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Compressive and Failure Strength of Sand Stone with Different Strengthen Materials

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Abstract Composite materials have advantages of giving new properties for the component materials. Therefore fundamental of forming and fabrication of composites material has been used to enhance the mechanical compressive and failure strength of deteriorates ancient materials. Habu Temple has been often in the observing of a lot of scientific research. Natural weathering like rains, moisture, salty groundwater absorption and changing temperature can damage or even may weaken the strength of such deteriorates ancient buildings. Sandstones are of the main construction building materials of this ancient temple. Compressive strength of sandstones is affected by weathering conditions. Samples of ancient Nubian sandstones are coated with Paraloid 44 (B44), Paraloid 72 (B72), Ethyle silicate and Wacker (OH100). The results showed that in general, Mechanical Compressive strength of sandstone decreases due to salty groundwater action. Ethyle silicate coating material is more efficient and gives considerable protection about over 250% enhancement when the sample immersed in water gives a about over 140 % enhancement.

Keywords: *sandstone, compressive strength of rock, coating rocks, temples*

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1. Introduction

Deterioration of historical building is caused by weathering conditions like atmospheric pollution, salty Groundwater absorption [1]. Many researches were on deterioration of marble and limestone [2-8] while little for sandstones. Sandstones are the most famous building material and obtaining information and data for mechanical properties of such natural stone is of great important [9].

M. Ludovico-Marques et al. [10] investigated the mechanical compressive strength of ancient building sandstone; the results showed that pores of sandstone had great effect on the compressive behaviors.

Li and Aubertin [11] study analytically effect of porosity on magnitude of mechanical uniaxial strength in both compression and tension. Sandstone is a natural composite material containing quartz as main matrix phase combined with clay and low calcite cement [12]. The rehabilitation, strengthening, and Conservation of ancient building are remarkable works in a lot of societies, therefore deeply understanding the ancient material behaviors give good and satisfied results for rehabilitation process [13]. A lot of development in the experimental and numerical investigations of ancient building rehabilitation is occurred [14].

The objectivity of the present study is to use fabrication process of composite material to fill the porosity of ancient pharonic deteriorates sandstones with chemical solvent. The mechanical compressive behaviors of the coated sandstone are investigated for deteriorates rock and for rehabilitation ones. The chemical coating protects the surface of sandstones from weathering conditions.

2. Materials and Characterization

Table 1 XRD analysis results of Habu Sandstone Samples

Sample	Major minerals	Minor minerals
1	Quartz	
2	Quartz	
3	Quartz	Kaolinite Microcline Albite
4	Quartz Halite	Albite Microline Kaolinite Calite

Table 2. Chemical Composition of coated materials

Materials	Chemical composition
Paraloid B44	Methyl methacrylate (MMA) co-polymer
Paraloid B72	Co-polymere ethylmetacry-metylacrylate
ethyle silicate	$Si(OC_2H_5)_4$
wacker OH100	Cyclohexylmethyl-dimethoxysilane

Nubian historical sandstones taken form Qurna mountain near Habu temple in upper Egypt are used. The x-ray diffraction of this material are analyzed for four specimens and shown in (Figure 1). Components taken from XRD of each specimen are listed in Table 1. The chemical coating material which are Paraloid 44 (B44), Paraloid 72 (B72), Ethyle silicate and Wacker (OH100), are listed in Table 2.

