

## Review on investigation of corrosion behavior of reinforced concrete with supplementary cementitious materials.

## Revisión sobre la investigación del comportamiento a la corrosión del hormigón armado con materiales cementantes suplementarios.

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### ABSTRACT

Cement concrete is the most widely used material for various constructions. Properly designed and prepared concrete results in good strength and durability. Sometime these mixes are found to be inadequate, hence variety of admixtures are used along with cement. A certain percentage of cement will be replaced separately with metakaolin and silica fumes. Hence the flexural strength test of concrete and evaluation of corrosion behavior of the reinforcement can be performed. The study of flexural property of concrete will be conducted at 7 or 28 days characteristic strength with different replacement level of cement (i.e.0%, 5%, 10%, 15%, 20%). Corrosion behavior of reinforcement will be evaluated based on half-cell potential. Concrete samples will be cured in either fresh water or 4% NaCl saline water for 7 or 28 days of curing period. We assumed that the addition of silica fumes and metakaolin will improve the flexural strength characteristics of concrete and corrosion resistivity of reinforcement.

Keywords: Flexural strength, corrosion, metakaolin, silica fumes.

### RESUMEN

El hormigón de cemento es el material más utilizado para diversas construcciones. El concreto correctamente diseñado y preparado da como resultado una buena resistencia y durabilidad. En ocasiones, estas mezclas resultan inadecuadas, por lo que se utilizan diversos aditivos junto con el cemento. Un cierto porcentaje de cemento se reemplazará por separado con metacaolín y vapores de sílice. Por lo tanto, se puede realizar la prueba de resistencia a la flexión del hormigón y la evaluación del comportamiento a la corrosión

del refuerzo. El estudio de la propiedad de flexión del hormigón se realizará a los 7 o 28 días de resistencia característica con diferente nivel de reemplazo de cemento (es decir, 0%, 5%, 10%, 15%, 20%). El comportamiento de corrosión del refuerzo se evaluará en función del potencial de media celda. Las muestras de concreto se curarán en agua dulce de agua salina con NaCl al 4% durante 7 o 28 días de período de curado. Asumimos que la adición de vapores de sílice y metacaolín mejorará las características de resistencia a la flexión del hormigón y la resistividad a la corrosión del refuerzo.

Palabras clave: Resistencia a la flexión, corrosión, metacaolín, humos de sílice.

## INTRODUCTION

Flexural strength is one measure of the tensile strength of concrete. It is a measure of the resistance failure in bending for an unreinforced concrete beam or slab. Flexural strength is expressed as modulus of rupture in psi and determined using standard test methods ASTM C 293. The paper describes the flexural strength and corrosion behavior of reinforced concrete with supplementary cementitious material. Flexural strength of concrete is crucial in structural mechanics because it ensures the structure meets building code and doesn't threaten public safety. Corrosion is a natural process that occurs when the steel rebar with in reinforced concrete structure rusts. Concrete corrosion is defined as the "destruction of metal by chemical, electrochemical, and electrolytic reaction with in its environment". Corrosion of reinforcing steel cause the deterioration of concrete. There are several methods for the repairing of damaged concrete. Such as applying anti corrosion paint, removing the rust over the bars, applying bonding agent on concrete. In this paper we have discussed about the corrosion as well as flexural strength behavior of high performance concrete prepared by the addition of metakaolin and silica fumes as a partial replacement of cement to a certain percentage. 28 days flexural strength was determined to obtain the optimum percentage of metakaolin and silica. Accelerated corrosion methods are used to reduce the time period of testing.

