Study of Technology of Stucco Decoration During the Seljuk Period in Zanjan Province
(Last Resting-place of Pir Ahmad Zahrnoosh, Ghorveh Chatholic Mosque, Sojas Catholic Mosque)¹

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Abstract
In ancient India and China, renders in clay and gypsum plasters were used to produce a smooth surface over rough stone or mud brick walls, while in early Egyptian tombs, walls were coated with lime and gypsum plaster and the finished surface was often painted or decorated. Molded stucco was employed throughout the Roman Empire. The Romans used mixtures of lime and sand to build up preparatory layers over which finer applications of gypsum, lime, sand and marble dust were made. Pozzolanic materials were sometimes added to produce a more rapid set. Following the fall of the Roman Empire, the addition of marble dust to plaster - in order to allow the production of fine detail and a hard, smooth finish in hand-modeled and molded decoration - was not used until the Renaissance. Around the 4th century BC, the Romans discovered the fundamentals of the hydraulic set of lime, which by the addition of highly reactive forms of silica and alumina, such as volcanic earths, could solidify rapidly even under water. There was little use of hydraulic mortar after the Roman period until the 18th century (Poop & Arto,1986, p. 38).

Plaster-molding industry of Seljuk period enjoyed prominent artistic aspects due to the changes of architectural-related arts which may be considered as a critical factor for different plaster-molding methods & procedures compared to former & latter periods. This stucco decoration is the result of interaction between various variables. This paper aims to determine these unsolved variables using laboratory methods such as XRF and XRD. The paper’s main subject is to determine the factors influencing the stucco decoration art during the Seljuk period. Zanjan is one of the 31 provinces of Iran. After arriving in Persia, the Seljuqs adopted the Persian culture and used the Persian language as the official language of the government, and played an important role in the development of the Turko-Persian tradition which features "Persian culture patronized by Turkic rulers”. Today, they are remembered as great patrons of Persian culture, literature, language, art, and architecture.

Keywords: Stucco Decoration, Seljuk, XRD, XRF, Study of Materials

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Introduction

Zanjan is one of the 31 provinces of Iran. Boasting an area of 22,164 km², it occupies 1.34% of the country’s territory. The average population density in Zanjan is 4.4 people per km. In the northwest of Iran, Zanjan shares borders with seven provinces (East Azerbaijan, West Azerbaijan, Hamadan, Kurdistan, Gilan, Ghazvin and Ardabil).

Stucco decoration and plaster-coated items were used by locals for a long time and are broadly used around the world now (Aslan, 2006). Plaster-coated items now can be seen in Europe and they are being used to cover stone buildings because of its cheap costs.

The oldest evidence about their application dates back to 9000 years ago in Syria. We also know that about 5000 year ago, Egyptians cooked plaster stones in special kilns and then converted them into smaller parts and chowder and finally mixed this powder with water and used it as brick-adhesive material in buildings (Aslan, 2006).

It may be clearly seen in Hopes Pyramid. Ancient Egyptians stucco the human body by plaster, too. Romans made many copies of their statues using stucco decoration method. This kind of plaster was famous as "Plaster of Paris" which was produced by calcification of gypsum in Paris in 1700.

The changes of stucco decoration art can be seen during the Islamic period especially in "Seljuk" and "Ilkhani" periods. As it is noted, this type of art accepted some deletions or addition within Islamic periods. For instance, in the beginning of Seljuk period, gypsum was not used in wall covers but a few years later, it was used in "Qerniz" stucco decoration items. This paper thoroughly analyzes the stucco decorations and studies their effects in stability of stucco decoration of Seljuk period (Tabrizi, Karimzadeh, & Mohammad Ali; 1984).

