Physiognomies and Strength Investigation of Concrete Part Blended by Wood Ash

Smruti Saswati Dash¹, Siba Prasad Mishra* and Sagarika Panda¹

¹Civil Engineering Department, Centurion University of Technology and Management, Bhubaneswar, India.

Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2021/v11i530416

Editor(s):
(1) Dr. Wen-Cheng Liu, National United University, China.

Reviewers:
(1) Shaymaa Alsamia, University of Kufa, Iraq.
(2) Ali A. Khamees, Thi-qar University, Iraq.
(3) Shaoyun Pu, Southeast University, China.

Complete Peer review History: https://www.sdiarticle4.com/review-history/71262

Original Research Article

Received 10 May 2021
Accepted 16 July 2021
Published 20 July 2021

ABSTRACT

Introduction: Cement during its manufacture emits enormous CO₂ and heat to the atmosphere and deteriorate the environment affecting its sustainability. Wood ashes (WA) are the by-products wood based power plants, timber mills as wood dust, barks from forestry, paper industry, and forest fire are simple wastes and are noxious to atmosphere. Present study is investigating the strength and durability of concrete when blended with 0%, 10%, 30%, and 40% wood ash replacing cement to have these wastes effective waste management.

Methodology: The process of investigation is to find the chemical constituents of fly ash, and its suitability to part substitute cement by using X-ray fluorescent spectrometer (XRF), and digital compressive testing machine (CTM) and Universal Testing Machine (UTM) to verify the physical, chemical, and mechanical properties to assess appropriate strength of wood ash blended concrete (WABC).

Results: Strength characteristic at various proportion of mix of (WABC) on testing exhibited decreasing trend on increasing WA percent. The blended concrete exhibited the required compressive strength at 10% addition of WA and after curing for 28days. By utilizing wood ash as cement substitute the environment can be saved from black carbon and further deterioration.

*Corresponding author: E-mail: 2sibamishra@gmail.com;
Keywords: Cement substitute; Strengths of concrete; Wood ash; UTM; XRF-Spectrometer; volatile matter furnace.

1. INTRODUCTION

Various industrial wastes and by-products in ash form received from various industrial processes using wood as fuel which degrade the environment by producing CO$_2$ and other noxious gases. The wood ash waste management is a herculean task. Presently the basic constituent of concrete is cement which during its manufacture produces huge environmental deteriorating gases. Bio-diesel which is a renewable energy source can be extracted from wood scrap and produces huge wood ash wastes and so also from small scale boiler units in manufacturing process. Generally log of hard wood produce more wood ash than the soft wood. Wood ash (WA) have other uses are land filling, soil supplement, and like additive, metal recovery, cement substitute etc. Chee et al. [1], Ottosen et al. [2], Kanan et al. [3]

Many other industrials wastes such as construction and demolition wastes (C& D wastes), red mud, GGBS, fly ash etc. are tested for replacing cement in cement concrete production. So to ameliorate the disposal of wood waste, it is preferred to add wood ash as a part substitute of the cementous material, cement after testing the constituent studies, the ingredient distribution within concrete and the strength characteristics like Compressive strength tests, tensile strength tests, split tensile tests Ban et al. [4], Leroy et al. [4], Butt et al. [5], Leroy et al. [6], Faruqi et al. [7].

1.1 Carbon Foot Print and Cement Industry

Science daily has reported cement is one among the silent climate exterminator as it produces huge amount of GHG gas particularly Carbon dioxide during manufacture and concrete production. India consumed of 337MMT during 2018-2019, and predicted to surge up to 550MMT 2025, https://aeee.in/emission-reduction-approaches-for-the-cement-industry/. The cement industries yields $\approx$ 5% of global anthropogenic CO$_2$ emissions which constitutes chemical process 50% and 40% from burning clinker @ $\approx$800kg of CO$_2$ /MT of cement manufactured (Narayan S,https://www.linkedin.com/pulse/environmental-social-impacts-cement- industries-narayanan/). The environmental impacts are dust, CO$_2$ and environmental deterioration at quarry sites of limestone.

1.2 Objective of the Research

Review of literature warrants the following repetitive confirmation studies of cement concrete using wood ash as a blending material for cement in cement concrete. They are:

1. To know can wood waste ash (WA) replace concrete of M 20 grade chemically or structurally.
2. Can wood ash blended concrete (WABC) has similar workability like normal CC.
3. Can WABC meet the standards of mechanical properties such as compressive, splitting tensile and flexural strength as plain ordinary equal grade CC M-20.
4. To finalize the optimum doses of WA in % to substitute cement that can satisfy the grade of CC M-20
5. The success of retaining strength of WABC can allure RMC industries and save the environment from worsening.

1.3 Review of Literature

Cement concrete is main construction material of the modern civil architecture. Production of cement involves huge amount of noxious gas and Green House Gases (GHG) gas emissions like NO$_x$, SO$_2$, CO, CO$_2$ and many other noxious gases that pollute the air and health adversities. Attempts are made to replace cement by fly ash, Ground granulated blast furnace slag (GGBS) (Das and Mishra [8], Red mud (Nayak and Mishra [9]) and many other industrial wastes to down surge the use of cement. The wood ash waste is common from nature in the form of rice husk ash, Municipal solid waste ash, can be used to replace partly the cement in concrete. The properly incinerated wood ash has exceptional possibility to be deployed as a pozzolanic admixture that can activate the cementous materials, [10,11].

