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# Economic and Environmental Reliable Concrete Incorporating Sawdust Ash as an Alternative of Cement in Concrete Production

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***Abstract*: This study examined the physical properties of concrete as well as the chemical composition of sawdust ash (SDA) to ascertain its approval as a pozzolanic material or concrete. The and compressive strength, Density and slump value, setting time were tested from hardened and fresh concrete mixes respectively, by adding 5%, 10%, 15%, 20%, 25% and 30% by weight of ordinary Portland cement with SDA. The concrete cubes were tested at the ages of 7, 14, 21, and 28 days. Chemical analysis test on SDA revealed that the material is a viable pozzolan due to the combination of major constituents such as $SiO_2$, $Al_2O_3$ and $Fe_2O_3$ is greater than 70 as recommended by approved standards. The slump value lessened as the inclusion of SDA increased at all percentages. It was observed that SDA addition to the concrete mix reduced the workability if compared to the control mix of (0% SDA). Also, the density of the concrete cubes increased but not significantly. At 28 days curing age, and 5% SDA incorporation, the concrete had a compressive strength of 28.8N/mm$^2$ which met the standard of a normal concrete.**

***Keywords*: Sawdust ash, Compressive strength, Workability, Pozzolanic material, Setting time.**

## 1. Introduction

A major issue emerging from the broad utilization of wood ash and timber handling squander as aggregates in concrete and biomass used in power generation is related to the fiery debris created in noteworthy amounts as a reuse product from the burning of such forestry. Moreover, the utilization of ranger service and timber item fabricating squander such as sawdust, woodchips, wood bark, sawmill scraps and difficult chips as fuel source for the generation of electrical control offers an exceedingly productive strategy of transfer for the previously mentioned squander materials. In Europe, particularly Portugal, two units of pilot biomass-fuelled control plants have been built for the generation of power in arrange to supplement the control request of the national electric gridlines nearby with other ordinary control plants that utilize fossil powers.

As wood waste ash comprises of exceedingly fine sizes of matter, which can be effectively rendered airborne by winds, such a medium of disuse transfer may result in ensuing issues, specifically, respiratory wellbeing issues to inhabitants staying close to the transfer location of the wood ash material. Also, defilement of groundwater assets can moreover be anticipated to happen from the filtering of the overwhelming metal substance of fiery debris or by leakage of rainwater (Udoeyo, Inyang, Young, & Oparadu, 2006) and (Raheem, Olasunkanmi, & Folorunso, 2012).

Therefore, the use of wood ash as a landfilling material requires proper treatment and disintegration since this material is non-biodegradable and could lead to environmental other environmental crises. Subsequently, such a strategy of transfer is uneconomical over the long term. As a result of the uneconomical nature of the reuse of these materials as a land filing agent, it has been studied by several pieces of research that they can be best used as concrete material when either as alternative fine aggregate or cement.

In expansion, the recent rise within the concrete world has caused a gigantic increase in the request for cement which is an important aggregate of concrete. The generation of cement includes a seriously utilize raw natural resources such as limestone, whereas at the same time, discharges tall amounts of carbon dioxide into the air. Studies uncover that for the generation of each 600 kg of cement, roughly 400 kg of carbon dioxide gas is discharged into the environment. The expanded request of cement suggests a better rate of natural disintegration due to the limestone extraction exercises, a better necessity of fossil fills and a higher rate of greenhouse gas release. Hence, consolidation of forestry waste as cement or partial replacement of cement in the manufacturing of concrete will be advantageous not as it were in natural terms for concrete material but too in generation costs of the previously mentioned materials. However, this study is focused on generating an economic and environmental reliable concrete incorporating sawdust ash as an alternative of cement in concrete production.

