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A Review on Partial Replacement of Cement in Concrete by Three Supplementary Materials

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Abstract

This paper explores the consequence of replacing cement by fly ash, rice husk ash and lime in concrete. For widespread use of these supplementary materials it is important to ensure the quality of resultant concrete. In this paper literature related with workability, density, compressive strength, flexural strength and splitting tensile strength are analyzed. Main advantages and drawbacks of using these materials in terms of engineering properties are mentioned. Another aim of this review is to identify major research needed in this field to use these materials worldwide given that concrete is the most extensively used man-made material.

Keywords: *Cement; Concrete; Fly Ash; Lime; Rice Husk Ash.*

1. Introduction

The increasing demand of conventional construction materials has encouraged the designers to use substitutive materials in construction. We know portland cement is the chief binder material in concrete but it is responsible for production of about 90% CO_2 (Singh *et al.*, 2015). In this paper we presented experimental data of replacing cement by fly ash, lime and Rice Husk Ash (RHA). Fly ash is self-possessed of the non-combustible mineral portion of coal (Pitroda *et al.*, 2012). About 43% is fly ash were recycled, often used as a pozzolan to a replacement or partial replacement for portland cement in concrete production in United States of America (USA) (wikipedia). India first used fly ash in the construction of rihand dam in uttar pradesh in 1962 (Gull *et al.*, 2020). Generally fly ash particles are spherical in shape and diameter ranges from less than 1 μm – 150 μm (Krishna *et al.*, 2019). It is found from the microstructural and the strength test results that the reactivity of fly ash is minimal due to less amount of $Ca(OH)_2$ to be consumed (Horpibulsuk *et al.*, 2009) which is different from concrete technology. Many researchers in concrete technology (Owens, 1979; Mitsui, 1994; Ollivier and Massat, 1996; Chindaprasirt *et al.*, 2004) have attempted to use waste pozzolanic materials from industries to reduce the input of cement.

The morphological features of fly ash were studied by Scanning Electron Microscopic (SEM) image analyzer as presented in Fig.1. From the Fig.1 it can be seen that the most fly ash particles are in spherical shape, have smooth surface and regular size, thus when fly ash is used in concrete it may improve the workability of concrete.

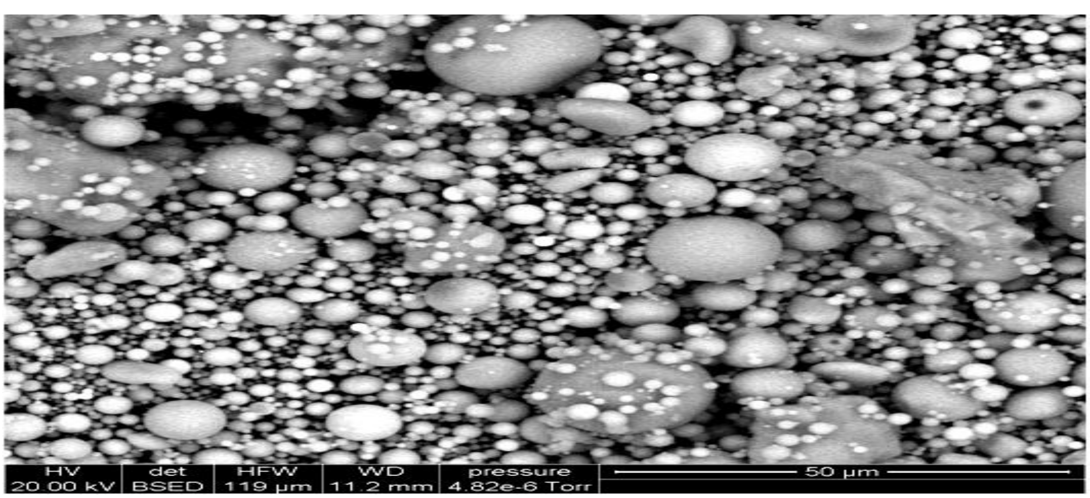

Fig. 1: SEM micrograph of fly ash particle (Sahmaran *et al.*, 2007)

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Fly ash has median particle size 16.23 µm and specific gravity 2.180 (g/cm^3) (Ranjbar *et al.*, 2014). Several researchers analyzed ideal level of replacement for strength and durability properties of concrete such as (Singh *et al.*, 2015; Krishna *et al.*, 2019; Gull *et al.*, 2020; Ariff *et al.*, 2019; Susan, 2019). From their work it is found that 10% to 15% replacement of cement by fly ash gives satisfactory outcomes in terms of compressive strength, tensile strength and flexural strength. In this paper 20%, 30% and 35% replacement data is also added which also produces reasonable results. In most of the cases interval of cement replacing was 5% to 10%. In future further work can be done by taking closely spaced interval of percentage such as 2% or 3%, which may bring significant change in result.

About 600 million tons of rice paddies are produced globally, where annual production of rice husk is 120 million tons (Krishna *et al.*, 2019). 22% of weight represents husk and 78% of weight represents rice, broken rice and bran after milling process of the paddy (Krishna *et al.*, 2016). (Khan *et al.*, 2012) discussed about solving the environmental issue because of using RHA in concrete and it was summarized that 25% RHA as a replacement of Ordinary Portland Cement (OPC) gave the similar strength like the concrete composed of 100% OPC. RHA has pozzolanic properties so some attempts have been made in rice producing countries to use RHA as partial replacement of hydraulic cement in concrete. RHA provides several advantages, improved workability and durability properties in the produced mortar or concrete are notable among that (Arulkumaran *et al.*, 2019). This material is actually a super pozzolan since it has silica about 85% to 90% (Washington *et al.*, 2017). Ideal level of replacement for strength and durability properties of concrete is analyzed by (Washington *et al.*, 2017; Lee *et al.*, 2019; Krishna *et al.*, 2016; Arulkumaran *et al.*, 2019; Khan *et al.*, 2014). After having a close look at their data it is noted that 10% to 15% replacement of cement by RHA shows positive outcome in terms of compressive, tensile and flexural strength. In this paper 30% and 35% replacement data is also added which also represents higher compressive, tensile and flexural strength. Usually interval of cement replacement is 5% to 10% in all the researches. Further studies can be carried out by taking densely spaced interval of percentage like 2% or 3% to get more meaningful results.