Seljuk Architecture

In spite of the fact that the emergence of a new racial element in Seljuk dynasty formed a strong family class, Iran’s architecture kept using its former status. Some architectural aspects were also developed including the application of double-coated domes and a number of architectural decorations and building-construction methods. However, plans and buildings’ characteristics of aforementioned period were affected by different new actions but kept their Persian identity and originality of Iran’s ancient tradition. Religious and other types of architecture during this period -particularly between Arab’s invasion of Iran and emergence of Seljuk dynasty- enjoyed ancient formats such as "Four Arcades" or "Atashkade" (meaning fireplace) formats.
Originated from Sassanid period, the “Four Arcades” format is shaped by a dome over four columns contacted to arcs. They converted into the temple or dome-house of mosques especially in west zone. It’s said that veranda was modeled by Parthians from their maternal land -Khorasan- since mosques were built in Khorasan with verandas including the adytum and precinct with short walls. They were similar to small mosques discovered by "Gadar" in "Bamian" in 1962 (Godar, 1985). South regions, however, preferred roofed upper chambers including a central dome similar to Sassanid building of "Karkhe" veranda. A certain building not, however, restricted to a certain geographical borders. When Seljuk architectures need new constructions, they discovered a few instance of Islamic religious buildings which were built according to ancient plans.

**Last Resting-Place of "Pir Ahmad Zahrnoosh"**

Last resting-place of "Molana Ghotb Aldin Abhari" renowned as "Pir Ahmad Zahrnoosh" is located in southern part of Abhar town in the middle of "Pir" square. Its geographical coordinates are 3608184 & 5694912 and it is 1516 meters above free waters level (Figure 1,2). The dome house is constructed by bricks and with a "Four Arcades & Dome" model. The building’s model seems like it is twenty-sided from outside due to the fractures in piers and as cruciform inside view. Entrance of building is from the north side and it is made through a small gate. The opposite sides of central space are almost assymmetric. Walls are completely simple without any special decorations and there are niches inside some of them. There is a staircase just after the entrance under the north ceiling of dome-house which directs to a relatively small crypt. The crypt is rectangular form with a narrow-roofed corridor which its beautiful ceiling is in a herring-bone form. There were three tombs at the bottom of the crypt which were demolished by unauthorized diggers so there is no tombstone or inscription left at the moment (Figure 3,4).
Figure 1: Last Resting-Place of Pir Ahmad Zahr Noosh (Source: Author, 2016)

Figure 2: Entrance of Crypt in Dome-House of Last Resting-Place of Pir Ahmad Zahr Noosh After Repairs (Source: Author, 2016)

Figure 3: XRD Test and Determination of Indicator Elements in Last Resting Place of Pir Ahmad Zahr Noosh (Source: Atomic Energy Organization of Iran, 2016)
Ghorveh Catholic Mosque

Ghorveh village is located in Zanjan province between "Takestan" and "Abhar" around 15 km close to Abhar town. Its geographical coordinations are 29° 22" & 36° 3".

Ghorveh Catholic Mosque was registered as national monuments in 1341 (1962) under registration No. 433 (Figure 5).

Similar to other mosques of Seljuk period, this mosque was constructed by Four Arcades method and its beautiful brick dome is placed over four elephant-shaped columns. Ceiling of elephant-shaped columns is positioned on a 45° thick board and 5 & 7 steep arcs is constructed by high stems so that four alternate elephant-shaped columns as well as four the same ceilings form square plan temple as circle. Elephant-shaped columns and small ceilings are commonly decorated by geometric bricks and there are smaller ceilings with 5 & 7 high stems, and steep arcs are over them successively which form the base of ceiling’s dome (Kiani, 2004). There are three light windows in a row in the dome-house of mosque which direct the light inside the dome-house monotonously (Figure 6,7).
Figure 5: Inscriptions around the Dome-House and Elephant-Shaped Columns in Ghorveh Catholic Mosque Related to Seljuk Period
(Source: Author, 2016)

Figure 6: XRD Test and Determination of Indicator Elements in Ghorveh Catholic Mosque (Source: Atomic Energy Organization of Iran, 2016)
Sojas Catholic Mosque

It’s located in Sojas village, 35 km southwest of Soltanieh in Zanjan province and it belongs to Seljuk period. The mosque’s main building is a square dome-house. It is 9.5 by 9.5 m² with a high rising dome. Remained vestiges indicate that there were other constructions connected to the main building and they were gradually destroyed (Cultural Heritage Organization, 1998).

