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Zone of Transition in Seljuq Dome Chambers of Iran

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ABSTRACT: Architecturally, the Seljuqs' dominion makes a significant shift from the Pre-Islamic Sassanid squinches to a sophisticated transition mechanism employed to change the walls of a square chamber to an octagonal base to set a dome. This initiated a new construction methodology to hybridize the previous experiences of Sassanid domes with new architectural tendencies. The reason is that the previous understanding of the transition zone was a makeshift in quality, not consistent enough for future architectural adventures in creating larger structures. Although a cursory investigation of transition zones of Seljuq dome chambers in some respects might reveal a fairly homogeneous framework, it has never meant the stagnation of architectural creativity in different parts of Seljuk territory. On the other hand, the typology and local schools of Seljuq transitions zones of dome chambers have not been thoroughly considered by geographical centralism in Iran. For a better understanding of the standardization of various techniques considered in Seljuq architecture between 11th and 12th centuries to span the cubic structure in a circular plan, this project is aimed to clarify three various schools of architectural articulation concerning transition zone in the Seljuq dome chambers of Iran.

Keywords: *Seljuq Architecture, Dome Chamber, Transition Zone, Islamic Architecture.*

INTRODUCTION

After the Seljuk's defeat of Ghaznavid dynasty in 1040 AD and demolishing the Buyid dynasty in Baghdad, they established themselves as new protectors of Abbasid Caliphate in 1055 AD. Within fifty years, the Seljuqs created a vast empire, encompassing all of Iran, and much of Anatolia. Under Seljuq sultanate, Iran had a period of material, cultural wealth as well as creativity in art and architecture (Bosworth, 2007, 280).

Ever since the 1930s, when medieval Iranian architecture began to be studied in depth, attempts have been made to define the characteristics of the typical Seljuq mosques in Iran (Hillenbrand, 1976). Although the dome and vaults were prevalent in the Sassanian architecture in Iran (Woolley, 1961; Reber, 1882, 131), the great change from the pre-Seljuq system was the use of sophisticated transition zones in the Seljuq architecture. However, to embark upon a historical study on the initial employment of the idea of transition area for dome chambers in architectural construction is a complex task, since it is not easy to pinpoint the place and time at which this mechanism was first developed. Apparently, the Sassanid architecture was pioneer in this filed where all of the royal structures were equipped with a series of consequence-rounded arches in edges to support the dome (Godard, 1965, 80). Dietrich and O'Kane defined squinches as adjoining semi domes occurred in the Sassanid buildings in Kiz, Bozpar, Negar, and Sarvestan (Dietrich & O'Kane, 1990), while it has been suggested that the appearance of the cutting-edge technology of domes on squinches originated from north-eastern Iran (Safaipour, 2013), where the change from the Sassanid squinch, rehabilitated due to the existence of an added rib in Samanid mausoleum (301-331/914-943), was dictated by utilitarian reasons rather than by fashion. Here, each squinch is composed of two concave niches separated by a kind of buttress (Carrillo, 2016), and this segmentation of the traditional squinch is intended as a new trend of strengthening unit. Since this practice first flourished in the northwestern of Iran, it was long held that this area was in general the cradle of this technique where the spreading of this model by travelling architects along with the Seljuqs' invasions developed and

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introduced this deformation through the Seljuq territories accepting local variations. This short essay has focused on the topic of transition zones of Seljuqs' dome chambers in Iran.

MATERIALS AND METHODS

The application of construction geography as a young building material has always been underestimated for using the field of building archaeology in Iran. Hence, the main focus of attention in this paper is to classify similar transition zones all around Iran during Seljuq period, and therefore a better understanding of the evolution of the constructional concepts of dome chambers in this period. The scale of existing research on this topic is only covered dome chambers with quadrilateral plans of which their original arrangement of structures has not affected for centuries. In other words, the inclusion of specimens in this paper is not an indication of their individual importance, but rather as part of structural challenge they have to overcome before reaching the circular plan of the dome. Otherwise, this paper does not cover Seljuq structures with polyhedral plans in which the construction process never encountered a serious challenge to reach the dome. A comparative study has been applied to determine various boundaries of technical challenges involved in transition zones.

LITERATURE REVIEW

The typological exploration of Seljuq's dome chambers, mounted on a rehabilitated pre-Islamic transition zone is an issue that scholar's explanations have only covered some generalities of which the ground breaking investigation of Hillenbrand is merely limited to the Northwest of Iran; hence, it is essentially impossible to confirm any hypothesis about its finality through the Seljuq dominion in Iran. Moreover, he suggested a homogeneous local school for the Seljuq domed mosque (Hillenbrand, 1976).

It is not surprising that there have been no clear boundaries between what have been known as the load-bearing unit of shouldered arch and the description of decorative member of muqarnas, since what can be seen in any transition zone of dome chambers has the common characteristic of concave niches encompassing several lobes which are corbelled to create a stalactite shape form[1]. From this point of view, many historians have used these terms counterintuitively (Creswell, 1952, 159; Grabar, 1986, 230; Ettinghausen & Grabar, 2000, 200; Bloom, 1988; Kazimi Shishvan & Maleki 2018; Shahbazi et al., 2019), and others even went further by considering the transition zone as a result of the fragmentation of the squinch, stating that it ceased to be mere architectural supports, and became a recurring ornamental device in Islamic architecture (Carrillo, 2016). Thus, misunderstanding towards the contrast between muqarnas and shouldered arch leads to the complicated and sometimes contradictory results. In a study undertaken by Pirniya he proposed the theory of the architectural unity for all Seljuq buildings in Iran in which the composition of a transition zone in one point has followed the same language of other regions. After about half a century, the authenticity of this theory came under fire by the author, then a structural analysis was conducted assuming several scenarios over Seljuq domes to clarify its geographical characteristics as well as static behaviors in different parts of Iran (Moradi & Omrani, 2019, 98). Here, our purpose is to discuss the local empirical approaches of different regions towards the transition zones in Iran.

