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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.

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INTRODUCTION

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

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

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

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:

XRF (X-Ray Fluorescence)

SEM (Scanning Electron Microscope

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?

Non-destructive

Accuracy

Fast

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).

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

This machine produces an accumulated beam of high energy electrons. This beam generate 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 ?

Non-destructive

Fast

Accurate

Intuitive(User friendly) interface

Easy to operate

EXPERIMENTAL SAMPLES AND TEST MATRIX

SAMPLES

Old mortars

The new mortar

Basically samples are divided into two different categories:

Mortars

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

Table 1. Test matrix

*: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:

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

Polishing the sample in coating machine (SEM)

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

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

Conducted the experiment. (SEM&XRF)



Figure 3. XRF & SEM sampling

Preparing new mortar sample: Fig.4

First:

two different sizes of molds were made:

40mm x 40mm x 40 mm

40mm x 40 mm x 160 mm Next:

Material were prepared.

Material balance and weighted

Material were mixed by hand properly.

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

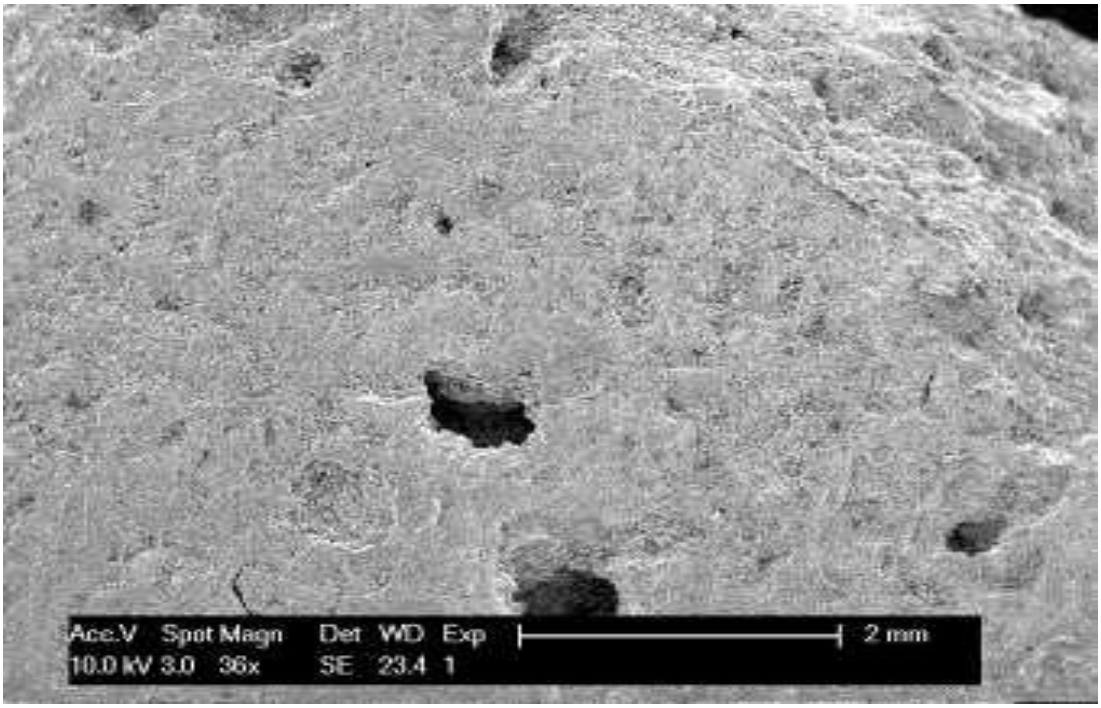
SEM

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:

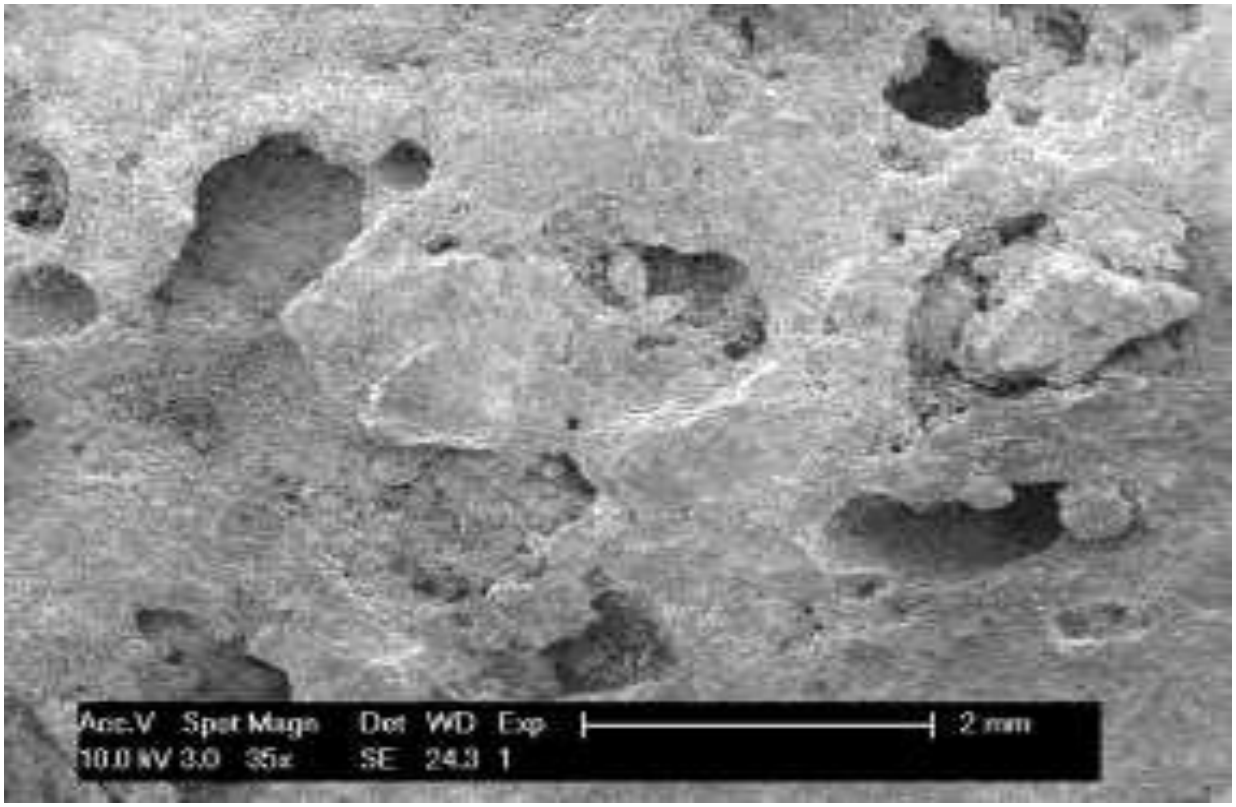
2 mm

500 µm

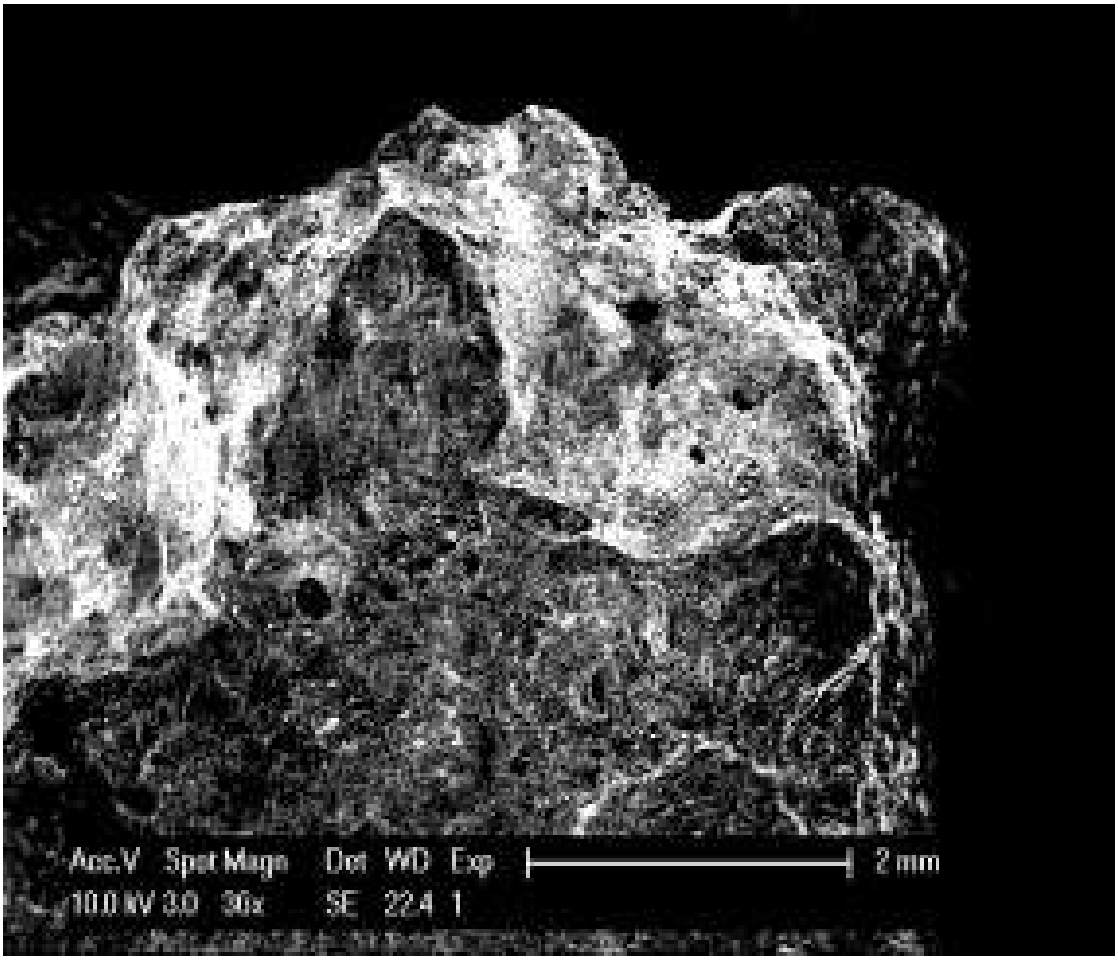
KKP



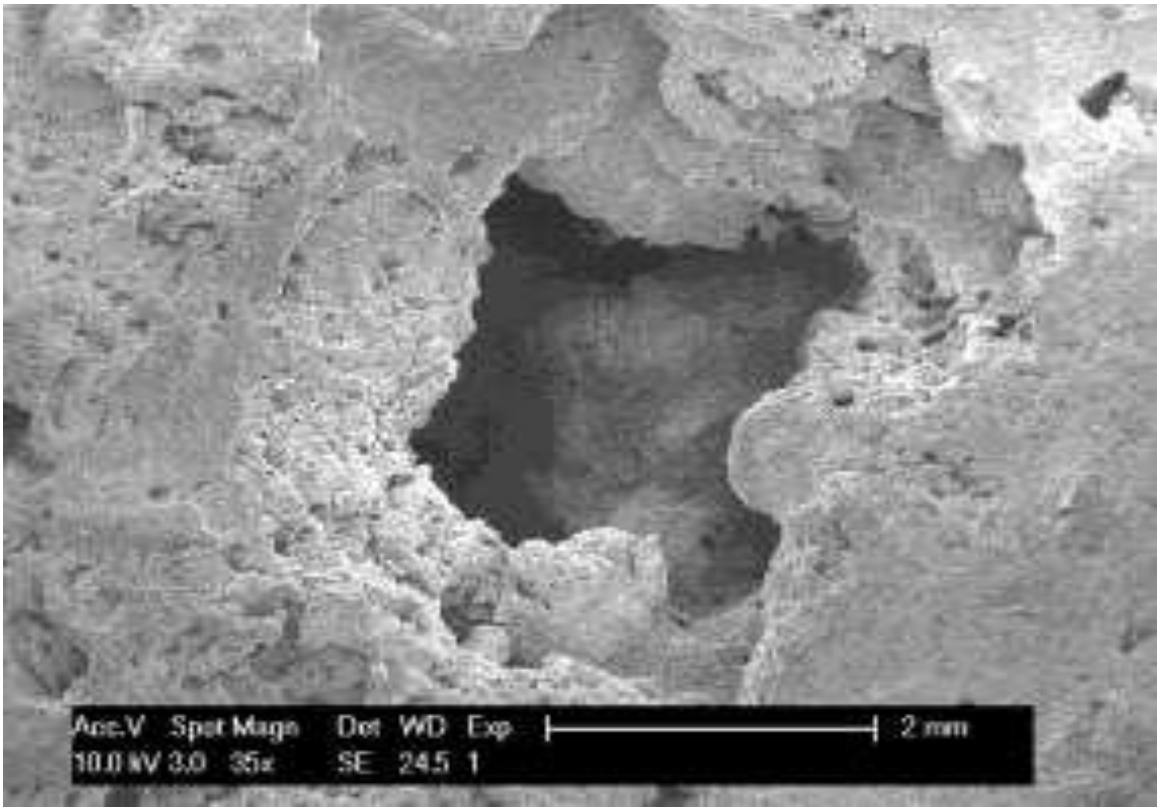
KFT


