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Experimental study to enhance the strength of local motor used for traditional constructions in Siwa Oasis - Egypt

Wael Kamel [a], Shafik Khoury [b] and Nuha Khalil [a]

[a] *Arab Academy for Science, Tech. and Maritime Transport Construction and Building Dept., College of Eng. and Technology*
E-mail: wael_kamel@yahoo.com

[b] *Structural Eng. Dept., Faculty of Eng., Alexandria University, Alexandria, Egypt*

Siwa Oasis faces an important challenge: concrete blocks start invading the oasis, destroying its unique architectural style. Siwan start to use reinforced concrete to face the weakness of their local materials used in construction. This research aims to study the characteristics of local materials used in construction in Siwa, and to investigate other available materials in order to enhance the strength of construction materials. After performing the chemical analysis of these materials, an experimental work was performed to suggest the best mix enhancing the compressive strength of siwan mortar. The results indicate that the compressive strength of actual siwan mortar is 13.5 kg/cm^2. While the proposed mortar consists of Silt from lake: Silt from mountain: Badya: sommar ash, following the ratios 4: 1: 1: 1 by weight, with Molasses incorporated by 3.5% of the total solid materials by weight. A compressive strength of 64.8 kg/cm^2 at the age of 28 days was reached. At later ages, it is expected that the mix strength exceeds 80 kg/cm^2. This strength is accepted for the proposed new mix to be used as a new binder made of local materials.

تواجه واحة سيوة عدة تحديات منها غزو الكتل الخرسانية التى تدمر طرازها المعمارى الفريد، حيث بدأ سكان الواحة فى إستخدام الخرسانة المسلحة لمواجهة ضعف المواد المحلية المستخدمة فى الطرق التقليدية فى التشييد. يهدف هذا البحث الى دراسة خصائص المواد المحلية المستخدمة فى البناء فى سيوة ومن ثم دراسة مواد أخرى متوافرة بالواحة بهدف تحسين مقاومة مواد البناء. بعد إجراء التحليل الكيميائى لمواد البناء المتوافرة بالواحة، تم إجراء دراسة عملية بهدف إقتراح نسب أفضل خلطة تؤدى الى تحسين مقاومة المادة الرابطة. وقد أثبتت النتائج أن مقاومة الضغط للمادة الرابطة المستخدمة فى الوقت الحالى بسيوة تصل الى ١٣,٥ كجم/سم٢. بينما كانت الخلطة المقترحة عبارة عن طفلة بحيرات : طفلة جبلية : بادية : قش السومار بنسب ٤ : ١ : ١ : ١ بالوزن، مع إضافة العسل الأسود بنسبة ٣,٥ % من المادة الصلبة بالوزن. وقد حققت مقاومة الضغط لهذه الخلطة بعد ٢٨ يوم ٦٤,٨ كجم/سم٢، ولعمر عينة أكبر من المتوقع أن تصل المقاومة الى ٨٠ كجم/سم٢ وهو اجهاد مقبول للأستخدام كمادة رابطة جديدة مكونة من مواد محلية.

Keywords: Sommar ash, Mortar, Non-Cementing binder, Silt, Construction

1. Introduction

For long years, Egypt has remained traditionally the hub of tourists interested in the history and the valuable heritage of ancient Egyptian monuments spread all over the country. Egypt possesses a huge cultural heritage manifest in the Pharaonic, Roman, Coptic and Islamic monuments. Tourism in Egypt is a mainstay and an essential pillar of economic activity, with tourist revenue representing about 25% of Egypt's total foreign currency income.

Egyptian Center for Economic Studies (ECES) conducted a study which concluded that the direct impact of foreign tourists' spending on total output in 1999 was $ 3.6 billion dollars (4.4 percent of GDP). As for employment, foreign tourists' spending directly supported 1.2 million jobs in various economic sectors. The total number of jobs directly and indirectly associated with foreign tourists' spending is 2.7 million. Therefore, tourism's ability to contribute positively to Egypt's economic goals earns that activity a higher rank on Egypt's policy priority list [1].

Although tourism industry in Egypt has traditionally focused on cultural tourism, especially with the presence of ancient Egyptian antiquities, but Egypt has embarked into comprehensive and diversified tourism, such as eco-tourism [2].

According to the World Tourism Organization (WTO), the demand for ecotourism and nature-oriented tours is on such a rapid rise that ecotourism has become the fastest growing segment of the tourism industry. WTO indicated that Nature-based tourism, which includes ecotourism, has been estimated to account between 10% and 15% of all international travel expenditures [3]. Ecotourism can bring numerous socio-economic benefits to Egypt. It generates foreign exchange, creates local employment, stimulates national and local economies, and increases environmental awareness and education, while preserving the resources tourists come to experience and enjoy.

Ecotourism in Egypt is mainly focused in five major oases located in Egyptian Western Desert, these oases are Baharia, Dakhla, Farafra, Fayoum, Kharga, and the most important Siwa [4]. Siwa Oasis possesses all elements necessary to apply the eco-tourism because it has unspoiled environment, it contains unique flora and fauna, and it is rich of historical monuments and it has a unique architectural style. The Siwa Oasis was declared a protected area in the year 2002, which is very important to guarantee the sustainable development of the Oasis [5].

In this respect, appropriate management structures as well as adequate design are required to ensure that tourism enhances and respects the natural environment.

However, Siwa Oasis faces different challenges such as the invasion of concrete blocks destroying its natural environment; changes in economic activities; the negative impact of human behavior on the surrounding environment; and the lack of control over nature. In fact, since Siwa got opened to the other cities in Egypt, the current techniques of construction and living started replacing the traditional techniques, destroying its unique architectural style. Actually, most of Siwan build their constructions using reinforced concrete to face problems concerning the weakness of their local building materials.

