Effect of Pure Precipitated Micro Silica on Biological Properties of Mortar

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***Abstract*-Mortar and concrete which forms major component in the construction Industry as it is cheap, easily available and convenient to cast. But drawback of these materials is weak in tension so, it cracks under sustained loading and due to aggressive environmental agents which ultimately reduce the life of the structure which are built using these materials. This process of damage occurs in the early life of the building structure and during its lifetime. Bioengineered Self-repairing concrete biologically produces calcium carbonate crystals to seal cracks that appear on the surface of the concrete structures. It could be possible to motivate the growth and population of useful bacteria by adding another material, such as a silica since the first bacteria having evolved on earth because of silicon. In this study, the effects of pure precipitated micro silica (PPMS) as a partial replacement (0.5, 1, 1.5, and 2) % by weight of cement in mortars are reported. The properties investigated include biological total bacterial growth and population properties in addition to the compressive strength, bending strength, density, and conductivity, with scanning electron microscope test for each sample is done to make sure that the PPMS will keep or improve these properties. The research indicates that PPMS is an effective mineral addition for designing durable concrete presenting an optimal performance when the replacement ratio of cement is around 1 wt%.**

Key words: sustainability, bacillus, self-healing, biohealing, bacterial concrete.

I. INTRODUCTION

The production of Ordinary Portland Cement (OPC), the main ingredient in normal concrete unfortunately, emits vast amounts of carbon-dioxide gas into the atmosphere which has major contributions to greenhouse effect and thereby causing global warming; hence it is obvious to use either alternate or other materials as part replacement [1]. Some alternate or supplementary pozzolanic materials like Fly ash, silica fume, Rice husk ash, Ground Granulated Blast furnace Slag, and High Reactive Metakaolin can be used for cement as partial replacement in concrete and should lead to global sustainable development and lowest possible environmental impact and energy saving [2].

It is a well-known fact that concrete structures are very susceptible to cracking which allows chemicals and water to enter and degrade the concrete, reducing the performance of the structure and also requires expensive maintenance in the form of repairs. Cracking in the surface layer of concrete mainly reduces its durability, since cracks are responsible for the transport of liquids and gasses that could potentially contain deleterious substances. When micro cracks growth reaches the reinforcement, not only the concrete itself may be damaged, but also corrosion occurs in the reinforcement due to exposure to water and oxygen, and possibly CO2 and chlorides too. Micro-cracks are therefore the main cause to structural failure.

One way to circumvent costly manual maintenance and repair is to incorporate an autonomous self -healing mechanism in concrete. One such an alternative repair mechanism is currently being studied, i.e. a novel technique based on the application of biominerilization of bacteria in concrete [3].

The incorporation of silica fume in concrete is useful to increase the compressive strength [4-7], decrease the drying shrinkage [6, 7], and the permeability [8]. Also the incorporation of silica fume in concrete is effective to increase the bond strength with the steel reinforcement [9, 10], and abrasion resistance [11].

From biological view, silicon also acts as a bioprotectant against fungal attack [12]. In addition, it is reported that bacteria use silicon-based autotrophy as a source of energy to support CO_2 fixation [13] It is also being proposed that there is a possibility of first bacteria having evolved on earth because of silicon [14]. Consequently, the use of silica fume concrete in civil structures is wide spreading [15, 16].

In this paper we investigate the different mechanical properties like compressive strength, flexural strength, and physical properties like density and thermal conductivity, and biological properties of concrete incorporating pure precipitated silica micro particles with the (0.5, 1, 1.5, 2) % by weight in addition to the scanning electron microscope observation.

