Effect of mineral and chemical admixtures on the properties of mortar and concrete – A review

Rahul Singh, S.M. Gupta and Babita Saini

Since many decades, construction work is being carried out on a large scale all over the world. To make concrete able to adjust in different environment, the use of admixtures came in lime light. Construction without affecting the strength of concrete is the need of the hour. In this context different admixtures have been used in concrete. This article provides a detailed review of various studies on concrete with admixtures over the years.

INTRODUCTION

Construction plays an important role in the welfare and development of Nation's economy. Exposure to different environmental conditions for construction is one of the major challenge faced by both the under developed and developing countries all over the world. The majority of the constructional issues are related to making amendments in properties of concrete so that it can be used according to the need. Concrete is a composition of materials which is made up of filler (fine and coarse aggregate) and binder constituents (cement and water). The binder constituents glue the filler together to form a synthetic conglomerate. Concrete is strong in compression but weak in tension. In order to make desirable changes in properties of concrete various studies have been carried out with the use of admixtures. Admixtures are the ingredients other than the key ones that are being added during the process of mixing. They make concrete to adjust to different atmospheres and at different steps of construction to make the process convenient. Adequate precaution during the use of admixtures should be taken as they should not affect the strength of concrete. They should be environment friendly and easily degradable. Some of them are available in natural state and few are being obtained through scientific processes. Admixtures can be classified into following categories.

1. Mineral admixtures
2. Chemical admixtures

Mineral admixtures

Mineral admixtures are inorganic in nature that has pozzolanic or hydraulic properties. These fine grained materials are added to the mixture to improve concrete properties or as replacement of cement. Various types of mineral admixtures are fly ash, ground granulated blast furnace slag, silica fume, high reactivity metakaolin, rice husk ash, etc.

Fly ash is byproduct of coal fired electricity generating thermal power plants. It used to replace cement partially up to 60%. Its properties depend on type of coal burnt. Siliceous fly ash and calcareous fly ash are mainly two types of fly ash. Former one is pozzolanic while later has latent hydraulic

Table 1. Properties of concrete with fly ash as partial replacement of cement

Author	Concrete mix	% Used (fly ash)	Admixture or Additive used	Properties studied	Results reported (for fly ash)
(Limbachiya, 2012) [1]	20,30,35	30	Recycled concrete aggregates (0,30,50,100) %	Compressive, flexural and elastic modulus	Decrease in flexural , elastic modulus but increase in compressive strength
(Gudmundur, 2011) [2]	70	20,40,60, 80,100	Study of slag at same percent of replacement	Setting time, Compressive strength (CS)	Less early age compressive strength, setting time close to control mix
(Boga, 2012) [3]	30	15,30,45	-	Hardness, split tensile strength (ST), compressive strength, chloride ion permeability	Max S.T. at 15%, C.S. increased with 15% fly ash but decreased with 30%, 45% fly ash
(Katherine, 2012) [4]	65	(60, 80,90)	Study of slag as well as their combination at same value in different ratios	Compressive strength, elastic modulus	At 60% and 80% compressive strength increased, elastic modulus increased and after that no change was observed
(Xianming, 2011) [5]	35	20 ,25	One case with metakaoilin (5%)	Compressive strength, youngs modulus, modulus of rigidity	1 and 7 day's strength reduced but 28 day strength improved.

properties. The research work done in previous years using fly ash as replacement of cement has been discussed in Tables 1 and 2.

Above table depicts that the optimum replacement to cement by fly ash in the case of mortar was 15%. Also in case of concrete optimum replacement to cement by fly ash was found to be near 15%. The study also analyzed that it was better to use fly ash with components like lime stone and TEA (Triethanol Amine).

