Investigation of Concrete Prepared with Waste Materials and Reinforced using Coconut Fiber

Vishav Gupta[1], Tarun Sharma[2]

[1]Student, [2]Assitant Professor

Department of Civil Engineering Chandigarh University

Gharuan, Mohali

[1]vishavgupta13@gmail.com [2]tarun.sharma@cumail.in

Abstract

A demand for more ecologically friendly practices has made investigation of sustainable and eco-friendly building materials essential. In this work, the characteristics of concrete made with waste materials as additives—alccofine, bagasse ash, and coconut fiber—are examined. Alccofine, a byproduct of distillation of alcohol, was used in instead of a portion of cement, and bagasse ash, a byproduct of sugarcane industry, was used in place of fine aggregate. In order to improve the mechanical and fracture resistant characteristics of the concrete, coconut fibers were used as reinforcement. To measure the compressive strength, tensile and flexural strength of concrete specimens, and various mix proportions were prepared and analyzed. The experimental findings showed that the characteristics of concrete were significantly enhanced by the addition of alccofine and bagasse ash. The specimens' acceptable compressive, tensile and flexural strength values suggested they were suitable for structural applications. Further, the use of coconut fibers improved the concrete's strength and fracture resistance much further. The study demonstrates the possibility of using alccofine, bagasse ash, and coconut fiber as additives in the manufacturing of concrete to improve its strength properties. By minimizing waste production, the use of these waste products not only encourages sustainable practices but also has economic advantages by lowering the need for conventional resources. Additionally, the use of coconut fibers improves the concrete's overall strength and functionality. These results open the door for improvements in the strength-enhanced concrete technology sector by offering insightful information for the production and application of eco-friendly building materials.

Keywords: Strength characteristics; waste materials; natural fiber; eco-friendly construction.

1. Introduction

Due to its potential advantages in terms of sustainability, resource conservation, and waste management, the use of waste materials in concrete has attracted a lot of interest recently. Several waste products have been examined to see if they may replace some of the traditional concrete constituents. Since cement manufacturing plants emit huge volumes of carbon dioxide into the atmosphere, it is one of the leading contributors of environmental pollution. Due to a variety of issues, including toxic gas emissions throughout the process of making cement, continual depletion of essential elements for cement production, and rising cement production costs, there's an urgency to restrict the consumption of cement in concrete manufacturing (Sivakumar et al. 2017). The use of supplemental cementitious materials (SCMs) as a partial or complete substitute for cement can reduce the use of significant amounts of cement in the construction of concrete. The latest developments in SCMs have resulted in Ambuja Cements Pvt Ltd, one of India's largest cement generating plant, developing an innovative micro-mineral SCM called Alccofine (Sharma et al. 2016). There are three forms of alccofine commercially accessible on the market based on calcium content: alccofine-1101, alccofine-1203, and alccofine-1206. Alccofine-1101 is a high calcium silicate content material used largely for grouting and soil stabilization (Gupta et al. 2015). Alccofine-1203 is a low calcium silicate content substance used as an SCM to replace silica fume in the production of high-strength and high-performance concrete (HSC/HPC). In a similar way alccofine-1206 is a low calcium silicate content substance that is utilized in the production of a variety of concretes (Kumar et al. Citation2016). Table 1 shows the chemical and physical characteristics of alccofine-1203 in accordance with ASTM C 989-99 standards. Alccofine-1203 is an extremely refined substance derived from GGBS, a waste product of India's iron ore industry. The powder Alccofine-1203 is very fine. Alccofine-1203 comprises extremely small particles that have a fineness of 12,000 cm^2/gm and a unique chemistry because of its controlled granulation process (Ansari et al. 2015; Jindal et al. 2018; Soni et al. 2019; Pawar and Saoji 2013).

SCBA (sugar cane bagasse ash) is an ordinary byproduct of the ethanol and sugarcane industries. SCBA is typically utilised as a fertiliser or dumped of in landfills, raising environmental problems. Because of the availability and pozzolanic properties of SCBA, research in recent years has mostly focused on its usage in construction materials. Some studies in the past carried out on utilizing bagasse ash in concrete industry has shown improvement in all strength (compressive, tensile and flexural) characteristics (Khambra et al. 2023; Kumar et al. 2016; Rafieizonooz et al. 2016; Gupta et al. 2018; Raut et al. 2033).

Natural fibers in concrete are gaining popularity as an environmentally friendly substitute to synthetic fibers. Natural fibers obtained from diverse plant sources can be used to strengthen concrete and give other benefits. Coconut fibers, obtained from coconut husk, have been studied as a possible addition in concrete to increase its mechanical characteristics and durability in past few years by some researcher (Gamage et al. 2022; Ahmad et al. 2017; Asyarf et al. 2022; Bamigboye et al. 2020; Ramli et al. 2013).

As far as the literature is concern, there has been minimal study on evaluating the strength characteristics of concrete using alccofine, bagasse ash and coconut fiber all together. Keeping this in view, the present study investigates the behavior of concrete produced as partial replacement of cement with alcoofine, partial replacement of fine aggregates with bagasse ash and addition of coconut fiber to it.

2. Materials

2.1 Cement

In the experimental investigation, ordinary Portland cement (43 Grade) complying to IS: 8112-1989 is utilized to cast the concrete samples. Table 1 lists the characteristics and composition of cement.

Table 1 Physical properties and composition of ordinary Portland cement

<table>
<tr><td colspan="9">Physical properties</td></tr>
<tr><td colspan="2">Fineness (%)</td><td colspan="2">2.01</td><td colspan="3" rowspan="4">Compressive strength (N/mm^2) at</td><td>3 days</td><td>26.1</td></tr>
<tr><td colspan="2">Standard consistency (%)</td><td colspan="2">30</td><td>7 days</td><td>36.8</td></tr>
<tr><td colspan="2">Initial setting time (minutes)</td><td colspan="2">69</td><td>28 days</td><td>46.2</td></tr>
<tr><td colspan="2">Final setting time (minutes)</td><td colspan="2">618</td><td></td><td></td></tr>
<tr><td colspan="9">Chemical composition</td></tr>
<tr><td>Constituent</td><td>CaO</td><td>SiO_2</td><td>Al_2O_3</td><td>Fe_2O_3</td><td>MgO</td><td>SO_3</td><td>Cl</td><td>Loss of ignition</td></tr>
<tr><td>Content (%)</td><td>46.54</td><td>31.52</td><td>6.58</td><td>4.83</td><td>1.12</td><td>0.98</td><td>0.03</td><td>5.82</td></tr>
</table>

2.2 Natural Aggregates

The coarse and fine natural aggregate with IS: 383-1970 grading is obtained from a nearby stone crusher. Fine aggregate has specific gravity, fineness modulus, and water absorption of 2.68, 2.75, and 0.08%, respectively. The specific gravity, fineness modulus, and water absorption of a coarse aggregate of nominal size 20 mm are 2.64, 6.69, and 0.018%, respectively. Coarse aggregate has a crushing value of 22.7% and an impact value of 17.8%.

2.2 Alccofine

The alccofine used in the present study was obtained from Ambuja Cement Ltd. at a cost of Rs 110/kg and was kept at dry place in sealed bags so as to prevent entry of moisture to it. The alccofine contains around 35% of silicon dioxide which is almost similar to its composition in cement and hence it may be easily replaced with cement.