Lime is an inorganic mineral composed of calcium oxides and hydroxides generally. Lime is still used in big quantities as building and engineering materials (Thakur, 2019). Lime concrete makes a good base for load bearing walls, columns and floors because it has a degree of flexibility that regular concrete does not (Suneel *et al.*, 2017). It was widely used before the portland cement (Thakur, 2019). Chemically, by burning calcite ($CaCO_3$), CO_2 is removed and calcite transformed into calcium oxide (CaO) which is known as lime. When reacted with water, lime slowly converted into a mineral named portlanite in the reaction ($CaO + H_2O = Ca(OH)_2$) (Thakur, 2019; Yadav, 2019).

Lime concrete shows volumetric stability. It also resists weathering effects and is very hard-wearing (Thakur, 2019). To reduce the environmental problems partial replacement of lime in concrete was discussed by (Thakur, 2019; Suneel *et al.*, 2017; Yadav, 2019). It is detected from their data that 10% to 30% replacement of cement by lime shows optimistic effect in the compressive strength but tensile and flexural strength is reduced. Further research should be carried forward to get results beyond 30% like 40% or even more. Fig.2 represents all these three supplementary materials of cement.

Fig. 2: (a) Fly Ash (b) Rice Husk Ash (c) Lime

2. Chemical properties

It is observed from Table 1 that fly ash and RHA has high percentage (60.5% and 79.84%) of silicon dioxide (SiO_2) composition than lime.

Table 1: Chemical properties of fly ash, RHA and lime

Components	Fly ash (%) Authors		RHA (%) Authors	Lime (%) Authors
	(Singh *et al.*, 2015)	(Pandian, 2013)	(Krishna *et al.*, 2016)	(Thakur, 2019)
Silicon dioxide (SiO_2)	60.5	38-63	79.84	0.59
Sulphur trioxide (SO_3)	0.20	-	-	1.00
Reactive Silica (SiO_2)	33.4	-	-	-
Chlorides (Cl)	0.01	-	-	-
Magnesium oxide (MgO)	0.60	0.01-0.5	0.19	-
Loss on Ignition	1.10	0.2-3.4	0.08	-
Sodium oxide (Na_2O)	0.10	-	-	-
Insoluble Residue	-	-	-	-
Aluminium oxide (Al_2O_3)	-	27-44	0.14	21.0
Ferric oxide (Fe_2O_3)	-	3.3-6.4	1.16	3.70
Calcium oxide (CaO)	-	0.2-8	0.55	6.90
Potassium oxide (K_2O)	-	-	2.90	0.90

2.1 Chemical reactions

In RHA, 80-85% by weight is silica. Sulphate attack, which is a prime reason of the shortage of durability in concrete, is the loss of strength by reaction with hydration product calcium hydroxide [$Ca(OH)_2$] and strength generous calcium silicate hydrate (C-S-H). When sodium sulphate (Na_2SO_4) attacks $Ca(OH)_2$ expansive ettringites are produced as needle shaped crystals, causing amount increases up to 125% which could produce tensile stresses resulting in cracks. Though decalcification of C-S-H in Na_2SO_4 attack is made insignificant. RHA also decreases the permeability of concrete by the wrapping consequence of their un-reacted particles (Suneel *et al.*, 2017). Calcium hydroxide (lime) is comparatively insoluble in water; it is an adequate amount that its solutions are basic according to the subsequent reaction:

$$Ca(OH)_2 \rightarrow Ca^{2+} + 2\ OH^-$$

3. Results and Discussion

This section discusses the results on various tests performed by the different researchers on fresh and hardened concrete made from partially replacement of fly ash, RHA and lime.

3.1 Workability test

The workability of concrete is an important property which is defined by its ability to place in the formwork easily. For normal concrete, workability is measured in terms of height of a slump cone. While for mortar and Self-Consolidating Concrete (SCC), it is measured in terms of slump flow. Various researchers have reported that the workability of concrete or mortar improves when fly ash is used in the mixes (Sahmaran *et al.*, 2007; Nath and Sarker, 2011; Sun *et al.*, 2019). Slump value increased about 21% and 32% when cement was replaced by fly ash in the mix at 30% and 40% respectively (Nath and Sarker, 2011). Similar trend of higher slump values were also reported in (Sahmaran *et al.*, 2007; Sun *et al.*, 2019).The reason of this higher value could be attributed by the shape and smooth surface of the fly ash particles which give better lubrication or less friction among the particles. On contrary, no or very little improvement in the slump is also reported when fly ash was used in the mix (Oner *et al.*, 2005). For 58% fly ash in the mix, slump value was increased only about 4%. This can be due to different types of fly ash where the morphology varies. Nevertheless, it can be said that if right fly ash type can be ensured, it can be an alternative of water reducing agent in the mix.

The workability of concrete was reduced as the percentages of RHA increased in the mixes (Chao-Lung *et al.*, 2011; Adinna *et al.*, 2019; Srinivasreddy *et al.*, 2013). For 12% RHA in the mix, slump value of concrete was reduced about 75% (Adinna *et al.*, 2019). This lower workability can be ascribed by the micro fine particles and thus the higher surface area as well as high carbon content in the RHA required higher amount of super plasticizer in the concrete mixes to have the desire workability (Chao-Lung *et al.*, 2019). Similar to the RHA, slump value of concrete was also reduced as the percentages of lime content increased in the mix (Holland *et al.*, 2012). Table 2 and Fig.3 represent the effect of percentages of various binder content in the concrete workability as reported in the literatures. It can be seen that the fly ash has less effect in the workability than RHA and lime.