Acc.V Spot Magn Det WD Exp 2 mm
10.0 kV 3.0 35x SE 24.3 1

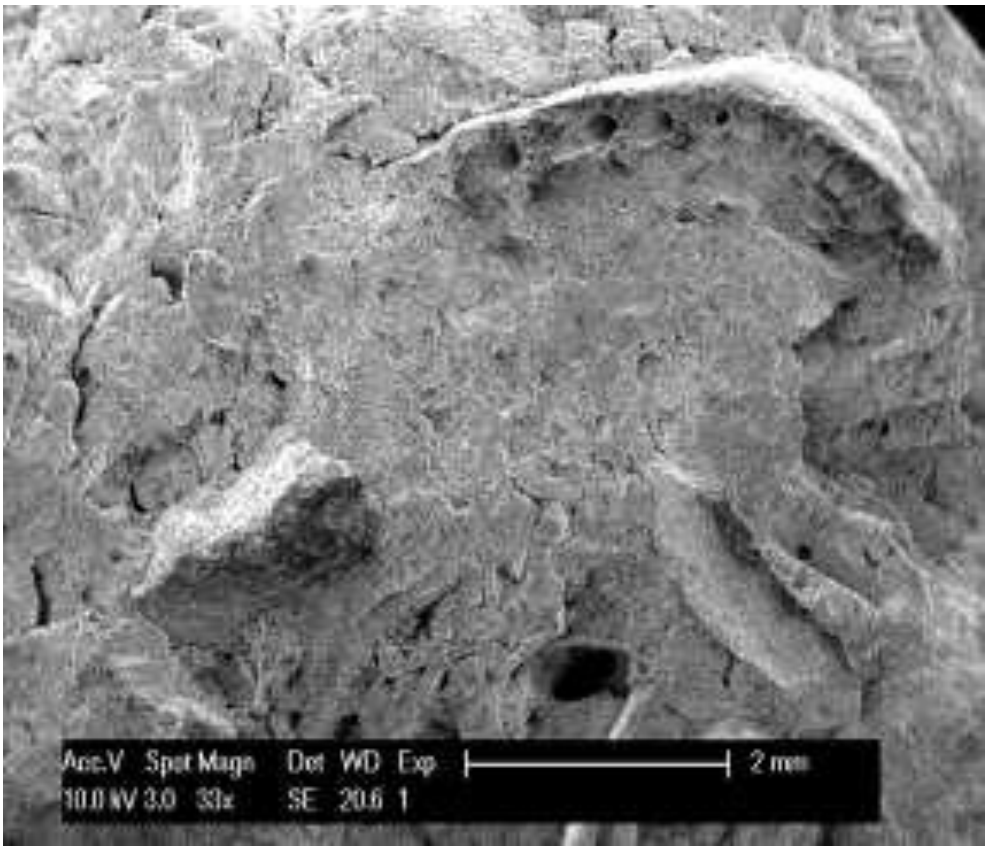
OTM


Acc.V Spot Magn Det WD Exp 2 mm
10.0 kV 3.0 30x SE 22.4 1

SM



NM



