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Proof of Conceptual Study on Alternate Binders

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Abstract: *Concrete is most widely used construction material in the world next to water. It is estimated that every day around 3km^3 of concrete is cast globally. Besides, manufacture of cement is highly energy intensive, consumes voluminous natural resources and causes environmental health hazards. In addition, it produces considerable amount of green-house gases like CO_2. Apparently, this is the cause of concern among the researchers global-wide regarding cement, which is impelling them to develop alternate materials that could replace cement completely. Keeping this essential need in mind, an attempt is made in this paper to formulate and study the proof of concept of the binder properties by considering 6 different groups of binders, namely, phosphates, carbonates, Magnesium Oxide, Di-Ammonium Phosphate, Poly Vinyl Alcohol and Geo-Polymer. Conclusions are drawn on their suitability as promising alternate binders for future concrete.*

Keywords: *Alternate binder, phosphates, Carbonates, Magnesium Oxide, Di-Ammonium Phosphate, Poly Vinyl Alcohol and Geo-Polymer, Fly Ash, Clay, Borax.*

I. Introduction

Cement is an important constituent material in concrete which is used in all types of civil engineering works. India is the second largest cement manufacturing nation next to China. Cement Concrete is most widely used,sinceit can be cast to any shape and size with and without steel reinforcements. Cementitious materials have played a major role in structural construction since ancient times, in all the civilizations [1-2]. Egyptians used calcined gypsum as cement, Romans and Greeks used lime to make mortar. Romans found that cement could be made that can set under water and applied this in construction of harbors. And, cement was made by adding crushed volcanic ash to lime and was later called pozzolanic cement, named after the village of Pozzuoli near Vesuvius. Britain used crushed brick and tile, where volcanic ash was scarce [3]. During Industrialization phase of history, there was a huge demand of newer materials to suit various industrial requirements. Joseph Aspdin acquired patent in 1824 for Portland cement, named after Portland stone, a widely used construction stone in England at that time. But his cement was not that strong as it was not heated at optimum temperatures. In 1845, Isaac Johnson made the first modern Portland cement with the existing materials after calcination at higher temperature ranges from $1400^0C – 1500^0C$ [4-7].

Cement has definitely revolutionized the construction industry but it has its fair share in environmental degradation and global greenhouse effect. Cement industry primarily produces CO_2, a major green-house gas. It contributes up to 5% of worldwide man-made emissions; in which 50% attributes to chemical processes and the rest accounts for burning of fuel.

There has been a growing interest since past century in reduction of CO_2 emissions. With respect to this, there have been a lot of debates of late on global scale and also special emphasize was made to develop alternate binders that could replace OPC completely. And thus, this subject of research in alternate binders is finding the need of the ever. In addition, utilization of industrial by-products like Fly Ash, sand, micro-silica, lime powder, silica powder, Quartz powder(QP), natural pozzolana like clay are to be utilized in manufacture of Alternate binders[8-10].This is essentially required because manufacture of OPC requires high quantum of natural resources, it is high energy intensive and causes land and air pollution which leads to health hazards like lung function impairment, chronic lung diseases, carcinoma of lungs, stomach and colon, Silicosis.
Considering all the above mentioned facts, it is inevitable to develop alternate binders with low energy intensive, eco-friendly nature, economical with good affordability without compromising strength.

Alternate Binders are the materials other than cement which react with Fine Aggregate, Coarse Aggregate, Pozzolanic materials, and other additives to form a hard mass.

Binders can be classified into 2 categories: Hydraulic Binders and Non-hydraulic binders. In case of Hydraulic binders, water is used for mixing of constituents of concrete, it sets and hardens with hydration process. In case of Non-hydraulic binders, the constituent materials are mixed together to form a solid mass by chemical reaction i.e.; chemical cross-linking [11, 12]. In general, Non- hydraulic binders produce high strength materials without water curing. As this setting takes hardly a day, these alternate non-hydraulic binders are highly useful for manufacture of pre-cast concrete elements, repair works and mass concreting with enhanced durability and mechanical strength.

A very little amount of published research work is available on Alternate Binders.

The present work comprises of formulating and evaluating 6 different kinds of mortars with different binders which will be discussed later.

Experimental Study:

6 different sets of families of binders namely:

1. Phosphate based
2. Carbonate based
3. Magnesium Oxide (MgO) based
4. Di-Ammonium Phosphate based
5. Geo Polymer based
6. Poly Vinyl Alcohol based are developed with different filler materials such as Fly Ash, clay, sand, brick powder and Alumina clay.