## SILICA FUMES

Silica fume (micro-silica) has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties and improving the chemical durability of concrete. The hydration of Portland cement produces calcium silicate hydrates (CSH), calcium hydroxide (CH) etc. When silica fume is added to fresh concrete it chemically reacts with the CH to produces additional CSH. The benefit of this reaction is to increase the strength and chemical resistance. [Chakraborty Pranab, (2017)]

### FLEXURAL STRENGTH OF SILICA FUME CONCRETE

The Portland cement was replaced with silica fume by 0%, 3%, 6%, 9%, 12% and 15%. The conclusion is that when silica fume is incorporated, the rate of cement hydration increases at the early hours due to the release of OH ions and alkalis into the pore fluid. [Chakraborty Pranab, (2017)]

The study was conducted to check the influence of silica fume on tensile and flexural strength of concrete. It is obtained that the concrete gains its strength with increasing silica fume content up to 6% to 7.5% for all w/b ratios. The 7<sup>th</sup> day strength is maximum at around 7.5% and 28th day strength is maximum at around 6.0% for cement silica fume replacement for both splitting tensile and flexural strength test. [Kumar Aneel, Iqbal Faisal, (2018)]

The purpose of the work was to find the optimum quantity of silica fume to resistate cement in order to get better properties of hardened concrete. The replacement levels of cement were 5%, 10% and 15% with water/binder ratio keeping constant at 0.45. Percentage change in compressive strength, split tensile strength and flexural strength for 15% replacement of cement with silica fume gives optimum results. [Santosh Patil Hiteshkumar, Dwivedi A K, (2017)]

The paper deals with the review of silica fume utilization in concrete production and its effect on the concrete. The addition of silica fume reduces the workability and in some cases it improves workability. The tensile strength, flexural strength and modulus of elasticity of silica fume concrete is almost similar to the referral concrete. [Srivastava Vikas, Harison Alvin, (2014)]

The author represented a detailed experimental study of compressive strength, split tensile strength, flexural strength at age of 7 and 28 days with partial replacement of cement with silica fume. The investigation was carried by M35 grade concrete with replacement levels 0, 5, 10, 15 and 20%. It is observed that silica fume have a more pronounced effect on the flexural strength than the split tensile strength. [Amudhavalli N K, Mathew Jeena, (2012)]

### CORROSION RESISTANCE OF SILICA FUME CONCRETE

The experimental work was mainly concerned with the effect of different silica-fume dosages in varied curing periods and curing-water environments on the resistance of concrete to corrosion-related damage. Each group included concrete samples with 0, 10, 15, 20, and 25% silica fume by weight replacing ordinary Portland cement. [Safwan A Khedr, Ahmed F Idriss, (1996)]

The compressive strength of concrete increase in replacement level in a range of 8-12%, below this range there is no significant change in compressive strength of concrete

and above this range the compressive strength decreases. Split tensile strength and flexure strength of concrete shows an increase in tendency up to limit of 10-15%. Durability parameters like absorption, permeability, sulphate attack and chloride penetration resistance also improves. [Imam Ashhad, Kumar Vikash, (2018)]

The paper investigated the electrical resistivity and the corrosion behaviour of steel in concrete with silica fume. The results obtained were electrical resistivity of concrete increase 2.5 times with addition of 6% of silica fume and 12% of silica fume increase electrical resistivity by 5 times. So addition of silica fume can reduce the corrosion of steel reinforcement. [Dotto J M R, Muller I L, (2004)]

Corrosion behavior of carbon steel and stainless steel was studied for 365 days for three different mixes. Which are complete CPC (composite Portland Cement), 80% CPC and 20% silica fume and 80% CPC and 20% fly ash the specimens where designed and casted according to ACI 211.1 standard. [Bastidas M David, Miguel Angel Baltazar-Zamora, (2019)]

Corrosion behaviour of reinforcement with supplementary cementitious material was evaluated based on half cell potential and corrosion current density, electrical conductivity tomography and reinforcement cross section loss. Corrosion resistance of high early strength cement was highest, followed by OPC and SRC. [VanrakPichitnam, YodsudjaiWanchai, (2020)]

## METAKAOLIN

Metakaolin is the anhydrous calcined form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume. Metakaolin is a cost efficient.

