated again with segment AH, GF, ED, and CB as base line thus resulting a 4 octagons surrounding the central octagon. This is the basic grid upon which whole configuration of building will be followed upon.

Proposed octagonal configuration corresponds to the measured dimension of Taj Mahal (56.90 x 56.90) as per the previous researches.

**Step 04**

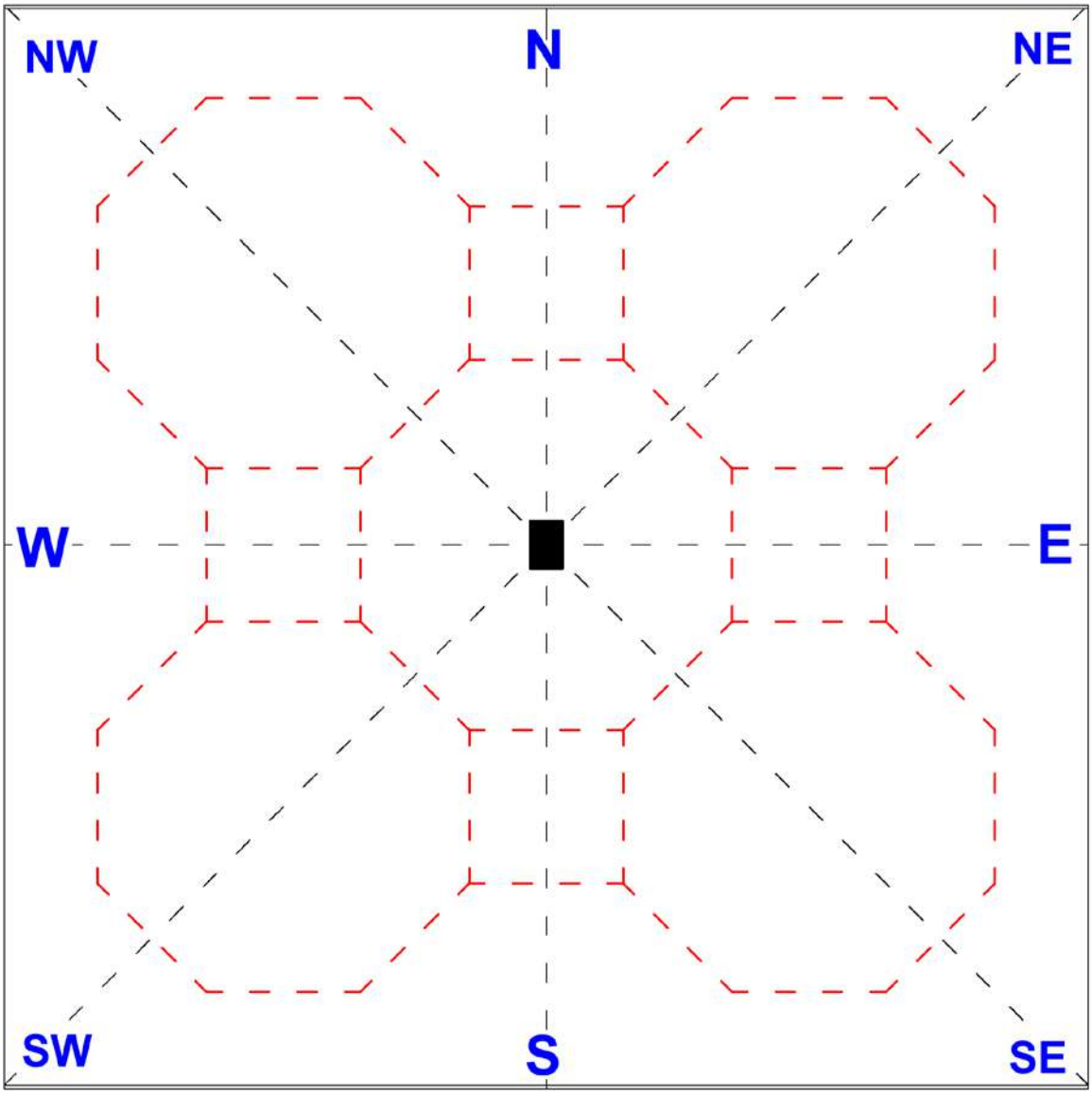


*Fig 13: Source Author*

Proposed geometry is now aligned to the 8 cardinal directions with centre of the geometry corresponding to the centre of all directions. This centre would be the place to house sarcophagi of Mumtaz Mahal which will at the centre of universe philosophically.

Important point to be noted is there are 4 octagons and 4 small squares to the composition with their centre corresponding to the 8 cardinal directions.

**Step 05**

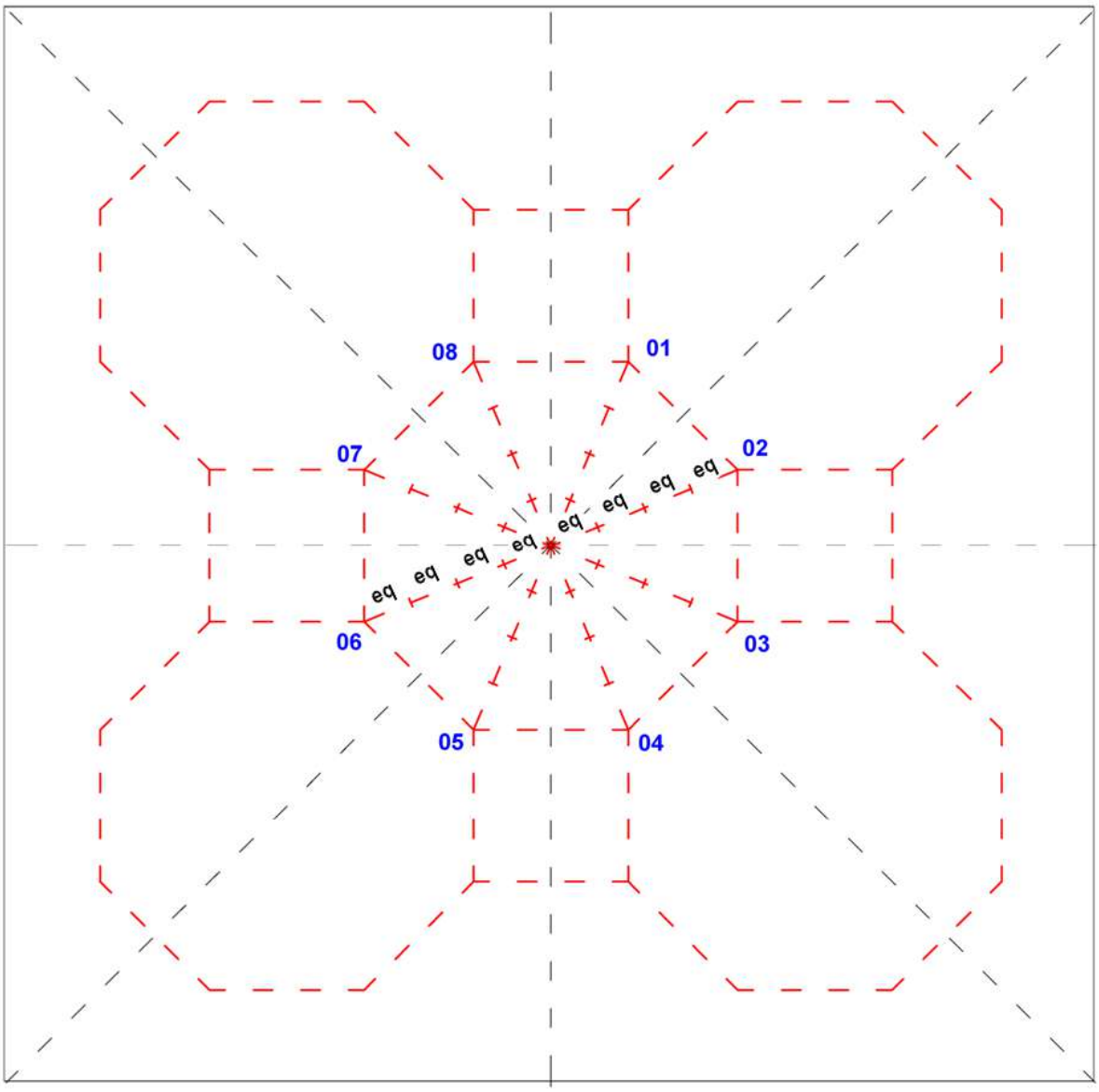


*Fig 14: Source Author*

Working from the central octagon one need to connect the two opposite vertexes to generate Line segment (01, 05), (02, 06), (03, 07), (04, 08). These line segment need to be further divided into 8 equal segments of length 1.5 gaz.

**Step 06**

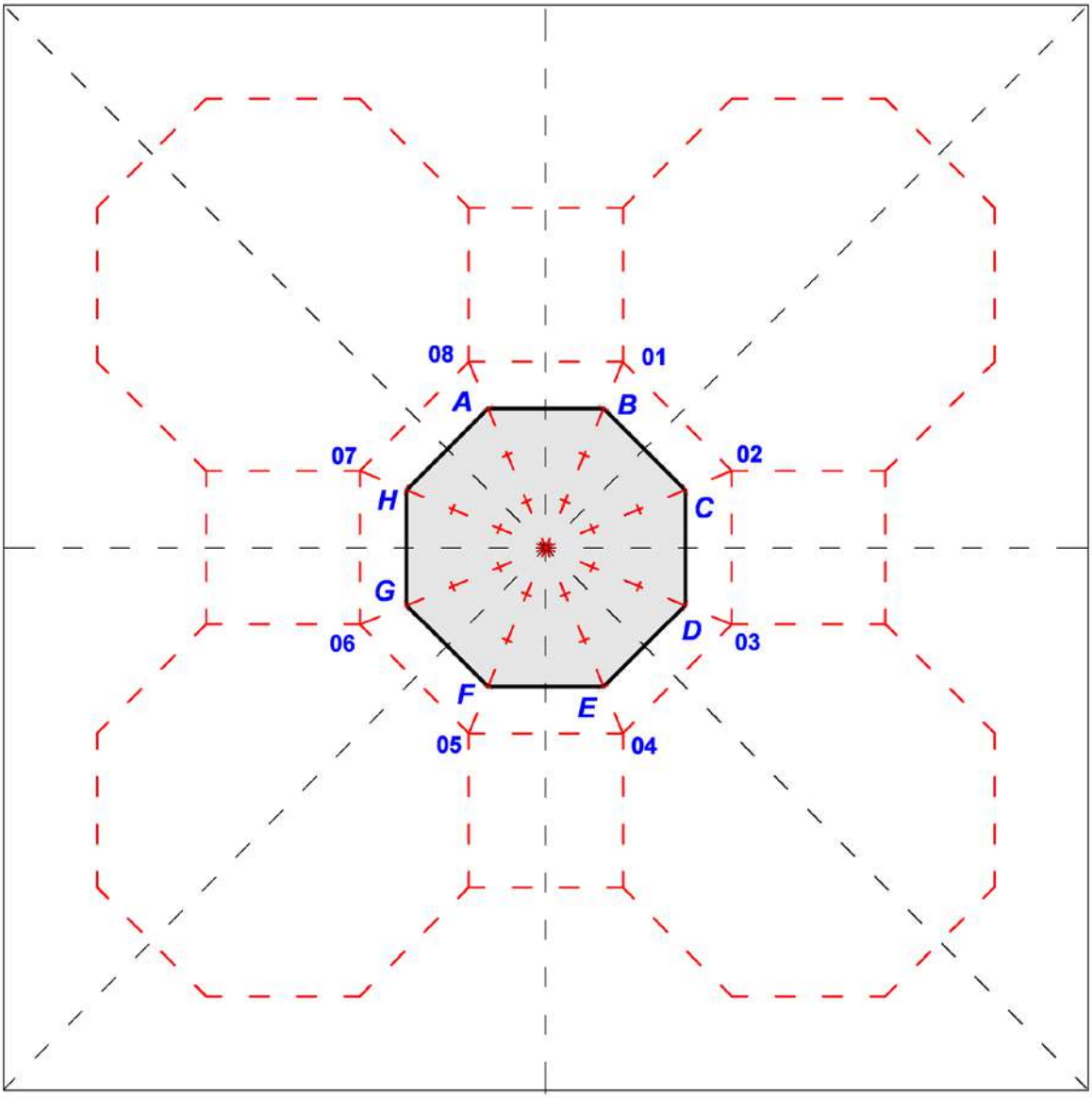


*Fig 15: Source Author*

Octagon ***(A, B, C, D, E, F, G, H)*** generated is the central octagonal room with each side measuring 24 feet corresponding to the measured dimension. (*The central hall has the form of an octagon, 24 feet to a side, with two tiers of eight radiating niches.)* [12]

Measured length of Octagon (A,B,C,D,E,F,G,H) **= 7.32 m = 24 feet = 9 gaz**

**Step 07**

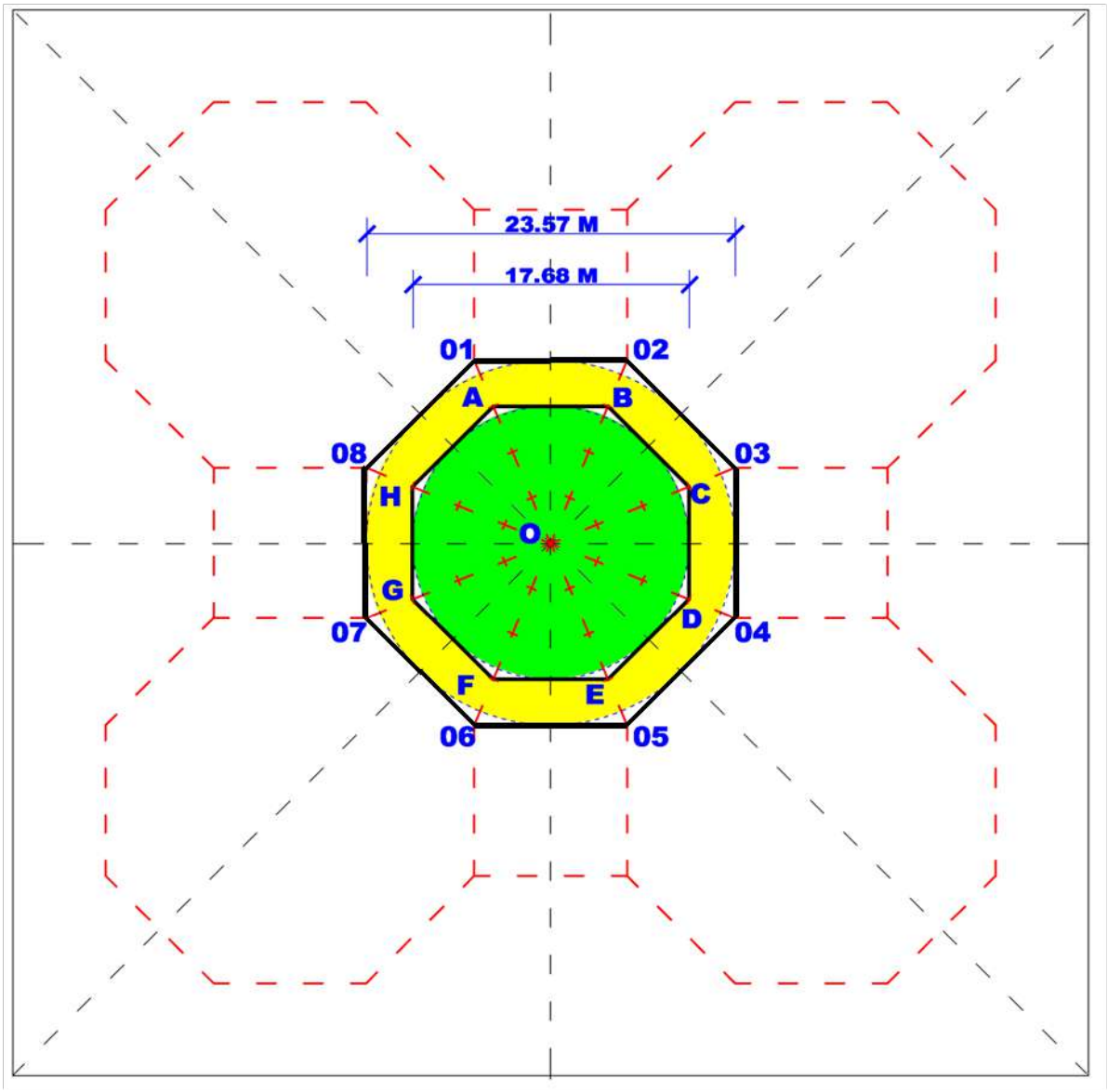


*Fig 15: Source Author*

A circle(green) inscribing an octagon (A,B,C,D,E,F,G,H) with diameter of 17.68 m (58 feet) would be the inner dome of the chamber, whereas circle(yellow) inscribed in outer octagon would form the outer shell of the dome.(diameter = 23.57 m)

