

REVIEW PAPER

REVIEW OF AN ANCIENT PERSIAN LIME MORTAR “SAROOJ”

Mohammad Mehdi Masoumi^{1*}, Hanieh Banakar² & Bahar Boroomand³

¹Department of Civil Engineering, Young Researchers and Elite Club of Islamic Azad University, Science and Research Branch, Fars, Iran

²Department of Textile Engineering, Isfahan University of Technology, Isfahan, Iran

³Department of Architecture, Central Tehran Branch Islamic Azad University, Tehran, Iran

*Corresponding Author: m.masoumi@rocketmail.com

Abstract: Sarooj is an ancient Persian lime mortar of great antiquity which is hydraulic lime mortars and so compatible with the environment because of its ingredients. Sarooj has been used frequently in Iran since 1200 B.C. until the last decades, especially in the southern area; across the Persian Gulf, the most different climates which proves that Sarooj is highly compatible with different climates. The more practical methods of setting procedure of Sarooj is explained in detail. One of the most important features of Sarooj is its impermeable characteristic among mortars. Sarooj has not been a major highlight among researchers for many years, but recently this material has started to gain some interest among researchers in Iran. This paper highlight the importance and benefit of Sarooj in construction by revieweing its ingredients, chemical and mix design, additives, and physical properties of Sarooj.

Keywords: Ancient Persian lime mortar, Sarooj, Sarooj ingredients and process

1.0 Introduction

Mud seems to be the first binding material employed to fabricate mortars in ancient buildings, which has been in use till now in some areas all over the world. In ancient Egypt, mud mortars were used to joint mud bricks, while for the joining of carved stone blocks gypsum was preferred [1]. However, there are many monuments and historical sites in Iran, which some of them have been built more than two thousand years ago such as Anahita temple, Goodin hill, Takht-e Soleymān, Persepolis, Chogha Zanbil and so forth. Their building materials included stone and mortar such as mud, grout, clay and “Sarooj” (lime mortar). Chogha Zanbil built about 1250 BC, is an ancient Elamite complex in the south-west of Iran. Sarooj has been used in some wings of the monument such as in its water refinery and in some rooms [2]. In the ancient Elamite hydraulic lime mortar was known as Sarooj [3] and lime mortar is one of the oldest known types of mortar. Most references declare lime mortar dating back to the 4th century BC and

widely used in Ancient Rome and Greece, when it largely replaced the clay and gypsum mortars common to Ancient Egyptian construction [4]. Chogha Zanbil is a crystal clear proof showing that some of these references are not precise. For the preparation of mortars and concretes, various materials were employed; gypsum and lime were used for rendering since ancient times, but in structural mortars and concretes the use of lime was dominated, possibly because of problems created by gypsum [1].

The Ancient Egyptian used impurity gypsum while the Roman used slaked lime with which composed ash and broken potteries so that they could provide hydraulic lime like for example in Pantheon, Rome [5]. The Roman expanded the technique of adding pozzolanic materials to lime-based mortars all over their empire [6] but there is no historical evidence that how they learned this technique. It is probable that they learned from Persians regarding the fact that Sarooj had been used in Chogha Zanbil (1250 B.C.) many centuries before the Romans [7]. In the past, Sarooj was so valuable for the Iranians, having built structures, which highly linked with water, such as water reservoirs, ponds or cisterns (Ab-Anbar). Sarooj has been used in many buildings which have remained structurally sound after many years [5, 8] bearing in mind that Iran is earthquake-prone [9]. The last time that Sarooj was mostly used in Iran was about eighty years ago [10] and then it was replaced with cement [3].

This paper explains the use of Sarooj in Persian archeological buildings throughout modern Iran, the chemical and mechanical properties of Sarooj and its variety of ingredients in this territory.

2.0 Sarooj in Iran

From Iranian architecture point of view, Sarooj has a great position in Iranian architecture and architects hold the view that Sarooj is inseparable part of the Iranian culture. One of Iranian famous structure is Si-o-se Pol Bridge in Isfahan, highly ranked as being one of the most well-known structures of the Safavid dynasty, was made with Sarooj [11]. Sarooj is a traditional and ancient lime mortar, in the group of hydraulic mortars which needs moist or being engulfed in water, so that its setting procedure could perform better and faster. It is included slaked lime, sand, water and clay, sometimes ash into the bargain, in the next parts Sarooj ingredients and preparation are explained. Moreover, it was carried out in humid climates or where a quite a bit amount of water was available. Sarooj is impermeable as plaster and that is why it has been used frequently in the southern half of Iran, especially across Persian Gulf [11].

