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Utilization of Cement Kiln Dust and Wood Ash as a Partial Replacement of Cement in Concrete

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ABSTRACT:

Sustainability involves that the needs of the present generation are met without wasting, polluting, harming or destroying the environment. Nowadays, there is a global need to use waste materials to substitute cement for limiting its environmental impact and converting these wastes into useful products for sustainability. This study involves the use of cement kiln dust (CKD), waste by-product generated during manufacturing of cement clinker and Prosopis juliflora wood ash (WA), a residue generated due to combustion of wood, which acts as a fuel in brick industry. Prosopis juliflora (species), with its deep penetrating roots, not only lowers the ground water level but also increases the salinity level. This research aims at utilizing both cement kiln dust (CKD) and Prosopis juliflora wood ash (WA) as a partial replacement of cement (20%, 30%, 40% w/w) and its effects on normal consistency, setting times, compressive strength (at 7,21 & 28 days) of blended cement cubes. Test results show increase in water consistency and setting time with the addition of CKD. The compressive strength of concrete specimens (150x150x150 mm) decreased with the addition of CKD. The results indicate that CKD and WA can be utilized upto 30% as an optimum replacement of cement in concrete. This application will not only reduce the environmental problems associated with CKD and WA disposals but also it will be a step towards sustainable development by reducing the demand of cement needed in cement industry, hence reducing energy requirements and CO^2 emissions during cement manufacturing process.

Keywords — **Cement kiln dust (CKD), Wood ash, sustainability, concrete**

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I. INTRODUCTION

Portland cement plays an important role in the production of mortar and concrete, and thus acts as a major constructional material of choice in building and structures. Approximately 3.6 billion metric tons of cement is produced globally every year, with volume predicted to rise to more than 5 billion metric tons by 2030. The industry is growing particularly rapidly in developing countries having a high demand for infrastructure and housing. Manufacturing of one ton of ordinary Portland cement requires 60-130 kg of fuel oil or equivalent and about 110 KWh of electricity (Felekoglu et al., 2007). In average, it requires about 2.8 ton raw materials (including fuels and other materials) (Marku et al., 2012). In the meanwhile, cement industry is arguably regarded as the second largest producer of greenhouse gases (Najim et al., 2014). Every ton of cement releases 0.9-1.1 ton of carbon dioxide (CO^2), a major greenhouse gas, into the atmosphere, which adversely affects earth's climate pattern (National Ready Mixed Concrete Association, 2012). Due to increasing urbanization and industrialization from the last few years, the increasing cement generation has arisen certain challenges such as energy and resource conservation, cost of production and above all cement kiln dust (CKD) generation during cement clinker manufacturing has become one of the major environmental and economical issues. Cement kiln dust (CKD) is characterized by solid highly alkaline material removed from the cement kiln with exhaust gases and collected at bag house filters or electrostatic precipitators. Modern manufacturing technique makes it possible to reuse the cement CKD into cement kiln as raw feed that not only reduces the amount of CKD managed outside the kiln but also reduces the use of limestone and other raw materials, thus saves natural resources and helps to conserve energy. But this is limited by the alkalis concentration in CKD, which may cause the alkalis content in cement to exceed the allowable limit (i.e., not more than 0.6%) in addition to decreasing the efficiency of the kiln and creating equipment failures (Maslehuddin et al., 2009). Kunal et al. [1] provides a general review on the CKD utilization in making cement paste/mortar or concrete. As CKD is generated from cement kiln during cement manufacturing, it shows properties similar to cement and thus, acts as potential replacement to Portland cement. Al-Mabrook [2] studied the ability of using CKD in cement mortar and hollow cement bricks by replacing cement (10%, 20%, 30%, 40% and 50%). Increase in compressive strength was observed in mixtures containing 30% CKD and it was concluded that increasing CKD quantity in mixtures increases the tricalcium silicate content that led to an increase in compressive strength at early stages. Abo-El-Enien [3] studied the utilization of CKD in the cement industry and building products. CKD was used as a partial substitute of blast furnace slag cement. Strength development in Portland cement pastes with the addition of kiln meal and CKD was investigated. The results showed a high degree of hydration and lower compressive strength than the addition of free cement. Sri Ravindrarajah [4] reported results of an investigation into the usage of CKD in concrete, as a partial replacement of cement. The percentages of cement replacement by weight were 0, 25, 50, 75, and 100 in cement paste and 0, 15, 25, 35, and 45 in both 1:1.5:3 and 1:2:4 concretes. The results showed that CKD is a cementitious material and it causes the following effects such as retarding setting time, increase in compressive strength. Ramakrishnan [5] made a comparative study of concrete properties prepared with cement blended with CKD versus the properties of corresponding concrete made with plain Portland cement. The blended cement was produced by blending 5% CKD with 95% by weight of regular Type I cement. Test results indicated that addition of CKD slightly retarded the setting times of cement. The properties of fresh blended cement concrete mixtures were almost similar to those of plain cement concrete mixtures. Bhatty [7–11] found that CKD blended cement had reduced workability, setting times and strength which was due to the presence of alkalies in the dust. Cement kiln dust after reducing the alkalinity can be used in cement–concrete system and may have positive effect on cement–concrete properties. In an earlier study, the properties of cement mortar and pastes incorporating CKD were evaluated [14]. In that study, CKD was incorporated in ASTM C 150 Type I cement. It was reported that CKD does not adversely affect the properties of cement. There was no increase in the water requirement for maintaining a required slump due to the addition of CKD. The initial and final setting times of CKD cement mixtures decreased slightly but they were well within the ASTM C 150 requirements. Udoeyo et al. (2006) determined the compressive strength of concrete made with varying percentages (5, 10, 15, 20, 25, and 30 by weight of cement) of waste wood ash (WWA). Abdullahi (2006) studied the influence of wood ash (WA) on the slump of concrete. He used wood ash as partial replacement of cement in varying percentages (0, 10, 20, 30, and 40%) in concrete mixture proportion of 1:2:4. Test result showed that mixtures with greater wood ash content require greater water content to achieve a reasonable workability.