II. METHODOLOGY

In this research work the pure precipitated micro silica have been selected to improve the crack self-healing ability of mortar, the ratio of cement to sand was 1:3 and the water c content was 0.55% which gave the best mixing homogeneity any further addition of water led to rapid solidification of the cast which affected the homogeneity of mixing . The silica has been mixed with mortar for 0.5, 1, 1.5 and 2% of cement weight. The thermal conductivity, density, compressive and flexural strength of concrete for 28 days has been tested. To study properties of additive - cement and PPMS mixture SEM and EDS have been used. Also to detect whether the addition of silica has an effect on growth of bacteria or not and what's the kind of bacteria biological test was done by the following procedure:

Biological examination - Antibacterial activity was assessed by using Kirby–Bauer disc-diffusion method [17] with Mueller–Hinton agar as a medium. About 15 ml of sterile molten medium was poured into Petri plates and allowed to solidify for ∼5 min followed by swabbing of 0.1 ml inoculum (from 24 h old culture) uniformly over the agar. One microgram of different silicon sources was loaded individually on sterile discs (5 mm) followed by incubation of plates at 37°C for 24 h. Antibiotic discs, chloramphenicol (30 g concentration) and streptomycin (10 g concentration), were used as positive control for Gram-negative and -positive bacteria, respectively. After incubation, the inhibition zone around the disc was measured with a transparent ruler and the experiment was performed in triplicates [18].

Compressive Strength Test - The compressive strength test was conducted to determine the strength development of mortar specimens at 28 days. For each age, three (3) specimens were prepared. The compressive strength was determined following C109 / C109M – 13 at the crosshead velocity of 0.1 MPa/s.

Bending strength test- was conducted according to ASTM C0348-02. Beam specimens were tested with a span length of 16 cm at the crosshead velocity of 0.1 MPa/s.

Microstructure examination - Microstructure examinations on original and $PPMSiO_2$ mortar at 28 age using Scanning Electron Microscope (SEM).

Chemical composition analysis- was done by EDX analysis for pure precipitated micro silica as shown in figure 1

Density measurement-was done by dividing the weight over volume for each sample.

Thermal Conductivity test - was conducted according to ASTM C417-05.

Fig. 3 SEM image of concrete with 1% $PPMSiO_2$

Fig. 3 SEM image of mortar with 1% $PPMSiO_2$

Fig. 3 SEM image of mortar with 1% $PPMSiO_2$

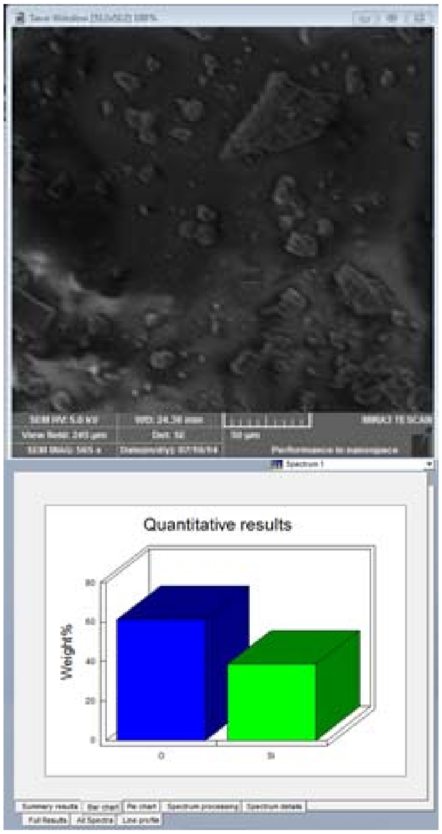

Figure 1. SEM image and EDX analysis of $PPMSiO_2$

III. RESULTS AND DISCUSION

Results of mechanical, physical and biological tests are shown in the following paragraphs.

Figs. 2 and 3 the image of SEM shows of mortar without additive and, when 1% by weight of PPMS particles additive have been used in mortar mixed design. In Fig. 1 the concrete particle have almost plane shape and in Fig. 2 the shape is convert to the circular shape and finer size and subsequently resulted in improving mortar physical properties as shown in figs. 4 and 5. The additive creates new crystal structure in cement past. The result is indicated that 1% by weight of PPMS particles additive is improving mortar by lowering the density and thermal conductivity.