Phosphate and Di-Ammonium Phosphates are purchased from local market. Sodium silicate was purchased from local chemical suppliers. Magnesium oxide, Sodium Carbonate, Calcium Carbonate, Poly Vinyl Alcohol, Magnesium Sulphate, Magnesium chloride were purchased from HiMedia Laboratories Pvt. Ltd; Mumbai. Clay, Sand and brick powder were obtained locally. Fly Ash was collected from Tuticorin Thermal Energy Power plant. Fineness modulus of sand used was 1.93. Potable tap water was used for mixing of materials.

PVC cylindrical moulds were prepared using PVC pipe of 83mm internal diameter and 25mm thickness with single vertical split for de-moulding purpose. 33 combinations were prepared as indicated in Table 1 using various binders mentioned earlier. The mixes prepared are cast into the PVC cylinder moulds and finished after compaction. After 24hrs, cast specimens are de-moulded and are found to be suitable for making concrete .The observations are tabulated in Table1.

Fig 1 to Fig 7 shows various categories of different families of binders used.

Fig 1

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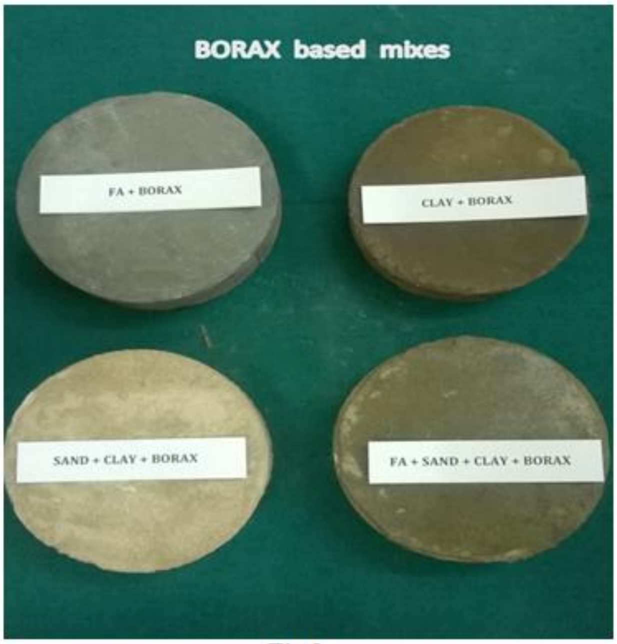