2.3 Bagasse ash

The bagasse ash was collected from The Morinda co-operative sugar mills Ltd. Morinda, Mohali, India and was stored in sealed bags so as to prevent any entry of moisture to it. The specific gravity of bagasse ash was 2.22 and was black in color. The fineness modulus of bagasse ash was 2.54 and it contained almost 70% silicon dioxide.

2.4 Water

The concrete was cast and cured using potable water in accordance with IS: 456-2000 (reaffirmed in 2011).

3. Material proportions

The materials were proportioned conforming to IS: 10262-2009 for mix design with proportion by weight of cement: sand: coarse aggregate (1: 2: 4) for NA concrete; and water-cement ratio was fixed as 0.5 as per IS: 456-2000. The cement was replaced with alccofine in varying proportions (5, 10, 15 and 20%); the natural fine aggregates were replaced with bagasse ash (10, 20, 30 and 40%); and coconut fiber was added in varying percentages of 1, 1.5 and 2%. Using these materials proportions, 132 cube samples of size 150 mm x 150 mm x 150 mm have been cast to determine compressive of concrete. The concrete samples have been cast in steel moulds and water curing has been used under standard conditions. The cube samples have been tested as per the procedure conforming to IS: 516 - 1959 for determining compressive strength at 3, 7 and 28 days. Table 1 lists the various combination of mixture on which strength tests were performed.

Table 1. Various combinations used the strength characteristics

Sr. No.	Series No.	No. of samples		
	AF- Alccofine, BA – bottom ash, CF – coconut fiber	Compressive Strength (3, 7 and 28 days)	Tensile Strength (3, 7 and 28 days)	Flexural strength (3, 7 and 28 days)
Natural aggregate concrete specimens (C – cement, FA – fine aggregate, CA – coarse aggregate)				
1	M1– C:FA:CA :: 1:1:2	9	9	3
2	M21– C+AF(5%):FA:CA :: 1:1:2	9	9	3
3	M22–C+AF(10%):FA+:CA :: 1:1:2	9	9	3
	M23–C+AF(15%):FA:CA :: 1:1:2	9	9	3
4	M24–C+AF(20%):FA:CA :: 1:1:2	9	9	3
5	N31– C:FA+BA(10%):CA :: 1:1:2	9	9	3
6	N32– C:FA+BA(20%):CA :: 1:1:2	9	9	3
7	N33– C:FA+BA(30%):CA :: 1:1:2	9	9	3
8	N34– C:FA+BA(40%):CA :: 1:1:2	9	9	3
9	O41– C:FA:CA :: 1:1:2+1% CF	9	9	3
10	O42– C:FA:CA :: 1:1:2+1.5% CF	9	9	3
11	O43– C:FA:CA :: 1:1:2+2% CF	9	9	3
12	P51–C+AF(15%):FA+BA(30%):CA :: 1:1:2+1% CF	9	9	3
13	P52–C+AF(15%):FA+BA(30%):CA :: 1:1:2+1.5% CF	9	9	3
14	P53–C+AF(15%):FA+BA(30%):CA :: 1:1:2+2% CF	9	9	3
	Total samples	135	135	45
	Final total	315		

4. Results and Discussion

4.1 Effect of admixtures on compressive strength of concrete with curing

4.1.1 Effect of partial replacement of cement with alccofine on compressive strength

The compressive strength of concrete varies with the alccofine content substituting cement in normal concrete as shown in Figure 1. There is increase in compressive strength of concrete with increasing alccofine content as well as with age and the maximum strength is attained at 15% alccofine content; the higher content of alccofine decreasing the strength. The alccofine substituting the cement in concrete acts as micro-filler occupying the smaller voids in concrete mass making it more compact and hence its compressive strength increases. The optimum alccofine substituent to cement in concrete will fill the voids optimally giving compact mass and if higher contents of alccofine substitute cement, the concrete will be less compact thus decreasing the compressive strength. A similar result on adding alccofine to concrete was reported in the past by few researchers (Ansari et al. 2015).

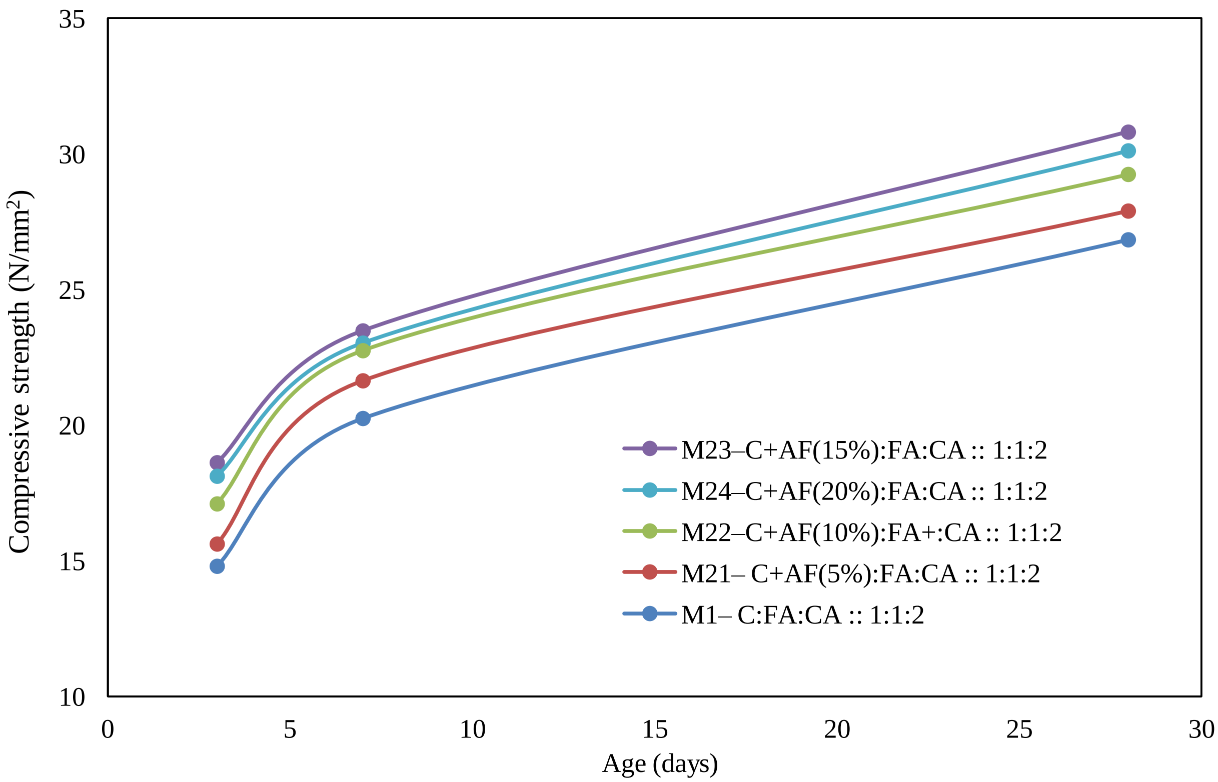

Figure 1. Compressive strength of nominal concrete with varying alccofine content

