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Experimental Analysis on Utilizing Sugarcane Bagasse Ash as a Replacement for Cement

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Abstract. Construction industry is estimated to consume nearly 30-35% of natural resources and associated to major global pollutions. It is essential to move our path into a sustainable way of construction practices, to conserve natural resources for the future generation. Several researchers had investigated the various possibilities of alternatives to produce sustainable green building materials from industrial by-products, for example, blast furnace slag, fly ash and silica (SiO_2). Presently, there has been an attempt to use the large amount of Sugarcane Bagasse Ash (SBA) which is formed when using the bagasse-biomass fuel in electric generation industry. Due to availability of Cement kiln dust (CKD) and Sugarcane Bagasse Ash (SBA) in large amounts, it appears to be cost effective and eco-friendly by the applications for these industrial by-products. The overall goal of this research study was to replace cement by certain percentage through potential applications for the Cement kiln dust (CKD) and Sugarcane Bagasse Ash (SBA) based on a detailed characterization of the materials. The analyses are discussed in terms of Setting time, Consistency test and Compressive Strength. As a result, Sugarcane Bagasse Ash (SBA) for a certain percentage replaced in cement increases the strength of mortar cube but if it exceeds 20%, then the strength starts to decrease.

Introduction

Concrete is an essential product since it is a vital part in development of construction industry. It is one of the most broadly utilized materials on the earth. Roughly 3.6 billion metric tonnes [10] of concrete are manufactured globally each year, with volume anticipated to ascend to in excess of 5 billion metric tons by 2030. The business is filling especially quickly in agricultural nations having an appeal for framework and lodging. Concrete [9] is made by mixing clinker with gypsum under controlled environment. The concrete creation process requires nuclear power for delivering clinker in revolving furnaces. Each huge load of concrete deliveries 0.9 to 1.1 ton of carbon dioxide (CO_2), a significant ozone harming substance, into the air, which unfavorably influences earth's environment. Then again, huge amounts of residue, generally known as cement kiln dust (CKD), is formed during the manufacture of Portland concrete clinker by the dry cycle. Cement kiln dust [4], by nature is a fine-grained, strong, profoundly soluble material, the particles width range between few μm and 50 μm that eliminated from concrete furnace fumes gas via air pollution control equipments. A portion of the produced CKD could be reused into concrete furnace as crude feed. However, this is restricted by the alkali's concentration in CKD, which cause the salts content in concrete surpass as far as possible (i.e., not over 0.6%) [8] as well as diminishing the efficiency of the kiln and creating equipment malfunction.

Research Significance

When Cement Kiln Dust [4] and Sugarcane Bagasse Ash [7][2] are used as the engineering materials, it will reduce the generation of waste which will create a better environment. Due to its vast range of applications, it can be utilized as a pozzolanic material in the construction industry.

Literature review

Waqas ahmad et. al (2021) [7] explored the effect of sugarcane bagasse ash in cement-based composites. In his research, it is found out that SBA contains amorphous silica which makes it a good pozzolanic material. Also, SBA needs less amount of water to achieve its consistency. The strength of the cement-based composites increases when added upto optimum amount (10%), while further addition has reduced the strength of the composites. Banger et al. (2017) [2] utilized bagasse ash for the research work in crushed and sieved through sieve of size 150 micron and passing out portion is utilized in concrete as a partial substitution of concrete in the proportion of 2% 4%, 6%, 8% and 10% by weight of the cement. The test results shows that the strength of concrete is increased when adding Sugarcane Bagasse Ash (SBA) at greater percentage. Sadek et al. (2017) [6] incorporated cement kiln dust in paving blocks and results shows that upto 10% of CKD can be used as a partial replacement of cement. On replacing upto 40% CKD in paving blocks, it reduces the quality of the blocks considerably.

Abdulkadir et al. (2014) [1] evaluates the suitability of Sugarcane Bagasse Ash as a partial replacement of cement in concrete production. They obtained the SBA and burnt at 700º C and to attain the standard size of particles, the SBA is made to pass through the 45µm sieve. It was then used to replace OPC by weight in ratio of 0%, 10%, 20% and 30% respectively. The result shows that there is decrease in the concrete density with increase in percentage replacement of SBA. Kunal et al. (2014) [4] analyzed the effect of bacterial treated cement kiln dust mortar. It is found out that the strength of the mortar increase when adding CKD upto 10% but further addition reduces the strength due to lower cement content.

From the study of Relan & Saxena (2015) [5], it is concluded that there is an increase in workability whenever adding an appropriate percentage of SBA in concrete. It is presumed that finely grounded SBA can be effectively utilized in concrete as a replacement of cement and is answerable for higher compressive qualities than ordinary Portland cement (keeping amount of cement as constant). The results shows that the cement could be beneficially replaced with SBA up to 12.5 % for M35 concrete. The review also uncovers that the compressive strength increased up to 10 % replacement and when its beyond 15 % replacement, the strength was found to be decreasing.