Pre-Seljuq Technology of The Transition Zone

Period of transitions were critical in architecture (Huerta, 2012). According to the architectural evidence, one of the most incontrovertible mechanisms of reaching an octagonal base in order to set a dome had been appeared to be used in Baz-e-Hour which should be taken into account as one of the earliest remnants of the Sassanids' Chahar-Tagi archetype, located in Khorasan; Northeast of Iran (Pope 1982; Akbari 2011), where a series of wooden beams are set in corbelled manner on the corners of the square cubic (see Fig. 1). A continuous sequence of concentric arches in the Ardashir Palace (224-240 AD) as well as Sarvestan royal building (420-438 AD) reveals the fact that this technique became much more generalized during the Sassanid era due to the scarcity of wooden sources in Central Iran. Although the earliest employment of the conic squinch in Iran is a debate of studies, with no doubt it was prevailed till the early Islamic ages (see Fig. 1).

As a result of the building practice, by understanding how the thrust line affects the transition zone, the science of the

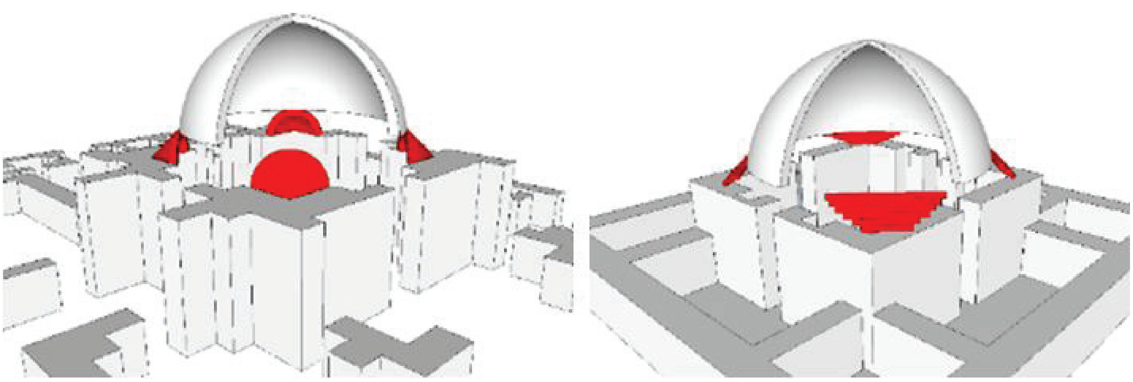


Fig. 1: Transition mechanism of pre-Seljuq structures. Right: Baz-e-Hour; Left: Sarvestan palace.

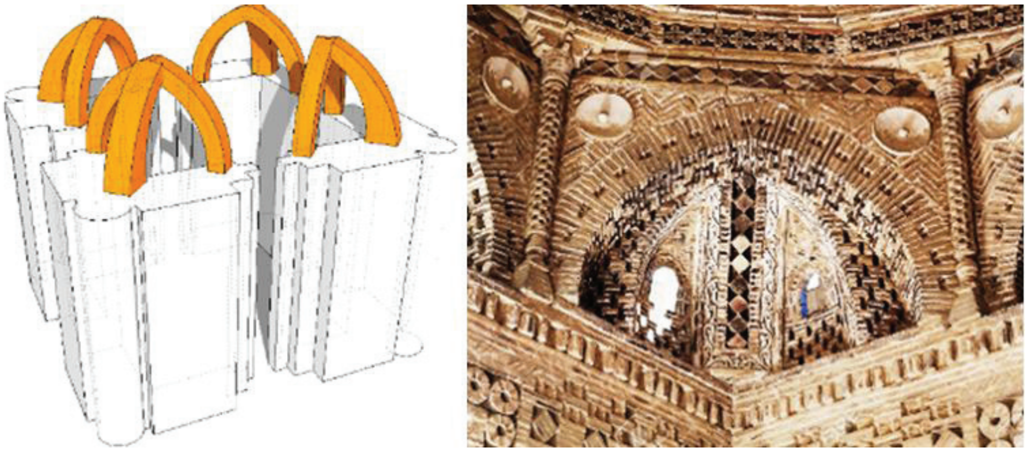


Fig. 2: Transition mechanism in the Samanid mausoleum, reinforced using a rib-shape buttress.

construction technology of the squinch entered the next phase, since it was conclusively proven that by loading a conic squinch, the thrust line will not only distribute through the conic geometry, but also will be transferred through a straight direction along with a line, passing the apices of the squinch and reaching the edges, where the two load-bearing walls meet. Hence, the idea of channeling force through a semi-conic geometry had immediately been replaced by the modern tendency of focusing on the rib-shape buttresses, which became the most conspicuous element of the Samanid mausoleum (301-331/914-943). Thus, the rib unit was an indispensable device to support the crown of the pointed squinch, following an arithmetical procedure (see Fig. 2). Although it is difficult to interpret why and when masons came to conclusion to assemble a reinforced squinch system; however, this is the earliest successful solution of a new attitude towards the transition zone (Safaipour, 2013).

