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A CAMERA OBSCURA SUNDIAL: S. ASTVAZAZIN CHURCH IN ARENI, ARMENIA

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Abstract

The construction of the ancient buildings was largely based on geometric projective rules. The analysis of these rules allows to understand the level of the constructors' knowledge and to interpret the meaning of these architecture. Today this research can be more easily approached thanks to the current survey techniques and to accuracy tools, which simplify the survey of monuments. The analysis of Armenian churches highlighted the importance of the role of light, both in the building construction and in the spatial meaning linked to the liturgy. In this paper the case of S. Astvazazin church in Armenia is presented.

Keywords

Armenia, solar orientation, churches, integrated survey.

1. *Introduction: historical and environmental context*

S. Astvazazin church in Armenia is dedicated to the Virgin Mary ('Astvazazin' in Armenian, 'Theotocos' in Greek = She who generated God).

It was built on a plateau looking over the Arp'a river valley near Areni, a village not too far from Azerbaijan border.

Historians claim S. Astvazazin church was built by the architect-sculptor Momik in 1321. He (?-1333/9), probably coming from Cilicia

Fig. 1: the church of St. Astvazazin in Areni, Armenia. The local stone makes the building blend with the landscape

between 1302 and 1304. His activity as architect and sculptor was focused within the area of influence of the monastery of Noravank and throughout the valley of the Arp'a where he have experimented different compositionals of the church building. Momik was later involved in the design of other monumental sites like Novarank, where he proposed an ascensional (vertical) liturgical path – still under investigation.

S. Astvazazin represents the apex of Momik's creativity; the building stands out for its harmonious symmetry.

Looking from the outside, it appears as a compact structure, composed by a cube surmounted by a cylinder and a cone.

The building was realized with the local stone, which is a pinkish red basalt, perfectly matching the surrounding mountain landscape. In fact when we approaching the church from the street, it's not visually impact, as it blends mimetically into the rocks (Fig. 1).

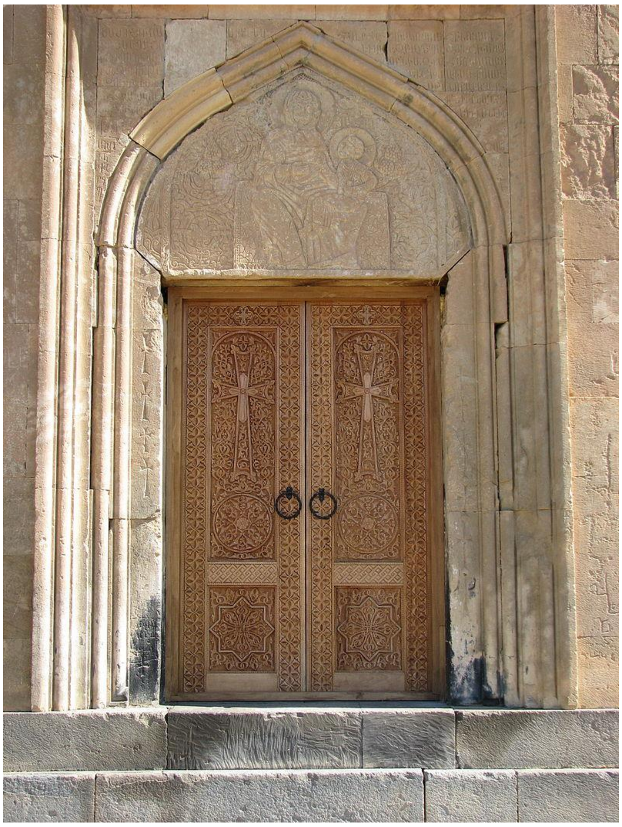

Fig. 2: the entrance door surmounted by the lunette with the sculpture representing the Madonna and Child attributed to Momik sculptor

The small building belongs to the typology of the cross-shaped churches inscribed within a rectangle and the planimetric dimension is 8,95 by 6,97 metres. Two entrances – one South and one West – can be found on the parallelepiped base.

On the Eastern side, two niches with the shape of dihedra,– typical of Armenian architecture – define the recessed apse. These niches are shaped in the wall, to delimit the portion of the apse inside, and generally have a triangular plant. (Cuneo 1988).

A double-light cross shaped window opens at the centre and it is marked by the same embracing cornice.

Two additional windows are over the two accesses and conclude the decorative motif. On the North side wall, the window is simplified both in shape and decoration and complete the external symmetry.

The two entrance doors are surmounted by lunettes: on the Southern door there is a flowered cross in low relief, whilst on the Western door there is a fine representation of the Virgin with the Child. The historians attributed to Momik both the works in the lunettes (Fig. 2).

From a composition point of view, the church is sitting on the edge of the first cliff rising from the valley; this site was the original location of the ancient Areni village. The current building stand on a three steps base, with each step measuring about 76 cm in height and made of grey basalt.

The inside of the church is quite interesting as it differs from the other Armenian churches.