Many a materials have been tested as part substitute of cement in cement concrete (CC) like fly ash [Siddique, [12], Lahri et al., [13] silica fume [Lee et al. [14], Ahamed et al [15] pulverized fuel ash [Turker et al. [16], Jonida [17] volcanic ash [Kayali [18] rice husk ash
incinerated wood ash can be better substitute from the literature review it reveals that C114 and satisfy the standards imposed in ASTM followability, increases bleeding and subsidence reported that wood ash improves the self-cementitious property enances strength and durability of concrete when partly added. The problem of release of noxious gas to air, disposal of waste, and reduces environmental degradation, Yeoh et al. [23], Chopra et al. [24], Della et al. [25], Bheel et al. [19], Lo, Fang-C et al. [26].

Municipality solid waste ash (MSWA) was tested for its part replacement to cement in concrete. The MSW was burnt either by the method of Refuse-Derived Fuel (DRF) method or mass-burning procedure to yield in an incinerator where large particle remains at bottom and finer in the chimney. The bottom (grate) ash containing calcium (24-27%), silicates and small amount of alumina can be partly substituted to cement as admixture Meheta, [27], Damtoft 28], Lahri et al. [13].

Biomass ash is a by-product in coal based thermal power plant which cannot be disposed easily. It is observed that some of the dried vegetation burned ash has better similarity as pozzolanic materials than coal ash and can replace 20% cement in cement concrete. These wastes excreted from these power plants as by-product have problems of disposal and later deteriorates the environmental. The chemical and strength properties bio ash or coal ash blended cement have common properties and can be substitute cement up to 20% that meet the standards of ASTM C618 specification. The biomass-coal blended cements had similar compressive strengths as coal fly ash cements, Wang et al. [29], Tkaczewskal et al. [30], Garcia et. al. [31].

Several investigators worked on wood ash as supplementary cementitious material (SCM) for ordinary or self-compacting concrete (SCC). The optimum part replacement wood ash to cement was found to be 15% in the production of ordinary and self-compacting concrete, Abdullah, [32], and Subramaniam et al. [33]. Yang et al. [34] reported that wood ash improves the flowability, increases bleeding and subsidence and satisfy the standards imposed in ASTM C114 [35].

From the literature review it reveals that incinerated wood ash can be better substitute retaining the strength and durability mechanical properties of cement concrete. Present research deals with the similarity in chemical constituent, particle distribution at various proportions of mix, mechanical strength properties compressive, and tensile, of concrete.

2. METHODS AND METHODOLOGY

Wood ash when extracted from burning of waste wood has problems of disposal. About 70% are used for land filling ditches and underground places, 20% above the surface in dump yards and management for reuse as additives, fertilizers, metal recovery etc., NCASI bulletin [36], Elinwa et al. [37]. Whether the wood ash can replace cement in conventional ready mix concrete (RMC), then its properties like workability, water absorptivity, compressive strength (comp and split tensile), flexural rigidity, bulk density, durability tests like chloride and sulphate attacks, and acid resistance strengths for the normal and the blended concrete need to be verified. Also chloride and sulphate attack tests were conducted to assess the durability of the WABC. Before use of wood ash to substitute cement in cement concrete (CC), it is required to investigate the similarity in composition of fly ash (proven as a replacement) and wood ash. As the property of wood ash varies depending upon tree size, type of log, age of tree etc., there is necessity of knowing the combustion temperature, and hydrodynamics of the furnace and the type of tree cut to waste. For use of WA as a replacement of cement, the test to be conducted batch leaching of wood waste ash (WWA) which signifies toxicity on leaching of solid waste ash extracted on adding water (ASTM-D3987- [38])

The physical, chemical, compositional, mechanical properties of the WABC at various proportion of substitute by WA were obtained. The various tests for structural test conducted were characteristics like visual, chemical composition, and Mineralogy of wood ash. After finding the suitability to replace cement, the cement concrete (CC) was prepared by substituting cement by WA at various percentage of blending. The physical, chemical, mechanical strengths were to be found for M-20 grade concrete using various Indian standard specifications, ASTM, various codes, and laboratory procedures. The physical, compositional, structural, mechanical and mechanical properties of WA, Cement, concrete, the instruments and machines used were XRF

[Adesanya et al. [19] and corn cob ash (CCA) [Bheel et al. [19] and Subramaniam et al. [33]. Yang et al. [34] reported that wood ash improves the flowability, increases bleeding and subsidence and satisfy the standards imposed in ASTM C114 [35].]

Rice Husk Ash (RHA) or rice bran ash can be achieved in the process of incineration of rice husk at various temp., (within 700°C to 1000°C) evolving fine pozzolana materials having fine silica specific surface area (54 – 81Kg/m²). This property enhances strength and durability of concrete when partly added. The problem of release of noxious gas to air, disposal of waste, and reduces environmental degradation, Yeoh et al. [23], Chopra et al. [24], Della et al. [25], Bheel et al. [19], Lo, Fang-C et al. [26].