Exploring the reflective ceiling plan of the Nain Mosque (fourth/tenth century), presenting a conservative set of double-rib buttresses holding the pointed arch frame in which the additional units act at the level of the voussoir of squinch, is a proof of its acceptance among masonry projects (Fig. 3). It is important to make this distinction that the transition challenge in Nain Mosque has never led to increasing the cubic dimensions; in other words, a connected set of reinforced pointed arches was sufficed to resize the diagonal of the square and hold the thrust of the dome. It is very probable that the appearance of the similar rule in such a different place is a demonstration of travelling masters who were in search of the basic knowledge of construction, which is fit.

Very near Bukhara lies the village of Tim, the location of the Arab-Ata, a mausoleum built between 366/977-367/978 (Carrillo, 2016). Here, the simplicity of previous mechanisms of transition zones has been replaced by a modern arrange of concave niches, depending on the particular circumstance of the units to remain in equilibrium. Having followed this instruction, the result will be two segregated levels integrated as a unit. First level includes two concave niches converging on the diagonal of the square, such as setting the stage to mount the upper arch, and enhancing the ability of thrust distribution which affects the whole net (Morad & Omrani 2019, 67). A front view of this combination presents a tri-foiled arch whose concept appeared as blind arches on the non-bearing sections of the dome chamber, providing a highly dynamic transition to the structure (Fig. 4).

Apparently, this technique is not an alien system in central Iran, where the definite feature of that appears in a new architectural language, assembled inside the pointed squinches. Particular

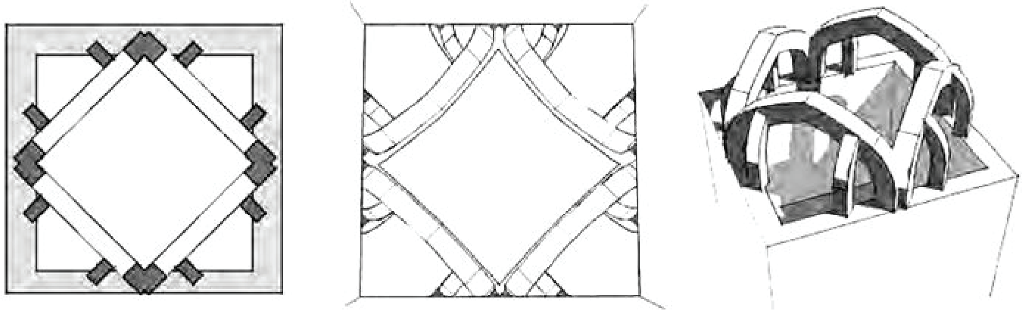


Fig. 3: The composition of the transition zone in the Nain Mosque. (Safaipour, 2013)

Fig. 4: Transition zone in the Arab-Ata mausoleum (366/977) (Carrillo, 2016).

interest is the shrine of Davazdah-Imam at Yazd, built around two years before the beginning of the Seljuq invasion (429/1039). Using the analogy with the Arab-Ata, this structure signifies a multiplication of previous experiences. When it comes to design the transition zone for this mausoleum, as an empirical calculation, the pointed frame of the transition zone rehabilitated in connection with the shouldered arch system. Here, the relevant parameter to determine the maximum height of the transition zone is the dimensions of the pointed frame, which holds the niches to withstand against the thrust. Having considered all the structural benefits of what has been built, the presence of such combination would suffice as a buttress and decoration without causing extra expenditures. However, this idea is less conservative than that of Samanid mausolea or Nain mosque, which the single units support the squinch. Instead, a solid net of the shouldered arch facilitates it to endure when a great weight is loading the transition zone and this allows to have a system of internal compressive forces which transmit the loads through this member (Fig 5).

Relations Between Materials and Dimensions in the Seljuq Dominion

In some cases, it is open to doubt whether this new technology did change the size of very early specimens of new project or not. While the dimensions of dome chamber in the Samanid mausoleum (10*10m) does not reflect an architectural turn point in terms of diameter in analogy with the pre-Islamic project like those in Niasar (14*14m), Negar (12*12m), Sarvestan (13*13m), and Firouzabad (12*12m). One might propose the idea of requisite for rethinking about the traditional transition zones of the ancient engineering, considering the relatively expensive Sassanid technique of lime mortar that covered a huge percentage of high quality stone materials as filler, which would have been replaced by brick structures including limited amount of lime, for a huge construction fee to keep costs down; evidently, as the Seljuq's solution to make the whole construction much lighter.

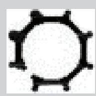
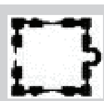
Although the lack of abundant architectural evidence makes it impossible to have a chronological study of this transition, but with reference to the Table 1, interestingly, the distribution of the stone and lime masonry in comparison with the brick and lime structures in Iran reveals the fact that the inaccessibility to the lime sources in the early Seljuq homelands in Northeast of Iran (Mollai, 2009; Dehkordi 2017) should be considered as one of the most probable reasons for new attitude towards masonry. To put this into perspective, comparing the two contemporary structures of Gonbad-e-Jabaliyya in Kerman Province and Mumina Khatun in Nakhjivan, both dating back to

Fig. 5: Transition zone of the Davazdah Imam Mausoleum (426/1037) at Yazd Province.