3.0 Sarooj across the World

In other countries such as Oman, Sarooj was found in places where Iranian culture and civilization were dominated in the past [10]. Therefore, it is not out of expectation that Sarooj was found in Afghanistan with the same ingredients on the whole [16]. Their method to make Sarooj was also similar to the Iranian method. Sarooj as for artificial pozzolana was produced by burning (calcining) clay. Calcined Clay pozzolans was mixed with lime and water and was applied as a cementitious material in construction [1].

4.0 Traditional Sarooj Preparation in the South of Iran

People in the south of Iran (Bushehr), especially in villages where could not access to the ordinary Portland cement, traditionally used to make Sarooj in three definite stages apart. In the first stage, 3 parts of dung were added to 1 part clay and then kneaded and mixed thoroughly. Afterwards, the mixture was thrown in a trench in the ground and then water was added to it. After one or two days, the wet mixture was pulled up from the trench, spread on the ground with approximately 5 cm thickness and grooves were made on it while rectangular or square tablets were made (dimensions about 20 to 30 cm) so that after drying they can easily be divided into casts. After a couple of days, these casts were completely dried, known as “Kheshtak”. In the second stage, some shavings and brushwood were spread on the ground. Then the dried casts (Kheshtaks) were laid on them with a little distance apart then ready for burning. The shavings and brushwood were burnt under the Kheshtaks which were heated completely. In the third stage, all the casts became loose, but clay was baked in the casts, hence, they were more or less stiff. They were crushed and ground and this step of Sarooj making was the most difficult stage (In the past, they did not have specific grinder, therefore, the casts were shattered with stiff sticks in hours) after shattering all the casts, 1 part of lime was mixed with 20 parts of the shattered casts. This product named Sarooj. People hold the view that the quality of Sarooj depended on its fineness, means the finer diameter of ingredients, the better Sarooj. Its color was either grayish brown or dark gray. This method was used up until fifty years ago [14].

5.0 Ingredients of Sarooj and Preparation

Sarooj is divided into two groups, first, Sarooj Sard (cold Sarooj) and second Sarooj Garm (warm Sarooj) [12]. “Warm Sarooj” is a hydraulic lime mortar, obtained from slaked lime which contains clay. This mortar is abundantly found in the south of Iran, along the northern coast of the Persian Gulf. The most famous Sarooj of this kind belong to Khamir Harbor. “Cold Sarooj” binders were made up of lime and ash, mixed with water, so that it could be very durable. Clay and sand used to be mixed as filler and also

as the skeleton of the mortar [13]. Wool and hair also used to be added for preventing the mortar from crack [12, 13]. Sarooj had diverse ingredients, particularly differences in composition of ingredients, which spring from a variety of climates in Iran. Furthermore, regarding the differences in the structure wings, Sarooj was used. The general ingredients for all types of Sarooj are: slaked lime, clay and sand. Ash, obtained from burning animal dung was also added. Manure and fertilizers such as bran of rice, fibers (wool and hair or remains of plants such as sugar cane), and water were among the ingredients. Milk and albumin were also used occasionally [14]. Egg-containing Sarooj was used in Kabar dam, which was built during the Sassanid Empire and also in Bandben Castle in Gilan (in north of Iran) [15]. Archeologists believe that egg could enhance the mortar strength [11]. Common ingredients in most other lime-based mortars are slaked lime, water, fiber as reinforcement and sand, but the rest of the ingredients such as milk, egg specially albumin, fertilizer, dung (manure) made Sarooj be slightly much different.

6.0 Ingredient Properties

6.1 Lime

All mortars include filler (around 80 % of the mortar volume) and binder (less than 20%). Lime acts as a binder in Sarooj and this is the main reason that Sarooj has been put into the hydraulic lime mortars group. Carbon dioxide (CO_2) does not tend to react with lime, unless when moisture is available. In the chemical process, water substitutes for carbon dioxide and then turns it into limestone. Sarooj properties depend on the lime's quality and type. The amount of magnesium in lime is directly linked to the resistance and plasticity of the mortar. Calcium accelerates the process of lime setting while Sarooj naturally has a long setting time. The process has two stages, the first stage is binding and the second stage is strengthening [16].

