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STUDY ON STRENGTH AND DURABILITY CHARACTERISTICS OF TREATED AND UNTREATED CLAY WITH CEMENT MORTAR

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ABSTRACT: The scope of the present study is to investigate the effect of untreated, chemically, and thermally treated clay as a cement replacement material for cement towards the performance of cement mortar with respect to strength and durability characteristics. The characterization of the untreated and treated clay samples were investigated through XRF (X-ray fluorescence), XRD (X-ray diffraction), DTA/TGA (Differential Thermal Analysis/Thermo gravimetric analysis), FTIR (Fourier Transform Infrared spectroscopy), and FESEM (Field Emission Scanning Electron Microscopy). The untreated and treated clay samples as cement replacement material in cement mortar were prepared using a mix ratio of 1 part of cement and 3 part of sand (1:3) with water to cement ratio of 0.4. The PPC replacement by clay was 0 to 20% with an increment interval of 2.5% from 0. Three series of specimens were casted with untreated, chemically, and thermally treated clay samples and tested at the age of 28 days of curing. An effort has been made to focus on the clay samples towards their influence of pozzolanic activity, contribution towards strength and durability studies. The cube compressive strength, cylinder compressive strength, split tensile strength, and flexural strength of cement mortar with untreated, chemically and thermally treated clay at the replacement levels of 2.5%, 5.0%, 7.5%, 10.0%, 12.5%, 15.0%, 17.5% and 20.0% of cement were studied. The optimum replacement of untreated, chemically, and thermally treated clay samples of KA, KP, AN, and OP has been evaluated. The relationship between the cube compressive strength, cylinder compressive strength, split tensile strength and flexural strength of the three series of the specimen has arrived.

I. INTRODUCTION

The three benefits of pozzolan used in cement mortar and concrete:

- The economic gain obtained by replacing a large part of the cement due to cheaper, pollution free, natural pozzolan or industrial by-products.
- The secondary product of the blended cement reduces the environmental cost associated with the greenhouse gasses emitted during cement production.
- Increased durability of the end product.

The increased blending of pozzolan with Portland cement is of limited interference in the conventional manufacture process and offers the occasion to create value by changing large amounts of industrial and society waste into durable construction material. These pozzolanic reaction products fill up in pores and effect in a refining of the pore size distribution of the structure. This results in a lowered permeability of the binder. The role of the pozzolanic reaction to cement strength is generally developed at later curing stages, depending on the pozzolanic activity. The pozzolan finer than the Portland cement, the decrease in early strength is usually less than the conventional strength. It can be clarified by the filler effect, in which small SCM grains fill the space between the cement particles, due to the effect of a much denser binder. The acceleration of the Portland cement hydration reactions can also partially accommodate the loss of early strength.

The improved chemical resistance to the ingress and harmful action of belligerent solutions constitute one of the main advantages of pozzolan blended cement. The enhanced durability of the pozzolan-blended binders enables an increase in the service life of structures and reduces the cost and meets the challenging need to replace damaged construction. Hence, clay (treated and untreated clay) in optimum proportion improves the quality of mortar /concrete by

- Increasing Compressive Strength
- Protecting steel reinforcement from corrosion
- Reducing Permeability, Voids, Expansion and Heat of Hydration
- Reducing creep, cracks, and microcracking
- Increasing Resistance to chloride attack and sulfate attack
- Reducing alkali-aggregate reaction and Autogenous Healing

II. SCOPE OF THE WORK

Clay samples partially replaced with cement will reduce CO_2 emission, energy consumption of cement production and also the cost of the building materials. Hence, an attempt Is carried out to investigate the clay as a cement replacement material in cement mortar.

The research work is to be carried out with the untreated, chemically and thermally treated clay replaced with cement in cement mortar for the evaluation of strength and durability characteristics

DETAILS OF EXPERIMENTAL INVESTIGATION

EXPERIMENTAL PROGRAMME

Materials

The properties of all the materials used in this study are giveCement: Portland Pozzolana Cement conforming to IS: 1489 (Part I) -1987 was used for the present experimental investigation. Its specific gravity is 3.10. The cement was tested as per IS: 4031 - 1988. The results are given in Table 3.1.

Fine Aggregate: The river sand is screened and washed to remove all the organic and inorganic compounds that are likely to present in it. Natural river sand with fraction passing through 4.75 mm sieve and retained on 600 μ sieve was used and tested as per IS: 2386 - 1963. The fineness modulus of sand used is 2.75 with a specific gravity of 2.70. The sieve analyses of fine aggregate are presented in Table 3.2 and conforming to grading zone III of IS: 383 – 1970.

Water: Potable tap water available in the laboratory with pH value of 7.0 ± 1 and conforming to the requirements of IS: 456 - 2000 was used for mixing and curing the specimens as well.