For the XRF test OTM

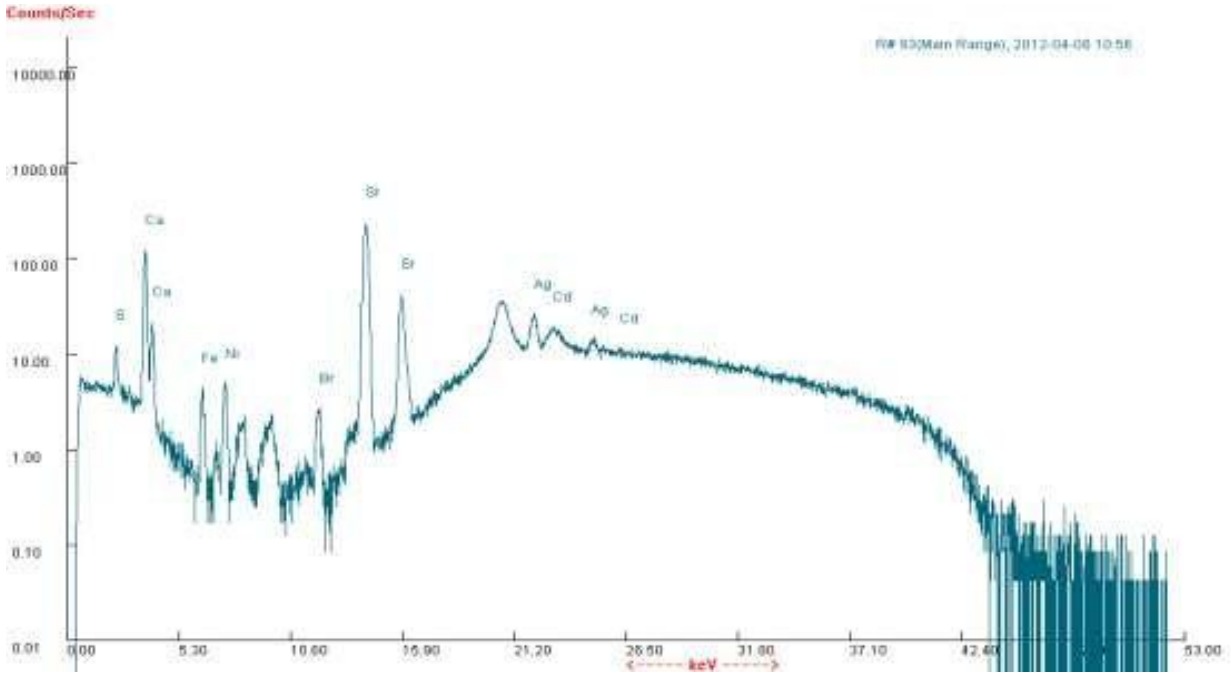


Figure 7. XRF plot for Al Tawawil House NM

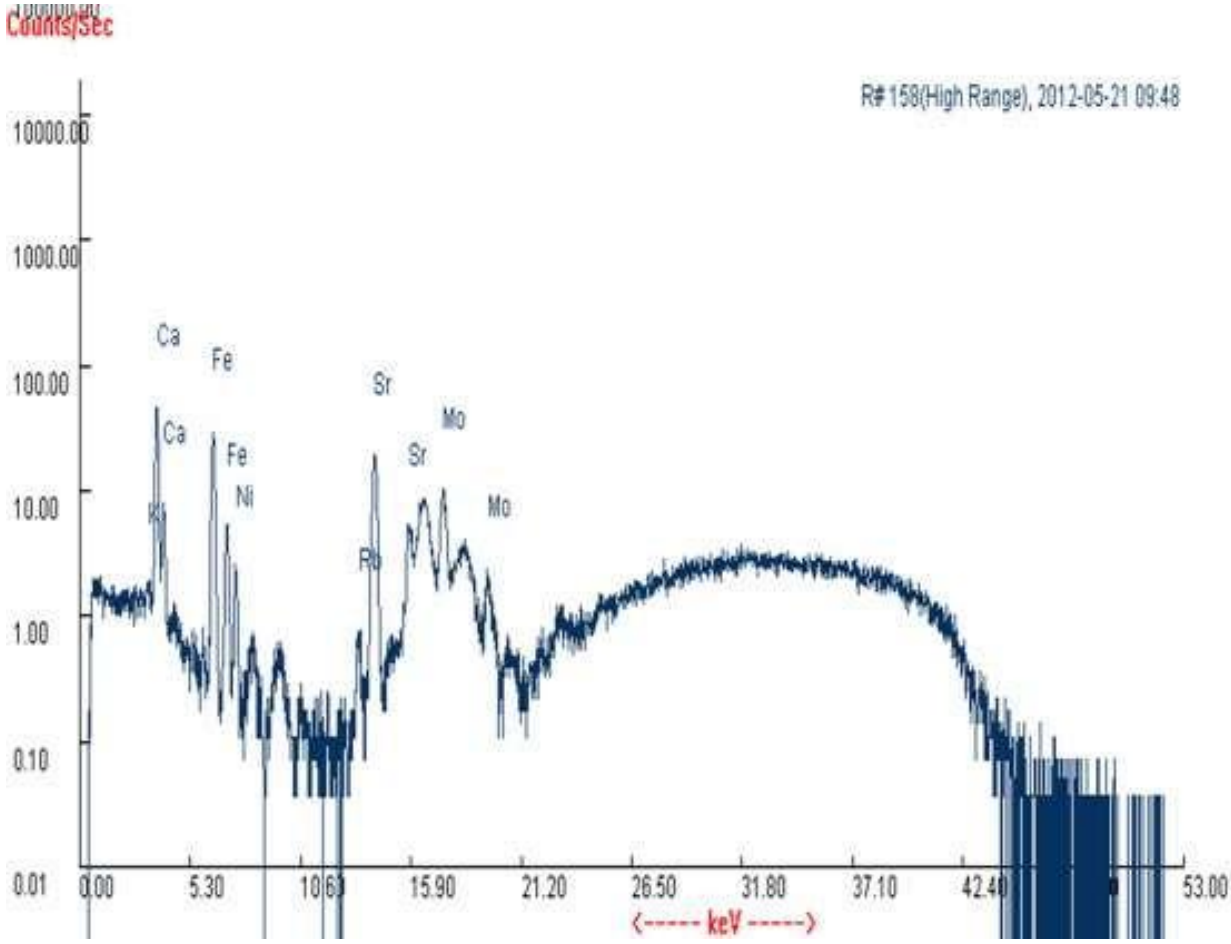


