Fresh and Hardened Properties of Pozzo-Lime Concrete with Silica fume and Rice husk ash

S. Ragav[1], Dr. R. Malathy[2]

[1]*PG Student, Department of Civil Engineering, Sona College of Technology, Salem – 636005, Tamil Nadu, India*
[2]*Professor, HOD/Dean – R&D, Department of Civil Engineering, Sona College of Technology, Salem – 636005, Tamil Nadu, India*

---***---

Abstract - *In order to reduce the enormous carbon emission & energy consumption due to cement usage, hydraulic lime mixed with silica-rich pozzolans to form a Pozzo-Lime concrete gaining scope in current trends. This study deals with the effect of fresh and hardened properties on hydraulic lime - silica fume, hydraulic lime - rice husk ash & hydraulic lime - silica fume - rice husk ash concrete mixes and compared with cement concrete mix. Around 20 percent of cement is used in Pozzo-Lime binder. Results show that low workability and less fresh & hardened densities were observed on Pozzo-Lime mixes compared with cement mix. Pozzo-Lime mixes exhibits more initial and final setting times. The strength development in Pozzo-Lime concrete is continuous but less than cement concrete.*

Key Words: **Hydraulic Lime, Silica fume, Rice husk ash, Pozzolans, Pozzo-Lime, Workability.**

1. INTRODUCTION

Next to water, concrete is the most used material in the world. The cement used in the concrete as a binder is obtained by burning of Limestone and siliceous materials above 1450 ^{0}C and with addition of gypsum to the cement clinker. This process liberates more carbon dioxide and use of energy in the form of fuel. It is responsible for 5 to 8 percent of the total global carbon emissions. Bogue compounds such as Tricalcium Silicate (Alite), Dicalcium Silicate (Blite), Tricalcium Aluminate (Aluminate), Tetracalcium Aluminoferrite (Ferrite) in the cement gets reacted with water to form a Calcium Silicate Hydrate (C-S-H gel). This is the main reaction product of cement binder and is the main source of concrete strength. This process is called a Hydration and the reaction generates Heat i.e. Exothermic. It gradually bonds together the individual fine and coarse aggregate to form a solid mass as a concrete. Hence, to minimize the enormous usage of cement and to use naturally available & less embodied energy materials in the concrete, pozzolan-lime can be adopted as a binder.

Lime is the natural material obtained by heating the limestones. When water is added with fat lime and slaked to form hydraulic lime (calcium hydroxide), which was used as a major binder in concrete at olden days. Later, the lime concrete was fully replaced by Portland cement concrete due to its high strength and early setting time. Now lime is used only for preservation of historic buildings and temples. In early periods, natural organic additions were added with lime to make it workable, high bonding, early setting and more strength [1]. Nahida Kadum et al. [2], explained that silica-rich pozzolans can be mixed with hydraulic lime to produce a sustainable binder and without usage of Portland cement it can be used as a structural concrete. Generally, pozzo-lime binder has more setting time and low early strength development. According to Ali allahverdi et al. [3], By incorporating alkaline compounds in lime-natural pozzolan binder, setting time can be reduced to some extent. sodium sulphate is the effective chemical activator and sodium hydroxide is the effective set accelerator for the lime-natural pozzolan cement [3].

Ana L. Velosa et al. [4], conducted different curing condition on expanded clay residue addition with hydraulic lime concrete and explains 95% relative humidity curing than 65% relative humidity and saturated curing. Also, curing condition produce significant changes only on latter stages not in early times. Nancy L Holland et al. [5], explained there is a linear decline in a strength with increase in the relative percentage of hydrated lime (43%) in replacement of cement. Seyed Alireza Zareei et al. [6] investigated the use of rice husk ash up to 25% in high strength concrete with 10% of micro silica. It shows that 20% RHA & 10% micro silica in cement concrete leads to the maximum strength of 93 MPa. Peter A. Adesina et al. [7], replaced the conventional cement concrete with rice husk ash and lime at different percentages up to 25% to form RHA-Lime-cement concrete. Compressive strength of RHA-Lime-cement concrete was generally found lower than that of the conventional concrete. It is observed, there is an increase in strength of the RHA-Lime concrete when compared to the RHA-concrete as investigated by F.A. Olutoge [8].

