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Review Paper on Partial Replacement of Cement by Kaolinitic Clays or Calcined Clay

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Abstract – *Cement is the major constituent being used in construction industry due to its high strength, easy availability, durability etc but apart from it, it also have some negative impact on environment as it is one of the major greenhouse gas emitter, So it is very necessary to reduce the cement by using supplementary cementitious materials such as Flyash, Silica Fume, Kaolin Clays etc without sacrificing strength & durability. Flyash, Silica Fume etc are having its availability in finite quantity and may be inadequate for future needs, Clay being plenty in quantity proves best option for Supplementary cementitious material. Therefore this paper presents the review of some research paper which uses Kaolinitic or Calcined clays for partially replacing cement. Research in this field & positive results in their research work are important to study further in sustainable construction activities and need to implement for sustainable construction.*

Key Words: Kaolinitic Clays, Calcined Clay, sustainable construction, Supplementary Cementitious material, pozzolona's.

1. INTRODUCTION

Ordinary Portland Cement (OPC) is used as a key constituent in the construction sector. During the production of OPC, large amount of carbon dioxide is emitted making OPC a major environmental pollutant. The production of OPC contributed approximately 5-7% of greenhouse gas [1]. To overcome this problem, the best way is to reduce the cement use by partially replacing it with supplementary cementitious material or pozzolanic material, Pozzolanic materials are siliceous and aluminous materials, which in themselves possess little or no cementitious value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration, at ordinary temperature, to form compounds, possessing cementitious properties.

Various materials such as Flyash, Ground Granulated Blast furnace Slag (GGBS), silica fume etc are well established pozzolanic materials, the use of fly ash as a pozzolana is well established in a number of countries abroad, but it has come in vogue in India only recently. Besides these, there are a large number of pozzolanic clay deposits of stained and impure kaolin's, ferruginous or ocherous earths, altered laterites and bauxites, certain shales, etc, available in different parts of the country, which yield highly reactive pozzolanic materials & Hence due to its large quantity , Clays becomes best option to satisfy future need for supplementary cementitious material.

2. LITERATURE REVIEWS

M.Antoni, J.Rossen,et al,[2] stated that cement can be replaced up to 45% using Metakaolin & Limestone, By using metakaolin only, Cement is replaced by utmost 30% while using metakaolin and limestone 45% of the Cement is substituted. Experimental investigation was carried out by replacing cement 15%, 30%, 45% & 60% using metakaolin & Limestone, Six Prisms of size 40mm*40mm were casted for compressive strength evaluation at 1,7,28 & 90days, while for Flexural Strength evaluation three prisms were casted of size 120mm*40mm*40mm. Apart from it Thermo gravimetric analysis was carried out to study evolution of Calcium hydroxide , porosity is being evaluated using Mercury Intrusion Porosimetry (MIP) & XRD test was performed to have idea of texture , ettringite formation etc. Thermodynamic modeling was carried out using Gibbs free energy minimization programme to evaluate formation of C-A-S-H gel.

After observing the results of experimental study, the authors inferred that maximum replacement achieved is 45% without sacrificing the strength as 60% replacement of cement results in decrease in compressive strength by 7%. From Thermo gravimetric analysis it is inferred that limestone acts as filler material only as sample containing limestone and Cement as binary blend does not show decrease in calcium hydroxide, while metakaolin acts as pozzolona as sample having metakaolin & cement as binary blend shows decreased quantity of calcium hydroxide, XRD data show the development of the main crystalline alumina containing hydrate phases for all the blends. From MIP study it show's increase in porosity but pore radius decreases, Although there is a general trend of decreasing strength with increasing porosity, the correlation for this small number of points is not strong and up to 45% level of blending there is almost no decrease in strength despite a significant increase in porosity, After Studying all the major parameters authors concluded that cement can be replaced by metakaolin up to 30% and can be replaced 45% using metakaolin & Limestone.

Alejandra Tironi, Alberto Scian, et al [3] conducted study to explore the interaction between the filler effect and

pozzolanic effect caused by calcined clay obtained from low grade kaolin and limestone filler (LF). Mortar mix of 1:3 proportion was selected as reference for study and Five Different mixes are selected that reference mix (PC) , mix with 10% limestone filler (10LF), mix with 30% calcined clay (30CC), mix with 5% Limestone filler & 15% Calcined Clay (5LF15CC), mix with 10% Limestone filler & 30% Calcined Clay (10LF30CC), Compressive Strength is worked out on cubes of size 25mm*25mm*25mm at 2,7,28 & 90 Days, where average of five cubes is taken for compressive strength, after that porosity is worked out using Mercury Intrusion Porosimeter (MIP) & after that Hydration is studied using chemical analysis.

After observing the results, authors inferred that early age strength of the specimen with limestone (5LF15CC) is maximum due to incomplete pozzolanic action at early age and due to filler effect, while at 90Days strength of the specimen with calcined clay (30CC) is maximum due to pozzolanic action. From MIP they studied the effect on pore diameter where it is found that pore diameter reduces with increase in calcined clay content while porosity increases and strength remains unaffected.

Alejandra Tironi, Claudia .C. Castellano, et al [4] conducted study to examine the influence of type of kaolinite in raw clay on performance of calcined clay as supplementary cementitious material and to study properties such as hydration, porosity etc. Two Kaolinitic clays were characterized, calcined then ground and used as partial replacement of Portland cement at 15% and 30% by mass. Apart from experimental study, Literature review study is also being done, Four mixes were selected for study that 15% & 30% replacement of cement with low kaolinite(disordered structure) clay named as 15A2 & 30A2 while for high kaolinite (Ordered structure) 15A1 & 15A2. Compressive Strength Test is done on cube of size 25mm*25mm*25mm at 2, 7 and 28 days, The crystalline hydration phases were identified by XRD analyses on powdered paste samples, while the amount of hydration compounds were determined using Thermo gravimetric Analysis (TGA) & Pore Size distribution was carried out using Mercury Intrusion Porosimeter.