Table 2. Properties of mortar with fly ash as partial replacement of cement

Author	Mortar	% Used (fly ash)	Admixture or Additive used	Properties studied	Results reported (for fly ash)
(Heinz, 2009)[6]	1 : 3 : 0.5 (c:sand:w)	25	TEA	Dissolution of Ca, Fe and early age strength.	Strength increased
(Nochaiya, 2009) [7]	water/(PC+FA) ratio of 0.5	5,10,20,30	Silica fume (2.5, 5,10)% by wt of cement	Normal consistency, setting time, workability and compressive strength	water requirement decreased, initial and final setting time increased, workability and compressive strength increased
(Yilmaz, 2007) [8]	Cement to sand (1 : 3) , w/c 0.5	(5,10,20) of clinker	Gypsum (5%), Limestone (5,10,15)% and dolomistic limestone (5,10,15)% with fly ash	Compressive strength, setting time, soundness	Strength decreased and setting time prolonged
(Vahid, 2012) [9]	w/c =0.45	20, 60	Case of slag also studied at 60 %	Indentation modulus, hardness	degradation of mechanical properties on exposed to heat
(Xianming, 2011) [5]	Water cement ratio -0.45	20 ,25	One case with metakaoilin (5%)	Compressive Strength, young's modulus, modulus of rigidity	1 and 7 day's strength reduced but 28 day strength improved.

Table 3. Properties of concrete with ground granulated slag as partial replacement of cement

Authors	Concrete Mix	Replacement by GGBFS (%)	Additive or Condition	Properties studied	Results
(Shariq, 2009) [10]	25,35,45	20,40,60	_	Compressive strength in (cubes and cylinders)	Increase in strength was observed with 40% replacement of cement
(Xianming, 2011)	35	50	_	Comparison of Compressive strength, young's modulus, modulus of rigidity with replacement of cement by Ultra fine fly ash, fly ash, metakaolin and Silica fume	1st and 28th days strength improved with GGBFS but young's modulus and modulus of toughness reduced
Gengying Li et al (2001) [11]	80	15	Combined with fly ash (25,40) in presence of super plasticizer	Compressive strength, sulfate attack Compared to HFAC high-volume FA high-strength concrete at 40% replacement of cement	23.3% greater strength achieved, Superior to HFAC
(Latha, 2012) [12]	20,40,60	10, 20, 30, 40, 50,60,70	HVFA (high volume fly ash) (at same percent) for comparison of results	Strength efficiency factor (S.E.F.), compressive strength	Increased performance in strength and durability, S.E.F. higher in case of GGBS.
(Nazari, 2010) [13]	Cement 450kg/ m^3	15,30,45,60	SiO_2 nanoparticles as binder (1, 2,3,4)%	Split tensile strength	The split tensile strength (STS) of concrete increased upto 45% replacement of cement by GGBFS where as when greater % was used ie 60% then STS decreased.

Table 4. Properties of mortar with GGBFS as partial replacement of cement

Authors	Mortar	Replacement by GGBFS (%)	Additive or Condition	Properties studied	Results
Hwang [14]	w/(c+s) ratios [0.35,0.47, 0.59]	0,10,20, 30,40	fly ash	Comparison with fly ash, Penetration resistance, setting time	Longer setting time, slag increased penetration resistance
(Xianming, 2011) [5]	Water cement ratio 0.45	50	-	Comparison of Compressive strength, young's modulus, modulus of rigidity with replacement of cement by Ultra fine fly ash, fly ash, metakaolin and Silica fume	1st and 28th days strength improved with GGBFS but young's modulus and modulus of toughness reduced
(Wang, 2007) [15]	w/c ratio (0.23, 0.47,0.71)	5, 10,20,50,80,100	Tested at different temperatures (25, 105, 200, 440, 580, 800, 1080)°C	Compressive strength, elastic modulus	Compressive strength is more susceptible to temperature rise effect
(Boukendakdji, 2011) [16]	Six test for each super plasticizer with 1.2, 1.4, 1.6, 1.8, 2.0, 2.2 (w/c 0.4)	10,15,20,25	Poly carboxylate (PC) based and naphthalene sulphonate based super plasticize	Workability and compressive strength	Workability improved up to 20 % of slag, p.c. based super plasticizer gave higher compressive strength
(Alhozaimy, 2012) [17]	1 : 3 : 0.5	10,20, 30,40,	Ground dune sand (GDS) (10, 20, 30, 40)	Setting time , compressive strength	Compressive strength decreased by increasing GDS and GGBS, initial and final setting time increased
(Nataraja, 2013) [18]	mortar mix 1:3, w/c= 0.5	0, 25, 50,75 and 100%	sulphonated napthalene polymers based super plasticizer	Flow characteristic, compressive strength	Flow decreased with replacement, compressive strength decreased

Ground granulated blast furnace slag (GGBFS) -

Is a by-product of steel production and having latent hydraulic properties. It is used to replace cement up to 80% by mass. The research study done in previous years using ground granulated blast furnace slag as replacement of cement has been shown in Tables 3 and 4.