2. Siwa oasis location and characteristics

2.1. Siwa location

Siwa oasis is located at the western edge of Egypt, at about 65 km east of the Libyan border, and 300 km south west of Marsa Matrouh as shown in fig. 1-a. The oasis is about 82 km long and a width varying between 2 and 20 km. It lies between longitudes (25° 12') and (26° 05') East, and latitudes (29° 05') and (29° 20') North. Most of the central part of the oasis lies below the sea water level.

The western boundary of the oasis begins at Al-Maraqi and the eastern boundary at Al-Zeitun, with the town of Siwa lying at the center as shown in fig. 1-b.

Although most of the population lives in the town of Siwa, a few other villages are scattered around the oasis. Al-Maraqi, Khabisah, Abu Shuruf and Al-Zeitun are the most important of these villages. There are several salt lakes in Siwa, the largest being the famous lake of Al-Zeitun, which begins at gabal Dakrur and extends for more than 25 km, averaging 5 km in width.

Siwa is one of the most beautiful oases of Egypt. It contains many historical monuments and beautiful tourist places, such as: Temple of Amoun, Gabal Al-Mawta, Cleopatra and Abu Shuruf Springs, Gabal Dakrur, Al Zeitun Village, and the fortification Shali. This fortification dates from the 13th century and located in the center of modern Siwa. Due to a heavy rain in 1940, this fortification collapsed. Some of its buildings are still in use, but due to their construction of salt, mud brick, and rock, they fall more into ruin each year. Mud bricks have been used for centuries in traditional constructions in the oasis. In recent times, all of these constructions suffer mainly from the rain rather than any human devastation [6].

2.2. Siwa at the present time

With the beginning of the 20th century, new style of buildings started to appear in the oasis. These constructions were built using reinforced concrete, and using completely different architecture style. The new

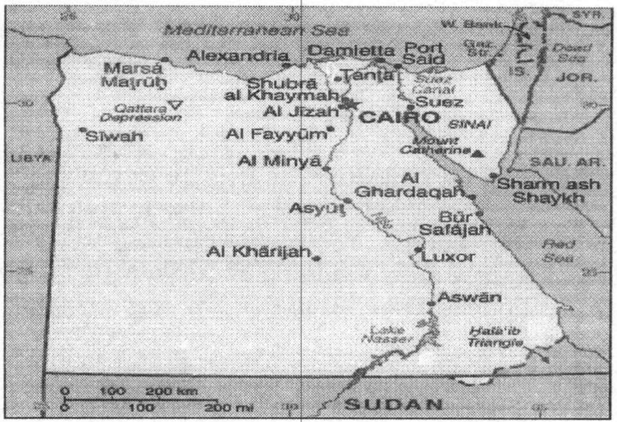

Fig. 1-a. Map of Egypt showing the location of Siwa Oasis.

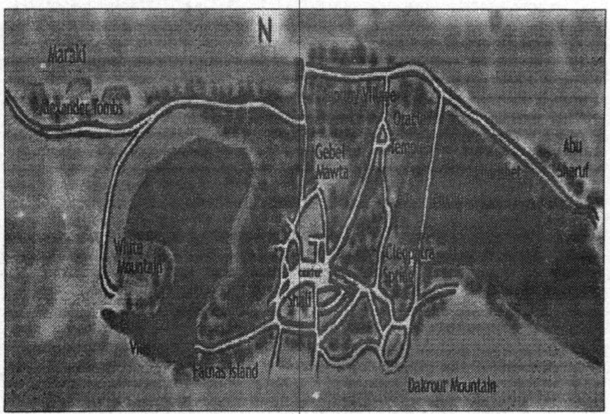

Fig. 1-b. Map of Siwa Oasis.

constructions look odd to the surrounding environment.

The new center of Siwa is located around the ruins of the old town of Shali. As shown in fig. 2, the difference between the two styles is clear; the ruins of Shali give it a unique and distinguishing style, while the new constructions destroys completely the architectural style of the oasis [7].

2.3. Local raw materials and traditional construction method in siwa

The local materials found in Siwa actually are:

• "Karsheef", sort of stone found at the shores of the salt lakes,
• Silt of the surrounding lakes (Silt L),
• Silt of surrounding mountains (Silt M),
• "Badya", fine material found in the "White Mountain",
• "Sommar", fine reeds which grows naturally on the sides of the salt lakes, and
• Other materials as palm trees and olive trees wood.

In the traditional construction method in Siwa, the Karsheef play the role of coarse aggregate in conventional concrete, while the binder is "Siwan mortar" which is a mix of the two types of silt and water. The current mixing proportion of Siwan mortar is 4 (Silt L) : 1 (Silt M) : 1 water [8].

The traditional method of construction in Siwa oasis has been developed by experience. It should be pointed out that there is no evidence for performing any kinds of tests to ensure the validity of the traditional construction technique in Siwa Oasis.

A typical house in Siwa consists of 4 main elements: bearing walls, ground level floor, intermediate floor, and roof.

1. *Bearing walls*: are traditionally built using Karsheef particles that are bonded together with a siwan mortar. Karsheef stones are broken into smaller particles of about 40×20×15 cm. The first layer of Karsheef particles are aligned on the scratched ground, then, Siwan mortar is pushed into the spaces between the Karsheef particles in order to bond them strongly. Another layer of Karsheef is then arranged above the first one, and the process is repeated till a height about 1 meter. The first portion of the wall is typically left for two days during the summer (and nearly two weeks in winter) to reach the complete drying condition; and then, the execution of the second portion of wall could start.
2. *Ground level floor*: is typically made of stone particles cut into large pieces of square shape and placed on the ground without any bonding.
3. *Intermediate floor:* consists of palm trees wood arranged with span of about 1.5 m, and placed perpendicularly on top of two parallel walls spaced at 4 to 5 meters. The palm trees wood is then covered with olive trees wood. The final layer is palm trees wood which is placed above the olive trees wood.
4. *Roof*: is constructed similarly to the intermediate floor, except the final palm trees wood which is replaced by a layer of Karsheef and siwan mortar.

These information were collected through several discussions with Siwa Oasis residents during the authers field trips to the oasis [8].