4.1.2 Effect of partial replacement of fine aggregates with bottom ash on compressive strength

The compressive strength of concrete varies with the bottom ash content substituting fine aggregates in normal concrete as shown in Figure 2. There is increase in compressive strength of concrete with increasing bottom ash content as well as with age and the maximum strength is attained at 30% bottom ash content; the higher content of bottom ash decreasing the strength. The bottom ash substituting the fine aggregates augmented the pozzolanic reaction and the fine spread of C-S-H gel and formation of extra C-S-H gel due to consumption of portlandite by pozzolanic action bottom ash resulted in higher compressive strength of concrete mix. The optimum bottom ash substituent to fine aggregate in concrete will fill the voids optimally giving compact mass. As the bottom ash is a porous coarse material, the amount of water demand rises when higher content bottom ash is added, reducing mix workability and causing difficulties during compaction, resulting in concrete with a high number of pores and lesser compressive strength. A similar result on adding bottom ash by replacing fine aggregates to concrete was reported in the past by few researchers (Khambra et al. 2023; Kumar et al. 2016).

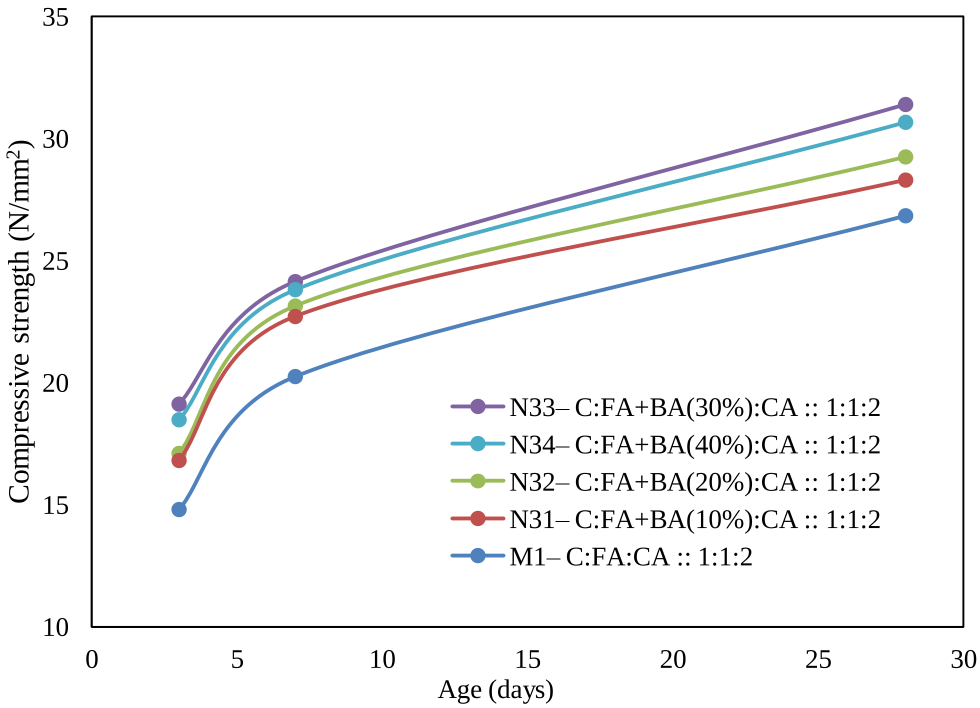

Figure 2. Compressive strength of nominal concrete with varying bottom ash content

4.1.3 Effect of addition of coconut fiber on compressive strength

The compressive strength of concrete varies with the addition of coconut fiber in normal concrete as shown in Figure 3. There is increase in compressive strength of concrete with increasing coconut fiber content as well as with age and the maximum strength is attained at 1.5% coconut fiber content; the higher content of coconut fiber beyond 1.5% decreasing the strength. The reduction may be attributed to the lower workability of new concrete due to its higher fiber content, as well as poor compaction while sample casting, which results in the production of air spaces, or the diluting of the cemented matrix/hardened cement paste mixture due to the inclusion of fibers. A similar result on adding natural fiber to concrete was reported in the past by few researchers (Gamage et al. 2022; Ahmad et al. 2020).

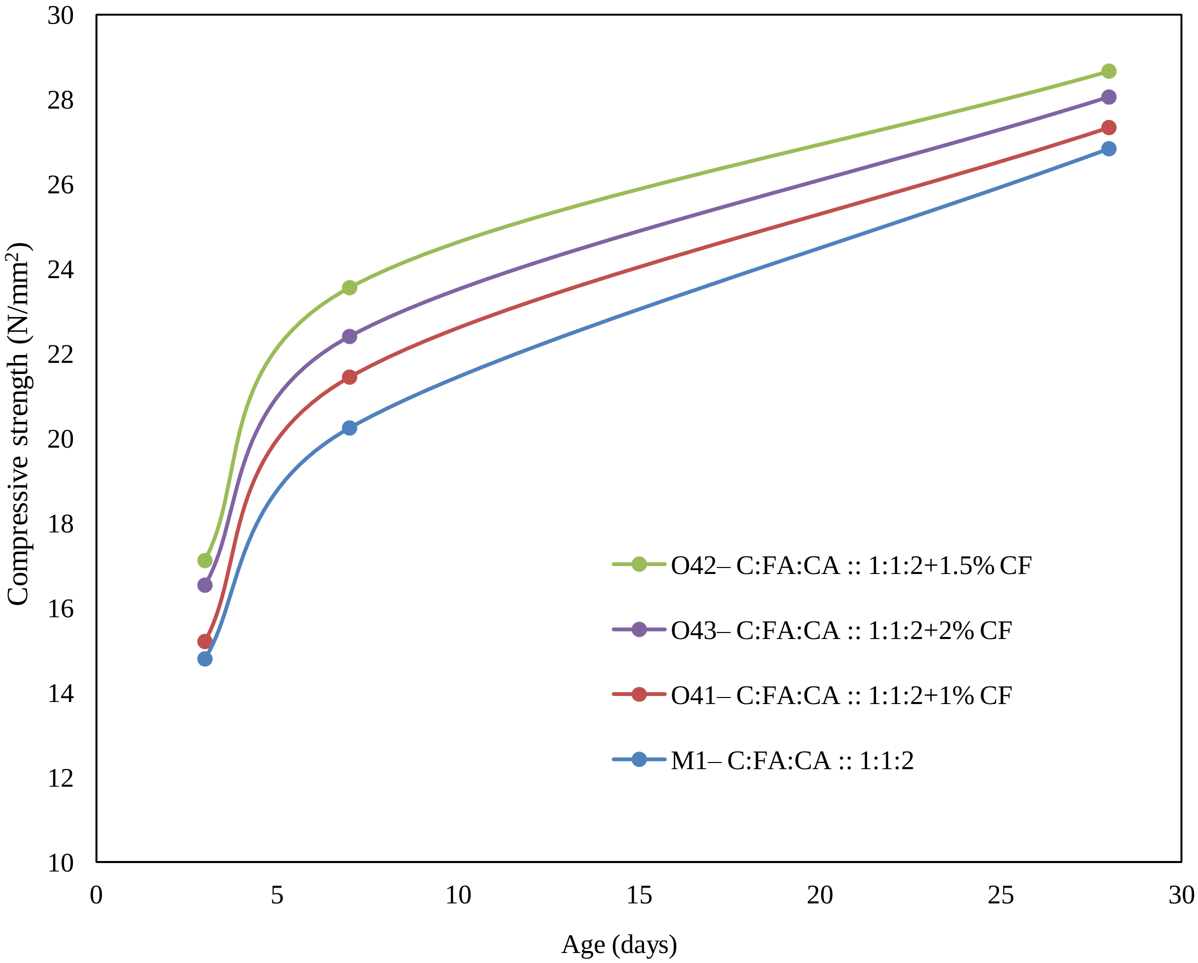

Figure 3. Compressive strength of nominal concrete with varying coconut fiber content

