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Introduction

Islamic art favors geometry in general and geometrical proportion in particular which carry great importance in the design process of Islamic art [1]. Islamic architecture has long been known as the embodiment of mathematical and geometrical premises [2]. In an architectural monument all dimensions, both in its integrity (height, length and width) and in its components (including geometrical surface patterns), are interrelated and never divorced from geometry [3]. Geometry as science for selection of structural dimensions such as height, length and width of the building and its structural elements governs the structural behavior of the building, the behavior that follows the geometry. e right geometry makes the building behave correctly [3]. In Persian architecture, it is geometry that provides diverse stylistic developments for constructions and designs; not only to serve a function, but also to evoke an emotional response by harmonization of the constructional elements, such as domes and columns and decorative elements [1]. Seyyid Hossein Nasr argued that geometry and rhythm manifest a doctrine of unity which is central to Islam, upon which Islamic art developed based on mathematical ratios and proportions which represent the very heart of Islam [4].

On the other hand, geometry involves proportions and prime roots that are considered the most beautiful proportions (the proportions of beauty) [4]. Proportion in architecture can be said to be ‘‘an harmonious relationship between the parts, with and within the whole’’

(shell) with some internal voids for reducing the weight and protecting the lower parts [7].

Regarding di erent eras, there are numerous innovative architectural contributions made during Seljuks among which is advancing the use of conical domes [21]. Some of the most enduring signs of Seljuk architecture are the distinct types of polyhedral and conical domes which still stand in Iran as seen in Figure 1. ese edi ces are commonly well-known as a primitive architectural formula for the Islamic funerary buildings topped with conical and polyhedral shells which mainly appeared in the Seljuk period [8] (Figure 1).

During the Ilkhanid period, the construction of conical and polyhedral domes decreased considerably in comparison with the Seljuk era, but still there were two speci c architectural achievements during this period, small brick connectors and extensive use of turquoise tile works as can be seen in Figure 2 [8].

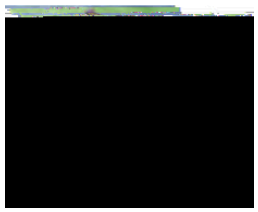
e construction of conical and polyhedral domes became less important during the Timurid period due to two main reasons, by developing the use of pointed domes and with the introduction of the bulbous style [8]. It should be noted that these domes have also been built in hot-arid areas like Qom in this era. Its reason is mainly attributed to the fact that some great conical domes have been destroyed by sunnis[1] in Ilkhanids era which lead to the usage of conical domes as the symbol of shias'[2] buildings. at is why the usage of these domes became common in Qom and kashan a er Ilkhani era without having any congruence with hot and dry climate of these cities [18]. Case studies of Timurids era show the emergence of polyhedral and pyramidal domes in religious complexes and hot-arid areas. Figure 3 shows case studies of Timurid era [22].

Still we can see the trace of these domes in di erent eras which surely shows their popularity among Muslims [23]. Another important point is that conical domes have appeared in religious complexes a erward and not as an individual funerary building. In some cases, the sanctuary's proportion can easily be addressed by conical domes and there is no need to construct domes with larger spans or heights. Shahzade Ebrahim in Kashan is among one of these complexes as can be seen below. is conical dome has been designed in a site with a lot of cypresses and near one of Kashan's old gates to attract attention when entering city. erefore polyhedral dome is in complete agreement with required dimension, the shape of cypresses and location of the complex in city. at is why their construction continued in some cases even a er Ilkhanids era (Figure 4).

Furthermore, the construction of conical domes have made progresses in following eras including the increased number of hedrons[3] and increased height of drums as can be below Figure 5.

Case Studies' Information

Twenty- ve samples of conical domes, which were built in Iran,



were subjects of this analysis. Authors examine plans of conical domes to test their hypothesis. Tables 1 and 2 show the descriptive and quantitative features of case studies respectively. In Table 2, exterior diameter (E) shows either diameter of the circular plan or diameter of the circle that surrounds polygon or has been surrounded by polygon. Moreover, O Ratio (external to internal diameter Ratio) is introduced to reveal geometry and proportion of plans which is the purpose of this paper. M and N Ratios help show the overall form of conical domes. In Table 2, dimensions are based on plans acquired from di erent papers. ese plans have been drawn and dimensioned again by authors to nd out exact gures (Tables 1 and 2).

Discussion

Regarding the variety of case studies, it can be realized that conical and polyhedral domes are so various and have di erent morphological features and plan forms in each era. Generally, Islamic domes present a wide variety of sizes and types, but some geometric properties were repeatedly used in their composition designs. Nevertheless, no two samples are exactly the same [7].

rough geometrical analysis of case studies, the authors have noticed the value near the √2 Ratio (with an approximation of less than 0.08) or in some cases the value near the √3 Ratio (with an approximation of less than 0.04) for plan's external diameter to internal diameter (O) for most case studies. In architecture dating back to prehistory, particularly in Islamic arts and architecture, the most important geometric proportional systems are: the proportions of the golden mean and the primary three proportional roots √2, √3 and √5, on which all Islamic arts and architectural forms, especially their geometric pattern design, are based [1]. e usage of √2 and √3 Ratio and modules in Iranian architecture in pre-Islamic era and Islamic era show an exact system of proportions which have been widely used [24]. ese Ratios can be seen and followed in the below diagrams of superimposed squares and circles (Figures 6 and 7).