Both the dimensions correspond to the measured dimension as quoted. An octagon with 24 feet side will give us an inscribed circle of 58 feet.

| | | | |
|---|---|---|---|
| **Inner Dome** | **= 17.68 m (dia)** | **= 58 ft** | **= 21.75 gaz** |
| **Outer Dome** | **= 23.57 m (dia)** | **= 73.32 ft** | **= 29.00 g** |

**Step 08**

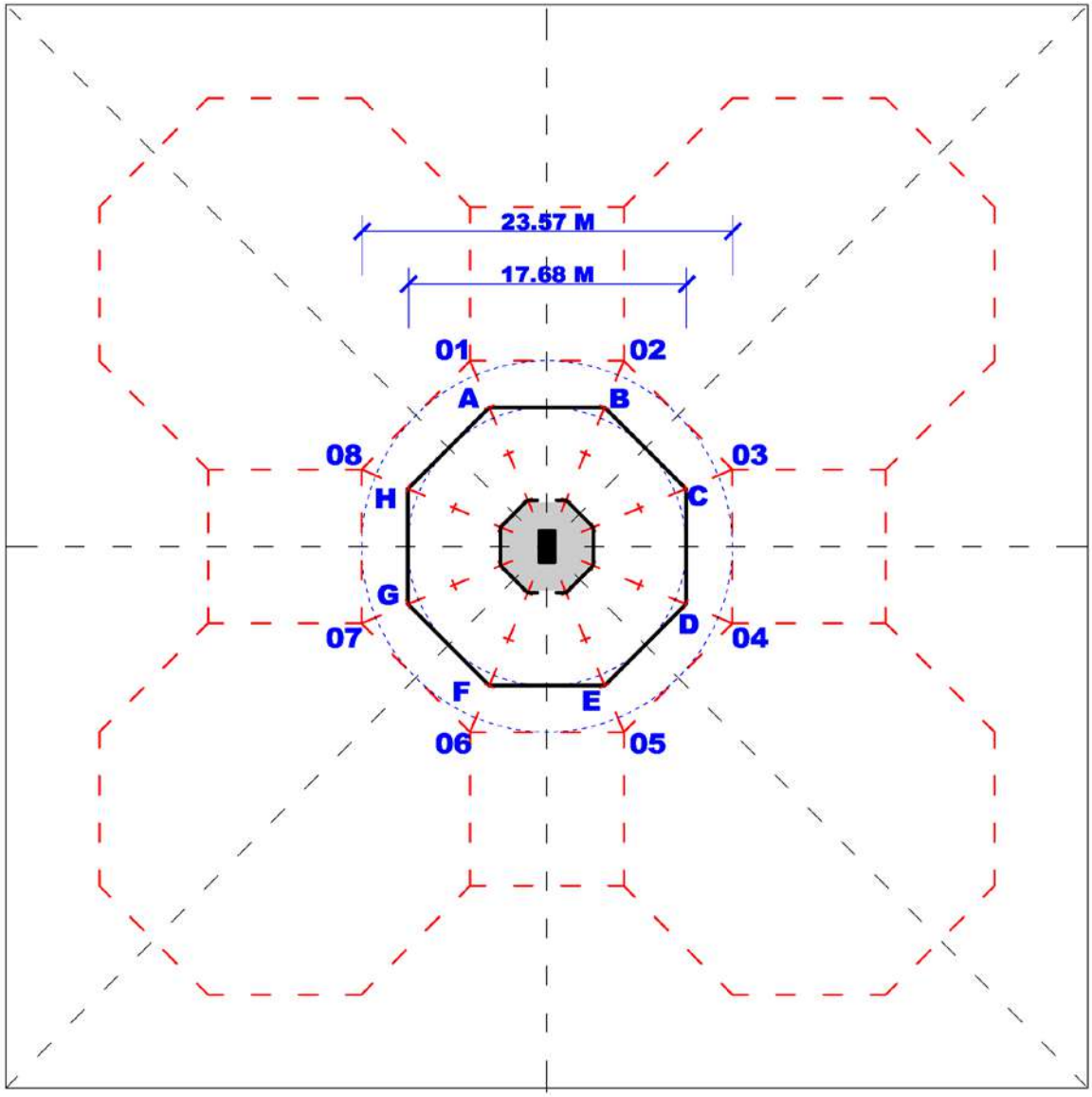


*Fig 16: Source Author*

Innermost Smallest octagon of equal division thus generated is the perforated marble screen a more private space surrounding the sarcophagi of Mumtaj Mahal. This octagonal screen will have two entrances corresponding to the North and South directions. An octagonal screen with in the central octagon chamber surrounded by the octagonal outer chambers intensifying the paradisiacal symbolism of number 8.

**Length of inner Octagon = 2.44m = 8 feet = 3 gaj (panels 3 equal part @ 1gaz)**

*Each side of the octagon is divided into 3 by marble frames. The corners are fortified by posts ending in kalasha finials the frames are filled with jails.* [13]

**Step 09**

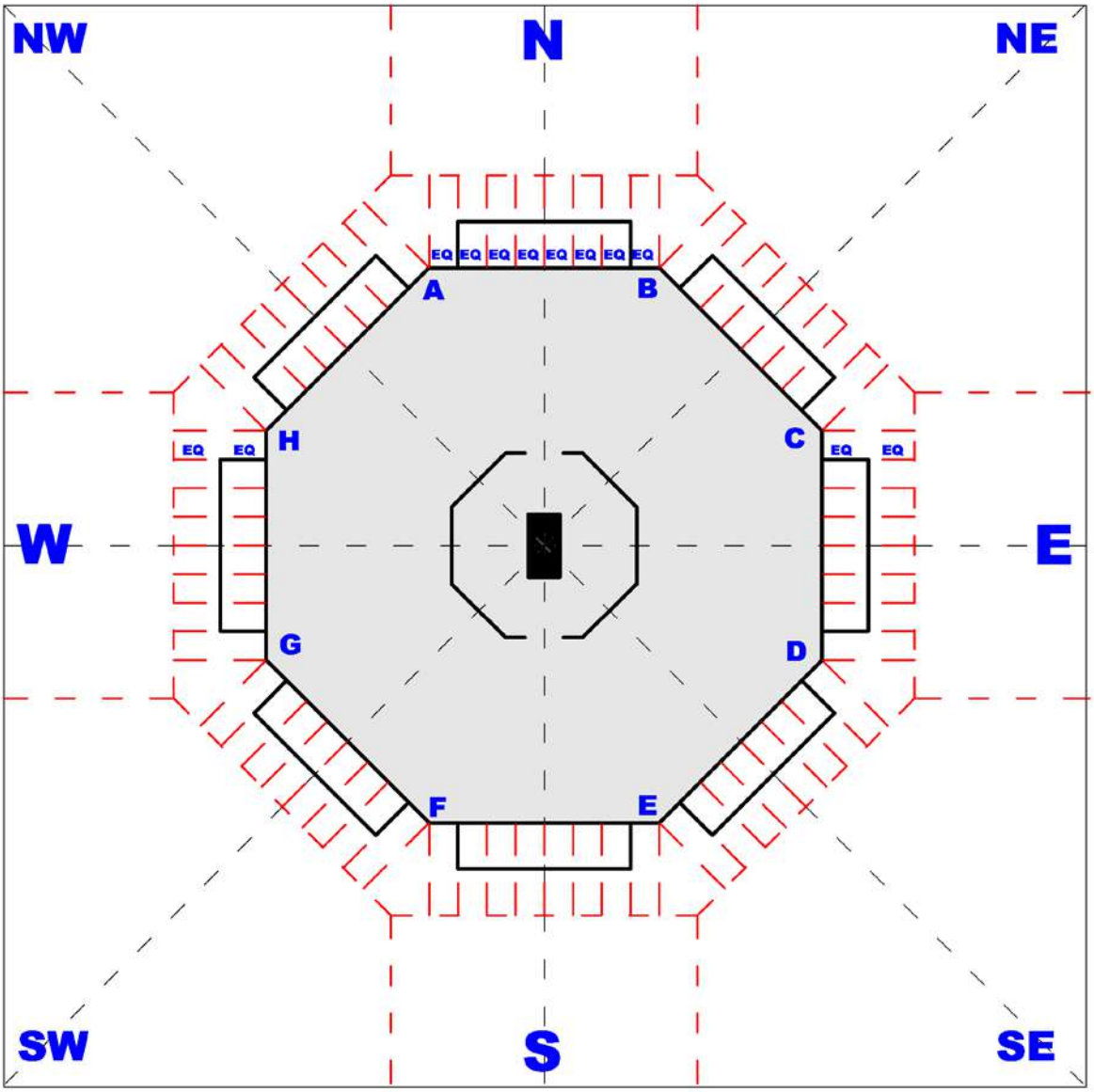


*Fig 17: Source Author*

Eight sides of the central octagonal will have two tiers of 8 radiating niches termed as "**nashiman".** These can be formed simply by dividing the sides of octagon into 8 equal parts, the depth of niches is half of distance between the inner and outer octagon as shown in the fig. Those on the main cardinal axis are open and fitted with screens which transmit daylight into the central octagonal chamber. Niches dimension

**length = 5.49 m = 18 feet = 6.75 gaz**

**Depth = 1.47 m = 4.82 feet = 1.81 gaz**

**Step 10**

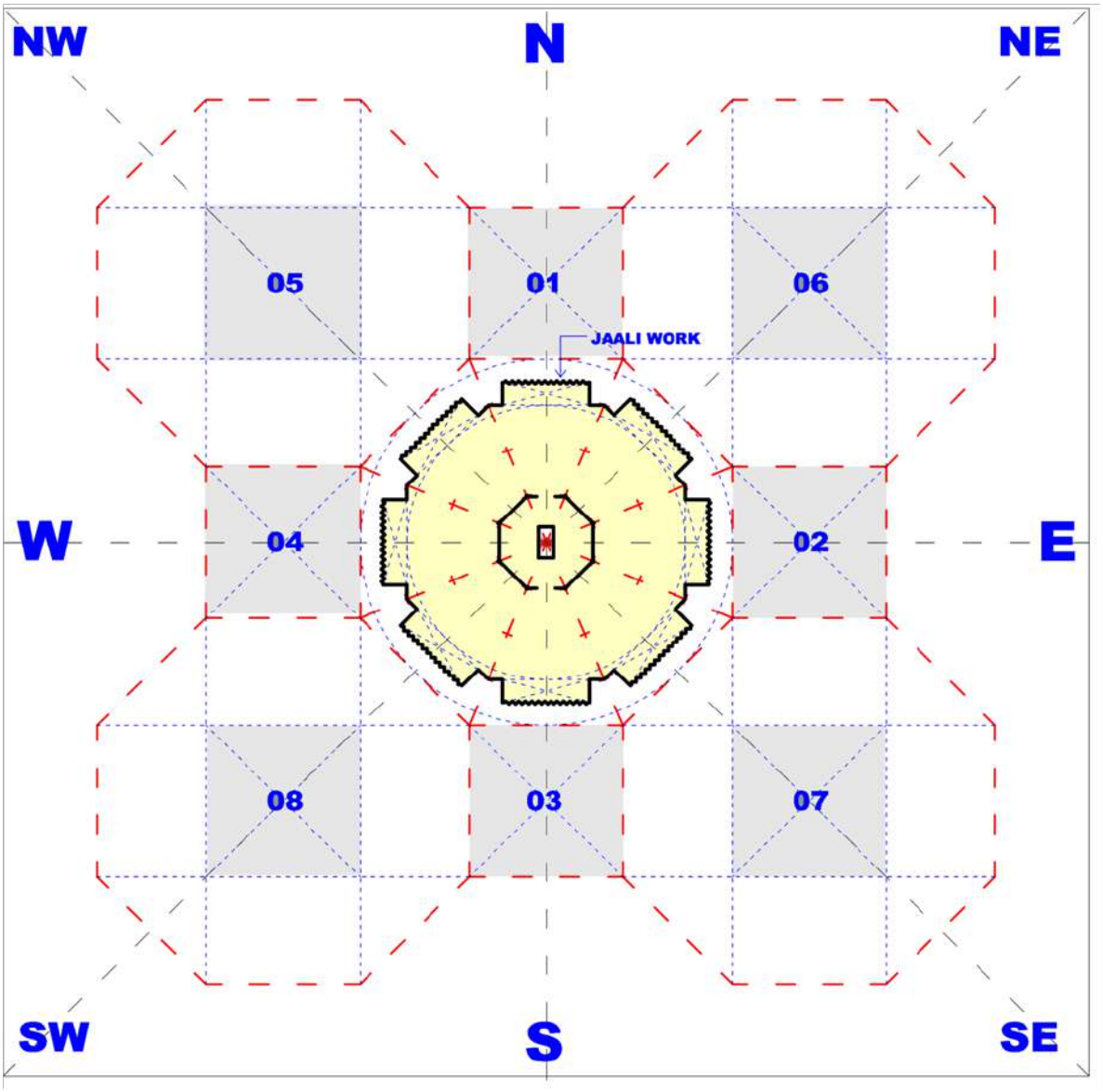


*Fig 18: Source Author*

Once the central chamber is completed focus now shifted to the outer octagons of the composition. Presence of square along with octagon adds different dimension to the composition. Taking the projection lines as shown in the fig one can generate 8 equal squares corresponding to the 8 cardinal directions.

