Study on the Efficacy of Natural Pozzolans in Cement Mortar

Ashish Shukla and Nakul Gupta

Abstract With the advent of the Industrial Revolution, science and technology grew rapidly with the producing era coming into view. The early industrial sectors engaged in small scale production of the major pollutant, smoke. Owing to the emergence of numerous factories and large scale jobs, the problems of industrial contaminating activities began to assume much importance. These issues made the burning up of industrial as well as agricultural waste products from industrial activities become the main focus of waste eradication study for environmental, economical, as well as technical reasons. Discarding of waste techniques became the problem emerging from constant industrial and technological development. Partial replacement of pozzolans by manufacturing waste product is not just efficient but an improvement to features of clean as well as cynical concrete. This is because it involves reducing the shrinkage, minimizing the cracks, as well as enhancing the sturdiness. Besides, the safe removal of waste substances serves as a means of shielding the surroundings from contamination. The main purpose of this research is to observe the ability and strength of the mortar by mixing the calcined clay in a mortar mix in the proportion of 0, 4, 8, 12, 16 and 20% and with this, the effect of mortar on HCl and acetic acid mixed in water in a proportional proportion has been studied.

Keywords Carbon emission · Pollution · Calcined clay · HCl · Acetic acid · Compressive strength · Water absorption test · Sorptivity test

1 Introduction

In today's era, concrete/cement mortar is proving to be the most commonly used component in the field of construction. Cement mortar are not environmentally friendly materials, either for production purposes, for utilization, or for disposal. The need for concrete in the construction sector is increasing ever increasing due

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to which the main component of the concrete is also increasing the requirement of cement [1, 2]. Researchers replaced calcined clay in the form of wastes with cement to reduce pollution of the construction area in their constant search so that both the production and consumption of cement could be reduced [3]. To obtain suitable raw materials for making these materials substantial amount of water and energy are involved. Also, sand quarrying with other aggregates results into environmental pollution and annihilation. Concrete mortar therefore is affirmation for the large supply of carbon discharges into the environment. Researchers affirm that concrete causes the emission of approximately 5% of global overall quantity of carbon release which brings greenhouse gases. Due to continuous production of component cement used mainly in the construction sector, there is a very harmful effect in the environment as CO_2 and other harmful gases emit during cement production [2]. In order to reduce the need for cement instead of cement in concrete, supplementary cementitious material (i.e., pozzolans) is partly replaced with cement. These pozzolans are added to reduce the permeability of concrete and mortar, to increase strength, make cheaper or to influence other properties [4]. For this reason, "calcined clay" has been used on mortar in this research work, and the mixing of this supplemental material has been studied in response to mortar [5].

Components like cement mortars and concrete play important roles in the development of all the countries around the world in the construction sector. Concrete and cement mortars are used on the second number after water consumption across the world [6]. According to his research, Mehta informed that by 2050, these components of the manufacturing sector will be produced in such a large quantity which will affect the environment and economic situation [7]. According to researcher's research, around 1.6 billion metric tonnes of cement are produced in the whole world [8]. Many researchers have used calcined clay and other pozzolans to study their research in which they found that the calcined clay gets a parallel strength of cement on partial mixing with cement [9–14]. Mining as well as processing of calcined Kaolin in the industries generates huge volume of waste. Kaolin is a vital raw substance for utilization in different manufacturing sections. There are two types of wastes produced by the kaolin industrial sector that processes the primary kaolin. The first Kaolin waste is derived from the premium processing step which involves the partitioning of river sand from the ore. Another form of waste product is seen during the next production stage consisting of liquid filtrate to segregate the improved particles as well as cleansing [15]. Apart from water, concrete is another material used globally. It hardens and solidifies after combination with water as well as after placement because of the chemical process called hydration. Water mixes with cement to bind other particles together and they form sturdy resources [16].

The main purpose of this research is to observe the ability and strength of the mortar by mixing the calcined clay in a mortar mix in the proportion of 0, 4, 8, 12, 16 and 20% and with this, the effect of mortar on HCl and acetic acid mixed in water in a proportional proportion has been studied. And their results have been detected in 7, 28 and 90 days intervals.

