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Evaluation of Lime Mortar and Conservation Techniques in Traditional Elements

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ABSTRACT

Architecture and construction methods have been developed by the people who have been living around the word through centuries. Unlike now, in the past the quality of building materials were so different, because of lack of process control and variability in the local sources. Hence each place had different building materials comparing to other places. For many years, lime mortar had been used as the main mortar material in Sharjah traditional masonry. The source of the lime was mainly from coral and lime stones which could be found on the coastal area. This paper aims to prove the compatibility between existing and old lime plus the efficiency of using lime mortar in Sharjah restoration projects. The study has three aims: The first aim is to identify and examine the chemical components of old mortar samples that exist in different heritage buildings in Sharjah by XRF and SEM tests. The second aim is to prepare a new mortar samples with components based on the first aim and examine them by the same tests in the first stages. The last aim is to determine the quality of the new mortar in existing restoration projects in Sharjah city that are exposed to harsh environment factors.

Keywords: *Restoration, Lime Mortar, Traditional Masonry, Materials properties, XRF and SEM*

1. Introduction

In the most cases there is no information about the old materials and mixes. Hence, these facts urge Conservators to work on the materials before any conservation project.

Basically, the property of the building materials is divided into two main groups:

I. Physical properties (e.g. Weight, Size, density, Strength, Color etc.)

II. Chemical properties (e.g. Chemical Components, Flammability, Internal structure, etc.)

Actually, depends on what we are looking for in terms of scientific information, an appropriate test(s) must be done.

In this paper we worked on two most popular tests in the field of Historical Building Studies, these two tests are:

1. XRF (X-Ray Fluorescence)

2. SEM (Scanning Electron Microscope

I. XRF (X-Ray Fluorescence):

Basically, it works on wavelength-scattering spectroscopic principals. It is used for analyzing major and trace elements in minerals, rocks and sediments.

In addition, the main idea about the XRF is to provide the microstructure images which are related to transferring energy between orbitals. Hence, the electrons which gain or drop their energy level move between orbital layers.[2]

- **Why are we using XRF?**
  1. Non-destructive
  2. Accuracy
  3. Fast
  4. Large chemical analysis for major and minor elements in rocks and sediments (Si, Ti, Al, Fe, Mn, Mn, Mg, Ca, Na, K, P & Ba, Ce, Co, Cu, Ga, La, Nb, Ni, Rb, Sc, Sr, Rh, U, V, Y, Zr, Zn).

II. SEM (Scanning Electron Microscope):[3][4][5]

This machine produces an accumulated beam of high energy electrons. This beam generates variety of signals at the surface of sample.

These signals give different information about the sample such as Texture (morphology), Chemical components, Crystalline structure and Materials orientation.

- Why are we using SEM?

1. Non-destructive
2. Fast
3. Accurate
4. Intuitive (User friendly) interface
5. Easy to operate

2. EXPERIMENTAL SAMPLES AND TEST MATRIX

2.1 SAMPLES

- Old Mortars
- The new mortar

Basically, samples are divided into two different categories

I. Mortars
II. Plasters

- Samples are taken from different places in Sharjah Emirates.
- Table 1; shows the samples description.

Sample	The Sample Material	Location	The Code
1	Mortar	Sharjah/ Al Tawawil House	OTM
2	Mortar	Sharjah/ Heritage area	SM
3	Plaster	Khoor Kalbaa/ The Old Tower	KKP

		Plaster	
4	Mortar	Khoor Fakkan Tower	KFT
5	Mortar	Heeritage Area/ New mix	NM

The mixed items are:

1. Crushed Bricks

2. Crushed Shell (up to 1.5 mm)

3.Lime Putty

4.Black sand (2mm- 5mm)

5-Sarooj

Figure 1: Raw materials are used for the new mortar mix

XRF and SEM Tests set up

At this test we use portable XRF equipment which is similar to the fixed one, but is easier to work. Fig.2

Figure 2: XRF (Portable)

- Sampling: Fig 3

To use these devices, it is necessary to prepare the sample in the right way. There are several steps should be followed to prepare the sample. These steps are:

1. Cutting the sample to a size that we need, about 40mm*40mm*40mm. (SEM&XRF)

2. Polishing the sample in coating machine (SEM)

3. Crushing the sample to have a very fine mass of powder. (XRF)

4. Put the crushed sample on the chamber. (SEM&XRF)

5. Conducted the experiment. (SEM&XRF)

Figure 3: XRF & SEM sampling

- Preparing new mortar sample: Fig.4

First:

two different sizes of molds were made:

i. 40mm x 40mm x 40 mm

ii. 40mm x 40 mm x 160 mm Next:

1. Material were prepared.

2. Material balance and weighted

3. Material were mixed by hand properly.

4. The material casted in the molds and have been left for months to be ready

Figure 4: Steps to use to produce the new mortar

Results:

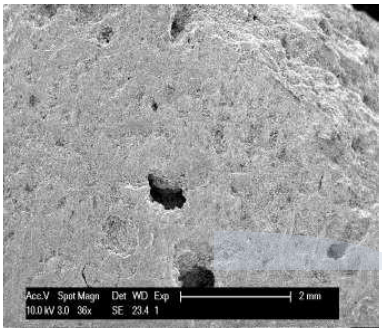
- **SEM**

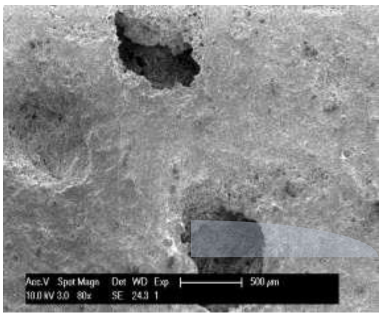
As it was mentioned before, in the test matrix, there are four different samples that had been examined by the SEM. There were two different scales used for each sample:

1. 2 mm

2. 500 µm

- KKP





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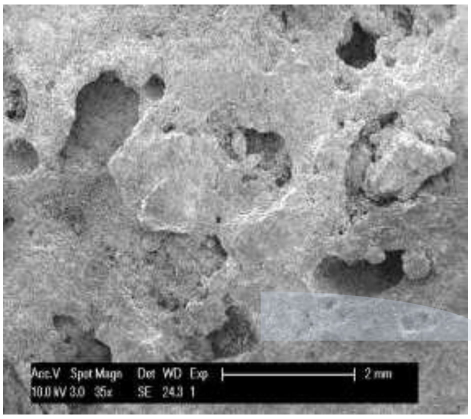
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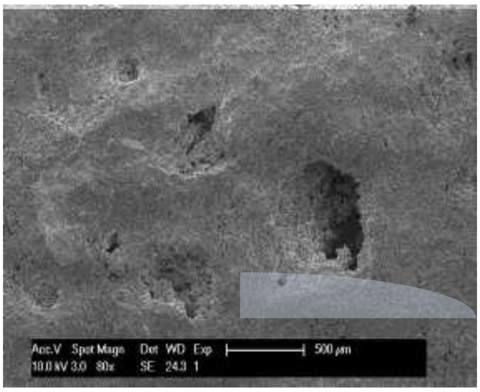
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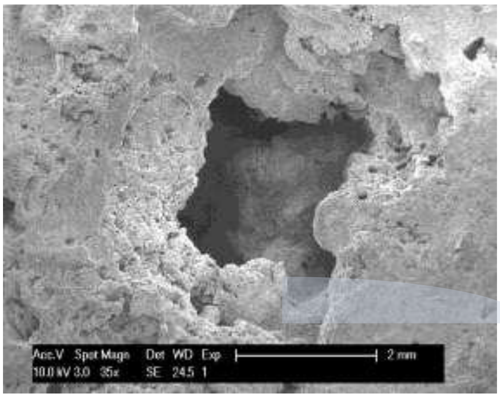
- SM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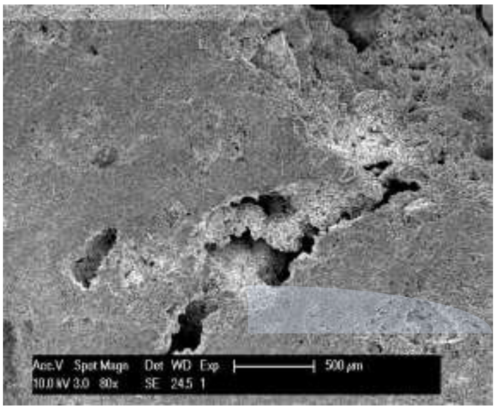
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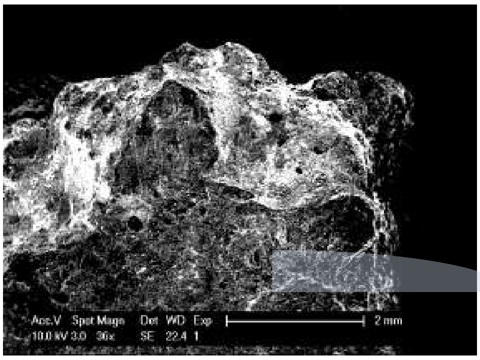
- OTM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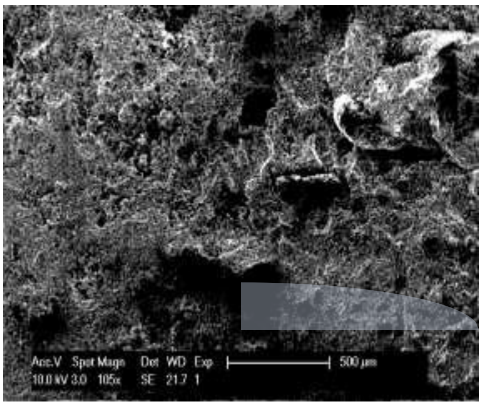
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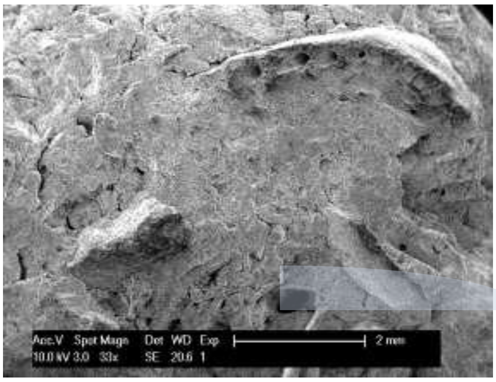
- NM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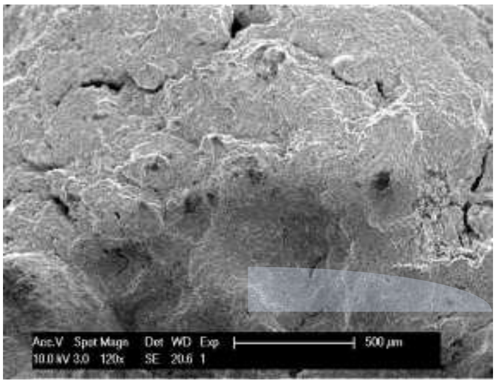
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- For the XRF test
- OTM