II. RESEARCH SIGNIFICANCE

Engineers and researchers have been compelled to find new alternative materials due to excessive consumption of the natural resources. The natural resources is getting depleted due to over utilization in cement manufacturing, which demands for its conservation. Moreover, various landfill scarcity and environmental problems are the other factors owing to the inefficient management of wastes produced from various industries. This situation demands the construction industry stakeholders to investigate new alternative materials and develop novel methodologies for effective use of wastes produced from industry. This research determines the cementitious property of new blended cement through mixing the CKD and WA in different proportions. The blended new material is further used for the laboratory testing to find its physical properties and strength assessment by determining the compressive strength of cubes for the optimum mix proportion and water cement ratio of the new blended cement material. When cement kiln dust and wood ash are used as the engineering materials it will reduce the dumped waste which will create a better environment. Due to its vast range of applications it can be utilized as a pozzolana in the construction industry.

III. METHODOLOGY

A. Raw Materials

The landfilled CKD was acquired from the waste dumbed area at ACC Cement Plant, Madukkarai, Coimbatore. The Wood ash was freshly burnt and collected from the brick production industry in Tirunelveli. Both the by-products are procured and transported to the laboratory for the further processing of the materials which going to be utilized for our research.

B. Material Processing

In this research the ball mill is used which 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. 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.

C. Physical properties test

This part includes the study of fineness, consistency and setting time, specific gravity of the blended cement. The materials sieved through 75 micron and used for consistency and setting time tests in different mix proportions of CKD and WA.

	CEMENT (OPC)	CKD	WOOD ASH
CKD_{10} + WA_{10}	80	10	10
CKD_{20} + WA_{10}	70	20	10
CKD_{30} + WA_{10}	60	30	10

Table 1: Different Mix proportions of CKD and WA

D. Casting of Cube

The mortar cubes (M20 grade) of size 150x150x150 mm for all trial mixes were casted. The wet curing process was carried out after unmoulding the cubes using gunny bags. The casted mortar cubes of various mix proportions of CKD and WA are tested for compressive strength using UTM machine at 7^{th}, 21^{st} and 28^{th} day.