4.1.4 Effect of addition of coconut fiber on compressive strength of alccofine and bottom ash prepared concrete

The effect of addition of varying content of coconut fiber on optimum content of alccofine (15%) replacing cement and bottom ash ash (30%) replacing fine aggregates is shown on Figure 4. After a curing period of 28 days, the compressive strength of C:FA:CA :: 1:1:4 was 26.84N/mm^2 which increased to 32.1N/mm^2 on adding 1%; further increased to 34.85N/mm^2 on adding 1.5% CF and there after decreased to 33.72N/mm^2 when 2% CF content was added. A highest increase in compressive strength was noticed at for C+AF(15%):FA+BA(30%):CA :: 1:1:2+1.5% CF and this mixture may be treated as optimum one for increasing compressive strength of nominal concrete. The increase in strength on adding CF may be due to the better bonding and packing of individual particles with fiber and the decrease in strength on adding higher content of CF may be attributed to lower workability.

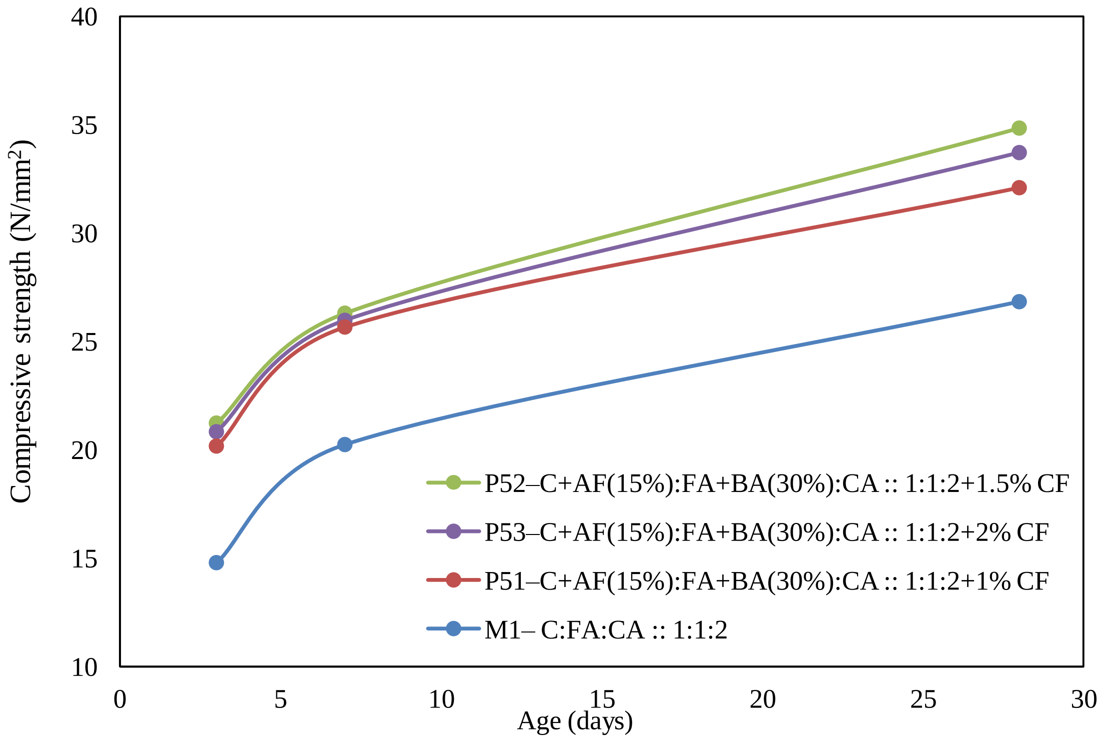

Figure 4. Compressive strength of alccofine and bottom ash added concrete with varying coconut fiber content

4.2 Effect of admixtures on tensile strength of concrete with curing

4.2.1 Effect of partial replacement of cement with alccofine on tensile strength

Figure 5 demonstrates the effect of varying content of alccofine by replacing cement on tensile strength of concrete. The tensile strength of concrete increases with higher alccofine content as well as with age, and the maximum strength is obtained at 15% alccofine concentration; and higher alccofine percentage, lowers the strength. The alccofine that replaces cement in concrete functions as a micro-filler, filling tiny spaces in the concrete mass, rendering it more compact and therefore increasing tensile strength. The appropriate alccofine replacement to cement fills the empty spaces optimally, resulting in compact mass, whereas greater concentrations of alccofine substitute cement would result in less compact concrete, lowering tensile strength. Few researchers previously observed a similar outcome when introducing alccofine to concrete (Jindal et al. 2018; Soni et al. 2019).

