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"Assessment of Composite Concrete using Fly Ash & Lime Sludge" - A Literature Review

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Abstract—

Cement, aggregates, water, and additional ingredients if needed make up concrete, a compound building material. There are numerous inventions that use concrete's various qualities. Cement is the primary ingredient that gives concrete its strength. The aggregate is bound together by Portland cement and other cementation ingredients like as fly ash and slag cement. Other chemical admixtures are also used to achieve different properties. Water is then added to this dry composite through a chemical process called hydration, which gives it shape before it solidifies and hardens into rock-hard strength. The other components are joined to create a solid material that mimics stone once the cement and water have reacted. Lime sludge is another substance that can be used as a cement substitute. The industries that produce lime sludge include those that manufacture paper, acetylene, sugar, fertilizer, sodium chromate, soda ash, and water softening facilities. Each year, these businesses generate roughly 4.5 million tons of sludge. In contrast, fly ash is a naturally occurring material that is produced when coal is burned. The precipitators in the smokestacks of coal-burning power plants suck it out to reduce pollution. In India, 120 coal-based thermal power plants generate about 112 million tons of fly ash yearly. This study evaluated previous research that looked at how modern waste materials, like fly ash and lime sludge, affect the compressive, tensile, and flexural qualities of concrete. Additionally, the use of such by products makes the concrete environmentally friendly. The study demonstrates that concrete's strength parameters change dramatically when cement is partially substituted with any waste product, which eventually lowers carbon emissions. It also found that fly ash reduces the cement content for a given grade of concrete in order to achieve characteristic strength.

Keywords*: Composite Concrete, Lime Sludge, Fly Ash, Compressive Strength, Tensile Strength, Flexural Strength.*

1. Introduction -

About 7% of the world's carbon dioxide (CO2) emissions come from the energy-intensive cement industry [1][2]. It is well known that one of the main drivers of the greenhouse effect and global warming is CO2. Therefore, research has expanded on the utilization of by-product cementing elements such FA and granulated slag in order to create and use blended cement more frequently rather than Ordinary Portland Cement (OPC) [3][4]. In recent years, PPC production has exceeded 70% of cement demand in India [5]. However, rising electricity demand has also led to increased coal usage and, as a result, increased fly ash production.

The world produces millions of tons of fly ash annually, an industrial byproduct that not only pollutes the environment but also takes up a lot of storage space on limited land. Thus, it is practical to use fly ash in place of cement to the greatest extent possible in order to save money, energy, and the environment [1]. Fly ash is one of the most popular and widely used pozzolanic materials worldwide [1]. Tons of this garbage would be disposed of untreated, causing contamination of the soil, water, and air, as well as the loss of plants and animals. Fly ash's use in concrete has increased dramatically due to its high silica and aluminum reactive form concentration [6].[7]. In mortar formulations consisting of cement, fine aggregate, and water, coarse aggregate is usually avoided. Despite the potential advantages of using fly ash in mortar, similar to concrete, there haven't been many studies conducted on the topic thus far [1]. Fly ash and other Supplementary Cementing Materials (SCM) can partially replace OPC, depending on the resources available [8][9]. Greener concrete production is possible even though natural aggregates can be replaced with different materials in terms of energy and resource use [8] [10]. The capacity of fly ash to increase concrete's durability without sacrificing strength has garnered a lot of interest in certain situations when it comes to its adoption [11]. [12] The recovery of trash from usable products and the use of waste as raw materials in building whenever feasible are the main focuses of current global trends [6]. According to the current study, FA could have been more useful in cement, however it was used in a number of tests without any admixtures. Calcium hydroxide's lime content and lime-silica ratio are increased by 10% CLS, a by-product of the acetylene industry, which improves FA's effectiveness.

FLY ASH **-** The use of fly ash in civil engineering is essential due to its economic and environmental benefits (Ravina and Mehta, 1986; Matkovi´c, 1990). The amount of cement FA can replace is limited by the amount of free lime in the ash. The reactivity of FA is influenced not only by its chemical composition but also by the amount of glassy phase present, the specific surface area (SSA), the burning temperature of coal or lignite, the

phase composition, and other parameters (Matkovi´c, 1990). Tillman et al. (2012) state that FA is a pozzolanic chemical. Pozzolanic materials are those that, when exposed to lime and water, produce insoluble cementitious compounds but have little to no cementing action when left alone (Montgomery et al., 1981).

