INTERNATIONAL JOURNAL FOR INNOVATIVE RESEARCH IN MULTIDISCIPLINARY FIELD ISSN: 2455-0620 Volume - 5, Issue - 6, June – 2019
Monthly, Peer-Reviewed, Refereed, Indexed Journal with IC Value: 86.87 Scientific Journal Impact Factor: 6.497
Received on : 16/06/2019 Accepted on : 19/06/2019 Publication Date: 30/06/2019

HISTORICAL TECHNOLOGY OF PRODUCTION OF GYPSUM MORTAR OF HISTROIC MONUMENTS IN CENTRAL ASIA: A REVIEW

[1] Kamilov Shukrullo Khabibillaevich, [2] Kamilov Khabibilla Khamidovich

[1]Master, researcher of the Department "Building materials and chemistry", Tashkent Institute of Architecture and Construction, Tashkent, Uzbekistan
[2]Candidate of Technical Sciences, Professor of the Department "Technology of building materials, products and structures", Tashkent Institute of Architecture and Construction, Uzbekistan

Abstract: *The article addresses the issue of the historical technology for the production of gypsum-based mortars used in the historical monuments of Central Asia. It also provides data on the historic structures of the kilns, fuel, gypsum calcination technology, as well as the types of gypsum-based mortars used in the construction of historical monuments of Central Asia, in particular Uzbekistan.*

Key Words: *gypsum, ganch, clay, tsemyanka, calcination, kilns, mortars, architectural monuments.*

1. INTRODUCTION:

The study of building materials of architectural monuments is of considerable interest not only for opening the page of the history of material culture, but also for taking into account the centuries-old experience of craftsmen in the use of local raw materials and the production technology of works during restoration. Investigating the material, it is necessary to find out how many centuries, in what construction and in what conditions this material worked or what factors caused its destruction. In addition, it is necessary to determine from what components, in what proportions and in what way it was prepared.

Unfortunately, written sources devoted to the description of the manufacturing technology of ancient building materials have not reached our time. As a rule, the ancient masters kept their practical knowledge in secret. Usually they passed from mouth to mouth, from father to son, from teacher to student. Some fragmentary information received from old-timers of settlements near monuments is often distorted and exaggerated. But all this can not show the properties of the materials used in antiquity: their characteristics and formulation. Therefore, the manufacturing technology of old-time materials to the present time remains to the end unresolved.

The greatest interest represents building mortars used in the construction of ancient structures. Vast majority of ancient mortars often contains the active filler, which creating the basis of the mortar, simultaneously chemically reacts with one or several components of the binder. The scope and types of mortars in the architectural monuments of Central Asia developed primarily under the influence of the local natural and climatic conditions of the region. Along with clay, mortars based on calcined gypsum and ganch were used in construction of historical monuments [1-3].

Ganch (local name in Central Asia) or gazha (local name in the Caucasus) is a binder obtained by calcining a natural mixture of gypsum with clay. Gypsum content is from 40 to 70% [4].

In Central Asia, the following types of gypsum-containing minerals are the most commonly used - natural gypsum, natural anhydrite, ganch and arzyk, from which our ancestors successfully obtained binders. In literary sources information on the use of natural anhydrite in historical monuments is absent. Arzyk, like ganch, is a type of mechanical mixture of calcium sulfate dihydrate with loess loams. Arzyk differs from ganch only in its structure: ganch has a stone-like structure, and arzyk – earthy texture. Arzyk is very porous and loose, in appearance it resembles a dirty gray sponge. After calcination the arzyk is inferior in its quality to the calcined ganch, but it is quite suitable for wall construction [5-6]. Due to the loose structure the arzyk was ground and then calcinated (boiled) in boilers [5]. Such artisan technology of arzyk calcination is practiced even at the present time.

Natural gypsum and ganch were calcinated in filled round kilns (khumdons), the shape and structure of which allowed placing the calcinable materials in the form of a dome over a firebox that occupied all the space inside the kiln. In literary sources there is fragmentary information about ganch calcining. In our opinion, the equipment of ancient ceramic hearths and kilns should be identical with the khumdon for calcining ganch. Therefore, our further research was focused on the study of ancient kilns.