2 Literature Review

2.1 Leonard (1991)

As stated by Leonard John Murdock, a neat pieced good quality brick offers satisfactory aggregates, with great strength as well as concreteness if the brick is from good quality rock; a well-engineered as well as connected brick if graded gives good concrete option for average strength. When second-hand blocks are utilized, it is imperative to get rid of every plaster so that the calcium sulfate content will not prevent setting or lead to disintegration within a short period. Always make sure to avoid blocks with sulfates soluble of more than or up to 0.50%. It is advisable to utilize brick aggregates that are highly saturated due to comparatively soaring absorbency level. It is also not advisable to use porous kind of block as aggregates in non-breakable concrete activities due to the problem of diffusion of dampness that might cause decomposition of steel fortification [17].

2.2 Al Saffar (2018)

In his paper, he told that the cement mortar reports on the effectiveness of the calcined clay (CC) on the strength characteristics of the calcining temperature (800 for 1 h). A set of eight different mortar blends was inserted and tested with different cement replacement levels (2.5–20% from the weight of cement). Based on the results of these tests, the impact on the aspects of strength in the cement mortar was discussed and analyzed. Tested mortar tests have identified tensile strength, compressed power, coefficient of water absorption, water absorption and the results of softness. FTIR and XRF tests were made to identify chemical composition and minerals. The result of this investigation is clear by the power test and shows significant improvement in the mechanical properties [18].

2.3 Sabir (1996)

He has replaced metakaolin with cement in proportion to 0, 5, 10, 15, 20, 25 and 30% in his experimental research work. (I) According to their experiment, they showed that metakaolin reacted with liberated lime and acted as a resistant to chloride. (II) He found that compression strength is good on the replacement of 25% metakaolin. (III) The microstructure of mixed mortar composed of metakaolin displays the compact structure and a homogeneous structure [19].

Table 1 Chemical properties of cement

S. No.	Chemical properties	Percentage
1	SiO_2	20.98
2	Al_2O_3	5.42
3	Fe_2O_3	3.92
4	CaO	62.85
5	MgO	1.76
6	Na_2	0.28
7	K_2O	0.53
8	SO_3	2.36
9	Loss on ignition	1.90

Table 2 Physical properties of cement

S. No.	Physical properties	Test result
1	Normal consistency	32%
2	Final setting time	255 min
4	Initial setting time	75 min
5	Color	Gray
6	Specific gravity	3.14

3 Raw Materials Used

3.1 Ordinary Portland Cement (OPC)

Concretes mortar or cements are described as substances having cohesive and adhesive characteristics that enable it to bind mineral pieces in a compressed solid when mixed with water. The cement bought for this test and use was of forty-three (43) grade. The attributes are as in Tables 1 and 2.

3.2 Fine Aggregate

Sand. Example of the form of sand used is river sand. The dimension of the fine aggregate used is less than or equal to 4.75 mm. The characteristics of the river sand testing are shown in Table 3.

Table 3 Physical properties of sand

S. No.	Physical properties	Test result
1	Specific gravity	2.60
2	Water absorption	1.10%
3	Fineness modulus	3.30%
4	Compacted bulk density	1644 kg/m^3
5	Zone	II

3.3 Calcined Clay

Calcined clay cement is a kind of low carbon cement. The main components of calcined clay are selected stone, clinker and gypsum. The chemical component of calcined clay used in this experimental work is stated in Table 4. And Fig. 1 illustrates calcined clay in the example [20].

