# Kiln-Dust as Partial Replacement of Cement in Concrete

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**Abstract**

*This research investigates the strength characteristics of concrete made with cement-kiln-dust with a view to determine the influence of replacing certain percentage of ordinary Portland cement with kiln-dust in cement kiln-dust concrete. The research was carried out in accordance with British standard BS (812, 882, 1881 and 4550). The kiln-dust was mechanically grounded into powder with grinding machine and sieved with a stack of BS sieve. The powdered kiln-dust was mixed with ordinary Portland cement in three different proportions of 10%, 20% and 30% content of kiln-dust which was used for experiment. Two hundred and forty 100mmX100mm concrete cubes were casted, cured and crushed including the controls specimens to failure to determine the compressive strength. The result of 28$^{th}$ day compressive strength for 10%, 20% and 30% replacement of OPC with kiln-dust were 27.5N/mm$^2$, 26.66N/mm$^2$ and 26.57N/mm$^2$ respectively. The water cement ratio for the mix proportion was 0.66, 0.75 and 0.87 for 10%, 20% and 30% replacement. The research concludes that OPC can be replaced with 10%, 20% and 30% of kiln-dust content in concrete.*

***Key words:*** *Kiln-dust, Compressive strength, Concrete.*

## 1. Introduction

Most developing countries like Nigeria have been suffering from an acute shortage of construction materials, principally because of the ever increasing demand for new construction works. The continuous demand for new construction works has triggered a continual increase in the cost of conventional building materials like cement.

The construction industry depends heavily on cementeous materials as binding agents in her operation to develop shelters and roads infrastructural works. Many cementeous materials has been used as binding agents in concrete, mortar and sandcrete block but the most commonly used are cement and bitumen [2].

In Nigeria, cement is the generally used binder for construction works. Thus the demand for cement in Nigeria became higher than the supply and this has jacked up the price of cement beyond the level that an average income earner in Nigeria can afford [3]. This situation has necessitated the development of alternative and cheaper materials like kiln-dust, Rice-husk, Groundnut shell ash and other pozzolanas to mention a few to replace cement in concrete, mortar and sandcrete blocks [5 & 3].

The idea of using waste materials like Kiln-dust, rice-husk and groundnut shell ash as an alternative to cement have long been experimented. Apart from saving the cost of disposal, their use in construction protects the environment from pollution which could be harmful to human life [4 & 1]. Kiln-dust sometimes known as precipitator's dust is produced abundantly during the production process of ordinary Portland cement (OPC).

The dust is a waste product. Its chemical and physical composition varies from plant to plant. These variations are due to the variation in the raw materials used, location and types of collection used [1]. The behavior of the kiln-dust generally governed the choice of collection of the material for any construction work [1].

This research work was primarily informed as a result of forces of demand in the conventional cement which triggered the price of Portland cement in Nigeria beyond the reach of an average income earner in Nigeria. The knowledge of the practical usefulness of the kiln-dust will go a long way to benefit contractors, researchers as well as the society at large. However, the fundamental question to be ask here is, suppose local waste material like kiln-dust was used as a partial replacement of cement in concrete for construction, could it have performed

better than conventional cement in terms of strength, durability and cost wise?

This research is aimed at providing an answer to this question. The specific objectives of this research includes

1. To determine the physical and chemical composition of the kiln- dust

2. To determine the influence of kiln-dust on the strength characteristic of the cement kiln-dust concrete

3. To determine the required percentage content of ordinary Portland cement(OPC) that can be replace with kiln-dust in cement-kiln- dust concrete for high strength concrete.

4. To achieve these set objective, series of experiment where carried out as described in the next section.

## 2. Materials and Method

### 2.1 Material Collection

A number of materials where collected and used in the course of this study. The materials include: kiln-dust, fine aggregate (sand), coarse aggregate (crushed stoned), ordinary Portland cement (OPC) and water. The kiln-dust was obtained from dangote cement in gboko, formal benue cement company (BCC). The fine and coarse aggregate where obtain from flooded pit and river in jos where the research was conducted.

