A Review on Strength Properties of concrete by using Clays and Alum as Supplementary Cementitious Materials

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Abstract: **Concrete is one of the most popular construction materials used since hundred years ago. Concrete production needs natural resources like water, coarse aggregates, fine aggregates and cement, whose production is costly due to natural resources and energy required. Cement manufacturing is recognized to be major source of CO_2 emission in atmosphere and responsible for air pollution. Several studies have been carried out to investigate the possibility of using dissimilar materials for partial replacement of cement in concrete to reduce pollution and achieve healthy environment. By considering all these aspects and need, Alum, Kaolin clay and Bentonite clay can be beneficial as partial replacement of cement in concrete. The present paper is an effort to quantify the 7 and 28 days cementitious efficiency of Alum, Kaolin clay and Bentonite clay in concrete at the various replacement levels with the help of literature review found and studied. This paper consists of a review extensively conducted on publications related to utilization of natural materials as partial cement replacement with an intention to develop a process so as to produce an Eco-friendly concrete having similar or higher strength.**

Keywords: **Alum, Kaolin clay, Bentonite clay, Ordinary Portland cement (Grade 53)**

I) Introduction:-

Every year, there are huge demands of components of the raw materials for the production of Ordinary Portland cement concrete turning into to extensive exploring natural resources. Efforts have been made to recycled, cheaper, environment friendly materials worldwide to produce durable, high strength life cycle, cost effecting long lasting concrete. Therefore, it is always encourages to find new technologies for the construction industries. The construction industry has taken considerable strides forward over the last two or three decades with regard to trials in the use of one or another Cementitious materials generally identified as Pozzolanas, for the compounding of various cement based products. These have not only resulted an improving the compressive strength value attained thereby but also in qualities like ability to set and harden under water. Among these coal fly-ash, blast furnace slag, rice hulk ash, silica fume, or meta-kaolin are the most common ones. Other like gypsum, gypsum fines, Portland cement, cement kiln dust, lime dust, stone dust, and Calcined clay are also in use, due to economic and environmental concerns, different methods of making cement products are being considered. It is thought that some substances like Alum, Kaolin clay and Bentonite clay will be beneficial to some properties of Portland Cement Concrete (both fresh and hardened).Such as segregation and compressive strength since the particles of Kaolin are fine so when it is wet, it is sticky and preventing the segregation and suspending the aggregate uniformly. Bentonite clay is having swelling properties so when it is wet, it swells and filled up the air voids in concrete to avoid cracks in concrete. Alum (Aluminium sulphate) is mostly used as an accelerator for concrete. Alum is a major component in concrete accelerator and wide application in concrete as waterproofing agent, expansive and accelerator.

Alum [Aluminium sulphate [$(A1_2(SO_4)_3 \cdot 18H_2O)$] is substance containing Aluminium and sulphate. When Aluminium sulphate adds in the concrete, it accelerates the hydration of cement, magnifies the dry shrinkage and enhance the early strength, but reduce the late strength of concrete. The anhydrous calcinated aluminium sulphate employed according to the inventing teaching acts at least as a thermal starter of a reaction, namely the cement hydration and differs from all other strength accelerator including aluminium sulphate containing water of crystallization. Kaolin clay [$Al_2SI_2O_5(OH)_4$].This clay is containing a high percentage of Kaolinite ($Al_2O_3.2SiO_2.2H_2O$).The properties of clay vary considerably and strongly depend on its composition in mineral structure. Kaolin clay, both primary state and secondary states are widely available in the crust of the earth and its proper thermal treatment leads to the Dehydroxilation of the Kaolinite and easily available in Gujarat, Maharashtra.etc. It is a Dehydroxylated form of the clay mineral Kaolinite. Stone having higher percentage of Kaolinite are known as China clay or Kaolin clay. It was traditionally used in the Porcelain manufacturing i.e. Ceramic material. High grade Kaolin clay is having higher percentage of Kaolinite > 65% and lower grade having Kaolinite percentages between 40 to 65%. Mostly low grade is used in construction. Kaolin is basically very fine clay so it is added after the water and initial mixing. This was done to keep the kaolin from the coating in aggregate or clumping together. Bentonite usually forms from weathering of volcanic ash, most often in the presence of water. For industrial purposes, two main classes of Bentonite exist: sodium Bentonite and Calcium Bentonite. Sodium Bentonite [$Na(al\ Fe\ Zn)_2(Al\ Si)_4O_{10}(OH)_2\ H_2O$] is usually termed as Bentonite**.** Concrete is produced by partial replacement of Ordinary Portland Cement with mineral admixtures. Bentonite clay improves compressive strength of cement. Sodium Bentonite expands when wet, absorbing as much as several times its dry mass in water. Because of its excellent colloidal properties, it is often used in drilling mud for oil and gas wells and boreholes for Geotechnical and Environmental investigations. The property of swelling also makes Sodium Bentonite useful as a sealant, since it provides a self-sealing, low permeability barrier. It is used to line the base of landfills to prevent migration of lichets for quarantining metal pollutants of groundwater and for the sealing of subsurface.