Properties of slaked lime (Calcium hydroxide)

1. In the reaction, Quicklime releases heat and its volume increases. This depends on the type of lime. The more CaO in the mortar, the more reaction will have with water and finally the volume will be increased. Therefore, if there is enough CaO, the volume rises twice or evens 3.5 times as much as its first volume, with at least 25% increase in volume.
2. The specific weight of Slaked lime is about 2.2 kg/m^3 , moist (wet) paste of lime is 1.4 kg/m^3 and dry paste is 0.7 kg/m^3 .
3. Slaked lime powder size often is less than 2mm in diameter.
4. The volume of the mortar (lime and sand) and slaked lime is constant. After binding and strengthening no contraction, neither shrinkage nor volume changes occur.

5. After 28 days, the pressure tolerance of the mortar with 1 part of lime and 3 parts of sand placed in a humid environment was 1MPa. This mortar is suitable for outdoor usages so that it can absorb CO_2 and then gradually gains strength [14].

6.2 Silica and Ash

In producing Sarooj mortar, active silica is an important material which is known as amorphous silica. In order to provide the silica, it was usual to use the ash, which was made by burning charcoal for baths or burning the dung of animals. Nowadays, silica fume (micro silica) is substituted for conventional ashes. Adding micro silica to Sarooj mortar would result in a remarkable increase in its mechanical resistance, and both tensile and compressive strength. This is due to a decrease in both porosities percentile and voids between ingredients in the binding stage and also the pozzolana characteristic of micro silica. Increasing the tensile strength as a result of using micro silica will lead to a decline in the strains which comes from freezing conditions. Additionally, the amount of micro silica is an important factor and using an excess of it will delay the setting of Sarooj [14].

The amount of ash and silica provided from burning some vegetation is shown in Table 1. Table 1 shows that rice husk has the highest amount of ash and silica (93%) while specific weight is 2290 kg/m^3 , which is used as a pozzolana material to produce pozzolana cement. Survey and consideration results on the physical, chemical, mechanical and thermal properties of ash are hereunder:

1. 200 kg husk is produced from 1000 kg rice, which provides about 40 kg ash after burning.
2. Across the world, rice husk ash has 85 to 95 % silica.
3. The binding property of rice husk ash decreases with increasing temperature and heating time, e.g. the maximum binding property would be at 500°C and 2 hours heat treatment, while it will drop at 1100°C .
4. In order to affect separating mineral material from cellulose in the husk, it is necessary to access air and to extract carbon dioxide from its surroundings during the burning process. This condition controls carbon removal and consequent physical changes in silica.
5. Properties of crystalline silica in rice husk ash have an inverse relation with binding property.
6. The relation between grinding time and fineness of ash at different temperatures determines that the specific area is reduced for a specified time by increasing the ignition temperature [14]. According to a report by a Malaysian research team, the husk burnt at a temperature not exceeding 690°C . The heating and cooling ramps, burning duration, in addition to the temperature inside the furnace are

shown in Figure 1. The specific surface area of the ash is shown in Figure 2 representing the grinding time against the average particle size. It can be seen clearly that the surface area increased only slightly by increasing the grinding time. In their experiment, rice husk ash was ground using a Los Angeles machine, the size decreased from 63.8 to 11.5 μm for a grinding time of 90 to 360 minutes, respectively [17].

7. The rice husk ash can be used as an artificial pozzolana. Physical and chemical properties are included in the N category, according to ASTM~c618 Standard.
8. For a mortar with a constant rice husk ash, the amount of required water is decreased with increasing the fineness of ash [14].

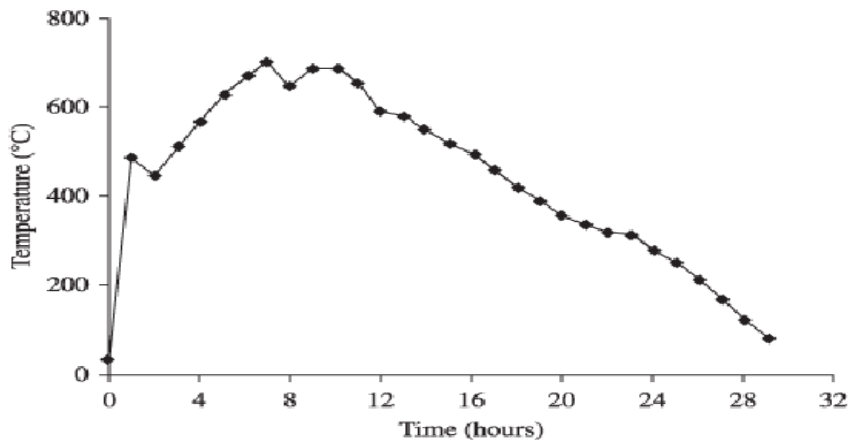


Figure 1. The burning temperature and heat treatment duration of rice husk ash [17]