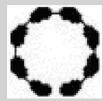
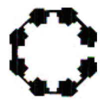
582/1203 AD, will clarify different approaches towards statical challenges where the 18m height of Gonbad-e-Jabaliyya is a naive effort towards reaching a lofty structure in front of the 25m height of Mumina Khatun’s remains even without adding the approximate height of 8-10m of its demolished dome. Apparently, the fears over displacement in Gonbad-e-Jabaliyya had forced the mason to think about thicker walls, where it caught more than 3m; but, with the help of new materials besides innovative architectural techniques in Mumina Khatun, the maximum width of the wall does not exceed more than 1/85m and this is not just a number, but a definite success due to the application of the new materials (brick and lime) in the Seljuq architecture.

Otherwise, the architecture of the Seljuqs was incapable of any change for the better without material changes in principles and forms, while stone and lime mortar were inadequate for the further development without an entire change, since it was purely irreproachable to reach the concave form of niches in the shouldered arch by carving the high-quality stone materials, a complicated stereotomic problem. In general, the initiated experience of brick material was not reliable enough for much bigger domes, but the multiplicity of the conic squinch became the dominant feature of the Seljuq architecture when it was on its peak, where the excessive dimension of Nizam al-Mulk Dome (15m) and Gazvin Mosque (15.2m) was absolutely out of touch during the Sassanid era (Moradi & Omrani, 2019, 67). (Table 1)

Table 1: The approximate height and width of walls in Seljuq's tombs.

Material	Inner Diameter	Height	Width of Wall	Plan	Date	Building
Brick/lime	11	10	07.		1166	**Gonbad-e-Sorkh**
Brick/lime	15	11	0.6		1081	**Kharagan Tower**
Brick/lime	16	20	1.45		1155	**Borj-e-Toghrol**
Brick/lime	7.5	12	0.9		1184	**Borj-e-Modavar**
Brick/lime	5	13	0.8		1201	**Se-Gonbad**
Brick/lime	10	13	1.2		1214	**Gonbad-e-Kabud**
Brick/lime	5	10	0.6		6th	**Borj-e-Damavand**
Brick/lime	7	14.5	0.9		1111	**Borj-e-Mehmandust**
Brick/lime	13.83	25	1.85		1203	**Mumina Khatun**
Brick/lime	8.5	11	1.45		1050	**Davazdah Imam**

Continiue of Table 1: The approximate height and width of walls in Seljuq's tombs.

Material	Inner Diameter	Height	Width of Wall	Plan	Date	Building
Stone/lime	8.9	12	1.5		1069	**Gonbad-e-Ali**
Stone/lime	7	15	1.57		1164	**Sheikh Jonaid**
Stone/lime	11	18	3.10		1203	**Gonbad-e-Jabaliyya**

Seljuq Technology of Transition Zone

Undoubtedly, a fresh feeling in construction technology appeared during the Seljuq dominion when the principle distinction between height of the buildings depends on their revolutionary system of transition zones, when it was vital to create well-deserved structures to reflect the Seljuq magnificence. One important fact about political transition from east to the west of Iran during the Seljuq dominion is a massive range of possibilities to adapt and develop the prior architectural traditions, like those in the aforementioned buildings of Ismail Samanid and Arab-Ata mausoleum. It is evident that, the evolution of the transition zones during Seljuq architecture begins with the earliest departure from the construction forms of the pre-Seljuq ages in northwest Iran. Likewise, Seljuq masons had the opportunity to experience different schools including those edifices, which employ various principles of local knowledge related to the transition zone. In other words, the Seljuq mechanism of transition zone found its full expression as a standard system on the previous monuments, from whence it spreads through its territory, where the seed had already been sown in the powerful architecture poles like central and northwest of Iran. Anyway, this approximate simultaneous attitude had never followed the same rules in the whole Seljuq dominion. When we come to Seljuq time, however, the localization determines the architectural forms and the articulation of the transition zone is not an exception. In order to spotlight various tendencies over this architectural unit in Seljuq dominion, three distinguishable school related to the transition zone has been classified due to the field studies.

Northwest of Iran

With regard to the Seljuq boundaries, in particular the strategic importance of the frontlines, with no doubt, Northwest of Iran would be on the top, since this place had always played a vital role in spreading Seljuq policies to the West (Moradi & Omrani 2019, 72). According to the historians, this point of Iran experienced the collusion of Muslims (Seljuqs) and Non-Muslims (the Byzantine) (Zaporozhets, 2012), where the unprecedented number of unknown tombs to commemorate those ceased in the holy war (Jahad) is a testimony for its sacredness. A superficial review of the Seljuq architectural remnant in this region, such as Marand Mosque (485/1106), Urmia Mosque (5th century), Se-Gonbad (580/1201), Borj-e-Modavr (563/1184), Gonbad-e-Sorkh (542/1163), Gonbad-e-Kabud (593/1241), and Mumina Khatun (582/1203) will reveal the fact that despite other parts of Iran, a large variety of plans from square to octagonal, dodecahedral, and circular were common. Since the challenge of transition has a close tie with the geometry of plan, as well as number of the sides, the science of transition from dodecahedron or even octagon to a circle base would not follow controversial arrangements. Thus, from a structural point of view, a radial series of pointed arches would suffice to create a dome in Borj-e-Modaver[2] (the circular tower), Gonbad-e-Kabud, and Mumina Khatun, while in other specimens, the existence of a capable transition mechanism would be inevitable owing to the geometry.