From the previous research work it was found that in both cases (mortar and concrete) cement replacement by GGBFS lies between 40-50%. It was also seen that Poly carboxylate base super plasticizer was better option to be used with GGBFS.

High reactivity metakaolin

HRM is a processed aluminosilicatic pozzolan that is quite reactive. It is a finely ground material that reacts with slaked lime at low temperature and moisture to form strong but slowly hardening cement. It is manufactured by calcinations of purified kaolinite between 650-700^{o}C in a kiln. It produces concrete with durability and strength as with silica fume. It is bright white in color. So it is preferred for architectural concrete. Table 5 gives a general overview about the work done with HRM in previous years.

It has been observed that optimum replacement of cement by HRM lies in the range of 8-10%. It was also observed that very less work has been done to study effect of HRM on mortar.

Table 5. Properties of concrete with HRM as partial replacement of cement

Authors Or References	Concrete mix	Replacement % by HRM	Additive or Condition used	Properties studied	Results (for HRM)
(Boddy, 2001) [19]	25	0, 8, 12 With w/c = 0.30 or 0.40	SPN super plasticizer	Early age Strength, bulk diffusion, rapid chloride permeability, Resistivity Long term- chloride propagation	Strength increased with decrease in w/c and increasing metakaolin. High metakaolin and lower w/c decreased diffusion, permeability conductivity and increased resistivity
(Erhan Guneyisi , 2012) [20]	75 to 86 MPa w/c = (0.25,0.35)	(5 and 15)%	A separate case was studied at same % replacement of cement by silica fume	Compressive and split tensile strength (S.T.S.), Water sorptivity, gas permeability	Strength increased with increase in silica fume and metakaolin. S.T.S. had same strength pattern as C.S., sorptivity coefficient decreased.
Gruber et al (2001) [21]	w/c = 0.30 or 0.40	(5,10,15, 20)%	SPN super plasticizer	Chloride ion diffusion, bulk diffusion, expansion	HRM reduced chloride ion diffusion; bulk diffusion reduced with increase in HRM.
(Shelorkar, 2013) [22]	M60 (w/c=0.29)	(0, 4,6, 8) %	A high performance Superplacticizer (1% by mass)	Compressive strength (CS.), chloride permeability test (CPT)	CS increased, CPT decreased
(Patil, 2012) [23]	M 50,	(5,7.5, 10,12.5,15) %	Polycarboxylic ether polymer	Compressive Strength, chloride and sulfate attack	CS sulfate and chloride resistance increased upto 7.5% then decreased for 10, 12.5 and 15%.
Guneyisi et al (2007) [24]	M 60	w/c = (0.35,0.55) (0, 10,20)%	High-range water-reducing admixture (Sulphonated naphthalene)	Compressive and split tensile strength, water absorption, drying shrinkage and weight loss	CS increased max for w/c 10%, STS increased, water absorption decreased, shrinkage decreased with increase in metakaolin
(Jian-Tong Ding ,2002) [25]	M 40	(0, 5 10,15)% w/ binder ratio= 0.35	In presence of High-range water reducing Admixture (4.63) and Retarder (1.16)	Slump, compressive strength, free shrinkage, restrained shrinkage cracking (RSC), Chloride diffusivity	MK increases compressive strength at same pace as SF. Shrinkage decreased in both cases. RSC was less than control in both cases.

Table 6. Properties of concrete with silica fume as partial replacement of cement

