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Clay as a Partial Replacement of Cementitious Material in Cement

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Abstract - The effect of raw clay and chemically treated clay on Mechanical properties of Cement Mortar has been investigated through number of tests .The material such as raw clay and chemically treated clay can be used in mortar after necessary treatment with Potassium Hydroxide (KOH), result as to bring high strength because clay will become very fine particles with rough surface after reacting with KOH and also filling some pores in concrete. In this project work, Ordinary Portland Cement (OPC) is replaced by 5%, 10%, 15%, and 20% of raw clay and treated clay. The Compressive strength of Cement Mortar mix 1:4 at 7th, 14th, and 28th day of curing period is determined along with the workability property of fresh Cement Mortar and results are analysed, compared with the conventional mix. It is proved that the Cement Mortar obtained by admixing chemically treated clay has many advantageous over conventional Cement Mortar.

Main objectives are:

Investigate the properties of fresh cement mortar when cement is partially replaced by untreated clay and chemically treated clay.

Investigate the compressive strength when the cement partially replaced by untreated clay and chemically treated clay.

Investigate the suitability of using the untreated clay and chemically treated clay as a partial replacing material in cement mortar.

Keywords- Ordinary Portland Cement (OPC), Calcium Silicate Hydrate (CSH), Potassium Hydroxide (KoH), Cube Compressive Strength (f_{ck})

1. Introduction

The most popular engineering material is Concrete. Concrete is generally considered as a proper construction material for many Civil works (such as highways and streets, bridges, dams, large buildings, airport runways, irrigation structure, breakwaters, Piers and docks, sidewalks, silos, farm buildings, homes, even barges and ships) and Military applications. It is strong and durable. It is casted in many shapes and is economical.

Pozzolanic materials are widely used in concrete and mortar for various reasons, particularly for reducing the amount of cement required for making concrete and mortar which lead to a reduction in construction cost. Moreover, most Pozzolanic materials are the by-product materials and the use of these materials leads to reduction in waste and save in energy consumption to produce cement. Most recently blended and multi-blended cement by incorporating industrial by-products pozzolanic materials are becoming an active area of research because of their improved properties such as workability, long-term strength and durability.

In general, each of these materials possesses different properties and reacts differently in the presence of water and usually has limitations while some have contrasting influences on properties of concrete and mortar. The combination of two or more kinds of mineral admixtures has emerged as a superior choice over single admixture to improve concrete and mortar properties. The development of ternary (containing two types of pozzolans) and quaternary (containing three types of pozzolans) composite cement is relatively rare. Though the Binary Composite Cements (BCC) (containing one type of Pozzolans) are commonly used and is nowadays further studies to investigate and improve the performance of BCC are in progress but those are not used at larger scale. Whereas, the research to develop the multi-blended cement containing three or more pozzolanic materials to replace cement partially is rather rare.

The presence of clay in cement mortar gives detrimental or deleterious effect to cement mortar. If clay is added with cement and fine aggregate do not contain silt or clay then the cement mortar undergoes a pozzolanic reactivity. Therefore, it is proposed to make an attempt to

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evaluate this clay incorporated concrete mortar specimen.

A significant demand exists for housing in Economically Weather Countries, where it has been estimated that more than 100 million people are homeless and about one billion people are inadequately housed. Approximately twenty-one million new housing units are required each year. The main costs of shelter provision are land purchase, building materials, machinery, man-power and loan interest payments. Building materials are often the single largest component of housing cost in Less Economically Developed Countries. The Cost of building material is 70% of total cost of buildings.

Worldwide, over ten billion tons of concrete are being produced each year. In the United States, the annual production of over 500 million tons implies about two tons for each man, woman and child. Such volumes require vast amounts of natural resources for aggregate and cement production. In addition, it has been estimated that the production of one ton of Portland cement causes the release of one ton of CO_2 into the atmosphere. CO_2 is known to be a greenhouse gas that contributes to global warming, and the cement industry alone generates about 7% of cement productions.

