Effect of supplementary cementitious material on chemical resistance of concrete

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Abstract: Recently the supplementary cementitious materials are used in the world widely in ready-mixed concrete because of it is economic and environmental benefits; they focusing on them has been increase in the recent years. Whether they come from industrial waste, agro wasted or with products, the SCM may be varied involving loose fasten to improve cement strength. SCM may contain slag cement, rice husk, fly ash, silica fume, and common pozzolans, to name a few. These components are used in combining with ordinary Portland cement (OPC). The use of those materials in concrete will part cut back the consumption of cement, which, in turn, will reduce construction prices, providing materials suppliers, contractors and engineers with substantial blessings. This paper is reviewed the use of metakaolin (MK) and rice husk ash as fractional alteration of cement in mortar and concrete has been extensively widely in lately years. (SCM; Metakaolin, Rice husk ash) is investigated.

1. Introduction
Concrete is the largest used in structure building constructions over the world, it is basically contain from small pieces of aggregates in cement past. This dentifrice is composed of a blend of hydration produce, unreacted cement and water. It is easy, simple to produce in technologically, concrete is count as the old and the headmost material that is utilized in the world widely. The research shows that the used of Portland cement had been increased from 3 million MT to 1.5 billion MT for more than a century (1890-1990).

As shown in figure 1, this increase value, as stated CEMBUREAU, started near the end of 20th century (Aitcin, 2000). So that, it is not unforeseen to consider that procedure of creating cements are between the third biggest CO2 producers in the world. Depending on (Malhotra, 2002), through this operation, for any ton of cement made, more than half of full Carbon dioxide radiation are freed into the atmosphere. This startling piling in Carbon dioxide radiation separated from refer recreation has been envisaged by (Muga et al., 2005) and is shown in Fig. 2. Cement process to produce it rely on numerous different factors as shown in Fig. 2. More often than not, the produce of cement excessively power heavy produce procedure because of the power and the consuming of the other natural resources per ton are evaluated to be closely to 4 GJ and 1.5 ton, respectively (Muga et al., 2005; Malhotra, 1993). The emission of CO2 appraises based on compressive strength of cement through the mixing and segregation of different kind of concrete already used in construction sites in Korea. To hostilities the above-mentioned issues, the use of cement can have changed by SM. Those material can have classified as natural resource or synthetic. These previous materials can be located in natural
resources pozzolans and tuffs, the other can be obtained from metallurgical slags, condensed silica fume and fly ashes (Mehta, 1989; RILEM 73-SBC Committee, 1988; Sersale, 1983; ACI Committee 226, 1987; Malhotra, 1987). Most of the (SCM) are by products; thus, it implication not only serves as an priceless means to maintain ecological resources, but also enhances cement construction characteristic, including its uninterrupted (Aitcin, 1998; Malhotra and Mehta, 1996; Mehta and Monteiro, 2006).

![Global production of cement according to CEMBUREAU (Aitcin, 2000).](image)

**Figure 1.** Global production of cement according to CEMBUREAU (Aitcin, 2000).

Moreover, because of the fillers impact and the response of the pozzolanic traits to enhancing cement showing its performance, substances had been more and more utilized in high-power and too much performance cement it’s known as (HPC and HSC). To increase the strength and the hardness, and the HSC mechanistic properties, it’s far critical ratio for the water/casing to be reduced and the content casing material will be accelerated. Therefore, terrific-plasticizer (SP) should used to update the silica fume, coal fly ash or natural pozzolan ratio with water. Due to the mixture of those superior traits, HSC has been used considerably as a higher opportunity for off-shore structures, close to-shore and excessive-upward push buildings, bridges, and nuclear containment as compared to its ordinary-energy counterpart.

Not with standing their important position in robust concrete and producing long lasting, if the cement replacement average is elevated these (SCM) can decrease the early strength of concrete, especially (Naik and Singh, 1998; Mehta, 1994). This paper is reviewed the use of rice husk ash and metakaolin (MK) as fractional alteration of cement in mortar and the used of concrete extensively widely in lately years. (SCM; Metakaolin, Rice husk ash) is investigated.