Authors or Reference	Concrete mix	Replacement by SF (%)	Additive / Condition Used	Properties studied	Results (for SF)
Ganesh Babu et al (1994) [26]	20- 100 MPa	5,10,16,20,30,40	Super plasticizer (0-2)%	Compressive strength	As SF and w/c increased the strength decreased
Bhanja et al (2002) [27]	w/ binder ratio (0.26, 0.30,0.34, 0.38, 0.42)	0, 5, 10,15,2025	Super plasticizer 3.5% by wt of cement	Flexural strength (FS), split tensile strength (S.T.S.)	S.T.S. increases with replacement, F.S. has more effect than S.T.S.
Lam et al (1997) [28]	w/c 0.3, 0.4, 0.5	5%	Fly ash (0, 20,40)% In combination with S.F. (0, 15, 25,45,55)% separately	Tensile and compressive strength	Increased effect on tensile and compressive strength of cylinders
Jianyong et al (1997) [29]	M 50	15, 10, 5	Slag at 10,15,20% respectively to each % of SF, Super plasticizer (1%)	Compressive strength, split tensile strength, rupture strength	Lower compressive strength, high split tensile strength, rupture strength improved
Duval et al (1997) [30]	w/ binder 0.25, 0.30, 0.35, 0.45	0,10,20, 30	Naphthalene Sulphonated super plasticizer	Workability, compressive strength	Workability loss increased with increase in SF content. Compressive strength depends on w/c more than on % replacement.
Mustafa Saridemir (2013) [31]	70 to 105 MPa w/c 0.25	5,10,15, 20, 25	polycarboxylic ether based super plasticizer, Ground pumice (GP) alone and with combination to SF at same %	Compressive strength, E_c	SF gives higher compressive strength than GP and control. E_c is higher for SF relatively to GP.
Shannag (2000) [32]	69- 110 MPa, w/c =0.35	0, 5, 10 , 15, 20, 25	Natural pozzolana (15)% Super plasticizer (0.03)%	Workability, compressive strength, E_c , Split tensile strength	High workability achieved, rate of increase of E_c was less than compressive strength. S.T.S. showed inconsistency
J. M. R. etal (2004) [33]	w/binder ratio 0.50,0.65, 0.80	0, 16,12	_	Compressive strength, electrical resistivity	CS and electrical resistance increased with increase in % of SF.,

Silica fume

It is a byproduct of production of silicon and ferrosilicon alloy. It is similar to fly ash but has size 100 times smaller resulting in high surface to volume ratio and much faster pozzolanic reaction. It is used to increase the strength and durability of concrete but often it requires the use of super plasticizers for workability. Many authors carried out their investigation on various properties of concrete and mortars with silica fume (SF).

The previous research work by different authors using SF as replacement of cement has been shown in Tables 6 and 7.

Table 7. Properties of mortar with silica fume as partial replacement of cement

Authors or Reference	Mortar	Replacement by SF (%)	Additive / Condition used	Properties studied	Results (for SF)
(Rodriguez, 2012) [34]	w / binder =0.30, Sand / binder =2.0	5,10,20 For both SSF and DSF.	Super plasticizer (1.1 to 2.0)%	Compressive strength, permeability	Compressive strength greater in SSF, permeability reduced.
Appa .Rao (2001) [35]	w/c (0.35, 0.40, 0.45, 0.50) (c/ sand) 1:3	0 to 30	-	Compressive strength	Compressive strength increased as SF increased on 0.35 and 0.40 up to optimum % in early ages (3 and 7). At 0.50, increase in SF increases strength at 7, 28 and 90 days also.

Table 8. Properties of concrete with Rice Husk Ash as partial replacement of cement

Authors or Reference	Mix	Replacement by RH (%)	Additional condition	Properties studied	Results (for RHA)
(Rodriguez de Sensale, 2005) [36]	w/c 0.50, 0.40,0.32	0, 10, 20	At low %	Compressive strength, split tensile strength, air permeability	C.S. with RHA increased but S.T.S. and air permeability decreased.
Rodriguez de Sensale, 2010) [37]	Agg./ binder 2.75	0, 5, 10, 15	Super plasticizer for 0.32- 0.52, 0.40- 0.10	Air permeability, chloride ion penetration, sulfate resistance	A.P. reduced with RHA, CL penetration value decreased, rise in sulfate resistance.
(Sakr, 2006) [38]	w/ c 0.40	0, 5, 10, 15, 20	SP (max -15%),	Compressive strength , sulfate resistance, Separate test with SF at same % for comparison	After 15% increase in RHA, CS reduced , SF showed better sulfate resistance
(Muthadhi ,2013) [39]	W binder = 0.30, 0.33, 0.36, 0.44	10, 15, 20, 30	Poly carboxylic ether polymer based SP	Compressive strength, chloride permeability, water absorption	CS improved, chloride permeability reduced, water absorption reduced
(Shoaib, 1996) [40]	70 MPa w/c = 0.25 to 0.3	10 to 30%	Plasticizer (25 ml/ kg of cement)	Rate of hydration (R.O.H.), compressive strength	R.O.H decreased, max strength at 15%
(Alireza Naji, 2010)[41]	M 35	5, 10, 15, 20	Two types of RHA (5 micron and 95 micron)	Water absorption(w.a.), compressive strength, workability	RHA increased CS, w.a. decreased, workability improved
(Hwang Chao Lung, 2011) [42]	M 55 w/b 0.25, 0.35, 0.47	0, 10, 20, 30	Super plasticizer	Compressive strength, electrical resistance (e.r.), ultra sonic pulse velocity (U.P.V.)	CS increased at later stages ,e.r. increases, U.P.V. reduced
(Ramasamy, 2011) [43]	M30, M60	5, 10, 15, 20	Super plasticizer	Water absorption, rapid chloride permeability	Water absorption reduced, R.C.P. reduced,

