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TITLE: HISTORY AND MORPHOLOGY OF RASMI
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INTRODUCTION

Rasmi is a type of structural frame for vaults, first used in Moorish Cordova, quickly establishing as a conventional method in the Moorish sphere. With an elapse of two centuries, the form for the first time reappeared in a relatively sophisticated manner in Iran, from where it evolved into a highly sophisticated and diverse chapter of architectural knowledge-art in the Indo-Iranian sphere. Although the phenomenon was introduced to Christian Europe mainly in the late gothic and baroque eras, it did not improve much in morphology, and more importantly did not establish a tradition, remaining for the rest of its history, a specialty of the Moorish and Indo-Iranian architectures.

Rasmi comprises of the projection of a two dimensional star polygon plan over a cone, sphere, or segment of sphere rising directly over the plan. In another definition, the full and complete rasmi comprises of the interlace of complete arches of uniform profile, vertically rising over intersecting chords of corresponding length that bridge all angles of a regular polygon over a horizontal plane, without passing through the centroid.

This highly symmetrical model with its diverse morphological capabilities as will be discussed is primarily used for the construction of structural frames for masonry vaults, though thanks to aesthetic quality it has also been regularly used for decorative ends.

Despite its established position in architecture, the phenomenon is almost completely unknown to scholars as an independent technique. The research under process by the author intends to identify the phenomenon for the first time on a scientific scale, and document its history, evolution, morphology, and taxonomy.

STATE OF KNOWLEDGE AND LITTERATURE

There are only three books with any particular chapter allocated to rasmi. All three serve as manuals on the design of *kaarbandi*, stalactite and *gereh* (quasi-crystal arabesque), and are authored by two masters and two academic architects who trace their trainings to the same source. The oldest among these is claimed to have been published by the late royal architect of Iran, Us Hossein Lorzaadé in the '70s; the second, published by the Organization for Cultural Heritage in the '80s, authored by Us Asqar Sha'rbaaf, a contract mason of Lorzaadé; and the third, by Architects Hossein Mofid and Mahnaaz Ra'eiszadé in 1988, is indeed an expansion of the first book, with additions based on private tutorials by the late royal architect.

Other than these, the phenomenon of rasmi is only noted through mere citation of existing samples, only by very few scholars with any attention to its existence. It should be noted that neither archaeologists who specialize on Indo-Iranian architecture, nor historians of architecture have made any statement beyond the mere mention of "star vaults" or "kite vaults" in particular buildings.

To complete the want of research, no literature exists on the history of the form, its morphology, evolution, taxonomy, and mathematics; this last topic, with the exception of some general works by Thomas Bradwardine of 14th century England, and Kepler, on the topic of star polygons.

Knowledge on the craft therefore remains largely as trade secret in the possession of a handful of masters from Indo-Iran and Morocco. Yet, not every mason trained in the two architectural traditions possesses the knowledge of such sophisticated skills in masonry as stalactite or rasmi. Factors such as the intelligence of the disciple and the availability of a skilled instructor can ensure the survival or propagation of the skill. Authors Mofid and Ra'eiszadé have provided extensive details on the lives and works of some masters.

SCOPES OF THE STUDY

The study in progress is the first ever of its kind. This leaves a vast horizon of knowledge untapped and undocumented. To meet the scopes recommended by a master's level research, the author realizes the primary need for the introduction, definition and establishment of the phenomenon and its current or proposed terminology into the English architectural vocabulary, followed by an initial documentation of its history and evolution.

LIMITATIONS

As an individual work, more so bound by the time and scope of a master's research, a number of serious limitations are imposed upon the current project. The primary limitation is upon the gathering of data. Interview with masters from the Moorish architectural heritage is beyond the financial means of this study. Further a complete scan of every single monument from Morocco to India is an impossible task to expect from a one man team. Even at that the mere first hand scanning of a narrowed down list of monuments with existing samples of rasmi, proves an impossible task for one person. This task requires teamwork and sufficient fund for site survey of every structure with a possible use of rasmi.

The other limitation comes in at the mathematical stage. The need to delve into the geometry of the form implies a much more extended research in mathematics, the state of knowledge on star polygons, and the discovery of those aspects that deal with the applications of the field to spherical geometry, which maybe proposed for a PhD level research.

METHODOLOGY

Thus the methodology adopted by the author is defined by the scopes and limitations. For the task of identification of rasmis on monuments, scanning was carried out through available pictures of existing structures from Europe, Africa, and Asia. To narrow down the geographical scope, two factors were taken note of:

1) Because the form is primarily a novelty of Moslem structures, structures from Moslem lands or under Moslem influence were given priority over others.
2) Because the technique is among the ulterior Masonic skills, it was decided that if it doesn't appear on the most significant masterpieces of each land, then it may also not exist in the more inferior works in the locality.

With this approach, the task was made easier to browse first through those architectural traditions with the least influence from Middle East, leaving those traditions with more use of the arctuated methods, as well as the modern heritage. This leaves the detailed

physical scanning of all existing structures in Asia, Europe and Africa to further studies, where the existing limitations of funds, manpower and time are no longer an issue.