## 2. Review on studies of wood ash as concrete aggregate

The study of (Teixeira, Camões, & Branco, 2019), considered the behaviour of concrete with 20, 49 and 60% wood fly fiery debris as a concrete constituent. The wood fly cinder was extracted by burning of timbers and paper industry. The researchers made a comparison with a routine concrete and with concrete with same cement substitution of wood fly ash by weight. It was examined a few environmental factors, like as: worldwide warming, ozone layer consumption, Fermentation Potential, Eutrophication Potential, Arrangement Potential of Tropospheric ozone and Abiotic Consumption Potential of Fossil Resources. They observed that with the increment on the wood fly ash quantity, the values of the environmental indicator diminished. Concluding that concretes made with wood fly fiery debris had distant properties compared to that made from coal fly ash.

Although, the results showed that the behaviour of wood fly ash concrete is very similar to the coal fly ash concrete, which is the most pozzolanic material used in the world. In terms of durability, it was verified that WFA improved the most of the durability characteristics with the exception of carbonation resistance. However, more experimental analysis needs to be developed in terms of wood fly ash concrete durability. Results suggested that using wood fly ash to replace cement is a valuable sustainable option for concrete production. This manuscript discusses the key factors and attempts to provide new information about the application of the wood fly ash on concrete (Horsakulthai, Phiuvanna, & Kaenbud, 2011).

In the study of (Do Couto, Nogueira, Sandoval, Schwantes-Cezario, & Morales, 2019), they studied the Valorisation of wood fly ash on concrete. The findings from this study revealed that higher proportions of wood fly ash created an adverse effect on the concrete properties when compared to the controlled concrete. In spite of the fact that, the result of wood fly ash concrete is exceptionally comparative to the coal fly ash concrete (control mix), which is the foremost pozzolanic fabric utilized within the world. In terms of durability, it was confirmed that WFA made strides the foremost of the durability characteristics with the exemption of carbonation resistance. Be that as it may, more test investigation must be created in terms of wood fly fiery remains concrete strength. Their study recommended that utilizing wood fly ash to supplant cement could be an important feasible alternative for concrete generation. This original copy talks about the key variables and endeavours to supply unused data almost the application of the wood fly ash on concrete.

It would seem clear that (Udoeyo, Inyang, Young, & Oparadu, 2006) investigated the effect of wood ash on properties of fresh concrete manufacture by substituting cement with 5, 10, 15, 20, 25 and 30% wood ash by weight of cement. The result from their study showed that as the percentages of wood ash increased from 5 to 30%, the slump value reduced noticeably. At 20, 25 and 30% wood ash inclusion in the concrete mix, the fresh concrete property (slump value) were equal to zero respectively. Also, at 5, 10 and 15% wood ash addition, the slump values were recorded as 8, 5 and 2.5mm respectively. Comparing these values to the control mix whose slump value is 62mm, it can be concluded that incorporating wood ash in concrete mix can reduce the workability of fresh concrete. Their findings are in accordance with the observations of (Cheah & Ramli, 2011).

According to (Fava, Naik, & Pierpaoli, 2018), they studied the compressive strength of hardened concrete produced by partially replacing wood ash with cementious constituents at increasing percentages of 5, 8 and 12% by weight of cement. The result from their study discovered an appreciable increase in compressive strength of wood ash concrete cured for 28 and 365days respectively compared to the control concrete. At 28 days and 365 freshwater curing ages, the control mix has a compressive strength 34Mpa and 44Mpa respectively. While, the wood ash concrete had its maximum compressive strength of 36Mpa and 46Mpa at 28 days curing ages. In summary, their result showed a slight increase in compressive strength value ranging from 1 to 2% increase.

A related study has been carried out by (Horsakulthai, Phiuvanna, & Kaenbud, 2011). They explored the corrosion resistance of bagasse-rice husk-wood ash blended cement concrete by impressed voltage by partially replacing with BRWA at the percentage by weight of 10% and 20% by weight of binder.

After several laboratory experiment, it was discovered that at 20% BRWA replacement, the concrete had the largest value of compressive strength at 7 to 180 freshwater curing ages. Also, increase in the content of BRWA reduced concrete chloride infiltration. The diffusion coefficient was dwindled by 30–40% and 65–70% for concrete containing 10% BRWA and 20% BRWA compared to the conventional concrete produced from same mix proportion.

