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A Review - Effect on Strength and Durability Properties of Cement Mortar Replaced By Metakaolin and Flyash as Fine Aggregate

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Abstract - In this paper, the effect of metakaolin and fly ash on strength and durability properties of cement mortar was investigated. Different types of replacement of metakaolin and flyash (0%, 8%, 16%, and 24%) in cement of cement mortar of grade 1:3 and curing with sea water. Strength and durability properties such as compressive strength and acid resistivity were evaluated for all the mixes of cement mortar. Results also show that the strength properties of cement mortar has improved having 12% fly ash and 12% metakaolin replacement is responsible for minor strength loss but leads to outstanding durability improvement of the cement mortar found to be low resistance to acid attack.
Keywords: Mortar, Metakaolin, Flyash, Acid Attack and Compressive strength.

I. INTRODUCTION

Every concrete structure should perform its intended function through the expected life time of the structure, irrespective of external exposure conditions. The ability of concrete to withstand any environmental condition that may result in premature failures or several damages is a major concern to the engineering professional. The deteriorating effect of acid media on cement based constructions has become a worrying problem all over the world. These media generally occur as acidic rains and mist, industrial and urban sewages and acidic ground water. The extent of attack depends not only on the type of concentration of attacking acid, but also on the properties of the material including the cement used. Acid attack is one of the phenomena that may disintegrate concrete structures depending on the type and concentration of acid. Certain acids such as oxalic acid are considered as harmless, while weak solutions of some acids have insignificant effects. Although acids generally attack and leach away the calcium compounds of the paste, they may not readily attack certain aggregates, such as siliceous aggregates calcareous aggregates often react readily with acids.

Acidic attack is one of the world's wide problems that may cause gradual but severe damages to concrete structures. Concrete can be attacked by the sulphates present in the soil or in the sea water, and by sulphuric acid produced from either sewage or sulphur dioxide present in the atmosphere of industrial cities. Most acid attacks of concrete are caused by a process of dissolution and leaching, converting the constituents of the cement paste into readily soluble salts. The degree of attack depends on the properties of the aggressive agent and its concentration. Damage is to be expected if the pH of the acidic solution is lower than six.

A. Aim and objectives

1) To determine the influence of using seawater as curing water on the behaviour of metakaolin and fly ash mortars.
2) To determine the strength behaviour of the cement mortar using various acid solutions.

B. Scope of this study

Concrete has been used in the construction industry for centuries. Many modifications and developments have been made to improve the performance of concrete, especially in terms of strength and durability.

The introduction of pozzolans as cement replacement materials in recent years seems to be successful. The use of pozzolan has proven to be an effective solution in enhancing the properties of concrete in terms of strength and durability. The current pozzolans in use are such as silica fume, fly ash and Metakaolin.

Unlike other pozzolans, Metakaolin is not a by-product which means its engineering values are well-controlled. Therefore, using metakaolin should promise some advantages compared to other cement replacement materials. In this case, studies are needed to study the performance of concrete using metakaolin. The performance of metakaolin-concrete will be compared to the cost of production of metakaolin to determine whether metakaolin is worthy to be developed as a new cement replacement material.

In addition, the use of metakaolin is not common in the Indian construction sector. This study will be able to enhance the understanding on the suitability of metakaolin as cement replacement material.

II. LITERATURE REVIEW

E.D. Lim et al (2015) this study reports the results of using seawater as mixing and curing water and different fly ash replacement ratios on the properties of reinforced mortars. The compressive strength, corrosion potential, corrosion current density and chloride content were the key means of measurement in determining the effects of seawater. Mortar specimens with 0%, 10%, 20%, 30%, 40%, and 50% fly ash replacement ratios and ordinary Portland cement mixed and cured with seawater and freshwater were prepared. Cylindrical specimens were prepared for compressive strength while rectangular prism specimens of size 4 cm x 4 cm x 16 cm were used for corrosion monitoring. Ten millimeter in diameter round steel bars were suspended in the specimens with constant cover of 5 mm in order to accelerate the corrosion process. In addition, the 20% fly ash replacement specimens were also cured in seawater using full immersion or wet burlaps. Results show that using seawater as mixing water can produce comparable compressive strength as freshwater especially when cured for longer periods.

Murali.G and Sruthee P(2012) experimentally studied the use of Metakaolin as a partial replacement substance for cement in concrete. The use of Metakaolin in concrete effectively enhanced the strength properties. The optimum level of replacement was reported as 7.5%. The result showed that 7.5% of Metakaolin increased the compressive strength of concrete by 14.2%, the split tensile strength by 7.9% and flexural strength by 9.3%.

