Engineering Properties of Self Compacting Concrete Incorporating Metakaolin and Rice Husk Ash: A Review

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Abstract. The paper is concerned with selecting materials for concrete that is both reducing the carbon emission and sustainable and the issues associated with achieving this. As the cement industry is the second-largest industrial emitter of carbon after the steel industry. The utilization of by-products, such as metakaolin and rice husk ash, as a partial replacement for cement can contribute to a series of beneficial performances by demonstrating economic, environmental, and technical advantages because it provides a new use for waste materials, produces cheaper mortar and concrete materials for low cost construction, and reduces carbon emissions. This paper reports a study carried out to investigate the effects of using metakaolin and rice husk ash. For this purpose, metakaolin was used to replace cement by weight in different proportions and fine aggregates were replaced by rice husk ash in proportion. Different properties such as compressive strength, durability properties and other properties at fresh state and hardened state are compared. Result showed significance improvement with the use of metakaolin and rice husk ash. Micro-structural analysis further confirmed the positive trend of results.

Keywords: Durability · Sustainability · Cement · Material selection
Carbon emission

Abbreviation

RHA	Rice Husk Ash
SCMs	Supplementry Cementitious Material
MK	Metakaolin

1 Introduction

The spontaneous research on material science progresses rapidly in last three decade. A lot of research is carried out to improve the mechanical & durability properties and reduce the impact on environment due to construction. Due to gradual reduction in skilled labour at construction site leads to evolvement of self-compacting concrete in later 1980s in Japan which can flow and consolidated under its own weight (EFNARC 2006). This can be achieved by limiting the aggregate content, ensuring a low water cementitious ratio and use of superplasticizer (Hajime and Masahiro 2003). To fulfil

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these requirement, a high amount of cementitious material need to used, which results in higher cost and higher impact on environment. It can be reduced by partial replacing the cement with SCMs. The mineral admixture blending improves the structural properties of concrete as well as indirectly reducing the pollution from manufacturing plant of cement (Nor and Hanizam 2011; Damtoft et al. 2008). RHA is an agricultural waste and can be used as partial replacement of Cement and fine aggregate. It can obtained by controlled burning of rice husk at 600–800 °C (Ganesan et al. 2007). Silica content in RHA is approx. 80–90% which suited for use as pozzolan to improve the secondary hydration results in betterment of microstructure.

MK is amorphous material that can be obtained by dehydrating Kaolin at temperature of about 800 °C (Carlos et al. 2006). Its reaction helps in refining the capillary porosity which improves the structural properties (Khani et al. 2009) and reduce the width of Interfacial transition zone (Vejmelkova et al. 2011; Jutice and Kurtis 2007).

2 State of Review

Kannan (2018) carried out an experiment to investigate the strength and durability property analysis of Self compacting concrete blended with Self Combusted Rice Husk Ash and Metakaolin. They used OPC 53 cement conforming to IS standard, Fine and Coarse aggregate from local site, commercially available MK, Rice Husk ash from uncontrolled Self Combusted Rice Husk and Sulphonated Naphthalene Polymer as Superplasticizer. They replace the cement with SCRHA or and MK in 5, 10, 15…30% in binary mix and 10, 20, 30…50 in ternary mix with mixture of SCRHA and MK in 1:1.

Mechanical properties test shows that replacement of cement with 15% SCRHA, 15% MK and mixture of SCRHA+MK 35% results in maximum increment in Compressive Strength. Similarly, 10–20% SCRHA, 20% MK and 40% SCRHA+MK shows maximum Split Tensile Strength. As far as concerned to Durability properties, with higher percentage of silica in SCRHA improves the chloride resistance; 20% SCRHA, 15% MK and 40% SCRHA+MK shows maximum resistance to chloride penetration. All mixes showing greater resistance against the chloride resistance comparative to control mix Open Circuit potential study show the reduction against corrosion. Mineralogical study shows that supplementary cementitious material densifies the concrete with additional production of CSH gel.

Gill and Siddique (2017) carried out an experiment to investigate the strength and microstructure properties of self-compacting concrete blended with MK as a replacement of cement and Rice Husk Ash as replacement of fine aggregate. They used OPC cement conforming to IS standard, Fine and coarse aggregate from local site, Rice Husk ash used of mean size less than 20 µm, MK used of mean size less than 1 µm and Conplast SP400 used as water demand reducing admixture. They used MK in different proportion of 5, 10, 15% and RHA of 10, 20, and 30%.

Compressive strength Test shows 24% increase in 28 day strength when 10–15% cement replaced with MK and 4–8% increase when 5–10% Fine aggregate replaced with RHA. In the ternary mixture, When 10% MK + 10% RHA replace the cement and fine aggregate, It show as high as 27% increment in 28 day compressive strength.

Similar to Compressive strength, Split Tensile strength Test also come with positive result as 10% Cement replacement with MK shows approx. 15% increment split tensile strength and 10% MK + 10% RHA show significant increase in Split Tensile strength.