With mortar more stress was laid on w/c, as a result it was seen that SF resulted better at w/c= 0.50. For both mortar and concrete, optimum replacement range of cement by SF lies between 10-25%.

Rice husk ash

It is generated during the milling process on the accumulated covering of rice grain. It is the agro waste in which appropriate amount of silica is present. Highly reactive RHA (Rice Husk Ash) is obtained when RHA is burnt under controlled condition. Residual RHA is produced with a lower quality due to high carbon content. High carbon content increases water demand and introduce dark color to mortar and concrete. It has a considerable amount of carbon which can have adverse effect on its pozzolanic activity. Tables 8 and 9 provide an overview about some work done with Rice Husk.

From the above study, in case of mortar it was observed that RHA resulted better at w/c = 0.32 with replacement range of cement by RHA between 10-15%. In case of concrete the optimum replacement range of cement by RHA was found between 10-20%.

Table 9. Properties of mortar with RHA as partial replacement of cement

Authors or Reference	Mortar	Replacement by RH (%)	Additional condition	Properties studied	Results (for RHA)
Rodriguez de Sensale, 2010) [37]	w/c 0.50, 0.40, 0.32	0, 5, 10, 15	Super plasticizer for 0.32- 0.52, 0.40- 0.10	Air permeability, chloride ion penetration, sulfate resistance	A.P. reduced with RHA, CL penetration value decreased, rise in sulfate resistance.

Chemical admixtures

Chemical admixtures are mainly in five categories i.e. accelerators, retarders, air entrainers, super plasticizers, pigments. Accelerators cause early strength gain and speeds setting time. Retarders delay the setting time. Air entrainers increase workability, durability and reduce bleeding. Super plasticizers increase the strength, workability by decreasing water. Pigments add colors.

Accelerators

Are the admixtures which reduces setting time of mortar and concrete. They also allow the concrete to be placed in winter in order to avoid any damage. Some of the accelerators are $CaCl_2$, Triethanol amine (TEA), Triisopropanol amine (TIPA), Calcium Nitrate(CN), Sodium Thiocynate, Oxalic acid, Calcium formate, Sodium carbonate, Sodium aluminates etc. Various research studies carried out about these accelerators have been discussed in Tables 10 and 11.