For the task of dating those remaining monuments with the application of rasmi, primarily two techniques were applied:

1) The dating of existing works was -for the lack of detailed archaeological data- based on the construction date given by the existing sources for the structures over which the rasmis appeared.
2) These given dates were further compared to the understanding of the author of the established styles and techniques of the corresponding eras. If the given date was deemed discrepant with the appearance of the work, further morphological analysis was conducted by the author, providing new speculations. In this light at least two works have been analyzed by the author that present a somewhat different appearance from the construction dates given them.

HISTORY

The oldest models of rasmi appear over two cloister vaults at the maqsura of the Great Mosque -Cordova, Spain, dating from 961-968 A.D. however, a number of similar works prevail over local structures in the area. These solutions clearly display the build up of knowledge of geometry in the mason, until the correct form is achieved through trial and error. The invention of the phenomenon is therefore inevitably credited to Moorish architecture. Indeed steadily establishing all throughout the Moorish sphere.

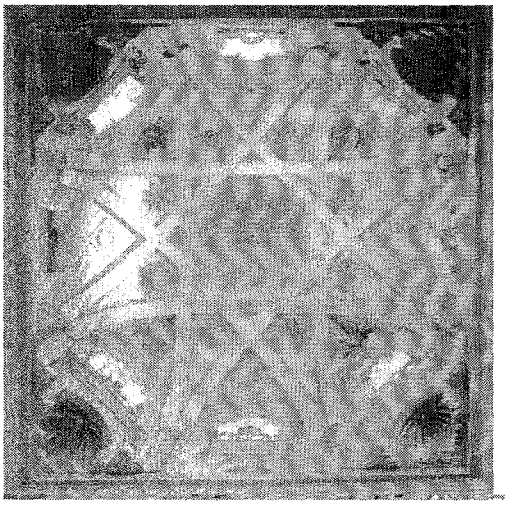


Fig.1. Cordova, 961-68 (Hoag '87)

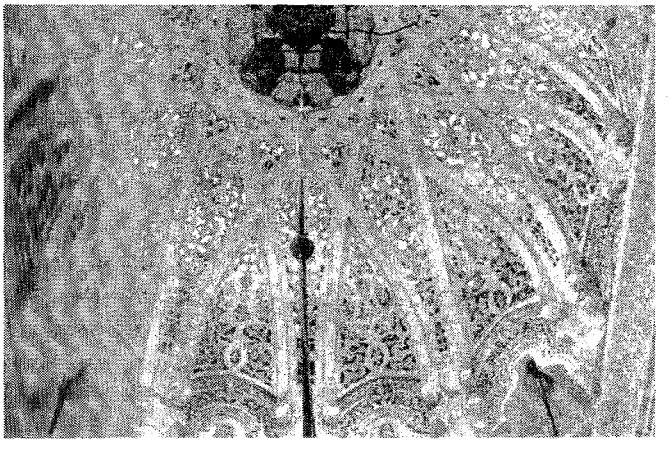


Fig.2. Tlemcen, 11th–15th c. (Hoag '87)

It should be understood that among a list of other reasons, rasmi is preferred in solving the complexities of *transition* by eliminating the need for a squinch network, through the smooth conversion of the usually square cloister to a semi spherical ceiling, by means of an interlace of arches.

Therefore as much as the Cordova samples retain the squinch over the corners, the positioning of the rasmi directly over the square speaks of the intention of the builder to introduce the new solution to discard with the awkward problem of transition through squinch alone. In this light later Moorish works abandon the ambition of the first samples. Although future works offer an improvement from the basic octagram to include star polygons of 12, 16 and 24, yet the existing models are unexceptionally built to frame the overhead cupola, leaving transition to the generic solutions of squinch and pendentive. This may have contributed to modern scholarship's oversee of the phenomenon as merely another minor arabesque motif in Moorish art, denying it the attention given stalactite.

The Moorish sphere offers a simple and limited line of evolution in the field of rasmi, as opposed to the Indo-Iranian, since here, rasmi is only used in its *full and complete* star polygonal form, with all extremities intact; and almost always as a last sequel. The terminology used here is expanded in detail in subchapters pertaining to morphology.

The sudden appearance of rasmi to the east of the Indo-Iranian sphere within two centuries, with no surviving evidence of its migration from the far west to the Orient is rather surprising. Despite the high ingenuity and aesthetics of the element, no example prevails over the structures of Shaam, Mesopotamia and Egypt before it reappears in a relatively advanced form over the tomb of Sultan Sanjar at Merv, Xorassan, in the 1130s.

Here the form appears in a clearly structural nature, as visible from its sturdy ribs, but towards the crown of the dome suddenly changes course, following a much more aesthetic profile.

The form is quite confusing with regards to its era, its first appearance in the Orient, and the fact that had this form evolved on its way from the Occident, no record exists of its evolution and the expected preceding links. However certainly whether initiated by the mason or conceptualized and demanded by the patron, the visionary must have been either weathered by years of rasmi construction, or highly gifted in geometry for his time, for it is not common to come across this level of three dimensional interpretations of geometric motifs with perfect structural justification. The preceding landmark achievement in the Tajol-Molk Dome in Isfahan for instance is the prime example of the peak of structural achievements by empirical geometry, however even there nothing slightly suggestible of a cornerstone for future developments in rasmi exists.