2.4. Problems related to traditional construction method

There are three main problems associated with the traditional construction methods in Siwa Oasis, these problems are:

1. Serviceability: in fact, Siwan houses cannot stand heavy rain. Although rain is rare in Siwa Oasis, but heavy rain could occur randomly. It has an adverse effect on the external walls, as silt particles start falling and the bond between them and Karsheef become weekend. The problem may undergo beyond serviceability and may reach safety.
2. Settlement: vertical cracks appear in most of the houses built in the oasis. The width of these cracks increases with the aging of the house fig. 3. The main reason for these cracks is settlement of the foundations which is constructed using karsheef and bonded with siwan morter.
3. Collapse: this problem may exceed both serviceability and settlement, and it may reach sudden collapse, as took place in Shali village when Siwa was subjected to heavy rain which destroyed half of the houses, and the remaining were not safe enough to be used again. Fig. 4 shows the ruins of Shali village collapsed after the heavy rain of year 1940.

3. Experimental Study

The main objective of this research is to study the characteristics of local materials used in construction in Siwa, and to investigate other available materials in order to enhance the strength of construction materials.

3.1. Properties and chemical composition of materials

Materials used in traditional constructions are Karsheef, silt from lake, and silt from mountain. While the white material known as "Badya", the ash (resulting from the combustion of the reed known as "Sommar"), and "Molasses" has not been experienced in Siwa Oasis up till now and will be investigated in this research [8].

1. *Karsheef:* is a stone naturally formed at the shores of the salt lakes. Its particles consist mainly of salt bonded with clay and fine sand. The stones have irregular shapes with different sizes, and its typical color is white gray. Chemical analysis of Karsheef was performed, and results are listed in table 1.

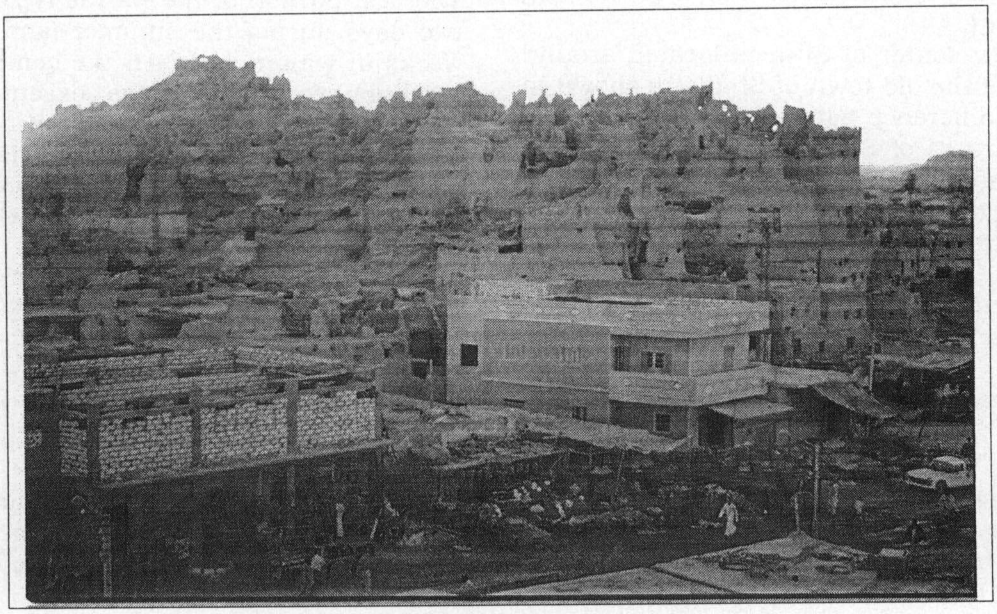

Fig. 2. The center of Siwa Oasis around Shali ruins.

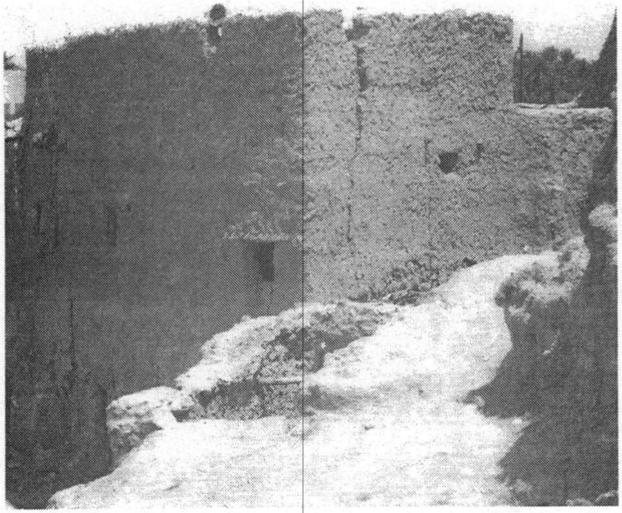

Fig. 3. Vertical cracks due to the foundation settlement.

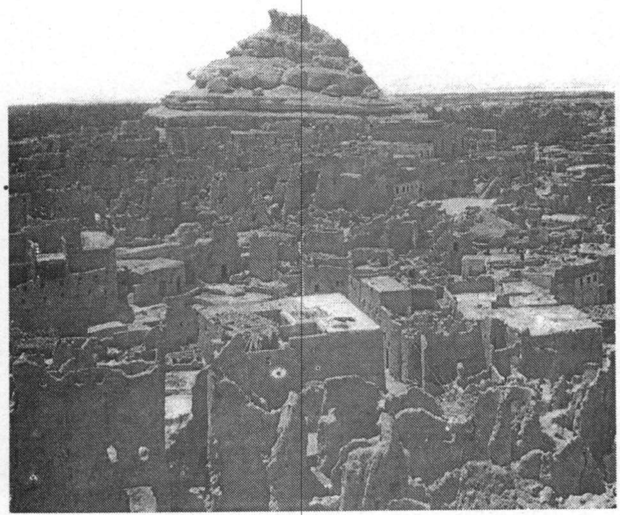

Fig. 4. Ruins of Shali Village.