The dome-house included east, west and north gates which the east and the west ones have been closed. Dome is positioned over four elephant-shaped columns through four piers, and the bottom of the columns is located to a 45° thick board. Four elephant-shaped columns as well as four small ceilings successively with 5 & 7 arcs and upper smaller arcs changed the square plan to circle. Surface of elephant-shaped columns and ceilings is decorated by brick works and words & tools style of them are produced interesting geometrical decorations. There are a row of beautiful small ceilings over the dome. Tilted nabbed dome is constructed by brick and its decorations are just five sided stars (Figure 8).

The present entrance is located at north pier and there are two big gates at east and west piers similar to veranda and adytum at the south side. There are decorations such as adytum in opposite of aforesaid adytum at east and west piers between the big gates to keep the space assymetric. The present adytum of mosque seems to be from Ilkhani period because of its stucco decoration style and application of colures and it is the same about the vestiges of old adytum beneath it (Figure 9,10).

This mosque is a masterpiece in terms of of its stucco decorations and inscriptions. There are four written inscription in the mosque without any data regarding their date of inscription. The first inscription is in the stem of dome which is plastered as primitive scripts writing style probably as old as the building.
itself. Inscription of elephant-shaped columns is written by beautiful "Sloth" writing style and probably dates back to Ilkhan period due to its style.

There is an invaluable inscription under the elephant-shaped columns as wide as 50 cm which includes a chapter of "Malak" from the Holy Quran (Newton Vilber, 1985). This inscription is restricted by two parallel lines on the top and the bottom lines. There is a small inscription over the lines as "Kofi" writing style probably dating back to the fifth Hijri century. The chapter of "Malek" written in "Naskh" writing method is decorated by a number of attractive stucco decorations and "Slimi" designs.

Regarding the architecture method and available inscriptions and the similarity of mosque’s building and other buildings and other buildings of Seljuk period, it probably dates back to the end of fifth Hijri century and some remedies and decorations are conducted in "Moghol" period (Figure 11,12).

Figure 8: East Facade of Sojas Catholic Mosque (Source: Author, 2016)
Figure 9: Stucco Decorations of Adytum in Sojas Catholic Mosque (Source: Author, 2016)

Figure 10: Without-Date Inscription in Dome Stem of Sojas Catholic Mosque Probably As Old As The Building (Source: Author, 2016)
Physical Tests

Step 1: Time of Primary Occlusion

Time of occlusion was tested using gypsum with different percentages of alum and without alum. Alum was milled well and became powder. The Physical and chemical tests were precisely scheduled and

Figure 11: XRD Test and Determination of Indicator Elements in Sojas Catholic Mosque
(Source: Atomic Energy Organization of Iran, 2016)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Concentration</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na2O</td>
<td>2.34 Wt %</td>
<td>8.2</td>
</tr>
<tr>
<td>MgO</td>
<td>0.80 Wt %</td>
<td>13.4</td>
</tr>
<tr>
<td>Al2O3</td>
<td>1.87 Wt %</td>
<td>103.4</td>
</tr>
<tr>
<td>SiO2</td>
<td>5.47 Wt %</td>
<td>672.6</td>
</tr>
<tr>
<td>P2O5</td>
<td>0.63 Wt %</td>
<td>174.0</td>
</tr>
<tr>
<td>SO3</td>
<td>44.64 Wt %</td>
<td>18509.8</td>
</tr>
<tr>
<td>Cl</td>
<td>0.19 Wt %</td>
<td>62.3</td>
</tr>
<tr>
<td>K2O</td>
<td>0.61 Wt %</td>
<td>237.4</td>
</tr>
<tr>
<td>CaO</td>
<td>41.02 Wt %</td>
<td>17619.6</td>
</tr>
<tr>
<td>Sc2O3</td>
<td>0.16 Wt %</td>
<td>50.2</td>
</tr>
<tr>
<td>TiO2</td>
<td>0.11 Wt %</td>
<td>44.6</td>
</tr>
<tr>
<td>Sr</td>
<td>0.87 Wt %</td>
<td>7291.4</td>
</tr>
<tr>
<td>Fe2O3</td>
<td>1.09 Wt %</td>
<td>2339.9</td>
</tr>
</tbody>
</table>