These would be the 8 main chambers surrounding the central chamber of Taj Mahal. All the sides of squares and octagons thus formed are equal in size.

**Step 11**

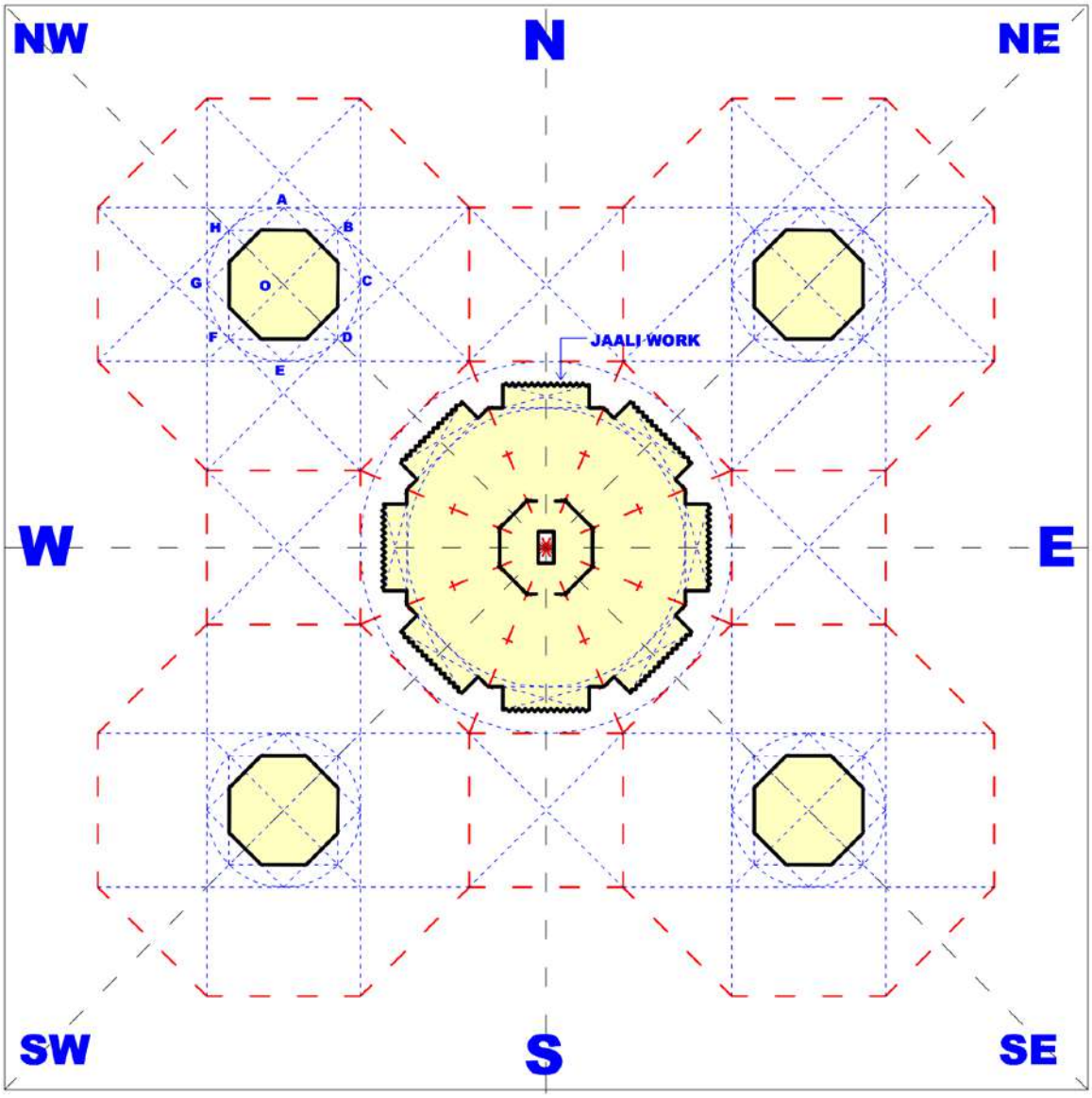


*Fig 19: Source Author*

A circle is drawn from the midpoint of given square as shown in the fig. This circle when get overlaid with cardinal direction will give 8 point (a,b,c,d,e,f,g,h). Joining main cardinal points(a,c,e,g) and secondary cardinal points (b,d,f,h) will generate 2 overlapping square thus forming the sacred **"Hisht- Bihisht"** symbol.

As studied before This symbol of ***Hasht- Bihisht*** can deducted into geometrical shape of a regular octagon by the process of delaminating internal enclosures.

Repeat this process at 3 other places to generate 4 octagonal chambers

**Step 12**

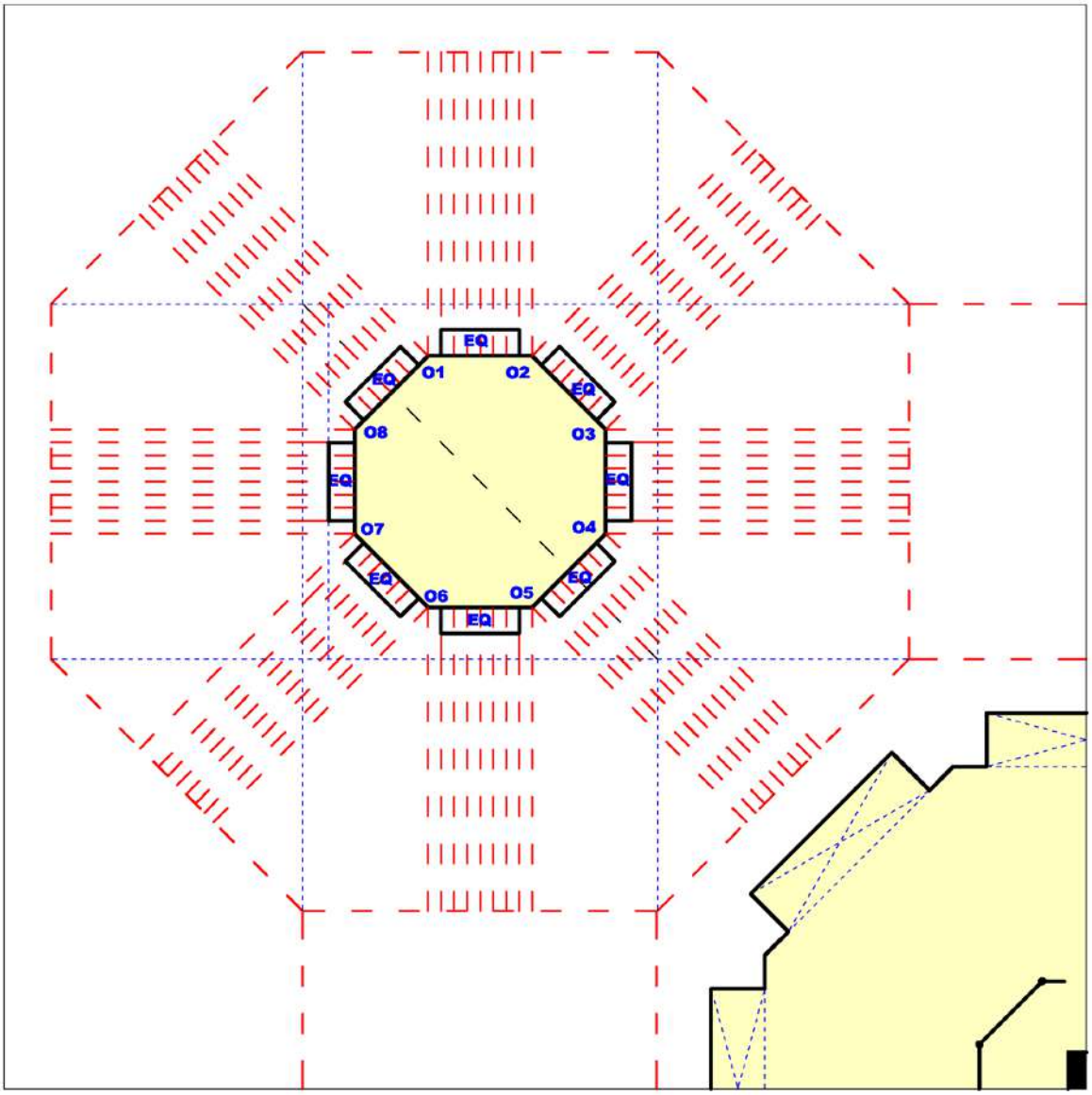


*Fig 20: Source Author*

Eight sides of the outer octagonal will have two floor of circumambulatory rooms with 8 radiating niches termed as "**nashiman".** These can be formed simply by dividing the sides of octagon into 8 equal parts, the depth of niches is again ½ the distance between central octagon and square grid as shown in the fig.

Niches dimension

**length = 2.86 m = 9.3 feet = 3.5 gaz**

**Depth = 0.71 m = 2.32 feet = 0.87gaz**

**Step 13**

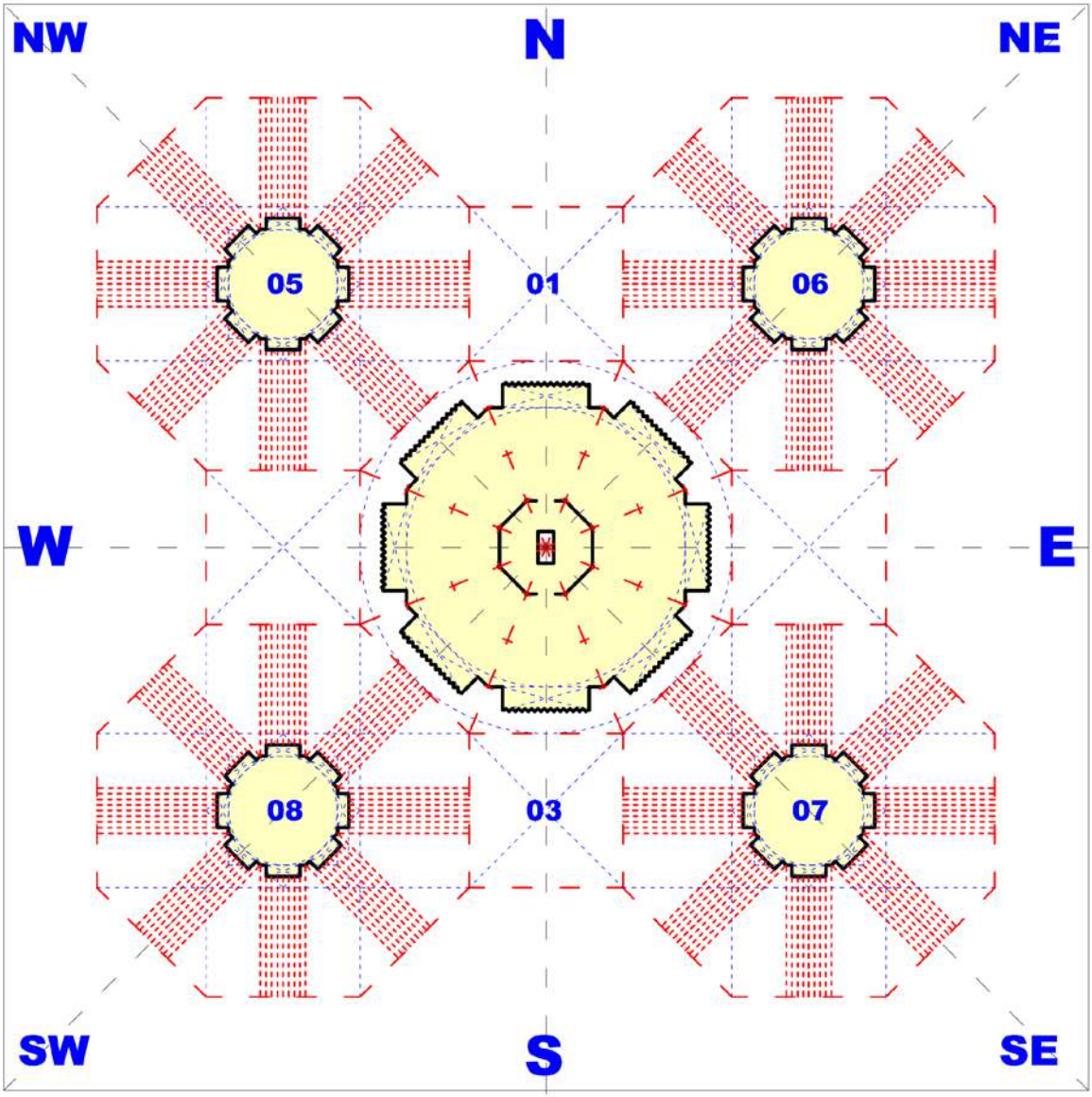


*Fig 21: Source Author*

The rooms thus generated are on the secondary cardinal grids to central octagonal chamber. These chambers are octagonal in shape thus intensifying the sacred dimension of the structures. The process of tessellation is underway in which unit item (octagon) is getting repeated again and again.

**Step 14**

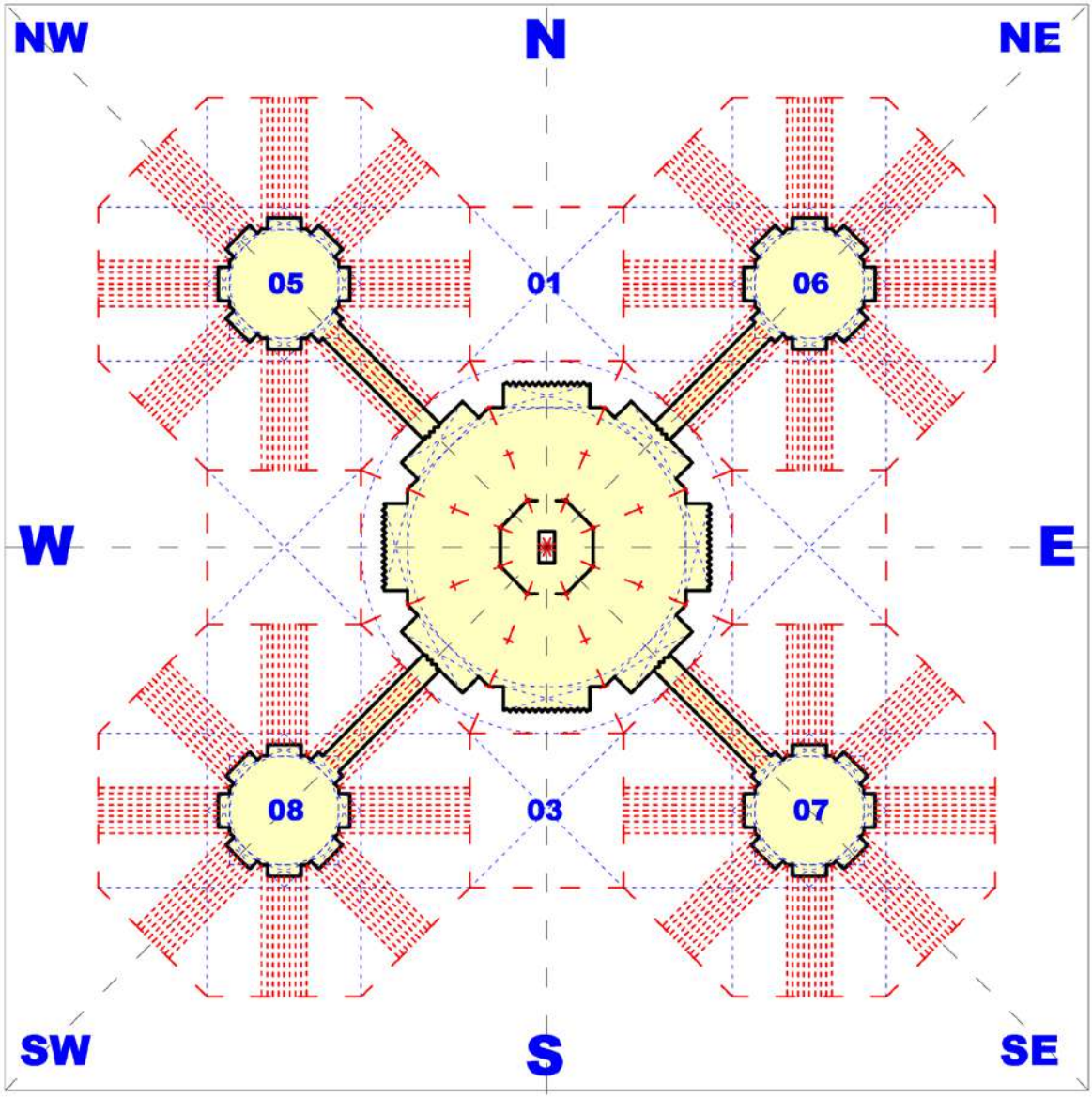


*Fig 22: Source Author*

Four octagonal outer chamber thus generated are connected to central chamber via connecting passages. These passages width corresponds to the 8 equal division grids as shown in the fiq.