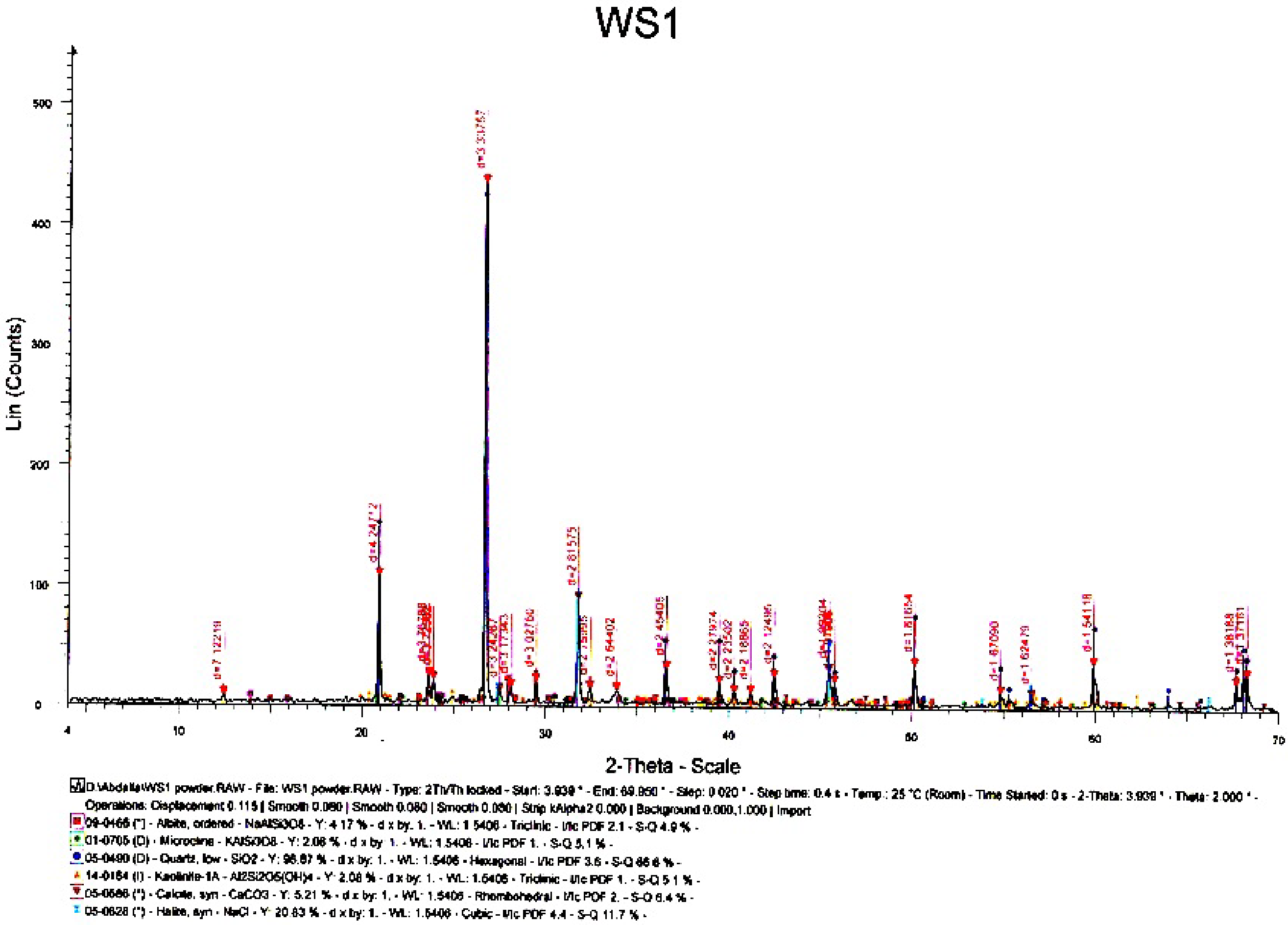


Figure 1. XRD for Nubian Sandstone

3. Experimental Work

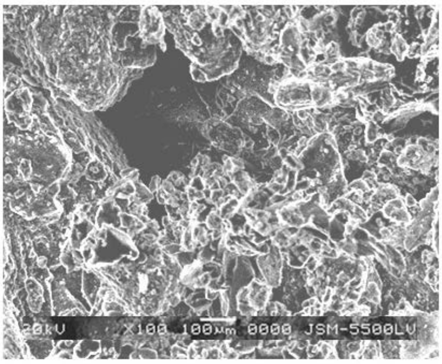
The as receives sandstones of (30 mm ×30 mm ×30 mm) are test in compassion using computerized universal testing machine (model WDW-100) at 1 mm/min cross head speed. Four groups of tested specimens are coated by chemical material Paraloid 44 (B44), Paraloid 72 (B72), Ethyle silicate and Wacker OH100. The coating process is performed by immersion of sandstones specimens into the coating chemicals for 72 hr for each (see Figure 2). The sandstones that coating with the varios solvent and that without coating for aim of comparison, are immersed in salty groundwater path for 15 days continuously. The compressive test is performed according to ASTM stander [18].