Table 2: Comparison of the slump value of fly Ash, RHA and lime for various percentages

Fly Ash (Ariff *et al.*, 2019)		Rice Husk Ash (Krishna *et al.*, 2016)		Lime (Holland *et al.*, 2012)	
% of replacement	Slump height (mm)	% of replacement	Slump height (mm)	% of replacement	Slump height (mm)
0%	7	0%	65	0%	100
10%	6	5%	55	6.49%	50
20%	6	10%	32	12.97%	50
30%	5	15%	14	16.24%	38
40%	5	20%	6	19.46%	12
50%	2	-	-	-	-

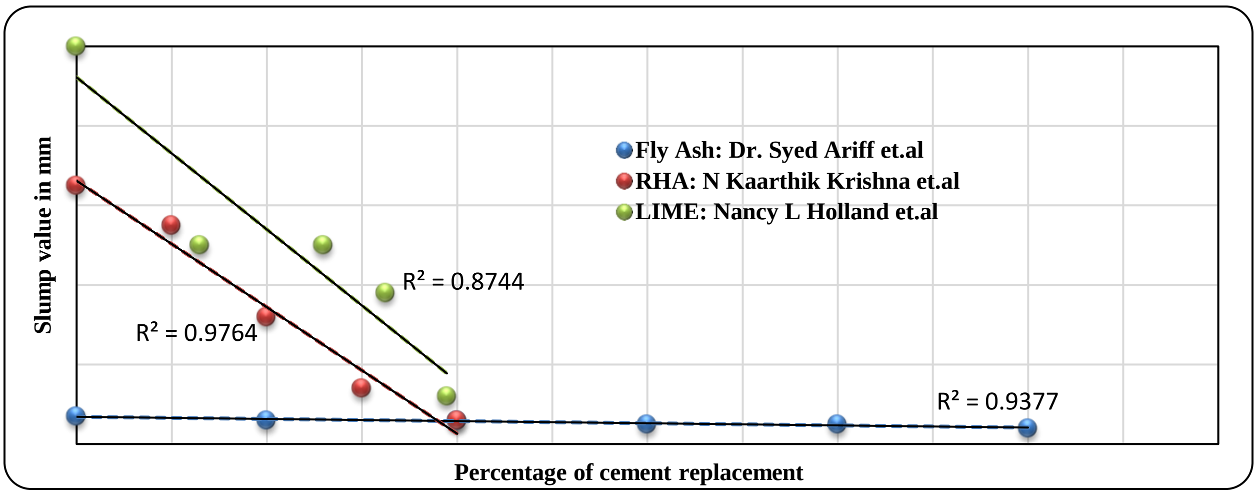

Fig. 3: Percentage of cement replacement vs slump value of (a) fly ash (b) RHA and (c) lime (Ariff *et al.*, 2019; Krishna *et al.*, 2016; Holland *et al.*, 2012)

3.2 Density test

Generally, it is believed that the higher density of concrete contributes to the higher strength and lower porosity. However, the density depends on many factors such as aggregates to binder ratio, water to cement ratio, degree of compaction, etc. It is an important parameter for concrete as its different compositions such as binders, fine aggregates and coarse aggregates have different physical and mechanical properties.

The density of cement mortar reduced as the percentages of fly ash content increased in the mixes (Rudzionis and Ivanauskas, 2004). In compare to the reference mortar (i.e. mix with 0% fly ash) about 5% and 17% lower density was found for the mortar mixes with 10% and 30% fly ash (Rudzionis and Ivanauskas, 2004). Density of concrete also related to the optimum content of fly ash. It was reported that the concrete density increased when 5% fly ash used in the mix but the density again reduced at 15% fly ash content in the mix (Perdana and Putera, 2018). In case of RHA, it was reported that the addition of different percentages of RHA didn't significantly affect the density of the concrete (Ardiantoro *et al.*, 2021). Similar conclusion was also drawn in a study where the density of RHA concrete found same for all replacement level (Ephraim *et al.*, 2012). Lime based concrete also exhibited the lower density of concrete (Malathy *et al.*, 2022). However, some contradictions in the results were also noticed due to fact that there are various types of lime and their properties differ significantly. Table 3 and Fig.4 show the graphical presentation of density of concrete at different percentages of fly ash and RHA reported in the literature. From the graph it is seen density is decreased progressively with rising percentage of cement replacement both in fly ash and RHA and results are similar at 7 days and 28 days.

Table 3: Comparison among density of fly Ash, RHA and lime for various percentages

	(Susan *et al.*, 2021)			(Adebara *et al.*, 2013)		
Sl. No	% replacement with fly ash	Density (Kg/m^3)		% replacement with RHA	Density (Kg/m^3)	
		7 Days	28 Days		7 Days	28 Days
1	0%	2129	2119	0%	2487.90	3037.04
2	15%	1894	1881	10%	2390.12	2660.57
3	20%	1765	1710	20%	2131.36	2308.15
4	25%	1757	1701	30%	2030.62	2082.96
5	30%	1747	1694	40%	2026.67	2056.30
6	-	-	-	50%	1981.23	2010.87