We have gone through several literatures and journals related to our research. Those literatures helped us to study about the previous research studies about SBA and CKD. It helped us to understand the various studies for utilizing this waste material in our research.

Methodology

This part includes the procurement and grinding of materials, study of properties of both CKD and SBA, Casting and testing of mortar cube. The SBA was freshly burnt and collected from the sugar production industry in Namakkal. Ball Mill is a type of grinder used to grind and blend materials. It works on the principle of impact and attrition. It is used to reduce the size of the materials to finer particles through impact process. We used this equipment to make the CKD and SBA to finer particles. The grinded materials are collected in larger quantities and those materials are sieved through 150 micron and 75-micron sieves to make it finer to equalize the fineness of the cement. The casting and testing [3] of mortar cubes for various mix proportions (60:40, 70:30, 85:15) %

are carried out in a controlled environment. The results from various tests for different mix proportions are determined and analyzed.

Laboratory Investigation

Preliminary actions carried out, initially, the procured materials are completely dried under the open sunlight to remove the water content from the collected materials. After drying of the procured materials, the grain sizes of the materials are reduced by grinding the materials in the ball mill to make it finer to equalize its fineness to the cement particles [3]. Then the grinded materials are sieved using the 75µm sieve. The laboratory investigation includes consistency test [3], compressive strength on 7th day for cement kiln dust (CKD) and Sugarcane Bagasse Ash (SBA) on various mix proportion.

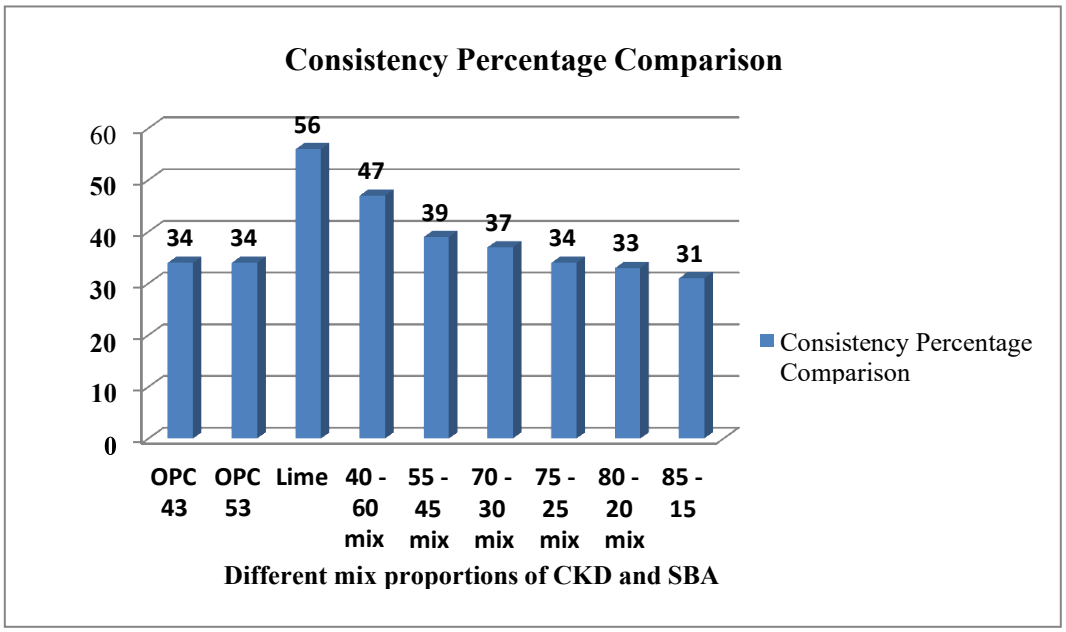

Fig 1. *Comparison of Consistency test for OPC 43, OPC 53 grade of cement, lime and different mix proportions of CKD and SBA.*

The above chart (refer fig.1) shows the comparison of consistency value of OPC 43, OPC 53 grade of cement, lime and different mix proportions of CKD and SBA. It shows that the lime is having higher consistency percentage than others due to higher amount of heat of hydration process. The two grade of cement gives the standard consistency value. In the different mix proportions of CKD and SBA the consistency percentage gets reduced along with increase in the CKD content. The silica in the CKD reacts well and forms paste by consuming lesser amount of water itself.

Table 1. 28th day compressive strength of 85:15 mix of CKD and SBA

Sample	Dial Gauge Reading (kN)	Load (N)	Compressive strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	6.5	6500	1.33	1.54
2	8	8000	1.63	
3	8.2	8200	1.67	

There is minimum strength is increased on 28th day compressive strength comparing (refer Table 1) with 7th and 21st day results. But still this strength is not sufficient for the mortar cube. The strength is very less even compared with the third-class brick. The pozzolonic properties in this new blended mix of CKD and SBA are very less and the bonding properties reduced due to this insufficient binding paste. The particle size distribution also will be a reason behind the low strength.