Figure 2. Samples of sandstones

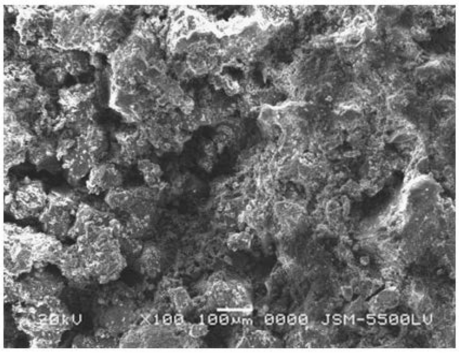
4. Results and Discussion

4.1. Microstructure Examination

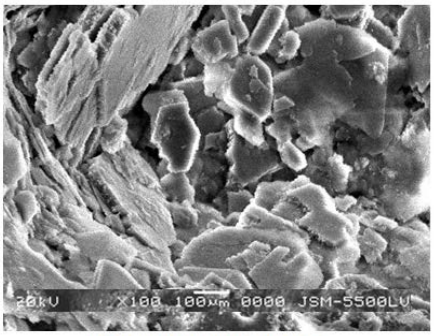
Figure 3 shows the distribution of the coated films on ancient Nubian sandstone. Coating using Paraloid 44 (B44) Forms a dense thick film and closes the porosity of sandstone. But these dense films are distributed inhomogeneously. The film of Paraloid 72 (B72) which is more homogeneous, is partially distributed between the grains of sandstone and it covers partially the grains of sandstone (see Figure 3a). Paraloid resin as coating materials is stronger and harder [15]. Paraloid 72 can penetrate through cracks as it makes adhering bridges between the fracture faces of cracked surfaces [16]. Figure 4a shows a homogenous of Waker (WAC) film between the grains of sandstone which give a good penetration inside the internal structure of sandstone. Figure (4-b) shows homogenous distribution and good penetration of ethyl silicates (ESI) between the grains of sandstone. Ethyl silicates initiate colloidal silica which is deposited inside the porous structure. The silica particles are chemically similar to the silicate minerals and hence they display a very good compatibility with stones having a silicate-based composition as sandstones [16].



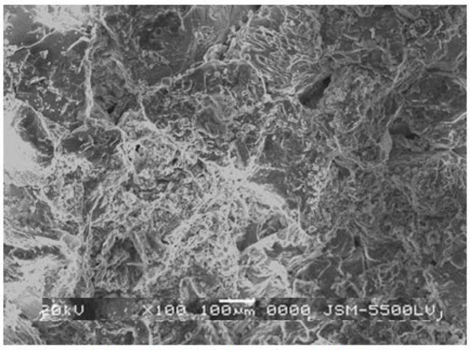
a) Sandstone Before Coated with B44



b) sandstone after B44

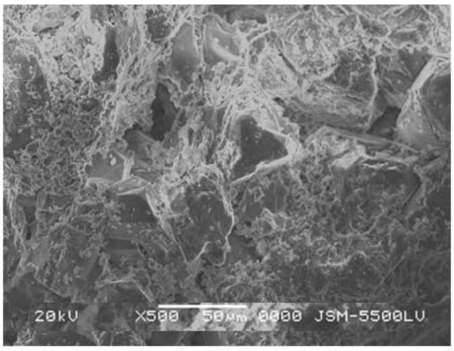


C) Sandstone Before B72

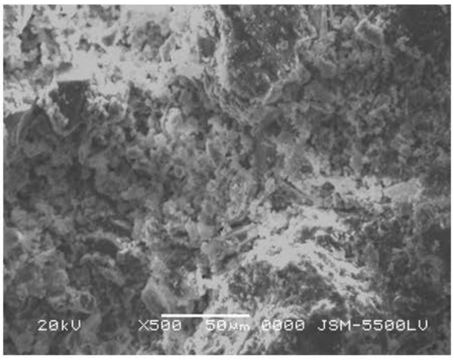


d) Sandstone after coated B72

Figure 3. SEM micrograph comparing sandstone after and before coated with B44 and b72



a)sandstone coated with WAC



b)Sandstone coated with ESI

Figure 4. SEM micrograph comparing sandstone after and before coated with ESI and WAC

4.2. Compressive Strength Enhancement

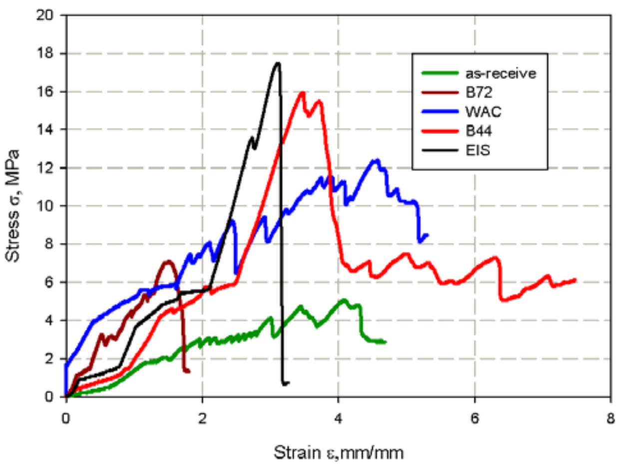


Figure 5. Compressive stress strain diagram of different coating materials

Table 3. compressive strength enhancement with different coating types

Coated material	strength	% increasing of strength
as-receive	4.87	
B44	7	43
B72	15.6	220
WAC	12	146
ESI	17.5	259