2. EXPERIMENTAL WORK

2.1. Materials used

Hydraulic lime of high purity according to the specifications of IS 6932 -1973 and IS 712 -1984 is used. Locally available, Ordinary Portland cement of grade 53 according to the specifications of IS 269: 2015 is used. Silica fume and Rice husk ash are used as pozzolans in the concrete. Micro silica or Silica fume is the most commonly used mineral admixture in high strength concrete due to its fine particle size of average diameter 150 nm. It is a very reactive and effective pozzolanic material of high purity of SiO_2 (99.5%) Content. Rice husk ash can be used as a pozzolan with cement due to its high silica content. This can be used with the cement prominently in the countries where the rice production is abundant. The rice husk should be burnt in the optimum temperature of 500 ^{0}C to 800 ^{0}C [9] rather than going for uncontrolled combustion to gain silica in the non-crystalline state. The composition of binders is shown in Table 1.

M-sand passes through 4.75 mm sieve is used as fine aggregate. M-sand has a specific gravity of 2.69, Bulk density of 1773 kg/m^3 and Fineness modulus of 3.82%. Natural gravel of maximum size of 20 mm is used as coarse aggregate. Gravel has a specific gravity of 2.81, Bulk density of 1680 kg/m^3 and Fineness modulus of 7.32%. Conplast SP430 which has a specific gravity of 1.22 is used as a superplasticizer. Salt-free tap water is used for making concrete.

Table -1: Physio-chemical properties of Binders

Property	Lime	Silica fume	Rice husk ash
Colour	White	White	Off White
Specific Gravity	2.74	2.63	2.25
Bulk Density	687 kg/m^3	760 kg/m^3	480.2 kg/m^3
Silica (SiO_2)	1.00%	99.88%	88.90%
Alumina (Al_2O_3)	-	0.043%	2.500%
Ferric Oxide (Fe_2O_3)	-	0.040%	2.190%
Calcium Oxide (CaO)	95%	0.001%	0.220%
Magnesium Oxide (MgO)	-	0.000%	-
Potassium Oxide (K_2O)	-	0.001%	0.69% (K_2O + Na_2O)
Sodium Oxide (Na_2O)	-	0.003%	
Chloride (Cl)	0.01%	-	-
Sulphate (So_4)	0.20%	-	-
Lead (Pb)	0.001%	-	-
LOI	-	0.015%	4.01%

2.2. Mix Proportions

M20 Concrete grade is designed based on IS 10262-2019 for reference concrete mix. According to the specific gravity of Lime, silica fume and Rice husk ash, aggregate contents were optimized from the control mix for Pozzo-lime mixes. Generally, equal amount of lime and pozzolans were used in the concrete. All Pozzo-Lime mixes have 20 percent of cement used in the binder. superplasticizer of 1 percent by the weight of binder is used in the mix. Water to binder ratio of 0.4 is used for REF and LSF mixes while Water to binder ratio of 0.5 is used for LSR and LRA mixes. The details of mix proportions were given in Table 2.

Table -2: Mix Proportions

Mix Id	Binder (kg/m³)				Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Water (kg/m³)	Superplasticizer (% of Binder)
	Cement	Lime	Silica fume	Rice husk ash				
REF	394	-	-	-	842.7	1120.4	157.6	1
LSF	78.8	157.6	157.6	-	842.7	1120.4	157.6	1
LRA	78.8	157.6	-	157.6	811.9	1079.5	197	1
LSR	78.8	157.6	78.8	78.8	817.9	1087.4	197	1

3. FRESH PROPERTIES

3.1. Setting time

Both initial and final setting time of Pozzo-Lime mixes were more compared with the reference mix. This due to the absence of Bogue compounds and C-S-H reaction takes place only by the reaction between Lime and Pozzolans. Chemical accelerators can be used to decrease the setting time. In order to reduce the setting time of Pozzo-Lime mixes, 20 percent ordinary Portland cement is added to the binder. Addition of 20 percent cement reduces both initial and final setting time up to 50 percent.

Table -3: Setting Time

Mix ID	Setting Time (Hrs)	
	Initial	Final
Lime	4.75	48.5
REF	0.75	10
LSF	2.25	24.5
LRA	3.5	27.25
LSR	2.5	22.5

3.2. workability

Addition of lime and pozzolans into cement leads to low workability, hence to keep the concrete workable superplasticizer of around 1% percent is added to all the mixes. The mix which contains rice husk ash absorbs more water while mixing and releases excess water in compacting. Hence, in order to get the sufficient flow, water to binder ratio of LRA and LSR mixes are kept as 0.5. Slump cone test and flow table test are done to determine the workability of mixes (Table 4). It shows that all Pozzo-Lime mixes exhibits low workability than reference mix.