By morphology, the work at Merv comprises of two superimposed sequels of the octagram -{8/2} and{8/3}- where the vosoirs of the second sequel break at the peak to form a third smaller octagram in the ensuing medallion or *Shamse*. The meticulous spherical calculation of the dome in relation to the proportion of its minor circles -hence the vosoirs of the first sequel -{8/2}- is understood from the fact that although the dome and the vosoirs of the second sequel follow a multi-centered pointed profile, those of the first, which do not extend beyond the 3D rotation of the first curve of the great circle of the dome, hence purely comprising of tangent circles of one homogenous sphere, follow a semicircular profile. The complexities at Merv can be summarized as:

1. The use of two superimposed rasmis, repeating only twice in the history of the form
2. The deconstruction of vosoirs over the top of the second rasmi and reconstruction of an octagram within the medallion, hence a phenomenon later nominated as *Yazdi*
3. Consideration of the accurate profile of sphere segments on the first and second rasmis, requiring mathematical simulations prior to construction

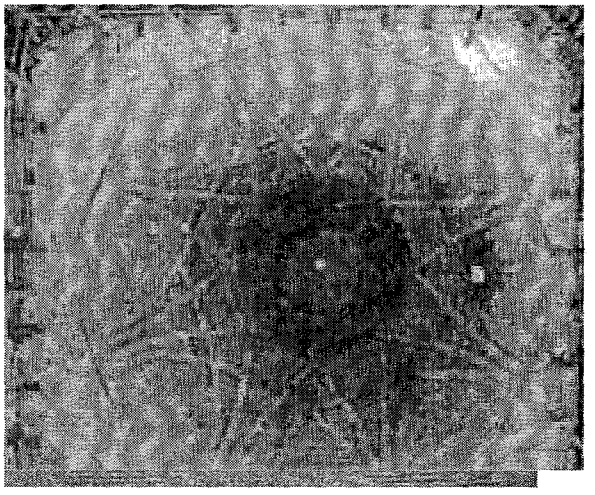


Fig.3. Merv, 1130s (whc.unesco.org)

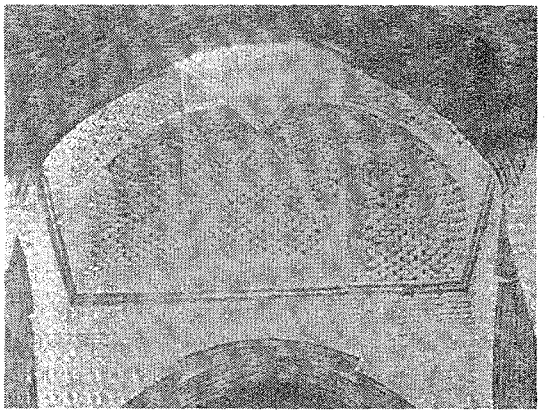


Fig.4. Isfahan, 14th c. (Guedes '79)

The second occurrence of rasmi in the Indo-Iranian sphere comes with a two centuries gap in a number of structures scattered over Iran. Among the surprising number of buildings with significant evolutionary forms of rasmi, the classical and probably older samples are some vaults over the hypostyles of the Jame' of Isfahan, as reconstructions of earlier works. Here the initial rasmi illiteracy of the builder is clearly exhibited by consecutive failures in the achievement of the correct octagram, before the ideal shape is achieved over two vaults just as witnessed Cordova four hundred years earlier. Although the reconstructions took place over damaged portions of previously existing Seljuk works, it is not clear if the Seljuk prototypes did in fact employ rasmi frames.

The final output here is the simplest form, in every sense but one a degeneration of the complex work at Merv. The only improvement over the latter is the final disposal of squinch. Here the ideal of transition from square to dome is achieved with the exclusive use of rasmi.

Simultaneous with or possibly slightly after this revival, a spree of experiments begin over Mogul sponsored constructions during Gazan Khan and Oljeitu, that mark the turning point in the distinctly Indo-Iranian evolutionary course of rasmi.

This starting point however is humble, shadowed by the golden age of rasmi at the beginning of 15th c. thanks to a renaissance patronized by Tamer Lane and his Gourkanid successors. Most adjustments and changes to rasmi that mark its Indo-Iranian revelations are exploited here, such that Safavid, Qajar and contemporary works follow the conventions of 15th c.

Although by 16th c. those areas of Xorassan under a more consistent rule of Shaybani Uzbeks witness a halt –if not decline- in the progress of rasmi, merely repeating old forms, the rest of Indo-Iran under the more prosperous Safavids and Gourkanids (i.e. Moguls of India) stages an era of establishment of rasmi as a key element in the architectural character of the school, with great developments in aesthetics, mathematics and structural knowledge.

The form is most likely introduced to India around the advent of Babur through its initial use in the Kabuli Baaq Masjed in the early 16th century, prospering parallel with Iran, establishing as an element in classical structures, with its peak during the reign of Jahanguir, after which its presence quickly camouflages in the more intricate but purely decorative Yazdi (*Qaleb bandi* in the Indian vocabulary) which takes over as the decoration for ceilings and iwans.

In Araaq al'Arab (Mesopotamia and the alluvial plains) not much can be stated from before the Safavid takeover due to a shortage of evidence. The Abbasid monuments remain largely in the dark, since not many perfectly intact structures stand from the flourishing age, and it is not clear if by the time of the pillage at mid 13th c. the royal monuments of the earlier eras were in good shape at all. Basra and Samara do not leave much evidence after the destruction, and had they housed any clue to the study of rasmi, the monuments must have deteriorated and vanished due to desertion. A simple reason for the dearth of rasmi in the pre-Safavid monuments of Araaq is the fact that at the advent of modern archaeology in the region in the past century, deterioration had largely tolled the buildings starting with roofs.