IV. RESULTS AND DISCUSSION

A. Standard Consistency test

The consistency test for various trial mixes were performed using Vicat apparatus as per IS: 4031-Part 4 – 1996. The test results shows that the consistency
values for all the mix proportions (Table 1) are higher than the standard consistency value of the OPC 43 cement (Fig.1). It is seen that with increasing CKD content (20%, 30%, 40%) water demand increases to maintain a normal consistency. Studies reported that increased water demand is due to high alkali, sulfate, volatile salts and free lime content in CKD compared with Portland cement [12-13]. It is due to the larger particle size higher than the fineness of cement. Larger the particle size the pores will be more and the bonding between the particles will be lesser. The water is separated while taking the paste, it is due to the C-S-H gel formed was very less and particle size plays vital role in it. In the different trial mix proportions of CKD and wood ash, the consistency percentage gets increases along with increase in the CKD content. The silica in the CKD do not reacts well

Material	Specific gravity
OPC	3.14
CKD	3.693
Wood ash	2.377
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Material	**Specific gravity**
OPC	3.14
CKD	3.693
Wood ash	2.377

Table 2: Specific gravity value for CKD, WA and OPC

and forms paste by consuming large amount of water itself.

B. Initial and final setting time

The setting time of the Portland cement is important as it also provides an indication of how long the cement will remain in plastic condition in addition to workability. The results show that initial setting time of various mix proportion (Fig 2) of CKD and WA is compared to the ordinary portland cement. In the different trial mix proportions of CKD and SCBA, the initial and final setting time increases along with increase in the CKD content. It is because of low rate of heat of hydration and formation of C-S-H gel takes more time compared to cement. This may be attributed to the coarseness and particle size irregularity of WA and lower specific gravity than cement which increases the viscosity of WA paste and thus, their water demand.

C. Specific gravity test

The specific gravity was determined by the Le Chatelier flask method. The test results shows that the specific gravity of cement kiln dust is slightly higher than the ordinary portland cement. (Table 2)

D. Compressive strength of the cube

The compressive strength for different mix proportions were tested as per Indian standard specifications [5]. From the compressive strength results, it is found out that the strength increases considerably when the percentage of cement kiln dust increases (Fig 4). Pavia and Regan (2010) [15] investigated the influence of cement kiln dust (CKD) on the properties of mortars made with a non-hydraulic binder of high available lime content (calcium lime – CL) and observed that the compressive strength increases with the CKD content with the exception of 5% CKD mortar. The 10% CKD addition resulted in the increase of 1.6% whereas the 15% and 20% CKD additions enhance strength by 7.3 and 8.3%, respectively. From the 7th day compressive strength, the result shows that there is reduced value of compressive strength. Due to low pozzolonic reaction and formation of C-S-H gel is minimum. The pores inside the cubes are also the main reason

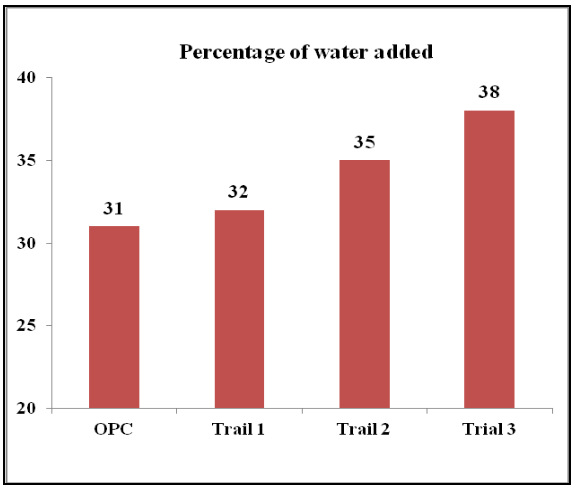


Fig 1: Consistency values showing trial mixes and percentage of water added during the test