FLY ASH

A by-product of coal-fired power plants, pulverized fuel ash, or FA, is a mineral additive used in cement and concrete. Fig. 1 shows a typical configuration of a coal-burning generating station. Pulverized coal is blasted into the furnace's burning zone at roughly 1500 ◦C (2700 ◦F), where its flammable components—mainly carbon, hydrogen, and oxygen—ignite. At this temperature, non-combustible minerals such as feldspar, pyrite, gypsum, quartz, calcite, and clay minerals melt and create tiny liquid droplets. The droplets carried by the exhaust gases from the burning zone cool rapidly, forming small, spherical, glassy particles. Mechanical and electrical precipitators or baghouses are used to capture solid particles from flue gasses. FA stands for the ash particles that "fly" out of the furnace along with the flue gases (Thomas, 2013). The features of FA are influenced by a variety of parameters, including the type of coal utilized, the burning conditions, the collection method, etc. (McCarthy and Dyer, 2019). Although FA's use as a pozzolanic element and its reaction potentials were first recognized in early 1914, a thorough investigation of its application in concrete was first published in the United States in 1937 (McCarthy and Dyer, 2019; Halstead). Previous studies from the 1980s have shown that by improving the microstructure of the paste, FA can significantly improve the mechanical and durability properties of concrete (Montgomery et al., 1981). Depending on the application, FA characteristics, location, climate, and specification constraints, FA has historically been added to concrete in proportions ranging from 15 to 25 percent by mass of the cementitious material component (Thomas, 2007). Reports state that up to 80% FA has occasionally been used to successfully lay concrete (Marceau et al., 2002). Class F and class C are the two categories into which ASTM divides the FAs used in concrete. The class F FA is a byproduct of burning bituminous coal. Class F FA contains a lot of iron, silica, and alumina but little calcium. It is a glassy substance that requires cement or lime to activate. Class C FA is produced by burning lignite and sub-bituminous coal. It has more calcium than class F FA. According to McCarthy and Dyer (2019) and Marceau et al. (2002), class C FA concrete gains strength far more quickly than class F FA concrete. In addition to being cost-effective, adding FA to concrete changes the properties of the concrete both during its fresh phase and after it has hardened, while also improving workability, strength, and drying shrinkage.

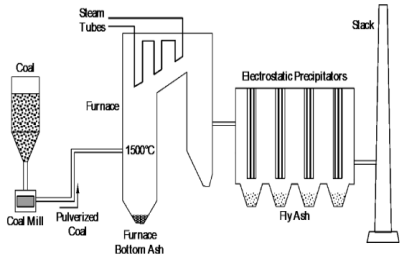

Fig. 1. A schematic diagram of a coal-fired electrical generating station (Thomas, 2013).

LIME SLUDGE - The problem of how to dispose of industrial waste is growing more and more important on a global scale. Sludge from paper mills, which is created by burning coal in thermal power plants, is a significant environmental problem in most industrialized countries across the world due to the extensive usage of paper and the requirement for electrical energy. Paper mill sludge cannot be utilized in a variety of other industrial processes. Because the paper mill sludge is useless, it is thrown away together with other waste cellulosic fiber, creating a major disposal problem. The technology used to pulp, wood, and make paper, the kind of effluent treatment that is utilized, the kind and source of coal, and the technique of collecting ash all have an impact on the properties of bio-solids. The composition of solid wastes produced by industrial sources varies; they can be inert inorganic (produced in collieries and mining) or organic (made in industries that make basic consumer goods), and they may even contain dangerous components (produced in the pesticide business). A worldwide change in the production of paper and paperboard was expected to make the Asia-Pacific region a major producer of paper mill waste. It was predicted that during the next 50 years, the amount of paper mill waste produced globally will rise by 48–86%. The kind of waste generated by parent industries is primarily determined by the raw materials used in different unit processes. Among these wastes from industrial sources are a variety of compounds, some of which are hazardous. The large and small plant categories both produce solid trash. Solid waste from the paper industry is typically produced at different stages of the paper-making process, such as the causticizing phase in the chemical recovery unit as lime sludge, and the raw material handling and preparation phases as sludge from the effluent treatment facilities. Typically, solid trash is disposed of in landfills, however incineration is growing in popularity. The amounts of chemicals of concern must be regularly shown to be below

practical regulatory levels before any solid residues are applied to the land. Studying the use and practicality of these industrial wastes as a cementitious/pozzolanic material in the building sector was the aim of this study.