It is further not clear in what state of architectural prosperity was Araaq at the arrival of Tamer Lane but one can draw the conclusion based on what remains of the constructions more from 16th c. that from the Safavid revival onwards, Araaq regains focus not as a hub of civilization and the seat of Caliphate, but as the center of Shi'ism, and likewise significant architectural undertakings are for the most part in the religious domain.

With new attention largely sponsored by the state and quickly taken into public hands, a flow of wealth is redirected to the region -in the form of *Mowqufaat* (trusts and donations), *Xoms* and *Zakaat* (religious tithes), as well as local business prospering on the flow of pilgrims- likewise boosting architectural projects -for the most part contributions from Iranian masons.

Progress in the field of rasmi is not much possible after the achievements of 15th to 17th centuries. In terms of aesthetic standards, conventions and proportions, everything needed has been explored in the 15th century, standardized and established in the 16th. In terms of mathematics, it follows the same rules as the other topics, impossible to add upon, but remaining to be opened and discussed. Thanks to this a turning point in the history of the form takes place, demanding the study of its evolution and mutations.

However, to fulfill the historical study,it should be noted that although the form is largely a novelty of Moorish and Indo-Iranian architectures and indeed appears almost nowhere else, it has nevertheless inspired a number of mostly religious structures outside the two spheres.

The most famous among these foreign adoptions are the rasmis of San Lorenzo Chapel in Turin, a Baroque construction by Guarino Guarini (1668-87) which draw inspiration from the nearest available Moorish legacies in Cordova. Other works belong mainly to the contemporary, where eclectic or revivalist sentiments have driven patrons and designers around the world to recreate historic styles almost entirely of religious nature, belonging either to Islam or any of the Indo-Iranian religions that may have previously made use of the element in their old monuments such as Jainism, Sikhism and Bahaism.

Some samples of such, known to the author include the Moorish rasmi over the main dome at Masjid Putra, Putra Jaya, Malaysia, as well as one over the Baabel Mecca at Masjedol Haraam (the Sanctuary) -Mecca, by Architect Jay Bonner.

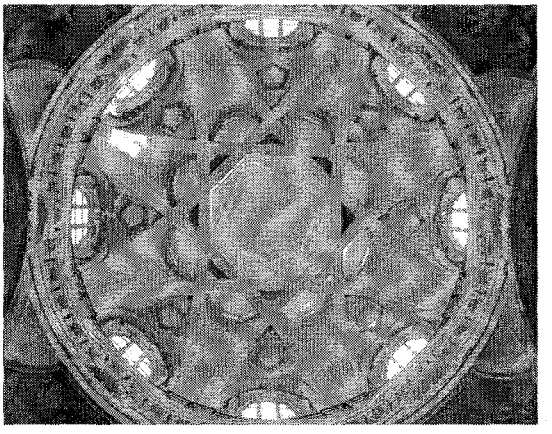


Fig.5. Rasmi, Turin, 1668-87 by Guarini (arc.miami.edu)

EVOLUTION AND TAXONOMY

As stated above, the only architectural sphere with significant experiments on rasmi is the Indo-Iranian school. Since after its introduction in Spain, it recedes into a structural frame for cupolas, it is only at Merv and then again with another 200 year elapse at Isfahan that it displays significant structural advancement, this second time turning into an object of experiments, and after proving highly adaptive, yet mathematically consistent, marking a dramatic evolution.

This topic delves into the historic analysis of rasmi along two major evolutionary lines. First, the various manifestations in the original context, as experimented and standardized by the Indo-Iranian school; and second, the three forms that mutate out of rasmi, yet linked to the mother form, together with the latter comprising the group known as *Kaar Bandi.*

Due to the wealth of samples from 15th century, it was originally thought that evolution in rasmi initially started at that century under Gourkanid sponsorship in Xorassan, however extended research brought to light many structures displaying manifestations not only from 14th c. but as discussed earlier and expanded in the following paragraphs, in the case of Merv from the 12th c, in much more sophisticated manner than later works.

Adaptations

The Indo-Iranian approach puts to examination the flexibility of rasmi to fit various outlines and shapes by trimming and amputation of regularly selected arms.

Merv is too reluctant over bold experiments, but Isfahan makes up for that in the 14th c. where the samples rise directly over the square, this time even without the help of squinch.

This progress is immediately followed by a bolder experiment establishing a new revelation known today as koune which in mathematical terms, comprises of the fitting of a polygon compound (at least one sequel in any regularly divisible star polygon) into one of its component polygons and amputating the protrusions of the prior from the perimeter of the latter. In spatial view, the circumscribing arches of the koune, or the sides of the circumscribing polygon, rest directly over the arches of the defining cloister, possibly fused into single entity.