Figure 12: XRF Test and Determination of Indicator Elements in Sojas Catholic mosque (Source: Atomic Energy Organization of Iran, 2016)
conducted in "Abhar" Islamic Azad University. First, alum powders were mixed with gypsum in different percentages from 1% through 5%. Then, mixed powder was added to a certain volume of water and time was controlled immediately after mixing the gypsum and alum powder with water. A sample without alum was also prepared by mixing 200 grs of gypsum and 230 grs of water without alum and controlled the time. In this step 1 were checked the time of occlusion by adding the alum to gypsum (Diagram 1).

<table>
<thead>
<tr>
<th>Time of Occlusion (min)</th>
<th>Water Residue (mgr)</th>
<th>Water (mgr)</th>
<th>Gypsum (Gr)</th>
<th>Alum (Gr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 min</td>
<td>60 mgr</td>
<td>230 mgr</td>
<td>198 Gr</td>
<td>2Gr (1%)</td>
</tr>
<tr>
<td>20 min</td>
<td>47 mgr</td>
<td>230 mgr</td>
<td>196 Gr</td>
<td>4Gr (2%)</td>
</tr>
<tr>
<td>17 min</td>
<td>39 mgr</td>
<td>230 mgr</td>
<td>194 Gr</td>
<td>6Gr (3%)</td>
</tr>
<tr>
<td>14 min</td>
<td>25 mgr</td>
<td>230 mgr</td>
<td>192 Gr</td>
<td>8Gr (4%)</td>
</tr>
<tr>
<td>13 min</td>
<td>16 mgr</td>
<td>230 mgr</td>
<td>190 Gr</td>
<td>10Gr (5%)</td>
</tr>
<tr>
<td>27 min</td>
<td>127 mgr</td>
<td>230 mgr</td>
<td>200 Gr</td>
<td>Without Alum</td>
</tr>
</tbody>
</table>

Step 1: Primary Occlusion Time of Gypsum and Alum Mix With Different Percentages-Gypsum Without Alum (Source: Author, 2016)

2grs (1%)

alum less

4grs (2%)

6grs (3%)

8grs (4%)

10grs (6%)

Alum Percentage in the Gypsum (gr)
Diagram 1: Diagram of Primary Occlusion Time of Gypsum and Alum Mix With Different Percentage-Gypsum Without Alum (Source: Author, 2016)

Step 2: Final Occlusion

The samples were checked after a week in university lab. Samples without alum was completely occluded and changed as a stone, i.e. it was impossible to make pattern on them. It was possible to make patterns on samples with 1%-5% alum. However, 4% and 5% sampled ones had hollowness form and became powder under hand pressure. Samples of 1%, 2% and 3% also had abilities to make pattern and stucco decoration completely by nail & cutter. This ability indicates key role of alum in stucco decoration during different periods. Lighter colors of these samples with various percentages of alum comparing to alumless samples, of course, emphasizes the aforementioned ability.

Step 3: Comparison of Moisture Reabsorption

To compare moisture reabsorption, we measured all samples in certain weights. Weight loss of samples equal to 14 grs as moisture changed them completely hard & tight so that it was hard to scratch them by nail. All samples with weight 56 grs after 1 hour placed inside 30 grs water as 6 separate resells. Time then started to compare moisture reabsorption in samples with 1%-5% alum and without alum samples. In fact, aimed to check the role of alum to absorb the moisture mixing the gypsum.