In fact, in the Western side it is possible to find two free polylobate pilasters which contribute to the unity of the indoor space.

Although a strong break occurs in the apse area, which perceptually separates the presbytery (Luschi, 2015).

This discontinuity is created through a difference of 84 cm in height, which defines and delimits the access level from the one of the altar, due to cult reasons (Fig. 4-7).

The central space is defined by two free polylobate pillar and by the presbytery. In the centre, a slender cylindrical drum rises from four pendentives and it is topped by a hemispherical dome, covered by a cone roof. The drum allows the passage of zenith light from eight windows, which are framed externally by moldings. The construction technology of the building is mainly based on masonry of rubble, covered with square and well finished blocks in stone.

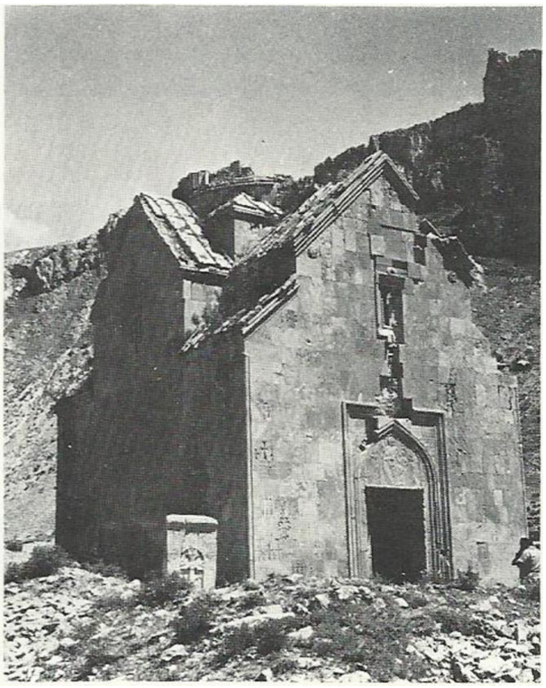

Fig. 3: the demolition status of the church caused by the earthquake

The whole of the top part collapsed after one of earthquakes it frequent in the area. Consequently, the church underwent a refurbishment and the drum was rebuilt, although some cracks from the earthquake are still visible on the side walls. (Fig. 3) The size of the damage is well supported by some historical photos (Cuneo, 1988), which highlight the loss of the drum, but also the integrity of the side walls where the openings are.

2. Protocols of Integrated survey for the church of Areni[1]

The methodology adopted for the survey project had to take into consideration several factors, such as the limited amount of time, the impossibility to carry bulky tools (like Laser

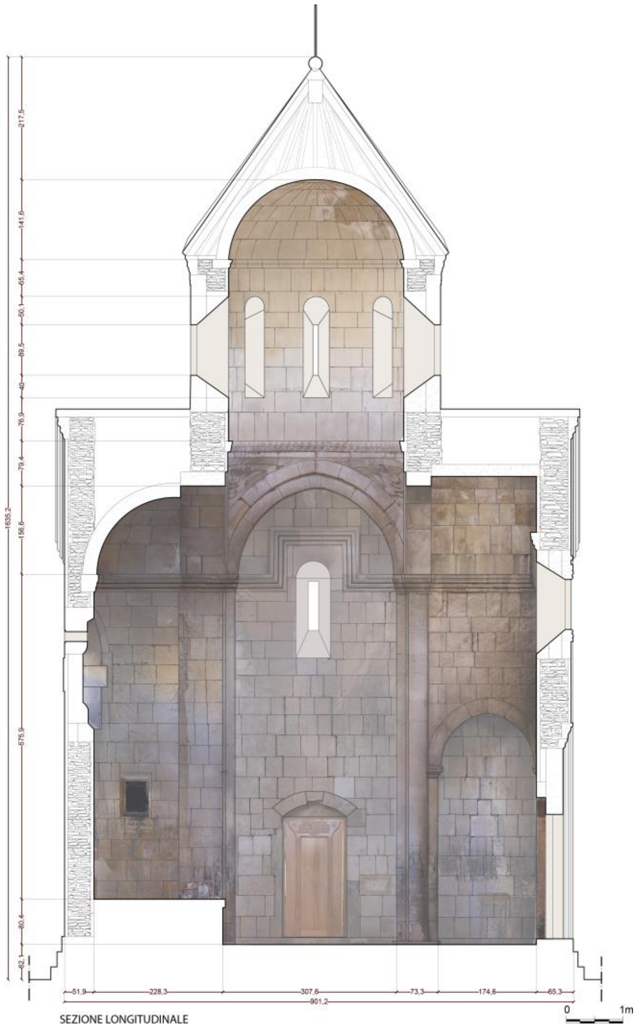

Fig. 4: longitudinal section highlights the purity of architecture and the division between the altar and the part dedicated to the faithful realized through difference in level.