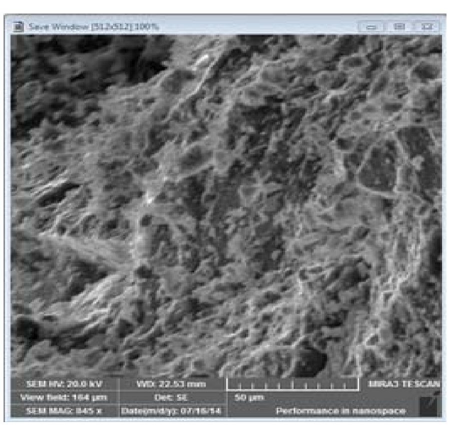
Fig. 2 SEM image of mortar without $PPMSiO_2$

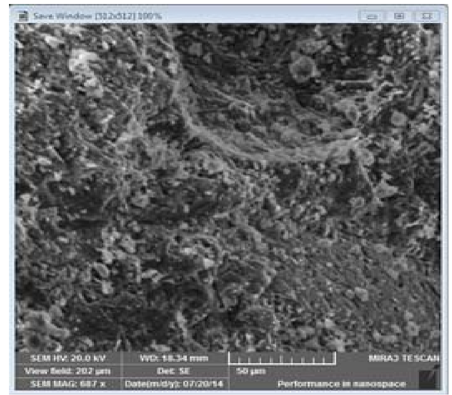
Fig. 3 SEM image of mortar with 1% $PPMSiO_2$

Fig.4 shows the result of adding $PPMSiO_2$ for thermal conductivity of concrete. The result is indicated appropriate improvement in the thermal insulation when adding 1% by weight of $PPMSiO_2$ while other percentage (0.5,1.5, 2) % had no effect on the conductivity.

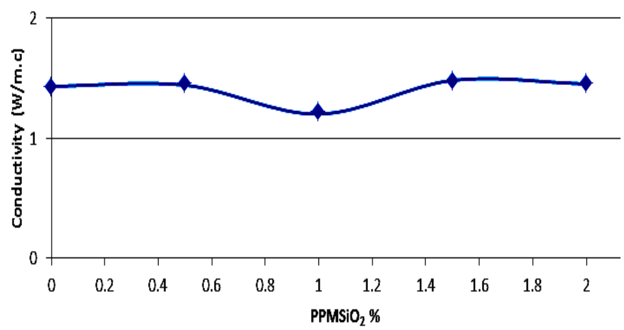

Fig. 4 shows the effect of adding PPMSiO2 on the thermal conductivity of mortar

Fig.5 shows the result of adding $PPMSiO_2$ for density of mortar. The result is indicated appropriate improvement in the density when adding all portions of $PPMSiO_2$ and the best improvement percentages were (0.5 and 1) % of $PPMSiO_2$.

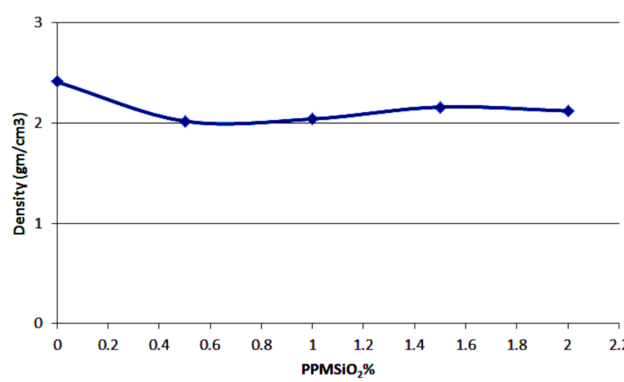

Fig. 5 shows the effect of adding PPMSiO2 on the density of mortar

Fig. 6 shows the effect of adding $PPMSiO_2$ for compressive strength of mortar. The results showed that the compressive strength was decreased in all percentages where the silica particles acts like discontinuity in the structure, which weakened the structure under the bending load except at 1% of $PPMSiO_2$ where the compressive strength was equal to that of mortar because the $PPMSiO_2$ particles act like obstacle against the compression crack propagation.
The PPMSiO2 specimens showed higher strength values than the reference plain mortar ones at the same ages. The rate of strength gain due to the addition of silica fume was higher at ratio of 1% and the rate of strength gain was decreased with the increased in the percentage of PPMSiO2%. The increase of strength due to the presences of silica fume can be related to its physical and chemical effects. The principal physical effect of silica fume is that it used as filler, which because of its fineness it can fit into spaces between the cement grins and the strength gain up to 7 days is mainly due to this action. The chemical effect of SF is due to its pozzolanic action. This action can be chemically simplified by the following reaction:
S (Amorphous silicate) + CH(Portland from cement hydration)→ Secondary C-S-H (calcium silicate hydrate)