**Connecting passage width = 1.43 m = 4.69 feet = 1.76 gaz**

**Step 15**

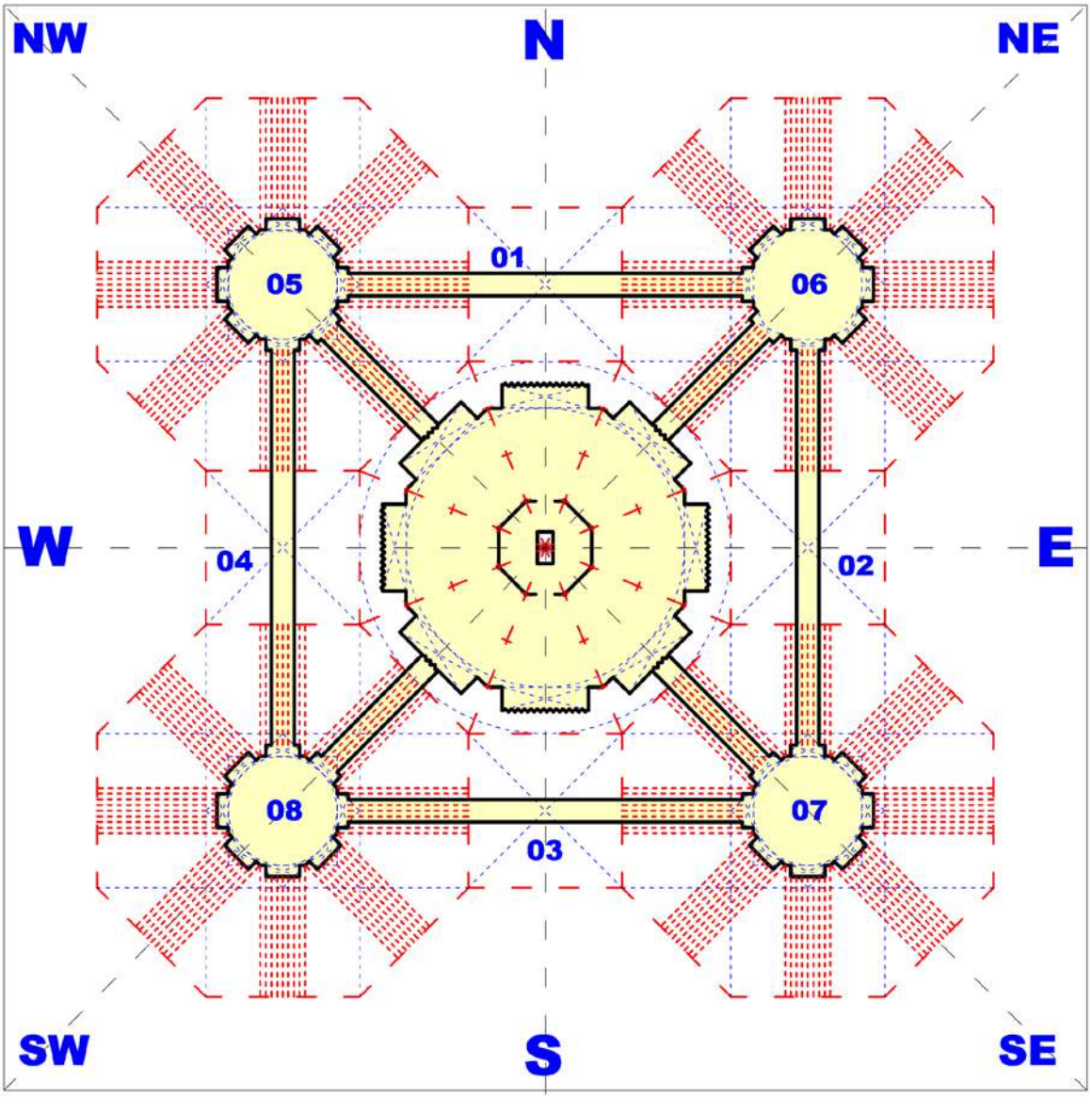


*Fig 23: Source Author*

Interconnecting the outer octagonal chamber with the same passage width will generate a circumambulatory passage to the central chamber. These rooms were originally used to chant the Koran and the visitor can circumambulate on each floor since they are interconnected.

**Step 16**

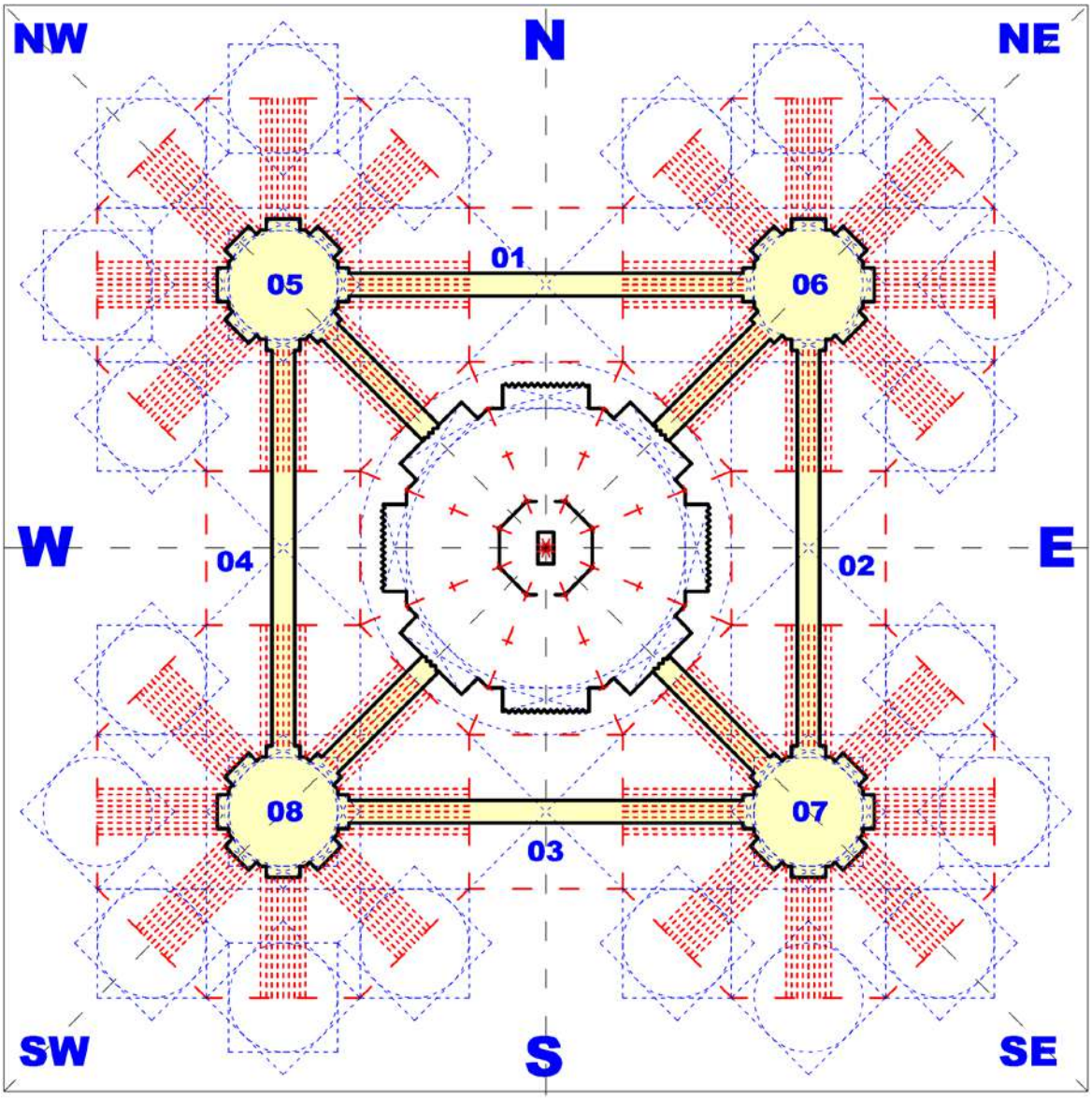


*Fig 24: Source Author*

The central outer octagonal grid "Hasht- Bihist" generated previously will be tessellated again on the sides of the octagon. This grid will generate the outer profile of the building as shown in the fig.
Chamber no. 01,02,03 & 04 will be the grand entrance portal corresponding to the cardinal directions.

**Step 17**

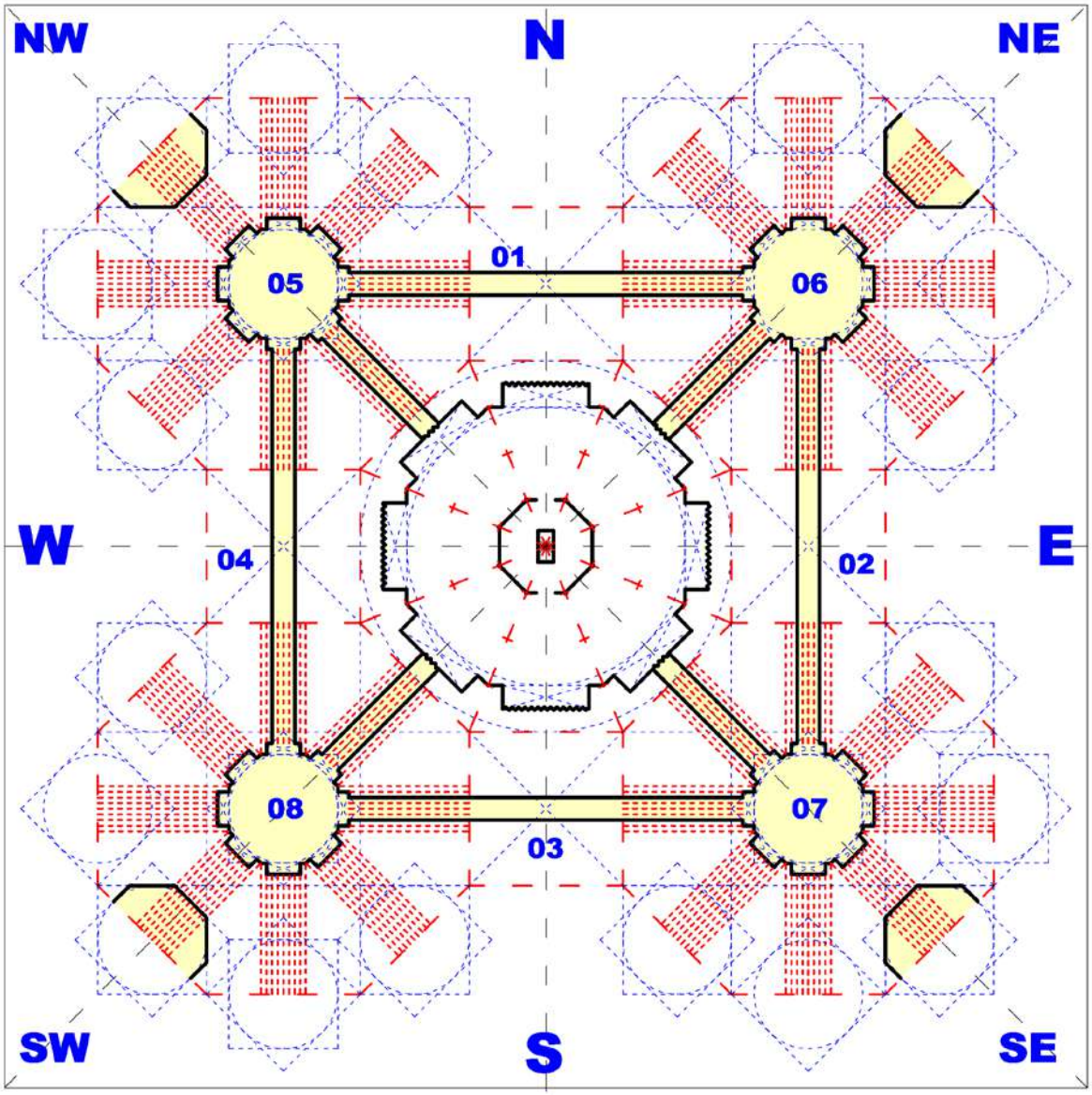


*Fig 25: Source Author*

A very important observation to note at this point is octagonal geometry are corresponding to secondary cardinal directions only , keeping or rather accentuating the process we can generate an outer ½ octagonal chamber on the external facade which would form the chamfered corner of the square building.

Divisional grid (red) generated previously when intersect with Hasht- Bihist grid (blue) generate an ½ octagon thus evolved.