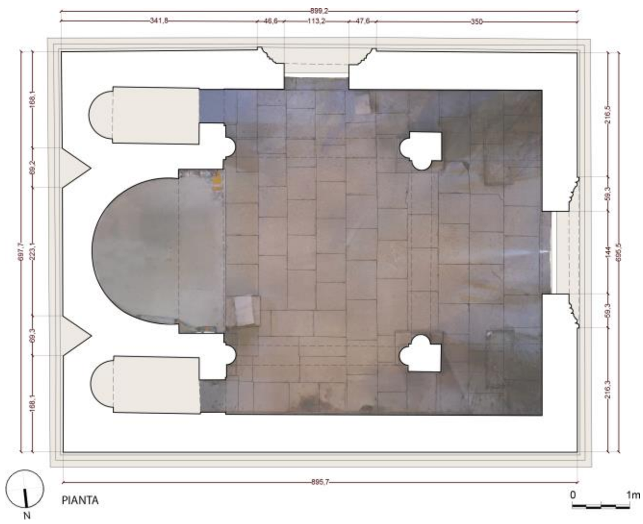

Fig. 5: plant highlights its simple structure and the unit space also ensured by the two polylobate pillars.

[1] The proposed work falls within the activities of the Italian-Armenian project: *The Making of the Silk Road in Vayots Dzor*. Armenian Italian Archaeological Expedition between Florence University and Yerevan State University. Head for research for SAGAS Department Michele Nucciotti, head for the research for DIDA Department and scientific responsible for the surveys Cecilia Luschi, coordinator for surveys Laura Aiello. Work group for the drawings and thematic studies: C.Luschi, L., Aiello, collaboratori: A. Vezzi, F. Trovatelli, N. Lecci, M. Zerbini, L. Pasqualotti, MT Paciolla..

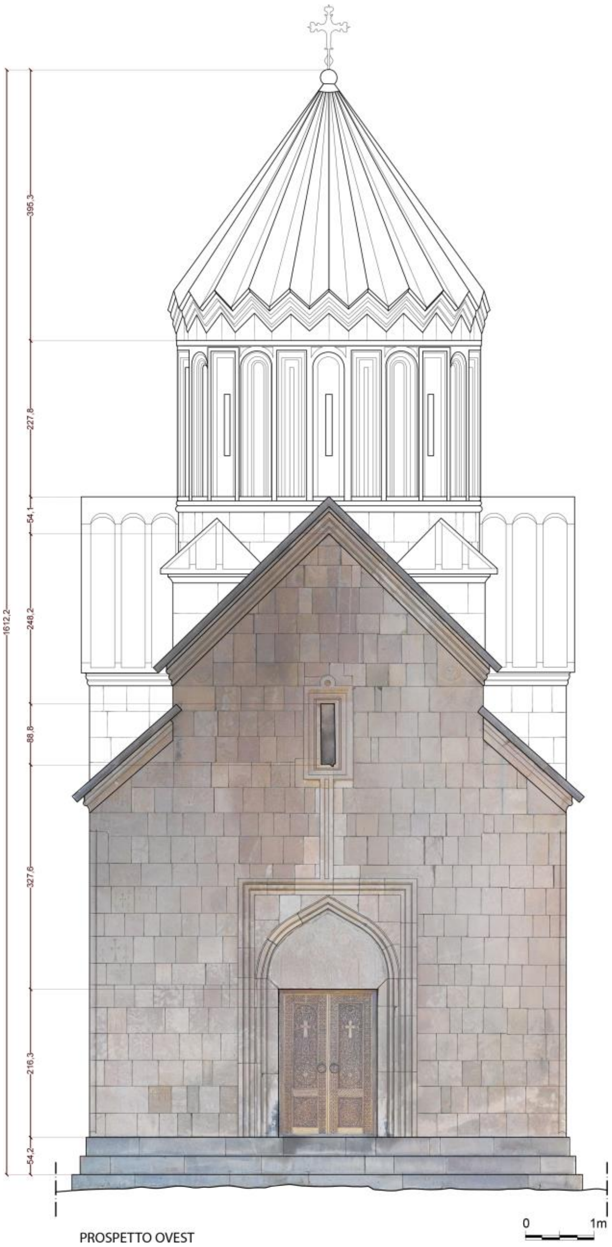

Fig. 6: west elevation with the lunette entrance and the frames that connect the openings, giving unity to the whole façade