Table 2. 28th day compressive strength of 70:30 mix of CKD and SBA

Sample	Dial Gauge Reading (kN)	Load (N)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	4.8	4800	0.97	1.07
2	5	5000	1.02	
3	6	6000	1.22	

There is no change in the compressive strength even the mix proportion are changed. Comparing with 85:15% mix proportion (refer Table 2), the compressive strength of 70:30 % mix gets reduced due to reduction in the silica content by reducing the CKD percentage.

From the compressive strength value (refer Table 3), it shows that there is decrease in the strength due to reduction in the CKD % in the mix proportion. It is because of reduction of silica content which is insufficient to form the C-S-H gel in the mortar cube and the pores inside the mortar cube also plays vital role in the reduction of the compressive strength.

Table 3. 28th day compressive strength of 60:40 mix of CKD and SBA

Sample	Dial Gauge Reading (kN)	Load (N)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	4	4000	0.81	1.08
2	6	6000	1.22	
3	6	6000	1.22	

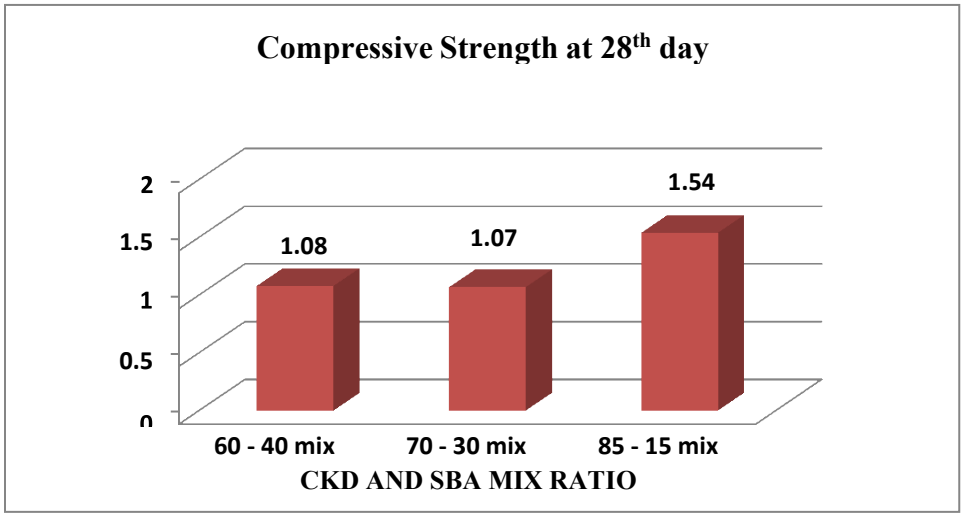

Fig 2. *Comparison Chart of Compressive Strength for Different Mix Proportions of CKD and SBA*

The compressive strength of 85:15% mix ratio of CKD and SBA at 7th, 21st and 28th day are 1.26, 1.44 and 1.54 N/mm². The 28th day compressive strength (refer fig.2) of 70:30 and 60:40% mix proportion of CKD and SBA are 1.07 and 1.08 N/mm². It shows that all the compressive strength values are very less compared to cement mortar strength. Even the compressive strength is lesser than the third-class brick. The strength gets reduced because of large number of pores distribution, insufficient pozzolonic reaction, low bonding, and reduction in C-S-H gel formation and may be of increased carbon content in SBA.

Results and Discussion

Comparing the consistency values of OPC 43, OPC 53 grade of cement, Lime and different mix proportions of CKD and SBA (85:15, 70:30, 60:40) the OPC 43 and 53 grade of cement attained their standard consistency value. The fineness of cement results that the permissible percentage of particle size above 90 micron is only 10%. So, the mix proportion of CKD and SBA sieved using 75-micron sieve to make it more finer particles. Then consistency test is carried out for the mix proportion of (60:40, 70:30, 85:15) % of CKD and SBA sieved through the 75 microns. The results of the consistency value lie between the standard consistency value (47%, 34% and 31% respectively) and shows that there is decrease in the consistency value by increase in the CKD percentage in mix proportion of the blended cement of CKD and SBA.

By comparing the results consistency obtained the water cement ratio increases with the decrease in the cement kiln dust (CKD).The strength is not attained up to the expected level. The compressive strength (refer fig.2) at 28th day of (85:15), (70:30), (60:40) % mix of CKD and SBA are 1.54, 1.07 and 1.08 N/mm² respectively. The reason for low strength is the formation of C-S-H Gel is very less compared to cement. And there is more porous formation while using this blended cement. It was likewise presumed that not just the pores size is deciding the mortar strength yet in addition its dissemination through fractal aspect D, where the compressive strength diminished with D value increased. Likewise, incorporation of SBA for a certain percentage replaced in cement increases the strength of mortar cube but if it exceeds 20 % the strength starts

to decrease. In any case, research should be carried to analyze the results of this study and furthermore evaluate the durability characteristics of the produced mortars.

Using cement kiln dust and sugarcane bagasse ash as a replacement of cement is effective utilization of waste generated in cement and sugar industry. Also, it reduces the harmful environmental and health impacts thus creating an eco-friendly environment.

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