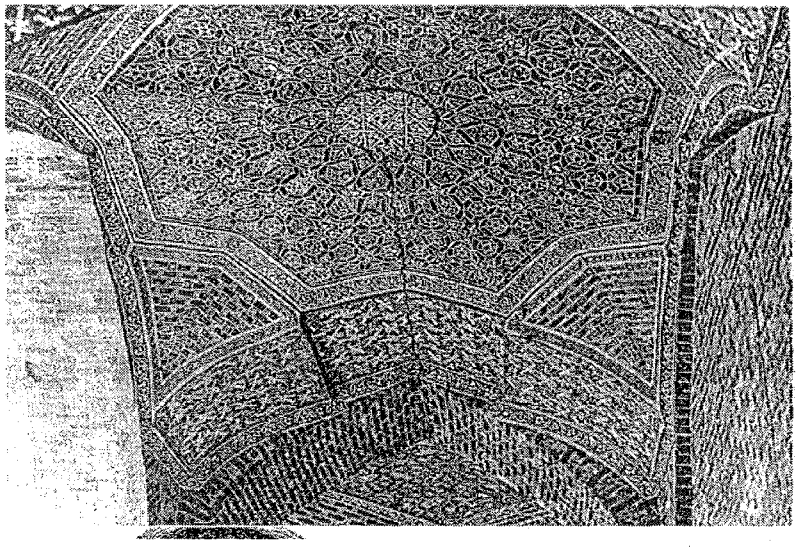


Fig.6. Koune of 8, Soltaniyé, 14th c. (Wilber '69)

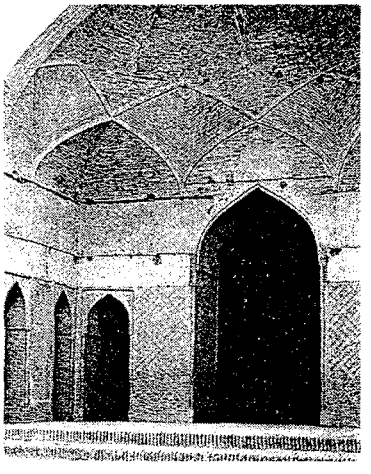


Fig.7. Nimkaar (halfdome), Ashtarjaan, 14th c. (Wilber '69)

The koune of 8 is however one of a number of phenomena that prove elusive to architectural taxonomy, since although it most likely evolved out of the squinch, and if not for the prominent character of its arches, very much resembles the pendentive, yet by virtue of mathematics, morphology and structure, is none other than rasmi.

The next experiment that establishes a new form in the inventory of rasmi in Indo-Iran is the half-dome. The portal of the maqsura at Jame' of Ashtarjaan, Isfahan displays the most primitive sample, {8/2}.

The next phase in the evolution of rasmi comes in the 15th c. where primarily through promotion by the Gourkanid court, numerous achievements are obtained in the field of architecture as a whole, and rasmi, in particular. Here the form and most of its conventional revelations, accepted by the Indo-Iranian practice, are standardized. The list of conventional forms in the century include other than the koune and nimkaar in every possible rasmi, such new revelations as the mono-pied which includes both the *koune deraaz* (long base) as well as the *Sousani*; and bi-pieds of other types than 8.

Gourkanid developments in India from 16th to 18th centuries are important only in the use of rasmis of high numbers. In the Greater Iran of the same period (including Mesopotamia), the classical methods established during the Gourkanids find space for repetition and refinement.

19th c. is in Iran a continuation of the heritage of India in the aspects of art and architecture, and in the development of rasmi an inclination towards intricate designs is visible. However expressions and experiments are more aggressive here.

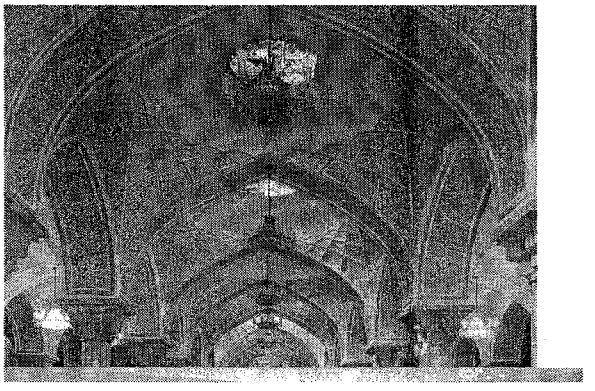
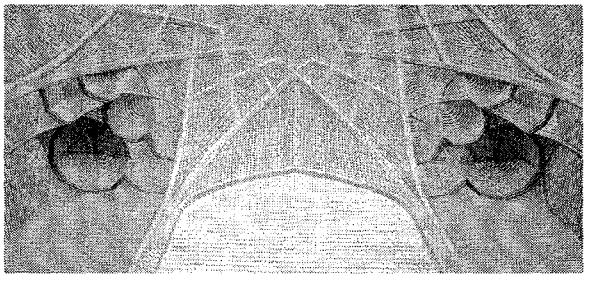


Fig.8. Koune deraaz of 20, Sepah Saalaar, Tehran, by Us Hossein Lorzaadé (Mofid '95)
Fig.9. Nimkaar of 20, Imam Hossein, Tehran, by Lorzaadé (Mofid '95)



Mutations

The evolution of rasmi in the Indo-Iranian sphere is not limited to revelations that are products of amputation and fitting, but from the very beginning embarks on new courses and interpretations parallel to and dictated by the mainstream order.

Three new forms evolve out of rasmi as discussed in the following paragraphs, two of them much earlier than the third which is a rather new addition to the family of forms in kaarbandi, first experimented as late as the 19th c.