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LIME SLUDGE

CATEGORISATION OF LIME SLUDGE

The different types of industrial waste fall into the following categories –

• Paper Sludge: According to research, up to 74% (dry basis) of lime sludge from the paper industry can be utilized as a raw material to create Portland cement clinker, which can result in OPC that meets IS:269-1989 and IS:8112-1989, respectively, Indian Standard Specifications.
• Carbide sludge: Carbide sludge can be employed as a source of calcareous material in the raw mix used to create cement clinker, according to research and development efforts. OPC that meets all three National Standard Specifications for cement can be produced by using up to 30 percent carbide sludge in the raw mix to make clinker, given the cement raw mix's tolerance limit for chloride content.
• Phospho-chalk: Phospho-chalk can be used as a raw mix ingredient in the manufacturing of cement clinker, according to research and development studies. Because of impurities like SO3 and P2O5, less than 8% of it is usable.
• Sugar Sludge: According to preliminary research, sugar sludge can be utilized as a source of calcareous material in the raw mix used to make cement clinker. To determine the impact of contaminants in sugar sludge on the performance of the cement (OPC) made from it, a thorough investigation is required.
• Chrome Sludge: Research has shown that up to 5% of chrome sludge can be utilized as a mineralizer. The mass use of chromium oxide is limited by its presence as an impurity up to 10 percent.

Characteristics of lime sludge

Very fine precipitated CaCO3 particles and leftover residue from the green liquor clarifier make up lime sludge. The following table lists the typical physico-chemical characteristics of lime sludge waste:

Table 1: Chemical properties of Lime sludge (Source: CRI-ENG-SP 965March 2000)

S NO	CONSTITUENTS	PERCENTAGE
1	Moisture Content	40 – 60
2	SiO2	2 – 8
3	Al2O3	0.8 – 1.2
4	Fe2O3	0.8 – 1.2
5	CaO	48 – 53
6	MgO	0.2 – 3.0
7	LOI	37 – 42
8	SO3	0.1 – 0.3
9	Na2O	0.8 – 2.0

2. OBJECTIVES OF THE STUDY

Clinker is replaced with lime sludge. If appropriately utilized, the lime sludge—which would have otherwise been a waste—will preserve important limestone deposits needed for cement manufacturing. In addition to being environmentally beneficial, lime sludge can be utilized as a raw material in the cement masonry and construction industries, offering improved performance, durability, and cost-effectiveness. However, a naturally occurring consequence of burning coal is fly ash. The precipitators in the smokestacks of coal-burning power plants suck it out to reduce pollution. Many researches have examined the use of fly ash and lime sludge as a reliable and practical cementitious material in concrete. Below is a synopsis of the study that has been done by different researchers on the utilization of these two industrial wastes in concrete. Concrete's durability and mechanical strength change depending on whether fly ash and lime sludge from industrial waste are used. To a fair degree, it is allowed to use these industrial wastes in place of some cement. The next part provides a thorough analysis of the literature on the durability and mechanical characteristics of different concrete mixes.

3. Literature Review –

Using fly ash and lime sludge, numerous research have been carried out to evaluate the mechanical properties of the concrete. Here, only a handful of the studies have been reviewed and discussed.

"Lipi Gaur (AMIE, CEng), Rameezut Tauheed, EFFECT OF LIME SLUDGE ON COMPRESSIVE STRENGTH OF CONCRETE 2023 IJCRT | Volume 11, Issue 6 June 2023 | ISSN: 2320-2882 pp 632 -664" - The various qualities of the materials utilized for mix design are investigated in this study project. To determine whether the material was suitable for mix design, quality tests were carried out. Following IS criteria, the mix design produced a 1:1.62:3.40 outcome. By replacing cement with varying volumes of lime sludge, the study aims to ascertain the concrete's compressive strength. In this experiment, 20% cement has been replaced with five amounts of lime sludge. 0%, 5%, 10%, 15%, and 20% of the total amount of solid waste are the five percentages. Experiments on concrete over 3, 7, and 28 days have shown that the more lime sludge added to the mix, the lower the concrete's compressive strength is when compared to controlled concrete. The compressive strength analysis carried out in this work offers a better knowledge of the cementitious properties and pozzolanic behavior of such by-products when used in construction.