As has often been pointed out (Torkaman, Ashori, & Sadr Momtazi, 2014) investigated the use of wood fiber waste, rice husk ash, and limestone powder waste as cement replacement materials for lightweight concrete blocks. In their study, cement was partially replaced with 25% of wood fiber waste, rice husk ash, and limestone respectively. Result from laboratory studies on concrete revealed that compressive strength of the concrete blocks due to the filler effect lessened with increasing cement inclusion. However, the findings revealed the impact of 25wt% substitution of RHA and LPW with Portland cement do not show a sudden delicate break in concrete cube at different loading. In their conclusion, they suggested the use of these materials as alternative to cement in concrete. Although, the use of such material such be limited to producing concrete member carrying low magnitude structural loading such as lintel beams.

## 3. Materials and methods

### *A. Materials*

1) Sawdust ash - Sawdust Ash (SDA): The Sawdust used for this study was obtained from marine base sawmill Port Harcourt, Rivers State. The sample was carefully collection to avoid mixing the sawdust with sand. The sawdust was heated and burnt into ashes by open burning in a metal container placed right inside a kiln firmly closed to avoid escape of smoke. The ash was grinded using hand grinding machine to the required level of fineness and sieved through

Table 1
Concrete Mix Proportion

| % Replacement | Cement (kg) | Saw dust Ash (kg) | Sand (kg) | Granite (kg) | Water (kg) | W/C |
|---|---|---|---|---|---|---|
| 0 | 14.58 | 0 | 29.16 | 58.32 | 7.29 | 0.5 |
| 5 | 13.88 | 0.7 | 29.16 | 58.32 | 7.29 | 0.5 |
| 10 | 13.12 | 1.5 | 29.16 | 58,32 | 7.29 | 0.5 |
| 15 | 12.38 | 2.2 | 29.16 | 58.32 | 7.29 | 0.5 |
| 20 | 11.66 | 2.29 | 29.16 | 58.32 | 7.29 | 0.5 |
| 25 | 10.93 | 3.65 | 29.16 | 58.32 | 7.29 | 0.5 |
| 30 | 10.21 | 4.37 | 29.16 | 58.32 | 7.29 | 0.5 |

425μm sieve in order to remove any impurity and larger size particles.


Fig. 1. Sawdust and sawdust ash after combustion

2) Coarse aggregate - The granite that was used for this research work is 20mm maximum size. It was sourced from a quarry in Port Harcourt in Nigeria.
3) Fine aggregate - The sand (sharp sand) used for the research work was sourced from Port Harcourt, rivers state, Nigeria. The impurity was removed and it conformed to the requirements of BS 882 (1992).
4) Ordinary Portland cement - The Ordinary Portland Cement (Dangote brand) was sourced from Port Harcourt, Rivers State and was conformed to the requirements of BS EN 197-1: 2000.
5) Water - The water used for the study was obtained from a sewage water tank in Civil Engineering Lab, at RSUST. The water is clean and free from any visible impurities. It conformed to BS EN 1008 (2002) requirements.

*B. Mix Design*

This mix ratio simply means one part of cement, two parts of fine aggregates and four parts of coarse aggregate to be used for a sample. This mixture shall be cured under three different curing conditions for 7, 14, 21 and 28days. Appropriate calculations of water, fine and coarse aggregates to be used are given below.

No of cubes = 72
Dimension of one mould = 150mm x 150mm x 150mm
Volume of ore cube = 0.15 x 0.15 x 0.15
= $0.003375m^3$
Density of concrete = $2400kg/m^3$
Mass of one cube = Density of concrete x volume of cube
= 0.003375 x 2400 = 8.1kg
Mass of 12 cubes = 12 x mass of 1 cube = 12 x 8.1 = 97.2kg
Because of voids in the material compaction, we give 5% void = $\frac{5}{100}$ x 97.2 = 4.86kg
Total mass of concrete = 4.86 + 97.2 = 102.06kg
Mass of constituent
Mix ratio 1:2:4 = 7
Mass of cement = $^1/_7$ x102.06 = 14.58kg
Mass of cement = $^2/_7$ x 102.06 = 29.16kg
Mass of $^3/_8$" gravel required = $^4/_7$ x 102.06 = 58.32
For water-cement ratio of 0.5
$\frac{w}{c} = 0.5$
Mass of water = 0.5 x 14.58 = 7.29kg
But 1kg = 1 litre
∴ Volume of water required = 7.29 litres