### 2. Supplementary cementitious materials

Usually, the concrete is flexible fabric which it consists in particular of, gravel, water, Portland cement and sand in concrete that will counted the main cementitious components. To this point, (SCM) were used extensively (60%), in prepared-combined cement because of it is herbal kind (PCA, 2000).
Figure 2. Carbon dioxide emissions due to the world production of cement (Muga et al., 2005)

If we take an example, for North America pioneered using those substances inside the Seventies. As shown in Fig. three, these by using product materials, which include fly ash, calcined clay, floor granulated blast furnace slag, calcined shale, and silica fume, could be mingled with the mixed cement to decorate the strength of concrete (Kosmatka et al., 2003). Those (SCM) can be both used in a mixture of two or even three (ternary combinations) or independently via concrete producers because of it is enormous availability. However, all of those natural substances duty are no longer immediately in cement. In reality, they must meet requirements for sure installed to reap the favoured effect on concrete. To showcase the characteristic of cementitious, a few of these materials, over with slag, may use personally. However, the used of (SCM) in cement is wonderful with a lot of approaches. Their use will ameliorate and will increase 1. The cement strength of; and the chloride ions and sulfate assault resistance 2. Characteristic of the rheological, it will make the pump concrete easier, finish and place.

Figure 3. Some of Supplementary cementitious materials. From the left to the right, class C fly ash, metakaolín (calcined clay), silica fume, class F fly ash, ground granulated blast furnace slag, and calcined shale (Kosmatka et al., 2003)
3. Material

3.1 Metakaolin
The anhydrous calcined shape of the mineral kaolinite, Minerals that contain or rich in kaolinit called china clay, customarily utilized within the fabrication of porcelain. The molecule measure of MK is littler than cement particles, but not as fine as silica rage great responsive MK appears great pozzolanic reactivity and lessening in CA (OH)₂ indeed as early as one day. The cement paste experiences particular densification. Densification incorporates an increment in quality and diminish in penetrability, the receptive MK is having the potential to compete with silica smoulder.

3.2 Rice husk ash
Rice husk ash acquired by burning in a precise way without producing natural pollution. Fabric of future as mineral added substances, Shapeless silica (90% SiO₂) in exceptionally better extent when burnt in controlled way, 5% carbon, 2% K₂O. The impact of rice husk fiery remains are Diminishes helpess to destructive attack and for another reason to progresses resistance to chloride permeation. Diminishes extensive porosity exceptionally moo porousness. Free lime displaying is decreases. Diminishes the absorbency of the structure. Improvements the resistance of concrete to corrosion. Lessening smaller scale breaking and moving forward freeze-thaw resistance. Moves forward capillary suction and quickened chloride diffusivity.

4. Hardened properties

4.1 Compressive strength
Compressive strength of concrete boost by using MK such as a partial replacement cement, however the finest extent substitution level of standard Portland cement by MK almost 20%, the compressive strength will increase when we attempting to increase MK and will reach the finest compressive quality by 10% substitution. Wild (1996), Brooks and Johari (2001) Cement glues containing from (5 to 20) % MK had the higher compressive Strengths at all ages start from 3 until 90 days and 10% will preforming most excellent in Table (1). its concluded that the combination of MK with concrete improve the quality and resistance of concrete and the mechanical properties.

Poon (2001), Jin and Li (2003) they discovered out that with increment of temperature to 800°C the properties of concrete will diminishes and will misfortune more of compressive quality. Observed reducing in compressive quality past 400 °C taken after by serious breaking and hazardous inside when the temperature rating from (400–800) °C, MK concretes endured more misfortune and had lesser remaining qualities than the other concretes.

| Concrete mixes | Compressive strength (Mpa) |
|---------------|---------------------------|
| OPC           | 87.0                      |
| MK5           | 91.5                      |
| MK10          | 104.0                     |
| MK15          | 103.5                     |