At a glance, it might be suggested that the limited breadth of Gonbad-e-Sorkh and Borj-e-Modavar[3] ruled the employment of simple shouldered arch to support the dome, while considering the idea of assembling the dome in the Marand Mosque (diameter≈ 7.6 m) and Urmia Mosque[4] (diameter≈ 10.7m), where the load-bearing concaved facets mounted on each other in two levels precisely, would devalue this assumption proposing the specific architectural genre of transition zone in the Northwest of Iran (Fig 6).

In Marand mosque[5], the transition zone is lavishly decorated, which the detail work is strong enough to accept this speculation that close relations between Tabriz (the major city during the Seljuq era) and Marand (the most important stop

Fig. 6: Transition mechanism in the Urmia mosque.

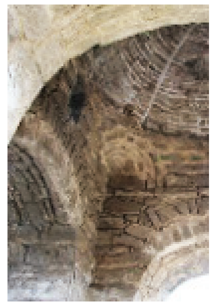
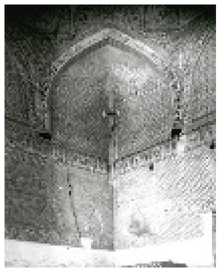
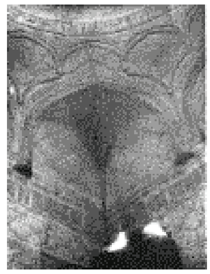
before Tabriz) would explain this aristocratic attitude toward this mosque[6]. Beyond comparison, what differentiates the principles of transition zone in this mosque with Urmia, is the continued tangled net of concaved niches, circling around the circumference of the cubic dome chamber even in the middle of the sides, which this would have led to the structural unity and equilibrium. Thus, its structural safety is ample. On the contrary, the considerable size of sides in Urmia Mosque in comparison with Marand Mosque, has dictated the lack of such a structural continuity. By its very nature, in Urmia Mosque, the middle of the sides will tend to yield downward making it relatively vulnerable. Although the application of the unilateral brick material in both cases provides the single resistance against compression, not tension, as a consequence a homogeneous appearance of transition zone in Marand (see Fig 7) would reflect a better behavior in comparison with the discontinues and heterogeneous system of Urmia, merely covering the edges. Thus, in Marand, in technical terms, the arch is statically hyperstatic or redundant.

Alborz School

Not far from the Northwest of Iran, a collection of unique Seljuq buildings encompassing three mosques in Gazvin (509/1130), Sujas (5th/11th century), Qorva (575/1196), and seven towers of Toghrol (534/1155), Kharragan (Eastern 460/1081, Western 486/1107), Mehmandust (490/1111), Chehel-Dokhtaran (464/1085), Lajim (443/1064), and Damavand (6th century)

Fig. 7: Marand Mosque; an interconnected set of concave units in the transition zone.

Table 2: Architectural similarities between the Sassanid transition zones and Seljuq's methods in the Alborz School.

Building	Ardestan Palace	Sarvestan Palace	Niasar Temple
Sassanid Mechanism of the Transition zone			
	Gazvin mosque	Qorva mosque	Sujas mosque
Seljuq Mechanism of the transition zone in Alborz School			

holds the second powerful construction pole of the fifth/eleventh century, stretching from the East most point of Northwest of Iran to the Raga (the important capital of Seljuqs') and its surrounding parallel to the Alborz mountains. In terms of diameter, although those of Qorva (5.5m) and Sujas (9.2m) are noticeably smaller, but Qazvin dome chamber (15.2m) is of a size to challenge in comparison with the Isfahan Mosque (15m) (Hillenbrand, 1976).

A purely different architectural statement appears in the Toghrol tower in which the diameter of the structure (16m) has exceeded the defined norms with the help of the circular plan, being well-deserved to be titled as a mega-structure (Moradi & Omrani 2019, 80). Like polyhedron structures of the Northwest Iran, the criterion of geometry governs conveniently as a certain guaranty for the stability of the transition zone in Kharragan, Mehmandust, and Damavand without overwhelming static challenges.

Although this issue is a matter of debate[7], the influence of the Sassanid modules of the transition zone in this region is irrefutable, where the articulation of a pointed frame supported by two concaved niches[8], a feature that had no hitherto existed in the northwest of Iran, which narrates the similar structural caprice of those in the Ardashir palace, Niasar temple, and Sarvestan royal building (Table. 2). However, details are noteworthy, as a radial series of smaller arches employed at the uppermost level of the transition zone before the circular base is the constant feature of this school. In spite of the fact that this technique famed exclusively along with the Alborz mountain range, the absence of a similar module in other parts of Iran would be enough to verify such a rule as a conspicuous characteristic of this region.

What is fascinating about this school is the close fraction of the height to the width of the pointed frame of transition zone in Qorva (1:1.3), Sujas (1:1.4), and Gazvin (1:1.36) which this promulgate a statical edict, since the eccentric increasing in vertical units, without thinking about buttressing members, would cause severe damages parallel to buckling, displacement, and deformation; Hence, this ratio could not overshoot this standard, which means that the pointed frame higher than this proportion can't be prepared. Otherwise, by scaling up, the safety coefficient will decrease as a corollary of the inferior proportions.

