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A REVIEW OF MICROSTRUCTURE PROPERTIES OF POROUS CONCRETE PAVEMENT INCORPORATING NANO SILICA

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ABSTRACT

Microstructure properties are one of important key for the strength of porous concrete pavement. Active pozzolanic admixtures such as nano silica become interest in modern concrete technology to obtain high performance properties. The objective of this paper is to review the microstructure properties of porous concrete pavement containing nano silica. Studies have shown that nano silica can be used as cement replacement or admixture in porous concrete mixture. Lack of study conducted for the microstructure properties of porous concrete pavement. The present study has been undertaken to review the microstructure properties of porous concrete pavement incorporating nano silica. From the literature review, it can be conclude that the existing of nano scale pozzolans such as nano silica helps to achieve more dense and better microstructural packing and more impermeable cement matrix.

Keywords: microstructure, porous concrete, pavement, nano silica.

INTRODUCTION

Research and development have demonstrated that the application of nanotechnology can improve the performance of traditional construction material such as cement and concrete [1, 2]. In recent years, new pozzolanic material containing nano silica particles has been available on the market and has been used in many applications of concrete technology [3]. Due to an ultrafine size, nano particles show unique physical and chemical properties different from those of conventional materials. Because of their unique properties, nano particles have been gaining increasing interest and been applied in many fields to produce new materials with novelty functions [4]. Properties of porous concrete pavement can be divide into several such as microstructure properties and mechanical properties. Previous research reports have investigated on the mechanical properties of porous concrete pavement. However, published articles and papers focusing on the microstructure properties of porous concrete pavement are rarely found. Therefore, the aim of this paper is to review microstructure properties of porous concrete pavement incorporating nano silica.

Nano silica

A new amorphous silica source recently introduced to the world of science is nano silica [5]. Among all the nanomaterials, nano silica is the most widely used material in the cement and concrete to improve the performance [6, 7]. Nano silica behaves not only as filler to improve the microstructure, but also as an activator to promote the pozzolanic reaction, which enhances the formation of hydrated products [8]. By replacing Portland cement with nano silica in certain amount, it will reduce the total amount of calcium-hydroxide (C-H) through pozzolanic reaction and change the porosity of the paste [2, 9]. Singh *et al*. [6] in their review summarized five roles of nano silica in cementitious system which is act as strength enhancement, reduce Ca-leaching, refine pore structure, increase durability and accelerate hydration rate. These five roles are important things in order to improve the performance of cement paste and concrete.

Porous concrete pavement

Generally, a porous concrete pavement produced by eliminating or removing the fine aggregates from the concrete mixture and leading to an increased the voids content, usually the range between 15 to 30 percent [10]. The voids in the structure are partially connected, so that the porous concrete increased in permeability to allow water penetration and filtration [11]. The strength of porous concrete is significantly affected by the porosity of its internal structure [12]. Recently, a lot of study by other researchers concentrated on how to improve the strength of the porous concrete. It was found that, the increasing in porosity will decrease the compressive strength and flexural strength of the porous concrete [13, 14, 15]. In porous concrete structure, hardened cement paste is one of the important parts. The strength of hardened porous concrete depends on the strength of hardened cement paste. According to Yang and Jiang [16], because of hardened cement paste is thin, the strength of the hardened cement paste is low. They also mentioned that, the existing of some pores and microcracks will influences the hardened cement paste strength greatly.

Microstructure properties

The term of 'microstructure' is used to describe the appearance of the material on the nanometer-centimeter length scale. The objective of the

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microstructural analysis is to support the findings shown in the mechanical testing analysis. It is important to notice that the performed microstructural analysis were qualitative with the objective to give additional information that can explain the results obtained in the other executed tests [17]. Additions of nano silica particles were found to influence hydration behaviour and lead to differences of the microstructure of hardened concrete [18].

Scanning electron microscopy (SEM)

Studies of the microstructure of cement paste and concrete have been largely done using electron microscopy [19]. The scanning electron microscopy uses a focused beam of high energy electrons to generate a variety of signals at the surface of solid specimens. The information from scanning electron microscopy included external morphology, chemical composition and also crystalline structure. Figure-1 and Figure-2 (1- Crystal, 2- C-S-H, 3- Pore) show the SEM photographs of cement pastes with and without nano silica respectively. These figures give good comparison between sample with nano silica and without nano silica. It was found in Figure-1 that calcium-silicate-hydrate (C-S-H) gel existed in the form 'stand alone' clusters, lapped and jointed together by many needle hydrates. Figure-2 shows the microstructure of cement paste with nano silica and it was observed that the microstructure was different from cement paste without nano silica. The texture of hydrate products was denser and compact [4]. The dense and compact structure of cement paste will result in better mechanical properties and strengthen the structure. As we can see in Figure-1, there is a lot of crystal in the structure. Different with Figure-2, the photograph show compact structure by adding nano silica. It is because, the role of nano silica were not only acting as nano filler, but also as an activator to promote hydration and to improve the microstructure of the cement paste if the nano silica were uniformly dispersed [4, 20]. Ji [21] also reveal from SEM that the microstructure of concrete with nano silica is more uniform and compact than that of normal concrete. Kong *et al*. [22] and Jo *et al*. [20] conclude in their study that, through SEM observation, an obvious microstructure improvement in mortar was found by adding nano silica. Haruehansapong *et al*. [3] found in their SEM analysis that, the nano silica particles significantly influences the microstructure of cement paste. The textures were more homogeneous, dense and compact compare to cement paste without nano silica. The small particles of nano silica can fill in the pores of cement paste resulted in better microstructural packing and more impermeable cement matrix. Indirectly, it increases the strength of porous concrete pavement.