The secondary calcium silicate hydrate is denser than the primary one and has superior chemical resistance due to its lower lime to silica ratio. The effect of this action can be seen more clearly after 28 days [19-21]. The used of SF can be enhancement the transition zone between aggregate and cement baste in concrete. This enhanced bonding is associated with the formation of a dense microstructure in the transition zone of the concrete containing $PPMSiO_2$ [21, 22]. Also, it can be noted that the strength value values of specimens containing 1.5 and 2% $PPMSiO_2$ replacement by cement weight were less than those of 1% $PPMSiO_2$ replacement and this may be due to the higher of $PPMSiO_2$ replacement of cement with silica fume (over 15%) the amount of cement in this mix decreased, then the liberated $Ca(OH)_2$ diminished, which reacted with reacted with the $PPMSiO_2$ to given CSH.

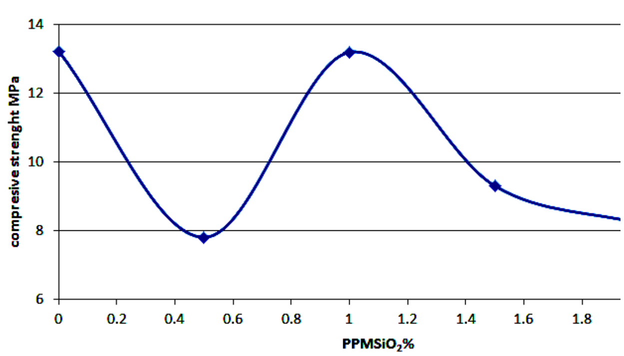

Fig. 6 shows the effect of adding PPMSiO2 on the compressive strength of mortar

Fig. 7 shows the effect of adding $PPMSiO_2$ for bending strength of mortar. The results showed that the bending strength was decreased in all percentages where the silica particles acts like discontinuity, which weakened the structure under the combined effect of compression and tension stresses during the bending loading.

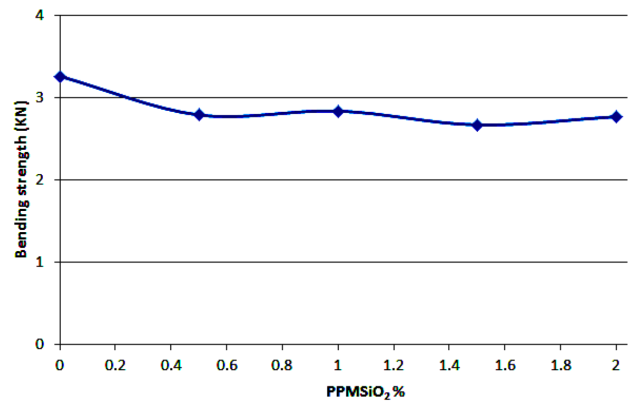

Fig. 7 shows the effect of adding PPMSiO2 on the bending strength of mortar

Table 1 shows the result of biological test for mortar before and after adding $PPMSiO_2$ particles in various percenages. The result is indicated appropriate growth and population in the density when adding (0.5 and 1) % of $PPMSiO_2$ further addition of $PPMSiO_2$ showed no growth of bacteria due to increase in mortar aggressiveness.

TABLE1. Biological Results

PPMSiO2 %	Biological Test Results
0	No growth
0.5	Positive Bacillus
1	Positive Bacillus
1.5	No growth
2	No growth

IV.CONCLUSIONS

This research indicates that PPMS is an effective mineral addition for designing durable mortar presenting an optimal performance when the replacement ratio of cement is around 1 wt% and as follows:

1. The minimum value for thermal conductivity was obtained with the use of 1% PPMS
as a partial replacement.
2. The maximum compressive strength of mortar was obtained in 1% .
3. The maximum bending strength was in 0% where adding the PPMS had a negative effect on the mortar.
4. Replacement of mortar by PPMS was effective in lowering the density for all percentages.
5. Best biological performance was obtained in 1% of PPMS.

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