The two earlier forms, namely Yazdi and Naxl-bandi appeared in a very distinguished character as early as the introduction of rasmi itself into Indo-Iran, at Merv in the 12th c.

Yazdi

The term applies to the deconstruction and symmetrical rearrangement of rasmi fragments for aesthetic ends. A diverse range of approaches have been identified that are unanimously termed as Yazdi by master masons in Iran; though in India, terms such as *Qaleb-bandi* and *Qaleb-kari* also apply.

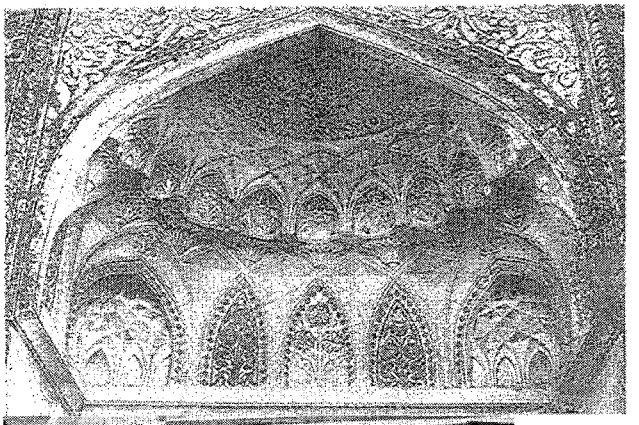
No in-depth analysis has taken place on the evolution, morphology and taxonomy of Yazdi, for which task the author has relied largely on advice received from the five available masters of the craft. In this regard the three sources interviewed directly, namely Architects Hossein Mofid, Mahnaaz Ra'eiszadé, and Us Mahmoud Nassiri, reflect the teachings and ideology of the two late Masters R.A. Lorzaadé and Us Asqar Sha'rbaaf.

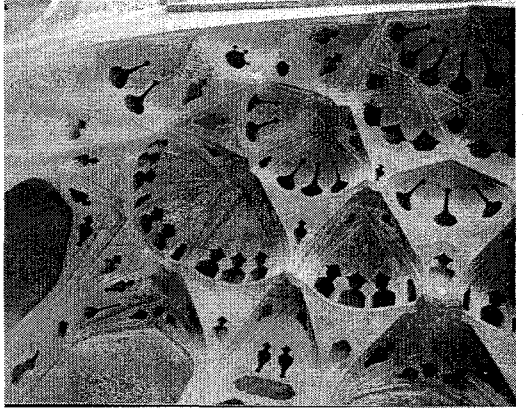
To facilitate future research, the author has identified roughly five forms of Yazdi. However the reconstitution of forms can take new courses, at times merging two or more approaches to introduce innovative results.

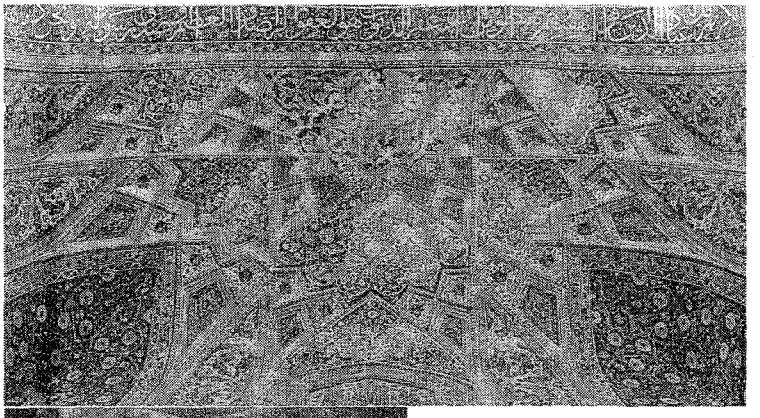
The oldest model appears over the rasmi compound framing the ceiling at the Seljuk tomb of Sultan Sanjar at Merv, from the 12th c. The form displayed here is a quasi-crystal octagram reconstituted in the medallion of the {8/3}.

Later samples don't reappear until the architectural renaissance of the 15th c. when the highest diversity of patterns is for the first time experimented. The models applied in Xorassan later find new place in the works of Persia and India, where from 16th to 18th century, bold experiments give way to a diverse collection of new forms.

19th century on the other hand marks the inheritance of the highly advanced Indian heritage by Iran, where a continuity of the same aesthetic approach is clearly visible in the works that ensue. One probable cause maybe the consistent and growing contact of mainly Yazdi merchants who maintain colonies in India to the present, and who may have reintroduced the higher aesthetic technology back home from India, where it flourished for some time. This may also explain the nomination of the form in Iran.