Table 4. Efficient of coating type to withstand after immersion in water

Coated material	strength	% increasing of strength
as-receive	4.87	
B44W	1.39	-71.45
B72W	7.5	54
WACW	10.85	122.79
ESIW	11.9	144.35

Figure 5 and Figure 6 show stress strain relation in compression, the curves for all specimens is not smooth, due to bridging between cracked faces through crack path. After peak load is reached cracks are developed due to coalescences of porosity inside the sandstones. At this case the fractured surfaces are visible and the localized strain increases. This increase in the localized strain lead to reduction in stress after peak load until brittle fracture is observed.

The compressive behavior of sandstones depends mainly on porosity [17]. Therefore, in general, the coated specimen of deteriorates sandstone give a considerable increase of strength about the as-receive ones because the coating material cover and deposit into pores of ancient sandstones (see Figure 4). The maximum compressive strength is obtained with specimen coated with Ethyl silicates (ESI) which is about 259% of the as-received ones (see Table 1 and Figure 6), this returned to the homogeneous distribution of Ethyl silicates, the uniform arrangement over the sandstone surface and the chemical compatibility coating between Ethyl silicates and sandstone. This coating acts like a bender agent for pores which is protect the stone from water and reduced its effect on compressive strength for all coating materials as shown in Figure 5 and Table 4. Whereas this trend deviated for sandstones coated with Paraloid 72 (B 72) this is due to that the bonding ability of it is poorer in the porous stones, and this characteristic forces the coating materials (consolidate) to not immerses into the stones layers and remains in outer layers of it, this case allow a high absorption of water into the inter layers of sandstones. Paraloid 44 (B44) has loner softening in both case for before and after immersion in water, this can be attributed to the thick Formed dense film which distributed over deteriorates sandstones.

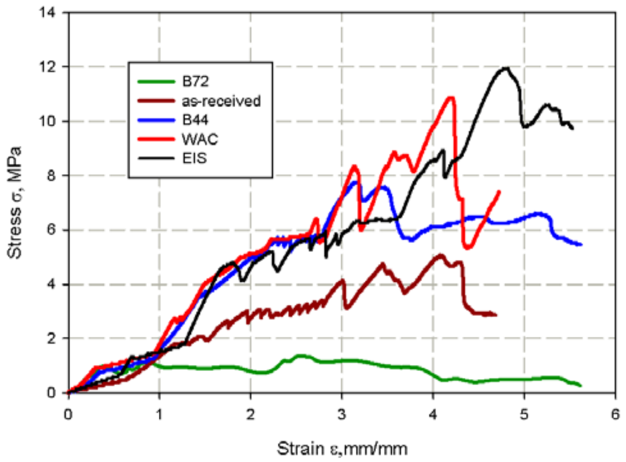


Figure 6. Compressive stress strain diagram for various coating materials after immersed in water

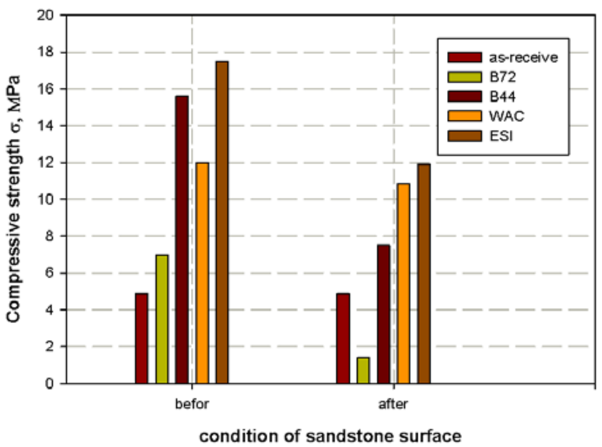


Figure 7. Efficient of coating material for weathering

5. Conclusion

Ancient deteriorates sandstones strength has enhanced without modification in its structures. Coating of sandstones with chemical solvent can perform enhancement of compressive strength. Ethyle silicate, Paraloid 44 (B44), and Wacker (OH100) give good compatibility with the sandstones and filled the pores of it. Therefore, these coating materials protect and make like cover or shield from water absorption. The sandstones with the coating materials can consider composite materials which have new absorption characteristic. Silica based coating is the more effective coating solvent for sandstones like Ethyle silicate, as it give considerable enhancement for deteriorates ancient sandstones more than 250 % in normal case and more than 140 % after subject to immersion in salty groundwater. Whereas, Paraloid 44 (B44) is lack of ability to bond with porous materials.

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