Table 4 Chemical component of calcined clay

S. No.	Chemical properties	Percentage
1	Al_2O_3	22.34
2	SiO_2	70.42
3	Fe_2O_3	2.34
4	MgO	0.16
5	CaO	0.49
6	TiO_2	1.1
7	Na_2O	0.1
8	SO_3	0.02
9	K_2O	0.19
10	Loss on ignition	2.84

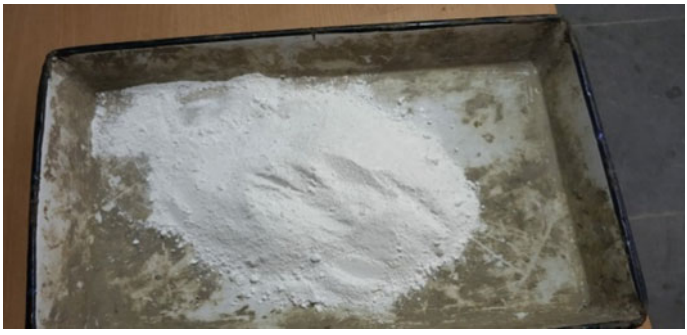

Fig. 1 Calcined clay

4 Methodology and Result

See Fig. 2.

4.1 Water Absorption Test for Cement Mortar

The experimentation technique is utilized for examining the frequency of absorption or water sorptivity using hydraulic cement. The test is carried out by measuring the increment in the weight of the sample from the water absorption as related to the time when just one section of the sample is in water.

Test technique. In this test, the samples are dried using oven device at a specific temperature and for a particular period of time. Then, they are kept in the desiccators for cooling effect. The water sorptivity is a porous substance which explains the capillary assimilation frequency of the porous substance that is exposed to the water surface. This is the standard parameter which defines the reinforced concrete covering quality. The entire experimental table given shows the ratio of calcined clay to CC0 to CC20 (Fig. 3 and Table 5).

4.2 Sorptivity Test

In this test, the results of the water increase absorption rate of cement mortar samples have been detected [21–24]. For the first time, cement mortars have been molded in

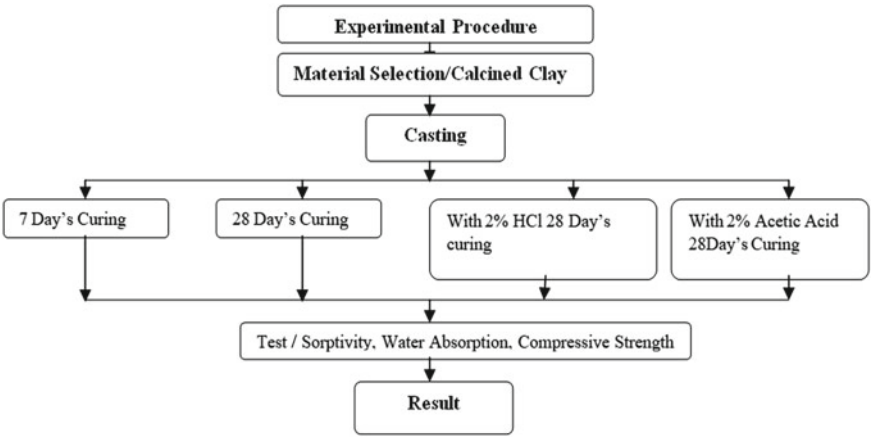

Fig. 2 Experimental methodology

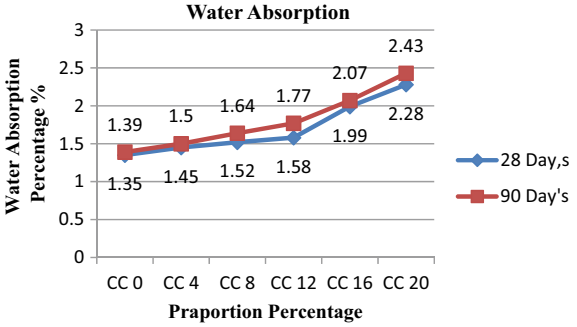

Fig. 3 Graph 1: Water absorption test value

Table 5 Water absorption test

S. No.	Addition proportion	Mix	Water absorption (%)	
			28 days	90 days
1	Calcined clay 0%	CC0	1.35	1.39
2	Calcined clay 4%	CC4	1.45	1.5
3	Calcined clay 8%	CC8	1.52	1.64
4	Calcined clay 12%	CC12	1.58	1.77
5	Calcined clay 16%	CC16	1.99	2.07
6	Calcined clay 20%	CC20	2.28	2.43

mortar samples and their results have been detected in 7 and 28 days intervals. The results of this test are shown in Table 6 (Fig. 4).