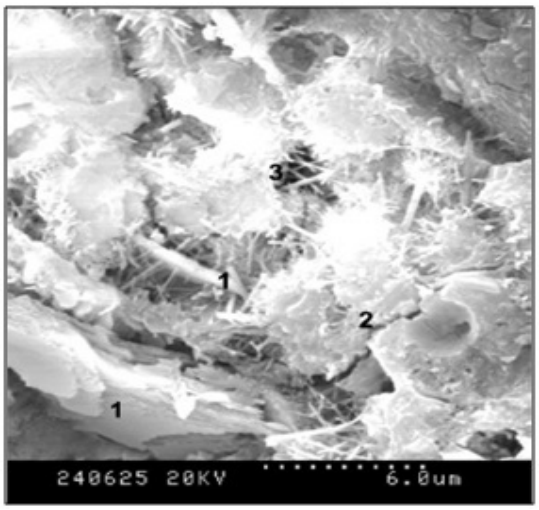

Figure-1. SEM without nano silica. Adapted [4].

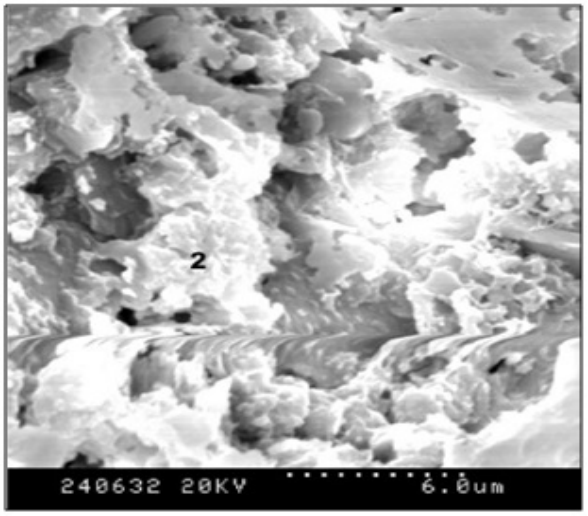

Figure-2. SEM with nano silica. Adapted [4].

X-ray diffraction (XRD)

XRD used to look at single crystal or polycrystalline materials. The use of XRD is often compared to the microscopy techniques. X-ray diffractograms of cement pastes containing different percentages of nano silica hydrated for 28 days are shown in Figure-3. The figure show that the cement pastes incorporating nano silica has lower intensity of the diffraction lines corresponding to C-H and higher intensity of diffraction lines of characteristics for C-S-H than those of the corresponding lines of the control mix. This is due to the pozzolanic reaction of nano silica with C-H to form the additional C-S-H phases [2]. The higher intensity of diffraction lines for C-S-H gives the denser of the structure. Indirectly, it will improves the properties of the cement paste, cement mortar and also concrete.

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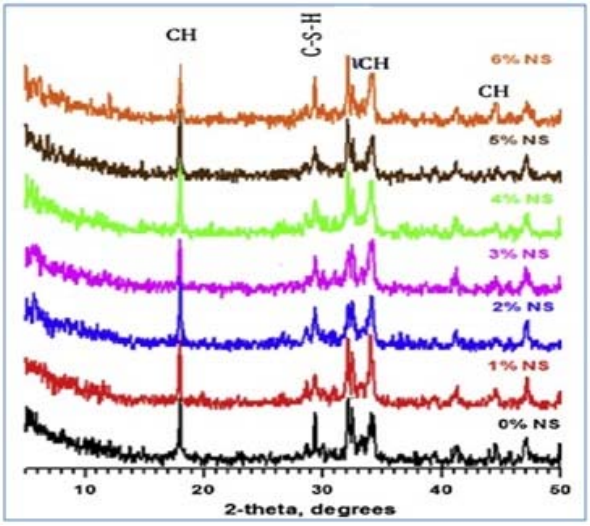

Figure-3. XRD pattern of cement paste containing different nano silica contents hydrated for 28 days. Adapted from [2].

Relation of microstructure in porous concrete pavement

Porous concrete pavement produced with little or no fine aggregates in the mixture. Without fine aggregates, the bonding effect of the concrete structure will decreased. In order to compensate strength loss in the porous concrete structure, nano silica is one of the options to strengthen it structure. By incorporating nano silica in the porous concrete mixture, it will act as nano filler in the cement paste binder and also react with C-H to form C-S-H. By observing SEM photograph and analyzing x-ray diffractograms of hardened porous concrete, it will reveal the microstructure properties. By incorporating nano silica in porous concrete mixture, it can be predict that it will improve the microstructure properties and also the mechanical properties. Li *et al*. [4] predicted that the strengthening effect of nano silica would be further enhanced in concrete because the nano silica improves not only the cement paste, but also the interface between paste and aggregates. Ye *et al*. [23] found in their study that incorporating nano silica can increase compressive strength of hardened cement paste and bond strengths of paste-aggregate interface.

CONCLUSIONS

This paper prepared to review the microstructure properties of porous concrete pavement incorporating nano silica. From the review, it was found that by incorporating nano silica in porous concrete mixture, it can be predict that the microstructure properties of porous concrete pavement will improve. From the review on the SEM observation, the texture of the cement paste containing nano silica was denser and compact. The XRD analyses show that by incorporating nano silica in cement paste, the intensity line of C-S-H higher than control cement paste. The existing of nano silica in porous concrete mixture will promote hydration and improve it microstructure properties. SEM and XRD examinations confirmed the formation of more hydrated products in presence of nano silica. Besides that, by incorporating nano silica in porous concrete mixture not only improves hardened cement paste, but also improves bond strengths of cement paste aggregate interface. Besides that, the incorporation of nano silica give better microstructural packing and more impermeable cement matrix. Indirectly, it will improve the strength of hardened porous concrete pavement.

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