### 2.2 Experimental Procedures

The experiment carried out for this research where group into two, the preliminary experiments and the main experiments.

### 2.2.1 Preliminary experiment

The quantity of the kiln-dust collected was grounded mechanically into powdered from using grinding machine. The powder was sieve through a stack of BS sieve size 300um, 150um, and 75um using mechanical sieve shaker to shake for 5 minute. Only powdered particles that pass through the 75um standard BS sieve (No 200) was collected and used for this experiment. The fine aggregate was natural sand from flooded pits which was of grading zone 1 of [7 & 8]. The coarse aggregate (crushed stone) was graded as satisfies [7] requirement for concrete graded coarse aggregate. Other preliminaries and test carried out include: apparent specific gravity of the kiln-dust, bulk density test, water absorption test, setting time test and chemical composition test as contained in the test result bellow.

### 2.2.2Main/major experiment

For the purpose of this research, three mix proportion of cement-kiln-dust concrete with 10%, 20% and 30% content of powdered kiln-dust were used for the experiment. From the water absorption test, the appropriate water cement ratio was decided for each mix proportion.

The materials (gravel, sand, cement, kiln-dust and water) were mixed together manually between five to ten minute (5-10 min) for each mix proportion and a uniform mix was achieved. Slump test for all the mix proportion were carried out according to [6]. A total of 240 cubes were casted for the three different mix proportions (10%, 20% and 30%) and for the control specimen. The specimens were cast in 100mm x 100mm steel cube moulds at ambient average room temperature of 32$^{o}$C which is higher than recommended temperature of 21.11$^{o}$C by the [13]. All the specimens in the cubes were compacted according to [9].

After 24hours, the mould was removed from the specimens, and the specimens are cured in a curing tank using ordinary tap water in accordance with [8]. The curing was done for 7, 14, 21, 28, and 90 days. At the end of each curing period, 15 cubes for each mixed proportion including the control mix will be removed from the curing tank and crushed manually to determine their compressive strength. Details of the result are shown on the next section.

Table 1.0 Quantity of materials in (kg) per cubic meter.

| material | Control mix | 10% | 20% | 30% |
|---|---|---|---|---|
| | 0% replacement | replacement | replacement | replacement |
| Sand | 8.365 | 8.365 | 8.365 | 8.365 |
| Gravel | 26.722 | 26.722 | 26.722 | 26.722 |
| Water | 0.705 | 0.911 | 0.930 | 0.971 |
| Cement | 1.253 | 1.127 | 1.002 | 0.876 |
| Kiln-dust | 0.00 | 0.125 | 0.251 | 0.377 |

## 3. Results and Discussion

This section presents the result of both preliminary test and the main test carried out in this research in a tabular form. The result of each the main test is presented in a separate table and discussed accordingly.

Table 2.1 Physical Properties of Materials.

| Property | Kiln-dust | Sand (from flooded pit) | Gravel | Cement |
|---|---|---|---|---|
| Apparent specific gravity | 2.72 | 2.50 | 2.67 | 2.59 |
| Sieve analysis | - | Zone 1 | Size 20mm | - |
| Finness modulus | 0.22 | - | - | 0.26 |
| Loose bulk density | - | - | 1337kg/m$^3$ | - |
| Compacted bulk density | - | - | 1413kg/m$^3$ | - |
| Water absorbtion | 40% | - | - | - |
| Initial setting time | 1hr 38min | - | - | 1hr 12mins |
| Final setting time | 8hr 56min | - | - | 4hrs 38mins |