Figure 8. XRF plot of the New Mortar KKP

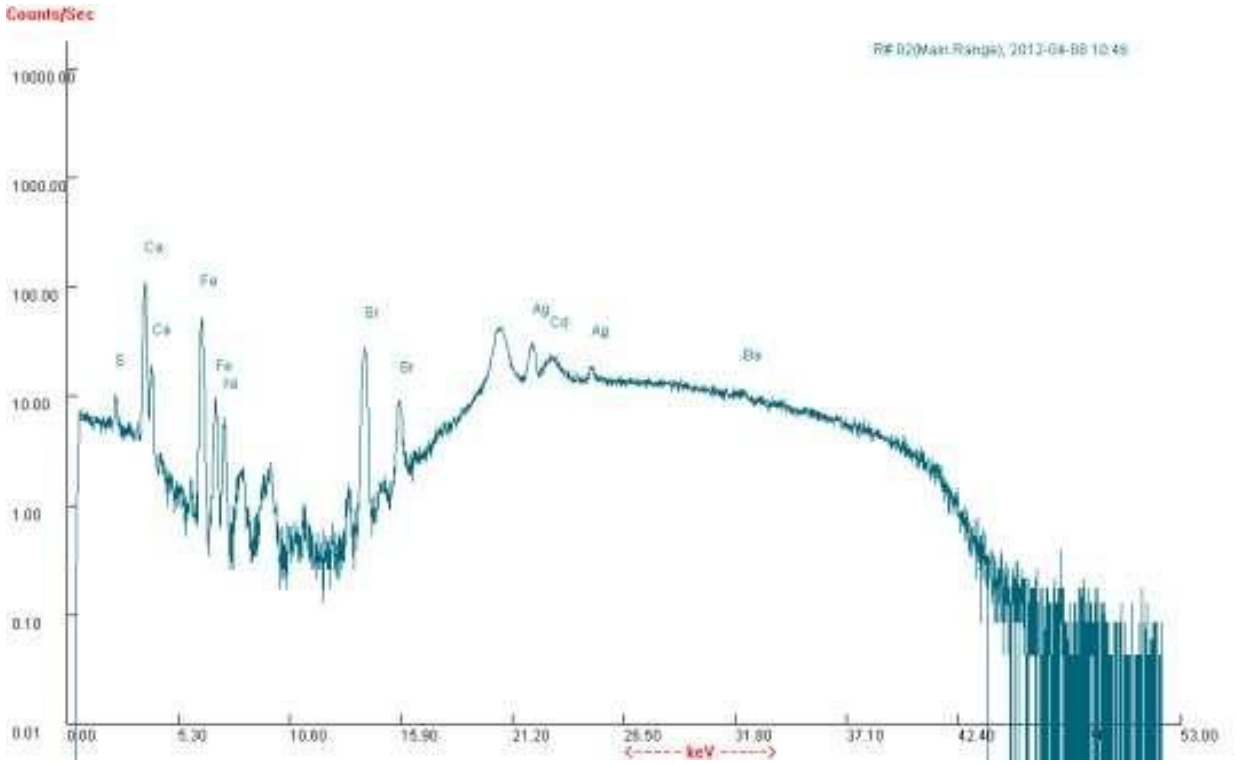


Figure 9. XRF plot of the Khour Kalba Plaster

SM

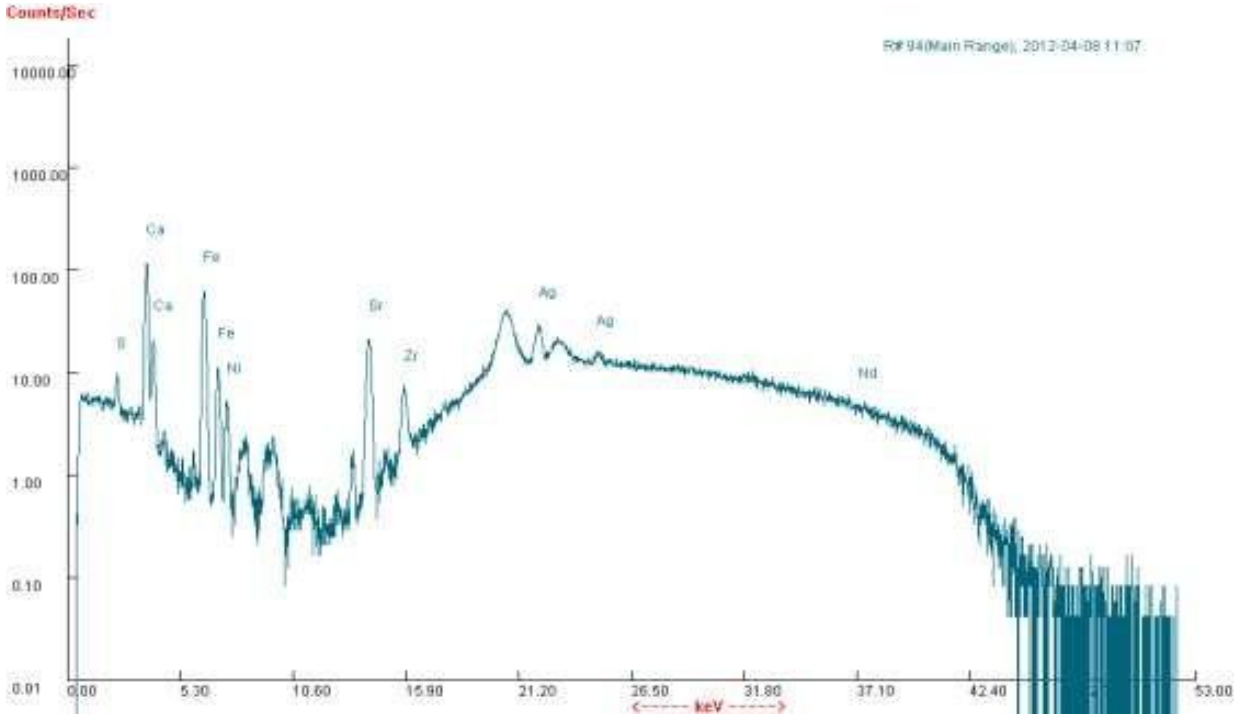