2. ANCIENT KILNS:

In order to study the design of ancient kilns for firing of building materials, we turned to archaeological research materials relating to ancient pottery [7-10] brick [11] kilns of Central Asia. Considering the archaeological materials associated with ancient kilns, it is regrettable to note that archaeologists mainly paid attention to the remains of ceramics and shards, as well as ancient coins. Unfortunately, very little attention has been paid to the remains of combustible material, ash and calcinable material. Archaeologists have collected a large amount of information about historical ceramic production, which can be divided into five chronological periods: the Bronze Age, the period of the formation of class society (it was of great importance for the development of crafts), the ancient period, the time of the formation of the feudal society and the Middle Ages [11,13-19].

Considering the design of kilns, it is safe to say that they were mainly two-chamber, i.e. consisted of a firebox and kiln [7-12]. There are also double-deck kilns [11]. In addition, over time, the design of these kilns improved (Fig. 1).

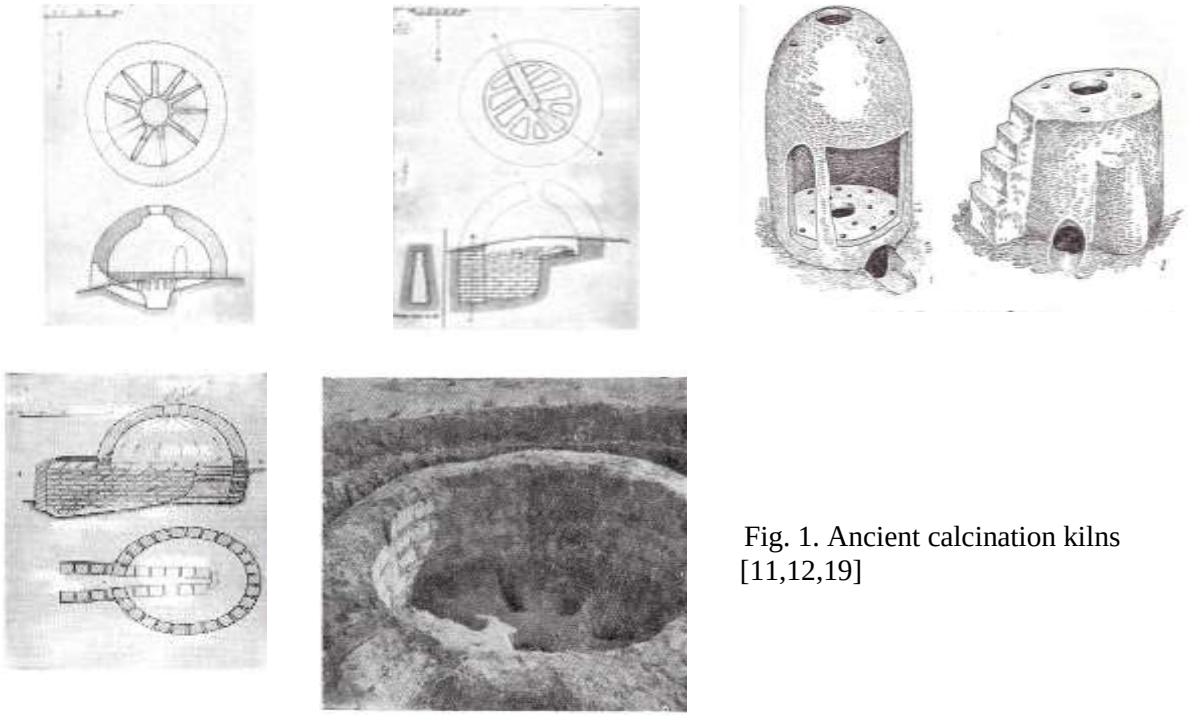

Fig. 1. Ancient calcination kilns [11,12,19]

The kilns considered were oval, round and rectangular. In particular, a rectangular furnace had an arched overlap of the firebox, round hearths with a supporting column in the center of the firebox [20]. It should be noted that the characteristic of all kilns is that they were mainly made of adobe. With very little modification, two-chamber kilns are even now being used to fire ceramic materials.