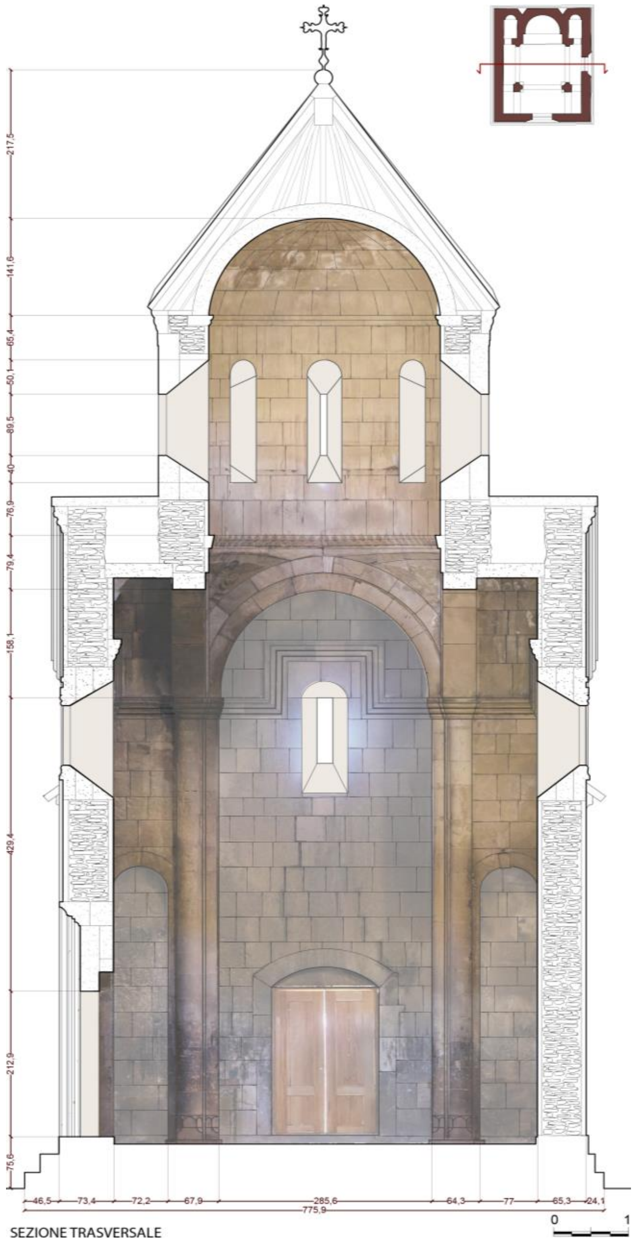

Fig. 7: cross section. The drum with the overhanging basin and the slender sack masonry are appreciated

Scan), he need to develop most of the work remotely from the surveyed object.

As a consequence, it was opted for a quick and economic solution, that does not interfere with result of a three-dimensional model, for further analysis purposes.

The requested output is not limited to formal and composition results. It also consists of an archae ological diachronic analysis of the building, static and seismic vulnerability analysis, comparative composition analysis to identify the measurement system used in the Middle Age in Armenia.

The survey project had to be set according to a time step of 10 days per each year, starting from 2014.

Therefore, a direct survey was carried out to approach the fundamental geometry of the building, in order to acquire the dimensions and the proportions together with a reliable metric survey, suitable for the change of scale (Migliari, 2001).

DIDA research unit collaborated with SAGAS Geography unit for the indirect survey phases, by planning georeferenced targets on every opening, in order to obtain a common ground for the views by the drone and the geographical localizations.

Those targets were measured also with the topographic station, which was available for a short time. For economic reasons, it was chosen to acquire all the points on the ground and the building silhouette for the elevations only through two sections.

Thanks to this, it was possible to define the general grid in which to develo p later the three-dimensional model, obtained with the dedicated software.

The pictures were taken with a SMC Pentax-DA 18-55mm, with two fixed 55 mm and 85 mm constant focus – in relation to the building portion. Every photo shoot is made of 100/150 pictures, with at least 3/5 known targets each; furthermore, targets are shared with the topographical and photographical (by the drone) surveys.

Different surveys methods were adopted in relation to the different drawing scales. Thanks to the most advanced technologies, it was possible to obtain a wide database for analysis from territorial to detail scale.

A drone, with its camera integrated with the three-dimensional photographic survey and local GIS data[2], was used to obtain 1:2000 scale cartography and 1:1 000 extracts (still missing for that area). Each surveyed object that had been converted in a three-dimensional model was placed in the new cartography, according to the specific latitude and longitude.

Being the archive documents almost entirely destructed during well-known historical facts, it was chosen to refer to Paolo Cuneo (Cuneo, 1988)'s great work as the scientific milestone for the topic.

During the different survey campaigns, metric and composition/functional issues were examined, according to the length of the staying – ten days each year, with at least three different sites per year.

The comparison between direct and topographical survey provided a congruent base to manage the final model, obtained with 3D modelling software. The final output is a 3Dm model, suitable for post-production animations (Gaiani, 2001) in obj format (Fig. 8).