The commercial MK transported a comparable conduct regard to concrete Quality. All these types of MK appear exceptionally kvalue at 28 days and were characterized as profoundly receptive pozzolana. Poon (2003) from the investigation about of a few of these analysts, the components influencing the compressive strength of concrete contain RHA is a w/c proportion.
Bui (2005) and De Sensale (2006), Chindaprasirta and Babaiefar (2007) recommended that the percentage of the w/c proportions increased by 0.30 to 0.34 will lead to increase the compressive strength with RHA increased by 0.30 to 0.34 will lead to increase the compressive strength with RHA increased by 0.30 to 0.34 will lead to increase the compressive strength with RHA increased by 20% at the curing ranges from 7 to 90 days, where the w/c proportion rating from 0.35 showed that more inconsistency. Whereas Isaia (2003) and Hwang (2011) determined that the compressive strength diminished when it is contain 30% RHA, Gastaldini (2010) appeared that the compressive quality expanded with RHA. There's signs in any case that at water-cement proportion of 0.50–0.65 compressive quality diminished with RHA.

Saraswathy and Tune (2007), Habeeb and Fayyadh (2009), all these researcher made advance research appeared that the compressive quality expanded and increase but add 30% RHA with the water cement proportion of (0.50 to 0.53) There's signal that at consistent w/c proportion, further more with curing until 90 days appeared that the compressive strength of concrete is much higher with RHA than the control specimen. In spite of the fact that no writing is accessible on the ideal dose of concrete containing RHA can observed in Table( 2), in any case analyses concurred Gastaldini and Hwang (2011) Shatat (2014) Mahmud (2016) suggested that the concrete containing RHA will developed advanced compressive strength higher than concrete without RHA Fig( 4).

Table 2. Optimal RHA replacement for strength development comparable to the control samples.

| Researchers                     | % RHA | W-b Ratio | Additional Comments                                      |
|---------------------------------|-------|-----------|----------------------------------------------------------|
| Mahmud et al. (2016)            | 20    | 0.25      | High strength high performance concrete                  |
| Foong et al. (2015)             | 15    | 0.35      | Manufactured sand was used as fine aggregate              |
| Bansal and Antil (2015)         | 10    | 0.43      | M30 Grade of Concrete                                    |
| Talsania et al. (2015)          | 10    | 0.3–0.4   | –                                                        |
| Khassaf et al. (2014a,b)        | 10    | 0.59      | –                                                        |
| Le et al. (2014)                | 10    | 0.33      | Coarse aggregate of the mix replaced by sand and fine aggregate |
| Muthandhi and Kothandaraman (2013) | 20   | –         | –                                                        |
| Abalaka (2013)                  | 15    | 0.50      | –                                                        |
| Nguyen (2011)                   | 20    | 0.18      | Superplasticiser added to the mix                         |
| Adenuga et al. (2010)           | 10    | 0.60      | –                                                        |
| Gastaldini et al. (2010)        | 20    | 0.35      | –                                                        |
| Habeeb and Mahmud (2010)        | 10    | 0.53      | –                                                        |
| Kartini et al. (2010)           | 20    | 0.68      | Superplasticiser added to the mix                         |
| Kumar and Rao (2010)            | 10    | –         | Superplasticiser added to the mix                         |
| Uduweriya and De Silva (2010)   | 20    | 0.75      | –                                                        |
| Dakroury and Gasser (2008)      | 30    | All       | –                                                        |
| Ganesan et al. (2008)           | 15    | –         | –                                                        |
| Saraswathy and Song (2007)      | 30    | –         | –                                                        |
| Mahmud et al. (1996)            | 15    | –         | –                                                        |
| Zhang et al. (1996)             | 10    | –         | –                                                        |

*W-b = water-binder.
Tuan (2011) credited this to expanded CAS-H compound, diminished pores and coming about thick concrete after many days decrease in compressive strength in connection to the control appeared in early days can be ascribed to deferred pozzolana exercises in RHA-concrete specimens.