Fig 3

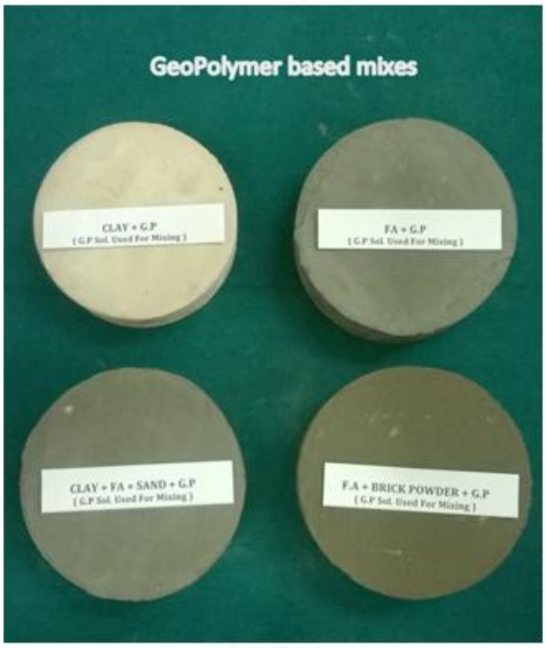

Fig 4

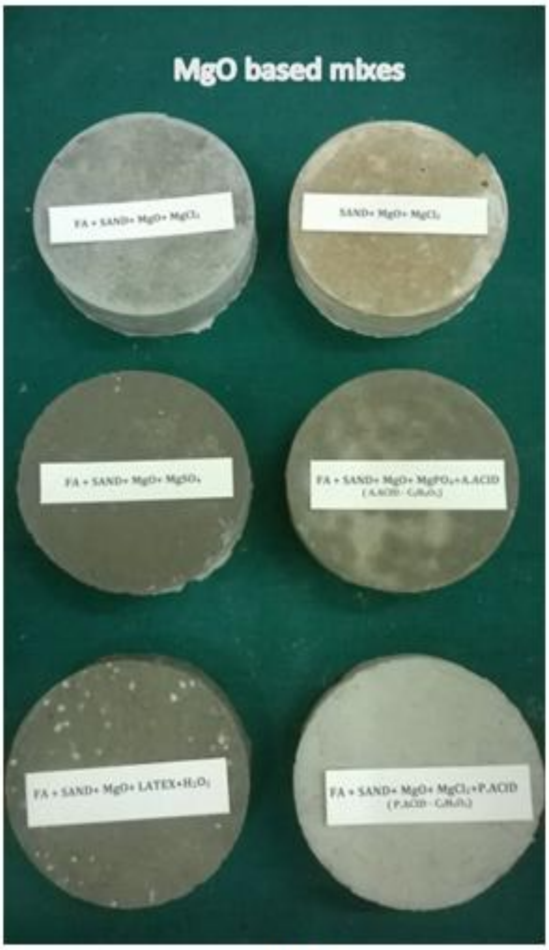

Fig 5

Fig 6

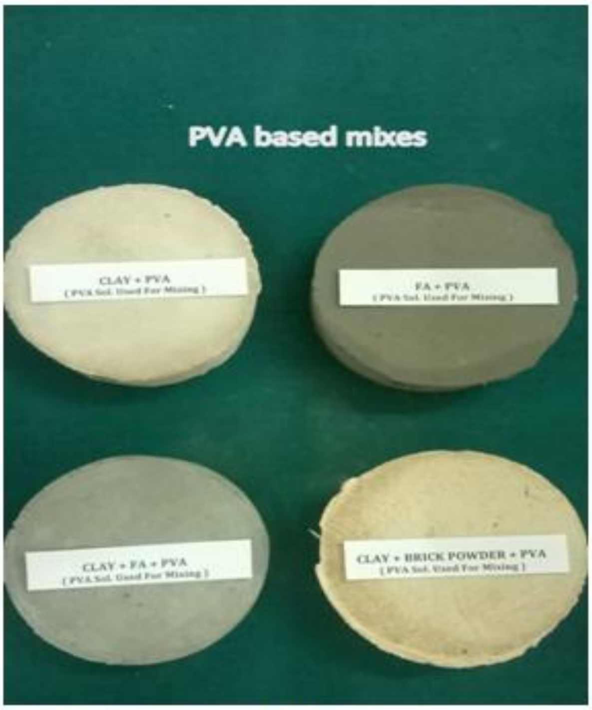

Fig 7

Table -1: Preliminary study report on Alternate Binders with Composition

Sl. No	Composition	Dry Density	Color	Nail penetration	Lateral shrinkage	Observations
1.	QP + FA + SP(10%)+Na_2SiO_3(10%)	1.64	Grey	Hard	NIL	Very slight leaching of phosphate on top surface. Light in weight.
2.	QP + FA + SP(15%)+Na_2SiO_3(15%)	1.61	Grey	Hard	NIL	Moderate leaching of phosphates on top surface. Light in weight.
3.	QP + FA + SP(20%)+Na_2SiO_3(20%)	1.65	Grey	Hard	1.2048	Moderate leaching of phosphates on top surface. Light in weight.
4.	QP + FA + SP(30%)+Na_2SiO_3(30%)	1.58	Grey	Hard	1.8072	Moderate leaching of phosphates on top surface. Light in weight.
5.	QP + FA + SP(40%)+Na_2SiO_3(40%)	1.54	Grey	Hard	NIL	More leaching and crystallization of phosphate on top surface.
6.	QP + FA + SP(50%)+Na_2SiO_3(50%)	1.30	Grey	Soft	NIL	Leaching and crystallization; dislodgement of particles observed.
7.	FA + SAND+ Na_2CO_3 + $CaCO_3$ (Na_2CO_3 , Ca_2CO_3 in 1:1 ratio)	1.66	Grey	Soft	NIL	Heavy Leaching and crystallization of Carbonates; dislodgement of particles observed.
8.	FA + SAND+ Na_2CO_3 + $CaCO_3$ (Na_2CO_3 , Ca_2CO_3 in 2:1 ratio)	1.87	Grey	V. Hard	NIL	Very hard mass yet excess leaching of carbonates and crystallization.
9.	FA + Na_2CO_3 + $CaCO_3$	1.45	Grey	V. Hard	NIL	Hard mass yet excess leaching of carbonates and crystallization, dislodgement occurred in top peripheral line.
10.	FA + SAND+ MgO+ $MgCl_2$	1.79	Grey	V. Hard	NIL	Smooth, shiny, crack-free and very hard mass.
11.	SAND+ MgO+ $MgCl_2$	1.85	sand color	V. Hard	2.2096	Smooth, shiny, crack-free and very hard mass; slight leaching of salts at the sides and bottom surface.
12.	FA + SAND+ MgO+ $MgSO_4$	1.90	Grey	V. Hard	NIL	Very hard, no crack, leaching and disbandment.
13.	FA+SAND+MgO+$MgPO_4$+A.ACID (A.ACID - $C_3H_4O_2$)	1.67	Grey	V. Hard	NIL	Very hard, no crack, leaching and disbandment.
14.	FA + SAND+ MgO+ LATEX+H_2O_2	1.54	Grey	V. Hard	NIL	Random spot leaching of MgO found on top surface; slightly glossy.
15.	FA + SAND+ MgO+$MgCl_2$+P.ACID (P.ACID - $C_3H_6O_2$)	1.34	Grey	Soft	NIL	Dislodgement of particles, less compaction