2. *Silts from the Lake and the Mountain:* the first type of silts (Silt L) is brought from the surrounding lakes; it is wet and has dark brown color. While the second type (Silt M) is brought from the surrounding hills or mountains; it is relatively fine and has a brown greenish color. The chemical analysis for the two types of silt is shown in table 1.

The chemical composition of a mixture of Silt M and Silt L following the ratio 1: 4, respectively, is simply calculated and included in table 1.

Prior to starting experiments, it was observed that both silts became stiff. It seems that the particles were bonded together due to the relatively high humidity and low temperature in Alexandria city as compared to Siwa Oasis. Therefore, in order to restore each type of silt to its original condition, the material was crushed using the Proctor apparatus, then screened on sieve No. 30 (0.6mm). The passing powders were used throughout the program.

3. *Badya:* is a white fine material found in mountain known as "White Mountain". In fact, it looks visually like the lime. Chemical analysis for Badya was also performed and the results are listed in table 1.

As shown in table 1, the main chemical composition of both silts is silica dioxide (SiO_2). Since the used silts are natural materials it was not of interest to find whether or not the high percentages of SiO_2 in both silts are in amorphous states. In addition, Silt L contains higher amount of ferric oxide (2 %) as compared to that found in Silt M (0.44 %). This may explain the difference in color between the two materials. It is obvious from the table that the main chemical component of Badya is Calcium Oxide. It is of interest to note that this material was investigated as an attempt to have some pozzolanic reaction with the silica dioxide.

4. *Sommar ash:* has been obtained by simple incineration of the reeds called "Sommar". The burning process took about 20 minutes. The ash was thereafter sprayed with water to ensure sudden cooling of burned ash. This step is the main key to get ash containing silica dioxide in amorphous state. The ash was left to dry at room temperature. The collected ash was then grinded manually and was thereafter screened on sieve No.100 (0.15 mm). The passing powders were used in the mixes. Figs. 5 and 6 show the Sommar reeds before burning, and after turning into ashes. It should be noted that the process mentioned above was similar to that previously reported for preparing ash out of rice husk [9]. It was assumed herein that the obtained ash contains moderate amount of silicon dioxide in amorphous state. Although chemical analysis of the obtained ash was not performed, the conclusion was left to test outputs.

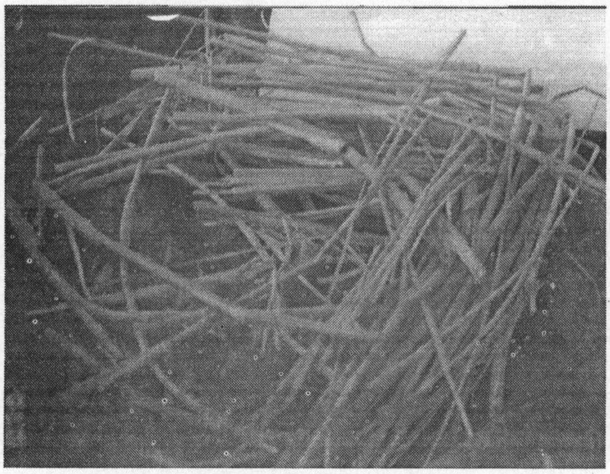

Fig. 5. Sommar before burning.

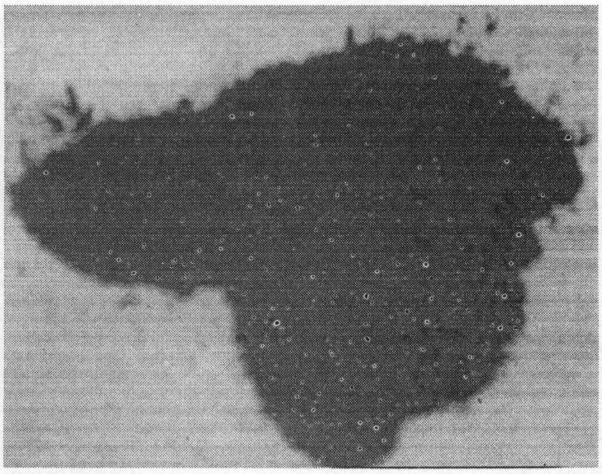

Fig. 6. Sommar after turning into ashes.

Table 1
Chemical composition for different material

Material	Chemical composition (% by weight)			
	Silica dioxide (SiO_2)	Calcium oxide (CaO)	Aluminum oxide (Al_2O_3)	Ferric oxide (Fe_2O_3)
Karsheef particles	11.308	6.06	1.2	0.32
Silt from lake	74.91	1.96	3.8	2.0
Silt from mountain	69.03	11.4	1.5	0.44
Mixture of 2 silts	73.7	3.80	3.30	1.70
Badya	8.3	63.6	0.5	0.24

3.2. Mix proportions and main variables

On the basis of the information collected by the author during several visits to Siwa Oasis, it was decided to use a mixing ratio between (Silt L) and (Silt M) equal to 4 : 1, respectively, as currently used by the builders in Siwa.

Preliminary trials were performed before coming up with the final mix proportions. In fact, it was the intent to keep the water content at 15% of the weight of solid materials in all mixes. However, while casting it was necessary to reach comparable workability through slight change of the required amount of water. Mix proportions of different materials are listed in table 2. As seen in the table, mix No. 3 that contained 80 % (Silt L) and 20 % (Silt M) is the Control mix.

The main variables studied in the research are: [1] effect of Badya, [2] effect of ash, [3] effect of molasses, [4] combined effects of Badya and Ash, and [5] effect of mortar age.

In order to evaluate the effect of each factor, it was attempted to keep other parameters constant to evaluate one variable at a time. The combined effects of two variables were explored too.