Table 2.2 Chemical composition

| Kiln-dust | Percentage present | Cement | Percentage present |
|---|---|---|---|
| CaO | 54.63 | CaO | 61.50 |
| SiO2 | 17.84 | SiO2 | 17.25 |
| $Al_2O_3$ | 5.14 | $Al_2O_3$ | 7.12 |
| $Fe_2O_3$ | 3.44 | $Fe_2O_3$ | 2.50 |
| MgO | 2.64 | MgO | 1.61 |
| $SO_3$ | 2.24 | $SO_3$ | 1.23 |
| NaO | 0.43 | NaO | 0.55 |
| $K_2O$ | 0.38 | $K_2O$ | 0.32 |
| Loss in ignition | 13.26 | | 7.85 |

Source (field data) Soroka (1979)

The summary of the result in table 2a and 2b of the test carried out indicate compliance with standard of [7] for sieve analysis of fine and coarse aggregate. The specific gravity and water absorption satisfy [7 & 12]. The initial and final setting time of the kiln-dust was long but still within the stipulation of BS812. The bulk density (loose and compacted) of 1337kg/m$^3$ and 1413kg/m$^3$ indicate that the granite used for the experiment is of heavy weight since this values falls outside the value of 300 to 1200kg/m$^3$ specified by [7] for light weight aggregate.
The chemical composition shows that the percentage of Cao, Sio3and $Al_2O_3$ present was up to 70% indicating the kiln-dust can be used as cementeous material to partially replace cement in construction works.

Table 3. Workability test

| Kiln-dust content (%) | Slump (mm) | Compaction factor |
|---|---|---|
| 10% replacement | 45 | 0.93 |
| 20% replacement | 43 | 0.92 |
| 30% replacement | 38 | 0.92 |

The result of the slump test and compaction factors shown above on fresh concrete indicated concrete ranging from low to high workability. This result was within the specification of [6].

Table 4. Variations with Age of Compressive Strength

| w/c ratio | OPC | %of OPC replaced with kiln dust | Compressive strength ($N/mm^2$) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 7 days | 14 days | 21 days | 28 days | 90 days |
| 0.45 | Control mix | 0 | 18.30 | 24.61 | 28.52 | 31.85 | 32.30 |
| 0.66 | | 10 | 15.55 | 20.55 | 24.15 | 27.50 | 28.62 |
| 0.75 | | 20 | 13.87 | 19.38 | 23.86 | 26.66 | 27.40 |
| 0.87 | | 30 | 10.20 | 14.81 | 20.34 | 26.57 | 26.96 |

