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Chemical Analysis of Silica Fume Infused Self Healing Concrete

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Abstract: ***Self healing technique using mineral and chemical admixtures are gaining momentum nowadays. Admixtures like silica fume, marble dust, fly ash, ground granulated blast furnace slag, limestone powder are being experimented nowadays as self healing agents. In this experimental examination, silica fume has been used as a healing agent (12.5% replacement). Cracks were induced and the specimens were subjected to continuous water exposure for 28 days. After 28 days, the specimens were tested for healing effect and the healing products were chemically analyzed by means of FESEM analysis, EDAX, thin section test and XRD analysis. From FESEM and EDAX analysis, for silica fume mix, portlandite formation was evident. Thin section analysis showed the morphology of anorthite feldspar. XRD analysis showed that excess silica content in silica fume actively involved in faster healing process resulting in the formation of calcite, calcium hydroxide and calcium carbonate. All the test results indicated that self healing property can be achieved using silica fume as mineral admixture. In addition to the healing property, incorporating silica fume reduces the consumption of cement, thereby reducing the air pollution caused by the cement industries as well as resulting in the production of eco-friendly concrete.***

Keywords: Self healing, admixtures, Ca/Si ratio, portlandite, anorthite

I. INTRODUCTION

Continuous inspection and maintenance of large scale infrastructure is very difficult and sometimes not feasible. Higher end diagnosis procedure for maintenance and repair work requires huge amount of labour and cost. As like the outer bark damage of trees and outer skin damage of animals, which heals automatically, the concrete mix adopted with self healing additives and admixtures is a very beneficial solution in the future years, eliminating a part of repair and maintenance cost [1]. The main objectives of this research work is to chemically analyze the self healing concrete with silica fume as mineral admixture by means of FESEM, EDAX, Thin Section test and XRD [2]. Optimum percentage of Silica fume is found to be 12.5% based on the compressive strength values obtained for various percentages [3].

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II. EXPERIMENTAL PROGRAM

For determining the healing compound formation over the cracks, chemical tests like FESEM & EDAX (Fig 1), thin section test (Fig 2) and XRD analysis (Fig.3) have been carried out.

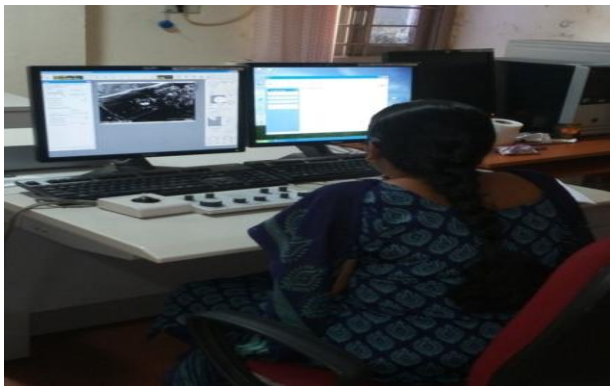

Fig. 1. FESEM and EDAX test

Fig. 2. Petrological microscope

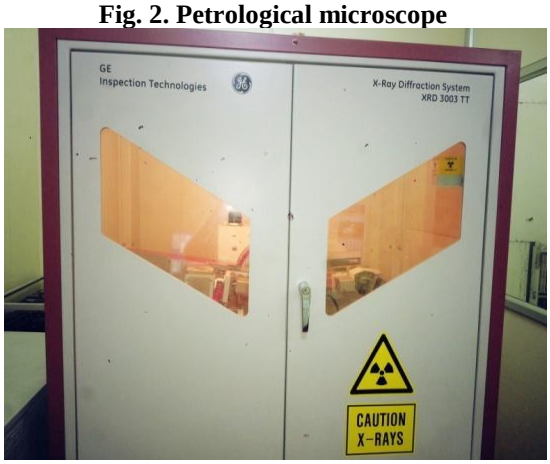

Fig. 3. XRD analysis

Based on the previous researches done in the field of concrete chemistry, based on the calcium to silica ratio as obtained from EDAX images and analysis, it can be found out that the healing products are either CSH gel or portlandite [4].