16.	**FA + DAP BINDER (DAP BINDER Used For Mixing)**	1.34	Grey	Soft	1.2048	No hardness, not resisting nail penetration
17.	**CLAY + DAP BINDER (DAP BINDER Used For Mixing)**	1.82	Dark Brown	V.Hard	9.6386	Very hard. Metallic sound. Highly cohesive, excess shrinkage.
18.	**FA + CLAY + DAP BINDER (DAP BINDER Used For Mixing)**	1.53	Brown	Soft	1.8072	Moderate shrinkage. Soft, mild popouts observed on the finished surface.
19.	**FA + SAND + DAP BINDER (DAP BINDER Used For Mixing)**	1.63	Grey	Soft	NIL	Soft, no cracks but mild leaching observed
20.	**SAND +CLAY + DAP BINDER (DAP BINDER Used For Mixing)**	2.04	Brown	V.Hard	6.0241	Very hard, stone like mass, no cracks or leaching; high shrinkage.
21.	**FA+ SAND +CLAY+ DAP BINDER (DAP BINDER Used For Mixing)**	1.87	Light Brown	Hard	4.2169	Moderately hard; mild shrinkage, no cracks or leaching.
22.	**FA + BORAX**	1.50	Grey	Soft	NIL	Soft material, yet maintained shape and size without cracks or leaching.
23.	**CLAY + BORAX**	1.97	Dark brown	V.Hard	12.6506	Very strong, high shrinkage. No cracks or leaching.
24.	**FA + SAND + CLAY + BORAX**	1.76	Brown	Soft	2.4096	Soft material. No cracks or shrinkage.
25.	**SAND + W.CLAY + BORAX**	1.90	Very Light brown	Hard	2.4096	Moderately hard. No shrinkage but slight shrinkage.
26.	**W.CLAY + G.P (G.P Sol. Used For Mixing)**	1.64	Off-white	V.Hard	7.2289	Very hard mass like stone, no cracks or shrinkage or leaching.
27.	**FA + G.P (G.P Sol. Used For Mixing)**	1.47	Grey	V.Hard	1.8072	Very hard mass like stone, no cracks or shrinkage or leaching.
28.	**W.CLAY + FA + SAND + G.P (G.P Sol. Used For Mixing)**	1.79	Light Grey	V.Hard	1.2048	Very hard mass like stone, no cracks or shrinkage or leaching.
29.	**W.CLAY + FA + SAND + G.P (G.P Sol. Used For Mixing)**	1.73	Brown -ish grey	V.Hard	NIL	Very hard mass like stone, no cracks or shrinkage or leaching.
30.	**F.A + BRICK POWDER + G.P (G.P Sol. Used For Mixing)**	1.91	Off-white	Hard	3.6145	Very hard mass , no cracks or shrinkage or leaching.
31.	**W.CLAY + PVA**	1.45	Grey	V.Hard	NIL	Stone like mass, moderately strong, no cracks, Requires
32.	**W.CLAY+ FA + PVA (PVA Sol. Used For Mixing)**	2.01	Light grey	V.Hard	4.2169	Stone like mass, moderately strong, no cracks,slight shrinkage.
33.	**W.CLAY+BRICK POWDER+ PVA (PVA Sol. Used For Mixing)**	1.89	Light brown	Hard	5.4200	Moderately strong, slight shrinkage, no cracks.

II. Results and Discussions

The result are tabulated in table 1 for all 33 combinations with due observations. From the observations it is clear that some specimens have showed leaching and crystallization of salts used particularly, in specimens containing phosphates and of Carbonates. This indicates the need for optimization of mixes. Also it is observed many compositions observed were of stone like mass in 24 hours and therefore these materials are promising as future concrete. Wherever clay was used, specimen showed shrinkages, this indicates the need of use of shrinkage compensators.

Conclusions:

1. All of the 33 cast specimens were eco-friendly, economical and low cost materials.
2. All the specimens set in 12- 24 hours; some phosphate based mixes exhibited flash setting.
3. The mixes obtained with clay particularly exhibits high cohesion and therefore, loss in slump and moderate to excessive shrinkage.
4. Many mixes as indicated had been exhibited metallic sound.
5. All these mortars developed are suitable for structural applications, general repair works, also for treating the corroded areas.
6. Also, most of the mixes obtained are of good aesthetic appeal.

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