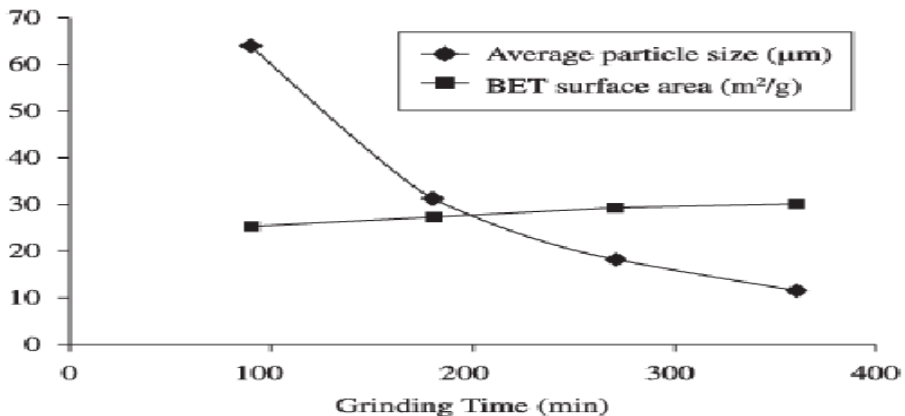


Figure 2. Average particle size and specific area of rice husk ash against grinding time [17]

Table 1: Percentage of ash and silica after burning some vegetation

Vegetation	Part of the vegetation used	Ash %	Silica %
Millet Hindi	Outer husk	12.55	88.7
Wheat	leaves	10.48	90.56
Corn	leaves	12.15	64.32
Bamboo	leaves	1.49	57.4
Bagasse	Internal part	14.71	73
Verbena	-	11.24	23.28
Sunflower	leaves	11.53	25.32
Rice husk	-	22.15	93

6.3 Clay and Sand

It is believed that the clay would never mix with Sarooj, the misconception is that clay could be used in all types of mortars except Sarooj due to the fact that clay gradually decays and deteriorates Sarooj. Contrary to this belief, most Iranian references point out that clay has been one of Sarooj ingredients. However, the amount of clay used as filler in Sarooj is small [14, 7]. Sand is supposed to increase the Sarooj mortar performance because sand acts as a binder like ash and lime. Different types of sand were used in Sarooj depending on the geographical locations where Sarooj was made. Sand and clay are the best fillers in the mortar; however, each one might have some disadvantages. When the amount of sand increases, the mortar adhesion reduces and consequently leads to lower strength of the mortar because sand does not react chemically with mortar. Furthermore, Clay increases adhesion; however, highly compressed clay causes cracks in Sarooj in the absence of moisture [11].

6.4 Fibers

Sarooj mortar would shrink after solidification. This characteristic leads to some crack formation on the surface of mortar and make some defects in its major role, which is being impermeable (figure 3) [16]. There are four important reasons for using fibers in Sarooj mortar:

- 1- Increasing the resistance of the mortar
- 2- Increasing the tensile strength and preventing cracks propagation [14].
- 3- The fineness of the fibers allows them to reinforce the mortar fraction of the concrete, delaying crack formation and propagation. This fineness also inhibits seeping through in the concrete, thereby reducing permeability and improving the surface characteristics of the hardened surface [18].

- 4- They also reduce the permeability of concrete and thus reduce seepage of water [18].

Hair fibers and some other natural fibers like straw which can be found around rivers and lakes, were used in Sarooj mortars [14]. Historically, horsehair was used in mortar and straw in mud bricks. By the 1960s, steel, glass, and synthetic fibers such as polypropylene fibers were used in concrete, and research into new fiber reinforced concretes continues today [18].