Laser-level was used as a great feedback tool in the realisation of the model together with plan and section drawings. Cross line laser level PLL

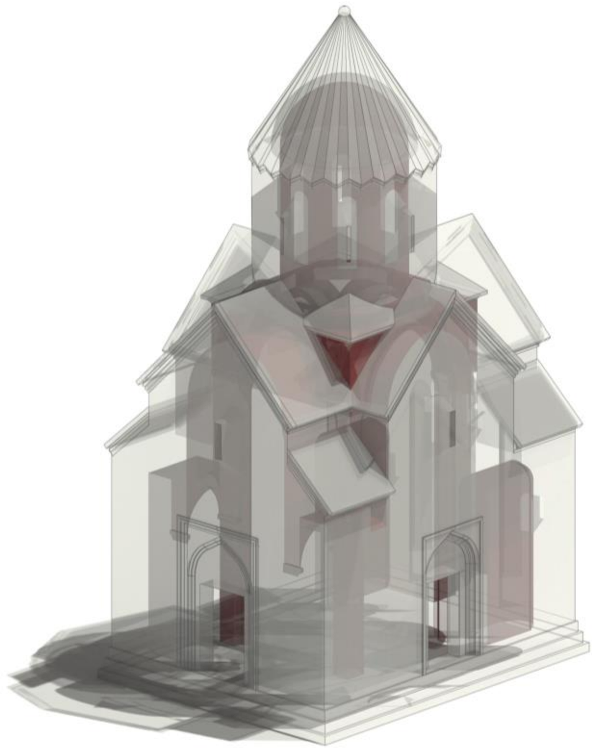

Fig. 8: the three-dimensional model obtained thanks to the integrated survey

360, set at a standard height of 120 cm from the main entrance sill, made the data collection process much quicker.

Furthermore, the darkness featuring the indoor spaces of Areni church (just like all the other Armenian churches) facilitated the use of the laser line level, up to the point that it is shown in the three-dimensional model.

Such device linked even more deeply the direct data collection with the model, reducing the post-production operations of calibration and rotations absorption. The height deformations were checked and corrected with the topographical survey.

The model was produced with a photo-modelling software such as Photoscan, which provided the Dense Cloud model used for the thematic orthophotos.

The orthophotos were produced according to dedicated software protocols (such as Archis), preferring the analytical protocol to the geometrical one.

Even for this phase, the topographic grid provided the base for a univocal localisation of the points in the space, serving as a sort of crossed feedback.

[2] for geographic studies and GIS surveys Margherita Azzari and Paola Zamperlin.

3. Light projections in the Church of Areni.

This model chosen to examine the kinesis of the light inside Areni Church after realizing that some of the openings had huge deformations in their internal sections. Furthermore, it was noticed that the light passing through these openings could project significative shapes at specific hours in the morning, namely geometrically defined shapes on the Northern wall.

Therefore, it became fundamental to focus not only on the general geometry, but also on the deformations of the openings, which had been finely surveyed. The exact East-West orientation of the building, in relation to the main access door, was confirmed by the GIS survey.

As consequence of the hypothesis of the alignment of the cardinal points with the church layout and continuous site checking, another building analysis methodology was set. It was assumed that, in order to survey a monument, it is fundamental to survey the position which it occupies in the territory. In other words, the orientation is a key factor in the characterisation of architecture. As the building takes into consideration geographical/astronomical factors, it is necessary to identify the operative (and consequently expressive) role of the orientation, in order to analyse the building shape meaning.

But how is it possible to understand the orientation of a building? A georeferenced survey provides the alignment with the magnetic North, which presents some grades of difference to East or West, in relation to the cardinal solar orientation.

Because of time and tools constraints, it was decided to carry on a gnomonic survey with a portable gnomon. (Aterini, 2005) (fig. 9).

In fact, a pole stuck in the ground determines the shade. In other words, the solar light projects the pole, drawing its image on the ground. At the local midday, when the sun is passing through the local meridian[3], the shade is the shortest of all the ones produced during the day. In fact, at sunrise and sunset the light has a direction which can be considered almost parallel to the horizontal plan,therefore the shade is unlimited and tends to infinite. During its day path, the sun reaches the zenith (the maximum height) at midday.

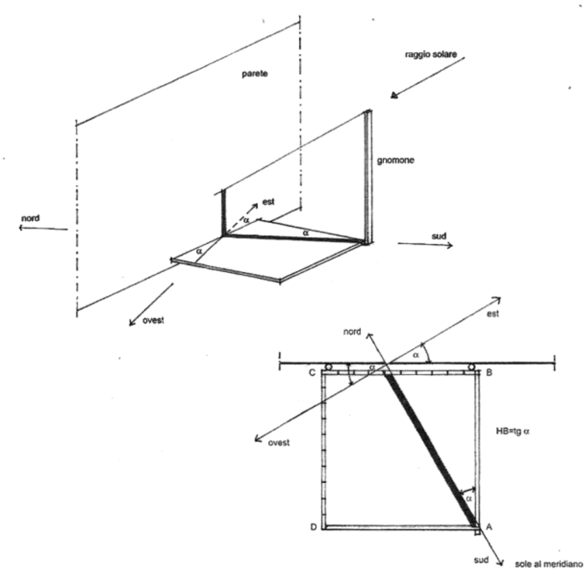

Fig. 9: The portable gnomon used during the survey

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Therefore, the luminous ray passing through the highest point of the stick (namely, the gnomon[5] that is a stylus or rod infixed in the ground whose shadow serves to measure the height of the Sun on the horizon and to determine the instant of the local noon) has the maximum inclination and meets the horizontal plan in the highest point of the pole, producing the shortest shadow.