The following abbreviations will be used to present the results in following tables and figures:

B for effect of Badya
A for effect of Ash
M for effect of Molasses
BA for combined effect of Badya and Ash
BAM for combined effect of Badya, Ash and Molasses

3.3. Mixing and casting procedures

The constituent solid materials were first mixed manually; then, the specified amounts of water and molasses were added gradually while mixing continued. It was observed during mixing that the presence of the fine ash affected adversely the consistency of the mortar. This was expected due to the relatively high surface area of the fine particles of ash. This finding coincides with those previously reported for rice husk ash [9]. From other prospective, the use of molasses improves the mortar consistency.

Although the flow test was not conducted to measure the consistency of fresh mortar, it may be reasonable to state that the consistency of each prepared mortar was stiff and could be considered to be equivalent to that for fresh concrete having a slump of 50 mm. This stiff mortar was similar to Siwan mortar currently used by the builders to bond the Karsheef particles together.

After the completions of mixing process, specimens were cast in two layers, and each layer was compacted using a compacting rod. A vibrating machine was used to complete the compaction of specimens. Two sizes of cubic specimens were made: 50 × 50 mm and 70.7 × 70.7 mm. Size effect was considered to be minimal and it was therefore ignored in the analysis of test results.

All specimens were thereafter exposed to comparable conditions. After casting, specimens were covered with wet burlap and stored in the laboratory for 24 hours. Then, the specimens were demoulded and left at room temperature covered with wet burlap for another 48 hours prior to starting the preparations process.

3.4. Specimens preparations

As an attempt to simulate the climatc conditions of Siwa, all specimens were exposed to identical conditions. Specimens were subjected to warm temperature typically in the range of 50°C.

This step was done by heating specimens in an oven during the day and left them at room temperature during night. This process continued for two weeks.

Thereafter, specimens were left at room temperature covered with wet burlap until the dates of testing. All specimens were air-dried for two hours before testing. Most specimens were tested under compression at the age of 56 days, while some of them were tested earlier at 28 days for comparative purposes. Treatments mentioned above were performed at the material laboratory in the Arab Academy for Science, Technology and Maritime Transport and also at the Egyptian Testing Center. All specimens were tested under compression in a 300 kN capacity universal compression testing machine. The deflection control mode was adopted using a rate of 2 mm/min.

4. Test results and discussions

4.1. Test results

The compressive strength results of all mixes are given in table 2. Each representative strength value is the average of two tests in most cases. It should be pointed out that the result of the control specimen at the age of 28 days (11.4 kg/cm^2) or at the age of 56 days (13.5 kg/cm^2) is considered as a standard to evaluate the performance of other mixes [8].

4.2. Discussion of results

The compressive strength of the tested specimens varied between 3.8 and 64.8 kg/cm^2. These noticeable differences among the specimens strength indicate that good selection of materials available in Siwa Oasis is of primary concern to improve the performance of the binder. The strength of mix BAM (f) will be calculated in later section.

4.2.1. Performance of Siwan mortar

The comparison between the compressive strength of silt M, silt L, and the mixing of 2 silts (mixes Silt L, Silt M and Control) are presented in fig. 7. The three mixes contained nearly the same water content as shown in table 2. The poorest strength among the three specimens is shown by Silt M (3.8 kg/cm^2).

Although the results of these subject specimens are unsatisfactory, it is evident that some kind of chemical reaction between the two types of silt exists. However, the compressive strength of the control specimen is only 13.5 kg/cm^2. Undoubtedly, the lower strength of the Siwan mortar is responsible to large extent for the defects, collapses, and other problems observed in Siwan houses as discussed earlier. This finding emphasizes the need of modifiying the Siwan mortar by introducing other materials available in Siwa. That is the target of this research.

4.2.2. Effect of Badya

The effect of adding Badya on the compressive strength of mortar is evaluated by comparing the results of specimens 3, 4, 6, 7, 6* and 7* shown in fig. 8. The presence of Badya improves the strength of the control specimen from13.5 kg/cm^2 (mix Control) to17.8 kg/cm^2 (mix B). This enhancement (F=4.3 kg/cm^2) is very minimal.

It seems that the lime in the Badya (63.6% CaO) reacts very little with the silicon dioxide (SiO_2) that exists in the silt mixture (73.7% SiO_2). This may be due to the crystalline state of SiO_2 in the silts. The comparison between mixes No. 6 (M) and No. 7 (BM) that contained 3.0 to 3.5 % molasses shows that the presence of Badya improves the strength from 24.5 kg/cm^2 to 38.8 kg/cm^2, with a strength gain of 14.3 kg/cm^2. Similar finding may be obtained by comparing the results of mixes No. 6* (M*) and No. 7* (BM*) that were tested at 28 days. It can be concluded that incorporating Badya only to Siwan Mortar is not very promising.

4.2.3. Effect of ash

As shown in fig. 9, the comparison of the results between mixes without ash (Control and M), and mixes with ash (A and AM) gave almost the same enhancement (F = 0.2 – 0.3 kg/cm^2). It indicates that the presence of ash does not play an important role in improving the mechanical properties of the control mortar. In fact, the strength improvement is more pronounced in the case of Badya-specimens as compared to ash-specimens as discussed in a later section.

Table 2
Mix proportions and test results

Mix no.	Mix designation	Blending ratio of solid materials				Percentage of liquid materials (%) by weight		Comp. strength (kg/cm^2)
		Silt L	Silt M	Badya (B)	Ash (A)	Mol (M)	Water	
1	Silt M	---	1	---	---	---	20 %	3.8
2	Silt L	1	---	---	---	---	18 %	7.4
3	Control	4	1	---	---	---	20 %	13.5
3*	Control *							11.4
4	B	4	1	1	---	---	19 %	17.8
5	A	4	1	---	1	---	18 %	13.7
6	M	4	1	---	---	3.1 %	13.6 %	24.5
6*	M*							15
7	BM	4	1	1	---	3.5 %	15 %	38.8
7*	BM*							25.4
8	AM	4	1	---	1	4.6 %	16 %	25.8
9	BA	4	1	1	1	---	20 %	57.2
10	BAM	4	1	1	1	4.6 %	15 %	f **
10*	BAM*							64.8

* Cured for relatively short period about 28 days.
** f will be calculated in a later section.