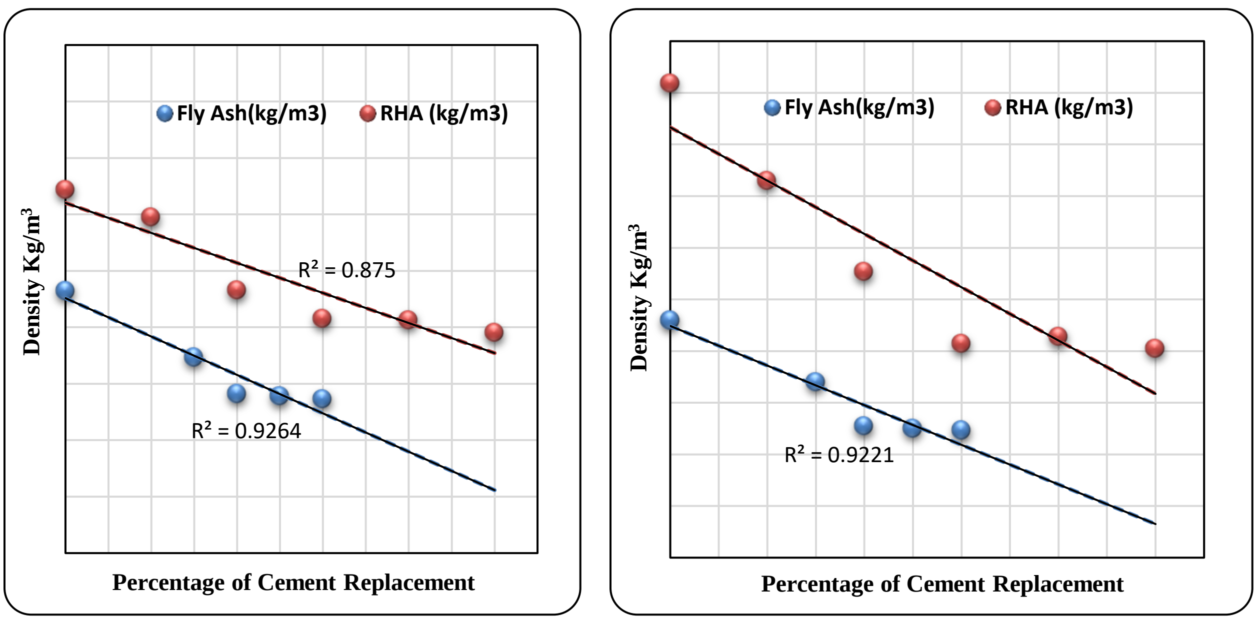

Fig.4: Concrete density at different percentages of fly ash and RHA at (a) 7 days and (b) 28 days reported in the literatures (Susan *et al.*, 2021; Adebara *et al.*, 2013)

3.3 Compressive strength test of concrete

The compressive strength of concrete determines its ability to resist under the applied loads. It is performed either on cube or cylindrical shape specimens where load is applied on the specimen's surface at a certain rate until failure occurs. Concrete compressive strength depends on many factors such as water to binder ratio, curing condition, quality of the materials and their compositions, etc. This section summarizes the compressive strength of concrete reported by the researchers when cement was replaced by the different percentages of fly ash, RHA and lime.

The optimum fly ash content in the concrete was found in a range of 25% to 50% depending on the types of fly ash. In compare to the reference concrete, a maximum of 25% higher strength was found in concrete with 30% fly ash and at 40% fly ash, this value was 16% (Nath and Sarker, 2011). In another study the optimum fly ash was 25% (Poon *et al.*, 2000). At 28 days, a maximum of 9% higher strength was found in concrete when 25% cement was replaced by fly ash. However, at 45% replacement level, about 8% lower compressive strength was reported in concrete (Ephraim *et al.*, 2012). Maximum 40% fly ash was considered the optimum level in the concrete mix in (Oner *et al.*, 2005). In another study this value was reported to be even 50% (Teja and Rao, 2018). The reason of better strength with fly ash was attributed by the better compaction in the mix due to its spherical shape. However, it must be noted that the early strength gain in concrete with fly ash is slow. This is due to the lack of availability of the free lime that requires adequate curing in fly ash concrete. However, at later curing age strength can be gained noticeably for the availability of lime in the matrix (Bendapudi and Saha, 2011). Another reason could also be that when fly ash is used in the concrete, the packing density of the mix improves thus higher strength can be obtained in the concrete samples (Sagara *et al.*, 2017). The strength development in concrete with different percentages of fly ash is also reported in Table 4 and Fig. 5.

Table 4: Comparison of compressive strength of concrete made by using fly ash, RHA and lime

Materials	Authors	Percentage	Main finding
Fly Ash	(Ariff *et al.*, 2019)	0 - 50	Highest strength and high workability is noted at 20%
	(Swarup *et al.*, 2017)	0 - 30	Up to 10% replacement is acceptable
	(Singh *et al.*, 2015)	0 - 60	Maximum strength is found at 10%
	(Gull *et al.*, 2020)	0 - 30	10% - 15 % replacement gives the best strength
	(Krishna *et al.*, 2019)	0 - 40	Maximum compressive strength is observed at 30% replacement.
	(Susan *et al.*, 2019)	0 - 30	Descending strength is observed up to 30%
RHA	(Washington *et al.*, 2017)	0 - 30	Replacement of RHA up to 20% is suitable
	(Krishna *et al.*, 2016)	0 - 20	Optimum strength is found near 10%
	(Arulkumaran *et al.*, 2019)	0 - 50	Maximum strength is achieved at 35%
	(Shukla *et al.*, 2011)	0 - 20	Significant improvement in strength is noted at 10%
	(Khan *et al.*, 2014)	0 - 35	Maximum strength is noted at 15%
Lime	(Yadav, 2019)	0 - 30	Maximum strength is noted at 30%
	(Anbuchezian and Kumar, 2018)	0 - 20	After 10% replacement, reduction of strength is noted
	(Maheswaran *et al.*, 2011)	0 - 30	After 10% replacement, reduction of strength is noted
	(N.Suneel *et al.*, 2017)	0 - 30	Highest strength and workability is noted at 30%

The compressive strength of concrete was also increased as the percentages of RHA content increased in the mixes. At 28 days, about 30% higher compressive strength was found in concrete with 12% of RHA than the reference concrete without any RHA (Adinna *et al.*, 2019). In another study, the optimum RHA content in concrete was reported in a range of 10% to 20% (Ismail and Waliuddin, 1996). The better strength of RHA concrete was attributed by its higher pozzolanic reaction and better filler effect which reduced the porosity in the matrix (Karim *et al.*, 2012). The ranges of optimum RHA content in concrete by various authors are also reported in Table 4. However, negative effect of RHA in concrete strength was also reported by some authors as illustrated in Fig.6.