3. FUEL:

Kilning is the most responsible operation. Unfortunately, there is not enough data about the fuel used by medieval craftsmen. Such material as ash in the kilns, the remains of coal had little interest of archaeologists until recently. But nevertheless, handwritten sources and ethnographic materials contain some data on the ashes of the furnaces and in some cases the name of a particular fuel of medieval potters. S.B. Lunina writes [15] that at the bottom of the firebox of the kiln there was a layer of pure gray ash with charred prickles and coals. In the fuel orifice and beyond it there was a layer of large charcoals. In addition to wood fuel and prickles, cane and wood chips were probably used. Ar-Razi [21] calls wood chips as fuel.

The main criterion for the selection of fuel was its ability to produce a hot, dry flame. Surely the fuel was carefully selected. Probably, sometimes the fuel changes when firing products of the same type (glazed or unglazed).

In general, it is preferable to use well-dried firewood for burning the material. According to ethnographic materials the following types of such fuel are known [12, 22]: willow twigs, steppe grasses, camel's-thorns, reed, cane «shah», brushwood, chigit (cotton seeds), etc. (Fig. 2).

Saxaul [23]

Wormwood [24]

Camel's-thorns [25]

Rice husk

Shuvok (mugwort)

Fig. 2. Some types of plants used as fuel

Wood fuel has a number of valuable qualities, among them: easy flammability, the ability to burn with a long flame and low ash content [22]. One of its main disadvantages is insufficient calorific value, however, this is partially eliminated by thorough drying. In addition, it should be noted that wood is a deficient material in Central Asia. The use of manure and litter, in our opinion, was excluded, firstly, because this fuel gives less heat, and secondly, it gives a lot of soot.

4. PREPARATION FOR CALCINATION:

According to [12], on the day of calcination in the morning masters began to prepare the kiln-khumdon, which was previously cleaned of ash. A boy was lowered into the firebox; he filled the bucket with ash and handed it to the top. Then the masters greased the fallen edges of the firebox with clay and straw and cleaned the holes connecting the kiln chamber with the firebox.

Based on the foregoing and analyzing the design of the kilns, it can be assumed that the gypsum stone was loaded into the khumdons through the opening located on the side wall, and in its absence through the hole in the upper part of the burning chamber. Before loading, in our opinion, the gypsum stone or ganch prepared for calcination was sorted by size. The smallest pieces were laid on the very top. After the furnace was loaded, the side opening was laid with bricks.

5. CALCINATION:

The mining and burning of the ganch was carried out by specialists called gachpaz [26]. According to the data cited, the burning in the khumdon took place as follows [12]: by evening, between five and six o'clock, a fire was set up in the pit under the kiln. First, dry firewood was burnt. Fuel was put gradually. Two donkey's bales of firewood were burned. Then the main fuel began to burn. Using pitchfork a person who fires a kiln threw fuel into the firebox with uniform, automatic movements, where it caught fire, without reaching the bottom. The kiln was heated for several hours. Ganch was calcinated for 6–7 hours (sometimes up to 24 hours [27]), than the fueling stopped, not immediately, but gradually, as it was believed that this was important for obtaining high-quality material [24].

According to the cited data [27], ganch was calcinated in khumdons at a temperature of 135–150°C for 8 hours, according to [2] - at a temperature of 200°C, and [3] - at 400°C and more. In our opinion, it would be correct to use the expression that the firing temperature of the material reached the indicated values, since the analysis of modern gypsum calcining plants shows that when calcining in rotary kilns, the temperature of the incoming gases is 700°C and that of the waste ones - 120°C, the flame temperature in the firebox of boilers for calcination reaches more than 700°C, the temperature is controlled, and the temperature uniformity (140-170°C) of the material to be calcinated achieved by constant mixing [28]. Unlike modern technology in the old days gypsum was burned in large pieces. Analysis of ancient pottery and brick kilns made it possible to find out [11, 22] that the temperature in the chamber during the burning of ceramic materials reached 1200°C.

