This research on Armenian architecture considers a somewhat wide chronological period.

Its effective range is the construction of churches and particularly, the development of domed spaces with their different geometric-constructive variations with relation to precise aesthetical and functional instances.

The objective is the definition of a field of investigation around the potentials of the «built form», that is the result of a compositive process through the coding of architectural rules.

The substantial predilection by the architects and the master builders for the construction of the dome —seen as the symbol of the divine perfection— sets matters of coherence in the composition among this form and the other spaces of the church.

During the 4th and the 5th centuries religious buildings were principally longitudinal spaces covered by barrel vaults and the dome was used only in small cruciform buildings used as funerary chapels or martyrria.

The 6th and the 7th centuries were characterized by an enormous spreading of domed buildings.

The regular celebration of the liturgy needs a longitudinal, east-west oriented plan. The dome introduces another principle: a radial form generated around a vertical central axis. The different compounds among liturgical rules and architectural forms produce different typologies.

Armenian architects built both longitudinal churches, introducing the dome in the middle, and central plan churches in which the vertical axis of the dome coincides with the centre of the entire composition. There is not chronological evolution, but they contemporarily experienced different architectural types.

The selection of cases-study that symbolize this phenomenon allows the understanding of the geometric and structural principles that lie under the built monument.

Each case-study has been «divided» into its architectural elements and re-assembled using geometric rules and designing proportions.

Beginning from a constructive technique that entrusts the resistance of the entire building to the performances of a stone and mortar core, Armenian builders develop a particular designing skill.

**THE DESIGN OF THE DOME FOR THE ARMENIAN SACRED BUILDINGS**

Apart from an extraordinary ability in drawing inspiration from the experiences about the building of central spaces by neighbouring traditions —the Roman one, through Byzantine culture, the Hellenistic and the Iranian ones— the Armenian experimentation on the dome in the designing of churches probably started for liturgical reasons. At the middle of the 5th century the division between Armenian and Byzantine cults caused the definition of Armenian own sacred ceremonial for the foundation of a
church and the dedication of the site on which it was built.¹

In many sacred texts some words as «gmbet», meaning dome, or «khoran», meaning canopy, are indifferently used meaning both the physical spaces and the symbolic dimension of heaven.

The definition of the sacred ceremony for the foundation of a new church established in the 5th century by Katoghikos Hovhannes I Mandakouni confirms the symbolic ground of some designing choices. The scholar Armen Zarian (1991) quotes the sacred text:

The saint clergy gathered around the Bishop goes toward the consecrated site, where twelve little and rough-shaped stones are brought... the first stone of foundation is set where the «bema» will be built; other stones are set at the four corners; ...then the architect is ordered to hold

Figure 1
Photos by the author documenting the constructive system used in historical Armenia: walls (a), elements of transition (b) and vaulting systems (c)
the measuring instrument and to trace on the ground according to the client’s will; ...the Bishop takes the hoe and symbolically furrows the ground and orders to set three stones at East, West, North and South and twelve stones at the center of the khoran; finally the place where the altar will be built is fixed.

ARCHITECTURAL AND CONSTRUCTIVE CHARACTERS OF DOMED CHURCHES

If we consider that the founding characteristic of a stone architecture is the expression of the coincidence of formal definition and structural code, the theoretical problem consists of the individuation of a specificity that determined in the Armenian construction the design of the architectural form in relation to the static-constructive model. Understanding the field of empiric or scientific knowledge and applications according to which the Armenian master builders and architects operated has a crucial importance in order to find both the limits and the virtues of these works. The characters of the Armenian historical architecture are not the product of a single mind, but, rather, the result of a collective critical conscience and can be investigated only considering which congruous geometric-structural model this specific culture chose.

The understanding of the constructive characters of Armenian architecture allows some important considerations about its forms.

The only constructive material is stone, more specifically many varieties of local easily workable tufa or more compact basalts equipped with a particular technique: masonry was composed by three vertical layers; a very thick central rubble-volcanic mortar core, like a sort of opus coementicium, between two external walls. These two walls are a sort of formwork for the central core that was cast through successive horizontal layers together with the two walls in order to compose a structural unity. Ashlars are perfectly polished only on the visible surface (figura 1a). The pillars were built with the same technique, such as pendentives or squinches, drum and vaults or domes (figuras 1b, c). For all these elements the main resistant part is the central core. On the contrary, some arches are properly stereotomic elements that bear the loads of the structures above. Not-stereotomic «false» arches often overlap stereotomic ones (figura 2).