Table 6 Sorptivity test

S. No.	Addition proportion	Mix	Sorptivity test (%)	
			28 days	90 days
1	Calcined clay 0%	CC0	0.45	0.43
2	Calcined clay 4%	CC4	0.48	0.46
3	Calcined clay 8%	CC8	0.53	0.5
4	Calcined clay 12%	CC12	0.57	0.52
5	Calcined clay 16%	CC16	0.67	0.6
6	Calcined clay 20%	CC20	0.92	0.87

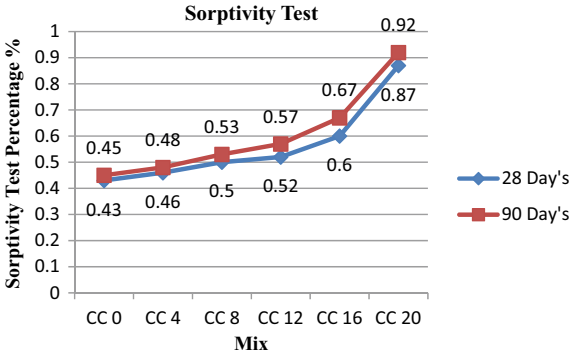

Fig. 4 Graph 2: Sorptivity test

Table 7 Compressive strength test on cement mortar

S. No.	Addition proportion	Mix	Compressive strength (N/mm^2)		
			7 days	28 days	90 days
1	Calcined clay 0%	CC0	34.67	43.33	46.14
2	Calcined clay 4%	CC4	34.11	44.97	49.24
3	Calcined clay 8%	CC8	33.26	42.16	50.15
4	Calcined clay 12%	CC12	33.11	40.21	51.97
5	Calcined clay 16%	CC16	31.16	37.67	48.94
6	Calcined clay 20%	CC20	28.24	36.55	47.86

4.3 Compressive Strength Experiment

Hydration process is a key factor for the strength of concrete and cement mortar. Due to the hydration process in cement mortar and concrete, the strength is very good [25, 26]. During this test, samples of cement mortar have been found to be the result of compression strength in the interval of 7 and 28 days. To achieve the results of the compression strength test, samples have been kept wet for 7 and 28 days in water. And then the cement mortar samples were taken out of the water and the results were obtained by CTM machine. The results of the compression strength are shown in Table 7 (Fig. 5).

4.4 Compressive Strength for Cement Mortar After 2% HCl Curing

HCl acid is a simple chlorine-based acid system with water. This is a confluence of water and hydrogen chloride. HCl is an important industrial chemical and chemical reagent. It is used in the production of polyvinyl chloride in plastic. HCl acid is also