**Step 18**

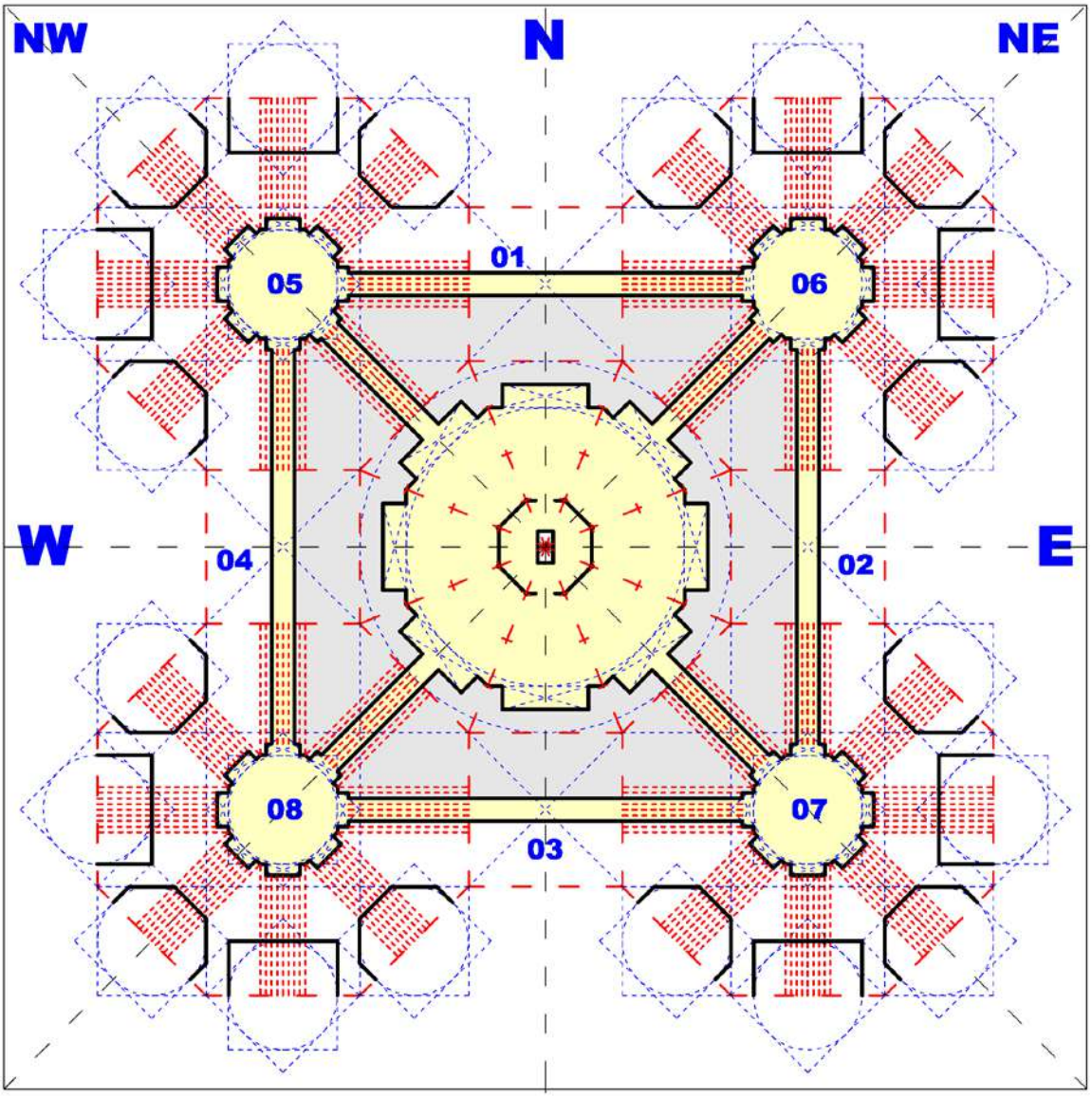


*Fig 26: Source Author*

Chambers thus formed corresponds to the cardinal directions. One on the main axis (N,S,E,W) will be rectangular in shape and others on secondary axis(NE,NW,SE,SW) will be semi octagonal.

**Step 19**

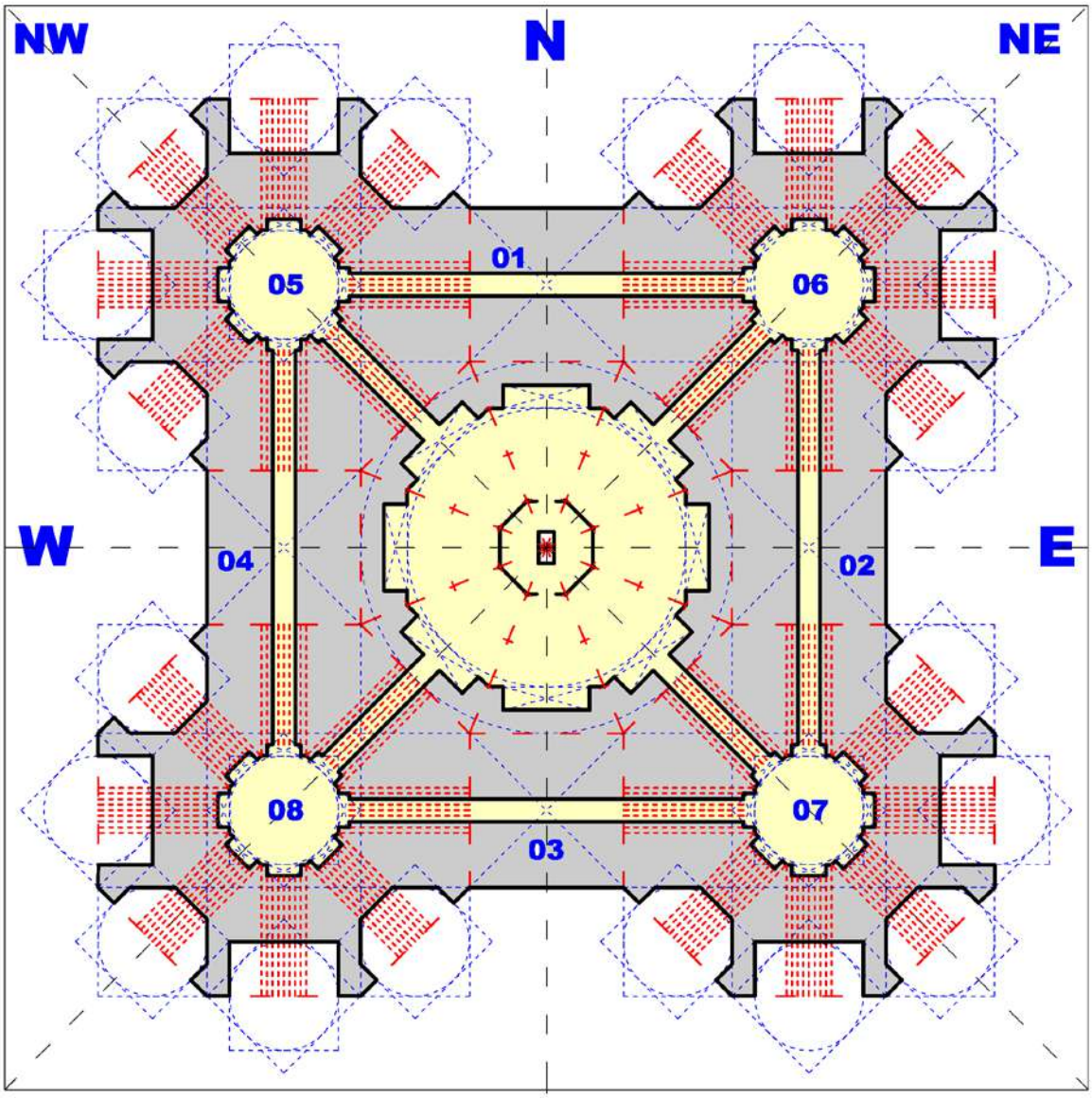


*Fig 27: Source Author*

One can start getting the feeling of the dejavu as the plan closely resembles the plan of Taj Mahal. What's missing are the grand Pishtaq, or vaulted archway on the main cardinal axis and square chambers.

**Step 20**

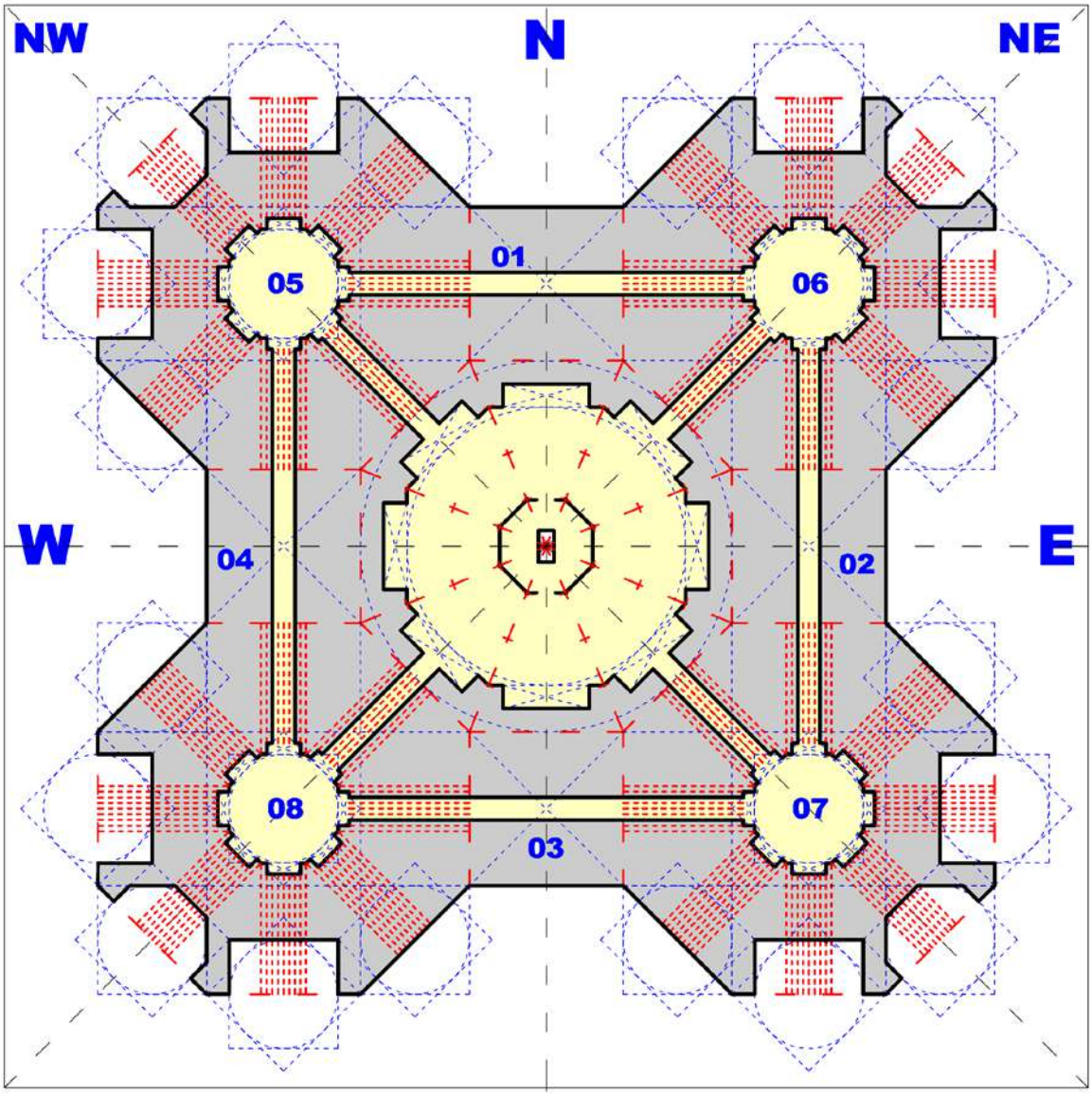


*Fig 28: Source Author*

A massive Pishatq thus proposed form's the main design element and needed large length and height. To accommodate semi octagonal chambers on the either sides of main cardinal axis are deleted as shown in the fig.

**Step 21**

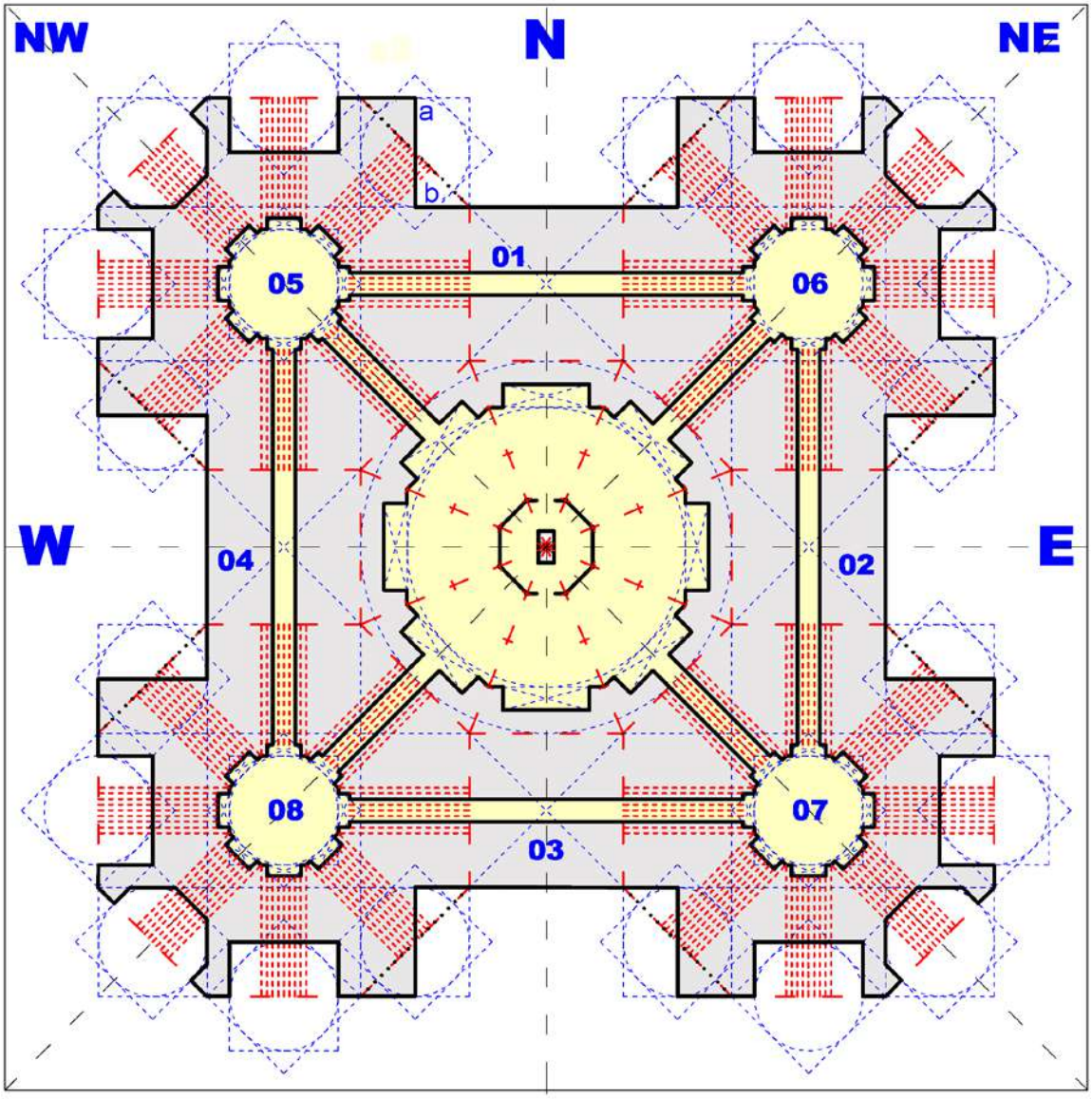


*Fig 29: Source Author*

A line segment AB from the centre of Hasht-Bihist grid when intersected with proposed profile will generate a large rectangular entrance portal to the composition on main cardinal axis

This process is repeated on the all 4 major axis, portal thus generated would be rectangular in profile.