A typical characteristic of this specific type of structure is the exiguosness of the vertical joints between the ashlars. This aspect has an important role in the definition of the static-constructive model: the absence of the geometric problem of the exact determination of the plan defining every single vertical joint distinguishes the Armenian approach from the pure stereotomic discipline in its Renaissance codification. An example of this meaningful difference is the construction of the conical vaults: the Armenian masters did not face the problem of the geometric form of the joint between ashlars while this will be a typical problem for the French stereotomy because of its important structural role in the distribution of the thrusts on masonry.

This constructive technique produces two consequences. The first one is a specific monolithic structural behaviour of the building: since the big, compact and homogeneous mass of the central rubble-mortar core had the charge of bearing and distributing loads towards the ground there are no differential reactions of the structure and the monuments collapse by big masses during the frequent seismic phenomena. In many monumental sites big structural portions (arches, vaults, pendentives, pillars) are still at the ground (figura 3).
The second one is an architectural consequence: this kind of three-layered structure led Armenian architects and master builders to experiment the possibility of building a double nature for the two visible surfaces. Outside there was always a sculptural approach through the composition of elementary solids hierarchically organized. Inside the vertical elements had a rectilinear profile and the covering systems were always curved spatial surfaces (figura 4).

The surface becomes the most important element for Armenian medieval architects. They privileges the geometrical perfection of the visible surface more than the solid definition of every single ashlar. The attempt of dissimulating, as far as possible, the joints, denying their tectonic value, is coherent with the building technique.

Somehow this aspect recalls to mind the typical approach of classical Greek architecture in which the aims were the organicity of the work and the sculptural, monolithic appearance of its elements through the use of sophisticated systems of equipment for the cut-stone blocks. In this sense and for these reasons we can state that Armenian architects develop a sort of «surface stereotomy». Although there is an undeniable theoretical and chronological distance between Armenian tradition and French or Spanish evolution on stereotomy, Armenian skilful constructive solutions both of «developable» surfaces (like the semi-cones of the squinches) and of «not developable» surfaces (like the hemispheres of the domes) widely demonstrate their advanced knowledge of Geometry.

THE «FAMILIES» OF DOMED CHURCHES

The design of the domed space becomes an occasion, for Armenian architects, to contemporarily experiment with very distant architectural models giving much more importance to composition than to the simple functional use of the building.

We can individuate different directions of experimentation on domed churches according as the degree of organic unity of the architectural composition of the space under the dome with the «smaller» spaces around it is more or less evident.

These different directions generate different «families» of architectural forms; more precisely there are three big families of religious architectures, characterized by an increasing degree of organicity of the spatial and constructive composition. These families...
didn’t develop in a temporal sequence from ‘simpler’ to more complex buildings, but rather as complex expression of an architectural research on the construction of the domed space melting liturgical rules, clients’ will and formal and geometrical ideas together.

These families are: longitudinal spaces, central spaces with double symmetry and central spaces with multiple symmetry.

In their definition there is somehow a reference to Strzygowski’s intuition about the formal potentials of Armenian architecture and the consequent need of analyzing it according to constructive forms.3

The elaboration of synthetic chronological tables is the first step to reach a deeper knowledge of this phenomenon. The domed monuments have been classified by centuries into three distinct groups. The criterion for the definition of the typological classes is intentionally synthetic, considering only the principles of symmetry adopted for the architectural composition, avoiding the definition of too many categories and aiming at an immediate understanding of the role of the domed space for the basic rules of the composition.

The first observation on these tables regards the absence of building activities during the 8th century that coincides with a period of political repression for Armenia.

The second remark is more important: there is no chronological evolution but Armenian architects contemporarily experience different architectural types.

The main part of this research concerns the central historical period for the domed architecture, between the end of the 6th century and the end of the 7th century; the second phase of new cultural growth is between the 10th and the 11th centuries when architects refer to the architectural models already developed and intensify their experimentation on central plan building.

The main part of the domed churches was generated by the constructive tradition of the big region called Ayrarat. It extends as far as Karin, at west, and Lake Van, at south. This investigation has the domed churches in Ayrarat as its object.

The selection of cases-study that can symbolize this wide experimentation allows the understanding of the geometric and structural principles lying under the built monument. Each case-study has been taken to pieces in order to re-design each architectural element starting from its geometry and to re-assemble it using the designing proportions.