Figure 10. XRF plot of Sharjah area

KFT

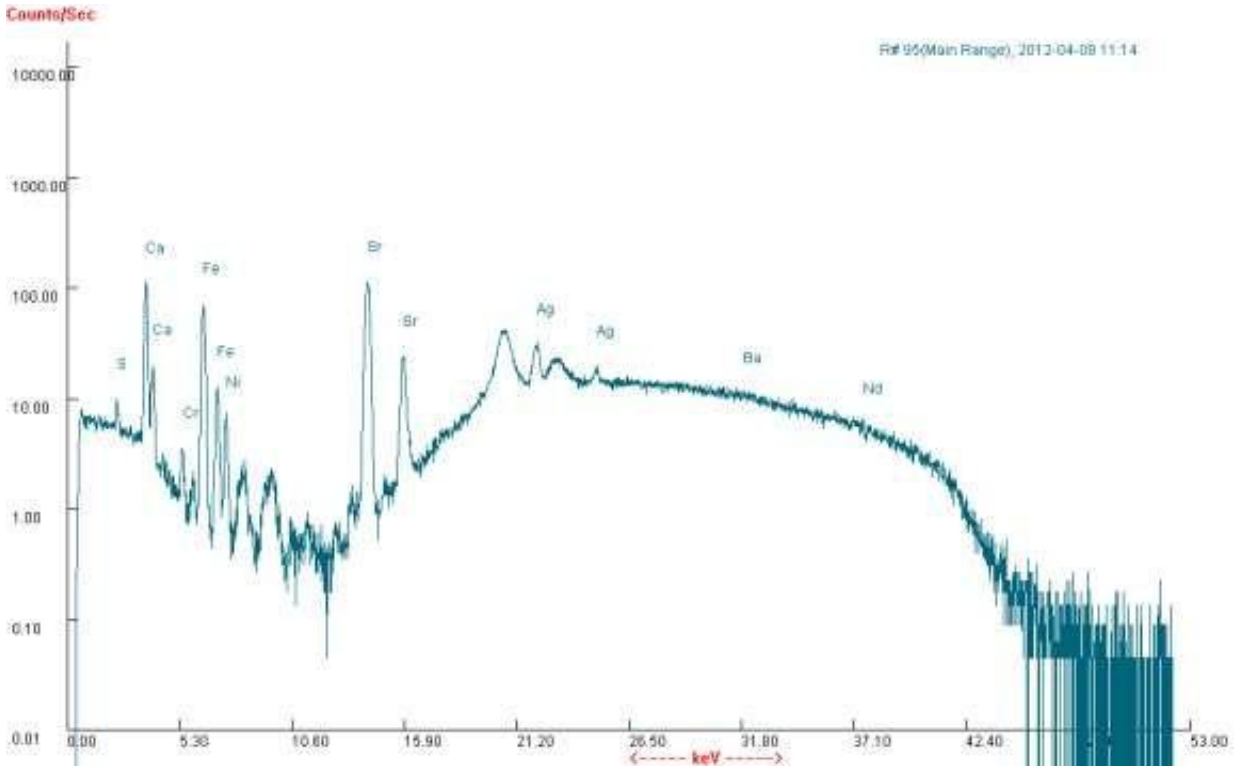


Figure 11. XRF plot of Khorfakkan Tower

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		M n	328.146
36	M n Error	47.49		M n Error	61.75		M n Error	47.7		M n Error	54.23		M n 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

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.

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.

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