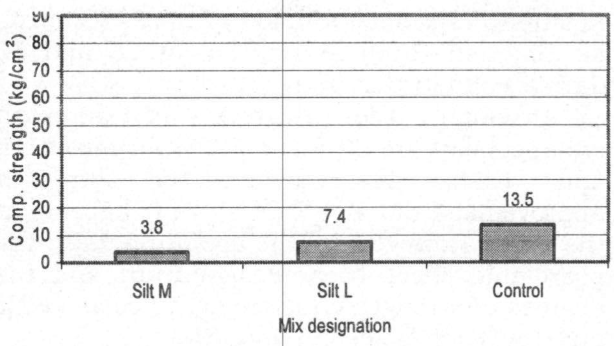

Fig. 7. Comparison between the compressive strength of silt M, silt L, and control mix.

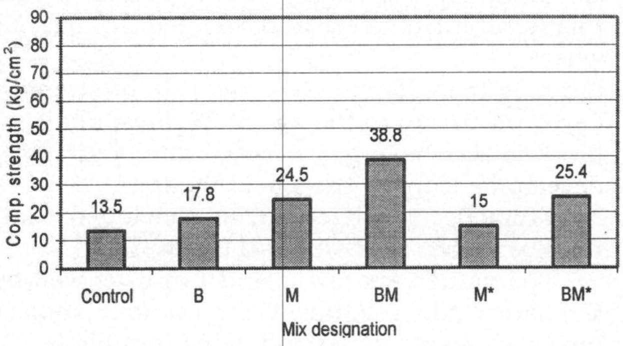

Fig. 8. Effect of Badya on motar compressive strength.

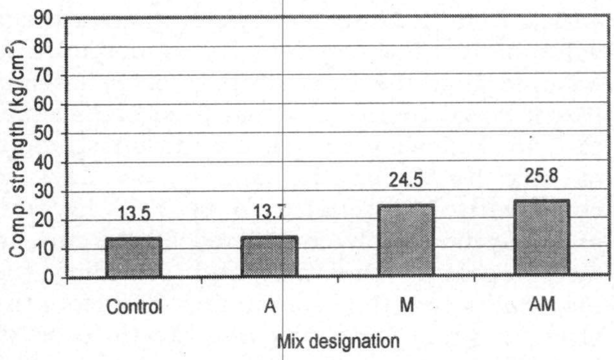

Fig. 9. Effect of ash on motar compressive strength.

4.2.4. *Effect of molasses*

Preliminary trials indicate that molasses may act as a water reducing admixture to improve the consistency of the mortar. It is obvious that molasses does not have a direct effect on the mortar strength; however it may improve the mortar strength through reducing the water content without affecting the consistency of the mortar.

As expected, the reduction in the water content from 20 % in the control mix to 13.6 % in mix (M) due to the presence of molasses caused a strength improvement from 13.5 kg/cm^2 to 24.5 kg/cm^2, indicating about 81 % improvement in the mortar strength fig. 10. In addition, mix BM with molasses exhibits 118 % higher strength than mix (B) without molasses fig. 10. Both specimens contained the same amount of Badya, but different percentages of water. Also, comparing the results of the ash mixes, (A) without molasses and AM with molasses, confirms the above findings.

Based on the above arguments, it may be concluded that molasses has positive effects on reducing the mixing water content, and hence, improving the strength of mortar. A dosage of molasses on the order of 3 to 4 % of solid materials weight is recommended to be introduced to Siwan mortar.

4.2.5. *Combined effects of Badya and ash*

Introduction of mix (BA), which incorporated both Badya and ash with the two types of silts, raises a critical issue. The result of this mix showed a different trend. Although both the Badya and the ash posses no cementitious values, it seems that the silica dioxide that is present in the ash reacts chemically with the calcium hydroxide in the Badya to create the cementing material Calcium Silicate Hydrate.

As shown in fig. 11, the compressive strength of mix (BA) at the age of 56 days reaches a value of 57.2 kg/cm^2, while the highest strength reached when using either Badya or ash is 17.8 kg/cm^2 for mix (B). Thus, it can be stated, on a quantitative basis, that the combined effects of Badya and ash are more pronounced than the effect of each material by itself.

4.2.6. *Effect of mortar age*

When molasses is introduced in mix (BAM) that contained the same mix proportions and ingredients of mix (BA), the water content is reduced from 20 % to 15 %, and hence the strength of mix (BAM) by the age of 28 days reached 64.8 kg/cm^2 as shown in fig. 12.

Unfortunatly, the strength of this mix (BAM) at the age of 56 days was not reliable due to some error in testing the specimens.

However, simple calculation given in the coming section indicates that the strength of mix (BAM) at the age of 56 days may exceed80 kg/cm^2. This finding is considered very promising in improving the construction quality in Siwa Oasis. Since Portland cement was not incorporated throughout the current program, the mortar strength that mainly depends on some type of pozzolanic reaction becomes more pronounced at later ages.

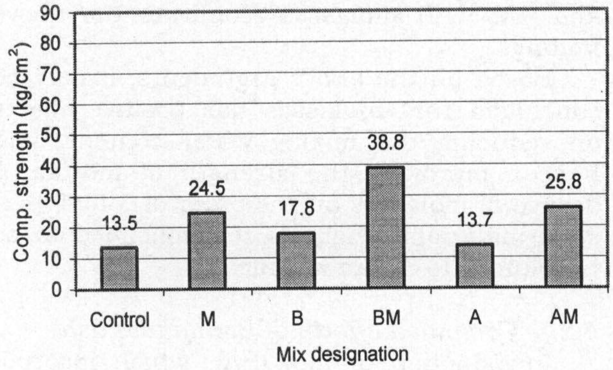

Fig. 10. Effect of Molasses on motar compressive strength.