In this way, we can grasp the general rules of these compositions through the study of few symbolic examples. The most useful tool for such an investigation is surely the digital modelling.

On the one hand, there is the family of the longitudinal spaces: in Armenia the introduction of the dome doesn’t implicate the designing of central plans but it means an attempt at inserting the new form in the most diffused building type, namely the space with one axis of symmetry.4

This introduction generates a sort of contradiction between the vertical proportions of the space under the dome and the longitudinal processional axis of the liturgical space and, consequently, some strong modification in the design of longitudinal plan buildings: the plan geometry of the composition does not correspond with the volumetric articulation any more. The space over which the dome is built becomes predominant so that builders try to give coherence to the whole building adding a further axis. This one is orthogonal to the east-west direction and it is not a symmetry axis.

The central spaces partially beat the contradiction. The entire composition gravitates around the vertical zenith axis through the centre of the domical sphere. This family splits into at least two different degrees of composite complexity: the first comprises central plan churches with double symmetry. The two axes of symmetry —east-west and north-south— are created by a system of four semicircular apses; the second family of central spaces groups all the buildings that have more than two axes of symmetry and more than four piers supporting the drum and the dome. They represent the highest degree of organicity.

The three-dimensional analysis considers the two principal problematic points of the construction of the domed space. The first one is the transition from the square plan to the circle at the base of the dome: the space under the dome has always a square or polygonal plan and it is always covered by a spherical dome. The principal problem about this aspect is the geometric solution of these two different parts. The second point is the more or less organic transition from the space under the dome to the smaller spaces around it.

So the cases-study has been chosen because they are representative of the various solutions for these aspects.
One axis-oriented churches

Among longitudinal churches Surp Sarkis church at Tekor represents a unique solution because it is probably the only survived example of a primitive form of geometric connection between pillars and dome. The almost total loss of the building due to an earthquake in 1912, and, then, to a systematic depredation of the monument during the 20th century imposes to choose one of the hypotheses regarding its inside and external spatial characteristics, particularly Toros Toramanian’s one.5

The space of the dome is almost at the centre of the entire composition between the nave and the presbytery, covered by barrel vaults, in transversal direction, and between two small aisles, covered with barrel vaults too. The extension of the span of entrance such as of the span of the presbytery are the geometrical repetition of the smaller square drawn by the edges of the pillars; instead the width of the aisles is produced by the «golden rectangle» built on the greater square drawn by the edges of the pillars. The four free-standing pillars support four horse-shoe-shaped arches, for which the springing plane is lower than the height of the centre of the arch; on the arches there is a quadrangular cornice. The square plan of the pillars and of the arches is transformed into an irregular polygonal plan through the introduction of four little diagonal stone elements and then into a regular octagon through inclined planes. Maybe there was no more transition elements under the dome (figura 5). The apparent oneness of the solution at Tekor finds comparison in the forms of transition that will be typical of the Seljuk architecture.6

This kind of solution reappears in the covering system of the gavit' between the 11th and the 13th centuries. In such buildings, the drum doesn’t exist, the cornice has very often a square plan and the transition between the square and the octagon is above it. If compared both with these gavit' and with Seljuk examples, the strange aspect of the solution at Tekor is the greater height of the inclined surfaces.

The church at the village of Ptghni, near Erevan, is one of the first example of longitudinal domed building dating back to the end of the 6th or the beginning of the 7th century. The plan is composed by a central domed space defined by wall-pillars and by a system of double arches supporting a drum through four conical vaults of transition. The central space is placed side by side between two deep arches and longitudinally between two barrel vaults defining the principal nave and the presbytery.7

In this case the square plan of the pillars is marked by a system of four double arches. A comparative analysis of the proportions between the span of the dome and the height of the drum in other coeval monuments allows the definition of the probable height of the disappeared octagonal drum on four conical vaults, of which only one survives. The dome is probably built on a further ring of eight smaller conical vaults. The western span at the entrance is longer than the eastern one. This principle favours the architects’ will of arranging the dome at the centre of the length of the building. Frequently the span of the dome sizes the length of the western span of the nave and the same length is attributed to the system composed by presbytery and apse.8

The complete three-dimensional model of this church clearly shows the interest of the architects for the double designing method on external and inside surfaces composing the architectural space (figura 6).