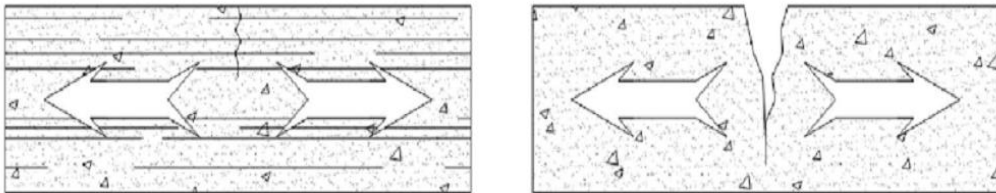


Figure 3: The effect of shrinkage of Sarooj mortar (a) with polymeric, metallic and glass fibers (b) without polymeric, metallic and glass fibers [16]

6.4.1 Natural Fibers

To reduce the detrimental effects of cracks, natural fibers including vegetable fibers and animal fibers such as camel and goat wool or horse and human hair were used [16]. For instance, wool fibers are strong, elastic, and have high moisture content [19]. Having high moisture content is really helpful because hydraulic mortars need to keep wet for a long time during solidification.

Additionally, hair is used as a fiber reinforcing material in concrete for the following reasons:

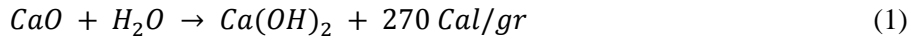
1. It has a high tensile strength which is equal to that of a copper wire with a similar diameter.
2. Hair, is a non-degradable material which does not cause environmental problems. So, its use as a fiber reinforcing material can minimize these problems.
3. It is also available in abundance and at a very low cost.
4. It reinforces the mortar and prevents it from spalling [18].

6.4.2 Synthetic Fibers

Fiber reinforcement was investigated as a means of decreasing the risk and extent of cracking and improving durability [20]. Polypropylene fibers are widely used in this respect. Polypropylene (PP) fiber was selected because it is less susceptible to chemical attack and is expected to minimize brittleness of the grout barrier [21].

7.0 Sarooj Mix Design

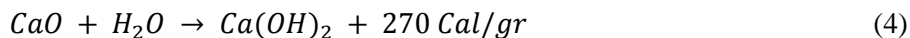
Before investigating the mix design of Sarooj, it is necessary to study about the possible interactions in Sarooj. In order to produce Sarooj, limestone is heated so that carbon dioxide will evaporate and lime or calcium dioxide will remain. By the time passing, calcium dioxide gradually and again absorbs carbon dioxide from the atmosphere and H₂O from the moisture of the weather. Solidification of lime mortar is done by silica and aluminate compounds which none of them depends on whether the reaction is reversible and can absorb the carbon dioxide. Quicklime should be mixed with water and create slaked lime so that can enter into the reaction.



The interaction between slaked lime and clay, which is the most important reaction in Sarooj mortar, is also the same in other hydraulic mortars. Two compounds can lead to the resistance of the mortar; firstly, CaSiO₃ and secondly, CaCO₃.



For Sarooj, the interaction is as below, it happens as a result of the existence of CO₂ and H₂O in the atmosphere, and also the final interactions between CaO and CO₂.



As it is shown, H_2O enters into the first equilibrium and exit from the second one. Therefore, it just acts as a catalyst. A dry ambience cannot be appropriate for all the interactions, because there is no H_2O to act as a catalyst, and as well water cannot be a proper ambience due to not having CO_2 . Moreover, in a composite of water and lime, the interaction will happen to mortar and CO_2 will exit from the water and give out by passing time. Hence, its amount would not be adequate for the interaction. After all, an ambience like baths which provides both CO_2 and H_2O is supposed to be a suitable place for doing these procedures and interaction [11].

8.0 Evaluation of Mix Design and the Compressive Strength of Sarooj

The cementing properties result from the reaction between burnt clay and lime ($Ca(OH)_2$) in the presence of water to form calcium silicate hydrate and calcium aluminate or calcium aluminum silicate. The reactivity with lime is a function of the temperature and burning duration of the clay, and also depends on the nature of the amorphous materials which, in turn, depends on the minerals making up the raw clay. Hence, an optimum calcination temperature exists for each soil, which will produce maximum compressive strength. This temperature is within the range of dehydroxylation and crystallization temperatures [22].

In the past, most Iranian references presented different mix designs for Sarooj because there was no code and usually the Sarooj was experimentally presented in general. In this work is attempted here to present the best reference of mix design. Respect to reactions in Sarooj and reliability of references, four reasonable mix designs selected eventually.

As shown in Table 2, there are significant differences in all patterns because of weather condition, kind and amount of the materials that were used. Each pattern is suitable for a specified climate. Some mix designs were chosen in order to select the best mix design in laboratory and common conditions. The samples which were made in a laboratory and were evaluated in Tehran University are shown in table 3. The results in Table 4 were obtained after making different samples (with dimensions $5 \times 5 \times 5 \text{ cm}^3$) from the above mix designs and the compressive strength of the samples. All the samples in this experiment were made in the water vapor bath. Moreover, all samples were made regarding to references in Table 2 and the best mix design was studied further [11].