In the above diagrams, the circle plays a major role in de ning and designing plans. e circle is an obvious example of a basic geometry, constituting all the proportional geometries inherent in traditional architecture. e circle of Unity is the most signi cant form, for it contains a circumference revolving around a xed center. It is therefore

[1]Sunni: One of the two main branches of Islam, differing from shia in its acceptance of the first three caliphs.

[2]Shia: One of the two main branches of Islam, regarding Ali, the fourth caliph, as Muhammad's first true successor.

[3]Hedrons: Denoting geometrical solids having a specified number of plane faces or denoting geometrical solids having faces of a specified shape.

Figure 3: Case studies of Timurids era. From left to right: Khaje ali saf [photo: 2]. Abbas shrine and Qasem [photo: http://mapcarta.com/27004910/Photos]. Ebrahim shrine [photo: 2]. Shams tabarsi [photo: 35]. Zeinolabedin [photo: http://mchto.blogfa.com/1391/03]. Bayazid bastami [photos:6].

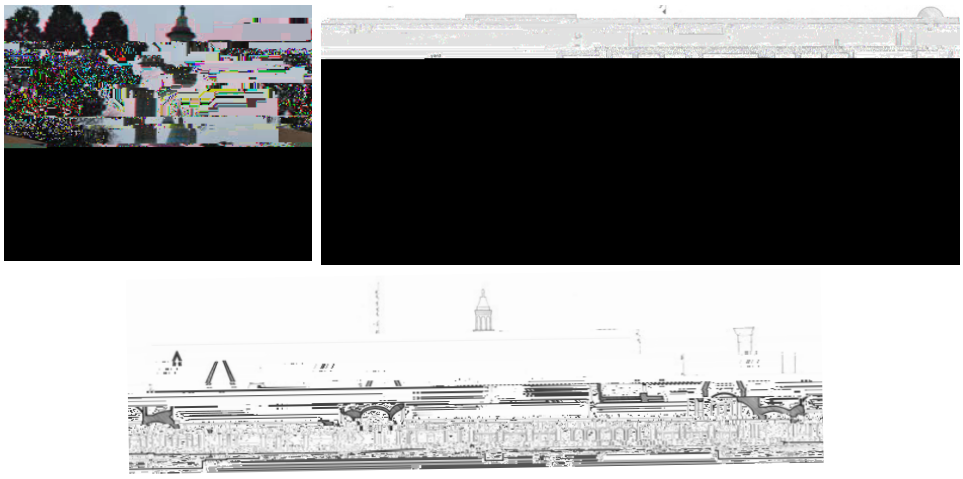


Figure 4: Shahzade Ebrahim in Kashan. From left to right: Shahzade Ebrahim among a lot of cypresses and near one of Kashan's old gates [photo: by authors]. Plan of the complex. section of the complex. Drawing: Cultural Heritage.

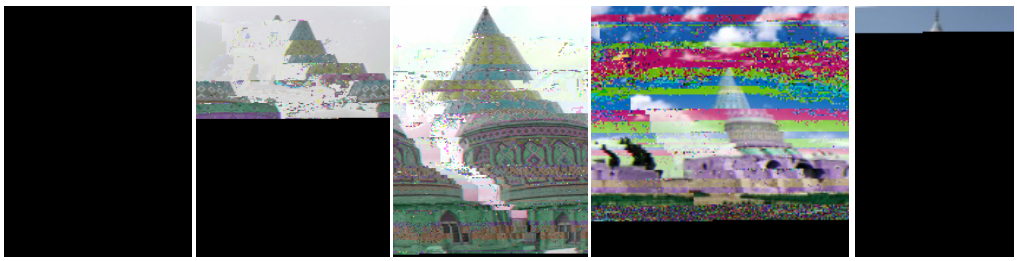


Figure 5: Case studies of other eras. From left to right: a and b) Mirneshane [photo: 11]. c and d) abulolo [photo: authors]. e) Shahzade Ebrahim [photo: authors].

Figure 6: Diagrams of superimposed squares and circles showing √2 proportion.

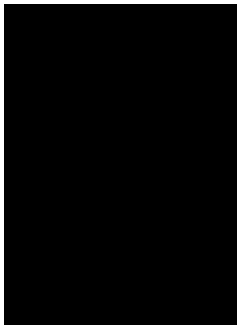


Figure 7: Diagrams of superimposed squares and circles showing √3 proportion.

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