### FLEXURAL STRENGTH OF METAKAOLIN CONCRETE

Metakaolin reacts with free calcium hydroxide to form stable, insoluble, strength adding cementitious compounds. Mix is prepared by partial replacement of cement with various metakaolin percentages (5, 10, 15, 20, and 25) for beam. Test result shows maximum flexural strength at 10 percent addition of metakaolin. [Mohammed Ashik M, Gomathi D, (2017)]

Metakaolin is a cementitious material used as admixture to produce high strength concrete. The replacement percentage of metakaolin is 5-25% with 5% increment each. We can conclude that metakaolin concrete increases the compressive strength and flexural strength than conventional concrete. The strength of concrete increase up to 15% cement

replacement and further increase in cement percentage reduces the strength. [Shirsath N Mohan, Jagtap A Sunny, (2017)]

The study of importance of adding polymer and metakaolin additive together on the mechanical and durability properties concretes was reported. It can be concluded that the addition of metakaolin accelerates the setting time and reduces workability. 5% of polymer and 15% of metakaolin are the optimum percentage to get an improvement in both strength and durability. [Wang Yan, Al Menhosh Adel, (2016)]

The cement was partially replaced by Metakaolin (MK). The replacement percentage of metakaolin is 0%, 5%, 10%, 15%. The increase in compressive strength of concrete of 5% (from 10% to 15%), Split tensile strength and flexural Strength of concrete increases of 4 % (from 8% to 12%). [Sivakumar R, Mohanraj N, (2017)]

The study was on partial replacement of cement with metakaolin as different percentage in M30 mix. The replacement levels were 10%, 15%, 20%, 25%, upto 30% (by weight) for Metakaolin. It was found that, the strength will be increased with addition of MK and amount of cement will be low, which reduces the emission of carbon dioxide during the production of cement. [Tony Cinaya, Merin Clara Mathan, (2016)]

#### CORROSION RESISTANCE OF METAKAOLIN CONCRETE

A poor Greek Kaolin with low kaolinite content was thermally treated at 650°C for 3h and the produced metakaolin was ground to appropriate fineness, a commercial metakaolin of high purity was also used. The use of metakaolin either as sand replacement up to 20% w/w or as a cement replacement up to 10% w/w improves the corrosion behavior of mortar specimens. Higher percentages of metakaolin decrease the corrosion resistance. [Batis G, Pantazopoulou P, Tsvivilis S, Badogiannis E, (2005)]

The objective of the study was to investigate the optimum replacements with respect to strength and durability were determined by varying the amount of MK as partial cement replacement. The optimum replacement level of OPC by MK was 10 %. As far as the durability properties are concerned, local MK found to reduce water permeability, absorption, and chloride permeability as the replacement percentage increases. [Dinakar P, Sriram G, (2013)]

A total five series of adjacent structural lightweight concrete (SLC) specimens, including the control specimen, were prepared to determine the effect of metakaolin addition on the corrosion behavior of reinforcing steel embedded in SLC specimens. It was observed that the use of metakaolin, as a cement replacement up to 15% w/w,

improved the corrosion resistance of SLC specimens. [KelestemurOguzhan, DemirelBahar, (2015)]

Paper investigated replacement of OPC by 15% metakaolin by weight and readymade PSC were used. Metakaolin specimen exhibits better performance in both the tests compressive strength as well as half-cell potential. [KondraivendhanB, Borade N Anita, (2017)]

The article deals with the effect of metakaolin (MK) and slag as supplementary cementitious materials in the concrete was investigated. From this it can be concluded that the concrete prepared with MK has better corrosion resistance as compared to the concrete prepared with slag. [NivruttiBorade Anita, Kondraivendhan B, (2019)]

## CONCLUSIONS

Based on above experiments, following conclusions are drawn:

- The addition of metakaolin to concrete leads to decrease in workability and optimum dosage obtained by replacing cement by metakaolin is 10%.
- The results show that the use of metakaolin as a cement replacement up to 10% w/w will improve the corrosion behavior of concrete.
- Using MK as a partial replacement for cement decreased the plastic density of the mixtures.
- Silica fume have greater fineness than cement.
- Addition of silica fume can reduce the corrosion of steel reinforcement.
- The optimum percentage of silica fume is obtained as 10 – 15% replacement of cement. At this percentage it shows greater flexural strength and corrosion resistance.

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Received: 15<sup>th</sup> February 2021; Accepted: 04<sup>th</sup> May 2021; First distributed: 04<sup>th</sup> May 2021