Fig.7 also summarized the effect of different percentages of RHA in concrete as reported in the literatures by different researchers. Lime as Supplementary Cementitious Materials (SCM) adding up to 30%, attained the highest compressive strength at all ages as compared to the reference concrete at 28 days. Similar range of lime content was also found to be the optimum content as it gave higher compressive strength in hydraulic lime based concrete

(Velosa and Cachim, 2009). In contrary, as the percentages of lime increased, the compressive strength of concrete also decreased (Holland *et al.*, 2012). It was reported that the quality of lime and curing conditions significantly affect the strength development in concrete.

From the discussion above, it can be postulated that optimum amount of SCM with some pozzolanic behavior can provide better strength in concrete. However, variations in the results are also reported and this is due to fact that different researchers used different size and type of SCM which led to different pozzolanic behavior in concrete mixes. Nevertheless, application of SCM in concrete can provide a great benefit to the environment as they are the byproducts coming from the power plant and agricultural waste.

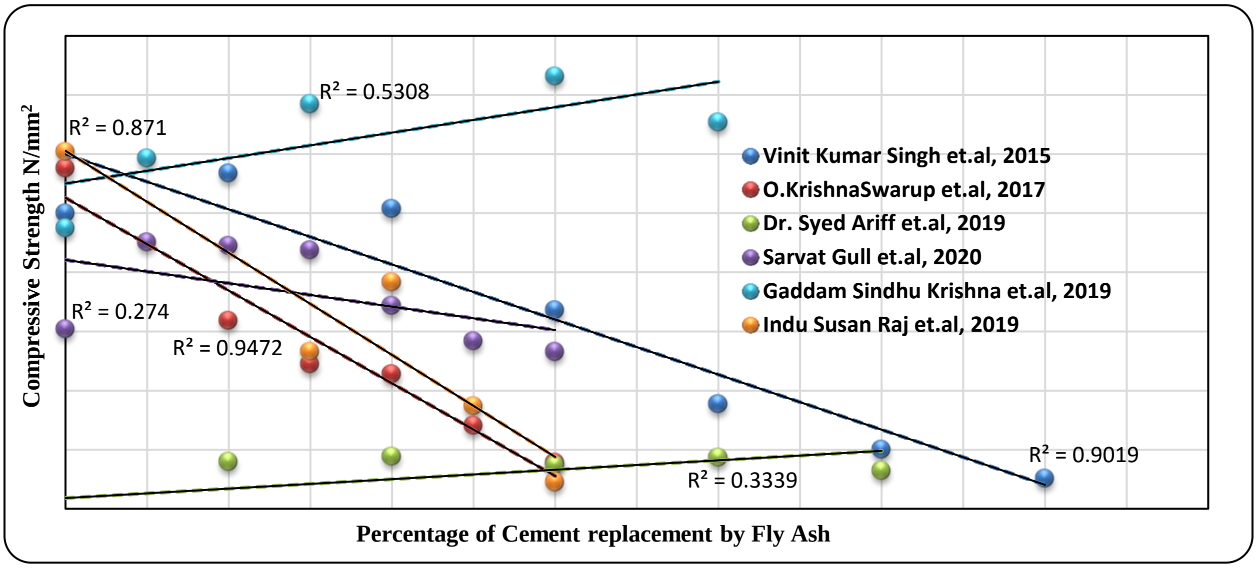

Fig. 5: Development of concrete compressive strength using fly ash (Singh *et al.*, 2015; Gull *et al.*, 2020; Krishna *et al.*, 2019; Ariff *et al.*, 2019; Susan *et al.*, 2019; Swarup *et al.*, 2017)

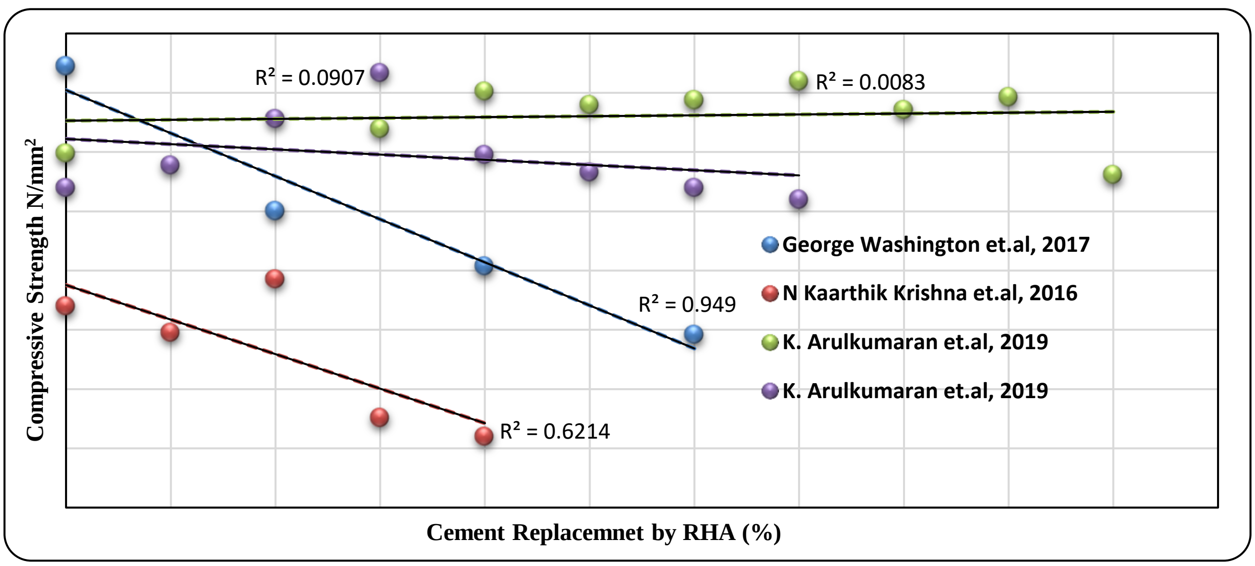

Fig. 6: Development of concrete compressive strength using different percentages of RHA (Singh et al., 2015; Gull *et al.*, 2020; Krishna *et al.*, 2016; Thakur, 2019)