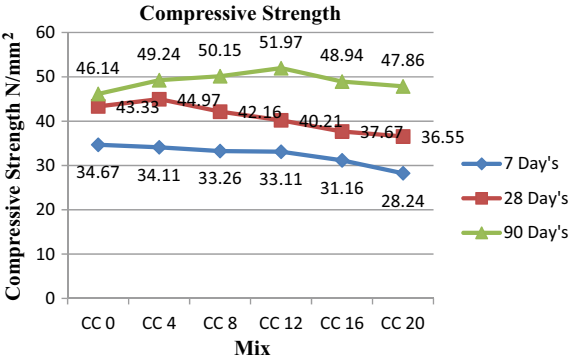

Fig. 5 Graph 3: Compressive strength of cement mortar

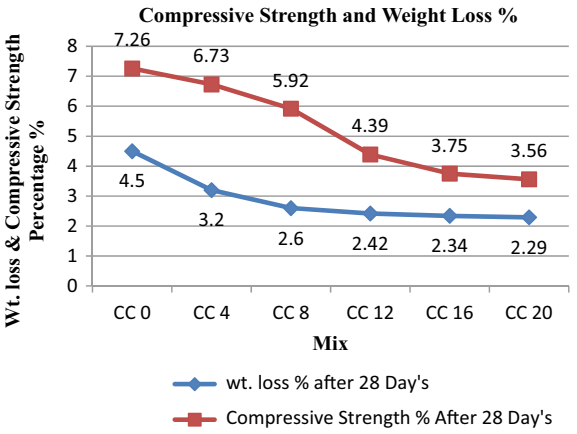

Fig. 6 Graph 4: Compressive strength and weight loss

used as a leather processing [27]. Cement mortar samples are soaked in mixed water for 28 days. The amount of 2% hydrochloric acid (HCl) in this water has been added. In this research, the effect was studied due to HCl acid on cement mortar and after the 28 days of HCl mixed water, the result of the compression strength of these samples was detected (Fig. 6 and Table 8).

4.5 Compressive Strength with Acetic Acid

After the formic acid, the second simplest carboxylic acid is acetic acid. It is an industrial chemical and chemical reagent. It is mainly used for polyvinyl acetate for wood glue, cellulose acetate for clothing, photographic film and synthetic fiber [28]. Cement mortar samples are soaked in mixed water for 28 days. The amount of 2% acetic acid in this water has been added. In this research, the effect was studied due

Table 8 Weight loss and compressive strength after HCl curing

S. No.	Addition proportion	Mix	Wt. loss percentage after 28 days	Compressive strength percentage after 28 days
1	Calcined clay 0%	CC0	4.5	7.26
2	Calcined clay 4%	CC4	3.2	6.73
3	Calcined clay 8%	CC8	2.6	5.92
4	Calcined clay 12%	CC12	2.42	4.39
5	Calcined clay 16%	CC16	2.34	3.75
6	Calcined clay 20%	CC20	2.29	3.56

to acetic acid on cement mortar and after the 28 days of acetic acid mixed water, the result of the compression power of these samples was detected (Fig. 7 and Table 9).

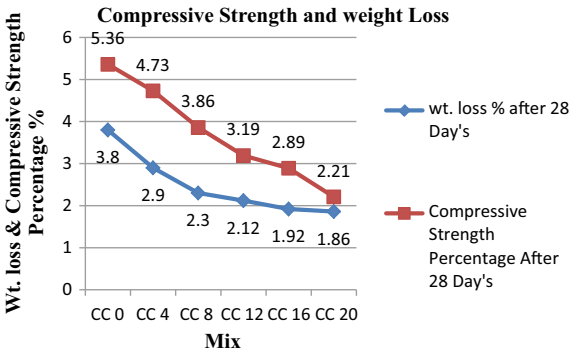

Fig. 7 Graph 5: Compressive strength and weight loss

Table 9 Weight loss and compressive strength after acetic acid curing

S. No.	Addition proportion	Mix	Wt. loss percentage after 28 days	Compressive strength percentage after 28 days
1	Calcined clay 0%	CC0	3.8	5.36
2	Calcined clay 4%	CC4	2.9	4.73
3	Calcined clay 8%	CC8	2.3	3.86
4	Calcined clay 12%	CC12	2.12	3.19
5	Calcined clay 16%	CC16	1.92	2.89
6	Calcined clay 20%	CC20	1.86	2.21

5 Conclusion

Based on current experimental analysis on partial replacement of calcined clay with cement mortar are as follows:

- As a result of the water absorption test, the water absorption has increased in every proportion for 28 and 90 days.
- As a result of the sorptivity test, there has been an increase in water absorption in every proportion for 28 and 90 days.
- Cement mortar affects the compression strength of mortar on increasing or decreasing the proportion of calcined clay in the mixture.
- In compression strength test, it was found that 90 days result in higher strength at 12% ratio.
- The compression strength test also found that during the 7 days interval the result is reduced continuously.
- Due to soaking of cement mortar in HCl and acetic acid mixed water for 28 days, mortar starts losing weight.

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