Municipality solid waste ash (MSWA) was tested for its part replacement to cement in concrete. The MSW was burnt either by the method of Refuse-Derived Fuel (DRF) method or mass-burning procedure to yield in an incinerator where large particle remains at bottom and finer in the chimney. The bottom (grate) ash containing calcium (24-27%), silicates and small amount of alumina can be partly substituted to cement as admixture Meheta, [27], Damtoft 28], Lahri et al. [13].

Biomass ash is a by-product in coal based thermal power plant which cannot be disposed easily. It is observed that some of the dried vegetation burned ash has better similarity as pozzolanic materials than coal ash and can replace 20% cement in cement concrete. These wastes excreted from these power plants as by-product have problems of disposal and later deteriorates the environmental. The chemical and strength properties bio ash or coal ash blended cement have common properties and can be substitute cement up to 20% that meet the standards of ASTM C618 specification. The biomass-coal blended cements had similar compressive strengths as coal fly ash cements, Wang et al. [29], Tkaczewskal et al. [30], Garcia et. al. [31].

Several investigators worked on wood ash as supplementary cementitious material (SCM) for ordinary or self-compacting concrete (SCC). The optimum part replacement wood ash to cement was found to be 15% in the production of ordinary and self-compacting concrete, Abdullah, [32], and Subramaniam et al. [33]. Yang et al. [34] reported that wood ash improves the flowability, increases bleeding and subsidence and satisfy the standards imposed in ASTM C114 [35].

From the literature review it reveals that incinerated wood ash can be better substitute retaining the strength and durability mechanical properties of cement concrete. Present research deals with the similarity in chemical constituent, particle distribution at various proportions of mix, mechanical strength properties compressive, and tensile, of concrete.

2. METHODS AND METHODOLOGY

Wood ash when extracted from burning of waste wood has problems of disposal. About 70% are used for land filling ditches and underground places, 20% above the surface in dump yards and management for reuse as additives, fertilizers, metal recovery etc., NCASI bulletin [36], Elinwa et al. [37]. Whether the wood ash can replace cement in conventional ready mix concrete (RMC), then its properties like workability, water absorptivity, compressive strength (comp and split tensile), flexural rigidity, bulk density, durability tests like chloride and sulphate attacks, and acid resistance strengths for the normal and the blended concrete need to be verified. Also chloride and sulphate attack tests were conducted to assess the durability of the WABC. Before use of wood ash to substitute cement in cement concrete (CC), it is required to investigate the similarity in composition of fly ash (proven as a replacement) and wood ash. As the property of wood ash varies depending upon tree size, type of log, age of tree etc., there is necessity of knowing the combustion temperature, and hydrodynamics of the furnace and the type of tree cut to waste. For use of WA as a replacement of cement, the test to be conducted batch leaching of wood waste ash (WWA) which signifies toxicity on leaching of solid waste ash extracted on adding water (ASTM-D3987- [38])

The physical, chemical, compositional, mechanical properties of the WABC at various proportion of substitute by WA were obtained. The various tests for structural test conducted were characteristics like visual, chemical composition, and Mineralogy of wood ash. After finding the suitability to replace cement, the cement concrete (CC) was prepared by substituting cement by WA at various percentage of blending. The physical, chemical, mechanical strengths were to be found for M-20 grade concrete using various Indian standard specifications, ASTM, various codes, and laboratory procedures. The physical, compositional, structural, mechanical and mechanical properties of WA, Cement, concrete, the instruments and machines used were XRF
spectrometer. The tests conducted were for cement concrete. The specific gravity test, consistency test, setting times (Initial & Final), slump test, compaction, compression, tensile and other strength tests were known to find the physical properties of the conventional CC.

The concrete cubes, beams and cylinders specimens were casted of sizes of cubes: 150X150 mm X150mm, cylinders: 150mmX300mm (diameter x length), and beam of size 150mm X150mm X 600mm of numbers of 15 of each variety were casted for testing as per IS: 10086 -1982, reaffirmed 2004 and later in 2008 for cubes and beams and for IS 516 (1959). After casting of the cubes they were submerged in water vat and the different mechanical tests were conducted. The conventional concrete and WABC performances at hardened stage were conducted 7days, 14days, 28days respectively.

2.1 Materials Used and their Properties

The materials for preparation cement concrete (CC) of the experimental works include, cement OPC (53-grade), Coarse aggregate (Black hard granite chips), Fine aggregate (river sand), Wood Waste Ash, tap water used for day to day use in CUTM.

2.1.1 Cement

The ordinary cement used is OPC; 53 grade having specific gravity (sp. gr.) as 3.05 (Type I cement), adhering to IS: 12269 of 1987(subsequently reaffirmed, [39]

2.1.2 Coarse aggregate

Coarse black hard Granite stone, machine crushed aggregates of size ranging 12mm to 20mm agreeing to IS : 2386 ( Part I) – 2002 (R),IS383- [40] collected from nearby quarry with sp. gr.2.62, and fineness modulus (FM) 7.08were taken for Grade analysis (Table 3.2). The allowable Fineness Modulus allowed for the coarse aggt is 5.5 to 8.0 http://site. iugaza.edu.ps/hbaker/files/2017/10/Fineness-Modulus.pdf

2.1.3 Fine aggregate

The river sand (quartz, silt free, light grey in colour, and free from organic impurities) was collected from the Mahanadi river and used as fine aggregate confirming IS code 383- [40] The physical properties of the sand used in the research have sp. gr. (2.72), Bulk density (15.45KN/m3), F.M. (2.80) and particle size variation0.09– 2.0mm.