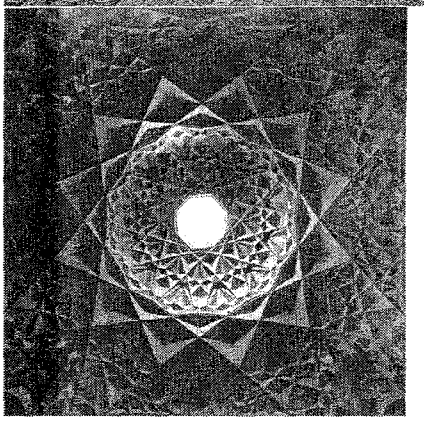


Fig.10. India, 18th c. (Koch '94)
Fig.12. Mahrouq, Nishabur, 20th c. (Reza Nour Bakhtiar)
Fig.11. Aliqabu, Isfahan, 17th c. (Reza Hashemi Nik)
Fig.13. Shah Ne'matollah, Mahan, 19th c. (Ardalan '79)

Naxl Bandi

Other than the first known model of Yazdi, the work at Merv displays a new and rare innovation, repeated only twice throughout the evolution of rasmi, both times, a mere reproduction of exactly the same form, indeed displaying the want of mathematical understanding in the builders of both imitations.

The composition comprises of a number of concentrically superimposed degrees of a rasmi (stellations of a star polygon). Both at Merv as well as the two other existing models, the form comprises of the two stellations of 8. It is surprising however that despite the extent of experiments in the Indo-Iranian sphere, this branch of rasmi has never received due attention.

The only two other occasions where the form reappears, both geometrically degenerated, are once over the dome chamber of the shrine of Jaami at Jaam, Xorassan, in the 15th c., and twice again over a dome chamber at Nowbar Bath, Tabriz, most likely from the 19th c.

Here the reproduction of the form at Merv degrades mathematically in that at Merv, the builder or designer has foreseen the fact that the vosoirs of the two stellations are not only different in rise, length, and angle of inclination, he has clearly understood the spherical implications of the resulting dome, which he intends as a multi-centered pointed type. For this reason the construction at hand clearly testifies to the fact that the designer/builder has previously simulated the desired spherical shape, segmented the model via the spherical projection of the vosoirs, calculated the curved profiles, and then applied the model to the real scale construction.

Evidence to this claim is the fact that the vosoirs of the {8/2} are semicircular –falling on the sphere of the first curve- and those of the {8/3} are roughly ovoid –following the profile of the first and second curves.

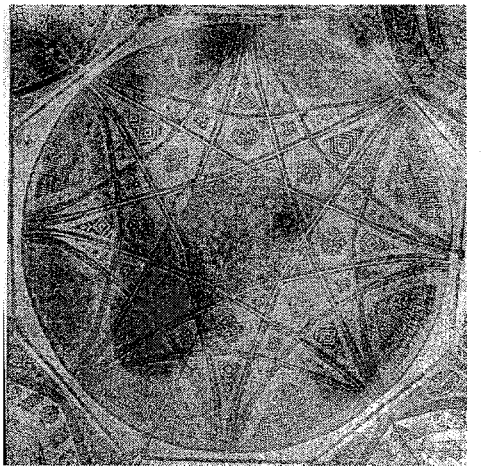


Fig.14. Jaam, 15th c. (Sha'rbaaf '81)

This mathematical accuracy is completely lost in the two later imitations, since here, both stellations of 8 are constructed with pointed arches. This shows that the builder could not comprehend the fact that the first stellation inevitably passes through the sphere of the first curve, itself a portion of a perfect sphere producing perfect semicircular segments over the vosoirs.

No terminology is found for the phenomenon at hand. For the purpose of identification therefore, the author proposes the term *Naxl Bandi* for this revelation/mutation of rasmi. This is to align the proposed name with other similar terms such as *Rasmi Bandi, Kaarbandi, Yazdi Bandi,* and *Kaase Bandi,* used in the taxonomy of works related to the Rasmi family. Further, *Naxl* –Persian for palm- suits the description of the form, since the phenomenon abstractly resembles the offshoot of leaves from the stem in a palm tree.

The author also suggests the form to be segregated from the orthodox rasmi, since here, it is not the application of rasmi in its unitary form, but that it comprises of the clustering of rasmi units that gives rise to a new revelation.

Although no ingenuity has taken place in the diverse possibilities (the phenomenon has only been experimented with the rasmi of 8), nevertheless the same rules that define the new form, can be applied to any other rasmi model.

Kase Bandi (Cup working, Cup Vaulting)

This phenomenon comprises of the juxtaposition of amputated rasmis such that the medallions/cupolas are tangent to each other. However what distinguishes the form from a cluster of full rasmis is the way these rasmi portions are amputated. It should be noted that unlike Yazdi, here, the medallion/cupola is always intact.

The field of kase bandi is the most mathematically -and logically- demanding chapter in rasmi, requiring a complete understanding and clarification of terms, conditions and geometrical disciplines and formulae that dictate the realm.

The oldest model known to the author appears over the ceiling of the prayer chamber at Masjede Nasirol Molk of Shiraz, dating to 1875 with a second revelation, with the same design

over that of Jame' of Qaazi at Arran of Kashan. These are first attempts and at that slightly defying the absolute mathematical rules convened by later advancements. Here, the fitting of the rasmis leads to four blind spots over the tangents that under current conventions cannot be filled by the existing rasmis, but in the samples under discussion have been circumvented through the manipulation of vosoirs.