**Step 22**

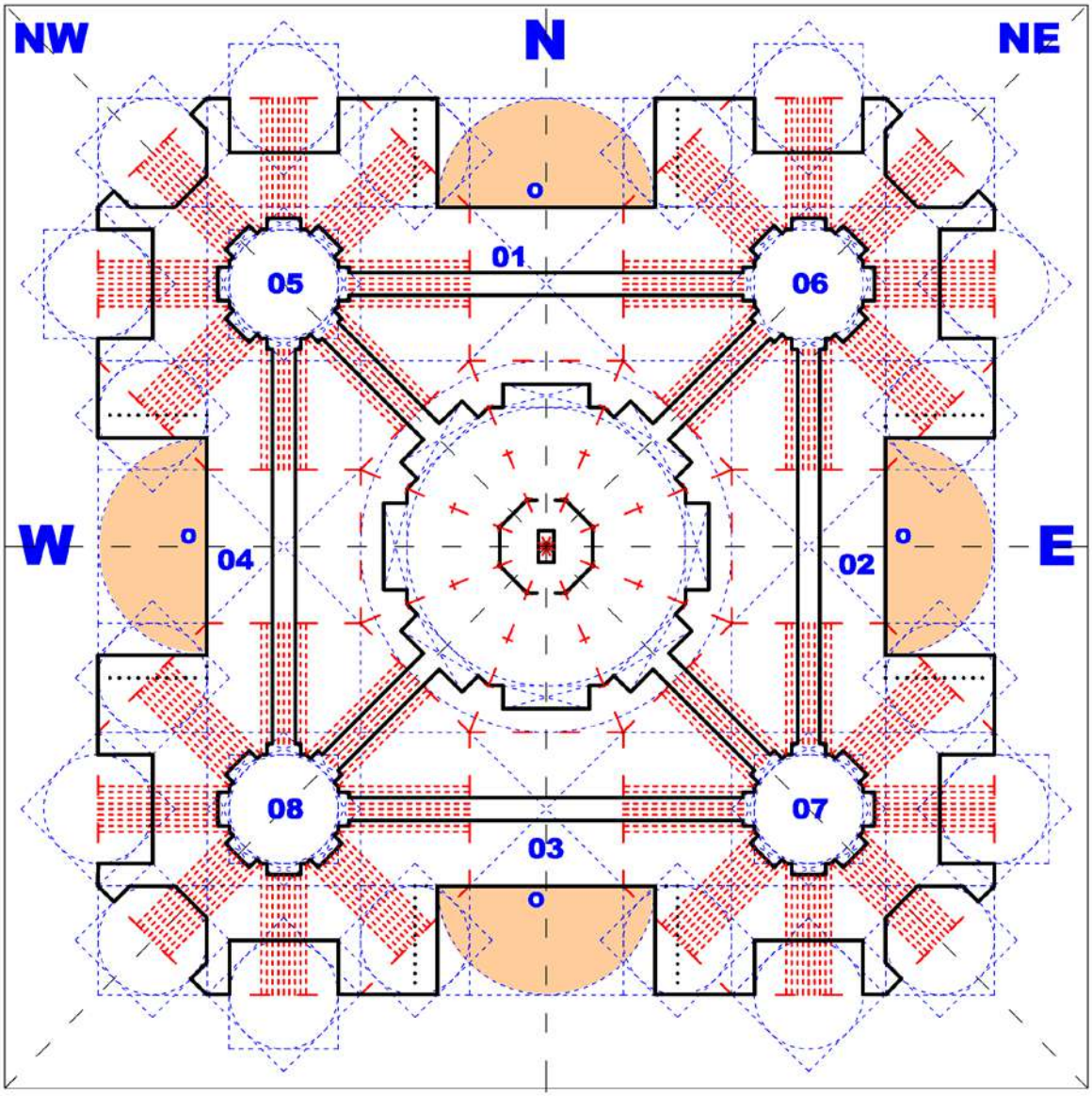


*Fig 30: Source Author*

The entrance portal generated currently cannot be used as arched gateway. If we draw a semicircle with centre O (mid point) and radii as depth of portal one gets a semicircle corresponding to the intersection of two square of Hasht- Bihist. Thus the line AB generated had to be moved to the intersection point as shown in the fig.

**Entrance portal** **length = 13.80 m**
**Depth = 6.90 m A perfect semicrle.**

**Step 23**

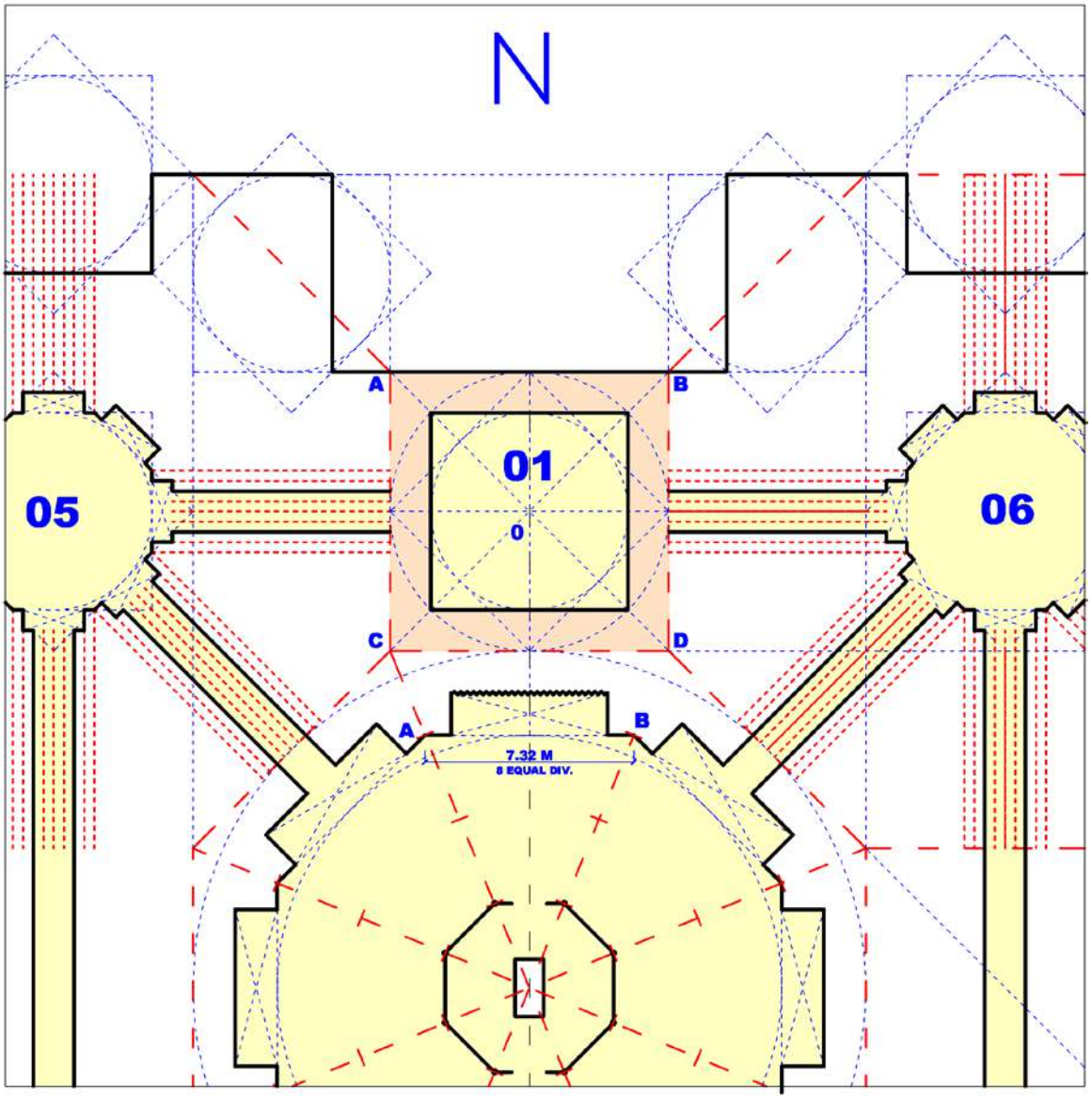


*Fig 31: Source Author*

Now to generate the 4 square chambers on main cardinal direction all you have to do is repeat the step 11 on square (A,B,C,D) to generate Hasht- Bihist grid. One of the two overlapping square generated corresponding to main cardinal direction is the entrance chamber.

Repeat the steps on other 3 entrance portal to generate the chambers.

| | | | |
|---|---|---|---|
| Entrance square chamber | **length = 11.04 m** | **= 36.22 feet** | **= 13.58 guz** |
| Entrance passage width | **width = 03.68 m** | **= 12.07 feet** | **= 4.53 guz** |

**Step 24**

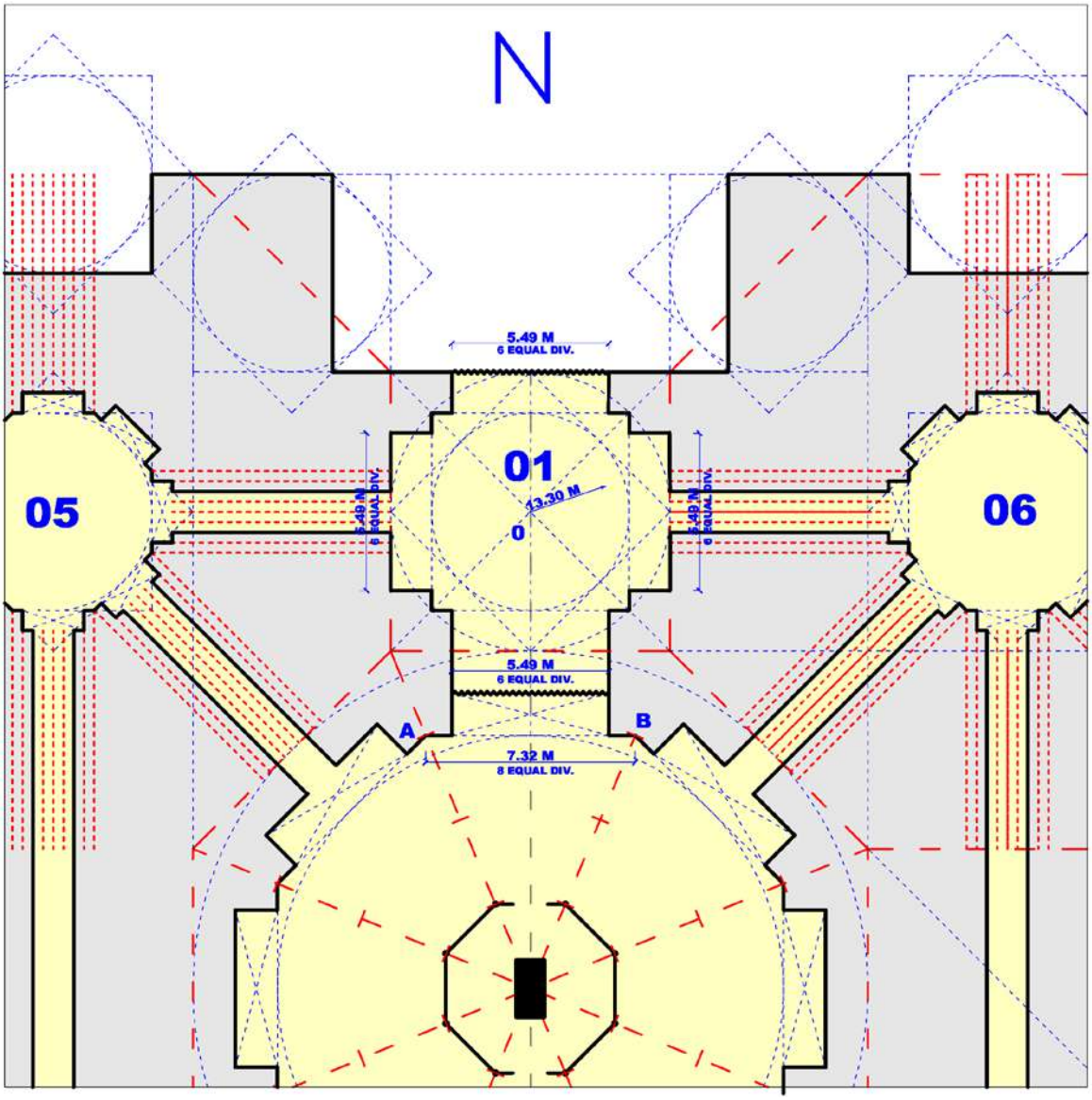


*Fig 32: Source Author*

Extending the internal octagonal chamber passage to the square chamber although way to the entrance portal, will generate a connection of outside world to the internal chamber.
Going by the symmetry repeating this process will also generate a symmetrical connection of 2 corridors as shown in the fig.

Repeat the steps on other 3 entrance portal to generate the chambers an its connections.