II) Scope and objectives:-

1) To enhance the properties of concrete.
2) To minimize the use of conventional materials at some extent.

II) Literature review:-

(1) Changyu Kan, Minzhang Lan, Lamai Kong and Jingbo Yang (2013), They performed the various tests like XRD and SEM tests on alum containing cement concrete to check alum effects on cement and concrete. They made different specimens of cement concrete by using alum with different proportions as partial replacement of cement. Also they performed compressive strength test, split tensile strength test and flexural strength test on specimens of alum cement concrete. After all observations and testing, they found that with the increases in the proportion of Alum (Aluminium sulphate), shorten the setting time of cement and increases dry shrinkage. Alum (Aluminium sulphate) accelerates the setting time of cement. Fluidity becomes higher. Compressive strength improves when addition 6 to 8% of Aluminium Sulphate in concrete. Aluminium sulphate is having Aluminium and Sulphate two different chemicals, these both chemicals react differently with cement. Aluminium reacts with the alkali (OH) found in Portland cement Concrete. When these two chemicals are combined, the reaction produced hydrogen gas. This is why, when the reaction occurs in wet concrete, tiny bubbles start occurring on the surface of a mix. Sulphate affects on the strength of concrete. The tiny bubbles effects are the typical types of attack by solutions of sodium sulphate or potassium sulphate. In cement paste, several chemical reactions related to Alum (Aluminium Sulphate) take place:

$$A1_2(SO_4)_3 + 3Ca(OH)_2 + 6H_2O \rightarrow 2Al(OH)_3 + 3(CaSO_4 \cdot 2H_2O) \quad (1)$$
$$C_3A + 3(CaSO_4 \cdot 2H_2O) + 26H_2O \rightarrow 3CaO \cdot A1_2O_3 \cdot 3CaSO_4 \cdot 32H_2O \quad (2)$$
$$A1_2(SO_4)_3 + 6Ca(OH)_2 + 26H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O \quad (3)$$
$$2Al(OH)_3 + 3Ca(OH)_2 + 3CaSO_4 + 26H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O \quad (4)$$

Sulphate ions react with calcium ions to form derived Gypsum(equ.1) which is more active than primitive Gypsum and can react with tricalcium Aluminates more easily to form Ettringite (Ettringite is a hydrous Calcium Aluminium Sulphate mineral) (equ.2). Aluminium Sulphate is able to react with calcium hydroxide to form Ettringite directly in absence of Tricalcium Aluminates.(equ.3). In (equ.4), the intermediate product Aluminium hydration generally cannot exist steadily so it soon turns into Ettringite at presence Hydroxide and Gypsum.

(2)H.I.Bendary, M.F.Abadir (2017), researchers have performed various tests on cement concrete containing Alum. Researchers have used Alum in various proportions as 2.5%, 5%, 7.5%, 10% to mix with cement in concrete. These all proportions were taken by considering weight of cement. According to various tests like initial and final setting time, fluidity test on cement containing alum with different proportions, they concluded that Initial setting time was unaffected but final setting time was increased up to 7.5% and after addition of more quantity of Alum in cement, it slightly decreases. They have also performed compressive strength, split tensile strength and flexural strength on cement concrete containing Alum. They concluded that addition of 7.5% improves compressive strength, flexural and split tensile strength for 28 days.

(3) Roszilah Hamid, Haider moh. Owaid (2013) in this study, researchers have used Alum sludge as partial replacement of cement. They have dried Alum sludge and made alum sludge powder. For research work, they have used Alum sludge powder in concrete as 6%, 9%, 12% and 15% by considering weight of cement. They have performed various tests like compressive, split tensile and flexural strength to check its feasibility in concrete for 7 and 28 days. After performing all tests, they concluded that Compressive strength improves by adding 6% of Alum sludge powder. Tensile as well as flexural strength also improved by addition of 6% of Alum sludge powder.