When all the fuel was fired, the firebox hole was laid with large bricks and covered with clay. After two days, the kilns were opened and the finished material was removed. It can be assumed that the calcination process was exactly the same. After calcination, the ganch was given necessary time to cool completely in the kiln. As according to the opinion of ancient masters, when grinding ganch before complete cooling, its strength decreases.

In the old days during one firing, the humdon with a diameter of about 2 m produced about 4-5 tons of calcined gypsum. The six-hour calcining of the gypsum in the ancient khumdons is insufficient, which is confirmed by the experimental data obtained by us [29]. The gypsum weighing 200 kg was calcined according to the old technology for 6.5 hours in a model of an ancient khumdon with a diameter of 60 cm. The loaded material was conditionally divided into two layers. Chemical analysis has determined that the lower layer consists mainly of gypsum (up to 70%) of high-temperature calcination, and the second upper layer contains mostly unfired gypsum (up to 50%) and calcium sulfate dihydrate. On this basis, it can be assumed that the 24 hour calcining will be more reliable.

5. GRINDING:

Grinding of the calcinated material was carried out on a tamped area using pigs of iron. This method of grinding was practiced even until the forties of the last century. During this period, even the services of tractors were used for grinding [30]. The ground material was sorted using sieves with different holes, which made it possible to immediately sort the material according to the grain size. From the point of view of the old experienced builders, to produce the most durable mortar, ganch should be ground to the size of grains of semolina [27].

6. MORTAR PREPARATION:

As is well known, a binder based on gaging plaster is characterized by rapid setting. Bearing in mind this property masters prepared mortars for specific purposes, which the mortar preparation methods depended on. Not only in the old days, but nowadays masters use the following types of mortar preparation - tezganch, gulganch, sokhtaganch, dogob and hovonda [26,31-33]. Prepared by these methods, the mortars had different setting times and strength properties.

For the dilution of ganch, a special person was appointed - ganchsoz, whose duty was to gradually dilute the ganch with water and give it to the working master as needed.

If the ganch was intended for pure plasters and decorating, it was cleaned of soot and smut after being unloaded from the kiln; after grinding it was a clean, white-colored material called gulganch [31]. Gulganch was used for the top layer of plaster, finishing work - making of carved and painted panels, grates, borders, stalactites and so on.

For the preparation of masonry mortar crude tezganch of grayish color was used [26]. The addition of sifted soil increased plastic properties of the raw ganch mortar.

To improve the properties of the mortar, various additives were used - unburned (clay, loess loam, kizil kesak (lump of dry clay), limestone, sand, etc.), burned (tsemyanka, lime, vegetable ash, etc.), organic (sheresh, egg, milk, suzme (sour milk), grape extracts , carpenter's glue, etc.), fibrous (reed fluff, finely chopped stalks of cereal, etc.), etc. [2,3,5, 26,27, 30-34]. Most often, these additives were used in combinations.

“Sheresh” is prepared from the roots of a mountain plant “Sarchuk” (genus *Eremurus*, family *Liliacaea*), which grows in Central Asia, Afghanistan, Iran, on mountain slopes from the Crimea and the Caucasus to the Altai and the Himalayas. The roots contain the eremuran polysaccharide, which is used to produce glue; paint is extracted from the leaves. Young shoots and roots of Eremurus are edible [35–37]. The roots of the plant are dug out in the fall, dried and crushed into powder. Its additives in small doses (0.5-1%) increase the water resistance and strength of gypsum [1,2, 27,33,34].

In our opinion, the ancient architect during the construction of a structure probably took into account all the above conditions, as evidenced by the existence of our ancient buildings.

7. CONCLUSION:

Working conditions of building materials have a strong influence on the basic characteristics of these materials in different ways. The composition of the material we can determine in the laboratory. Therefore, taking into account the above, it is necessary to determine the composition of the material during the study, namely: the name of the components, the proportions, and the methods of preparation.

In studies of building mortars of historical monuments, one encounters difficulties associated with determining the composition of a gypsum based mortar, since almost all the modifications of gypsum that are produced during calcining in the khumdons, after hydration, form calcium sulfate dihydrate.