4.2 Tensile strength
Tensile strength of concrete consolidating from (0, 5, 10, 15)% MK as halfway substitution of cement explored by Qian and li(2001) in Table (3). Tensile strength of concrete expanded methodically and increase by increasement percentage of MK. Replacement of Metakaolin with 5% percentge had minor impact on the bending strength of concrete. the 28-day bending strength expanded with perantage of 32% and 38%, separately substitution with (5 and 10)% replacement.

Courard (2003) decided the impact of MK increases on the bending strength of concrete. Cement containing (5–20)% MK and we can see that in fig (5). That will lead to diminish of the bending strength next 3 days and nearly achieved break even with strength after 7 days with Substitution of cement with metakaolin exceptionally possibly. In differentiate, higher strenght after 14 and 28 days has been achevied with mortar containing.

Figure 4. degree of hydration of cement in the RHA modified sample

Figure 5. bending strength of mortar with CEM, metakaolin and kaolin
Table 3. Tensile and bending strength of concrete with different metakaolin replacement (Qian and Li, 2001)

| Metakaolin content (% mass) | (0%) | (5%) | (10%) | (15%) |
|----------------------------|------|------|-------|-------|
| Tensile strength (MPa)     | 3.35 | 3.58 | 3.88  | 4.29  |
| Bending strength (MPa)     | 4.65 | 4.74 | 6.16  | 6.40  |

Neville (2003) the information of tensile strength is valuable to assess the pile beneath. Furthermore, the impact of tensile stress on the arrangement of breaks and the spread of the pressure locale of reinforced concrete. Neville (2003) the of lack of ability to preserve really axial load in coordinate strategy of measuring pliable quality, Graeraj and Venkatachalum (2015) with part cylinders and loading beam to disappointment capable to backhanded strategy in flexure utilized instep. The part ting ductile strength and modulus of crack individually as a strength known. Investigator also appeared that with increment in RHA substance from 15% to 17.65% and 28% individually will be able to increase the tensile strength with 28 days but diminish about 5.88% of the control examples at 20% substitution the cement with RHA. Khassaf (2014) moreover seen an increment at the 28 day, when they tried to increase the cement with 10% RHA they discover that the part ductile strength with percentage of 10% will be higher than the control from 56 days and above. They discovered that the concrete with RHA in this case the water-cement proportion can be able to influence on the tensile strength of concrete.

Utilizing the information, we get for the plot in Fig (6). we can see that for w/c proportions contain 0.40 and 0.45 that the compressive strength will rise and at that point diminished, however at water-cementations of (0.5 and 0.55) the part malleable quality expanded up to 10% substitution level and at that point diminished. The RHA concrete at higher w/c proportions can be noticed to the free water that can develop the strength and will form hydration prepare. RHA adsorbed a few of the blending water which may be cause hydration to halt at lower w/c proportions because of its permeable structure. From the comes about of the examinations conducted Talsania (2015) the modulus of spilt was watched to extend we they tried to add with RHA up to 20% substitution level and at that point diminished. Vinothan and Baskar (2015) discovered that when we blended RHA with cement the increasement will raise to 10%. Foong (2015) showed and illustrated that the concrete blends with RHA with proportion (6–15) % compared to the comparing blends without RHA will raises flexural tensile strength.

5. Durability properties

5.1 Alkali-silica reaction

Soluble base silica response ASR may be a concrete toughness issue whereby certain shapes of silica in totals respond with tall antacid pore arrangements, in concrete to make a reaction item that can be grown within the dampness and comes about in harming breaking of concrete. The measures more often than not reduce ASR issues by use or utilize low alkali Portland cement boost the concrete by blended with pozolana.
Moreover, investigation by Obla and Hime (2016) to survey the development of concrete made with typical stages of cement substitution with rice husk fiery debris will not cover that, further more to control harmful extension due to ASR in concrete by a fractional substitution of cement with RHA with percentage (12-15) % will be adequate, reliant on the nature of the aggregate. The component of entanglement of antacids and causing diminish in pH of arrangements later in the development mortar of concrete is sensitive to pH stage of the arrangement showed by add RHA within the concrete blend stifles the extension due to ASR.