**Step 25**

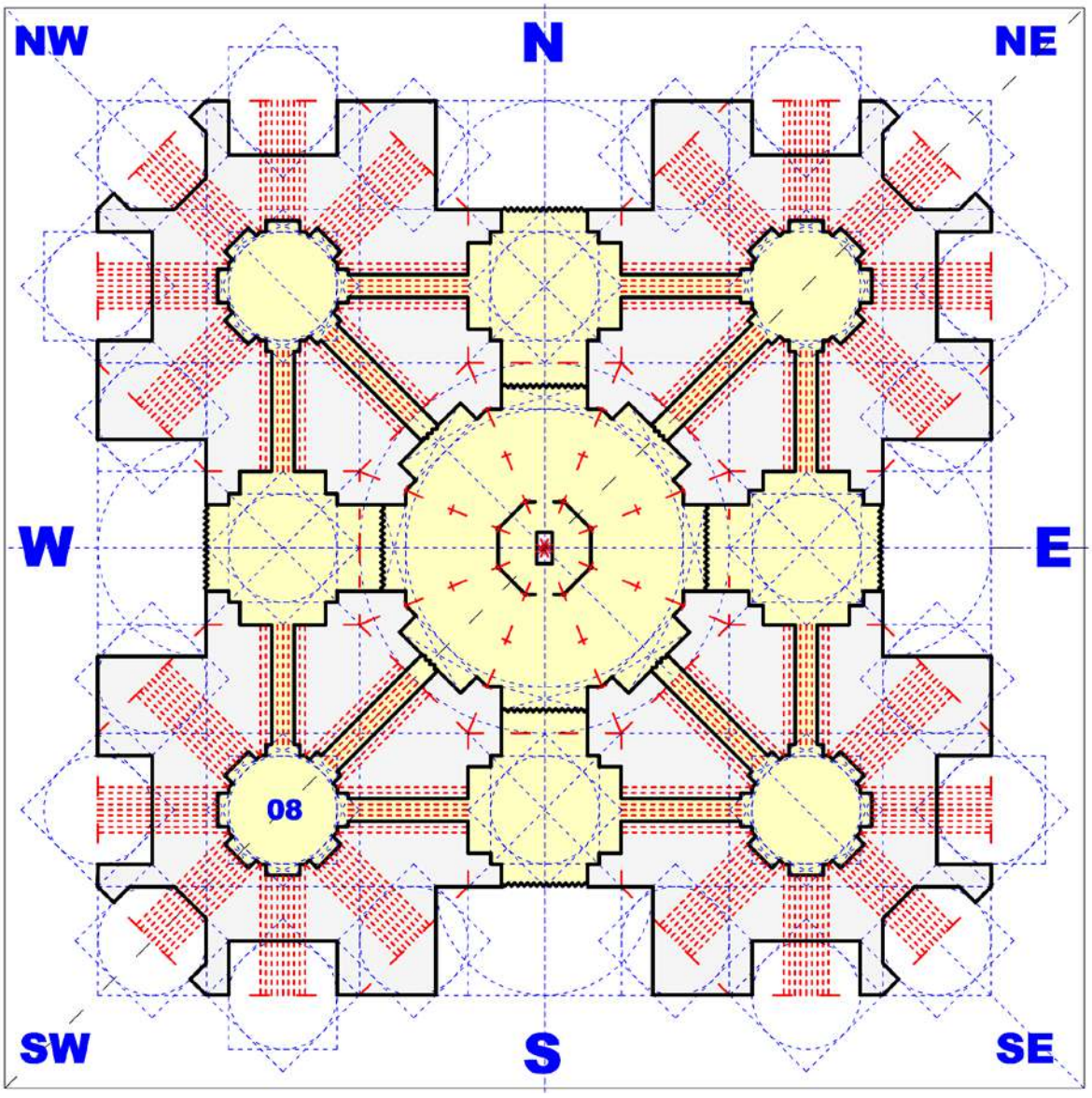


*Fig 33: Source Author*

This is the **Taj Mahal** floor plan generated purely out of geometry, except the connecting passage needs to be extended to the outer profile of the building.

**Step 26**

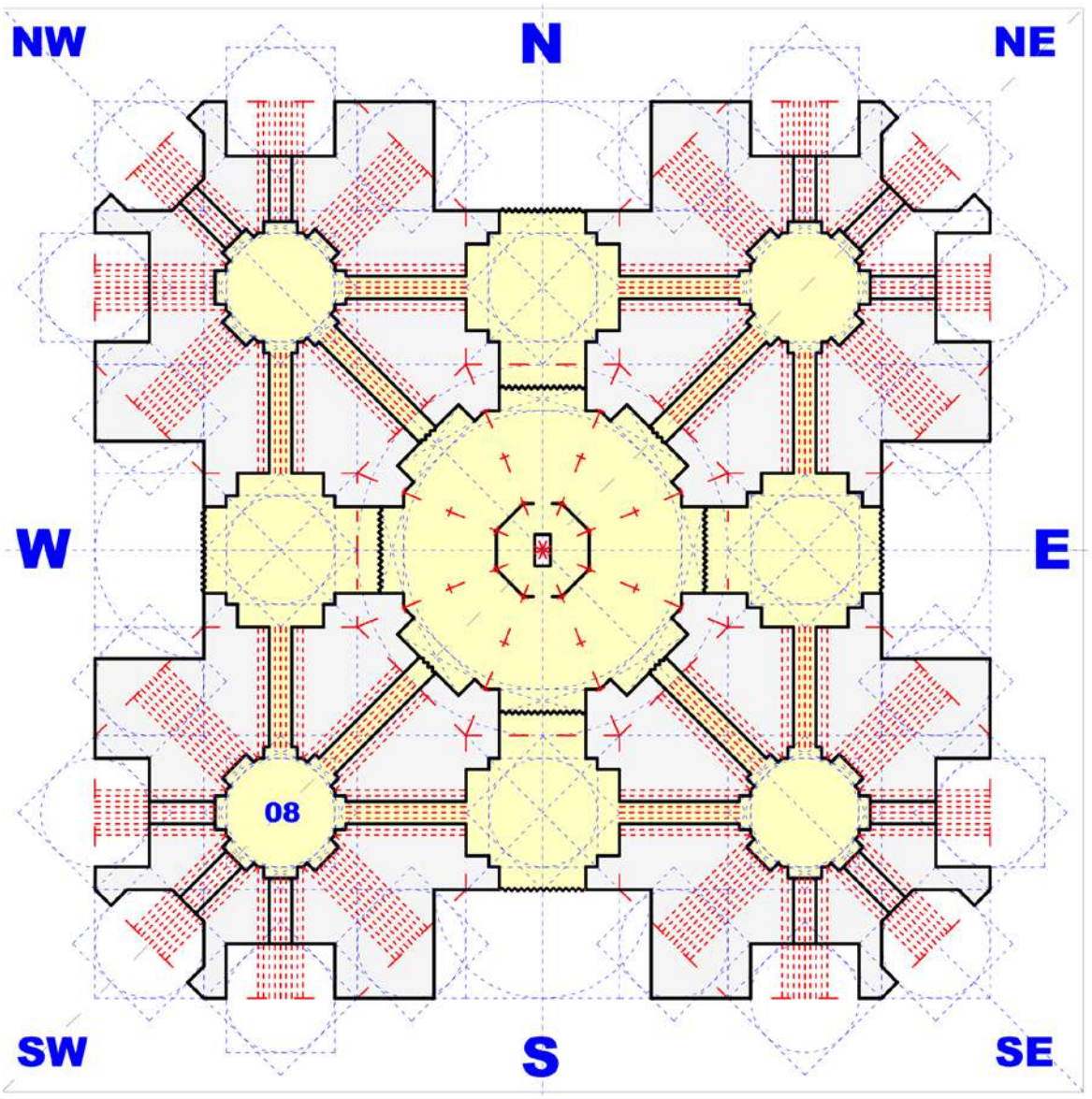


*Fig 34: Source Author*

Awesome would be the right word to describe the process of generating this plan. Finally we can say ***"This is the how the building plan of Taj Mahal is evolved from the single octagon."***

**Step 27**

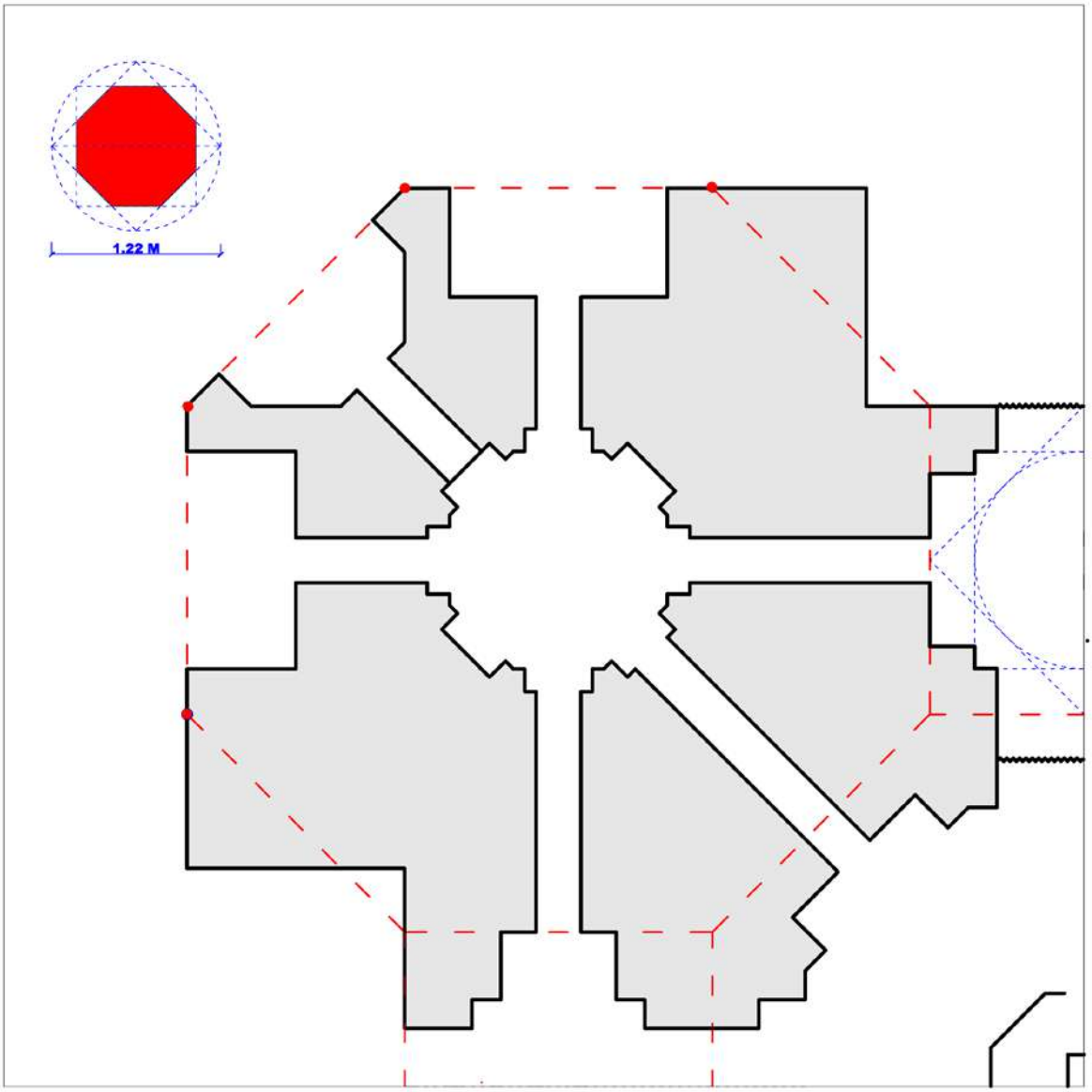


*Fig 35: Source Author*

Idea of decoding this whole plan came from the hint depicted on the building elevation in the form of a "Guldasta" the tall decorative spire. Location of this spire corresponds to the intersection of the octagon sides as shown in the fiq.

Although no dimensional figure recorded so far my logical reasoning are as follow:
Central octagonal room length is divided into 8 equal parts and called as divisional grid.
**Length of central octagon = 9.756 = 8 equal division of = 1.22 m**
**A octagon inscribed in the dia of 1.22m = Guldasta octagon**

**Step 28**

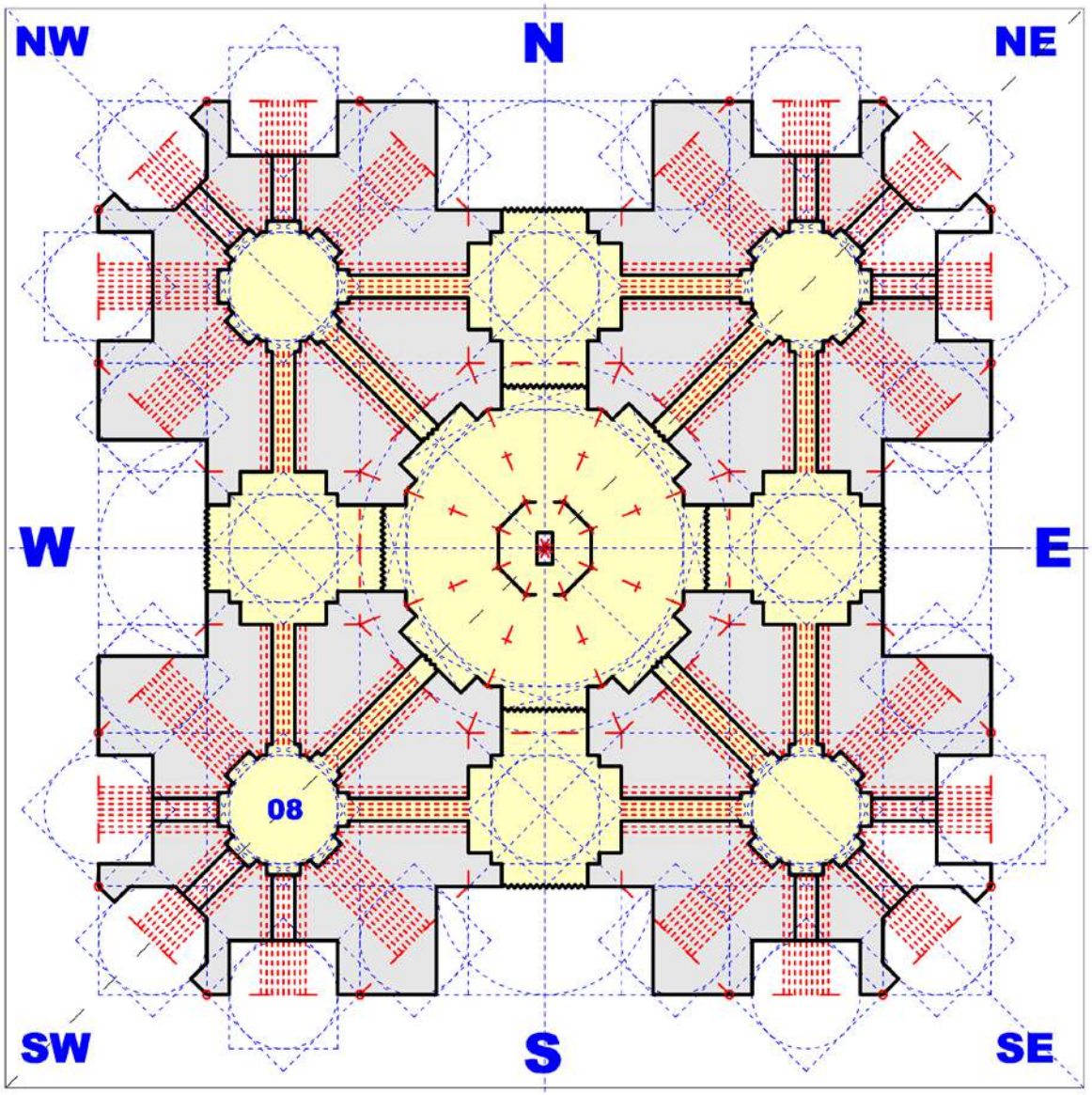


*Fig 36: Source Author*

The smallest octagon in the design called as “Guldasta” are repeated on all four sides of the plan corresponding to their respective octagons as shown in the fig.

The “Guldasta” (smallest octagon) also hold the key to elevation grids thus playing a very important role both in terms of decorative pier and grid system.

In next step we would be generating the location and size of minarets to complete the plan.