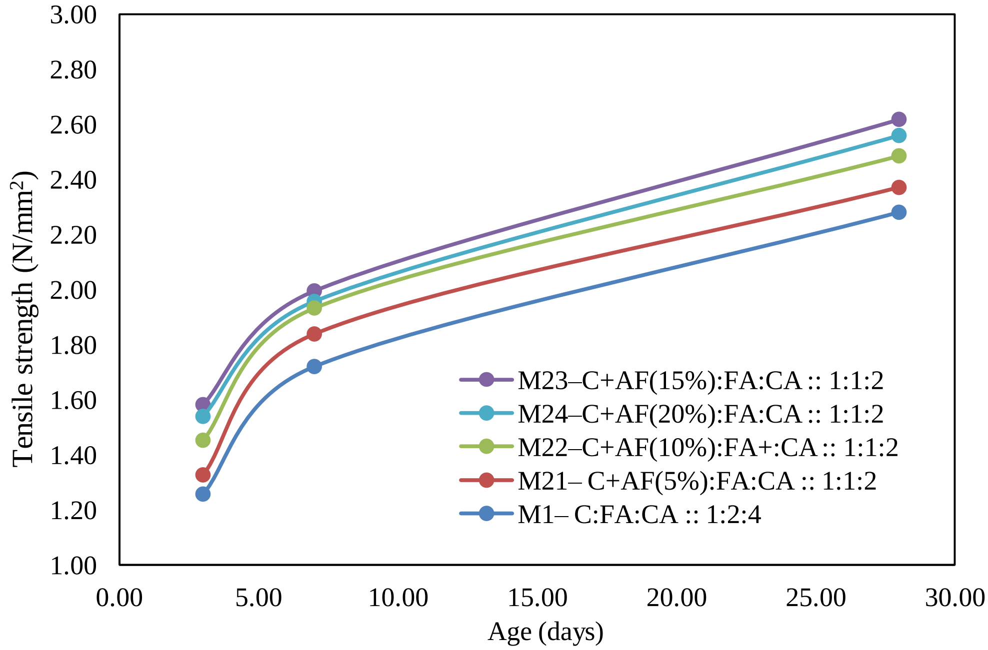

Figure 5. Tensile strength of nominal concrete with varying alccofine content

4.2.2 Effect of partial replacement of fine aggregates with bottom ash on tensile strength

As illustrated in Figure 6, the tensile strength of concrete changes with the amount of bottom ash substituted for fine particles in standard concrete. The tensile strength of concrete increases with higher bottom ash percentages as well as with age, and the maximum strength is achieved at 30% bottom ash content; and the further increase in BA content, lowers the strength. Bottom ash substituted for fine aggregates improved the pozzolanic reaction and fine spread of C-S-H gel, resulting in higher tensile strength of concrete mix owing to the utilization of portlandite by pozzolanic action bottom ash. The best bottom ash substitute for fine aggregate in concrete will fill voids ideally, resulting in compact mass. Because bottom ash is a porous coarse material, adding more bottom ash increases the quantity of water required, limiting mixture workability and creating issues for compaction, leading to concrete with a large number of pores and lower tensile strength. Few researchers had observed a similar outcome when adding bottom ash to concrete by substituting fine particles (Rafieizonooz et al. 2016; Gupta et al. 2018).

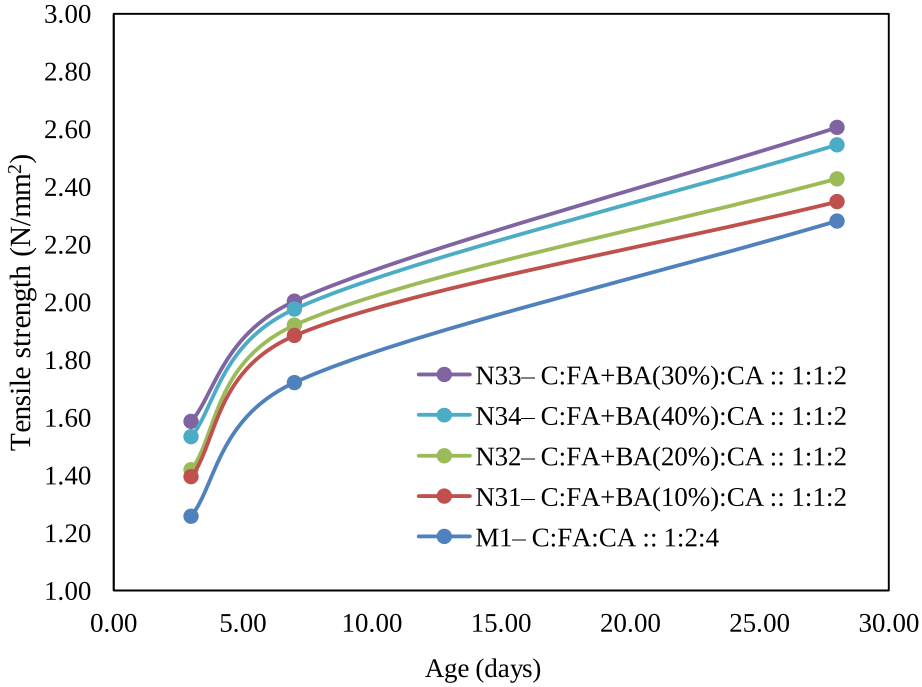

Figure 6. Tensile strength of nominal concrete with varying bottom ash content

4.1.3 Effect of addition of coconut fiber on tensile strength

Figure 7 illustrates how adding coconut fiber to standard concrete alters its tensile strength. The maximum tensile strength of concrete is reached at 1.5% coconut fiber content; and larger coconut fiber content over 1.5% decreases the strength. The tensile strength of concrete increased with age as well as with increasing coconut fiber content. The decline could be assigned to the smaller workability of freshly produced concrete because of its increased fiber content, as well as to inadequate compaction during sample casting, which creates air spaces, or the diluting effect of fiber inclusion on the mixture of cemented matrix and hardened cement paste. In the past, researchers that added coconut fiber to concrete obtained comparable results (Asyraf et al. 2022).

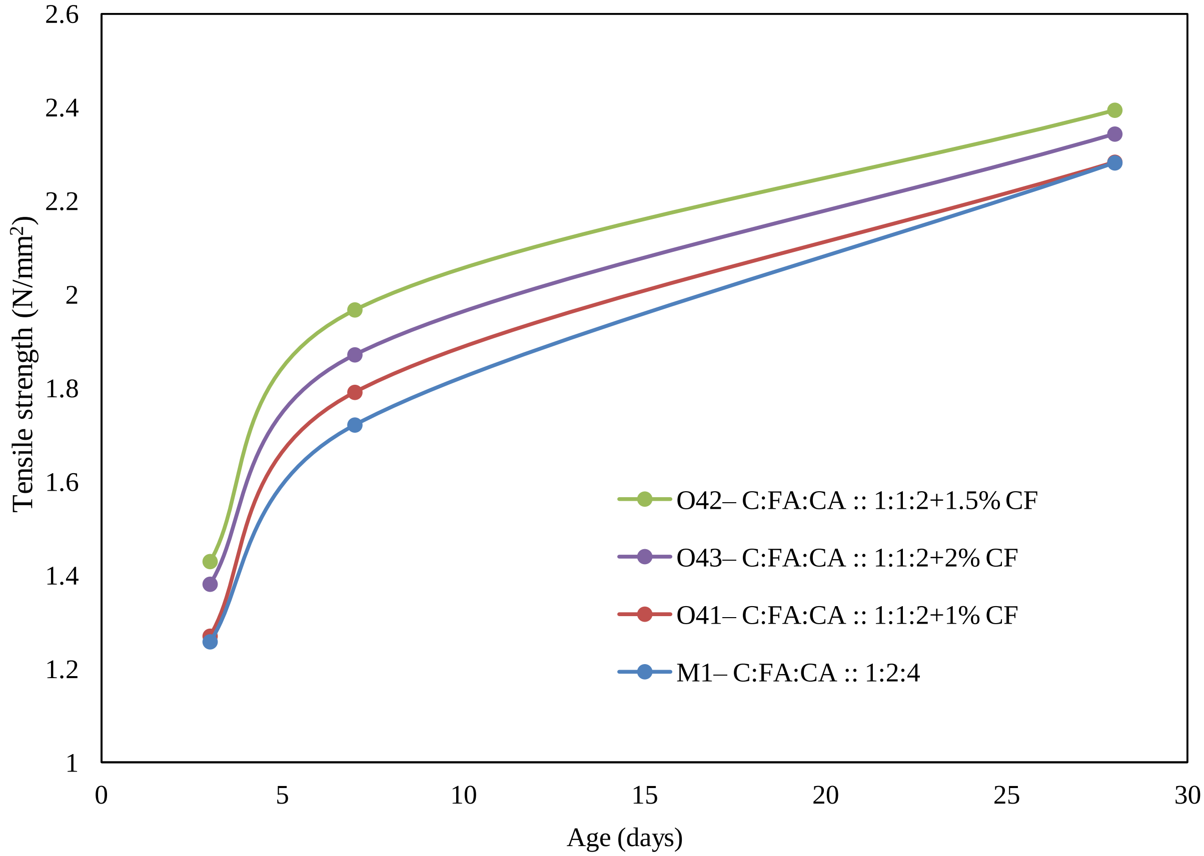

Figure 7. Tensile strength of nominal concrete with varying coconut fiber content