Calcium Silicate Hydrate (C-S-H) and Portlandite (CH) are the main hydrate phases in Portland cement pastes and blends of cement with supplementary cementitious materials (SCMs). C-S-H determines the important parameters of the final product like porosity, chemical binding capacity, and the nature and amount of secondary phases which in turn have influence on the mechanical and durability properties of concrete. Pure C-S-H by most synthesis routes only exists for Ca/Si = 1.50 or less, with most attempts to form C-S-H with higher Ca/Si causing the co-precipitation of portlandite. On the other hand, the C-S-H which forms with the hydration of plain Portland cement is generally reported to have an average Ca/Si of approximately 1.75, with lower values generally reported for cement pastes containing supplementary cementitious materials such as slag and fly ash. Hence from EDAX analysis [5] of silica fume mix, it can be found out that based on the Ca/Si ratio, the healed product is either C-S-H gel or portlandite.

III. RESULTS

A. FESEM And EDAX Analysis

The FESEM image of silica fume infused mix is shown in the figure 4. From FESEM image, the formation of Portlandite is evident by the appearance of fibrous mass.

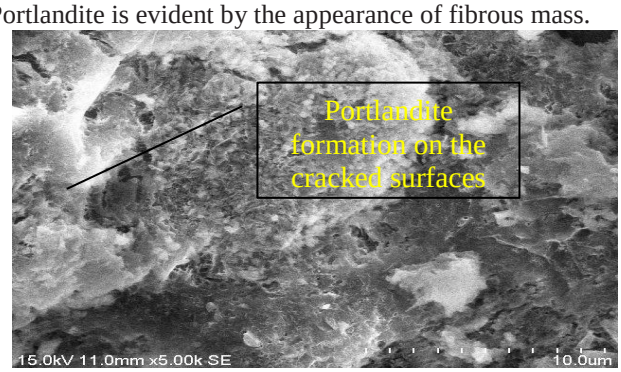

Fig. 4. FESEM image of silica fume mix

The EDAX image and the elemental composition of silica fume mix is shown in the figure 5.

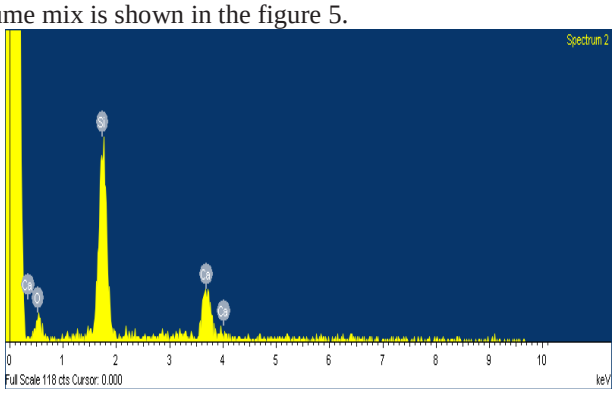

Fig. 5. EDAX image of silica fume mix

The elemental composition of 12.5% silica fume replace mix is presented in table I.

Table I Elemental composition of silica fume mix subjected to self healing

Element	Weight%	Atomic%
O K	19.71	32.50
Si K	52.21	49.03
Ca K	28.07	18.47
Total	100.00	

For 12.5% silica fume replaced mix, the Ca/Si ratio was 0.537, from which it has been evident that portlandite has been formed on the cracked surfaces of silica fume mix specimens due to additional pozzolanic reaction activated by the surplus silica fume particles.

B. Thin section analysis

For determining the morphology of healing products, thin section test used in the field of petrology has been used [6]. The healed products in the cracked zones are examined under petrological microscope. The photographic observations of silica fume mix (Fig. 6) indicated that the healed products took the morphology of anorthite feldspar having chemical formula $Ca_2Al_2Si_2O_8$.