Table -4: Workability of Mixes

Mix ID	Slump (mm)	Flow %
REF	165	60
LSF	270	20
LRA	250	58
LSR	200	56

3.3. Density

The fresh and hardened densities at 28 days of Pozzo-Lime mixes are less the reference mix because of Lime, Silica fume and Rice husk ash has a low specific gravity than cement. Out of all, LRA mix exhibits less density due to the presence of more Rice husk ash in it. Due to the low density, dead load of the concrete is reduced.

Table -5: Mix Densities

Mix ID	Density of Concrete Cubes (kg/m³)	
	Fresh Density	Hardened Density at 28 Days
REF	2610	2554
LSF	2553	2504
LRA	2269	2240
LSR	2400	2364

4. HARDENED PROPERTIES

All the four mixes were casted in cubes, cylinders and prims for strength tests. The compressive strength is taken for 7, 14 & 28 days, split tensile strength is taken for 14 & 28 days and flexural strength is taken for 28 days. Continuous strength development is observed at all mixes. All Pozzo-Lime mixes exhibits less strength compared with reference cement mix. High early strength is achieved in cement mix due to presence of Bogue compounds while in Pozzo-Lime mixes natural C-S-H reaction takes place for strength development.

Table -6: Strength tests on investigated mixes

Mix ID	Compressive Strength (MPa)			Split tensile strength (MPa)		Flexural Strength (MPa)
	7 Days	14 Days	28 Days	14 Days	28 Days	28 Days
REF	16.71	19.09	26.07	1.75	2.50	3.70
LSF	4.71	7.27	10.13	0.74	1.08	1.32
LRA	3.78	5.18	9.49	0.83	0.99	1.11
LSR	5.42	7.07	12.38	0.84	1.27	1.49

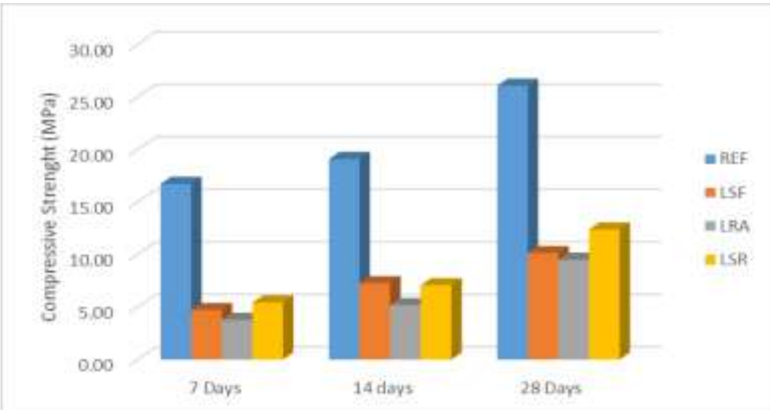

Chart -1: Compressive Strength

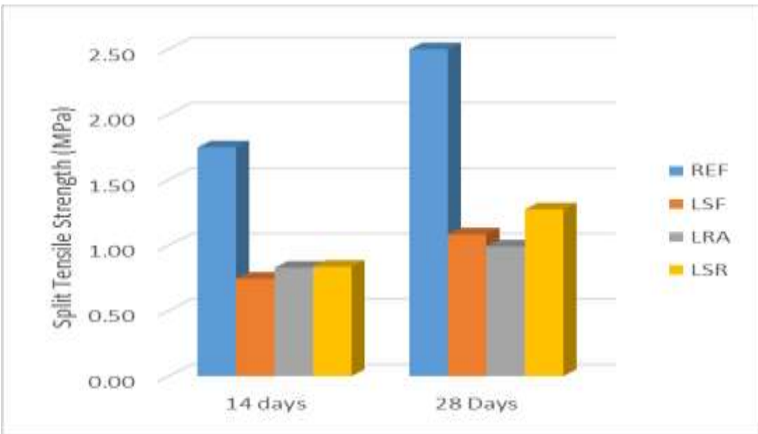

Chart -2: Split Tensile Strength

The compressive strength shows that all Pozzo-Lime mixes have achieved around 10 MPa at 28 days while reference cement mix achieved a target strength of around 26 MPa at 28 days. High early strength of around 16 MPa is achieved at 7 days by cement mix and out of Pozzo-Lime mixes, LSR mix exhibits 5.4 MPa at 7 days. Maximum compressive strength of 12.4 MPa is achieved by LSR mix at 28 days.