From a methodological point of view, it is important to develop coherent graphic schemes, which provide and verify the alignment with the cardinal points according to geographic coordinates (Areni 39°43'15" latitude North and 45°11'02" East). Additionally, they allow to find the direction of the sun rays, in relation to specific days of the year.

[3] The local meridian is the maximum circle of the celestial sphere passing through the celestial poles and the poles of the horizon called Zenith and Nadir. The local meridian is perpendicular to the observer's astronomical horizon.

[5] Gnomon (from the Greek γνωμων),

In fact the position of the Sun is variable in each day during the revolution of the Earth around it, since the inclination of 23° 26' of the Earth's rotation axis with respect to the plane of the ecliptic causes the Sun to travel a trajectory every different day, that is a spiral between the winter solstice and the summer solstice one and vice versa (Fantoni, 1988).

The procedure consists of drawing a square with a 1 m long external side; a vertical element - the gnomon- is placed on one vertex. It is a three-dimensional figure: the sixth part of a cube. After positioning the base square onto (or parallel to) the wall to survey, it is adjusted by means of a level. Two metersticks are applied on the sides opposite to the vertical corner, thanks to which it is possible to read in millimeters the dimension of the BH cathetus from the ABH triangle (Aterini, 2005) (Fig. 14).

If the measurement is taken at the real midday, the BH dimension tangent α angle, which is formed by the side of the wall facing midday and it is perpendicular to the sundial line.

To obtain a good result it is necessary to refer to the three following points:

1. Our focus it is not the directions provided by the compass, which is oriented according to the magnetic north pole, but the geographic poles of the Earth, ie the real points around whose axis rotates.

2. The Earth's axis undergoes a precession, making a complete 360 degree turn in 25.765 years. The position of the celestial poles also changes accordingly.

3. The celestial meridian of the place, that is, of a point on the earth's surface, represents the maximum circumference that passes ideally for the celestial poles and for the Zenith. It belongs to the meridian plane which contains the Zenith, the Poles and the terrestrial meridian for the same point. Every day the Sun reaches its maximum height on the horizon of the place when the center of the solar disk cuts the meridian plane, ie passes to the meridian; that instant is called culmination or true solar midday. The line of intersection of the meridian plane with the horizontal plane, tangent to the terrestrial globe at the observation point, is called the meridian line. The two extremes of this line identify the North and South cardinal points on the horizon.

From these observations, it is possible to state that there is no randomness in the architecture composition process: width, length and height have always been accurately thought since the setting of the site, which in the case of Areni Church lays on an existing base (modified for the purpose). The challenge consisted of studying the dynamics of the light inside the church, with the model obtained from the studies. It is clear how the reliability of the survey was extremely discuss, as the minimum error would have compromised the verification of the sunrays action. It is possible to claim that the challenge has been satisfactorily won (Fig. 15, 16).

3. Areni Church: a pseudo camera obscura sundial

The suggestive light projection noticed in S. Astvazazin church in Areni (Armenia) led to consider this building as a sort of sundial at dark room.

This is essentially a solar clock placed inside a building, consisting of a single hour line, that of the 12 o'clock in the Tempo Vero Locale; the ray of sunlight that enters from a small hole cleverly carved into the ceiling or wall strikes the line at the moment of the Sun's transit on the local meridian, when the star is at the highest point of its apparent path in the sky. During the year the position of this solar image can also give many "calendar type" indications such as detecting the summer and winter solstices, establishing the date of the equinoxes and some particular dates, as well as constituting an original and very precise astronomical instrument.

It looks like a solar clock realized inside the building thanks to a particular shape of the openings (one small circular opening and two more windows), which allow the light from the sunrise to pass through, therefore in the early hours of the morning (Fig. 10).

Generally, the solar image produced with this kind of devices can provide also 'of calendar' indications, such as winter and summer solstice, equinox and some specific dates, beside being an original and accurate astronomic tool.

The analysis focused in particular on the light coming from the Eastern wall of the church and projecting on the Northern wall - on the side of the wall where the small openings are.

As the sunrays project the image of the two cross-shaped openings on the adjacent wall, in a specific moment of the day the projecting process culminates in the fusion of the two crosses together, in the shape of a single cross.

Fig.10: the sun's rays project the two cross-shaped openings merged into a single cross.
The photo was taken on October 7th

Fig. 11: the two cross-shaped openings on the apse wall of the church, through which the sun passes in the morning

Fig. 12: Internal view of the apse area

Thanks to the three-dimensional model it was possible to investigate the variation of sunlight within the church.

It emerged that it is necessary to force the guidance system of each software, which follows magnetic north and not solar orientation. This generates an error, that is, a shift of different degrees, which has been compensated here by direct observation.