"Gabriela Rutkowska, Assessment of Fly Ash from Thermal Treatment of Sewage Sludge According to the Applicable Standards, Journal of Ecological Engineering 2023, 24(3), 20–34 https://doi.org/10.12911/22998993/157319 ISSN 2299–8993, License CC-BY 4.0" - The study's objective was to evaluate the qualities of fly ash obtained from the thermal treatment of sewage sludge with respect to EN 450-1, ASTM-C618-03, and ASTM C379-65T for use in concrete technology. The test findings obtained verify that the material under test has a different physicochemical composition and does not satisfy the requirements pertaining to the use of ash in concrete production. Furthermore, the study demonstrated that fly ash from the thermal treatment of sewage sludge might be used to modify regular concrete. After 28 and 56 days of maturity, the average compressive strength of concrete with 15% Cracow ash was found to be 48.1 MPa and 49.2 MPa, that of Warsaw ash to be 42.0 MPa and 45.1 MPa, and that of Łódź ash to be 36.2 MPa and 36.2 MPa. The measured amounts of heavy metals are below the leaching levels necessary to accept inert waste for disposal, the maximum values to be fulfilled for releasing waste water into the ground or water, and for compounds that are very detrimental to the aquatic environment. Based on this, it was determined that the heavy metal migration from concrete that has ash added to the aquatic environment is negligible and shouldn't pose a serious issue.

"Anudeep Kanthed and Dr. Rajeev Chandak, A Review of Experimental Study and Analysis on Strength of Concrete by using Hypo Sludge and Fly-Ash with Several Stages, International Journal of Research Publication and Reviews, Vol 4, no 8, pp 1160-1165 August 2023" - A by-product of the production of paper and board is hypo sludge. In India, waste paper is thought to account for 0.7% of all municipal garbage. In the paper business, paper sludge poses a significant environmental and economic challenge. Paper sludge has both weak and strong fibers. Weak leftover fibers are thrown away during the recycling process, whereas strong residual fibers are utilized to create recycled paper. There are now major issues with soil, water, and air pollution as a result of this settlement. To lessen the disposal issue, cement is being used in place of paper sludge. The waste paper behaves like cement because of the silica and magnesium characteristics, which lengthens the cement's setting time.

"Shubham Goswami1 , Dharmendra Kumar Shukla1 and Pramod Kumar Singh2 - Technical Evaluation of Sustainable Cement Containing Fly Ash and Carbide Lime Sludge, IOP Conf. Series: Earth and Environmental Science 795 (2021) 012040 IOP Publishing doi:10.1088/1755-1315/795/1/012040" - As a waste product, fly ash (FA) is utilized in the production of concrete, embankments, and Portland Pozzolana Cement (PPC). Globally, FA is still not being used effectively in terms of amount. Consequently, the current study uses Carbide Lime Sludge (CLS), an industrial waste, to increase the usage of FA in the manufacturing of sustainable cement. In terms of the physical characteristics of cement with PPC containing FA variable (15, 25, 35, and 45%), the efficient use of FA varying (5, 15, 25, and 35%) plus 10% CLS has been assessed. The study's findings would support the use of up to 45% FA plus CLS with a suitable compressive strength in order to save limestone and lower carbon dioxide emissions.

"P. Varsha, Asst. Prof. T. Chandrashekar, K. Anusha, Effect & Strength Characterstics of Concrete Using Lime Sludge and Flyash, International Journal of Science, Engineering and Technology 2020, ISSN (Online): 2348-4098 ISSN (Print): 2395-4752" - Concrete cubes were cast in this investigation using fly ash and lime sludge in place of cement (0% and 5%), as well as cement (0%, 5%, 10%, and 15%). The approach used in this study complies with the requirements of the IS code. According to our experimental research, when compared to regular concrete, the compressive strength is reduced when a portion of the cement is substituted with lime sludge powder. From a technical, environmental, and financial standpoint, the use of fly ash and lime sludge in concrete is a desirable building ingredient.