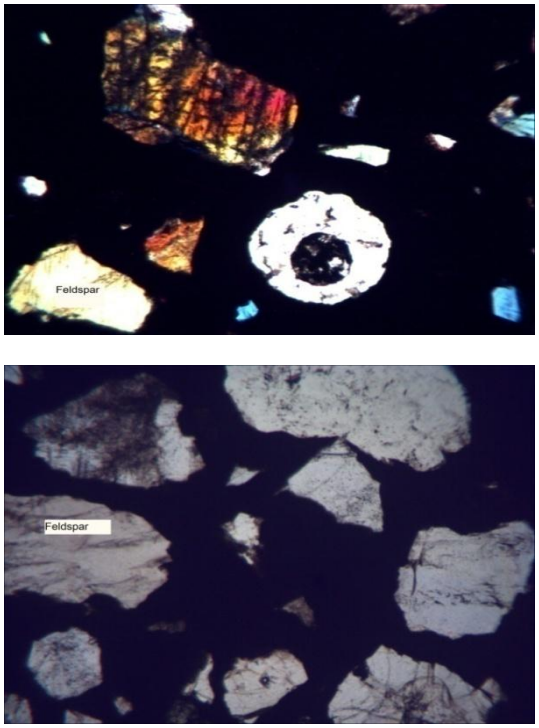

Fig. 6. Thin section analysis of silica fume mix

C. XRD analysis

For analysing the hydration products after complete healing of cracks, XRD analysis has been carried out. From XRD analysis of 12.5% silica fume replaced mix, the intensity of calcite, calcium hydroxide and silica content after healing, and the presence of other compounds like FeO, MgO after the hydration reaction are given in Table II and shown graphically in Fig. 7.

Table II Percentage of compounds present in silica fume mix

Name	Percentage present after healing
Silica content after healing	21.92
Iron oxide	24.32
Calcite	26.60
Magnesium oxide	29.60
Calcium hydroxide (Portlandite)	50.68

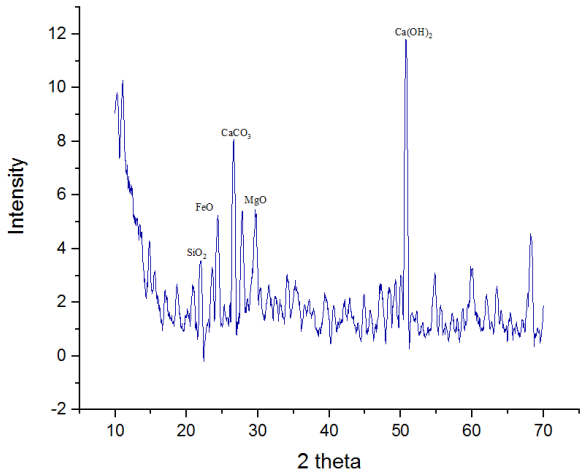

Fig. 7. XRD analysis of silica fume mix

IV. CONCLUSION

Based on the FESEM and EDAX analysis, a white precipitate was found to be formed on the cracked zones after healing. The healed product was determined based on Ca/Si ratio. Based on the researches carried out earlier by concrete experts, it can be made evident that Ca/Si ratio for Ordinary Portland Cement mix will be 1.75. When Ca/Si ratio decreases, it indicates the presence of supplementary cementitious materials. For the FESEM and EDAX analysis carried out in this experimental work, Silica fume mix had Ca/Si ratio of 0.537 from which it was evident that the fibrous mass formed on the cracked surface being portlandite. Even from XRD analysis, clear peaks indicating the presence of healed products was evident.

It has been evident from thin section analysis, the healed products in the cracked zones when examined under petrological microscope, the photographic observations indicated that the healed products took the morphology of anorthite feldspar which had the chemical formula of $Ca_2Al_2Si_2O_8$. Silica fume mix had the hydration products as calcite and calcium hydroxide; From the amount of silica content present in the raw state and after the hydration reaction, it can be made clear that a large amount of silica present in silica fume has been consumed which has been utilized for the formation of healing products in silica fume mix. The initial silica content in silica fume was 91.85% and that after hydration reaction being 21.92%.

Based on all the chemical tests carried out, presence of healing compounds was noticed and to be specific, the silica content in the silica fume played a vital role in effecting self healing ability in the concrete mixes. Silica fume being high in silica content gave good quantity of healing products and crack closure ability was a bit faster and even good efficiency being obtained with regard to crack closure.

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Dr Depaa RA B is currently working as Assistant Professor in the Department of Civil Engineering at Dr MGR Educational and Research Institute, Chennai. She has 9 years of teaching experience. She is a life member of ICI, ISTE, INSDAG and IAENG. She has published 9 papers in reputed journals and has presented papers in more than 10 conferences. She has also published two books. Her research areas include sustainable concrete technology, bridge Engineering and Structural Engineering.

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