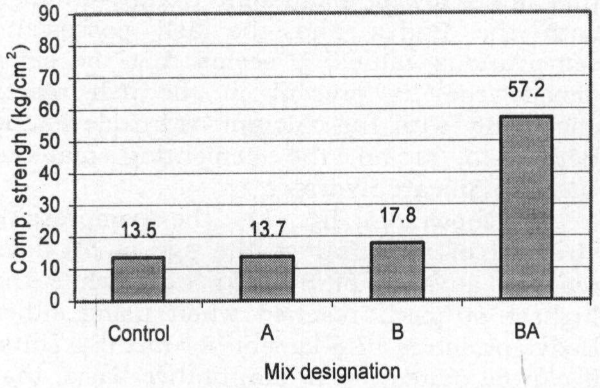

Fig. 11. Combined effect of Badya and ash on motar compressive strength.

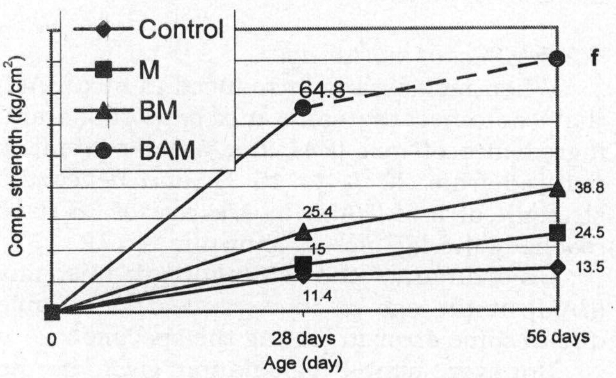

Fig. 12. Effect of age on motar compressive strength.

Results of specimens made of mixes (Control, M, BM and BAM) and tested at 28 and 56 days are illustrated in fig. 12.

Although the degrees of strength enhancement are 32% and 123% for mixes (M) and (BM), respectively, the strength improvement did not exceed 14.0 kg/cm^2 at the most. However, by the age of 56 days, the pozzolanic effect became significant and the degrees of strength enhancement became 82% and 187% for mixes (M) and (BM).

The compressive strength value "f" shown in fig. 12 may be estimated by simple calculations. The two angles α and β are therefore introduced and defined in fig. 13 where,

tan α is the assumed average rate of strength development up to the age of 28 days, and

tan β is the assumed average rate of strength development up to the age of 56 days.

From fig. 13, it could be concluded that: $\tan\beta = f / 56$, or $f = 56 \tan\beta$ eq. (1).

The values for tan α and tan β as well as the ratios (tan α / tan β) for the four subject mixes were calculated and listed in table 3.

It is evident from the previous table that the ratio α / β for the three considered mixes varied from 1.22 to 1.69 yielding an average value of 1.4. For conservative estimation it is believed that the ratio (tanα / tanβ) for mix (BAM) equal to 1.6, and tan β becomes equal to 1.45. Following eq. (1), the mortar strength of mix (BAM) at the age of 56 days is conservatively estimated to be 81.2 kg/cm^2, and may be simply considered 80 kg/cm^2. In fact, repeating this mix and providing the material is very time consuming. Therefore the strength value f is considered herein to be 80 Kg/cm^2, that is very promising value as mentioned earlier.

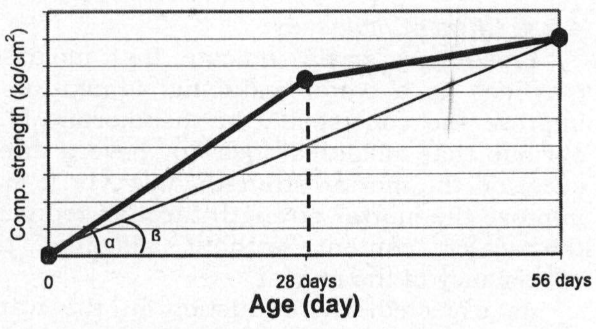

Fig.13. Definition of angles α and β.

Table 3
Calculated values for angles α and β

Mix. No.	Mix designation	Tan α	tan β	Ratio (tan α / tan β)
3	Control	0.407	0.241	1.69
6	M	0.536	0.438	1.22
7	BM	0.907	0.693	1.30
10	BAM	2.314	---	---

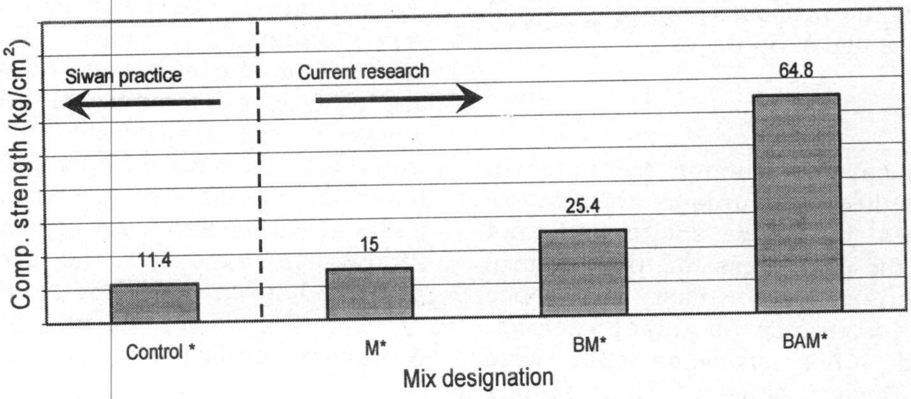

Fig. 14. Compressive strength of all tested samples at the age of 28 days

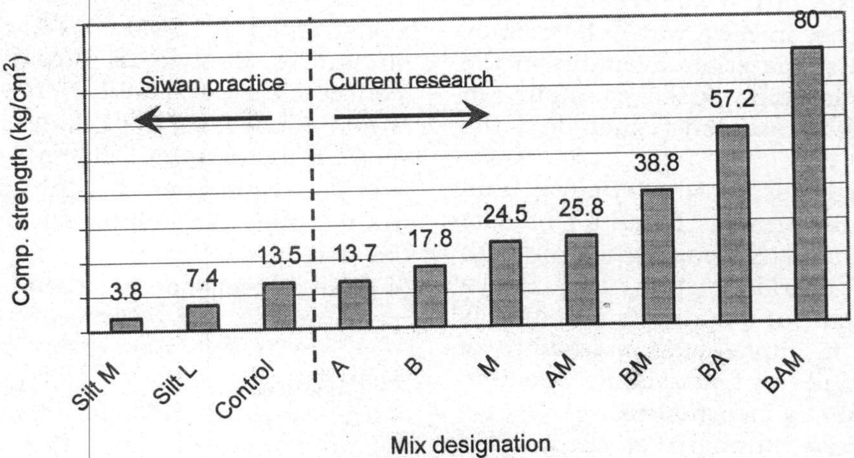

Fig. 15. Compressive strength of all tested samples at the age of 56 days.