## 4. Results and Discussion

The chemical composition of SDA is an important property governing its suitability for use as pozzolanic material in blended cement and concrete. ASTM C618 (ASTM, 1998) defines pozzolana as a siliceous and aluminous material which possesses little or no cementitious properties but in finely divided form may react with portlandite from the hydration of cement to form a product with cementitious properties. By definition of ASTM C618 (ASTM, 1998), the presence of significant quantities of silica and alumina compounds in biomass fly ash or other type of finely divided powder is mandatory in order to qualify as pozzolana. Table 2 presents the chemical constituents that makes material suitable for use according to ASTM C618 (ASTM, 1988) as mentioned above.

Table 2
Major Constituents of SDA

| Element | Average Value (%) |
|---|---|
| CaO | 51.67 |
| $SiO_2$ | 18.02 |
| $Al_2O_3$ | 1.25 |
| $Fe_2O_3$ | 10.5 |

(Department of chemical/petrochemical, Rivers State University, 2015)

*A. Sieve analysis*

The materials were air dried in laboratory, the aggregate were sieved. The portion passing through 20mm and retained on sieve 5mm was used for the coarse aggregates. The fine sand used was those that passes sieve 4.75mm. The test was conducted in accordance to relevant codes ASTM C117 and BS (1992). The materials were specified in BS 8110 page 36. The purpose of drying the aggregates before sampling was to avoid lumps particles and to avoid clogging of fewer sieves.

Table 3
Grading of Coarse Aggregate

| Sieve size(mm) | % passing by weight | BS 882-92 Limits |
|---|---|---|
| 20 | 100 | 100 |
| 14 | 100 | 90-100 |
| 10 | 70 | 50-85 |
| 5 | 6 | 0-10 |
| 2.36 | 0 | --- |

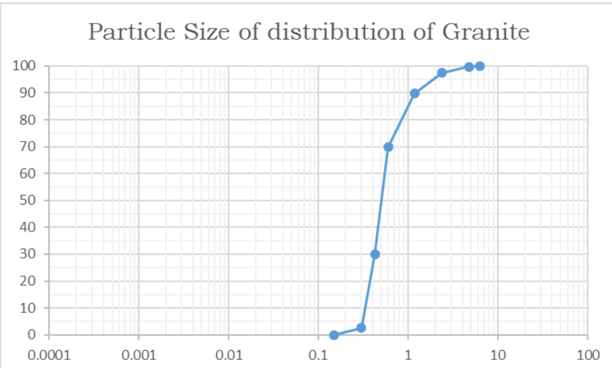


Fig. 2. Particle size distribution (PSD) curve for coarse aggregates

Table 4
Grading of fine aggregate

| Sieve size(mm) | % passing by weight | BS 882-92 Limits |
|---|---|---|
| 10.0 | 100 | 100 |
| 5.00 | 92 | 89-100 |
| 2.36 | 79.5 | 65-100 |
| 1.18 | 62.8 | 45-100 |
| 0.600 | 41.4 | 25-80 |
| 0.300 | 6.2 | 5-48 |
| 0.150 | 0.1 | 0-15 |