Table 10. Effect of accelerators on properties of concrete

Authors	Concrete mix	Admixture (% of concentration)	Additional condition	Properties studied	Results
(Arunakanthi, 2013) [44]	1:0.76:1.8 w/binder 0.3	(0.2, 0.5,1, 2) g/l of $CaCl_2$	Metakaolin (20%) in presence of a High performance superplasticiser (1%)	Compressive strength (CS) and Split tensile strength (STS)	CS and STS increases with conc. of $CaCl_2$
Devi et al, 2012) [45]	(1:1.517:3.38) w/c = 0.45	TEA (1,2,3,4) % By wt of cement	Quarry dust as fine aggregate	Compressive strength (CS), split tensile strength (TS), flexural strength (FS)	Increase in CS, STS, FS till 2%
(Aggoun, 2006) [46]	For Normal C_3S (M10 to M15) Low C_3S (M20 to M25) w/c 0.3	TEA (0.05%) Wt of cement	Compared with [CN(1%)+TEA]	Compressive strength	CS increases for both cement
(Aggoun, 2006) [46]	For Normal C_3S (M10 to M15) Low C_3S (M20 to M25) w/c=0.3	CN (1%)	Compared with [CN (1%) + TEA (0.05%)] and [CN (1%) + TIPA (0.05%)]	Compressive strength	CS increases for both cements
(Aggoun, 2006) [46]	For Normal C_3S (M10 to M15) Low C_3S (M20 to M25) w/c=0.3	TIPA (0.05%) by wt of cement	compared with [TIPA (0.05%) + CN (1%)]	Compressive strength	CS increases for both cements
(Venkatesh Reddy, 2005) [47]	M20 to M50	Na_2CO_3 (1,2,4,6,10, 15) g/l	$NaHCO_3$ used at same concentration	Setting time, compressive Strength, tensile strength	Setting time reduced, strength also reduced
(Smaoui , 2004) [48]	Fine: coarse agg = 0.41 Fine: coarse agg. = 40: 60	Na_2O_e 0.6% to 1.25%	–	Compressive strength, Tensile strength	Reduction in compressive , And tensile strength
(Yong-Soo Lee, 2013) [49]	w/c 0.52	Sodium Alluminate Powder and Tablet form 0.5, 1.0, 1.5%, 2%	–	Setting time, compression strength	Both get reduced

Table 11. Effect of accelerators on properties of mortar

Authors	Mortar	Admixture (% of concentration)	Additional condition	Properties studied	Results
(Kyle Riding, 2010) [50]	w/c =0.5, agg:c 2.75	0.06% to wt of cement ($CaCl_2$)	Diethanol- isopropanol amine(0.02%) alone and combined	strength	Combination of both increases the early age strength
(D. Heinz, 2009) [6]	1:3:0.5 (c:sand:w)	TEA (0.01 and 0.2) % by wt of cement	Fly ash (25%) As cement replacement	Early age strength	TEA effective in case of fly ash, For O.P.C. TEA showed no considerable effect
(Justane, 1995) [51]	w/c =0.40	Calcium Nitrate(CN) (0, 1.55,2.32, 3.10, 3.86,7.73)% Of cement wt	At two temp 5^0 and 7^oC	Early strength	CN had accelerating effect
(Paul J. Sanderberg, 2003) [52]	w/ c=0.42	TIPA (200ppm)	_	Early age strength	Significant strength gain (9%)
(Wise, 1995) **[53]**	For cement paste w/c =0.25	Calcium thiocynate (0,1.5,3)%	Compared with Sodium, potassium, Calcium ,lithium at same %	Early age strength	Gain in early age strength was seen
(Singh, 2003) [54]	c/sand =1:3	Oxalic acid (0.05, 0.1,0.25, 0.5,1,2,3,4) In ratio with HEC as 1:1, 2:1, 3:1,4:1	HEC (hydroxyethyl cellulose)	Setting time, early age strength	Setting time decreased, early age strength increased
(Mohamed Heikal , 2003) [55]	w/c for each cement 0.245, 0.325, 0.320-0.265	Calcium Formate 0, 0.25, 0.50, 0.75	3 types of cement was used i.e. opc, Pozzolanic (20% SF), 20% groun clay brick	Compressive strength	Early and later strength increased
(Yong-Soo Lee, 2013) [49]	w/c = 0.5	Sodium Alluminate Powder and Tablet form 0.5, 1.0, 1.5%, 2%	–	Setting time, compression strength	Both get reduced

$CaCl_2$ - it was observed from the table that for $CaCl_{2,}$ w/c ratio was kept between 0.3 to 0.5, for both mortar and concrete. It was concluded from the table that 1g/l was the optimum value for $CaCl_2$.

TEA - Previous literature reveals that for TEA, w/c was kept in the range of 0.45 to 0.5 for both mortar and concrete. The most optimum range of TEA for replacement of cement lies between 0.05%- 0.2%.

Retarders

Are the admixtures which are added in order to slow down the reaction and rate of setting down of concrete. By doing so concrete can remain in fresh mix condition before getting hardened. Some of the retarders are sugar, sodium gluconate, citric acid, lignosulfonate and polysaccharide. Following gives an idea about the work done with retarders has been provided in Tables 12 and 13.