In addition, it is necessary to find out what types of fillers and in what form were added to the mortar, whether these clay substances were included in the feedstock as an impurity or were introduced separately in the form of sifted soil.

If the mortar composition contains calcined products of clay minerals, then researchers can consider two variants. The first variant: the ganch was calcined at high temperature, as a result of which the clay minerals are dehydrated and anhydrous minerals are formed. The second one - a tsemyanka (dehydrated loess or crushed brick) was added to the finished calcined gypsum.

Thus, it should be noted that in order to obtain more specific data, it is necessary to further investigate the process of calcining gypsum stone according to the old technology and compare it with modern ones, because when using different modern technologies of calcining gypsum stone, which is produced from one quarry you can get gypsum of different brands.

REFERENCES:

1. Prityko G.I., Raw building materials. In the book. Construction materials of Uzbekistan. Collection. Publ. Acad. of Sci. UzSSR. Tashkent, 1951. p. 78-84.
2. Grazhdankina N.S. Ancient building materials of Turkmenistan. Proceedings of YTAKE. Vol. VIII. Publ. Acad. of Sci. of the Turkmen SSR. Ashgabat - 1958.
3. Grazhdankina N.S. Architectural and building materials of Central Asia. Tashkent, "Uzbekistan". 1989. p.
4. Great Soviet Encyclopedia. 10. State Sci. Publ. "GREAT SOVIET ENCYCLOPEDIA" 1952.
5. Khakimov A.Ya. Gypsum binders. In the book. Construction materials of Uzbekistan. Collection. Publ. Acad. of Sci. UzSSR. Tashkent, 1951. p. 125-160.
6. Bachinsky I. M. On the use of local building materials in Turkmenistan. Bulletin of Acad. of Sci. USSR. 1952. № 8.
7. Tolstoy S. G. Ancient Khorezm. The experience of historical and archaeological research. Ed. by Moscow State University. Moscow - 1948.
8. Lunina S.B. Technical arrangement of pottery kilns of medieval Merv. Transactions of YUTAKE. Vol. VIII. Publ. Acad. of Sci. of the Turkmen SSR. Ashgabat — 1958.
9. Vorobyov M.G. The experience of mapping pottery kilns for historical ethnographic atlas of Central Asia and Kazakhstan. In Coll.: Materials to the historical and ethnographic atlas of Central Asia and Kazakhstan. Acad. of Sci. of the USSR. Proceedings of the Institute of Ethnography named after N.N. Miklouho-Maclay. New series. Vol. XLVII1. Publ. Acad. of Sci. USSR. Moscow-Leningrad. 1961. p. 147-179.
10. Ekimova V.V. Pottery production in the Khiva district (based on materials of a trip to Uzbekistan in 1930). In the book. Pottery of Khorezm. Ed.: S.P. Tolstova and M.G. Vorobyova. Publ. Acad. of Sci. USSR. Moscow 1959.
11. Akhrarov I. Brick kiln of the XI century on the old settlement of Kuva. In Coll.: The history of material culture of Uzbekistan. Iss. 3. Acad. of Sci. UzSSR. Institute of History and Archeology. Publ. Acad. of Sci. UzSSR. Tashkent. 1962. p. 80-86.
12. Peshtereva E.M. Pottery production in Central Asia. Publ. Acad. of Sci. of the USSR. Moscow-Leningrad. 1959.
13. Bolelov S. B. Pottery of ancient Khorezm according to archaeological data (The second half of the 1st millennium BC - the first half of the 1st millennium AD): Dis. ... Cand. Hist. Sciences: Moscow, 2005. 242 p.
14. Rappoport P.V. Building production of ancient Russia in X-XIII centuries. St. Petersburg. RAN. 1994. 160 p.
15. Lunina S.B. Pottery industry in Merv, X - early XIII centuries. Proceedings of YUTAKE. Vol. XI. Publ. Acad. of Sci. of the Turkmen SSR. Ashgabat. 1962 p. 217-417.
16. Rtveladze E., Iskhakov M. Two medieval villages of Chaganian. IMKU. Issue 15. Publ. "Fan" of the Uzbek SSR. Tashkent. 1979. p.84-94.
17. Rakhmanov U. Excavations of the ceramic firebox of the Sapalli culture on Bustan 4. IMCU. Issue 15. Publ. "Fan" of the Uzbek SSR. Tashkent. 1979. p. 35-43.
18. Zaurova E.Z. Ceramic kilns of the 7th-8th centuries in the town of Gyaur-Kala of the ancient Merv. Proceedings of YUTAKE. Vol. XI. Publ. Acad. of Sci. of the Turkmen SSR. Ashgabat. 1962 p. 252-303.
19. Merezhkin L.I. To the characteristic of the ceramic kilns of the period of slavery and the early Middle Ages in Mervok oasis. Proceedings of YUTAKE. Vol. XI. Publ. Acad. of Sci. of the Turkmen SSR. Ashgabat. 1962 p. 12-40.
20. Sarianidi V.I., Ceramic industry of ancient Margian settlements. Proceedings of YTAKE. Vol. VIII. . Publ. Acad. of Sci. of the Turkmen SSR. Ashgabat -1958. p. 313-345.
21. Karimov U.I. Unknown essay by Ar-Razi "The Book of the Secret of Secrets." - Tashkent: Publ. Acad. of Sci. of UzSSR, 1957 - 193 p.