(4)Avni Desai (2016), researcher has searched out the use of Alum sludge in brick formations as well as in concrete. She has used Alum sludge powder for her research work. She has used Alum sludge powder as 0%, 6%, 9%, 12% and 15% in concrete. These all combinations were done by considering weight of cement. She has performed various strength tests on cement concrete. She has concluded that addition of 6% Alum sludge in concrete increases compressive strength, tensile strength and flexural strength of concrete.

(5)Gang Zhou, Weimin Cheng and Sen Cao (2015),in this research work they have used alkali free accelerator containing Aluminium Sulphate as main ingredient along with corrosion inhibitor and complexing agents in concrete. They have made five types of chemical raw materials apart from water represented by A, B, C, D and E. Material A which was containing Aluminium Sulphate as major constituent, material B was containing Sodium Fluoride as main constituent, material C was containing Tri-Ethanolamine as main constituent, material D was containing Poly-acryl amide as main constituent and material E was containing bentonite clay as main ingredient. They have performed initial, final setting time and compressive strength for 1 day and 28 days and they got best results on increasing percentages of Aluminium Sulphate in mixture. Increase of Aluminium sulphate improves setting time of cement. Below 55% of Aluminium sulphate improves compressive strength of concrete.

(6) Khalid Moh. Breesem,Faris Goreshi Faris,Isam Moh.Abdel-Magid (2014),researchers have used Alum sludge as 2%, 4%, 6%, 10%, 12%, 14% for addition in concrete by considering weight of cement. They have used alum sludge powder for addition in concrete. They have performed different tests like compressive, split tensile and flexural strength on concrete specimens

containing Alum sludge powder. They have concluded that 6% of Alum sludge improves the compressive strength of concrete for 3, 7 and 28 days.

(7)Junan Shen, David Griggs (2012), researchers have used Kaolin clay as partial replacement of fine aggregates as 1%, 2.5% and 5% in concrete by considering weight of cement. They have observed that Kaolin clay substitution above 3% leads to high air void content and 2% of Kaolin clay substitution improves optimal strength range. They have observed the chemical reactions between the Kaolin clay and cement. They have observed that the primary Cementitious products resulting from the process of cement hydration are: hydrated Calcium Silicates (C_2SHx, C_3S_2Hx), hydrated Calcium Aluminates (C_3AHx, C_4AHx), and hydrated Lime Ca $(OH)_2$. The first two cementitious products are primary cementitious products, while the hydrated lime is deposited as a separate crystalline solid phase. Cement particles bind the adjacent cement grains together during hardening, and form a hardened skeleton matrix, which encloses unaltered soil particles. In addition, the hydration of cement leads to the rise of the pore water pH value, which is caused by the dissociation of hydrated Lime (OH^- ions in particular). And the secondary Cementitious products occur when the hydrous Silica and Alumina gradually react with the Calcium ions liberated from the hydrolysis of cement, to form insoluble compounds that harden when cured to stabilize the soil. This secondary reaction was known as the Pozzolonic reaction. The reactions that take place in the soil–cement stabilization can be represented in form equations (1), (2), (3), and (4). These reactions were related to the Tricalcium silicate (C3S) only, because it was the most important constituent of Portland cement.

$C_3S + H_2O \rightarrow C_3S_2Hx$ (hydrated gel) + Ca (OH) (1a)
$C_3S + H_2O \rightarrow C_3S_2Hx$ (hydrated gel) + Ca (OH)2 (1b)
Ca(OH)2 → Ca++ + 2(OH) (2)
Ca++ + 2(OH)- + SiO2 (silicon dioxide) → CSH (3)
Ca++ + 2(OH)- + Al2O3 (aluminium oxide) → CAH (4)

They have also concluded that when this clay was mixed with cement in concrete as fine particles, it increases the shrinkage and reduces compressive strength so it was used with sand and water for better results. It was thought that Kaolin will be beneficial to some properties of Portland cement concrete (both fresh and hardened) such as segregation and compressive strength since the particles of Kaolin are fine. When it was wet, it sticks, preventing the Segregation aggregates suspending the aggregate uniformly

(8) Ramakrishnan, V.L. Narsimha (2010), researcher have used Kaolinite clay and calcined Kaolinite clay for adding in concrete and mortar. They have used natural Kaolinite clay and calcined kaolinite clay in various proportions as 5%, 10%, 15% and 20% by considering weight of cement. They have performed the workability, compressive strength for 7, 28 and 56 days and water absorption test on specimens of morter and concrete. They have observed that increases in the Calcination temperature of Kaolinite in mortar reduced water absorption level by 50%. Calcined kaolinite improved the compressive strength of concrete.