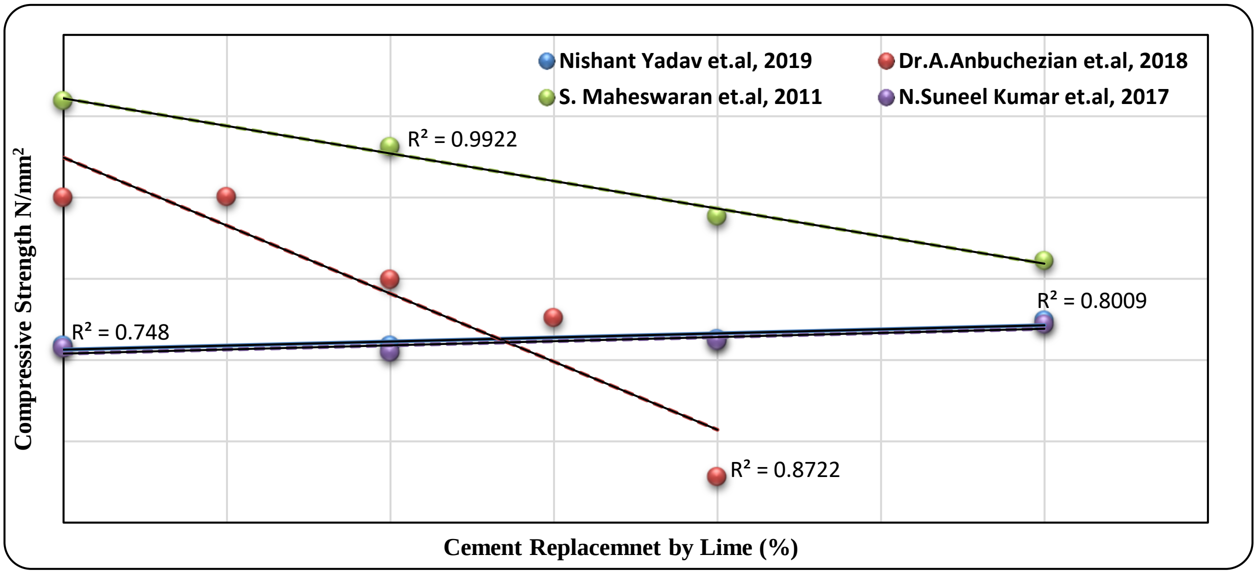

Fig. 7: Development of concrete compressive strength using different percentages of lime as reported in different literatures (N.Suneel *et al.*, 2017; Yadav, 2019; Anbuchezian and Kumar, 2018; Maheswaran *et al.*, 2011)

3.4 Tensile strength test of concrete

In designing the concrete structures, tensile strength of concrete is an important parameters as it has significant impact on the structural elements. It can be done on the specimens directly under uniaxial tensile test load or in split tensile test. This section summarized the tensile strength of concrete made from different percentages of fly ash, RHA and lime.

Table 5: Comparison of tensile strength of concrete made from different percentages of fly ash, RHA and lime

Materials	Authors	Percentage	Main finding
Fly Ash	(Ariff *et al.*, 2019)	0 - 50	After 30% of replacement, strength decreases.
	(Gull *et al.*, 2020)	0 - 30	After 10% of replacement, strength decreases considerably
RHA	(Krishna *et al.*, 2016)	0 - 20	Optimum strength and workability is found nearly at 10% of replacement
	(Arulkumaran *et al.*, 2019)	0 -50	35% replacement produces high strength as compared to control concrete
	(Shukla *et al.*, 2011)	0 - 20	Strength reduces at every % of replacement
	(Siddika *et al.*, 2018)	0 -15	Strength reduces at every % of replacement
	(Liew *et al.*, 2017)	0 - 25	Replacing 35% produces high strength
Lime	(Maheswaran *et al.*, 2011)	0 - 30	Strength reduces significantly
	(Anbuchezian and Kumar, 2018)	0 - 20	Strength progressively reduces at every % of replacement

It is revealed from Table 5 and Fig.8 to Fig.10 that fly ash adding up to 10% and even sometimes 30% as a replacement in the mix gave satisfactory tensile strength. In most cases, after 30% of replacement, tensile strength decreased gradually. In case of RHA, some researchers found that RHA adding up to maximum 20% as partial replacement of cement produces highest tensile strength (Karim *et al.*, 2012). Other researchers pointed out that strength decreases even at every replacement level. Similar to the RHA, inclusion of lime also showed gradual decrease in the tensile strength of concrete.

It is revealed from Table 5 that fly ash adding up to 10% and even sometimes 30% as a replacement of Portland Pozzolona Cement (PPC) gives satisfactory tensile strength. In general, after 30% of replacement strength decreased. Some researchers found that RHA adding up to maximum 35% as partial replacement of PPC produces highest tensile strength. Other researchers pointed out that strength decreases at every % of replacement. Tensile strength of concrete varied from 2.28 MPa to 2.52 MPa as the percentage of RHA increases from 0 to 10%. Lime adding up to even 30% partial replacement of PPC shows descending tensile strength at every % of replacement.

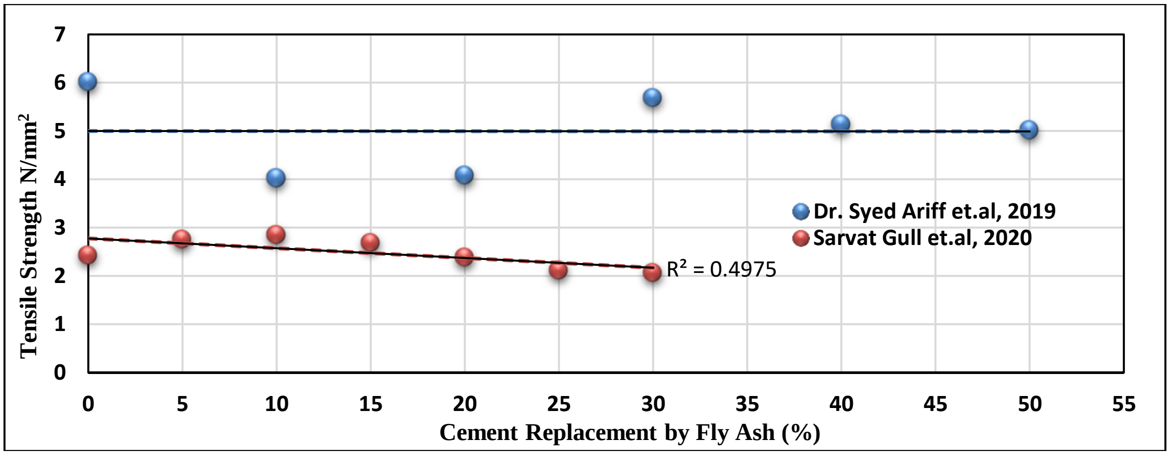

Fig. 8: Tensile strength behavior of concrete made from different percentages of fly ash (Gull *et al.*, 2020; Ariff *et al.*, 2019)