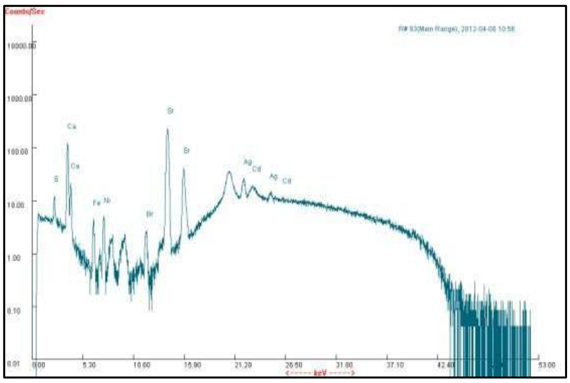

Figure 7: XRF plot for Al Tawawil House

- NM

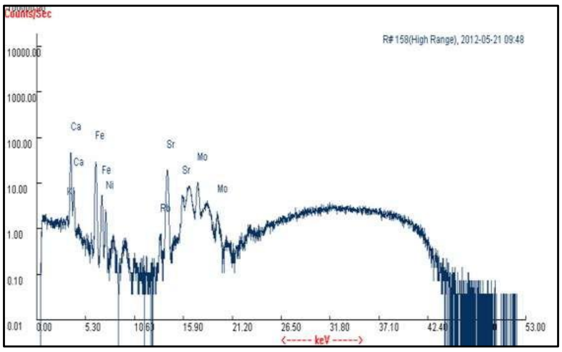

Figure 8: XRF plot of the New Mortar

- KKP

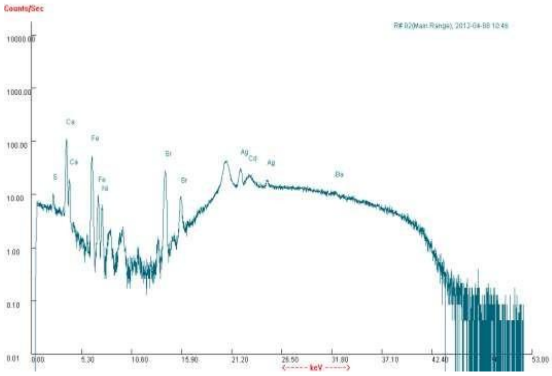

Figure 9: XRF plot of the Khour Kalba Plaster

- SM

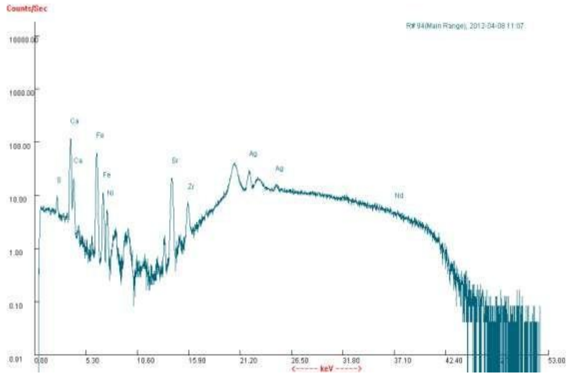

Figure 10: XRF plot of Sharjah area

- KFT

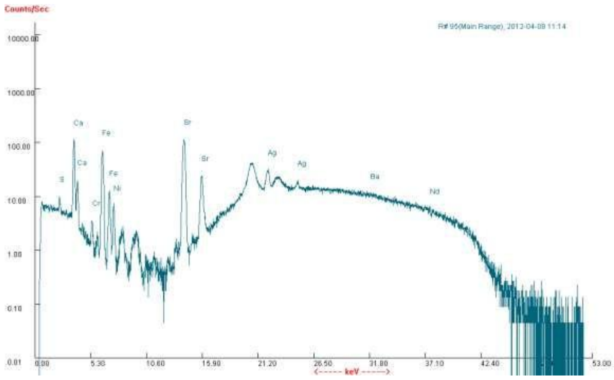

Figure 11: XRF plot of Khorfakkan Tower

Table 2: XRF data for the all samples

	Type	Units	Flags	Duration						
	Soil	ppm	8mm	90 sec						
	Location		Location		Location		Location		Location	
	Khour Kalba		H.O.Sharjah Old Tower		H.O.Sharjah Old Mortar		Khour Fakkan old tower		Sharjah new mix	
1	Mo	< LOD	Mo	< LOD	Mo	4.28	Mo	< LOD	Mo	1.695
2	Mo Error	2.7	Mo Error	3.21	Mo Error	1.91	Mo Error	2.89	Mo Error	2.016
3	Zr	30.34	Zr	38.03	Zr	26.33	Zr	43.83	Zr	66.67
4	Zr Error	2.8	Zr Error	6.63	Zr Error	2.68	Zr Error	4.49	Zr Error	4.466
5	Sr	259.3	Sr	2614.32	Sr	210.42	Sr	1088.25	Sr	854.243
6	Sr Error	5.34	Sr Error	18.19	Sr Error	4.92	Sr Error	11.1	Sr Error	10.01
7	U	< LOD	U	13.56	U	< LOD	U	< LOD	U	9.367
8	U Error	5.13	U Error	6.94	U Error	5.05	U Error	7.19	U Error	5.101
9	Rb	8.61	Rb	7.99	Rb	10.98	Rb	5.31	Rb	24.039
10	Rb Error	1.71	Rb Error	2.64	Rb Error	1.81	Rb Error	1.94	Rb Error	2.611
11	Th	< LOD	Th	4.51	Th	< LOD	Th	< LOD	Th	1.822
12	Th Error	3	Th Error	2.92	Th Error	3.28	Th Error	3.57	Th Error	2.457
13	Pb	< LOD	Pb	< LOD	Pb	7.63	Pb	8.27	Pb	5.816
14	Pb Error	4.84	Pb Error	5.88	Pb Error	3.61	Pb Error	3.89	Pb Error	3.716
15	Au	< LOD	Au	< LOD	Au	< LOD	Au	< LOD	Au	-0.888
16	Au Error	7.05	Au Error	8.6	Au Error	6.97	Au Error	7.58	Au Error	4.996
17	Se	< LOD	Se	< LOD	Se	< LOD	Se	< LOD	Se	-0.815
18	Se Error	3.11	Se Error	3.6	Se Error	3.02	Se Error	3.25	Se Error	2.09
19	As	< LOD	As	< LOD	As	< LOD	As	< LOD	As	3.139
20	As Error	4.05	As Error	4.64	As Error	4.32	As Error	4.77	As Error	3.139
21	Hg	< LOD	Hg	< LOD	Hg	< LOD	Hg	< LOD	Hg	3.931
22	Hg Error	9.3	Hg Error	10.77	Hg Error	10.02	Hg Error	9.81	Hg Error	7.188
23	Zn	10.56	Zn	< LOD	Zn	19.46	Zn	15.16	Zn	34.837
24	Zn Error	6.31	Zn Error	10.14	Zn Error	7.04	Zn Error	6.8	Zn Error	8.056
25	W	< LOD	W	< LOD	W	< LOD	W	< LOD	W	25.582
26	W Error	44.75	W Error	51.01	W Error	47.66	W Error	46.67	W Error	36.213