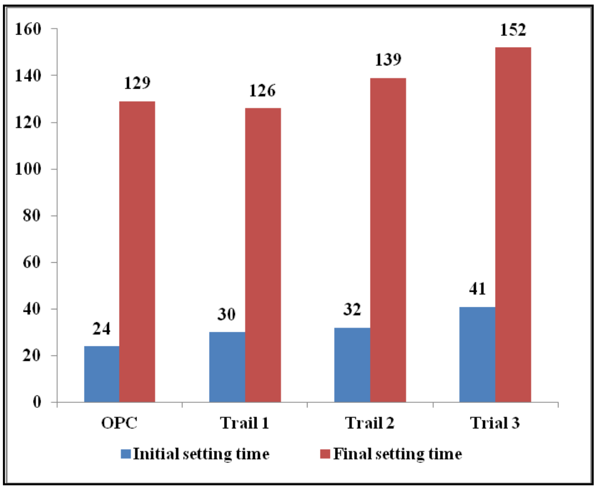


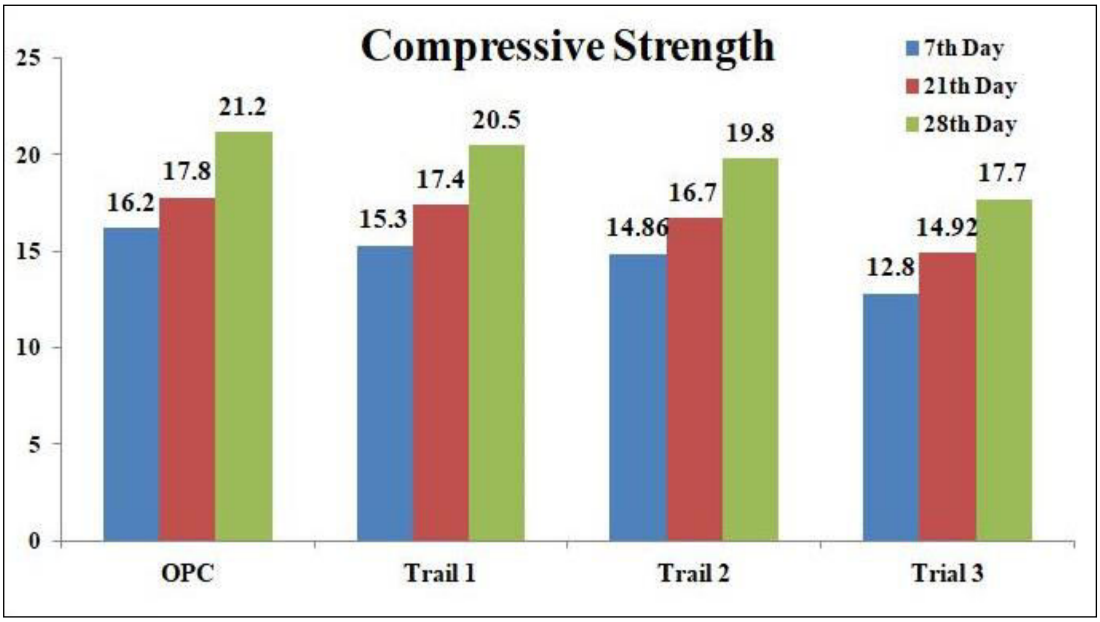
Fig 2: Initial and final setting time for different mix proportions

behind the reduction in the compressive strength of cubes (Trial 3 & 4). Before testing of cubes, it is noted that the outer surface of the cubes contains more number of pores. The pores are formed due to insufficient formation of C-S-H gel in the concrete cubes (Trail 3 and 4). Also from the results it clearly shows that compressive strength values decreases as cement kiln dust increases. Thereby we can effectively replace cement kiln dust and wood ash upto 10 percentage in the concrete.

Fig 3: Concrete cubes after testing

V. CONCLUSION

Using cement kiln dust and wood 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**.** The results of the standard consistency values show that there is increase in the consistency value by increase in the CKD percentage in mix proportion of the blended cement of CKD and WA. The silica in the CKD do not reacts well and forms paste by consuming larger amount of water itself. Also, the study shows that the initial setting time increases when there is a increase in CKD percentage, it is because the time taken for formation of C-S-H gel and process of heat of hydration is longer than the cement. The experimental result shows that the decrease in the compressive strength with use of cement kiln dust. The reason for low strength (Trial 3 and 4) 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. Therefore, with the use of cement kiln dust in partially replacement of cement upto 10 percentage, we can reduce the consumption of cement. Also it is best use of wood ash instead of land filling and make environment clean. CKD and wood ash can be effectively utilized in partial cement replacements leads to the reduction of cement demand, thus, reduce the demand of energy and carbon dioxide emission.

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