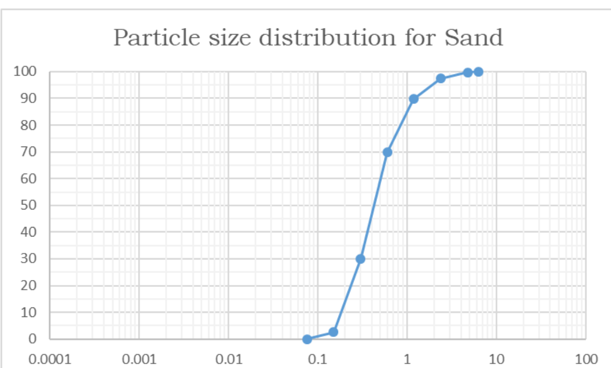


Fig. 3. Particle size distribution (PSD) curve for Fine aggregates

## B. *Workability*

The workability of concrete batches for different percentages of SDA using slump test is shown in Figure 5 and table 5. The mix samples with w/c ratio of 0.5 exhibited medium to high workability. It is obvious that workability of concrete reduces as the amount percentage of SDA increases. Concrete reduces, hence reducing the height of slump.

The addition SDA reduced the slump value of the concrete, with the same ratio. This shows that SDA absorbs moisture and this is due to the pozzolanic reaction that is taking place.

Fig. 4. Determination of Slump value on SDA fresh Concrete

Table 5
Effects of sawdust ash on the slump value

| Sawdust ash | Slump (mm) |
|---|---|
| 0% | 80 |
| 5% | 50 |
| 10% | 35 |
| 15% | 20 |
| 20% | 20 |
| 25% | 10 |
| 30% | 5 |

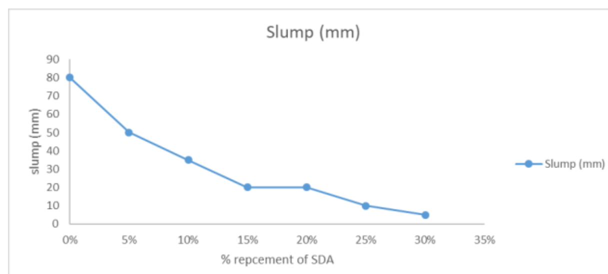


Fig. 5. Effect of SDA on the slump value

## C. *Bulk densities of concrete cubes*

The bulk densities of the concrete cubes cast at various days of curing are shown in Table 6 and Figure 6. The results show that the bulk density reduces as the percentage SDA increases. This could be attributed to the increase in voids in the concrete cubes as the percentage SDA increases. However, the bulk densities increase as the number of days of curing increases as the concrete cubes becomes denser.

Table 6
Bulk densities of concrete cubes with various percentages of SDA

| Saw dust ash replacement (%) | Bulk Density ($g/cm^3$) | | | |
|---|---|---|---|---|
| | 7 days | 14 days | 21 days | 28 days |
| 0 | 2.32 | 2.37 | 2.42 | 2.43 |
| 5 | 2.27 | 2.29 | 2.30 | 2.31 |
| 10 | 2.21 | 2.22 | 2.25 | 2.28 |
| 15 | 2.19 | 2.20 | 2.23 | 2.25 |
| 20 | 2.19 | 2.20 | 2.21 | 2.21 |
| 25 | 2.18 | 2.18 | 2.19 | 2.20 |
| 30 | 2.17 | 2.18 | 2.19 | 2.19 |

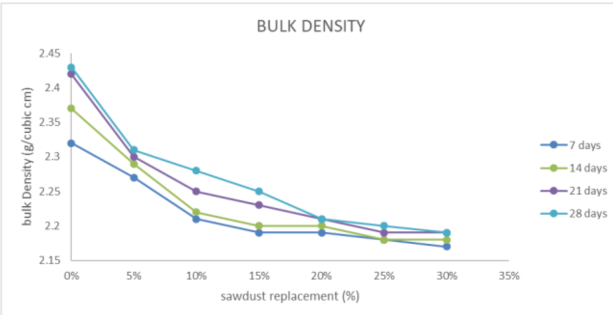


Fig. 6. Effect of SDA content on bulk density of concrete at different curing age

### D. *Compressive strength*

The effect of curing age on the compressive strength of Sawdust Ash concrete is shown below in table 7 and figure 8 for the various percentage replacements and their various densities.