4.2.4 Effect of addition of coconut fiber on tensile strength of alccofine and bottom ash prepared concrete

Figure 8 illustrates the impact of adding coconut fiber at varied concentrations on the ideal ratio of alccofine (15%) substituting cement and bottom ash (30%) substituting fine aggregates. After 28 days of curing, the tensile strength of C:FA:CA:: 1:1:4 was 2.28N/mm^2, which climbed to 2.69N/mm^2 with the addition of 1%, 2.92N/mm^2 with the addition of 1.5% CF, and finally dropped to 2.83N/mm^2 with the addition of 2% CF content. The mixture C+AF(15%):FA+BA(30%):CA:: 1:1:2+1.5%CF showed the maximum improvement in tensile strength, and may be considered the best one for raising the tensile strength of nominal concrete. The greater bonding and compaction of distinct granules with fiber may be the cause of a rise in strength with CF, while the loss in strength with more CF concentration may be ascribed to less workability.

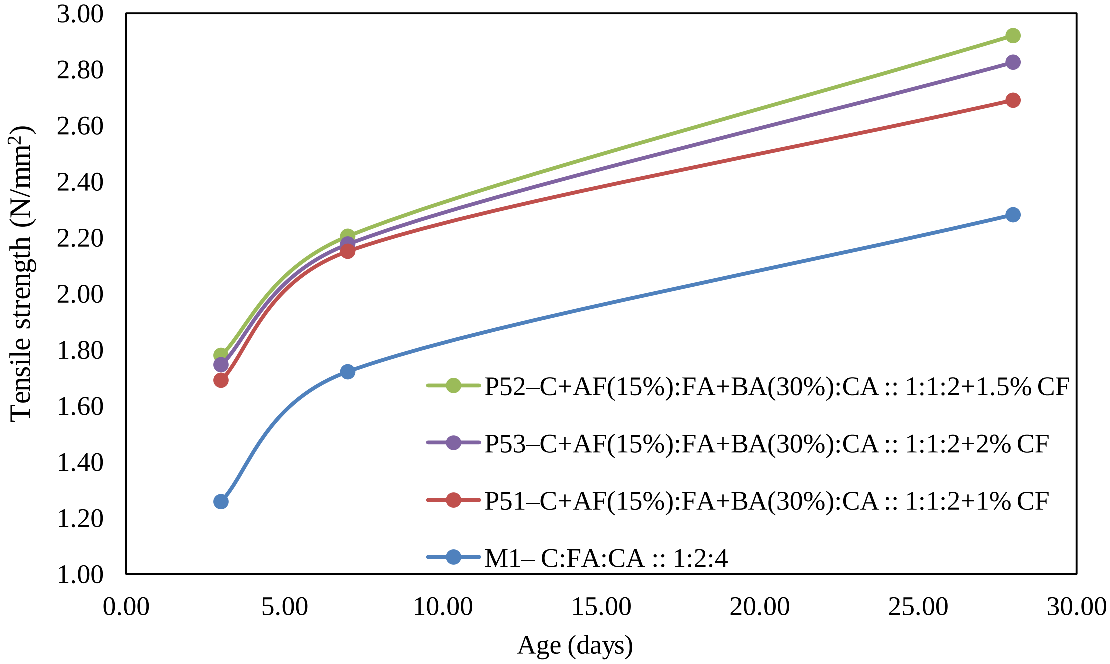

Figure 8. Tensile strength of alccofine and bottom ash added concrete with varying coconut fiber content

4.3 Effect of admixtures on flexural strength of concrete with curing

4.3.1 Effect of partial replacement of cement with alccofine on flexural strength

The impact of substituting different amounts of alccofine for cement on the flexural strength of concrete is shown in Figure 9. The highest possible flexural strength of concrete is attained at a 15% alccofine concentration; a greater alccofine percentage reduces the strength. The flexural strength improves with age and increased alccofine content. Alcofine, which takes the role of cement in concrete, fills up small gaps in the bulk of concrete to make it harder and boost flexural strength. While higher concentrations of alccofine substitute cement would produce less compact concrete, decreasing flexural strength, the proper alccofine substitution to cement fills the voids ideally, leading to compacted volume. Few scientists have previously noted a similar result when adding alccofine to concrete (Pawar and Saoji 2013).

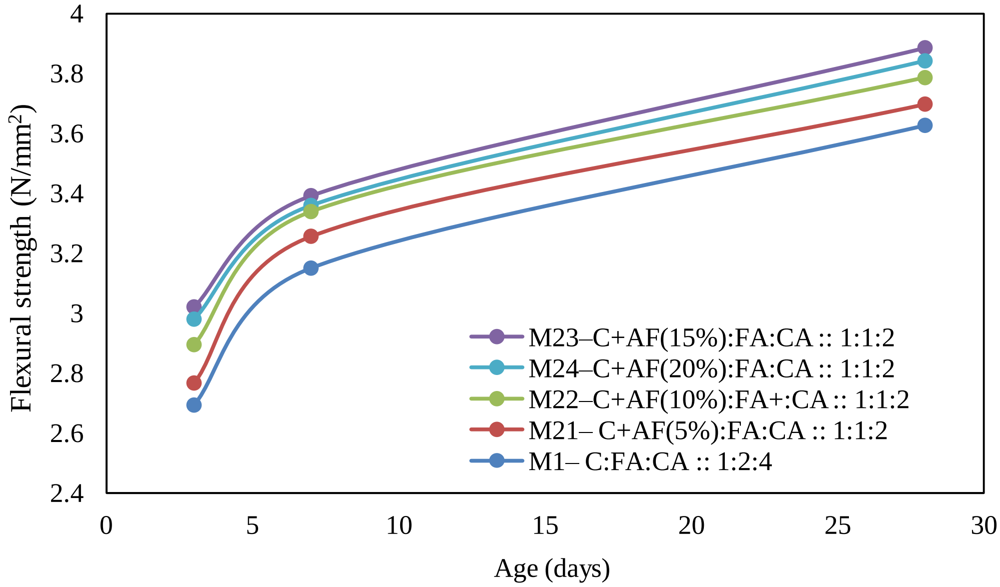

Figure 9. Flexural strength of nominal concrete with varying alccofine content

4.2.2 Effect of partial replacement of fine aggregates with bottom ash on flexural strength

As shown in Figure 10, the percentage of bottom ash replaced for fine particles in conventional concrete affects the flexural strength of the concrete. The maximum flexural strength of concrete is reached at 30% bottom ash content, and as bottom ash content increases further, the strength decreases. Since bottom ash uses portlandite through pozzolanic action, replacing fine aggregates with bottom ash increased the pozzolanic reaction and fine dispersion of C-S-H gel, increasing the flexural strength of the concrete mix. The optimal alternative for fine aggregate in concrete is bottom ash since it will fill cavities and provide a compact mass. Since bottom ash grains are spherical in form, it is thought to be owing to inadequate interlocking between the aggregates when higher content of BA was added. Few researchers had observed a similar outcome when adding bottom ash to concrete by substituting fine particles (Raut et al. 2023).