Changes of Samples after Moisture Absorption
4% and 5% samples changed after 2 hours and 10 minutes. The sample without alum also had this problem in a more severe way. 1% & 2% and 3% samples, however, kept their visual stabilities and
didn’t change with the moisture. We concluded that samples with 1%-3% alum help artists to occlude late. Gypsum samples with 1%-3% alum after stucco decoration and dryness require less time than pure gypsum samples for moisture of absorbed water and they tend to be more tolerant. Pure gypsum changes due to the precipitation and loss of its stability (Diagram 2).

<table>
<thead>
<tr>
<th>Visual Position Of Samples After Reabsorption</th>
<th>Time of Reabsorption (min)</th>
<th>Water Weight Plunging The Samples (mgr)</th>
<th>Mix Weight Of Gypsum &amp; Alum After Moisture Absorption (mgr)</th>
<th>Mix of Water &amp; Gypsum (Gr)</th>
<th>Alum (Gr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without collapse</td>
<td>130 min</td>
<td>13 mgr</td>
<td>30 mgr.</td>
<td>56 Gr</td>
<td>Mix of water &amp; gypsum (1%)</td>
</tr>
<tr>
<td>Without collapse</td>
<td>130 min</td>
<td>14 mgr</td>
<td>30 mgr</td>
<td>56 Gr</td>
<td>Mix of water &amp; gypsum (2%)</td>
</tr>
<tr>
<td>Without collapse</td>
<td>130 min</td>
<td>14 mgr</td>
<td>30 mgr</td>
<td>56 Gr</td>
<td>Mix of water &amp; gypsum (3%)</td>
</tr>
<tr>
<td>Collapsing</td>
<td>130 min</td>
<td>19 mgr</td>
<td>30 mgr</td>
<td>56 Gr</td>
<td>Mix of water &amp; gypsum (4%)</td>
</tr>
<tr>
<td>Collapsing &amp; form change</td>
<td>130 min</td>
<td>26 mgr</td>
<td>30 mgr</td>
<td>56 Gr</td>
<td>Mix of water &amp; gypsum (5%)</td>
</tr>
<tr>
<td>Collapsing &amp; form change</td>
<td>130 min</td>
<td>23 mgr</td>
<td>30 mgr</td>
<td>56 Gr</td>
<td>Gypsum without Alum</td>
</tr>
</tbody>
</table>

Step 2: Comparison of Moisture Reabsorption By Gypsum Mixed With Alum In Various Percentages- Gypsum Without Alum (Source: Author, 2016)
Diagram 2- Moisture Reabsorption Level in Gypsum and Alum Mix With Different Percentages-Gypsum without Alum
(Source: Author, 2016)
Conclusion

Discussed hypotheses concluded that study of technology during the Seljuk period in Zanjan province has a monotonous study of technology. Elemental analysis of three studied buildings indicate that elements such as Sodium, Magnesium, Potassium, Calcium, Iron, Phosphorus, Titanium, Sulphur, Scandium and Lead. All samples had alum (Al₂O₃) with completely approximate levels.

That supposed that materials of stucco decoration of buildings during the Seljuk period in Zanjan province were associated with climate and environmental conditions. Therefore, it is concluded that Al₂O₃ (alum) as an additive material is not associated with environmental conditions. However, Al₂O₃ reported in the building of Seljuk period in Ghazvin province. Alum helps the artist to both make pattern and stucco decoration owing to increasing the work time and also to protect the item against harmful agent and raises their stabilities. This characteristic, of course, belongs to items when mixing 1%-3% alum & gypsum. Physical tests confirm this hypothesis and XRF elemental analysis shows an amount of 2% alum in samples, too.

Architecture method during the Seljuk period may be seen in these three buildings. Their different applications, however, indicate different stucco decorations. Last resting-place of Pir Ahmad Zahr Noosh lacks stucco decoration as inscription and just contains simple stucco decorations under the dome-house. Ghorveh Catholic Mosque and Sojas Catholic Mosque contain plaster-molded inscriptions and the former inscriptions are the colored ones painted by next dynasties especially depth of letters are higher in Sojas Catholic Mosque and they are completely embossed. There are many beautiful geometrical designs in Sojas Catholic Mosque and these designs may be seen less in Ghorveh Catholic Mosque by the adytum.
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