From the result at 7days for 0% replacement decreased from 16.88N/mm$^2$ for Ordinary Portland Cement (OPC) to 8.44N/mm$^2$ for 30% replace with Sawdust Ash. Similar trend was observed at 14days of 0% replacement concrete from 18.66N/mm$^2$ decreased to 9.77N/mm$^2$ at 30% replacement also for 21 days 0% replacement from 22.22N/mm$^2$ decreases to 11.55N/mm$^2$ at 30% replacement and 28days, the control concrete which is 0% replacement has 31.11N/mm$^2$ while 30% Sawdust Ash replacement has 15.10N/mm$^2$. Therefore, these results indicate that concrete containing Sawdust Ash gain strength slowly at each curing age.

The two sawdust Ash percentage replacement concrete that has highest compressive strength that can be compared with the compressive strength of the control concrete is 5%, and 10% replacement at various curing age. Since all the specimen meet the minimum of 26N/mm$^2$ after 28days of curing recommended by BS 5254(1976) for masonry cement, Sawdust Ash concrete could be used for general concrete works where strength is of less importance, such as in mass concrete, floor screed and mortar. The compressive strength generally increase the curing period and decreased with increase amount of Sawdust Ash, therefore only 5% and 10% Sawdust Ash replacement can be substituted to achieve maximum strength. The finding of this study is making mends with that discovered by (Alex, Dhanalakshmi, & Ambedkar, 2016).

Fig. 7. Preparing SDA concrete cubes for compressive strength test

Table 7
Compressive strength of concrete with sawdust ash

| Sawdust ash replacement % | Comprehensive strength | | | |
|---|---|---|---|---|
| | 7 days | 14 days | 21 days | 28 days |
| 0 | 16.88 | 18.66 | 22.22 | 31.11 |
| 5 | 16.00 | 17.77 | 20.00 | 28.8 |
| 10 | 14.22 | 16.88 | 18.66 | 26.40 |
| 15 | 15.11 | 16.00 | 17.33 | 22.22 |
| 20 | 13.33 | 14.22 | 16.00 | 20.00 |
| 25 | 10.66 | 11.11 | 14.22 | 18.66 |
| 30 | 8.44 | 9.77 | 11.55 | 15.11 |

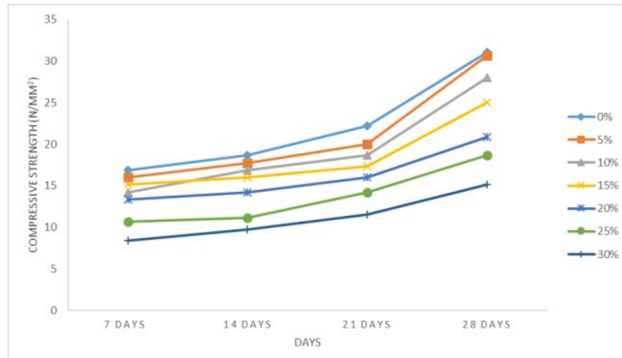


Fig. 8. Effect of SDA content on the compressive strength of concrete

### E. *Setting time of sawdust ash concrete*

Table 8
Average Setting Times for OPC-SDA mix

| % Replacement | Initial Setting Time (Mins) | Final Setting Time (Mins) |
|---|---|---|
| 0 | 65 | 83 |
| 5 | 90 | 210 |
| 10 | 253 | 330 |
| 15 | 275 | 375 |
| 20 | 289 | 401 |
| 25 | 305 | 425 |
| 30 | 326 | 442 |