In the case of the Katoghike at Talin four free-standing pillars support the same double arches linked through spherical pendentives creating a circu-
lar cornice. Even if the circular cornice could be fit for the building of the dome, here the architects decide to place a dodecagonal windowed drum. A double discontinuity is generated: the first one is a visual discontinuity, deriving from the common practice of dissimulating the point of contact between the base of the drum and the pendentives; the second one is a formal discontinuity between the two horizontal profiles, the circle of the pendentives and the polygon of the drum; such a condition can derive from the Byzantine tradition of dilating the space under the dome through the partial hiding of the lighting systems. The hemispherical dome is built on the drum by means of another complex level of transition alternating twelve very little conical vaults with ruled surfaces. The radius of the dome is 7.75 meters and defines both the height of the drum, and, probably, the external height of the vertex of the conical covering. The dome represents one more time the centre of the entire composition. The longitudinal axis is clearly evident and the presence of the dome is also marked by a second transversal axis with exaedrae in order to guarantee a best distribution of the masses, a best structural performance of the building and to introduce a cruciform compositive matrix even in a longitudinal building. Once more, the general proportions of the plan are not regulated by an unitary geometric layout but by operations of modular addition beginning from the principal domed fulcrum (figura 7).

Central churches with double symmetry

The spaces with double symmetry usually have two planes of symmetry: the east-west and the north-south planes and can be considered as organic evolutions of the cruciform composition of some longitudinal buildings. The intersection of the two planes is the zenith axis through the centre of the dome; the two axes usually end with apses.

The case of Surp Hovhannes church at Mastara is one of the most interesting for its singular interpretation of the geometric problem of transition and its well-finished solution. There are no pillars; the covering systems and the transitions are directly supported by the walls. On the edges of the mixtilinear masonry four big conical vaults are built generating an irregular octagonal plan. The passage to a regular octagon is solved by eight arches over the conical vaults and over the semi-domes of the apses. The drum has sixteen faces thanks to the interposition of eight smaller conical vaults. Before placing the dome a further transition with sixteen conical vaults forms a little polyhedron with thirty-two faces on which the dome is built. The liturgical east-west axis is marked only with a slightly thicker arch before eastern and western apses and through the building of prothesis and diaconicon near the eastern apse (figura 8).
Churches like Surp Hripsime at Ejmiacin represent a step towards the elaboration of the poly-lobed plan with more than two axes of symmetry. Each pillar splits into two vertical supports building diagonal niches and defining a first attempt of irregular octagonal composition (figura 9).

Central churches with multiple symmetry

One of the most beautiful examples of poly-lobed and perfectly central space is the little church of Surp Grigor at Aragats. Even if the basic idea seems quite evolved, the church probably constitutes one of the first experimentations on the spatial composition with radial symmetry in Ayrarat region. In this building the congruence between the domed form and the articulation of the smaller spaces around it is maximum. The symmetry is complete, without any concession to functionality or liturgy. Here all the niches are composed by two cylindrical intersecting walls and the vertical supports form the hexagonal plan. On the six arches there is the hexagonal drum with windows. On the level of the arches of the windows six conical vaults are placed composing a twelve-sided polyhedron of transition on which other twelve little conical vaults are built in order to form a twenty-four sided polygon circumscribing the circular springing of the hemispherical dome (figura 10).
GENERATION OF THE ARCHITECTURAL FORM WITH RELATION TO THE STATIC-CONSTRUCTIVE PRINCIPLES

Each architectural element is the result of a building process according to stone constructive technique. The disassembly of each case-study in its compositional architectural system has been furtherly developed in a disassembly of each element in its stone pieces.

Each architectural element could have many formal variations through the modification of the geometric parameters that builds it. For example the system of four arches on the pillars that mark the space under the dome: simple arches, double or triple arches produce different solutions for the spherical pendentives such as different variants of the transition with conical vaults according to the geometric intersection between their round arches and the faces of the drum.

The consideration of all these architectural models by means of so a powerful tool, three-dimensional virtual reconstructions, leads to a synthesis of the Armenian typical approach to architectural designing, distinguishing the different degrees of formal evolution. In one axis-oriented churches the most important space is that one under the dome; the other spaces are juxtaposed to it without a complete organic integration. The real experimentation concerns the domed space. Its ground base is always square and it is delimited by four piers; these ones can be free standing or linked to the masonry longitudinal walls of the church. The transition towards the dome is solved with spherical pendentives or conical squinches; this choice determines the horizontal profile of the drum, that can be circular, in the first case, or polygonal, in the second one. The polyhedral drum requires a further transition by means of other little squinches.