Another research was conducted in the Office of School Renovation in Bushehr (the south of Iran), making three types of Sarooj. The first type and the second type of Sarooj were made with regards to Hami Guide to Making Concrete and Encyclopedia of Iran and Islam respectively, and the third type was made regarding to the traditional preparation in the south of Iran. More information about the ingredients is shown in Table 5. After making samples (with dimensions $5 \times 5 \times 5 \text{ cm}^3$) from the above types, then

the compressive strength of the samples measured, Table 6 showed average compressive strength of some samples made from three types [14]. The compressive strength was designed to discover the first general compressive strength of Sarooj from structure engineering viewpoint in various combinations and the second, a purpose of figuring out the effects of ingredients in Sarooj.

Sand in Sarooj did not markedly affect the compressive strength. In order to complete the whole reactions in Sarooj, appropriate amounts of lime, clay and ashes are needed. The surpluses of these ingredients do not react in Sarooj and do not affect the compressive strength outstandingly. Fibers were used in some samples and they do not notably affect the tensile strength. They are used to prevent and stop cracks from promoting in Sarooj, and make Sarooj more watertight. As the data in Table 6, for type two, the more lime and clay were used, the less compressive strength was. Type three was traditionally made in the south of Iran and its performance also showed the same relation between the amount of lime and compressive strength as in type two. As it can be seen, the less amount of lime resulted in the more compressive strength. Experiments show that Sarooj needs more than twenty eight days for setting to gain its strength. The results showed that Sarooj is a good cement substitution at which impermeability is taken into consideration. File research shows that Sarooj has mix design diversities. Furthermore, there are a good number of methods to make Sarooj. According to the researchers, Sarooj was not as strong as ordinary pozzolana cement, however, Sarooj was durable and reluctant to chemical reactions after performance and finishing the process [11].

Table 2: Mix design pattern in four rational Iranian references [11]

Pattern	Reference	Lime	Ash	Clay	Sand	Fibers
1	Hami Guide of Making Concrete	10 parts	7 parts	1 part	1 part	5 Kg
2	Zomordashti Building Construction	35%	20%	-	40%	5%
3	Building Material (Ganjian)	10	7	-	1	30-50 Kg
4	Encyclopedia of Iran and Islam	4	1	6	-	If needed

Table 3: Variety of mix designs derived from Table 2

Cod e	N o.	Lime (criterio n)	Ash (criterio n)	Clay (criterio n)	Sand (criterio n)	Fib er	Wat er	Patte rn	explanati ons
A	1	10	7	1	1	5 Kg	40%	1	Volumetric measure
A	2	10	7	1	1	5 Kg	40%	1	Volumetric measure
B	1	28	7	42	-	-	7140 cc	4	Volumetric measure
B	2	28	7	42	-	-	8560 cc	4	Volumetric measure
B	3	28	7	42	-	-	8760 cc	4	Volumetric measure

Table 4: The compressive strength of the samples (Kg/cm²) [11]

Age of mix design samples	3 days	7 days	28 days	70 days
A1	2	6	24.46	79.3
A2	0	3	1	2
B1	2	4	27	-
B2	1	2.5	24	-
B3	0	0.1	0.85	-

Table 5: Variety of mix designs

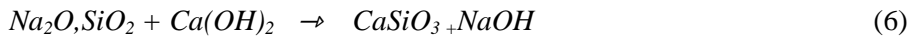
Sarooj type	Lime (criterion)	Ash (criterion)	Clay (criterion)	Sand (criterion)	Fiber	Water	According to pattern
Type 1	10	7	1	1	5 Kg	40 %	Hami Guide of Making Concrete
Type 2	28	7	42	-	-	50%	Encyclopedia of Iran and Islam
Type 3	1	9	3	-	-	20%	traditional Sarooj in south Iran

Table 6: The compressive strength of samples in the second experiment [14]

Age of sample Sarooj type	3 days compressive strength (Kg/cm ²)	7 days compressive strength (Kg/cm ²)	28 days compressive strength (Kg/cm ²)
Type 1	3.8	6.7	19.2
Type 2	1.8	3.8	13.2
Type 3	8.7	21.8	73.79