Tables 12. Effect of retarders on properties of concrete

Authors	Concrete mix	Admixture (% of concentration)	Additional condition	Properties studied	Results
(Weerachart Tangchirapat, 2006) [56]	Ratio of fine to coarse 45:55	POFA (Palm Oil Fuel ASH) (10, 20, 30, 40) % by wt of binder	Three size of POFA were tested OP, MP and SP	Initial and final setting time	Ordinary size POFA delayed initial and final time
(F. O. Okafor, 2008) [57]	1:2:4 w/c 0.4	Cassava flour (CF) (1, 2, 3, 5, 7, 10) % wt of cement	–	Initial and final setting time	Initial and final setting time was delayed up to 3%

Table 13. Effect of retarders on properties of mortar

Authors	Mortar	Admixture (% of concentration)	Additional condition	Properties studied	Results
(Singh, 1976) [58]	Cement paste w/c 0.5	Sodium gluconate (0.055, 0.110, 0.165 , 0.220, 0.275) % by wt of cement	Temperature was 25°C	Setting time	Cement hydration reaction was retarded.
(Thomas, 1983) [59]	Cement Paste w/c 0.2	Sugar 15 mM and 50 mM	_	Setting time	Cement hydration retarded
(Singh, 1986) [60]	Cement paste w/c 0.2, 0.25	Citric acid (0, 0.1, 0.2, 0.3, 0.4) % by wt	_	Setting time	At (0.2, 0.3, 0.4)% By wt of cement retarded the hydration of cement
(Singh, 2001) [61]	10 wt% RHA blended Portland cement	1 wt % lignosulphonate (LS)	2% wt $CaCl_2$ Alone and combination of both at same concentrations to compare	Setting time and Compressive strength	1% LS prolonged the setting time compressive strength was lower to control
(Maria C. Garci Juenger, 2001) [62]	Cement paste w/c 0.45	Sugar 1% by wt of cement	At different temperatures	Setting time	Hydration reaction Is delayed
(Moschner, 2009) [63]	Cement Paste 1 kg cement + 400 gm distill water w/c 0.4	Citric acid (0.1, 0.4, 0.5) % by wt ff cement	_	Setting time	Slow down of hydration product formation
(Peschard, 2005) [64]	p/ c 0.5% by wt of cement	Polysaccharides (P)	Cellulose ether, starch ether , native Starch, white dextrin, yellow dextrin were also tested	Setting time	Yellow dextrin retarded hydration to max p/c ratio increment lead to extend delay in hydration

DISCUSSION AND CONCLUSION

The presence of admixtures affect as well as change the fresh and hardened properties of concrete and the change in properties depends upon types of admixtures as well as on their proportion in which they are being used . As mentioned above, admixtures can be classified into categories of mineral as well as chemical admixtures. It has been observed from previous research studies that mineral admixture were used alone and also in combination.

The use of mineral admixtures was large as compared to the chemical admixtures in past. But in recent years chemical admixtures have gained demand. Selection of admixtures is up to the priority of designer and may vary according to quality of cement and ingredient materials of concrete. From the result of researchers it was found that different combinations of admixtures yielded different results.

Research work regarding chemical admixtures is yet to be explored as mineral admixture have been centre of interest since many years and in present time too. The combination of mineral and chemical admixture can create new field for work.

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Rahul Singh holds an M.Tech degree from NIT Kurukshetra, Haryana. He is an Assistant Professor in the Civil Engineering Department of Ajay Kumar Garg Engineering College, Ghaziabad (UP). He has presented and published few research papers in national conferences. His fields of interest are recent developments in concrete technology, use of daily waste materials in enhancing concrete properties and design of concrete structures.

Dr. S.M. Gupta holds a B.Sc. Civil (Hons.), an M.Tech. and PhD, all from Kurukshetra University, Kurukshetra, Haryana. He is a Professor in the Civil Engineering Department, National Institute of Technology, Kurukshetra. His fields of interest are structural engineering, high strength concrete and self compacting concrete.

Babita Saini holds a B.E. Civil (Hons.) from Punjab University, Chandigarh; M.Tech. and PhD degrees from Kurukshetra University, Kurukshetra, Haryana. She is an Associate Professor in the Civil Engineering Department, National Institute of Technology, Kurukshetra. Her fields of interest are concrete technology, design of concrete and steel structures.