The split tensile strength shows that Pozzo-Lime mixes exhibits nearly half of the strength achieved by the reference cement mix. LSR mix shows the maximum strength of 1.27 MPa at 28 days. The flexural strength shows that Pozzo-Lime mixes exhibits only forty percent of the strength achieved by the reference cement mix. LSR mix shows the maximum flexural strength of 1.49 MPa at 28 days of all Pozzo-Lime mixes.

5. CONCLUSIONS

Based on the observed results, following conclusions can be given

- Silica fume and Rice husk ash are the very effective pozzolanic materials found to be superior than other mineral admixtures due to their high silica content.
- The compressive strength of Pozzo-Lime mixes exhibits around 10 MPa at 28 days of curing with 20% of cement used in the binder.
- The strength gain is slow and continuous development is observed in all strength tests.
- Pozzo-Lime concrete exhibits less fresh and hardened densities, hence it will decrease the dead weight of the structure.
- Chemical accelerators can be used to optimize the setting time in similar with cement concrete.
- Pozzo-Lime concrete mixes investigated in this study, can be used for Mortar and Non-Structural purposes due the less strength observed.
- With inclusion of more cement content, their strength can be increased and it can be used for structural purpose.

REFERENCES

[1] Selvaraj Thirumalini, Ramadoss Ravi, Murugan Rajesh (2017), “Experimental investigation on physical and mechanical properties of lime mortar: Effect of organic addition”, Journal of Cultural.

[2] Nahida Kadum, Tareq al-Attar and Zyiad Al-Azzawi, “Evaluation of pozzolime mixtures as a sustainable binder to replace portland cement in structural concrete” ASCMCES-17, MATEC Web of Conferences 120, 02009 (2017).

[3] Ali allahverdi, jaleh ghorbani,” CHEMICAL ACTIVATION AND SET ACCELERATION OF LIME-NATURAL POZZOLAN CEMENT” Ceramics − Silikáty 50 (4) 193-199 (2006).

[4] Ana L. Velosa, Paulo B. Cachim,” Hydraulic-lime based concrete: Strength development using a pozzolanic addition and different curing conditions” Construction and Building Materials 23 (2009) 2107–2111

[5] Nancy L Holland, Anne B. Nichols, John M. Nichols,” THE USE OF HYDRATED LIME IN CONCRETE AS A CEMENT REPLACEMENT: EFFECT ON COMPRESSIVE STRENGTH” DOI: 10.1520/STP104459.

[6] Seyed Alireza Zareei, Farshad Ameri, Farzan Dorostkar, Mojtaba Ahmadi,” Rice husk ash as a partial replacement of cement in high strength concrete containing micro silica: Evaluating durability and mechanical properties” Case Studies in Construction Materials 7 (2017) 73–81.

[7] Peter A. Adesina, Festus A. Olutoge," Structural properties of sustainable concrete developed using rice husk ash and hydrated lime" Journal of Building Engineering 25 (2019) 100804.
[8] F.A. Olutoge, P.A. Adesina, Effects of rice husk ash prepared from charcoal-powered incinerator on the strength and durability properties of concrete, Constr. Build. Mater. 196 (2019) 386–394
[9] Deepa G Nair, Alex Fraaij, Adri A.K. Klaassen, Arno P.M. Kentgens," A structural investigation relating to the pozzolanic activity of rice husk ashes", Cement and Concrete Research 38 (2008) 861–869.
[10] Dr. Mohammed Mosleh Salman, Ammar A. muttar (2017)," THE MECHANICAL PROPERTIES OF LIME CONCRETE" Journal of Engineering and Sustainable Development, Vol. 21, No. 02, ISSN 2520-0917.
[11] H. V. Kale (1981)," Lime-Pozzolana Reactions and Evaluation of Pozzolanas" Transactions of the Indian Ceramic Society, 40:4, 152-154, DOI: 10.1080/0371750X.1981.10822538.
[12] IS 456:2000 Plain and Reinforced Concrete - Code of Practice [CED 2: Cement and Concrete]
[13] IS 10262: 2019 Concrete mix proportioning — guidelines.
[14] IS 269: 2015 code of practice for chemical and physical requirements of 33, 43, 53, 43S and 53S grades of Ordinary Portland cement.
[15] IS 6932: 1973 Laboratory Tests on Building Lime.
[16] IS 712: 1984 Specification for Building Limes [CED 4: Building Limes and Gypsum Products]
[17] IS 383: 1970 Specification for Coarse and Fine Aggregates from Natural Sources for Concrete [CED 2: Cement and Concrete]