27	Cu	< LOD	Cu	< LOD	Cu	< LOD	Cu	< LOD	Cu	13.186
28	Cu Error	17.48	Cu Error	19.85	Cu Error	18.57	Cu Error	18.82	Cu Error	13.243
29	Ni	< LOD	Ni	< LOD	Ni	< LOD	Ni	59.5	Ni	342.086
30	Ni Error	35.97	Ni Error	39.98	Ni Error	36.34	Ni Error	26.1	Ni Error	33.057
31	Co	< LOD	Co	< LOD	Co	< LOD	Co	< LOD	Co	160.968
32	Co Error	69.46	Co Error	32.43	Co Error	79.91	Co Error	83.57	Co Error	75.775
33	Fe	8364.27	Fe	602.18	Fe	10838.13	Fe	11408.1	Fe	20788.514
34	Fe Error	147.4	Fe Error	53.38	Fe Error	170.21	Fe Error	176.19	Fe Error	240.208
35	Mn	125.54	Mn	< LOD	Mn	122.15	Mn	162.82	Mn	328.146
36	Mn Error	47.49	Mn Error	61.75	Mn Error	47.7	Mn Error	54.23	Mn Error	59.768
37	Cr	44.51	Cr	< LOD	Cr	40.37	Cr	265.83	Cr	167.39
38	Cr Error	7.98	Cr Error	9.02	Cr Error	8.01	Cr Error	12.85	Cr Error	13.116
39	V	32.83	V	< LOD	V	35.98	V	25.12	V	41.215
40	V Error	11.76	V Error	9.58	V Error	11.91	V Error	12.05	V Error	16.396
41	Ti	457.33	Ti	< LOD	Ti	397.98	Ti	305.75	Ti	792.673
42	Ti Error	43.15	Ti Error	43.85	Ti Error	43.04	Ti Error	42.9	Ti Error	61.074
43	Sc	736.33	Sc	622.5	Sc	557.49	Sc	620.15	Sc	394.962
44	Sc Error	124.38	Sc Error	118.84	Sc Error	129.87	Sc Error	128.24	Sc Error	181.113
45	Ca	195483.9	Ca	201643.05	Ca	208177.08	Ca	196962.41	Ca	298349.125
46	Ca Error	690.44	Ca Error	662.65	Ca Error	726.11	Ca Error	714.6	Ca Error	1022.09
47	K	3015.13	K	1997.86	K	3345.5	K	2637.64	K	6541.463
48	K Error	180.94	K Error	160.97	K Error	191.49	K Error	183.3	K Error	289.01
49	S	59357.09	S	89669.23	S	56958.88	S	52424.09	S	486.18
50	S Error	946.19	S Error	1090.82	S Error	946.93	S Error	920.48	S Error	321.662
51	Ba	< LOD	Ba	< LOD	Ba	< LOD	Ba	< LOD	Ba	-247.716
52	Ba Error	51.86	Ba Error	49.82	Ba Error	50.38	Ba Error	52.02	Ba Error	34.109
53	Cs	< LOD	Cs	< LOD	Cs	< LOD	Cs	< LOD	Cs	-82.91
54	Cs Error	13.81	Cs Error	13.57	Cs Error	13.54	Cs Error	13.8	Cs Error	9.112
55	Te	< LOD	Te	< LOD	Te	< LOD	Te	< LOD	Te	-158.072
56	Te Error	41.58	Te Error	39.55	Te Error	39.42	Te Error	41.28	Te Error	26.937
57	Sb	< LOD	Sb	< LOD	Sb	< LOD	Sb	< LOD	Sb	-38.532
58	Sb Error	15.31	Sb Error	14.46	Sb Error	14.57	Sb Error	15.3	Sb Error	10.099
59	Sn	< LOD	Sn	< LOD	Sn	< LOD	Sn	< LOD	Sn	-26.847
60	Sn Error	11.97	Sn Error	11.48	Sn Error	11.69	Sn Error	11.82	Sn Error	7.864
61	Cd	< LOD	Cd	< LOD	Cd	< LOD	Cd	< LOD	Cd	-14.667