Cao (1997) investigated that as it may appear an opposite consequence. In his investigation, he noticed obvious splits in specimens with RHA by utilizing self-compacting performance concrete. The recognition of ASR items filled within the pores and kept within the lattice of the cement containing RHA proposed that these splits comes from hydration. He concluded that RHA particles will performance as micro aggregate and respond with alkali to produce ASR items.

Reblochon (2000) detailed that consolidation of aggregate reactivity MK as a fractional cement substitution with percentage of 15% which be adequate to control pernicious development with alkali silica in concrete. The component by which HRM will overwhelm development because of alkali silica response showed up to be capture of alkalis by the additional hydrates and a consequential diminish in pore arrangement by PH stage.

**5.2 Chloride resistance**

Strategies utilized by investigators Nehdi and Saraswathy (2007), Chindaprasirt and Rukzo (2008) to survey the capacity of concrete with RHA to resist chloride entrance. In spite of the fact that Stanish (2016) attested that none of the strategies is idealize, their comes about be that as it may concurred that consideration concrete containing RHA demonstrated to be sufficient resistance in connection and for control examples at substitution 40% and independent of the water-cement proportions and with all the curative level. This has been ascribed to many consequences that will be less permeability and better pore organizations of RHA specimens. The protection for steel in reinforcement concrete came through using of RHA with concrete and will be sufficient, in this manner diminishing the hazard of concrete weakening when the chloride able to preamble the concrete.

Investigation by Cabrera and Nuwaubian (1998) showed that Portland cement with MK and the Portland cement with PFA will able to give lower percentage of chloride spread coefficient than Portland cement paste. Bai (2003b) detailed that critical decreases in chloride infiltration profundities were watched when Portland cement diffusion with MK in concrete. Decreases expanded with both expanding add up to substitution level and expanding time when uncovered to seawater. All these was
ascribed to the comparative modifications in essential spread and chloride influential capacity with age displayed with diverse cover structures.

Investigation by Corard (2003) showed that Clear dissemination coefficient of mortar expanded with the increment in MK with percentage from 5% to15% because the comprising from (0, 10, 15) and 20% MK as partial substitution of cement, that as it may no dissemination was watched in mortar with 20% MK indeed after 1 year. There is no impact in kaolin and it will appeared on the opposite to accelerate the wonder of dissemination in contrast with the mention mixture. Poontl (2006) showed that Concrete has been penetrated by Chloride with (MK) at w/b proportions of 0.3 and 0.5. Both the MK concretes appeared lower add up to particle infiltration than the control. Concrete containing 0.3 water contain and with 10% MK showed that execution when water contain 0.5, 20% replacement and that was the most excellent.

6. Conclusion
Utilize of by-products or material such as rice husk ash debris, and MK in cement or concrete will acquired critical significance consequences since of the supplies of natural security and economic development within the future. Substitution of cement in in mortar has been broadly examined in later a long time by utilize the MK and RHA. The writing literature review illustrates that MK and RHA are active pozzolana.

- The early mechanical properties have been improved and the properties quality of mortar and cement paste.
- Decreases the water penetration of the partial substitution of cement with MK by capillary action of MK.
- Significant change will happen in Chemical composition when trying to add on part of the hydrated in pore solution metakaolin as partial substituting cement.
- We can improve the resistance of concrete to sulphate by supplement metakaolin with percentage of (10% - 15%) as a fractional substitution cement not less than that appearance stellar durability to sulphate.
- The percentage of metakaolin in concrete from 10% to 15% will be sufficient to Domination of destructive extending of ASR in concrete.
- The water-cement ration determines the compressive strength of concrete contain RHA as a partial substitution cement, control sampling will be development in strength and will be adequate by replace 10% RHA.
- The resistance of combination of RHA and microstructure concrete to operator of need such as, sulphate, chloride, in addition to make properties of shrinkage great will lead to create solid concrete when utilized.

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