8.1 Additives in Sarooj

One of Sarooj features is its long term process. In order to reduce the process time, additives are added. Thus, in the early days it cannot carry loads and needs a long time to become solid. The key to solve this problem was adding some additives to Sarooj. There are a variety of materials to promote early strength of Sarooj such as: sodium aluminate, sodium silicate, calcium aluminate, calcium silicate and so on. According to the experiments, materials accessibility and materials costs, sodium silicate were chosen. Reaction of sodium silicate and lime is as follow:



One measure of this additive plus one measure of lime to react with sodium silicate and with one measure of ash to react with Na^+ were added to the mortar. In this process, firstly there was Sodium silicate solved in water, then added to the mortar meanwhile, because of its high influence on the mortar, lead to making it stiff once Sodium silicate and the mortar were mixing. The results of sample A1 combined additive are shown in Figure 4. Without additive the sample strength was 6 Kg/cm² and with the additive, it became 17.8 Kg/cm², this demonstrates that strength of the sample A1 increased by 11.8 Kg/cm².

Additive in Sarooj helps Sarooj to gain strength significantly in the early days after production. There was a hope that additives could make the procedure shorter, they are

useful for restoration of ancient Persian civilization and construction, and would be more compatible with environment [11]. By mentioning all the monuments and buildings which were made with Sarooj and considering their lifetime, the following advantages are concluded:

1. Sarooj mortar had been compatible with Iran and the Middle East environment: Sarooj was highly well-matched with different climates and the situation of the Middle East such as rainy weather and also resistant to arid climates. It has been hard-wearing against watery, dried condition and furthermore long-lasting when an earthquake has happened, hence, it is of high compatibility with the environment.
2. Solid and durable (for many centuries): some building materials such as wood start to decay after it has been used and in some cases it is the same for bricks but Sarooj does not. It is way durable as it could be seen in Ziggurat Chogha Zanbil.
3. Low permeability which by passing time goes on and approaches to complete impermeability: At the beginning of the process Sarooj is engulfed by water so the water passes easily through it, but at the end of the process, Sarooj become a lot more impermeable and it is the reason for which Sarooj was used as a cover of the water reservoirs, ponds, and cisterns where water should have conserved especially in arid regions.
4. Some of Sarooj mortars having light color and suitable for facade and frontage.
5. Sarooj ingredients are abundant in Iran.

Nevertheless, Sarooj cannot be widely used today for the following reasons:

1. The mortar process takes relatively a long time: The logical reason for which Sarooj was occasionally used as plaster rather than structural frame is that Sarooj is not so firm and hard, moreover, its process that is much slower particularly in comparison with current ordinary Portland cement.
2. Sarooj has been replaced with the modern cements which have a faster process of the preparation.

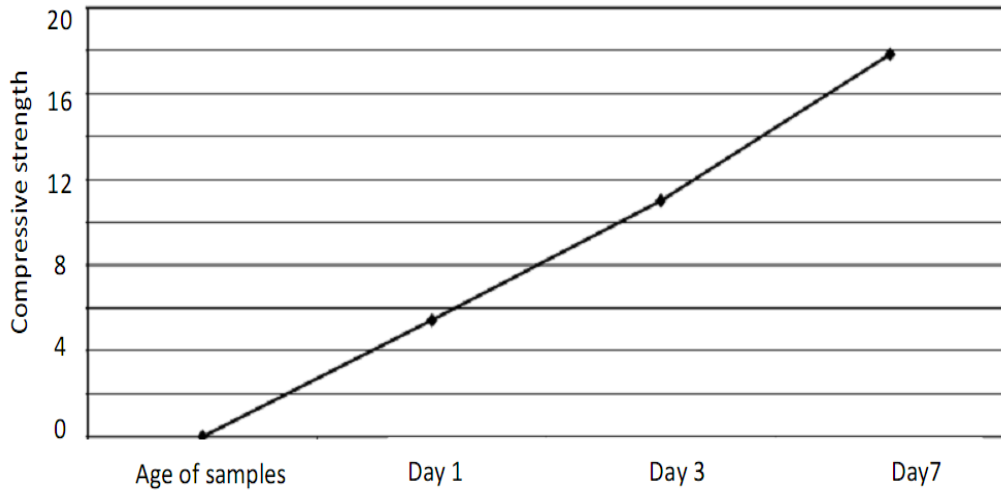


Figure 4: Compressive strength

9.0 Conclusion

Sarooj has lately been taken into consideration because of its merits. The most important benefits of Sarooj are being impermeable and exceedingly compatible with the environment. Therefore, Sarooj can be used at low cost while being an impermeable cover for road pavements, rock slopes and headwater channels. Furthermore, Sarooj is going to be industrialized in Iran after many experiments have been done on Sarooj in Tehran University, Islamic Azad University Tehran Branches and so forth.