Scanning Electron Microscope Image and X-Ray Diffraction shows more homogeneity in structure and increment in formation of CSH gel, which describes the rise in compressive strength. 10% MK + 10% RHA shows the densest structure confirm the increment in compressive and split tensile strength.

Chopra et al. (2015) carried out an experiment to investigate the effect of replacement of cement with RHA on the Mechanical and Durability property of Self Compacting Concrete. They used OPC 43 grade cement, Fine and coarse aggregate conforming to IS standard, RHA from local seller and Conplast SP430 used as Superplasticizer. Replaced the cement with 10, 20, 30% RHA. Workability is diminished as replacement increases. As high as 33% 28-day compressive strength increases and maximum increase in split tensile strength when 15% cement replaced with RHA. As far as concerned to durability properties, 15% replacement shows the maximum resistance to chloride penetration and minimum permeability. Improvement in Mechanical and Durability properties confirmed by XRD analysis, shows densest structure with 15% replacement.

Kannan and Ganesan (2015) carried out an experiment to investigate the resistance against Magnesium sulphate and rebar corrosion of self-compacting concrete incorporating RHA and MK. They used Type I cement (ASTM C150), gradation of aggregate according to ASTM C 136 standard provision, Rice Husk ash grinded to approx. 6 μm, MK and water reducing admixture Sulphonated Naphthalene polymer based. Depending upon the replacement of cement with RHA, MK (5, 10, 15…30) and RHK+MK (10, 20, 30, 40%).

Mechanical properties test results maximum increment in compressive strength with replacement of 15% RHA, 20% MK and 30% RHA+MK. As per Durability concern, specimen shows minimum loss in weight with replacement of 10% RHA, 20% MK and 20% RHA+MK when exposed to 1 year 5% Magnesium Sulphate environment. For Corrosion Resistance calculation, They used AC Impressed Voltage Technique, Result shows minimum Corrosion resistance with replacement of 10% RHA, 20% MK and 30% RHA+MK. Depending upon the chemical composition of C_3A, Specimen shows minimum weight loss when C_3A composition is 7%, 15–30%, 10–20% for RHA blended, MK blended and RHA+MK blended respectively. Similarly for Corrosion resistance, C_3A composition 6–7%, 30–35%, 20–25% for RHA blended, MK blended, RHA+MK blended respectively shows maximum resistance against Corrosion.

Kannan and Ganesan (2014) carried out an experiment to investigate the performance of Self Compacting Concrete in sulfuric acid and hydrochloric solution, to check the durability of concrete in degraded environment. They used Type I cement (ASTM C150), gradation of aggregate according to ASTM C 136 standard provision, Rice Husk ash grinded to approx. 6 μm, MK (1 μm) and water reducing admixture Sulphonated Naphthalene polymer based. Depending upon the replacement of cement with rice husk ash, MK (5, 10, 15…30) and rice husk ash, MK (10, 20, 30, 40%).

Result shows that replacement of cement with RHA greater than 20% leads to reduction in compressive strength, which may be due to reduction of workability and higher demand of water results in unhydrated RHA and act as mineral void in concrete. It tends them to use MK with RHA. This also helped in higher replacement of cement with RHA and MK. Thereafter, it exposed to 5% sulfuric acid solution which shows that less weight loss in 25% RHA, 5% MK and 40% RHA+MK than to control mix. When it expose to 5% hydrochloric acid solution, similar to sulfuric acid, shows less weight loss in 20% RHA, 5% MK and 40% RHA+MK than to control mix.

3 Observations

From above reported paper, the following conclusion may be made:

1. All mixes exhibit satisfactory fresh state properties up to 25% RHA & MK and 35% RHA+MK replacement to cement.
2. Replacement with RHA does not adversely affect the compressive strength up to 5–15%. Satisfactory increment in 28 day compressive strength when cement is replaced with 10–15% MK and 20–35% RHA+MK.
3. Equivalent or higher value Split Tensile Strength of mix when Cement is replaced with 10–20% RHA, 10–20% MK and 20–40% RHA+MK.
4. Resistance against chloride penetration show maximum when cement is replaced with 15–20% RHA, 10–15% MK and 30–40% RHA+MK.
5. Weight of loss in Sulfuric and Hydrochloric acid is minimum when cement is replaced with 25% RHA, 5% MK, 40% RHA+MK and 20% RHA, 5% MK, 40% RHA+MK respectively.
6. Concrete performed better in Magnesium Sulphate environment when replacement level is 10% MK, 20% MK, 20% RHA+MK.
7. Rebar corrosion is minimum, when cement is replaced with 10% RHA, 20% MK, 30% RHA+MK.
8. Concrete shows greater resistance against Magnesium Sulphate environment when C_3A composition is 7%, 15–30%, 10–20% in RHA, MK, RHA+MK blended respectively.
9. Concrete shows greater resistance against rebar when C_3A composition is 6–7%, 30–35%, 20–25% in RHA, MK, RHA+MK blended respectively.

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