However, a complete characterization study is missing in clay cement mortar. Since it is much stronger in compression and weak in tension, cement mortar is primarily used for its compressive strength. Therefore intensive research efforts have been devoted to the improvement of the compressive strength of mortar.

Every day the quality of cement mortar is improving to achieve better characteristics, lower prices and to be environmentally acceptable.

1.2 About Clay

Soil which is composed of very fine particles usually silicates of aluminum and magnesium. Clay soil impedes the flow of water, meaning it absorbs water slowly and then retains it for a long time. Wet clay soil is heavy and sticky and tends to swell from the added moisture. When dry, clay soil shrinks and settles.

Clay are ultra-fine grained (normally considered to be less than 2 micrometers in size on standard particles size classification) and so require special analytical techniques. Clay is fundamentally built of tetrahedral sheets and octahedral sheets. Clay suitable for use as a Pozzolanic is very widespread and is readily available in almost all regions of the world. They have been used as Cement replacement materials on large scale constructive programmers in a number of countries.

Clay minerals are Hydrous Aluminum Phyllosilicates sometimes with variable amounts of iron, magnesium, alkali metals, alkaline earths and other cautions. Clay has similar structure to the Micas and therefore form flat hexagonal sheets. Clay minerals are very common in fine grained sedimentary rocks such as shale, mudstone and in fine grained metamorphic slate and phyletic.Out of these, clay containing local sand could be used housing materials would be more cheaply and readily available. The main clays are found in Tropical regions. Clay minerals have ability to attract water molecules.

Clay has been used as admixture or blending material in constructions for thousand years. Although there exisit strong competition with industrial by-product or waste materials such as silica fume and fly ash .Clay is still an alternative of pozzolanic material for cement and concrete especially in developing countries.

1.3 Clay Cement Mortar

In addition to Cement, Sand is the major component needed for producing concrete and mortar for low cost housing components. In consequence there is a strong incentive to use sand that would not meet British standards with respect to grading and clay content.

However, the effect of clay on concrete performance are poorly understand and specifications restricting their use tend to be vague if clay containing local sand could be used, housing materials would be more cheaply and readily available.

Clay minerals have the ability to attract water molecules. The two essential functions of water in a mix are to hydrate the cement and to produce adequate workability. With clay in the mix, the amount of water needed for the good workability can be more than that need for hydration.

Parsons concluded that clay is much more detrimental to the strength of concrete if present as a surface coating surrounding the sand grains. Then if evenly distributed throughout the mass, many have concluded that the clay surface coatings weaken the sand cement paste bond. These reduce the cement mortar strength and durability. Parsons suggested that if the clay is distributed evenly within the sand, there is no detrimental effect, and might increase the strength of the cement mortar by filling the spaces.

Pozzolanic reaction

Clay – cement mixture cannot be regarded as sample mixture of hydrated cement matrix bonding together watered clay particles, but should be considered as a system in which both clay and hydrated cement combined through secondary reactions. When the mixture is in fresh state, caution exchange and flocculation effects occur, causing structural stabilization of clay.

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Description	Fine Aggregate (IS:383-1970)
Sieve analysis	Zone III
Specific gravity	2.7
Fineness modulus	2.75

During the hardening of clay–cement mixture, the hydration of cement takes place forming the usual cement hydration products C-S-H, Ca (OH) $_2$and hydrated aluminates. The Ca (OH) $_2$ formed in the primary phase, together with the soluble alkalis released during cement hydration which raise the pH and also cause a breakdown of Amorphous Alumina and Silica, which then could combine with the calcium ions liberated from the hydrolysis of cement to form a secondary cementitious material. The secondary reaction is called "Pozzolanic reaction".

Two mechanism by which clay might strengthen relatively weak concrete mixes, either pace filling by the fine clay particles on chemical reaction between the clay and a hydrating cement. The reason for partially replacing cement in mortar and concrete with Pozzolanic materials are diverse. They include strength and improvement in durability. They are also clear environmental advantages in reducing the quantity of cement used in construction materials. Among the Pozzolanic materials used in cement blast furnace slag and clay have been successfully listed.