In the case of thrust distribution, two distinguished approaches have been followed in the Northwest of Iran versus Alborz School. To understand the concept, it is only necessary to have some familiarity with the distribution of forces. As figure 8 demonstrates, the paradox of transmission of force to overcome thrust is a real contradiction in Marand and Qazvin mosque. It's hard to ensure that the overall form of the transition zone in Alborz School is more than a modified version of the Sassanid's retained techniques in which the load will affect the pointed frame breaking in tow branches, where the vertical thrust is constant (Fig 8) Although this method might present a saving of masonry, statically, the point of application of the thrust will lie within the thickness of the pointed frame. Here, the main threat lies in the fact that, theoretically, the criterion of a single arch is unsafe, in particular, when the structure grows in size, because the frame will be dangerously near the collapse situation due to the lack of any admissible support. In contrast, a tangled set of concave members in Marand Mosque is not

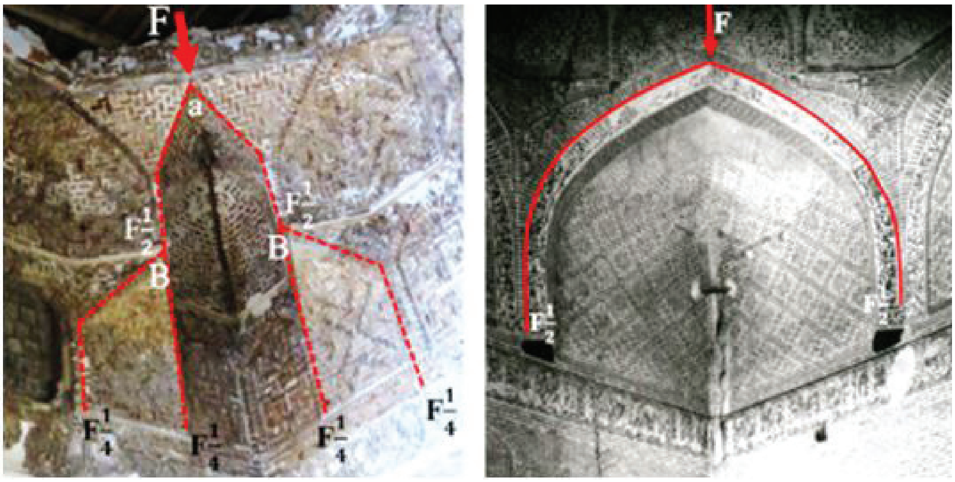


Fig. 8: The design strategy of the transition zone showing how thrust affects this part of the structure in Marand mosque (left) and Qazvin mosque (right). Statically, the single frame is on the verge of collapse without material of a better quality.

only safe, but surplus by increasing the number of these units which would ease the thrust transmission to the most loaded parts (in general the bearing walls) without a diminution of the safety. As a consequence, the interconnected members will distribute the thrust line along with the brick net whereas in every lower joints, this fraction will decrease to a half (Fig 8. left).

The characteristic of the dome chambers in the Northwest School, as well as the Alborz School does not necessarily warrant a lofty elevation owing to some architectural obstacles related to the composition of the transition zone. Following to the numerical results, the limited maximum height of approximate 10m (Urmia mosque) for the total height of dome chambers in the Northwest of Iran might have reflected the verification failure of the safety efficiency for larger proportions in this region. However, the successful combination of above-mentioned techniques leads to the new patterns of equilibrium which appears in central Iran where a very large percentage of high rise structures impose a substantial change in the theory of structure.

Central Iran

The intriguing obligation in which masons were forced to create lofty structures in central Iran, as the religious pole of the Seljuqs' (Morsalpour, 2018), made the quality enhancement of the transition zone central to their construction strategies. Hence, this region has gained its reputation as an axis of highly proportional buildings in comparison with the two aforementioned schools (Moradi & Omrani 2019, 76). Central Iran offers further developments on the transition zone, focusing on the combination of the two features of triangle shouldered arch with the pointed frame. This synthetic approach breathes life back into the Iranian architecture after the stop-start campaign of the early Islamic ages. Apparently, the idea of this combination first departed from Isfahan, where a fine example of this type is presented by the south-east (Nizam-al Mulk) and north-east (Taj-al Mulk) domes of Isfahan's Mosque, built in 464/1072 and 480/1088, respectively. Here, the squinch comprises four niches, the central one acting as a segment of barrel vault supported by a plain squinch, while the lateral niches retain the pointed concave design. Above the octagon proper is a sixteen-sided area before the base of the hemisphere dome itself; this latter structural solution like a "squinch net" has enriches the zone of transition (Carrillo, 2016), and the whole complex is used to stabilized the pointed frame. In most cases, each lobe is broken up by a series of sub-squinches, also lobbed, which increase the apparent depth of the squinch and constitute a varied array of facets set at different angles (Hillenbrand, 1976); that succor distributes the vertical loads of the dome. An arrangement hitherto is known only particularly in the Central Iran. The more lobs that the transition zone consists of, the more stability the shouldered arch net guaranteed (Moradi & Omrani 2019, 78). Although in terms of dimensions, the Gazvin Mosque broke a tie with the Isfahan Mosque, but with the help of an enhanced transition zone, as well as the rib technique supporting the dome, the vivid difference between the crown of the dome in the Isfahan mosque[9] introduced it as a lambency of sophistication. (Fig 9)

The architectural revivals of the combination of the transition zone strengthened by the presence of a triangular shouldered arch net have immediately become predominant in central Iran. Beside Isfahan domed mosques, a collection of this synthetic method in Ardestan Mosque (555/1176), Zavare Mosque (530/1151), Barsiyan Mosque (498/1119), and Golpayegan Mosque (512/1133) is strong enough to consider the hybridization of a simple shouldered arch (Northwest of Iran) and the single pointed arch (Alborz School) in the Central Iran[10]. In this school, although each building is a successful