(9)Ahmad Sufan A, Haryati Yaacob(2014),researchers have used kaolin clay as partial replacement of cement in concrete. They have used kaolin clay as 2%, 4%,6%,8%,10% and 12% for experimentation. All combinations were done by considering weight of cement. They performed various strength tests on specimens of concrete containing kaolin clay. And they got best results on addition of 8% of Kaolin in concrete.

(10)H.Yanguatin,J.Tobon,J.Ramirez(2016),researchers have added 2.7% of ferric nitrate to commercial Kaolin for making concrete. They have used kaolin clay Kaolin clay used in 0%, 2.5%, 5%,7.5% to add in concrete. Perform various tests to check workability of concrete. They have concluded that subsequent calcination increases compressive strengthat7daysfrom16 MPa to 22Mpa,27Mpa to 48MPa for 90days

(11) Syed Qasim Shabbir, Sajjad Ahmed and Ahsan Sarfraz (2016) researchers have used China clay (kaolin clay) waste for replacements of fine aggregates in conctrete. They have used china clay (Kaolin clay) as 15%, 30% and 50% to prepared different mix designing samples. And they performed various tests on sample specimens of concrete to check its feasibility in concrete. They have concluded that 30% of Kaolin clay waste as replacement of fine aggregates improves the compressive strength, flexural strength and tensile strength.

(12) E.Abdullah, R.P. Jaya, M.N.A Shahafuddin, H .Yaacob,M .H.Wan Ibrahim, F.M .Nazri, N .I. Ramli and A.A. Mohammed(2014), researchers have used Kaolin clay in concrete. They have used kaolin clay as 0%, 2.5%, 5%, 7.5% to add in concrete. They have performed various strength tests on concrete samples. They have concluded that 5% of Kaolin clay addition in concrete increases compressive strength.

(13)Noureddin Mesboua,Khaled Benyounes(2017), reseachers have performed experimental study to check the properties of concrete by addition of Bentonite clay. Addition of bentonite clay as 8%, 12%,14%,16% and 18% in cement concrete. They have concluded that 16% of Bentonite clay addition in concrete produced a stable grout without sedimentation and bleeding.

(14) M.Chandrakanth,N.S.Poorna Chandra Rao and K.Shrinivasa Rao(2012) They were used Bentonite as mineral admixture for partial replacement of cement by 0%, 5%, 10%, 15% and 20%. And M20 grade of concrete was designed. They were concluded that increase the Bentonite clay from 0 to 20% in concrete, workability decreases. 5% of Bentonite clay increases compressive strength, flexural strength and split tensile strength.

(15) M.Karthikeyan,P.Raja Rama chandran, A.Nandhini,And R. Vinodha(2015) They made Bentonite mix samples were made by using 0%,25%,30% and 35% by weight of cement for M25 mix 30% addition improves compressive strength.25% addition improves tensile and flexural strength.

(16) M.Chandrakanth, N.S.Poorna Chandra Rao, K.Srinivasa Rao(2016),researchers have used bentonite clay as partial replacement of cement in concrete. They have used bentonite clay in various proportions as 0%, 5%, 10%,15% for addition with the cement in concrete. These all proportions of bentonite mixing with cement have been taken by considering weight of cement. They have performed various strength tests on concrete samples. They have concluded that 5% bentonite clay improves compressive strength. 5% bentonite clay addition improves tensile strength and flexural strength.

IV) Conclusion:

According the review of literature, Alum Bentonite clay and Kaolin clay give best results when Alum 5%, Kaolin clay 2% and Bentonite clay 5% are used as partial replacement of cement in concrete. Alum forms Ettringite when mix with cement and produce air voids but after addition of Kaolin clay in this mixture, Kaolin clay fills the small air voids. Addition of Bentonite clay,fills up the all remain gaps and voids so that concrete become more strong**.** More addition of Alum can lower the swelling properties of Bentonite clay so it should be 5 to 6% only. Kaolin clay is very much fine so for better results it should be added after all ingredients and water mixing**.**

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