2.1.4 Wood waste Ash

Wood wastes were collected from a nearby timber saw mill sawing solid wood and were burnt to ashes. In the oven in CUTM lab the ash was put for 5hours for a temperature of 700°C to make the ash fit for blending with cement when cold. VOLATILE MATTER FURNACE; Model: VMF 10/6 Make: CARBOLITE Limited, UNITED KINGDOM was used to generate wood ash at a temperature of 700°C (Fig 1) The physical properties of the wood ash prepared have sp. gr as 2.48 and fineness modulus 6.2%. The chemical constituents of WA observed were XRF spectrometer and the results are in Table 3.

2.1.5 Water

The water used for the WABC is taken from the tap water supplied by the Centurion University of Technology and Management (CUTM), Bhubaneswar campus to its inmates provided for day to day use. The results of water sample were tested by XRF spectrometer as:

| Characteristic | Fineness | Sp.gr. | Normal consistency | Initial setting time | Final setting time |
|---------------|----------|--------|--------------------|----------------------|---------------------|
| OPC -53       | 225m²/kg | 3.1    | 33%                | 38mnts               | 545mnts             |
Table 2. Grade analysis of black hard granite stone chips 12mm-20mm coarse aggregate

| Sl. No | I.S. Sieve size in mm | Wt. Retained | Cumulative wt. retained (gms) | Cumulative % retained | % passing |
|--------|-----------------------|--------------|-------------------------------|----------------------|-----------|
| 1      | 80                    | -            | -                            | -                    | 100%      |
| 2      | 40 or 31.8 mm         | -            | -                            | -                    | 100%      |
| 3      | 20 or 16 mm           | 500gms       | 500gms                       | 10%                  | 88%       |
| 4      | 10                    | 4300gms      | 4800gms                      | 96%                  | 4%        |
| 6      | 4.75                  | 200gms       | 5000gms                      | 100%                 | -         |
| 7      | 2.36                  | -            | -                            | 100%                 | -         |
| 8      | 1.18                  | -            | -                            | 100%                 | -         |
| 9      | 0.60 µ                | -            | -                            | 100%                 | -         |
| 10     | 0.30 µ                | -            | -                            | 100%                 | -         |
| 11     | 0.15 µ                | -            | -                            | 100%                 | -         |
| Total  | 5000mm                |              | 706.00                       |                      |           |

Fineness Modulus (F.M.) = 706.00/100 = 7.06 (Within permissible limit)

Table 3. The chemical composition of wood ash used for part substitute of cement

| Chemicals present | Silicon dioxide (SiO₂) | Alumin oxide (Al₂O₃) | Ferric oxide (Fe₂O₃) | Calcium oxide (CaO) | Magnesium oxide (MgO) | Potassium oxide (K₂O) | Loss on Ignition (%) |
|-------------------|------------------------|----------------------|----------------------|----------------------|-----------------------|-----------------------|----------------------|
| WA                | SiO₂                   | Al₂O₃                | Fe₂O₃                | CaO                  | MgO                   | K₂O                   | 28.27                |
| In (%)            | 33.04                  | 15.20                | 9.53                 | 10.63                | 0.42                  | 2.62                  | 28.27                |

Fig. 1. The volatile matter furnace Model: VMF 10/6 Make: CARBOLITE Limited, UNITED KINGDOM in Lab for preparing wood ash

Table 4. The results of tap water used for cement concrete tested from the XRF spectrometer

| Parameter | pH | TDS | Alkalinity | Hardness | Sulphur S²⁻ | Chloride Cl⁻ | Ferric (Fe) |
|-----------|----|-----|------------|----------|--------------|--------------|-------------|
| Water at Laboratory | 6.65 | 305 | 49 | 135 | 216 | 249.6 | 46.3 |

Fig. 2. The X-Ray fluorescent spectrometer for chemical analysis (Make: PANalytical B.V.)
Table 5. The elements present in waste wood ash in % range used for part substitute of cement

| Element in Timber ash Composition(%) | Calcium (Ca) 7–33% | Pottassium (K) 3–4% | Magnesium (Mg) 1 – 2% | Sodium (Na) 0.3–1.3% | Phosphorus (P) 0.2–0.5% |
|--------------------------------------|---------------------|---------------------|----------------------|---------------------|-----------------------|
| Similar elements in OPC Cement       | 79%                 | 0.64                | nil                  | 0.21                | Nil                   |

Fig. 3. The XRF test results of OPC cement tested in the laboratory

The WA obtained from barks, and twigs generate more ash in comparison to that is formed from core wood and other inner parts varying (6% to 10%) of the unburnt wood.