22. Saiko E.V. The history of ceramic technology in Central Asia of VIII-XII centuries. Editor - Professor A.I. Augustinik. Publ. “Donish”, Dushanbe, 1966. -212 p.
23. https://ru.wikipedia.org/wiki/%D0%A1%D0%B0%D0%BA%D1%81%D0%B0%D1%83%D0%BB#/media/%D0%A4%D0%B0%D0%B9%D0%BB:Haloxylon_ammodendron.jpg
24. https://upload.wikimedia.org/wikipedia/commons/a/af/Wormwood_bush.jpg
25. http://www.gardengreen.ru/media/1/N_47.jpg
26. Pisarchik A. K.. Folk architecture of Samarkand, XIX-XX centuries (based on materials of I938-1941). Publ. "Donish" Dushanbe - 1974.
27. Bachinsky I.M. On the use of local building materials in Turkmenistan. Bull. of Acad. of Sci. of the USSR. 1952. № 8.
28. Gypsum materials and goods (production and use). Ref. book. Under the gen. ed. of A.V. Ferronskaya. -M .: Publ.ACB, 2007. - 488 p.
29. Kamilov Sh., Tulaganov A., Kamilov Kh., Laue S., Fisher H.-B. Gipshaltige Baumörtel der Historishen Denkmäler Zentralasiens. 1WEIMARER GIPSTAGUNG. Weimar Gypsum Conference. 30-31- März 2011. Weimar. BRD. S.331-342.
30. Khakimov A.Ya. Gypsum binders. In the book. Construction materials of Uzbekistan. Collection. Publ. Acad. of Sci. of UzSSR. Tashkent, 1951. p. 125-160.
31. Bulatov S. Uzbek folk applied ornamental art. (Teaching methodical manual) / (Ed: M. Usmanov and etc., worked by M. Tursunov and T. Maxmudov). T .; Mekhnat, 1991. 384 p: pictures.
32. Bulatov S., MukhtorovA. Ganchkorlik san'ati. Oliy oquv yurtlari uchun darslik /S. Bulalov, A. Muxtorov. - Ò.:Musiqa, 2006. p.124.
33. Zokhidov P.Sh. Architectural world. General edition. Tashkent – p. 1996 -240.
34. Znachko-Yavorsky I.L. Essays on the history of binders from ancient times to the middle of the XIX century. Institute of History and Science and Technology of the Acad. of Sci. of the USSR.. Publ. Acad. of Sci. of the USSR.. Moscow-Leningrad. 1963. 499 p.
35. Khokhryakhov A.P. Eremurus and their culture. Pub. Science, Moscow 1965, 129 p.
36. https://ru.wikipedia.org/wiki/%D0%AD%D1%80%D0%B5%D0%BC%D1%83%D1%80%D1%83%D1%81
37. N. I. Annenkov. Botanical Dictionary. - SPb .: Imper. Acad. of Sci., 1878. - p. 135.