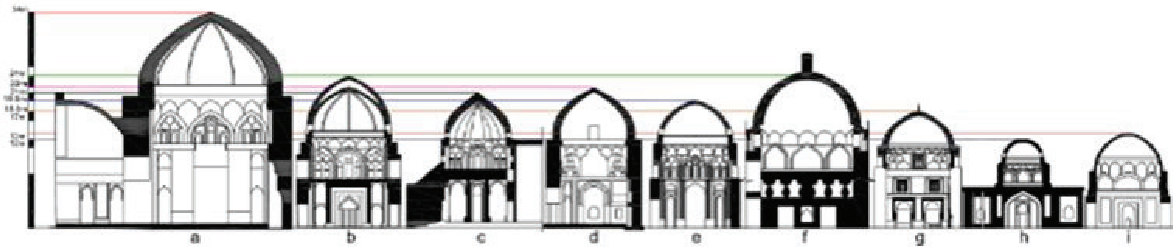
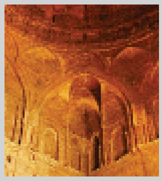
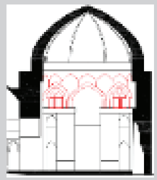
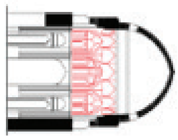
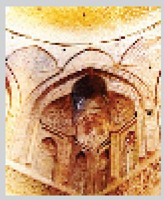
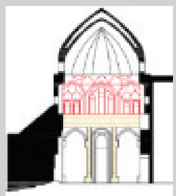
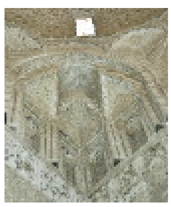
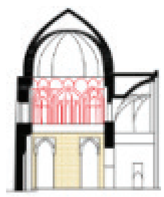
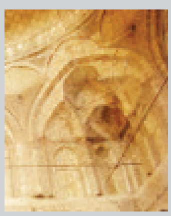
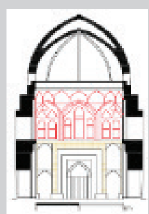
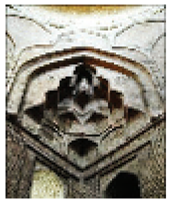
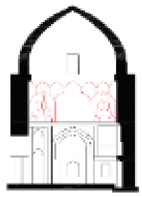
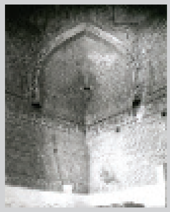
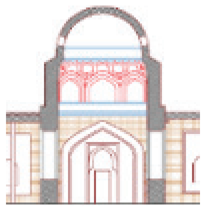
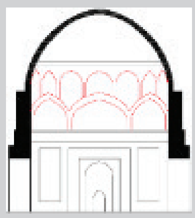
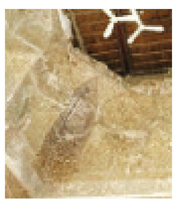
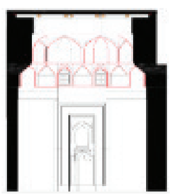
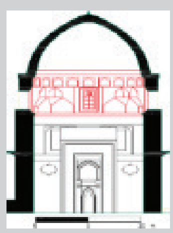


Fig. 9: Various dimensions of Seljuk's domed chambers in Central Iran in comparison with Northwest Iran caused by different technology used in the transition areas.
a: Nizam-al Mulk's dome; b: Barsian's Jami Mosque; c: Ardestan's Jami Mosque; d: Golpayegan's Jami Mosque; e: Taj-al Mulk's dome; f: Qazvin's Jami Mosque; g: Urmia's Jami Mosque; h: Qorveh's Jami Mosque; i: Sojas's Jami Mosque.

Table 3: Transition area in Seljuqs' dome chambers of Iran.

Ratio of Height to Diameter (m)	Maximum Height of Transition Area (m)	Type	Pic	Section	Date	Mosque
2.41	5.77	Squinch in connection with Shouldered Arch			1094	**Nizam- al Mulk**
1.90	5.82	Squinch in connection with Shouldered Arch			1102	**Taj- al Mulk**
2.13	5.10	Squinch in connection with Shouldered Arch			1176	**Ardestan**
2.12	5.32	Squinch in connection with Shouldered Arch			1151	**Zavareh**
2.14	5.13	Squinch in connection with Shouldered Arch			1119	**Barsian**

Continiue of Table 3: Transition area in Seljuqs' dome chambers of Iran.

Ratio of Height to Diameter (m)	Maximum Height of Transition Area (m)	Type	Pic	Section	Date	Mosque
2.40	5.90	Squinch in connection with Shouldered Arch			1133	**Golpayegan**
1.56	4.80	Squinch (Single frame)			1130	**Qazvin**
1.79	3.92	Squinch (Single frame)			1196	**Qorveh**
1.80	3.88	Squinch (Single frame)			5th	**Sojas**
demolished	.3.2	Shouldered Arch			1106	**Marand**
1.77	3.48	Shouldered Arch			1297	**Urmia**

experiment, the fraction of the height to the diameter of the transition zone in the Nizam–al Mulk's dome (2:41) reveals the most ambitious architectural demands for an imperial project while this fraction is disappointingly small in other specimens (Table 3).