3.1.2 Physical Properties of wood ash

Wood ash is generated by ignition of waste pieces/dusts of timber and physical chemical properties, Naik et al. [44] studied some of the physical properties were moisture content found that the range of moisture content was 13 – 22%, specific gravity was 1.65 – 2.48 and Fineness (%) retained by 45 µm sieves were 23-90%. On laboratory test the physical properties were found to be Tests are carried out with reference to Indian standards and the results were as Sp. gr. – 2.13 and bulk density was 768kg/m3 which are within limit and the colour, texture and fineness of WA were also permissible as per Chowdhury et al. [10]

3.2 Need for Study

Since percentage of calcium is higher in ash, so it is pertinent to study the pozzolanic properties of wood ash so that it can partly replace cement in concrete. In addition to reduce the CO2 concentration in air due to emission during cement manufacture, the WABC can make ash waste disposal easy. The wood ash when replace partially conventional OPC cement in commonly used M-20 concrete which does not need any mix design and can be supplied to users as RMC at site. The properties improvement is to be studied in the present research because the WA has properties of thermal resistant and a promising thermal insulation to mass concrete.

4. TESTING METHODS

4.1 Workability of WABC

The IS: 456-2000 [45] was followed for the workability, placing, and compaction of the cement concrete. The slump cone was as per IS: 7320 -1974 [46] have height 30cm, foot diameter 20cm, and truncated top diameter of 10cm. No plasticizers were added for workability of the concrete of M20 grade but the water to cement (W/C) ratio was maintained at 0.5. If super plasticizer (@2%) if would have added, the slump range would have been between 100mmto 160 mm. In the present conventional concrete the slump was 60mm. The various physical tests conducted were consistency, setting time (initial and final), slump test before the concrete were molded. The test results in physical test when the concrete was green were

It was observed that the slump values depleted and the slum values reduced to 60mm, 40mm, 32mm, 8mm and 0mm when blended with no cement, 10%, 20%, 30%, and 40% substitutions respectively of cement by incinerated WA. It may be due to low water cement ratio and fine particles WA.
4.1 Mechanical Properties

The concrete was prepared on mixing with different part substitute of WA by cement at 0% (WABS-0), 10% (WABS-10), 20% (WABS-20), 30% (WABS-30) and 40% (WABS-40) percentage and various mechanical tests were conducted in the laboratory after mixing, transportation, placing, flow, workability and curing of the conventional concrete M-20 grade has been done as per IS: 456-2000. The various blends to be tested were as It is proposed to test the mechanical properties of blended concrete such as compressive strength (comp. st.), split tensile test (STT) and Flexural strength (Fl. St.).

4.1.1 The compressive strength (Comp. St.)

The cubes were tested for their compressive strength by the help of either UTM (Universal testing machine) or DCTM (Digital Compression testing machine). The hardened orthodox concrete and WABC of 7, 14, 28 old were made, cured, and tested. The test results are in Table 7.

Compressive strength (Comp. St.) of the concrete after curing converts to hardened concrete cubes. The strength of the concrete was ascertained on testing in the laboratory by using the compressive testing machine and Universal Testing Machine (UTM).

The concrete cubical blocks (150mm X150 mm X150mm) were tested by either by the UTM (Universal testing Machine) or DCTM (Digital compression testing Machine) is measured asper the standard procedure given in IS:516-47.

Standard concrete cubes of dimensions 150 × 150 × 150 mm are prepared and tested in 1000MT capacity UTM. The compressive strength of average of three specimen showing variation within 10% were considered and reported after 7, 14 and 28 days of curing.

From the results at various mixes it is found that the optimum replacement cement by waste wood ash at 28days curing was found to be optimum at 10% substitute. The less difference is observed for 28 days for R0, R10 and R20. It may be due to lack of lime content in the mix, causing low comp. strength. Fly ash in concrete might have reduced the rate of hydration, and achieved early compressive strength.

4.1.2 Flexural Strength

Flexure strength (Fl St.) was conceded for the conventional concrete of M-20 grade and the strength out as per IS: 516-1959 (revised 2004) employing standard cement concrete beams of size 100mm × 100mm × 500 mm. The concrete beam was tested as simple supported placed as an effective 400 mm span which is loaded at the 1/3 points.
Table 7. Compressive strength (Replacement cement with waste wood ash)

| Slno. | Mix     | 7 days (N/mm²) | 14 days (N/mm²) | 28 days (N/mm²) |
|-------|---------|----------------|-----------------|-----------------|
| R0    | WABC- 0%| 14.71          | 19.21           | 22.12           |
| R10   | WABC-10%| 17.36          | 22.06           | 27.02           |
| R20   | WABC-20%| 11.93          | 15.81           | 18.56           |
| R30   | WABC-30%| 7.48           | 10.69           | 14.26           |
| R40   | WABC-40%| 3.84           | 6.72            | 7.89            |

Fig. 5. The compressive strength results at various blending of cement with WA

Table 8. Flexural strength (replacement of cement with wood waste ash)

| #   | Mix     | 7 days (N/mm²) | 14 days (N/mm²) | 28 days (N/mm²) |
|-----|---------|----------------|-----------------|-----------------|
| R0  | WABC- 0%| 2.68           | 3.06            | 3.29            |
| R10 | WAC-10%| 3.12           | 3.35            | 3.31            |
| R20 | WAC-20%| 2.85           | 3.21            | 3.42            |
| R30 | WAC-30%| 2.44           | 2.94            | 3.11            |
| R40 | WAC-40%| 2.23           | 2.39            | 3.02            |

Fig. 6. Flexural strength of concrete at 7, 14 and 28 days curing at various substitutes by WA
The Flexural strength results are presented in Table 8, and Fig. 6. From the Flexural strength results as observed from the blended concrete with waste wood ash, it was detected that the conventional mix without waste WA the strength of 3.29 N/mm² after 28 days curing. The Fl. St. of CC was increased to 3.21N/mm² and 3.42N/mm² with 10% and 20% replacement of cement by WA after 28 days. With time lapse the fl. St. of the 28days cured blended concrete was increased and for WABC-30 and WABC-40 exhibits diminishing trend.