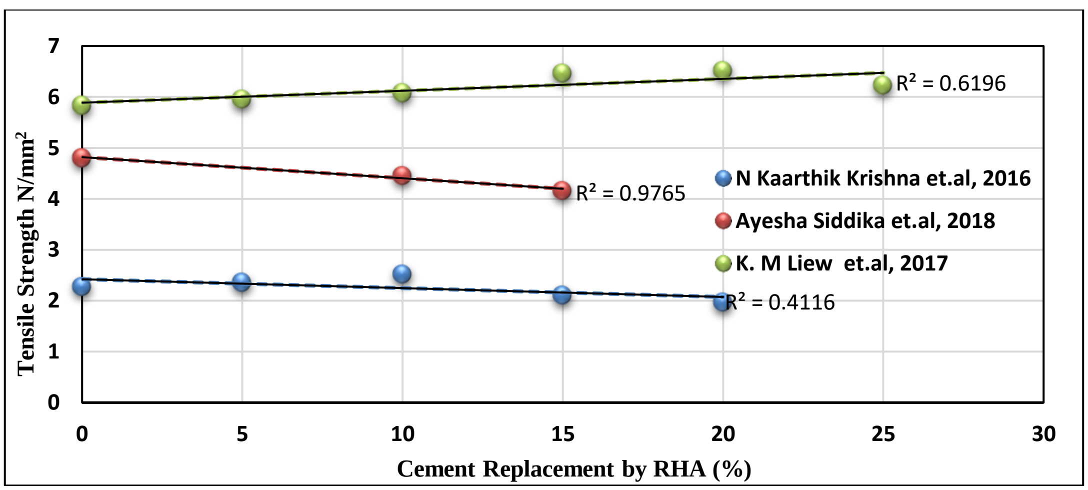

Fig. 9: Tensile strength behavior of concrete made from different percentages of RHA (Krishna *et al.*, 2016; Siddika *et al.*, 2018; Liew *et al.*, 2017)

3.5 Flexural strength test of concrete

The maximum flexural strength in concrete was found with 5% cement replacement by fly ash (Rudzionis and Ivanauskas, 2004). For 5% and 10% fly ash in the mix, a maximum of 22% and 15% higher flexural strength was found in concrete when comparing with control mix. In the same study for fly ash content of 15% and 30%, flexural strength was reduced by 2% and 34% (Rudzionis and Ivanauskas, 2004). Table 6 and Fig.11 to Fig.12 also summarized the flexural strength reported by different researchers. For flexural strength, the optimum fly ash and RHA content was found to be around 30% and 10%. No improvement in strength was reported when lime used in the concrete mix. The reason of this lower flexural strength was attributed by the lower degree of hydration of binders at higher replacement level of SCM.

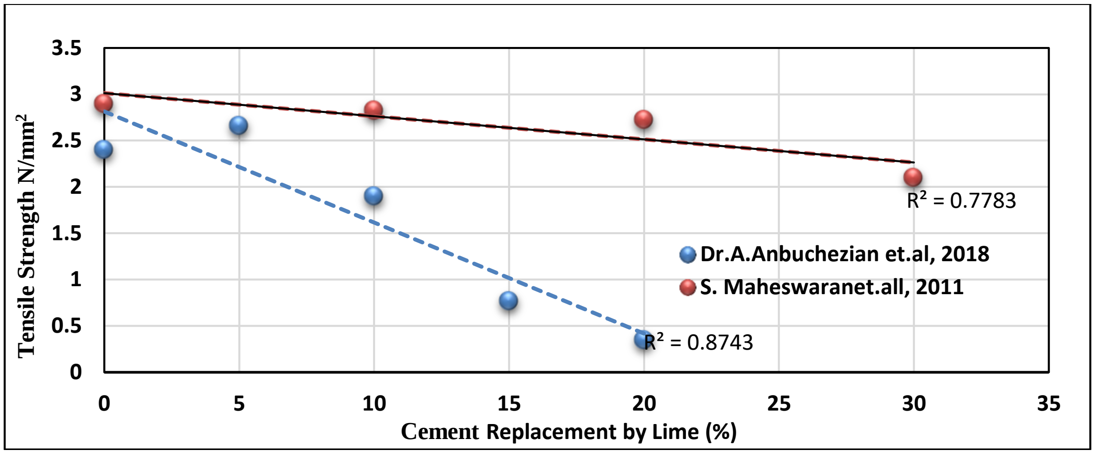

Fig. 10: Tensile strength behavior of concrete made from different percentages of lime (Anbuchezian and Kumar, 2018; Maheswaran *et al.*, 2011)

Table 6: Comparison of flexural strength of concrete made by using fly ash, RHA and lime

Materials	Authors	Percentage	Main finding
Fly Ash	(Gull *et al.*, 2020)	0 - 30	10% to 15 % replacement shows maximum efficiency in increasing the flexural strength
	(Krishna *et al.*, 2019)	0 - 40	Maximum flexural strength is obtained at 30% replacement
RHA	(Krishna *et al.*, 2016)	0 - 15	Highest flexural strength is found at 10% replacement
	(Shukla *et al.*, 2011)	0 - 20	Flexural strength increases up to 10% of replacement only
	(Siddika *et al.*, 2018)	0 -15	Flexural strength decreases gradually
	(Kumar *et al.*, 2011)	0 -15	Flexural strength decreases gradually
Lime	(Anbuchezian and Kumar, 2018)	0 - 20	Flexural strength decreases gradually