Milica M. Vlahovic et al (2011) tested durability of sulfur concrete with different fillers, as well as Portland cement concrete, in the solutions of HCl, H_2SO_4, and NaCl. Regarding mass changes, in the solutions of HCl and H2SO4 sulfur concrete with talc and fly ash exhibited higher durability, while in NaCl samples with alumina and microsilica were better. The type of filler did not affect durability regarding compressive strength. Strength loss was higher in the solution of HCl comparing to H_2SO_4, while negligible in NaCl which is in accordance with apparent porosity increase. It was also found that porosity increase was the highest for the sulfur concrete samples treated in HCl, a bit lower after treatment in H_2SO_4 and the lowest after treatment in NaCl which is connected with the mentioned compressive strength loss.

Hemant Chauhan et al (2011) made an attempt to use industrial wastes like activated Fly ash, Iron Oxide and Metakaolin as supplementary cementitious materials in various proportions. Using these mineral admixtures with OPC cement, five different types of concrete mixtures were prepared and same were used to find compressive strength of concrete cubes at 3,7,14,28 and 56 days. When OPC was replaced up to 42% with metakaolin, it gives strength up to 40.67 N/mm2 at a water cement ratio of 0.40 and at 0.55 ratio, it gave strength up to 25.47 N/mm2 at 56th day. They reported that it was possible to make the concrete economical by 42% replacement of cement with different percentages of mineral admixtures like Fly ash (30%), Metakaolin (10%) and iron oxide (2%).

Pacheco-Torgal and Said Jalali (2009) reported results of a wider investigation which aimed to understand the best option for the concrete pipe industry as far as sulphuric acid resistant is concerned, polymer addition or polymer impregnation. Results have shown that the use of polymer addition it is not economically attractive when compared to polymer impregnation. The increase of costs per meter of pipe is too high. The use of polymer impregnation enhances the chemical resistance of concrete considerably. Furthermore, it was economically viable, especially for smaller diameters. Results also have shown that using sulphate resistant cements improve the chemical resistance without cost increase.

Ramesh Babu et al (2006) investigate mechanical property and corrosion behavior of carbon steel using metakaolin (5–20%) as partial replacement in ordinary Portland cement (OPC). Compressive strength, resistivity, ultra pulse velocity, open circuit potential, studies on water absorption, weight loss were studied. It was found that up to 15% replacement of metakaolin in OPC improves the mechanical properties of concrete.

Y. F. Fan et al (2006) to study the compressive property of corroded concrete, accelerated corrosion test are performed on concrete C30. 6 corrosive solutions, including hydraulic acid solution(PH=2), hydraulic acid solution(PH=3), 10%NaCl solution, 20%NaCl solution, 10% Na_2SO_4 solution, 20%Na_2SO_4 solution, are applied as the corrosive medium. 6 series of corrosion tests, including 108 specimens, were carried out. Then mechanical property of all the corroded specimens is tested respectively. Compressive properties of the corroded specimens (e.g. compressive strength, stress-strain relation, elastic modulus etc.) are achieved.

Nabil M. Al-Akhras (2005) carried out an investigation by replacing cement with Metakaolin to find out the durability of concrete against sulphate attack. Three replacements of cement with Metakaolin (5, 10 and 15% by weight) were done with water cement ratio of 0.5 and 0.6. After the specified days, the samples were immersed in 5% sodium sulphate solution for 18 months. The effect of metakaolin addition proved to be beneficial in improving the resistance of concrete to sulphate attack. Metakaolin with water cement ratio of 0.5 exhibited better results in sulphate resistance than 0.6. Autoclaved cured specimens had better resistance against sulphate than moist cured specimens.

Badogiannis.E et al (2004) evaluated the effect of Metakaolin on concrete. Eight mix proportions were used to produce high-performance concrete, where Metakaolin replaced either cement or sand of 10% or 20% by weight of the control cement content. The strength development of Metakaolin concrete was evaluated using the efficiency factor (k value). With regard to strength development the poor Greek Metakaolin and commercially obtained Metakaolin yielded the same results. The replacement with cement gave better results than that of sand. When Metakaolin replaced cement, its positive effect on concrete strength generally started after 2 days where as in case of sand it started only after 90 days. Both Metakaolin exhibited very high k-values (close to 3.0 at 28 days) and are characterized as highly reactive pozzolanic materials that can lead to concrete production with excellent performance.

Pruckner (2004) quantified the effect of different types of chloride source on the concrete corrosivity, different mortars with OPC and 0.50 w/c were prepared, and various amounts of $CaCl_2$, NaCl and NaOH were added to the fresh mixtures. The corrosivity was primarily tested by measurements of electrical resistivity and acid capacity. The paper summarized the results of the study regarding the effect of both the type and amount of chloride source on concrete corrosivity. It was seen that the effect of NaCl added to fresh cement mortar appeared to give much less corrosive conditions than that of CaCl2. It was further observed that when $CaCl_2$ was added to the fresh mortar, the amount of dissolved hydroxyl ions or pH level was reduced and the acid capacity for $Ca(OH)_2$ or amount of $Ca(OH)_2$ was decreased.