"Chavan et al. (2020) Experimental Study On Strength Of Concrete By Partially Replacing Of Cement With Hypo Sludge, Oaijse, Volume 5, Issue 10. October 2020" A reality associated with the rise of environmental sustainability concerns is the growing volume of waste. From the paper mill, a significant amount of Hypo Sludge has emerged. Every year, about 300 million tons are manufactured. Environmental contamination results from their widespread disposal in landfills. Additionally, the manufacture of cement releases carbon dioxide, which contributes to global warming. Consequently, the innovative application of industrial waste as a stone additive in the production of concrete (concrete pavement) can aid in lessening the environmental issue. The investigation of the strength test of concrete mixed with hypo sludge is the focus of this research project. Hypo sludge is applied in amounts ranging from 10% to 40% by weight of cement in place of cement. There is also a significant decrease in power.

"Manjunatha H, R. Malathi, J Mahipal, R. Saritha, T. Ashok, Replacement of Cement with Hypo Sludge Flyash and Sand with Quarry Sand, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-12S2, October 2019", The impact of contemporary waste materials, specifically fly particles, lime slime, and quarry sand, on the compressive strength, cut-up elasticity, and

flexural properties of M30 grade concrete is examined in this paper. In this M30 grade strong concrete, sand is partially replaced by quarry dust (sand) (20 percent) in five aggregate extents, and lime slime (10 to 40 percent) and fly debris (10 to 20 percent) are used as resources. These five blends' effects are compared and controlled together. The blend quantity with partial bond replacement (10 percent lime ooze, 10 percent fly particles, and 20 percent quarry dust for midway sand substitution) typically produced the best results out of all the mixes.

"Devi et al. (2018) Durability Study on Hypo Sludge Concrete with Replacement of Fine Aggregate International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 03, Mar-2018" Cement, fine aggregate, and reinforcing aggregate are among the typical construction materials that are effectively in short supply due to the rapid growth in construction activities. In order to create inexpensive concrete and lessen the waste and pollution issues produced by hypo sludge, it is crucial to mix different amounts of fine aggregate with hypo sludge. This makes hypo sludge a lucrative building material. The purpose of these tests is to evaluate the subjects' endurance after 28 days. This study examines concrete strength tests and the overall percentage of ingredient replacement by the addition of fine aggregates, such as the Acid Attack, Sulfate Attack, Rapid Chloride Penetration, and Sorptivity Test. In accordance with IS: 10262-2009, mix design for M20 grade concrete is completed.

"G.L. Abhishek (2017) Experimental Study on Behaviour of Paper Sludge Concrete ISSN: 0976-3104 2017, IIOABJ Vol. 8, pp.73-78" Concrete is strong and durable while being a porous material that interacts with the environment. Paper fibers that generate a lot of solid waste can be used. examined cutting-edge uses of hypo sludge as a cementitious material to produce concrete instead of conventional concrete. In order to ascertain the maximum % of component substitution by cement replacement, this study looks at concrete strength tests, including compressive, tensile, and flexural strengths.

"T. Karthika and Ms. S. Shanti (2017) , Hypo Sludge as a Partial Replacement of Cement in Concrete. International Journal of Civil Engineering and Technology, 8(4), 2017, pp. 1645 –1651" This paper presents the results of an experimental investigation that was carried out to evaluate the effects of replacing cement with hypo sludge, an industrial waste product, on the flexural strength of concrete for M20, M25, and M30 Mix buildings. When paper is made, a lot of solid waste is usually produced. As a result, efforts are underway to develop low-cost concrete by adjusting the proportions of cement and hypo sludge.

"S. SUDHA, DURABILITY AND STRENGTH CHARACTER OF CONCRETE USING LIME SLUDGE AND FLYASH AS PARTIAL REPLACEMENT OF FINE AGGREGATE, International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 07 | July-2016", In this study, fly ash was used in place of fine aggregate (0% and 5%) and lime sludge was used in place of cement (0%, 5%, 10%, and 15%) to cast concrete cubes. This study's methodology conforms with the IS code's standards.

4. Conclusion

This study has looked at how modern waste materials, fly debris, lime residue, and sand mining can be used to improve considerable worth astounding solids. Previous studies have shown that the use of fly ash and lime sludge can extend the life of infrastructure and save maintenance expenses. Utilizing fly ash has advantages for the environment, economy, and technology. The use of sustainable cement would reduce carbon dioxide emissions and cement production costs. The fly ash and lime sludge mixture also reduces the cement's setting time. Therefore, based on earlier research, it can be concluded that using fly ash and lime sludge in concrete is a useful building material from a technical, environmental, and financial standpoint.

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