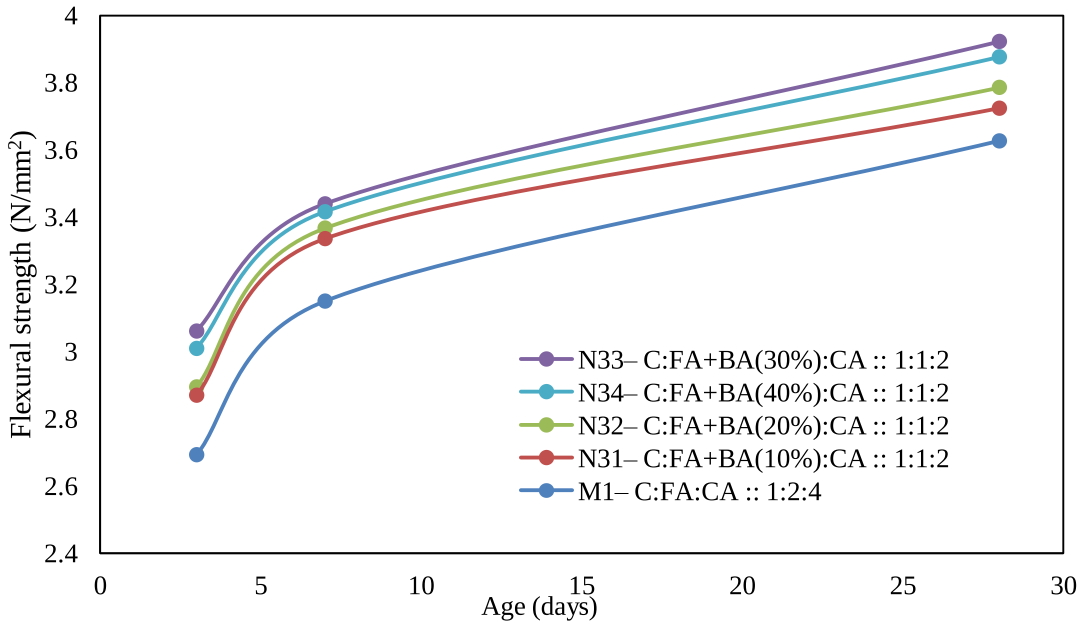

Figure 10. Flexural strength of nominal concrete with varying bottom ash content

4.1.3 Effect of addition of coconut fiber on tensile strength

Figure 11 shows how the addition of coconut fiber to normal concrete changes its flexural strength. The maximum flexural strength of concrete is achieved at 1.5% coconut fiber content, whereas coconut fiber level more than 1.5% reduces strength. The decrease could be attributed to the decreased workability of freshly produced concrete due to its increased fiber content, as well as insufficient compaction during sample casting, which creates air spaces, or to the diluting effect of fiber diversity on the combination of established structure and strengthened cement paste. Previously, investigators that incorporated coconut fiber to concrete had equivalent results (Bamigboye et al. 2020; Ramli et al. 2013).

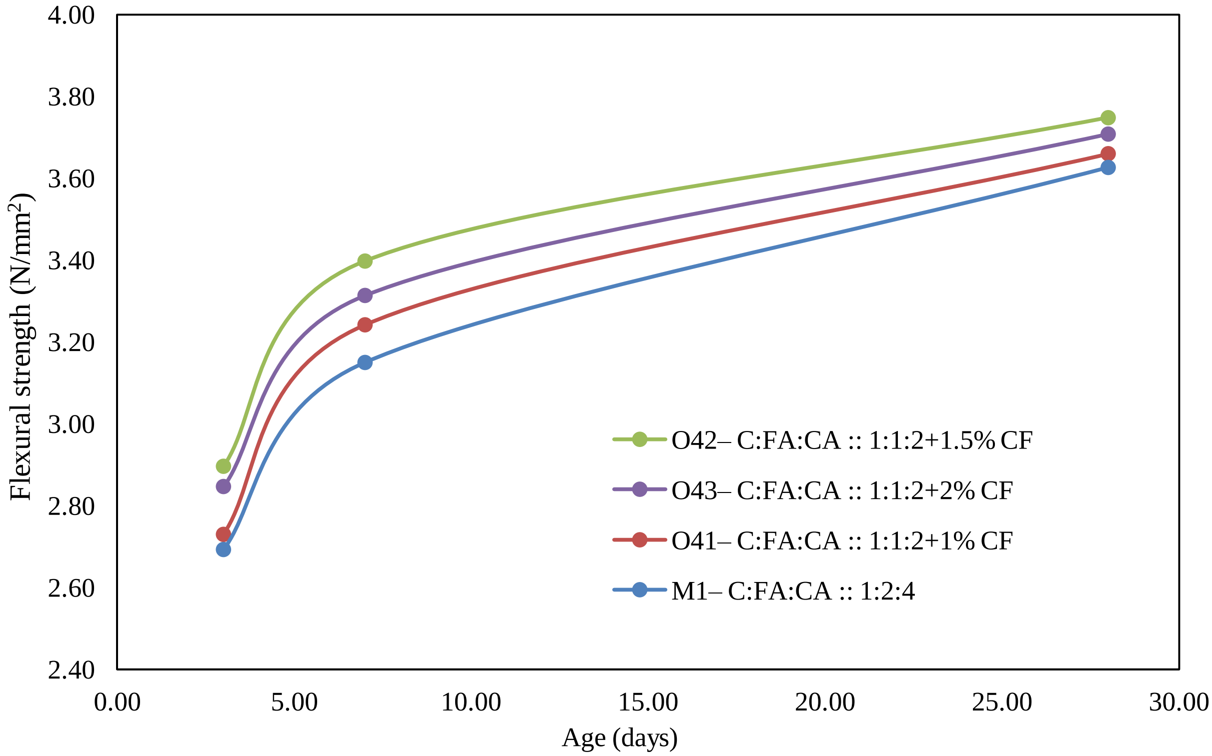

Figure 11. Flexural strength of nominal concrete with varying coconut fiber content

4.2.4 Effect of addition of coconut fiber on flexural strength of alccofine and bottom ash prepared concrete

Figure 12 depicts the effect of different amounts of coconut fibre on the optimal ratio of alccofine (15%) replacing cement and bottom ash (30%) replacing fine aggregates. The flexural strength of C:FA:CA:: 1:1:4 after 28 days of curing was 3.63N/mm^2, which improved to 3.97N/mm^2 with an increase of 1% CF, 4.13N/mm^2 with the introduction of 1.5% CF, and eventually reduced to 4.06N/mm^2 with the introduction of 2% CF content. The combination of C+AF(15%):FA+BA(30%):CA:: 1:1:2+1.5%CF enhanced flexural strength the most and may be regarded the best for increasing the flexural strength of standard concrete. Higher binding and compression of unique granules with fiber may generate a gain in durability with CF, but greater CF concentration causes a decrease in strength.