In the central plan churches with two axes of symmetry the field of variation of the domed space is similar to the previous one; the difference stays in the perfect organic integration among this space and the minor ones —semicircular apses covered by semi-domes.

In the central plan churches with multiple symmetry the plan has a polygonal form and the organicity is at its maximum level. The most remarkable variation is represented by churches with two diagonal axes of symmetry, in which the double problem of the transitions towards the drum and of its connection with the semi-domed cylindrical niches is solved by means of the combination of squinches and ruled surface elements, or through a series of superposed arches.

It is possible to extract an architectural lesson from the reconstruction of the formal and geometric model of the cases-study. The result gained with this research is the definition of a series of rules and of a formal catalogue of elements. This method is useful not only for an exact knowledge of the Armenian architectural monuments, but also for the purpose of their maintenance and restoration.

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NOTES

1. After the Council of Chalcedony, 451, the Armenians will constitute an autonomous religious enclave founding it on the only divine nature of Christ.
2. In order to avoid the side dismemberment of the two external walls of the masonry and increasing the scarce friction of the joints of the thin ashlars the Armenian builders experiment a series of technical expedients to ensure the transversal discontinuity between the two walls, as, for instance, the stagger of the horizontal joints and the vertical ting up of the ashlars by means of toothed or swallow-tailed joints.

The hypotheses regarding the building technique for barrel vaults can be two: their intrados was entirely built on wooden centering up to the casting of the mortar; the second hypotheses considers the possibility of building bearing stereotomic arches on which the vaults were built in order to economize the centering. The geometric properties of the dome, more than barrel vaults, allow the construction by successive horizontal layers, alternating it with the casting of the mortar. This operation does not imply a simplification of the struc-
tural behaviour: these are not «false domes» but properly thrusting structures for which the constructive technique by concentric horizontal rows and layers of mortar improves the cohesion of the parts and reduces the thrusts.

3. Josef Strzygowski’s work (1918) is the first systematic text on Armenian architecture, including detailed documentation about more than seventy monuments and comparing them with the architectural traditions of many other cultural contexts. For the first time there is an attempt of typological classification of the monuments writing out a «Typenkatalog». Strzygowski entitles the section at pages 70–71 of his book «Order of the Armenian historical churches by constructive forms». Churches are classified as: strahlenförmige kuppelbauten: domed radial building divided into domed churches with square plan and buttress-niches and pure radial churches with four, six or eight apses; längsgerichtete tonnenbauten: longitudinal buildings with barrel vaults and one or three naves; längsgerichtete kuppelbauten: longitudinal domed churches with three apses, one or three naves, without niches or domed hall. The most controversial aspect about this classification consists of the numerous and conscious chronological manipulations and risky comparisons that the scholar introduces in order to demonstrate the chronological supremacy of churches with domed central plan for Armenian architecture considered as the ancestress of the Arian architectural culture.

4. The terminology used to define these churches prevents from any misunderstanding with the basilican type; differently from it, the Armenian longitudinal domed buildings have reduced dimensions and always show a tendency towards the cruciform composition.

5. Another scholar, Charles Texier, in his travel notebook, draws a longitudinal section of the monument with a parabolic profile for the central dome, but this solution is completely non-existent in Armenia.

6. Rosintal (1928) analyzing the problem of the transition in the oriental architecture, introduces a clear distinction between the «Byzantine» pendentives, spherical elements, and the «Turkish» triangles, triangular surfaces. The triangular transition derives from the tendency of introducing the octagonal base between the square and the circle, with triangular inclined surfaces linking them. The second phase of formal development of these elements is the introduction of a further intermediary geometric figure, a polygon with more than eight sides, joined to the octagon through other triangular surfaces.

7. The most similar variation of this geometrical scheme is Surp Gayanè church at Ejmiacin, built between 630 and 636; in this case, beginning from a longitudinal plan, a kind of cruciform composition is experimented both in the plane proportions and in the construction of the architectural systems of coverings of the inside space and in the composition of the external volumes: here the pillars are free-standing generating two small aisles.

8. This tendency will be more and more evident with the diffusion of the so-called Armenian cruciform plan inside monastic complexes in which the presbytery is very short or even annihilated in some cases.

LIST OF REFERENCES