4.1.3 Split tensile strength

Split tensile test is conducted following the IS: 5816-1999. The cylindrical specimens of 150 mm diameter, and 300 mm height were tested after 7, 14, and 28 days of curing. The sp. tensile strength of average of 3 specimens was conducted and had shown variation with WABC-0, WABC-10, WABC-20, WABC-30, and WABC-40 was tested.

The split (Sp.) tensile strength of the orthodox concrete and the WABC at 10% cement substitute for M-20 concrete the split tensile strength were 3.29N/mm² and 3.39N/mm² at 28days curing which is found to be increasing. The 28 day split tensile strength for blended concrete was found to be gradually decreasing after WABC 10 onwards up to WABC40.

5. DISCUSSION

The current research is focused on the waste utilization of waste wood ash (WA) replacing cement in concrete to address the environmental issues. WABC were prepared on replacement of cement by WA at various percentages by weight at 0%, 10%, 20%, 30%, and 40% respectively. The present investigation is the impact of WA on physical and mechanical properties of wood waste ash on cement concrete.

Conclusion derived from the results drawn from the present research work.

1. On increasing the fraction of WA on substituting cement in the CC, the workability of concrete decreases, indicates the decrease in slump. It is attributed to higher water demand of WA. It is also inferred that the mix is sensibly cohesive, and workable.

2. On increase in replacement of percentage cement by WA, the performance of CC decreases. It may be due to the high WA demand for water. However, mixing at a 10% replacement level has a reduction of 40 mm in slump value which has sufficient usability for most active functions. The part substitute of cement in the concrete mixes with WA, the workability can be within limit.

3. The increase in WA substitute has reduced the mechanical properties i.e. comp. st., split tensile strength, and flexural strength in the hardened concrete specimen. This is mainly due to the water demand required by WA.

4. The mechanical properties (compressive strength, strength, flexural strength) identified of wood ash have increased by 10% to replace cement with wood ash. Further increases in the level of cement and WA installation have significantly reduced mechanical properties.

5. At 10% replacement level, it is evident that the compressive strength of the WA containing mixtures is higher than the compressed strength of the concrete at M20 grade, it is concluded that the concrete of the building grade can be produced by 10% installation or cement by WA.

Table 9. Split tensile strength (replacement of with wood waste ash)

| Slno. | Mix    | 7 days(N/mm²) | 14 days(N/mm²) | 28 days(N/mm²) |
|-------|--------|---------------|----------------|---------------|
| R0    | WABC-0 | 2.68          | 3.06           | 3.29          |
| R10   | WABC-10| 2.72          | 3.11           | 3.39          |
| R20   | WABC-20| 2.38          | 2.75           | 3.02          |
| R30   | WABC-30| 2.22          | 2.54           | 2.89          |
| R40   | WABC-40| 1.97          | 1.98           | 2.37          |
appropriate places to moderate the ready mix concrete industries can use WABC at replacement of waste wood ash by cement. The flexural test results are improved at optimum results like comp. stress, split tensile test and with others wastes like GGBS, silica fume, wood compacted concrete, use of plasticizers, blending further studies like durability tastes, making self concrete. Under the constraints of pandemics performance of improved strength behaviour substitutes; it is found that there can be characteristics of WA blended CC at various

6. CONCLUSION

The search for the improvement on the strength characteristics of WA blended CC at various substitutes; it is found that there can be performance of improved strength behaviour of concrete. Under the constraints of pandemics further studies like durability tastes, making self-compacted concrete, use of plasticizers, blending with others wastes like GGBS, silica fume, wood ash, red mud, or marble powder. The result reveals that at 10% WA substitute of cement, the results like comp. stress, split tensile test and flexural test results are improved at optimum replacement of waste wood ash by cement. The ready mix concrete industries can use WABC at appropriate places to moderate the present carbon foot print.

Table 10. Comparison of strength of WABC by various investigators

| Investigator                  | Year | % blend WA (Wt.) | Conditions                                      | Reference                  |
|-------------------------------|------|------------------|------------------------------------------------|----------------------------|
| Ghorpade V. G.                | 2012 | 10%              | M-30 grade CC                                   | Ghorpade et al. [49]       |
| Viet-Anh Vu et al.            | 2019 | 30%              | Mech. properties decrease, Heat capacity increase| Vu et al. [11]             |
| Ambili R et al                | 2019 | 07%              | OPC 43 grade, M-20, Comp. strength increases by 13%| Ambili R et al. [48]       |
| Raheem, A. A.,               | 2019 | 10% + 1.5% Nanosilica | Investigation of Workability & Comp. Strength of WACC Containing Nanosilica | Raheem, A.A. et al. [50]   |
| Hamid, Z et al.,              | 2020 | 10%              | M-25; admixture add increase the workability of concrete mix | Hamid, et al. [51]         |
| Iketun, B.D.,                | 2021 | 10% + 2% nanoTiO2 | Water absorption, workability and strength improved | Iketun, B.D., et al. [52] |
| Dash Smruti S.               | 2021 | 10%              | M-20grade, workability and strength improved    | Present study              |

Fig. 7. Graphical presentation of Split tensile strength versus replacement of waste wood ash

**DISCLAIMER**

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

**COMPETING INTERESTS**

Authors have declared that no competing interests exist.
REFERENCE

1. Chee BC, Mahyuddin R. The implementation of wood waste ash as a partial replacement material in the production of structural grade concrete and mortar: an overview. Resour Conserv Recycl. 2011;55:669–685.