**Step 29**

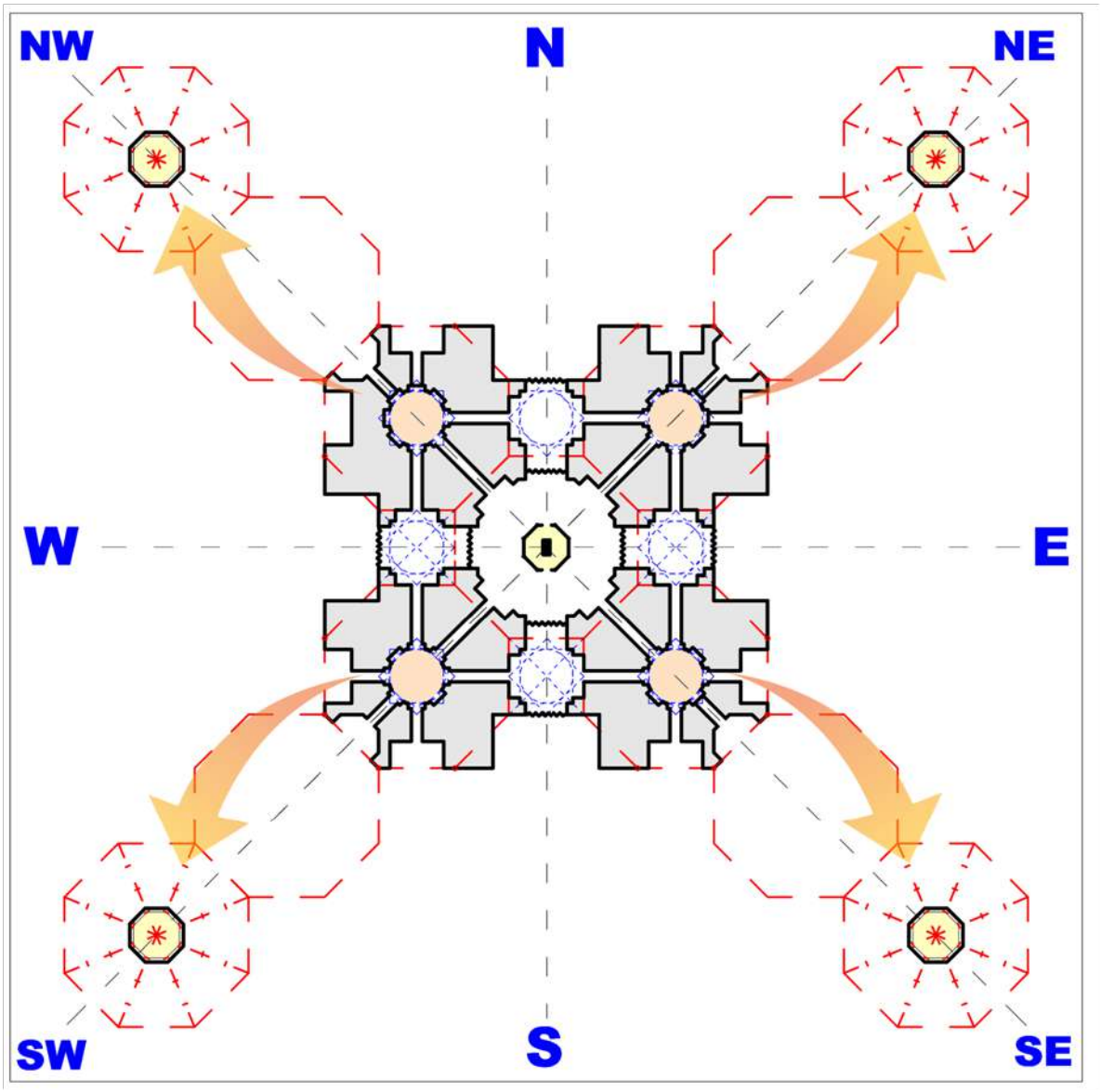


*Fig 37: Source Author*

In order to generate the plinth on which Taj Mahal sits, add 2 more main octagonal grids in the corresponding cardinal directions as shown. The small octagonal room generated previously will be repeated again and this would be the dimension of chamfered corners of the plinth.

This corner octagon holds a minaret in the centre whose dimensions corresponds to the innermost octagon of the central chamber. A circle inscribe in this octagon in the base dimensions of circular minarets

**The base dimension of generated inscribe circle die = 5.90 m – decorative = 5.65 m**
**Measured dimension of the circle die = 5.65 m**

**Step 30**

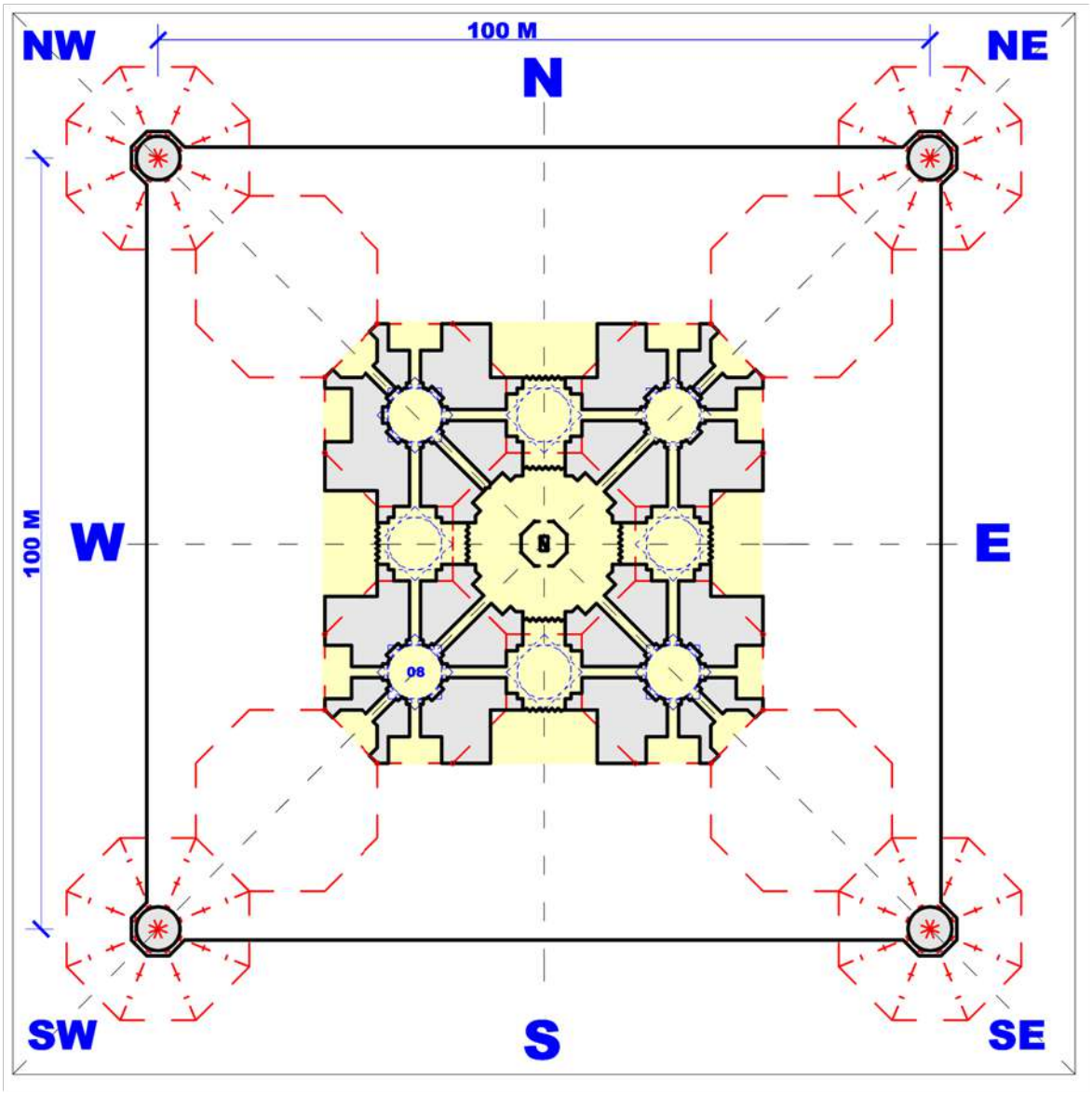


*Fig 38: Source Author*

As we complete the layout plan of the Taj Mahal it gives a new grid of 100M x 100 M which would be used for laying down the Taj Mahal complex.

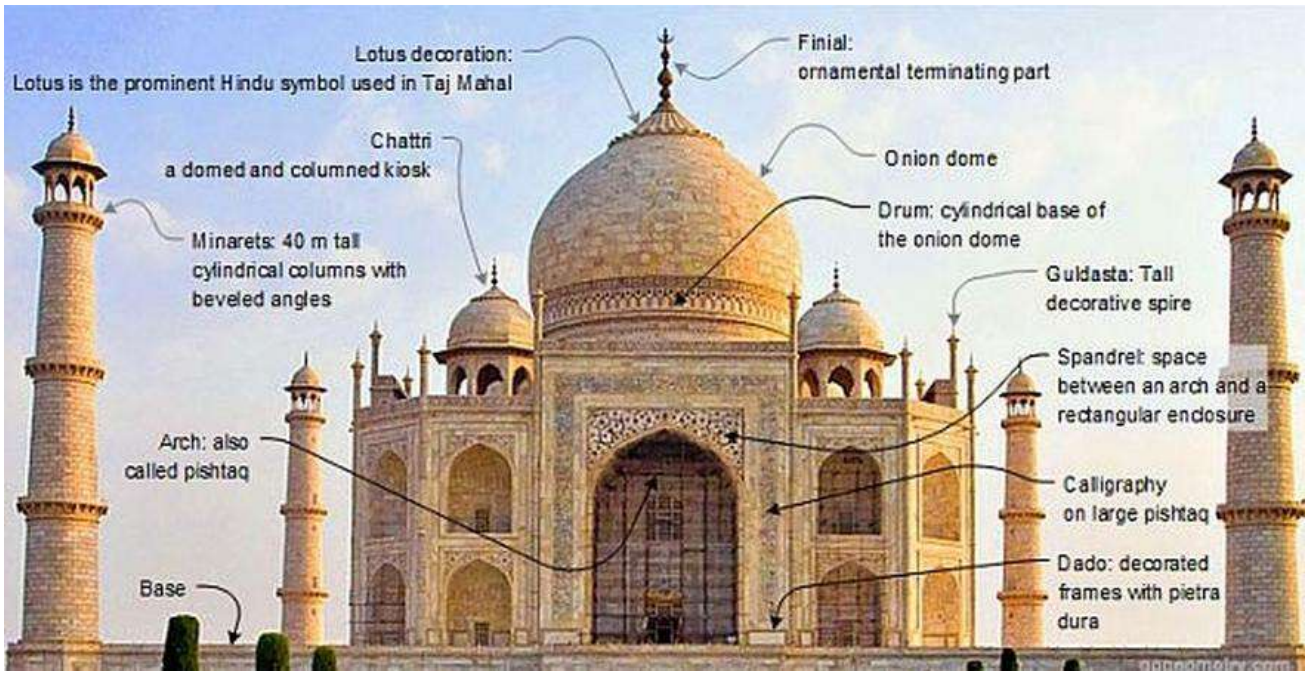


*Fig 39: Structral detail of Taj Mahal (Image source: http://planetden.com?architecture?taj-mahal-structural-wonder)*

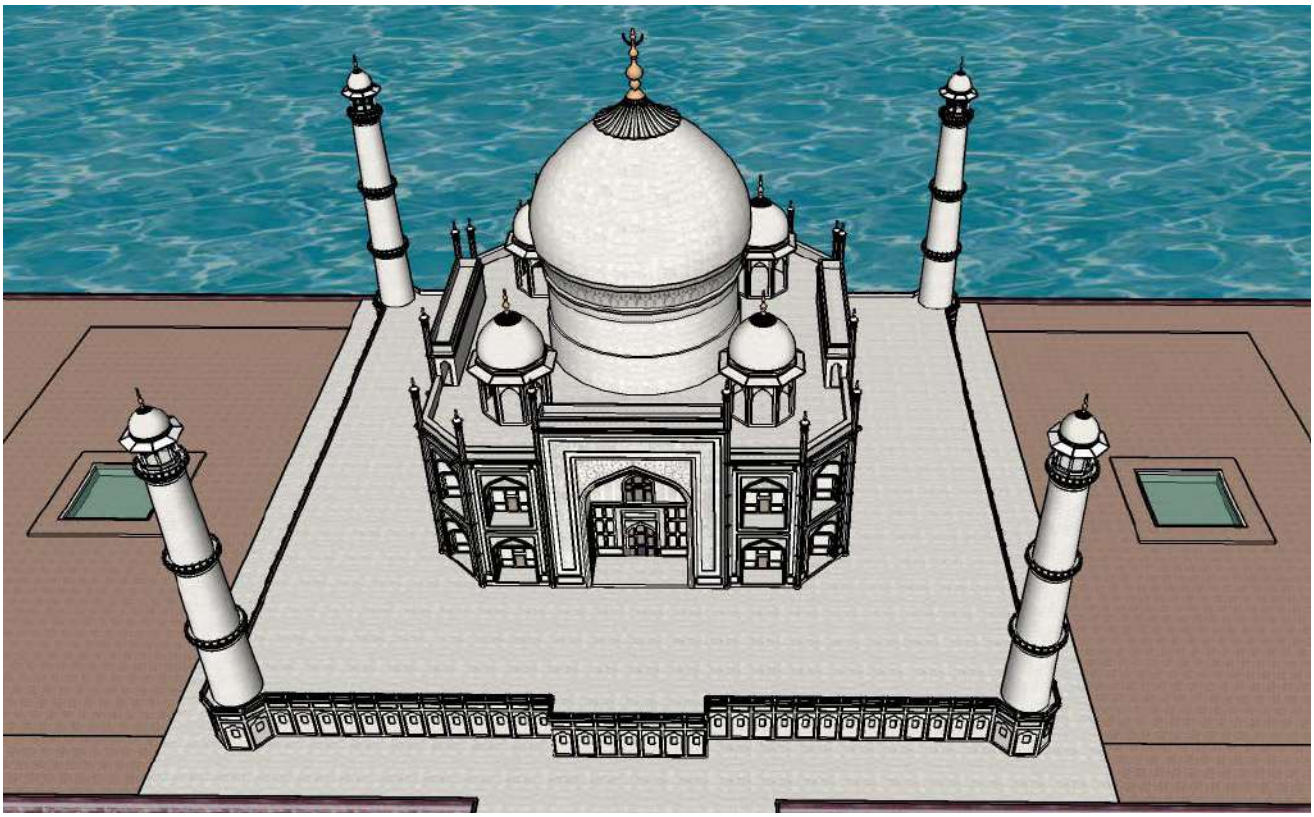

*Fig 40: Taj Mahal isometric view (Image source: author)*

## VIII. CONCLUSION

Taj Mahal complex, built during the mid- 16th century in Agra, had great significance in the history of Mughal architecture and landscape design. Previous research has focused on its antecedents, architecture, visual power and its location near the river Yamuna. None of them could conclude the dimensional organization.

The source of Mughal mausoleums' evolution of built forms are derivatives of octagonal geometry which can be classified as new discovery of **Hasht- Bihist Architecture**. This style of architecture can be used to decipher the evolution of other mausoleums' plans.

This unique derivation of building plan from sacred geometry of *Hasht- Bihisht* is very unique and witnessed only once in the history of Mughal architecture in India. This could be one of the reasons why Shah Jahan cut hands of the people who designed and built it?

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