The first thing to notice in this architecture is the shape of the window that allows the passage of sunlight is interesting for its stereotomic value. In fact, it should be noted that inside the apse surface is cylindrical.

The tests were carried out for dates established and distributed during the year.

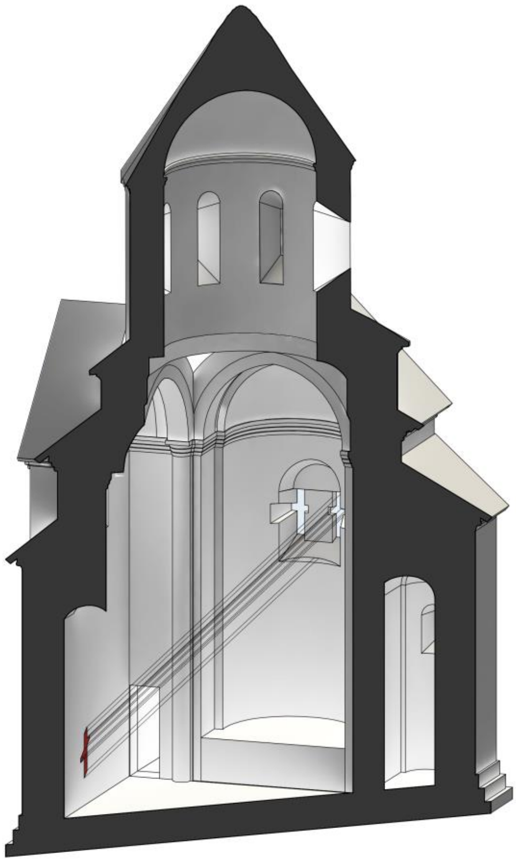

Fig. 13: diagram showing the projection made by the sun through the apse window

The study of the movement of the sun was represented by a sequence of images that highlights the variation of the images of the crosses.

The date of October 7th, the day of the mission and of the direct observation was privileged here. The phenomenon occurs in the early hours of the morning, so we checked the parallel projection performed by the sun's rays at 8.30 am, then at 9.00 am to 11.30 am

We then analyzed other dates of the year related to the cult.

Fig. 14-15-16: the first scheme shows the parallel projection performed by the sun's rays at 8.30.00 in the morning. The second one at 9.00 and the third one at 10.00

Fig. 17-18-19: the three diagrams illustrate the projection of light at 10.30am, 11.00am and 11.30am on October 7th

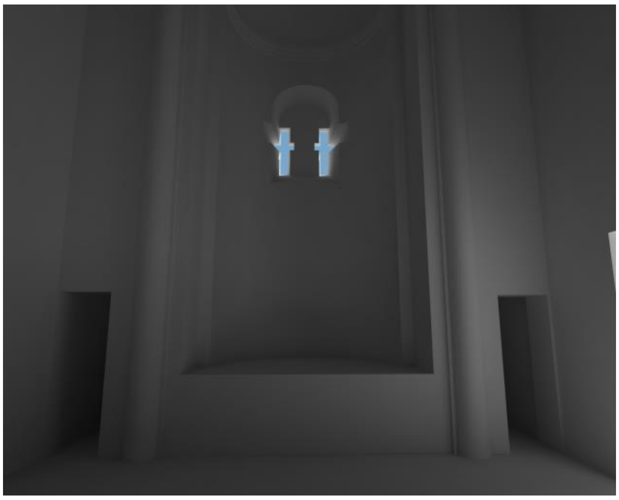

Fig. 20-21: the two diagrams illustrate the projection of the light at 12.00, and at 1.00 pm on 7 October

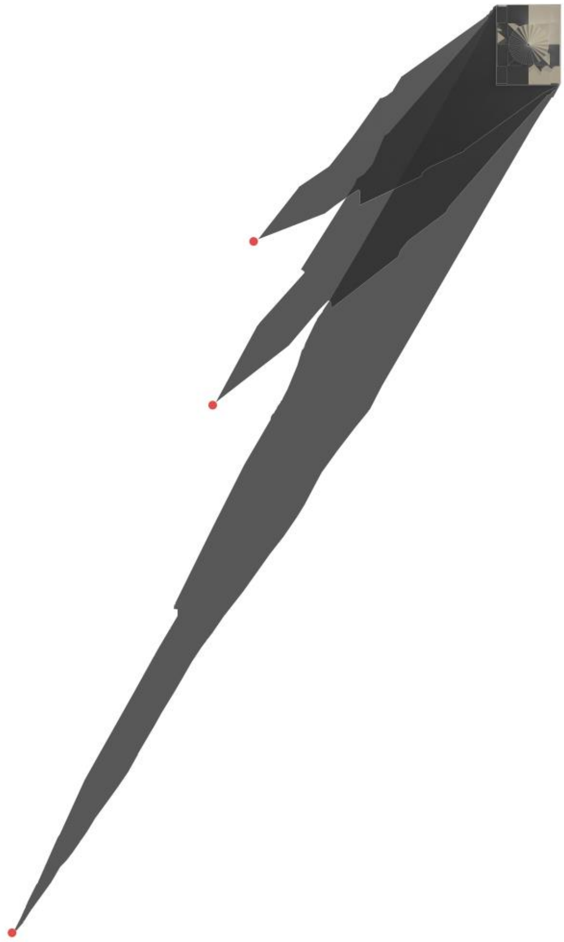

Fig. 22: the diagram illustrates the shadow of the church on December 8th at 9, at 10, at 11, another Marian feast