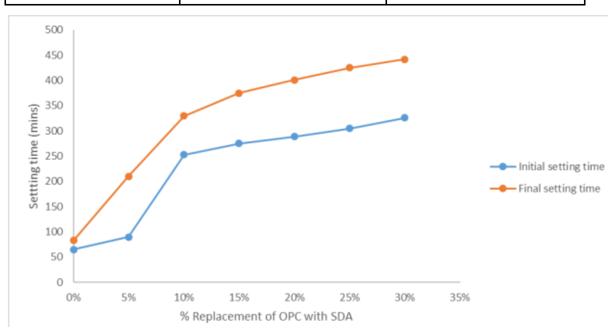


Fig. 9. Setting time of sawdust ash concrete

Table 8 and figure 9 below shows the setting time for each of the percentage replacement in Sawdust Ash concrete. The results are the average setting times of various OPC-SDA combinations. The figure below is a plot of the initial and final setting times versus the various percentage replacements. The setting times increases with increase in the amount of the SDA. The initial setting times increases from 1 hour, 5 minutes at 0% to 3 hours, 26 minutes at 30% replacement. While the final setting times increases from 1 hour, 26 minutes at 0% replacement to 4 hours, 22 minutes at 30% replacement. However, BS12 (1978) recommend initial and final setting times not to be more than 45 minutes at 10 hours respectively of which the SDA-OPC paste passes the final setting times.

## 5. Findings and Conclusion

1. The compacting factor values of the concrete reduced as the percentage of the SDA increased.
2. The bulk densities of concrete reduced as the percentage SDA replacement increased.
3. The compressive strength of concrete reduced as the percentage SDA replacement increased.
4. Sawdust Ash (SDA) is a suitable material for use as pozzolan, since it satisfied the requirement for such a material by having a combined ($SiO_2$ + $Al_2O_3$ + $Fe_2O_3$) of more than 70%.
5. Concrete becomes less workable as the SDA percentage increased, meaning that more water is required to make the mixes more workable. This simply means that SDA concrete has higher water demand.
6. The compressive strength generally increased the curing period and decreased with increased amount of SDA, therefore only 5% and 10% substitution is adequate to enjoy maximum benefit of strength gain.

## References

[1] Alex, J., Dhanalakshmi, J., & Ambedkar, B. (2016, 11 30). Experimental investigation on rice husk ash as cement replacement on concrete production. *Construction and Building Materials*, 127, 353-362.
[2] ASTM C 618 (1991), Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral Admixture in Portland Cement Concrete, Annual Book of ASTM Standards, Philadelphia, USA.
[3] BS 1881: Part 102 (1983), Methods for determination of Slump, British Standard Institution, London.
[4] BS 1881: Part 103 (1983), Methods for determination of Compacting factor, British Standard Institution, London.
[5] BS 5224 (1976), Standard Specification for Masonry Cement, British Standard Institution, London.
[6] Cheah, C., & Ramli, M. (2011, 5). The implementation of wood waste ash as a partial cement replacement material in the production of structural grade concrete and mortar: An overview. *Resources, Conservation and Recycling*, 55(7), 669-685.
[7] Fava, G., Naik, T., & Pierpaoli, M. (2018). Compressive strength and leaching behavior of mortars with biomass ash. *Recycling*, 3(3).
[8] Horsakulthai, V., Phiuvanna, S., & Kaenbud, W. (2011, 1). Investigation on the corrosion resistance of bagasse-rice husk-wood ash blended cement concrete by impressed voltage. *Construction and Building Materials*, 25(1), 54-60.
[9] Raheem, A., Olasunkanmi, B., & Folorunso, C. (2012, 12 3). Sawdust Ash as Partial Replacement for Cement in Concrete. *Organization, Technology and Management in Construction: An International Journal*, 4(2).
[10] Teixeira, E., Camões, A., & Branco, F. (2019, 6 1). Valorisation of wood fly ash on concrete. *Resources, Conservation and Recycling*, 145, 292-310. Elsevier B.V.
[11] Torkaman, J., Ashori, A., & Sadr Momtazi, A. (2014). Using wood fiber waste, rice husk ash, and limestone powder waste as cement replacement materials for lightweight concrete blocks. *Construction and Building Materials*, 50, 432-436.
[12] Udoeyo FF, Inyang H, Young DT, Oparadu EE. 2006. Potential of wood waste ash as an additive in concrete. *Journal of Materials in Civil Engineering* 18(4), 605–11.