RESULTS AND DISCUSSIONS

The development of Seljuq architecture was revolutionary, and an explosion of structural creativity which never reflected a purely Darwinist theory independent from exploring and developing preexisting architectural theories. From this point of view, the Seljuq transition zone is, in general, the old pre-Seljuq system, modified by the requirements of the exigencies of the new demand of construction. The higher structures of Seljuq era needed amenities, and Sassanid architecture could not afford (Moradi & Hoseinpour mizab, 2019). As a result, Seljuq architecture adapted and developed the Sassanid techniques but this diversity proceeded smoothly. Although Hillenbrand states having had no single type of transition mechanism had predominance throughout Iran during the Seljuq dominion and the factors which led to the adoption of one or another type in a given case are still obscure, his understanding of transition zone is actually incorrect and a cursory investigation of the transition zones in the Seljuq era helps to conclude that, firstly, no dome has an absolutely regular mechanism of a transition zone. Secondly, no two regions share the same technical approach. Finally, three different empirical attitudes towards the transition zone would be enough to consider three architectural schools encompassing the Northwest of Iran, Alborz, and Central Iran whose difference lies in the basic elements of construction of the transition zone rather than proportions. The local development of architectural experiences in these three classes is not categorized by periodical purification while geographical variations in the science of construction are inevitable. The first school, which one might go for convenience call the" Azerbaijan School", has prominent points of difference from the others and the significant character of the transition zone is an interconnected concaved niche. Although this guarantied the distribution of thrust line amazingly, it has its own limitations. An initial architectural calculation seems to confirm that the number of triangle lobs in this school had never exceeded the norm of two layers; thus, the architectural outputs are noticeably smaller. The Alborz school presents an involuntary imitation of the Sassanid technique as a structural obligation, and the ratio of width to the height in the pointed frame of the transition zone has always shown a concerted attempt to keep the same coefficient ratio (≈ l:1.4). An architectural correction of aforementioned practices was necessary to reach the higher elevations. In Isfahan, the experiences of other schools became incorporated into each other, introducing a pointed frame supported by the shouldered arch net. Having followed the Isfahan schools' instruction, the result will be a mutant mechanism for the transition zone to reach higher structures (Fig. 10).

Fig. 10: Distribution of Seljuk's Dome Chambers in Iran focusing on the various techniques of the transition zone. A: Urmia Mosque; B: Marand Mosque; C: Qazvin Mosque; D: Sojas Mosque; F: Qorva Mosque; J: Nizam- al Mulk Mosque; H: Taj- al Mulk Dome; I: Zavara Mosque; K: Ardestan Mosque; L: Golpayegan Mosque; and M: Barsian Mosque.

CONCLUSION

This is the first attempt for classifying Seljuk dome chambers in Iran from the static point of view. Unlike previous studies, not only has Seljuk architecture in Iran never followed an architectural unity, but the main characteristic of its appearance varies in different parts of Iran. Although the lack of abundant evidence of archaeological remains make it fairly impossible to investigate the construction history of transition zone in the span of Seljuk period, separate ideas to withstand the thrust of the dome creates three distinguishable attitudes towards channeling the thrust of the dome.

As architectural forms and structural solutions changed geographically, one possible hypothesis is that the master-builders were focused on applying their knowledge acquired by considering local science. Structural conditions related to each area to the projects they were actually building lead to the different approaches in shaping transition zones of Seljuk dome chambers in Iran, which are as follows:

a) Northwest of Iran, including shouldered arch.

b) Alborz School, representing an only pointed frame to support the dome.

c) Central Iran, focusing on the combination of these two techniques to achieve an admissible mechanism of shouldered arch which is supported with a pointed frame.

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END NOTES

1. Structurally, Muqarnas needs to be hanged with a series of connections to the structure during the construction process. In other words, it is more decorative rather than constructive, while each unit along with a Shouldered arch has this capability to succor and transfer the thrust line.

2. Although the exterior appearance of this building is following a cylindrical shape, the interior space has a square plan.

3. It might be suggested that the small samples like Gonbad-e-Sorkh and Borj-e-Modavar serve a scale model for the bigger domes.

4. Unfortunately, the transition zone of this mosque has been coated by plaster during the recent restorations.

5. Here, the total form of the dome has been vanished in the course of the history.

6. The authenticity of this theory would be doubled if we keep in mind that during the Mongol Invasion's a highly-decorated stucco Mihrab has been added to this mosque when Tabriz was served as the capital of the Islamic world.

7. Byzantine structures were of crucial influence to the deformation of early Islamic samples (Yildiz, 2011). Along with perso-Islamic traditions, however, Anatolia had a strong Byzantine and Armenian Christian heritage emerged with Central Asian Turkic nomadic, Northern Mesopotamian, and Crusader cultures. The exchange and synthesis of these different traditions is vividly reflected on Seljuq architecture and art (Galdieri, 1984).

8. The most common interpretation for this physical appearance lies in what should be titled as the "Architectural Obligation", since the simplest method to fill the distance between the crown of the pointed frame and edges, using masonry, create such a geometry.

9. The Maximum height of the Gazvin mosque is approximately 23m while this amount is about more than 34m for the Isfahan's mosque.

10. In this region, like polyhedral forms exist in the previous schools, the transition from an octagonal plan to the circular base does not wrestle with severe challenges in Sheikh Junayd (543/1164), Gonbad-e-Jabaliya (582/1203), and Gonbad-e-Ali (448/1069).

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