62	Cd Error	11.88	Cd Error	11.43	Cd Error	11.93	Cd Error	12.1	Cd Error	7.992
63	Ag	< LOD	Ag	< LOD	Ag	< LOD	Ag	< LOD	Ag	-9.113
64	Ag Error	7.48	Ag Error	7.49	Ag Error	7.36	Ag Error	7.49	Ag Error	4.94
65	Pd	< LOD	Pd	< LOD	Pd	< LOD	Pd	< LOD	Pd	-12.102
66	Pd Error	12.84	Pd Error	12.55	Pd Error	12.21	Pd Error	12.71	Pd Error	8.416

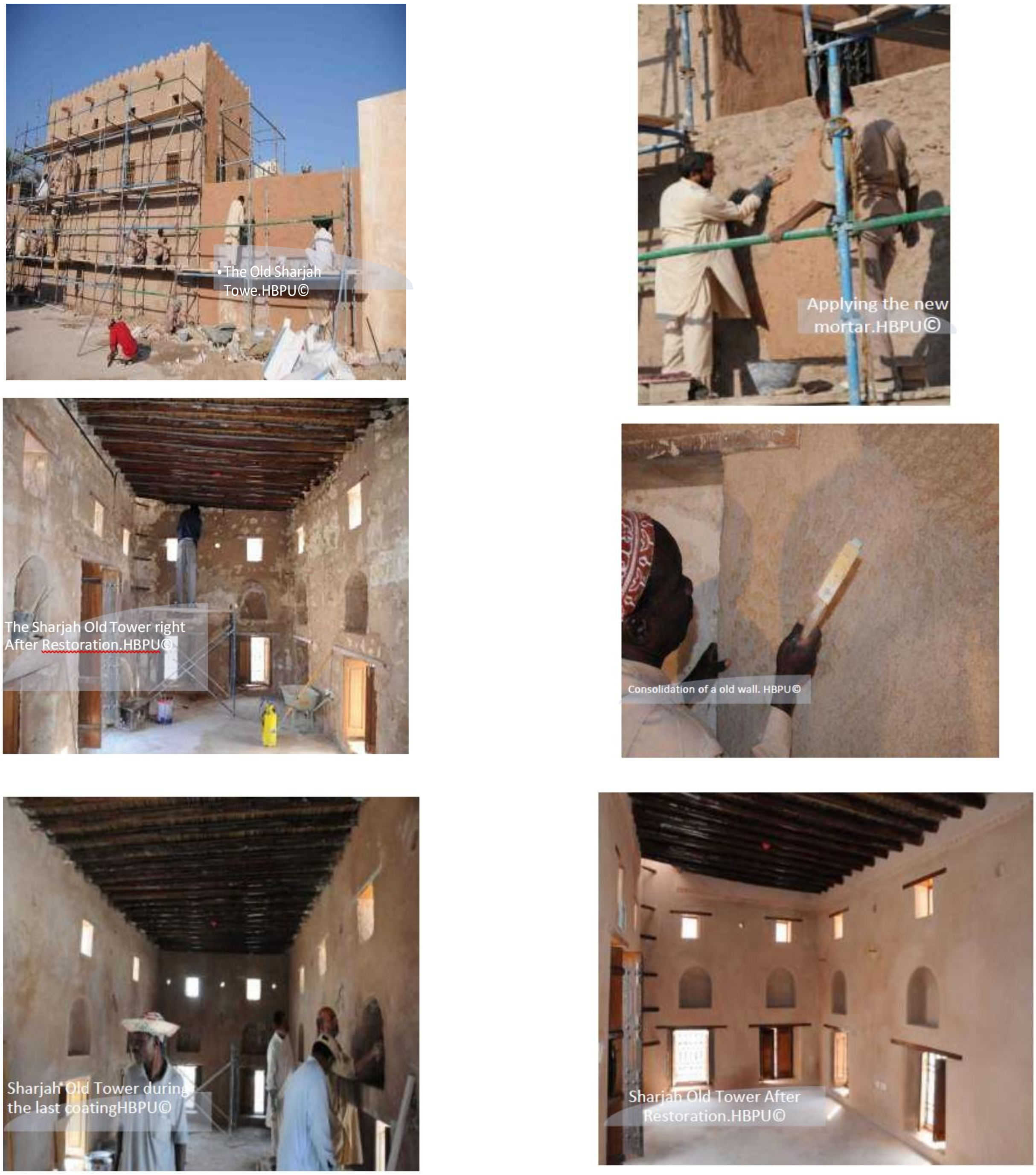

Figure 9: pictures of applying some of the new mortar in some Sharjah restoration projects

2. Discussion

- SEM test:

The results are the same and show that all mortars even the new one physically are the same.

The new mortar texture is very close to the old samples. So it means that our compositions is close to the traditional or old mixes which is a great achievement.

These details and pictures show that our new mix is very close to the old mixes here in Sharjah, and we are hoping to get to better results by more scientific and practical experiments.

- XRF test

It is noticeable that all of the samples have a same fundamental elements such as Ca, Fe, Sr, Sc, and etc; but the percentage is different. For example, for all the old samples, (Ca) has around 30-40% of the whole sample. Also (K) and (S) together can present more than 10 % of the sample size.

Other common elements such as (Sc) and (Cr) are reach into 3-4 %. (Rb), (Zr), and (V) are in all the old samples and the percentage is about 3% only.

The new mortar was almost a good match comparing with the all old mortars where it contains all the common elements that mentioned before. The similarity was not only in the existence of the elements, but also with the quantity and the distribution of them. For example the amount of the Ca in the new mortar is 238349.125 ppm and the average of the Ca in all the old mortar samples are 200566.25 ppm. This applied with all the other major elements which mentioned before. This indicates the good possibility that the new mortar could behave in the same way of old mortars. From this indication the aim of this search journal could be achievable (using the new mortar in Sharjah restoration projects).

It should be notice that there are elements are shown in the graphs that are not in existed in the samples such as (Ag). The reason behind that is due to the XRF device where it contains some metals which cannot be noticeable in the graph. However, during the analysis, the XRF will not include these elements as data as shown in the data tables.

3. Conclusion

In this research paper, various tests were conducted in order to examine the suitability of new lime mortar mix in Sharjah restoration projects. The tests that were conducted are SEM and XRF, are based on X-Ray technology.

For the SEM test results, it can be said that in general the old samples of the mortars contains more voids than the new mortar. However, there are fewer wrinkles in the old mortar samples and that because method of application. For the XRF tests results and graphs and can be easy noticed that all samples (old and new) has the same majors elements within same range such as Ca, K, Fe, Sr, S, and Mn.

We are hopping by combining experiences and science to gather in the field of restoration, get to a that level of knowledge to obtain more information from the past by analyzing the remaining of them. So our way of approach is one of the pioneer methods and we are hoping success in the future results.

Currently the authors are working in different aspects and different properties for the same topic such as the mechanical and chemical properties by different test. To explain, machine such as Universal Test Machine (UTM) and (XRD) will be used to investigate more about the new mortar.

4. Acknowledgment

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