2 Material Used and Properties

2.1 Clay

Raw Clay and chemically treated clay used for this study are collected from Deerannagar, Trichy.

Sample of raw clay

S. No	Name Of The Experiment	Sample of Clay
1.	Plastic Limit	22.85%
2.	Liquid limit	60.32%
3.	Shrinkage limit	30.5%

Table 1 Physical properties of clay

2.1 Cement

Ordinary Portland Cement (OPC) was used to cast the specimens with the guidelines given by IS269 (part IV) 1989 (33 Grade) in "Ultra Tech Cement".

Description	Cement
Standard consistency	33%
Initial setting time	32 mins
Final setting time	143 mins
Fineness modulus	6%
Specific gravity	3.1

Table 2 Properties of Cement

2.2 Sand

The river sand is screened and washed to remove all the organic and inorganic compounds that are likely to present in it. Sand has been sieved in 2.36mm (passed) and retained in 300µ.

2.3 Water

Potable water is generally considered satisfactory for mixing. Drinking water is suitable for making cement mortar. The qualities of samples are uniform and potable. pH value lies between 6 to 8 .The water is free from organic matter, also the solid content should be within permissible limit as per IS 456 2000 and conforming to IS 3025-1964.

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3 Clay Treatments

Untreated raw clay used for directly replaced this study's, The required amount of selected treated clay is immersed in the 0.25M concentration of KOH (15g of KOH in 1.5litres of water) and calcium oxide 1.5gm (solubility of Ca in water 1gm/840ml of water 25°C) solution for 1 day. After that these chemically treated clay can be dried in open sun light and there after crushed in to powder and stored separately. This clay sample used are chemically treated clay used for replacing cement in percentage varying 0%, 5%, 10%, 15%,up to 20%.

4 Results and Discussion

The compression test for raw clay and chemically treated clay is given below.

1 Compression test for raw clay

The cube compressive strength was carried out on both Fresh Cement Mortars and Clay Incorporated Cement Mortars with the cube size of 70.6mm x 70.6mm x 70.6mm. This test has been carried out on after$7^{th,}$ $14^{th}28^{th}$ days of curing.

Table1Compressive Strength of raw clay mortar specimen

Percentage of replacement	Average compressive strength N/mm^2		
	7^{th} day	14^{th} day	28^{th} day
0%	16.51	21.54	25.57
5%	17.12	22.37	26.15
10%	16.53	21.83	25.63
15%	14.16	18.31	21.56
20%	11.96	16.17	20.46

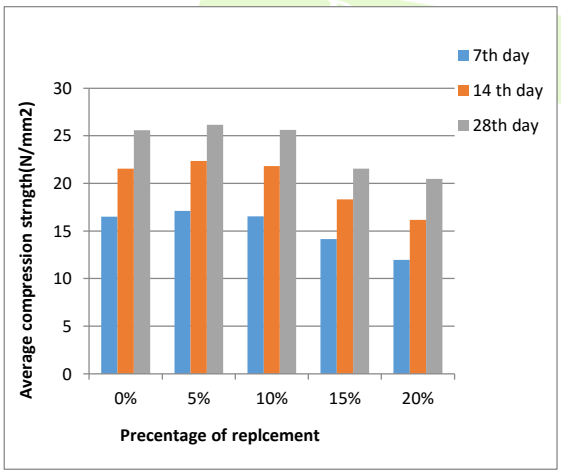

Fig.1 Compressive Strength of Raw Clay Mortar specimen

Discussions

With the inclusion of raw clay, the strength of cement mortar gradually increases up to a certain limit after gradually decreases.

With the inclusion of raw clay up to 15% the initial strength gain is observed in cement mortar.

In 14^{th} day curing the compressive strength value for 0% of replacement 21.54N/mm^2 and raw clay 5%, 10% was 22.37N/mm^2 ,21.83N/mm^2 ,and beyond this percentage of replacement of cement mortar strength was gradually reducing at reaching 16.17 for 20% N/mm^2 replacement percentage.