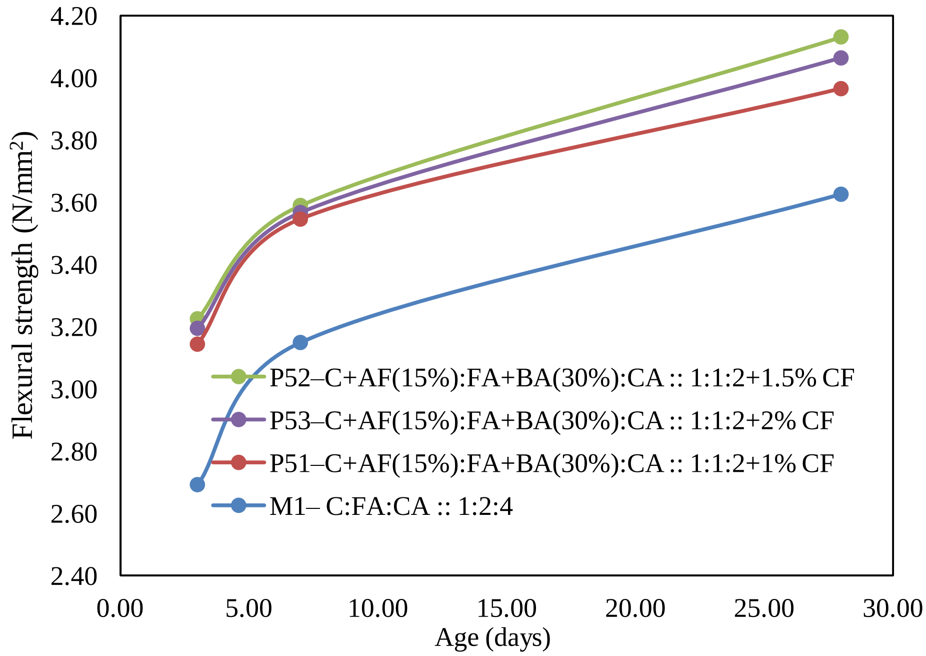

Figure 12. Flexural strength of alccofine and bottom ash added concrete with varying coconut fiber content

5. Conclusions

On the basis of experimental testing carried out in the laboratory on various combinations of alccofine (replacing cement), bottom ash (replacing fine aggregates) and addition of coconut fiber, the following major conclusions have been drawn:

1. The partial replacement of cement with 15% alccofine content increase compressive, tensile and flexural strength of nominal concrete for all curing periods. The compressive and the tensile strength increases by 15%; while the flexural strength increases by 7% on adding 15% alccofine to standard concrete after 28 days of curing.
2. The partial replacement of fine aggregates with 30% bottom ash boosts compressive, tensile and flexural strength of nominal concrete for all curing periods. The compressive and the tensile strength increases by 16% and 14% respectively; while the flexural strength increases by 8% on adding 30% bottom ash to standard concrete after 28 days of curing.
3. The addition of 1.5% coconut fiber to nominal concrete and concrete prepared with optimum allcofine and bottom ash contents also increases all strength characteristics of specimen for all curing periods. The compressive strength increases by 4.5%; while the tensile and flexural strength increases by 2.5% on adding 30% bottom ash to standard concrete after 28 days of curing. On adding 1.5% coconut fiber to C+AF(15%):FA+BA(30%):CA:: 1:1:2, the compressive and tensile strength increases by 24%; while the flexural strength increases by 12% to that of standard concrete after 28 days of curing.
4. The current study provides a cost-effective solution for waste management by utilizing it in concrete along with preserving the natural resources by reducing their percentages to prepare concrete.

References

1. Sivakumar, V. R., Kavitha, O. R., Arulraj, G. P., & Srisanthi, V. G. (2017). An experimental study on combined effects of glass fiber and Metakaolin on the rheological, mechanical, and durability properties of self-compacting concrete. *Applied Clay Science*, *147*, 123-127.
2. Ansari, U. S., Chaudhri, I. M., Ghuge, N. P., & Phatangre, R. R. (2015). High performance concrete with partial replacement of cement by alccofine and fly ash. *Indian Research Transaction*, *5*(2), 19-23.
3. Jindal, B. B., Singhal, D., Sharma, S., & Parveen, J. (2018). Enhancing mechanical and durability properties of geopolymer concrete with mineral admixture. *Computers and concrete*, *21*(3), 345-353.
4. Soni, M. K., & Singh, S. (2019). Statistical interpretation of marble dust and alccofine for soil stabilization. *Int. J. Innov. Technol. Explor. Eng*, *8*(7), 1609-1613.
5. Pawar, M. S., & Saoji, A. C. (2013). Effect of alccofine on self compacting concrete. *International Journal of Engineering and Science*, *2*(6), 05-09.
6. Khambra, G., & Shukla, P. (2023). Novel machine learning applications on fly ash based concrete: an overview. *Materials Today: Proceedings*, *80*, 3411-3417.
7. Kumar, D., Kumar, R., & Abbass, M. (2016). Study the effect of coal bottom ash on partial replacement of fine aggregate in concrete with sugarcane molasses as an admixture. *Department of Civil Engineering, SDDIET, Barwala*.
8. Rafieizonooz, M., Mirza, J., Salim, M. R., Hussin, M. W., & Khankhaje, E. (2016). Investigation of coal bottom ash and fly ash in concrete as replacement for sand and cement. *Construction and Building Materials*, *116*, 15-24.
9. Gupta, R., Ahmed, A., & Kumar Reddy Ithepalli, S. (2018). Evaluation of use of bottom ash in cement masonry and concrete regarding their mechanical properties. *Advanced Materials Letters*, *9*(8), 553-558.
10. Raut, A. N., Murmu, A. L., & Alomayri, T. (2023). Physico-Mechanical and thermal behavior of prolong heat Cured geopolymer blocks. *Construction and Building Materials*, *370*, 130309.
11. Gamage, S., Palitha, S., Meddage, D. P. P., Mendis, S., Azamathulla, H. M., & Rathnayake, U. (2022). Influence of crumb rubber and coconut coir on strength and durability characteristics of interlocking paving blocks. *Buildings*, *12*(7), 1001.
12. Ahmad, W., Farooq, S. H., Usman, M., Khan, M., Ahmad, A., Aslam, F., ... & Sufian, M. (2020). Effect of coconut fiber length and content on properties of high strength concrete. *Materials*, *13*(5), 1075.
13. Asyraf, M. R. M., Ishak, M. R., Syamsir, A., Nurazzi, N. M., Sabaruddin, F. A., Shazleen, S. S., & Razman, M. R. (2022). Mechanical properties of oil palm fibre-reinforced polymer composites: A review. *Journal of Materials Research and Technology*, *17*, 33-65.
14. Bamigboye, G., Ngene, B., Aladesuru, O., Mark, O., Adegoke, D., & Jolayemi, K. (2020). Compressive Behaviour of Coconut Fibre (Cocos nucifera) Reinforced Concrete at Elevated Temperatures. *Fibers*, *8*(1), 5.

15. Ramli, M., Kwan, W. H., & Abas, N. F. (2013). Strength and durability of coconut-fiber-reinforced concrete in aggressive environments. *Construction and Building Materials*, *38*, 554-566.