Table 3.1 Physical properties of Portland Pozzolana Cement

Sl. No	Test Particulars	Results Obtained	Requirements of1489(Part I) - 1987
1	Fineness (%)	6	Maximum 10
2	Normal consistency (%)	33	-
3	Initial setting time (min)	35	Minimum 30
4	Final setting time (min)	300	Maximum 600
5	Soundness (mm)	3.00	Maximum 10
6	Compressive strength (MPa) 28-days	28.09	Minimum 33
7	Specific gravity	3.10	-

Table 3.2 Sieve analysis of fine aggregate

Sl.No.	IS sieve designation	Percentage of passing	IS Recommended range	Remarks
1	10 mm	100	100	Conforming to Zone III as per IS:383-1970
2	4.75 mm	99.80	90-100	
3	2.36 mm	99.40	85-100	
4	1.18 mm	89.60	75-90	
5	600 μm	64.70	60-79	
6	300 μm	9.20	12-40	
7	150 μm	1.70	0-10	

Clay: The clay samples were collected from the four various places in Tamilnadu state, India. Four clay samples collected from Kaikalathur (KA), Kuchipalayam (KP), Anangur (AN) and Oviyampalayam (OP) of Namakkal and Perambalur district in Tamilnadu state were used for this study as show in Figure 3.1. The sample index of the clay samples is shown in Table 3.3.

Table 3.3 Identification of the clay samples

S. No	Sample ID	Latitude/ Longitude	Name of the place	District	State	Country
1	KA	11°50' 16.8"/ 78°49'8.4"	Kaikalathur	Perambalur	Tamil Nadu	India
2	KP	11°5'1.1"/ 77°56'22.56"	Kuchipalayam	Namakkal		
3	AN	11°23'48.97"/ 78°0'32.4"	Anangur			
4	OP	11°8' 9.6"/ 78°0'25.2"	Oviyampalayam			

The clay samples taken for investigation are as follows, 1. Untreated clay samples, 2. Chemically treated clay samples and 3. Thermally treated clay samples

Mix Proportion

The mortar mixes were prepared by a binder to sand ratio of 1:3 and W/C ratio 0.4. Mix proportion of cement mortar without replacement by clay is designated as Co and called as control. The mixtures of each sample having eight mixes with replacement of cement by clay between 0 to 20% with incremental increase of 2.5%. The thirty two mix identifications of untreated clay, chemically treated clay and thermally treated clay samples are shown in Table 3.4.

Table 3.4 Mix Identification of untreated, chemically and thermally treated clay with different replacement level at cement in cement mortar

Sl. No.	% of clay	Untreated clay				Chemically treated clay				Thermally treated clay			
1	0	Co	Co	Co	Co	Co	Co	Co	Co	Co	Co	Co	Co
2	2.5	KAU1	KPU1	ANU1	OPU1	KAC1	KPC1	ANC1	OPC1	KAT1	KPT1	ANT1	OPT1
3	5.0	KAU2	KPU2	ANU2	OPU2	KAC2	KPC2	ANC2	OPC2	KAT2	KPT2	ANT2	OPT2
4	7.5	KAU3	KPU3	ANU3	OPU3	KAC3	KPC3	ANC3	OPC3	KAT3	KPT3	ANT3	OPT3
5	10.0	KAU4	KPU4	ANU4	OPU4	KAC4	KPC4	ANC4	OPC4	KAT4	KPT4	ANT4	OPT4
6	12.5	KAU5	KPU5	ANU5	OPU5	KAC5	KPC5	ANC5	OPC5	KAT5	KPT5	ANT5	OPT5
7	15.0	KAU6	KPU6	ANU6	OPU6	KAC6	KPC6	ANC6	OPC6	KAT6	KPT6	ANT6	OPT6
8	17.5	KAU7	KPU7	ANU7	OPU7	KAC7	KPC7	ANC7	OPC7	KAT7	KPT7	ANT7	OPT7
9	20.0	KAU8	KPU8	ANU8	OPU8	KAC8	KPC8	ANC8	OPC8	KAT8	KPT8	ANT8	OPT8

Where,
KA ,KP, AN and OP
– Represented as place which were sample collected
U, C, and T – Represented as untreated, chemically and thermally treated clay
1 to 8 – Represented as replacement of cement by clay from 2.5% to 20% with the increment of 2.5%

III. SUMMARY OF CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

The study reported in this thesis includes the following topics:

- Strength and durability characteristics of untreated clay with cement mortar
- Strength and durability characteristics of chemically treated clay with cement mortar
- Strength and durability characteristics of thermally treated clay with cement mortar

Experiments were conducted on the untreated, chemically treated and thermally treated clay samples and given Identification, namely KA, KP, AN, and OP. These clay samples were obtained from Kaikalathur, Kuchipalayam, Anangur and Oviyampalayam in Tamil Nadu state. The cement is replaced by treated and untreated clay in cement mortar has been studied for strength and durability aspects at the age of 28 days. The conclusion from the different experimental studies such as strength, and durability properties are summarized below:

EFFECT OF TREATED AND UNTREATED CLAY ON THE STRENGTH PROPERTIES OF CEMENT MORTAR

General

The primary objective was to evaluate the strength properties of mortar with untreated, chemically treated and thermally treated clay at different replacement levels at the age of 28 days. The compressive strength, cylinder compressive strength, split tensile strength, and flexural strength were studied and the relationship between strength and durability characteristics have been arrived. The influence of each clay in the cement mortar admixture on the compressive strength of the mortar specimens at the ages of 28 days was investigated. The conclusions from the experimental investigations are as follows:

- Cement mortar with 2.5% of OPU gives the high strength and low chloride ion penetration of KAU, KPU, ANU and OPU at the age of 28 days.
- Cement mortar with 2.5% of KAC, KPC, ANC, and OPC gives maximum strength and durability characteristics of the cement mortar at the age of 28 days.
- Mortar containing 2.5% KAT, 2.5% KPT, 2.5% ANT and 2.5% OPT gives better performance concerning strength and durability than the all other mixes taken for investigation.

Cube Compressive Strength

- The untreated clay as CRM in cement mortar does not perform well with reference to the compressive strength, except in OPU samples.
- The reason for such poor pozzolanic activity can be due to the presence of organic matter in the untreated clays and the silt coating around the SiO_2 particles present in the clay, which may be providing inhibiting effects for the heat pozzolanic reaction.
- Changling He et al. (2000) & Neville &Brooks (1987), on investigation concluded that the untreated clay minerals with stable layer structures have low pozzolanic activity and have negative effects on the compressive strength due to the flaky texture and cleavage of the clay.The untreated sample appears as a loose packing of round-edged platelets. The reasons are multiple: the stable crystal structure of unaltered clay minerals reduces their chemical activity. The typical sheet-like microstructure and cleavage of clay minerals has a negative impact on the strength of the mass of mortar.
- Mohsen et al. (2010) & Pinaki Sengupta et al.(2008) reported that the clay particles are coated with patches containing Fe, Ti and Mn. The metallic components are surrounded the OPU particles shows the FESEM images, which performed better up to 10.0% replacement of cement by clay.
- The enhancement of compressive strength mainly depends on the replacement level of thermally and chemically treated clay, because of its high pozzolanic nature to form more densely packed C-S-H gel.
- The chemically treated clay samples KAC, KPC, ANC, and OPC as CRM in cement mortar increase the strength at 2.5% replacement level at the age of 28 days. The FESEM image of chemically treated clay indicates that the NaOH solutions are evenly distributed over the morphological surfaces.
- The KAT, KPT, ANT, and OPT, as CRM in cement mortar increase the strength at 2.5% replacement level at the age of 28 days. The FESEM Image of the thermally treated clay samples indicates that the particles are finely disintegrated which results in increasing the bonding between the particles of the cement matrix and form more densely packed C-S-H gel.

Cylinder Compressive Strength

- The cylinder compressive strength increases with increase in cube compressive strength. All the mechanisms stated for the behavior of cube compressive strength are also applicable for cylinder compressive strength behavior.

Split Tensile Strength

- The split tensile strength of the untreated clay cement mortar is not appreciable.
- At the age of 28 days, the maximum split tensile strength was observed for chemically treated clay cement mortar at the replacement level of 2.5%. From the FESEM analysis, it is evidently proven that the surfaces of chemically treated clay are covered with metallic components and particles are seems to be finely disintegrated which results in enhancement of tensile strength.
- At the replacement level of 2.5%, thermally treated clay cement mortar obtained maximum split tensile strength due to the elimination of micro fibers from the thermally treated clay samples.

Flexural Strength

The flexural strength of untreated clay samples taken for investigation does not yield better strength when compared to control specimen.

The flexural strength of the chemically treated clay is enhanced at the replacement level of 2.5%, because of the presence of organic micro fibers.

Due to the disintegration and formation of new virgin faces, the thermally treated clay with cement mortar achieves maximum flexural strength.

EFFECT OF TREATED AND UNTREATED CLAY ON DURABILITY CHARACTERISTICS OF CEMENT MORTAR

General

The main factor which causes the deterioration of mortar/concrete structure is permeability. Experiments were conducted with the available facilities to study permeability characteristic with different percentage replacement of cement by clay samples of untreated, chemically and thermally treated clay, for saturated water absorption, coefficient of water absorption, sorptivity, and rapid chloride ion penetration. The following are the conclusions arrived from the above studies:

The cement is replaced by treated and untreated clay in cement mortar, significantly reduces, saturated water absorption, Sorptivity, coefficient of water absorption and chloride ion penetration, when compared to control specimen

SUGGESTIONS FOR FUTURE WORK

The following are the some of the aspects recommended for further in depth study:

- Strength and durability characteristics of concrete can be evaluated by using best replacement level and type of clay material evaluated from this study.
- Performance evaluation of the strength and structural behavior of reinforced concrete structural members can be made by changing the types of clay and the mechanical activation of the clay.
- The investigation can be carried out to enhance the strength and the durability of the mortar / concrete by using different temperature for thermal and chemical treatment.

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