Similarly In 28^{th} day curing the compressive strength value for 0% of replacement 25.57N/mm^2 and raw clay 5% ,10% was 26.15N/mm^2 ,25.63N/mm^2 ,and beyond this percentage of replacement of cement mortar strength was gradually reducing at reaching 20.46 for 20% N/mm^2 replacement percentage. The reason for such variation for the first 10%the calcium,Al_2O_3 and Fe_2O_3 are present in raw clay and excess amount of raw clay do not react with fine aggregate therefore gradual reduction in strength was occur increasing percentage.

2 Compression test for treated clay

The cube compressive strength carried out with compressive testing machine capacity 3000KN. In this test, compressive strength for replacement levels of clay is 5% to 20% with percentage increases.

Table2 Compressive Strength of Treated clay mortar specimen

Percentage of replacement	Average compressive strength N/mm^2		
	7^{th} day	14^{th} day	28^{th} day
0%	16.51	21.54	25.57
5%	17.16	22.36	29.19
10%	16.80	22.01	27.91
15%	15.54	20.62	26.79
20%	13.82	18.18	20.58

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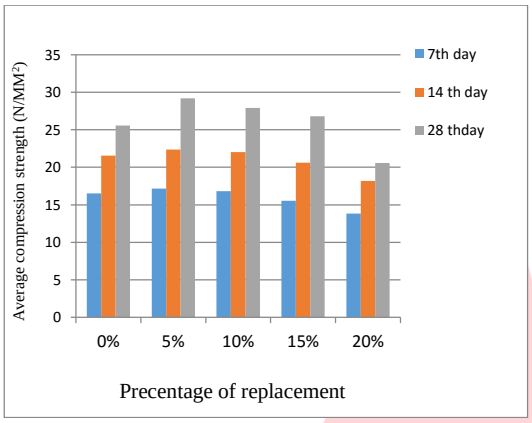

Fig.2 Compressive Strength of Treated Clay Mortar specimen

Discussions

With the inclusion of Treated Clay, the strength of cement mortar gradually increases up to a certain limit but gradually decreases.

With the inclusion of Treated Clay up to 15% the initial strength gain in cement mortar is high.

In 7th day curing the compressive strength value for 0% of replacement 16.51N/mm^2 and Treated Clay 5%, 10% was 17.16N/mm^2, 16.80 N/mm^2, and beyond this percentage of replacement of cement mortar strength was gradually reducing at reaching 20% for 13.82 N/mm^2 replacement percentages.

In 14th day curing the compressive strength value for 0% of replacement 21.54N/mm^2 and Treated Clay 5%, 10% was 22.36N/mm^2, 22.01N/mm^2, and beyond this percentage of replacement of cement mortar strength was gradually reducing at reaching 18.18for 20% N/mm^2 replacement percentage.

Similarly In 28th day curing the compressive strength value for 0% of replacement 25.57 N/mm^2 and Treated Clay 5% ,10% was 29.19 N/mm^2 , 27.91 N/mm^2 ,and beyond this percentage of replacement of cement mortar strength was gradually reducing at reaching 20.58 for 20% N/mm^2 replacement percentage. The reason for such variation for the first 10% When raw clay chemically treated with Potassium Hydroxide and Calcium Oxide used in cement mortar mix, this will certainly enable to bring high strength because the clay will become very fine particles after reacting with some bases as mentioned above by filling some pores in cement mortar.

CONCLUSIONS

Incorporation of untreated raw clay and chemically treated clay in cement mortar as supplementary cementitious materials by partial replacement of Portland cement has drastic effect in cement mortar properties. The workability of the concrete increases with the percentage of replacement of cement by clay increase.

The Compressive strength of cement mortar specimen has increased after incorporating clay, compression strength reached a maximum at10%, as it can be concluded that for replacement of cement to raw clay is efficiency, because the presence of Al_2O_3, Fe_2O_3 and calcium are present for the improves strength and pozzolanic activity. When raw clay chemically treated with Potassium Hydroxide and Calcium Oxide used in cement mortar mix, this will certainly enable to bring15% increase in compressive strength is observed because the clay become very fine particles after reacting with some bases as mentioned above by filling some pores in cement mortar.

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