2. Ottosen LM, Hansen EØ, Jensen PE, Kerkelund GM, Goltermann P. Wood ash used as partly sand and/or cement replacement in mortar. Int. J. of Sustainable Development and Planning. 2016;11(5):781-791. Available: https://doi.org/10.2495/SDP-V11-N5-781-791

3. Kannan V, Raja Priya P. Evaluation of the permeability of high strength concrete using metakaolin and wood ash as partial replacement for cement. SN Appl. Sci. 2021;3:90. Available: https://doi.org/10.1007/s42452-020-04024-y

4. Ban CC, Mahyuddin R. Mechanical strength, durability and drying shrinkage of structural mortar containing HCWA as partial replacement of cement. Constr Build Mater. 2012;30:320–329.

5. Batt AS, Garg A. Partial replacement of wood ash with ordinary Portland cement and foundry sand as fine aggregate, J Civil Env. Eng. 2017;7(2):1-5, DOI: 10.4172/2165-784X.100027

6. Leroy M, Hermann K, Rose A, Joseph N, Dupont F, Bienvenu N. Density and Strength of Mortar Made with the Mixture of Wood Ash, Crushed Gneiss and River Sand as Fine Aggregate. Journal of Materials Science and Chemical Engineering, 2018;6:109-120. DOI: 10.4236/msce.2018.64012.

7. Faruqi MHZ, Siddiqui FZ. A mini review of construction and demolition waste management in India. Waste Management & Research, 2020; 38(7):708-716. DOI: 10.1177/0734242X20916828

8. Das M, Nayak S, Mishra SP. Parametric Strategy for Composite Cement Concrete Blended with Fly Ash & Glass Fiber; Current J. of Applied Sc. and Tech. 2020;39(35):162-176. DOI: 10.9734/CJAST/2020/v39i3531065

9. Nayak S, Mishra SP, Panda S. Red Mud, the cutting edge of self-compacting concrete, INPRESSCO International Journal of Current Engineering and Technology, 2017;7(2):390 -396

10. Chowdhury S, Mishra M, Suganya O. The incorporation of wood waste ash as a partial cement replacement material for making structural grade concrete: An overview, Elsivier, A in Shams Engineering Journal, 2015;6(2):429-437, Available:https://doi.org/10.1016/j.jasej.2014.11.005

11. Vu VA, Cloutier A, Bissonnette B, Blanchet P, Duchesne J. The Effect of Wood Ash as a Partial Cement Replacement Material for Making Wood-Cement Panels. Materials (Basel). 2019;12(17), 2766. DOI: 10.3390/ma12172766

12. Siddique, R., “Performance characteristics of high-volume Class F fly ash concrete”, Cement and Concrete Research, 2004; 34(3):487-493.

13. Lahri A, Dixa S. Alternatives to Cement in Concrete – A Review. International Journal of Scientific & Engineering Research, 2015;6(10):50-56

14. Lee S, Moon HY, Swamy RN. “Sulfate attack and role of silica fume in resisting strength loss”, Cement & Concrete Composites, 2005;27:65-76.

15. Ahmed I, Kumar A, Rizvi SH, Ali M, Ali S. Effect of Silica Fume as Partial Replacement of Cement on Compressive Strength of Roller Compacting Concrete. Quest Research J. 2020;18( 2):145–149.

16. Turker F, Akoz F, Korals S, Yuzer N. “Effects of Magnesium sulfate concentration on the sulfate resistance of mortars with and without silica fume”, Cement and Concrete Research, 1997;27:205-214.

17. Jonida P, Ahmed A, John K, Fraser H. Palm Oil Fuel Ash as A Cement Replacement in Conc.. Mod App Matrl Sci 2018;1(1):4-8. DOI:10.32474/MAMS.2018.01.000102

18. Kayali O, Haque MN, Khatib JM. Sustainability and Emerging Concrete Materials and Their Relevance to the Middle East. Open Constr. Build. Technol. J. 2008;2:103–110.

19. Bheel N, Jokhio MA, Abbasi JA, Lashari HB, et al. Rice Husk Ash and Fly Ash Effects on the Mechanical Properties of Concrete, Eng. Tech. and applied Sc. Research, 2020;10(2):5402-5405. Available:https://doi.org/10.4088/etasr.3363.