Fig. 23: External view of the church

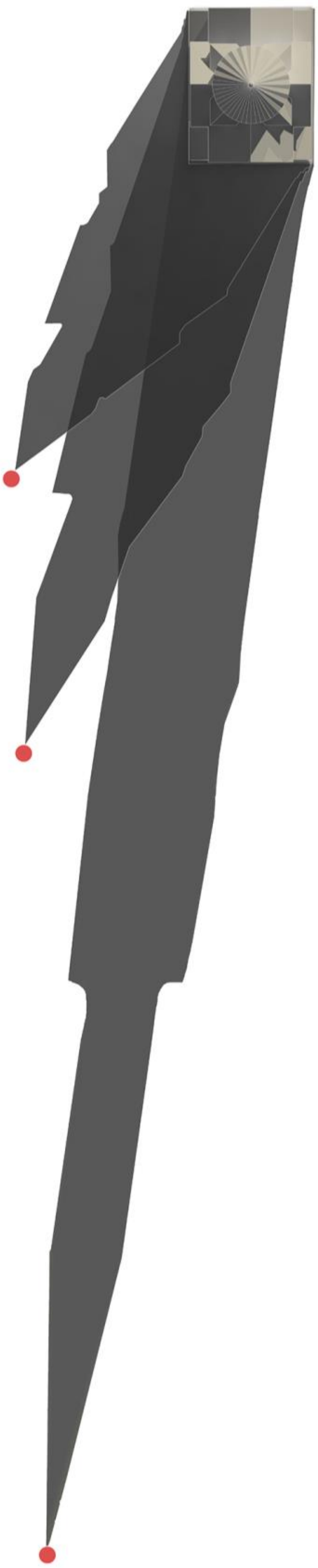

Fig. 24: The outline illustrates the shadow of the church on October 7th at 9, 10, 11

Fig. 25: the three-dimensional model

The hypothesis we are testing at the moment is that the building itself was also a sundial for the ancient village of Areni and therefore played an important role in measuring time. In fact, the shadow of the church is always visible from the place where the original village stood and therefore it is plausible that it marked the hour of the morning of work.

In this perspective, particular dates of the Marian cult have been studied. The month of October (harvest period in this part of Armenia) is probably the most important for this village which bases its economy on wine production.

4. Conclusions

The study of the building of S. Astvazazin church in Areni (Armenia) confirmed the hypothesis that the orientation was a fundamental reference for ancient builders.

This kind of considerations lead to the idea that buildings offer design solutions deriving from 'aware' options. The reasons for position and shape reveal also the cultural background of the constructors.

Therefore regular architectural shapes had to adapt to the environment and to the local declination of cosmic mechanics, such as direction and inclination of the sunrays. These buildings surviving in time are examples of how the architecture was conceived by high level space-time knowledge.

It is significative that the circular opening above the crosses projecting the light, draws a perfect circle on the opposite wall, just above the window: the 'eye' of light recalls the 'eye' of the divine. It is a surprising projective trick obtained by rounding the thickness of the walls in the splay of the window.

The event is highly symbolic and seems to highlight the liturgical timing of the Armenian ritual. What is more astonishing, beside the stereotomy knowledge, is the knowledge of the projection laws during the Medieval age (the church was built in 1321) and in such peripherical area (with a low stream of cultural confrontations), because not would have been possible achieve this kind of result without a deep knowledge of the topic.

At this regard, it is important to highlight the origin of Momik from the Cilicia area, namely a Mediterranean environment. It is possible to assume that he brought the necessary geometrical/projective knowledge, in order to manage and build such object.

It is also possible to affirm that, beside the knowledge of projective geometry, the builder/architect had to be aware of the fact that the Earth was not flat.

Furthermore, from the integrated survey it resulted that the building position was slightly rotated compared to the existing stone base. This is a confirmation of the will of directing the sunrays through the openings, to get the expected result described above.

It is possible to claim that the church behaves as a big sundial at dark room: a sort of solar clock that aims to mark specific days and hours, in relation to the cult (Fig. 13-24)

Further developments of the analysis translated the current data obtained in loco and compared it against the data from the year 1000, based on the precession motion of the Earth's axis.

The research presented here is still ongoing because during the expeditions it was noticed that there are Armenian churches with similar characteristics, ie architectures in which the deformation of the architectural elements is certainly intended as a function of the message to be transmitted through the expert projection of the sun's rays.

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