It is of great interest to state that the Egyptian Standard Specification (ESS 1292/1991) accepts bricks having strength exceeding 50 kg/cm^2 to be used as bearing walls in construction industry.

Fig. 14 and 15 show the compressive strength for all specimens at the ages of 28 and 56 days respectively. The beneficial effect of introducing the new materials studied through this work is obvious.

The mix design proposed herein is considered as "Modified Siwan Mortar". It can be produced considering the followings:

a. The proposed mortar consists of Silt L: Silt M: Badya: Ash, following the ratios 4:1:1:1 by weight. Molasses is incorporated by 3.5% of the total solid materials by weight.

b. The two silts and the Badya should be grinded and sieved on Sieve No. 30. The resulting powders are used. Obviously, any comparable screen may be accepted in practice.
c. The main key of producing good binder is the controlled burning process of the ash where sudden cooling of ash is a must. The burnt ash is to be dried and then grinded on Sieve No. 100 or other comparable screen.
The strength of the proposed mix may exceed 80 kg/cm^2 at the age of 56 days.

5. Conclusions

The traditional construction technique in Siwa oasis resulted into unique architecture style of shelters, but these shelters are not safe due to the weakness of the natural building materials used. Past experience indicates the occurance of many defects, collapses, and other problems that were observed in Siwan houses. This finding emphasizes the need of modifiying the Siwan mortar by introducing other materials available in Siwa. In this research, the construction process in Siwa was enhanced by adding new natural materials available in the oasis to the materials used actually in construction. This research concluded the followings:

1. Chemical analysis of silts, Badya, and Karsheef were performed. Results indicate that the main chemical composition of both silts is silicon dioxide, while the Badya contains mainly calcium oxide. This finding is promising since it implies the possibility of having some kind of pozzolanic reaction especially when ash is incorporated.
2. The compressive strength of the mortar currently used in Siwa Oasis is not promising (13.5 kg/cm^2) and may lead to very serious construction problems. Introducing only Badya to the Siwan mortar is not very promising as the strength enhancement over the control mortar varied from 4.3 kg/cm^2 up to 10.4 kg/cm^2 which is very minimal.
3. The incorporation of fine ash (passing Sieve No. 100) produced by burning "Sommar" affected adversely the consistency of the mortar; however, this can be overcome by the use of molasses. The addition of Ash is useless. The strengths of mortar with and without ash are very similar.
4. Molasses has positive effects on reducing the mixing water content and hence improving the strength of mortar. It is therefore recommended to be introduced to Siwan mortar. The recommended dosage is in the order of 3 to 4 % of the weight of solid materials.
5. The combined effect of Badya and Ash on the strength of the Siwan mortar may lead to very promising results. A compressive strength on the order of 57.2 kg/cm^2 at the age of 56 days was achieved. Moreover, when molasses was incorporated to that mix the water content reduces from 20% to 15% and hence the mortar strength could attain higher levels at earlier age (64.8 kg/cm^2 at the age of 28 days). At later ages, the mix strength may exceed 80 kg/cm^2 which is promising.

6. Recommendations

The research conducts the following recommendations:

- Different constructions and ecolodges constructed in Siwa Oasis should have the architectural style of the oasis in order to conserve the personality of the oasis.
- Additional tests are required at later ages to verify the strength of the proposed new binder.
- Other properties of the proposed binder rather than the compressive strength should be tested.
- More experimental data on the actual performance of Karsheef stones bonded together with the new binder is quite essential.
- The flexural behavior of the new binder when reinforced with the reeds (Sommar) could be very helpful.

References

[1] S. Tohamy and A. Swinscoe, The Economic Impact of Tourism in Egypt, Report, Egyptian Center for Economic Studies, Egypt (2000).

[2] H. Lascurain, Tourism, Ecotourism, and Protected Areas, Gland, Switzerland, IUCN Publications (1996).

[3] World Tourism Organization, Yearbook of Tourism Statistics, WTO Publications, Madrid, Spain (1996).

[4] V. Cassandra, the Western Desert of Egypt, AUC Press, Cairo (2000).

[5] EEAA, Egyptian Environmental Affair Agency - Department of Nature Conservation and National Biodiversity, National Strategy and Action Plan for Biodiversity Conservation, Annual Report, Egypt (1998).

[6] H. El-Taweel, Development of Siwa Oasis Center, Unpublished Ph.D Thesis, Alexandria University, Egypt (1993).

[7] W. Kamel and N. Khalil, Application of Ecotourism Concepts in Siwa Oasis, World Conference on Energy for Sustainable Development: Technology Advances and Environmental Issues, Cairo, Egypt, December (2004).

[8] N. Khalil, An Approach to Develop Ecolodges in Siwa Oasis Using Natural building Materials: Theoretical and

[9] Experimental Study, Unpublished Master Thesis, Arab academy for Science, Technology and Maritime Transport, Alexandria (2005).

[10] S. Khoury and A. Kurdi, Silica Fume Improves Concrete Strength: Is That True?, Third Alexandria Conference on Structural and Geotechnical Engineering (ACSGE3), Faculty of Engineering, Alexandria University, Alexandria, Egypt, December (1997).

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