10.0 Acknowledgement

This research would not have been possible without the guidance and the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study. We wish to thank foremost to Prof. M.E. Bahrololoom whom helped a lot to correct the structure of the paper and Ms. Z. Bahrololoomi, J. Masoumi, as well.

References

1. Moropoulou A, A. Bakolas, S. Anagnostopoulou , Composite materials in ancient structures, *Cement & Concrete Composites*, Volume 27, Issue 2, 2005.
2. Kardavani H., Ziggurat Chogha Zanbil (Persian language), *History Consideration journal*, 1th issue, P 52, 1970.

3. Heidari S., consider to field studies in formulation concrete thecnical publication (Persian language), 2th national conference on concrete, 2010.
4. Lucas, A . Ancient Egyptian Materials and Industries. USA: Kessinger Publishing, LLC. p. 584. ISBN 0-7661-5141-7, 2003.
5. Hejranfar A., Humayun Moteeie, Shirin Naderi , Mehri Ahmadi, “A new approach to use traditional storage tanks of drinking water (reservoirs) in arid and semi-arid regions under climate change conditions” (Persian language), The first International Conference on impermeable concretes of drinking water storage tanks, Gilan, Iran, 2011.
6. Davidovits F., Les mortiers de pouzzolanes artificielles chez vitruve evolution et historique architecturale. These de D.E.A. Paris, Universit, e Paris X-Nanterre, 1993.
7. Jamasebi H., PoorMohammadi Abatari M., Mardookhpour A., Water conveyance channels impermeated by Sarooj(Persian language), First National Conference on Civil Engineering, Zibakenar, Iran, 2012.
8. Khosravi M. Noruziyan E., Atarnezhad R., Tajrobekar Sh., consideration of making impermeable concrete with Sarooj (Persian language), Islamis Azad science journal, Issue 60, 2007.
9. Masoumi M., Influence of Oil Reservoir on Earthquake (IORE Theory). Research Journal of Environmental and Earth Sciences, 4(09), 818-822, 2012.
10. Kookhordi M., Be Yade Kookhord (in Persian language, in English means: Reminiscent of Kookhord), 1(2), 2003.
11. Farazman S., Atarnezhad R., Sarooj Introduction and Investigating of Sarooj as Compatiable Moratar with Environment (Persian language), first conference on enviromental engineering, Tehran, Iran, 2006.
12. Iranian Building code (Persian language), Design and Performance masonry structures, volume 80, 2005.
13. Hami A., Building material (Persian language), 50th issue, 1990.
14. Vafeghi M., Movahed zade M., Khaheh A., Evaluation of the compressive strength for some Kinds of Sarooj mortars in Bushehr province (Persian language), (2012)4th national conference on concrete, Tehran, Iran.
15. Database of Administration of Cultural Heritage, Handicrafts and Tourism Gilan Province, (Persian language), access in May 2013 on: <http://www.gchto.ir/en/>
16. Jamasbi H., Pourmohammadi M., ,Study of utilizing Saroj mortar in headwater channels, (Persian language), Proceedings of the 1rd International Conference on Non Osmosis Concrete(1st ICNOC)-Water Storage Tanks, Guilan, Iran, 2011.
17. Abood Habeeb Gh., Hilmi Bin Mahmud, , Study on properties of rice husk ash and its use as cement replacement material, Materials Research, ISSN 1516-1439, 2010.
18. Jain D. and Kothari A., Hair Fiber Reinforced Concrete, Research Journal of Recent Sciences, Vol. 1(ISC-2011), 128-133, 2012.
19. Watson K. H., Textiles and Clothing, Home Economics Association, Chicago, 1907.
20. Allan M.L., L.E. Kukacka, Strength and Durability of Polypropylene Fiber Reinforced Grouts, Cement and Concrete Research. Vol. 25, No. 3, pp. 511-521, 1995.
21. Okonkwo I.O., Improving the Durability of Radioactive Waste Grout Barriers Using Polypropylene Fibers, Proc. Waste Manage. 89, 715– 722, 1989.
22. Ali Al-Rawas A., A.W. Hagoa, Hilal Al-Sarmi, , Effect of lime, cement and Sarooj (artificial pozzolana) on the swelling potential of an expansive soil from Oman, Building and Environment, Elsevier 40, 681–687, 2005.