20. Adesanya DA, Raheem AA. “A study of the workability and compressive strength characteristics of corn cob ash blended...
cement concrete", Construction and Building Materials. 2009a;23:311–317.
21. Adesanya DA, Raheem AA. "Development of corn cob ash blended cement", Construction and Building Materials; 2009b;23:347 – 352.
22. Adesanya DA, Raheem AA. "A study of the permeability and acid attack of corn cob ash blended cements", Construction and Building Materials, 2010;24:403 – 409.
23. Yeoh AK, Bidin R, Chong CN, Tay CY. "The relationship between temperature and duration of burning of rice-husk in the development of amorphous rice-husk ash silica". Proceeding of Unido / Escap / RCTT, Malaysia; 1979.
24. Chopra SK, Ahluwalia SC, Laxmi S. Technology and Manufacture of Rice Husk Ash Masonry (RHAM) Cement. Proceeding of ESCAP/RCTT – 3rd. Workshop on Rice Husk Ash Cement, New Delhi; 1981.
25. Della VP, Kuhn I, Hotza D. Rice husk ash as an alternate source for active silica production. Materials Letters, 2002;57(4): 818-821.
26. Lo, Fang-C, Lee, Ming-G, Lo, Shang-L. Effect of coal ash and rice husk ash partial replacement in ordinary Portland cement on pervious concrete, Const. & Build. Mat., Sc. Direct. 2021;286(7):122947. Available:https://doi.org/10.1016/j.conbuildmat.2021.122947.
27. Mehta PK. Greening of concrete industry for sustainable development. Concr Int 2002;23–8.
28. Damtoft JS, et al. Sustainable development and climate change initiatives. Cem Concr Res. 2008; 38(2):115–27.
29. Wang S, Miller A, Llamazos E, Fonseca F, Baxter L. Biomass fly ash in concrete: mixture proportioning and mechanical properties. Fuel 2008;87(3).
30. Tkaczewska E, Malelepszy J. "Hydration of Coal–biomass Fly Ash Cement." Construction and Building Materials. 2009; 23(7):2694-700.
31. Garcia ML, Coutinho JS. Strength and durability of cement with forest waste bottom ash. Constr Build Mater 2013;897–910.
32. Abdullahi M. Characteristics of wood ash/OPC concrete. Leonardo Electron. J. Pract. Technol. 2008;8:9–16
33. Subramaniam P, Subasinghe K, Fonseka WRK. Wood ash as an effective raw material for concrete blocks. Int. J. Res. Eng. Technol. 2015;4:228–233.
34. Yang Z, Huddleston J, Brown H. Effects of Wood Ash on Properties of Concrete and Flowable Fill. Scientific Research, J. of Mate. Sc. and Chemical Eng. 2009;4(7):101-114. DOI: 10.4236/msce.2016.47013.
35. ASTM C114-00. Standard Test Methods for Chemical Analysis of Hydraulic Cement National Council for Air and Stream Improvement, Inc. (NCASI), "Alternative Management of Pulp and Paper Industry Solid Wastes," Technical Bulletin No. 655, NCASI, New York, N.Y., Nov. 1993;44.
36. Elinwa AU, Mahmodd YA. "Ash from timber waste as cement replacement material, Cement and Concrete Composites. 2002;24(2):219-222.
37. ASTM D3987 – 12. Standard Practice for Shake Extraction of Solid Waste with Water; ASTM International; 2020.
38. IS 12269, Specification for 53 grade ordinary Portland cement. Bureau of Indian Standards, New Delhi; 1987.
39. IS 383, 2016 Specification for coarse and fine aggregates from natural sources for concrete. Bureau of Indian Standards, New Delhi; 1970.
40. Campbell AG. Recycling and disposing of wood ash. TAPI J. 1990;73(9):141–3.
41. Dave N, Misra A, Ku, Srivastava A. 5 authors. Kaushik, S. K., Green quaternary composites. 2002;24(2):115-116.
42. Naik TR. Environmental-friendly concrete with industrial and post-consumer by-products. Report No. CBU-2004-21, REP-2004-570.
43. Mishra MK, Ragland KW, Baker AJ. "Wood ash composition as a function of furnace temperature." Biomass Bioen. 1993; 4(2):103–116.
44. IS 456 : 2000. Indian Standard. Plain and Reinforced Concrete -. Code of Practice. (Fourth Revision ).
45. IS 456 : 2000. Indian Standard. Plain and Reinforced Concrete -. Code of Practice. (Fourth Reprint November 2000)
46. IS 516-1959 (Reaffirmed 2018).Methods of test for strength of concrete,
47. Ambili R, Valsalakumar S., Study on Properties of Concrete with Partial
Replacement of Cement with Wood Ash.
Int. Res. J. of Eng. and Tech. (IRJET). 2019;6(6):1846-1854

49. Ghorpade VG. Effect of Wood Waste Ash on the Strength Characteristics of Concrete. Nature Environment and Pollution Technology. 2012;11(1):121-124.

50. Raheem AA, Ikotun BD. Investigation of Workability and Compressive Strength of Wood Ash Cement Concrete Containing Nanosilica. Adv. Materials Res., 1154, Trans Tech Publn., Ltd., 2019, 129–136. DOI:10.4028/www.scientific.net/amr.1154.129

51. Hamid Z, Rafiq S. A Comparative Study on Strength of Concrete Using Wood Ash as Partial Replacement of Cement IOP Conf. Ser.: Mater. Sci. Eng. 2020;2020955012043.

52. Ikotun BD, Raheem AA. Characteristics of Wood Ash Cement Mortar Incorporating Green-Synthesized Nano-TiO2. Int J Concr Struct Mater 2019;15:19. Available:https://doi.org/10.1186/s40069-021-00456-x

© 2021 Dash et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/71262