Interferences made by the authors from the study are The behavior of the mixture depends on structure of kaolinite that is disordered structure provides better pozzolanic activity and 30% replacement can be done, while for order structure only 15% replacement is suggested, By 30% replacement of low kaolinite clay 127% higher compressive strength is achieved while for 30% replacement of high kaolinite clay with ordered structure, compressive strength of 88% is achieved, From the XRD Analysis it is being said that ettringite for the Kaolinitic Blended cement is reduced as compared with Cement pastes, From TGA authors indicated reduction in Carbon Hydroxide content on blending with Kaolinitic clays, Apart from it Pore size reduces on using kaolinitic clays and for more effective decrement in pore size disordered structure is more preferred than ordered structure and hence authors concluded disordered kaolinitic clays to be more effective for partially replacing the cement as compared with ordered kaolinitic clays.

Karen Scrivener, Shashank Bishnoi, et al [5] conducted study to evaluate carbon emission of different supplementary cementitious material, In this paper clay containing kaolinite content of 40% is used for the study where cement is prepared by combining 50% Ground Clinker, 30% calcined clay, 15% Limestone and 5%gypsum. After the calcination of clay in rotary kiln or shuttle kilns, cement is manufactured and Durability aspect is studied, where porosity, Heat test, Permeability, etc. is tested and checked and result are provided as per literature reviews. Cost Studies or Cost factor is studied and after that Environmental assessment is evaluated based on Carbon Dioxide Emission. Apart from it Environmental assessment for the Fly-ash, GGBS, Ordinary Portland Cement, is also done and later comparison is made for the better bifurcation.

After observing the results, authors inferred that Carbon Dioxide emission for Limestone Calcined Clay Cements is minimum followed by Flyash followed by GGBS and then Ordinary Portland Cement (OPC). Cost to benefit ratio in case of Limestone Calcined Clay Cement is more as compare to OPC, From Mercury Intrusion Porosimeter (MIP) it is found that porosity of Limestone Calcined Clay Cement is minimum and permeability concluded from literature reviews is also found to be least in Limestone Calcined Clay cement as compared with Ordinary Portland cement

Hongjian Du, Sze Dai Pang [1] conducted study to understand the performance evaluation of High Performance Concrete containing Calcined Clay and Limestone powder partially replacing cement. Two level of cement replacement that is 30% & 45% by the combined use of CC and LS with a constant weight ratio of 2:1 was considered and compared with reference High Performance Concrete & Plasticizer is used to adjust the slump , Hydration study was performed by measuring heat flow with the help of isothermal calorimeter, later detailed study on hydration was carried out using XRD & TGA method of analysis , Apart from it different papers were reviewed and properties such as compressive strength , Young's modulus is concluded , After that cement is also replaced by using Quartz where replacement level is same as of calcined clay & Limestone and results are compared.

After observing results, It is found that Heat evolution in case of Limestone & Calcined Clay in concrete is maximum and with increase in replacement level heat flow also increases due to more space availability for the hydration of cement, Heat evolution in specimen containing Quartz is also more but less than Ternary blended concrete. Compared to the reference paste, Ternary paste with limestone & Calcined clay exhibited much higher chemical shrinkage, indicating more reaction occurs normalized to1 g of cement. From XRD it was concluded that ettringite formation was least in Ternary Blended paste as compared to OPC, Compressive Strength &

Elastic modulus for 30% replacement of cement with limestone and calcined clay is found to be maximum and hence 30% substitution level of the cement is suggested from the study

Thiago Costa Cardosa, Paulo Ricardo de Matos etal [6] studied the use of Uncalcined Clay and Limestone Powder as a supplementary cementitious material that is Special cement is formed by replacing the Clinkers with the help of Limestone and Uncalcined Clay, In this work two sets of ternary cements were produced one containing 55% weight and another containing 45% weight replacement of clinker with Clay and Limestone. Further the clay and limestone ratio is kept 30/15 for 45% and 40/15 for 55% replacement, After that mechanical and durability properties is worked out such as Compressive Strength, Hydration Test etc, For Compression Test Cylinder of size 50mm diameter and 100 mm height were casted and tested as per Brazilian standards, After that Thermo gravimetric analysis followed by XRD followed by Isothermal Calorimetry.

Inferences from study were Clinker Replacement up to 45% by the uncalcined clay and limestone shows positive results while Clinker Replacement up to 55% shows decrease in compressive strength. On increasing the clinker replacement level and the clay/limestone ratio, the optimum dosage of water reducing admixture increases. Heat Flow decreases on increasing the replacement of cement with uncalcined clay and limestone powder. Ettringite Peak is minimum for replacement level of 55% as compared to 45% which indicated stabilization of ettringite on addition of Clay.

3. CONCLUSIONS

Global warming is increasing day by day and at this stage it very necessary to reduce green house gas which can be attempted by decreasing the usage of cement with Natural Pozzolana's (Clay's), From the Literature it is concluded that cement can be replaced by using Calcined Clay or even Uncalcined clay up to 30% without compromising strength & durability aspect, On using Clay Ettringite peak reduces, pore diameter decreases, amount of calcium hydroxide & Carbon Dioxide emission decreases, Apart from it later Compressive Strength increases up to 30% replacement of cement by Clay, The main aim of research is to introduce economical & ecofriendly solution for construction industry with considering its desired properties.

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