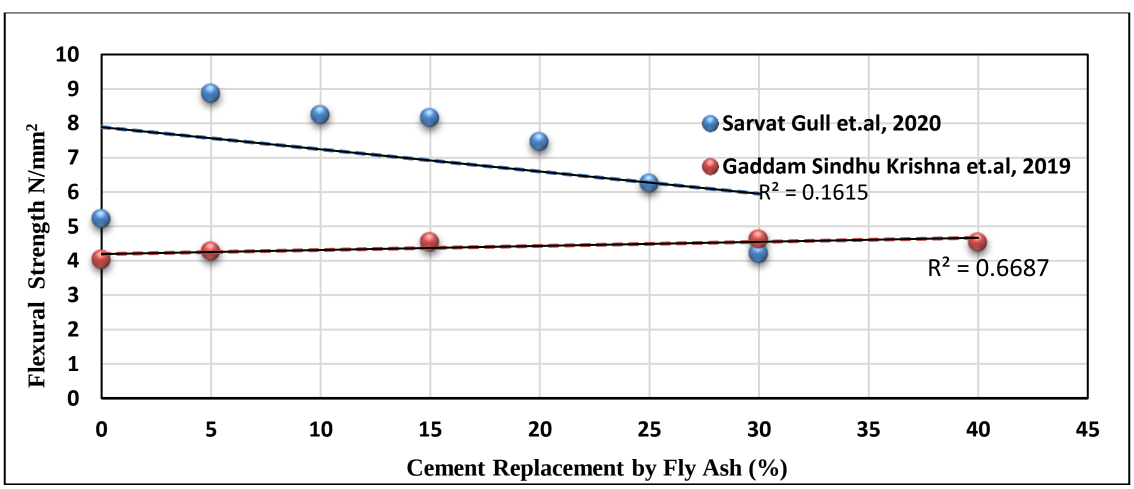

Fig. 11: Development of flexural strength of concrete made from different percentages of fly ash (Gull *et al.*, 2020; Krishna *et al.*, 2019)

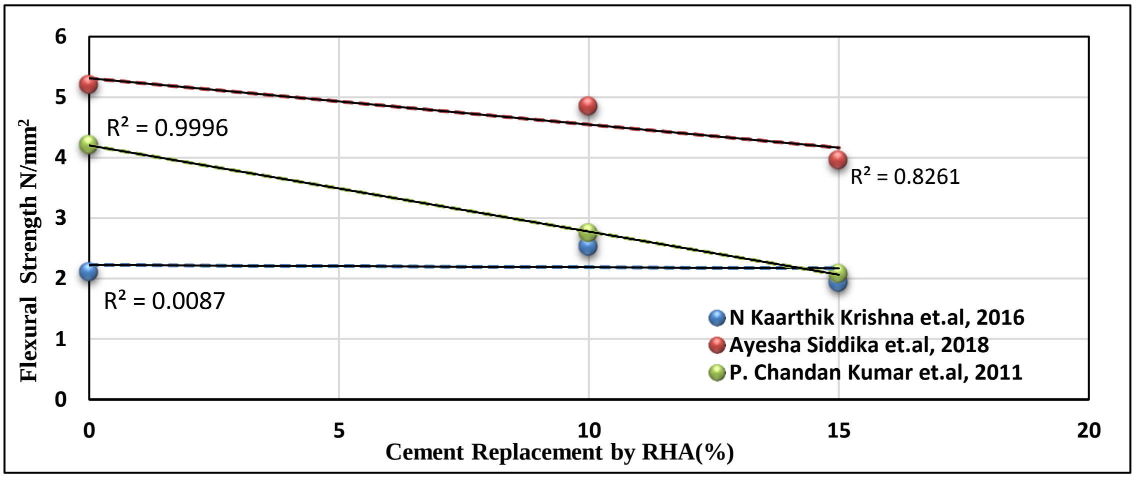

Fig. 12: Development of flexural strength of concrete made from different percentages of RHA (Krishna *et al.*, 2016; Siddika *et al.*, 2018; Kumar *et al.*, 2011)

4. Conclusion

The major findings of this review articles can be concluded as

From the physiochemical analysis for fly ash, RHA and lime as a cementitious material it is found that silica content is 60.5%, 79.84% and 0.59% respectively for three materials which reflects high percentage presence of silica in RHA and almost no silica in lime.

5% to 10% replacement of cement gives adequate slump value for RHA and lime and fly ash has the lowest slump value at all replacement percentage than other two supplementary materials.

By increasing percentage of cement replacement gradually density is also decreased regularly both in fly ash and RHA whereas no significant change is observed for lime replacement.

Adding up to 10%, 15% and 20% fly ash and RHA increased compressive strength is attained at all ages as compared to the traditional concrete at 28 days. But for lime maximum compressive strength was found at 30% replacement of cement.

Adding up to 10% fly ash and RHA as partial replacement of cement increases the tensile strength with respect to traditional concrete which is attained at 28 days. Scenario is different for replacement of lime as tensile strength has increased at only 5% replacement.

5% to 10% replacement of cement by fly ash and RHA increases the flexural strength whereas replacement of cement by lime decreases the strength.

Author's contribution

The study conceptualization, data collection were performed by A. Basit and S. Ahmed. Previous researches were reviewed by M. Islam, A. Basit and S. Paul. N. Hasan and M. Islam performed the draft preparation. A. Basit performed the final review and editing of the paper.

Conflict of interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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Highlights

- The consequence of replacing cement by fly ash, RHA and lime in concrete has been explored in this research.
- Previous researches related with slump test, density, compressive strength, flexural strength and splitting tensile strength are analyzed in this study.
- In this research, the optimum % of replacement are identified for all three supplementary materials.