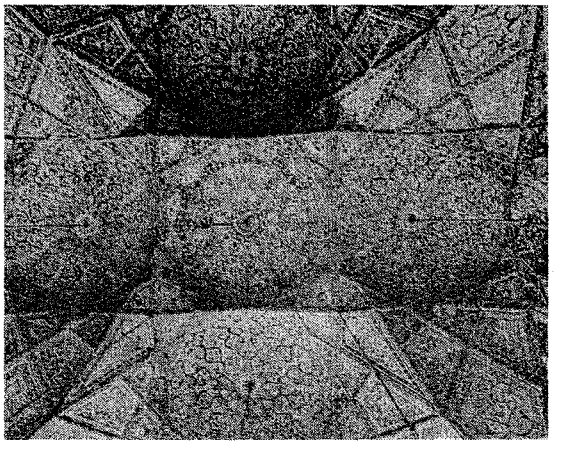


Fig.15. Cup work,Nasirol Molk, Shiraz, 1875 (Kiani '89)

Later advancements however have made up for the want of the first two works. 19th c. rasmis that precede kase bandi, clearly display the peak of the knowledge of geometry in the masters of the age. Towards the end of 19th c. cup vaulting developed further as a higher skill among a number of Tehrani masters -for the most part, pioneers and soul inheritors of the craft.

The names, biographies and works of these masters have been preserved through the soul efforts of Architects Hossein Mofid and Mahnaaz Ra'eiszadé, who documented the narrations and memories of the late Royal Architect Us Hossein Lorzadé, during his lifetime.

Based on the above, the largest contribution in cup vaulting has been through two of the greatest masters of late 19th and the whole of 20th c., both royal architects, Us Ja'far Xaane Kashi -originally from Kashan, assigned to Tehran as Royal Architect to the cabinets of Ahmad Shah of Qajar and Reza Shah the Pahlavi- and Us Hossein Lorzadé –the Royal Architect of Reza Shah, reassigned as Chief Architect of Eminent Shrines after the exile of the latter at the conclusion of WWII.

Numerous other master masons have been recorded by authors Mofid and Ra'eiszadé, who possessed some relative knowledge on the matter, including Us Asqar Sha'rbaaf who has authored the only other manual on the design of stalactites and kaarbandi.

However innovation –the ability to generate design as direct result of mathematical comprehension- only exists in the works of the two royal architects. It is here that the difference between comprehension of the topic and memorization of a number of generic designs is fully understood, for other masters for the most part, simply imitate and follow works previously produced by the two, proving incapable of understanding the mathematical potentials of the topic.

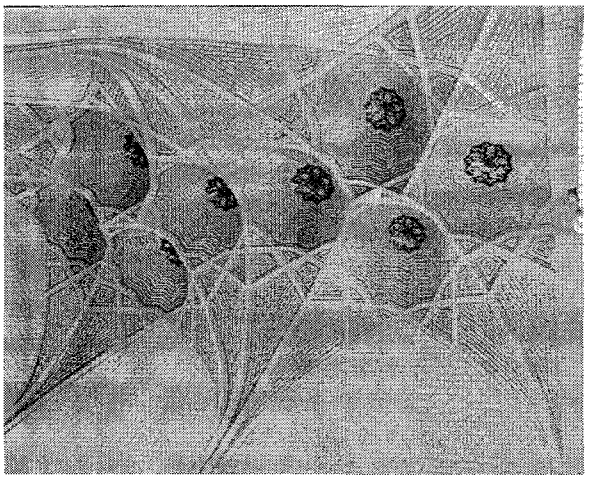
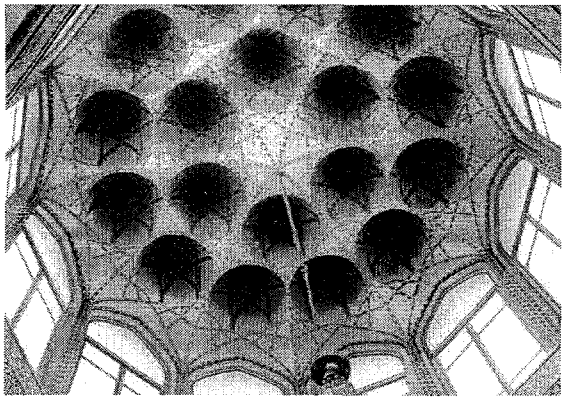


Fig.16. Eight cups of 10, Imam Hossein, Tehran, by Us Hossein Lorzaadé (Mofid '95)
Fig.17. Eighteen cups of 12, Imam Hossein, Tehran, by Lorzaadé (Mofid '95)



CONCLUSION

The entire family of architectural elements that comprises of rasmi and its mutations is termed as *Kaarbandi* in Persian. The techniques are still alive and practiced by limited number of builders in Indo-Iran, as well as Morocco. Existing models have been documented and drafted by archaeologists and historians of architecture, however only three books have ever dealt with the topic in particular, serving as manuals to the design and construction of other models.

However the phenomenon has gained little attention if any from scholars, and its history, evolution, taxonomy and morphology have never been documented prior to the current study.

The study at hand intends to lay the cornerstones of a potentially vast horizon of research on the subject matter. Proposals for future studies may include:

1) Detailed scanning of structures countries outside the indo-Iranian and Moorish spheres, for any evidence of the use of kaarbandi.
2) Detailed scanning of the monuments within the abovementioned spheres for the complete documentation of the existing works

3) Archaeological and chronographic survey of the existing models, for clarification of speculations on the development of rasmi
4) Structural analysis of rasmi vaults
5) Documentation of the existing state of mathematical knowledge and new research on star polygons, including spatial geometrical analysis
6) Modern applications

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