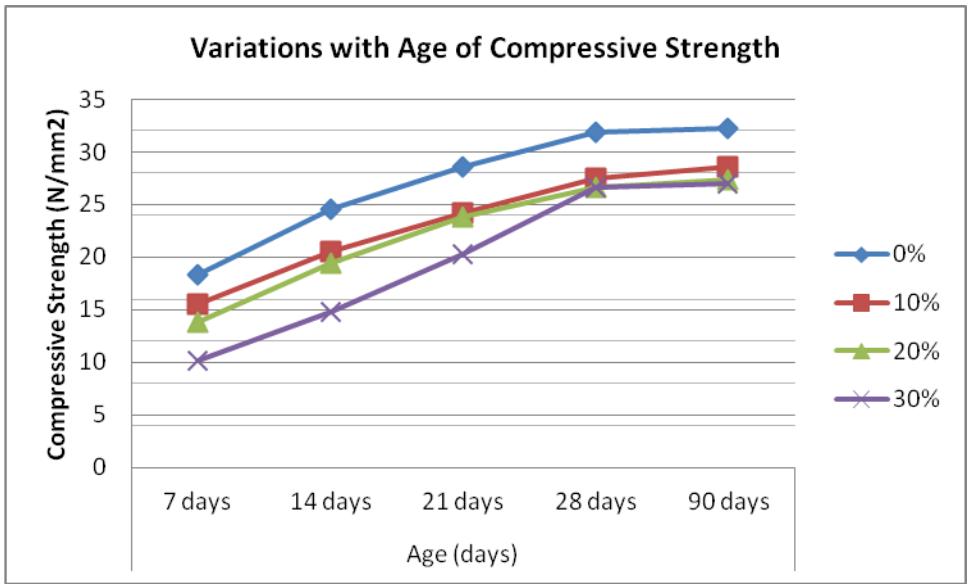
The result of compressive strength shown in table 4 reveals that at 28 days and 90 days of age, 0% (100% ordinary Portland cement) replacement gave the highest value of compressive strength of ($30.85N/mm^2$ and $31.0N/mm^2$ ) among all the mix proportions, but the strength decreases with an increase in the percentage of replacement by kiln-dust. For instance the $7^{th}$ day's strength of 10% replacement with kiln-dust was 85% of the 0% replacement and the $28^{th}$ day strength of 10% replacement with kiln-dust was 84% of 0% replacement. It was observed that in all the mix proportions, only the mix with 10% replacement attained 60% of its 28 day strength at 7 day. According to [13] concrete is expected to attain 60% of its 28 day compressive strength at 7 days. However, all the mix proportion (10%, 20% and 30% replacement) attained their expected compressive strength at 28 days. Similarly, there was a substantial difference between the $7^{th}$ day and $28^{th}$ day compressive strength for all the mix proportion. This was likely due to increase in hydration of the kiln-dust which normally occurs at a later age. This statement can be confirmed from the setting time period in table 29. With increase in age, more calcium hydroxide (a byproduct of ordinary Portland cement's hydration) is utilized by kiln-dust to produce more binding materials which will subsequently lead to more strength of the concrete [11]. It was also noticed that as the percentage of the ordinary Portland cement being replaced increases (i.e. as the kiln-dust content increase) the $28^{th}$ day and $90^{th}$ day compressive strength of the concrete decreases. Though for concrete grade C25, C30 respectively for all the mix, it was observed that the highest strength obtained on $28^{th}$ day was $27.50N/mm^2$ which was from 10% replacement and the lowest was $26.27N/mm^2$ which was from 30% replacement with kiln-dust. The rate of strength gain with age of the concrete is shown in table 6.

Table 6: Rate of Strength Gained with Age.

| W/C ratio | OPC as control mix | % of OPC replaced with kiln-dust | Age (in days) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 7 | 14 | 21 | 28 | 90 |
| 0.45 | 100% OPC | 0 | 0 | 6.31 | 3.71 | 3.33 | 0.45 |
| 0.66 | | 10 | 0 | 5.00 | 3.60 | 3.35 | 1.12 |
| 0.75 | | 20 | 0 | 5.51 | 4.48 | 2.80 | 0.74 |
| 0.87 | | 30 | 0 | 4.61 | 5.53 | 6.23 | 0.39 |

From the table 6 above, the control mix (100% OPC) and 10% replacement with kiln-dust indicate that the rate of strength gain decreases as the age of the concrete increases while 20% and 30% replacement with kiln-dust have no particular pattern.

Fig 1. Variation in Compressive Strength of Concrete with Age for the control mix and the entire % Replacement.




## 4. Conclusion

Based on the result of the test carried out on the compressive strength of the cement-kiln-dust concrete and the preliminary test carried out on the following conclusion were drawn

1. Ordinary Portland cement can be replaced with 10%, 20% and 30% with kiln-dust in concrete and still perform well as 0% replacement (100% cement).
2. The kiln-dust required high water cement ratio and longer period of setting time as compared to conventional OPC
3. The compressive strength of cement kiln-dust concrete decreases with increase in the percentage content of the kiln-dust
4. The highest compressive strength (28.62N/mm$^2$) was obtained from 10% replacement of OPC with kiln-dust at 90 days of age.

## 5. Recommendation

Based on the findings of this research work, it is recommended that further researches be carried out to establish the maximum percentage of OPC that can be replaced with kiln-dust in concrete. It is also recommended t hat similar research should be carried out in mortar.



## 6. References

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