Hobbs and Matthews (1998) pointed out that the reduction in water to cementitious ratio improves the acid resistance.

Fattuhi and Hughes (1988) determined the performance of cement paste subjected to sulphuric acid. According to them sulphuric acid largely occurs in industrial environments.

III. CONCLUSION

In the interest of the reliability of the study and the testing of factors of acidic attack of cement based materials., the overall major conclusions regarding their mechanical and durability properties, with cement replacement materials can be extracted.

Fly ash is a by-product with low pozzolanic activity being associated with early age compressive strength. This paper confirms that the use of 12% fly ash and 12% metakaolin based mixtures are responsible for minor strength loss but leads to an outstanding durability improvement.

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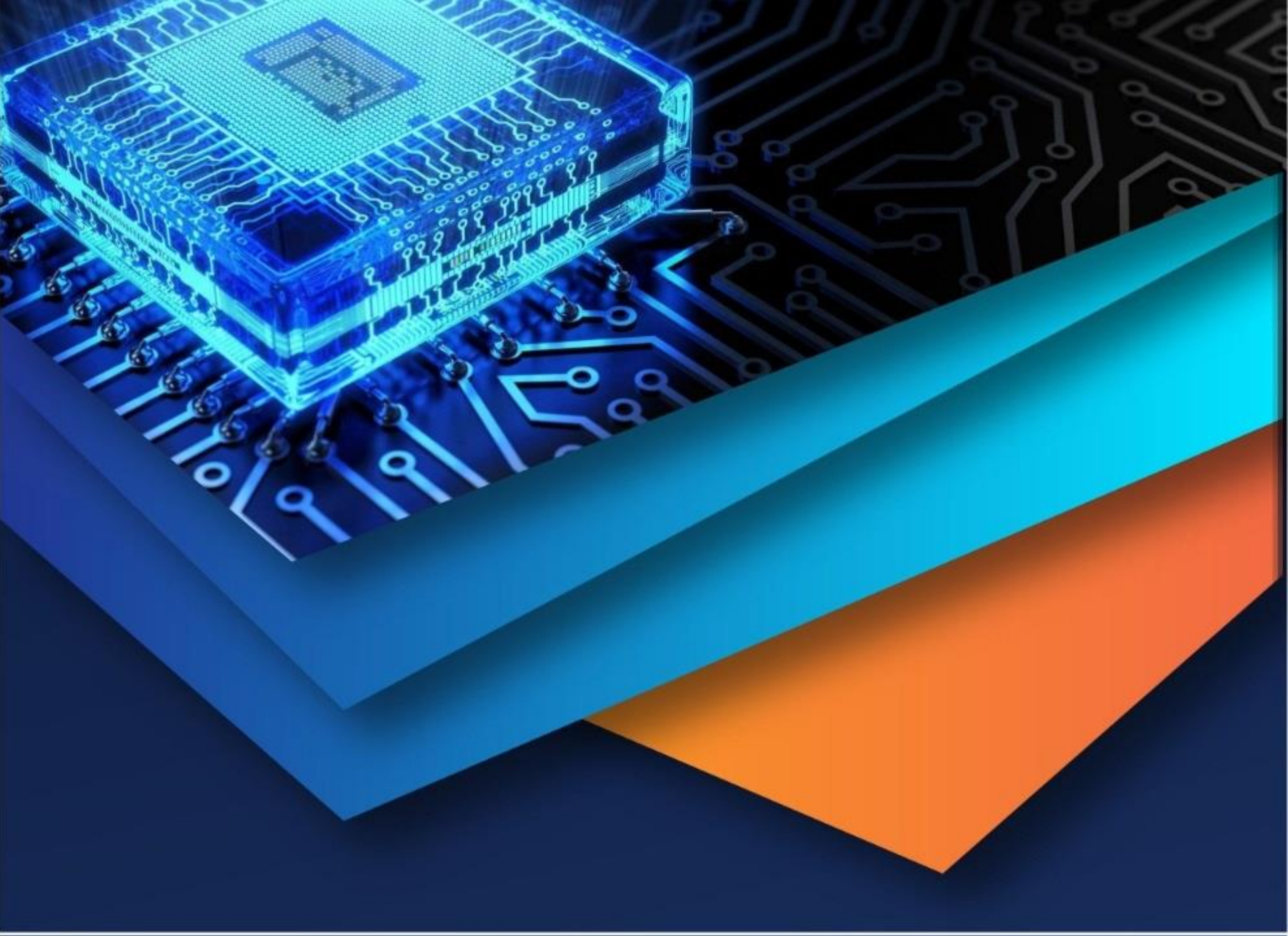

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