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Research Paper

Performance evaluation and statistical analysis of saw dust as concrete

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ABSTRACT

The utilization of industrial by products instead of the cementitious materials in concrete leads to sustainable environment and helps to reduce the environmental pollution. This part of the research concentrates on the performance evaluation of Saw Dust Ash (SDA) as a partial replacement for cement as well as the regression analysis among different parameters. It includes the setting time, fresh concrete properties and hardened concrete properties of the saw dust ash concrete. SDA was used by weight from 5% to 20% in steps of 5% to replace ordinary Portland cement. The fresh concrete properties indicate that the workability of SDA concrete decreases as the percentage replacement of SDA increases. The compressive strength, flexural and split tensile strength of the hardened concrete increases up to 10% of saw dust ash and then decreases. It is concluded that the optimum percentage to replace cement with saw dust ash is up to 10% for the reliable results. Further replacement would be detrimental to the strength of the concrete. The regression analyses to predict split tensile strength and flexural strength with respect to compressive strength shows very good correlation with regression coefficients of 0.979 and 0.911 respectively. The saw dust ash concrete was also found to be cheaper and friendlier to the environment than Portland cement concrete in the proportion to the percentage of cement replaced.

1 Introduction

Concrete is used as a construction material which dominates all other material due to its performance on resisting the applied force. Cement is the mixture of calcareous and silicious material which is the main constituent of concrete is being the reason for hydration and strength development [1]. Direct emission of CO_2 comes from breaking down of limestone while heating whereas CO2 emitted indirectly when the fossil fuels are heated inside the kiln [2]. Annual CO_2 emission from different sources is around 385 ppm with the increment of 2 ppm every year. The permissible limit of CO_2 emission should be below 350 ppm [3]. To reduce this emission of CO_2, it is very much required to find an alternative for cement [4]. Disposing issues on industrial by products, depletion of natural resources and the need to maintain sustainability all amplified to incorporate the industrial by products in concrete [5]. As a solution to reduce the CO_2 emission from cement manufacturing,

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the supplementary cementitious materials derived from agricultural wastes are used as partial for full replacement to the cement content in concrete [6].

It is estimated that 7.5 million tonnes of waste wood are produced in developing countries per year, with only 1.2 million tonnes recycled or reused and 0.3 million tonnes incinerated with energy recovery. The remaining 6 million tonnes, or 80%, are actually disposed of in landfills. Saw dust ash is produced at a rate of about 6 million tonnes per year [7]. As a result, waste saw dust is burned down to a finely powdered ash, which is then used to make concrete. Author [8] examined the effects of concrete properties when OPC of different grades was partially replaced by SDA. Sawdust was burned to ash and sieved through a 90-micron sieve. The study recommended that using SDA as a partial substitute for cement in all cement grades is up to a limit of 10% by volume.

One of the authors [9] investigated the effect of wood ash (WA) on concrete slump. Wood ash was used as a partial replacement material for cement in varying amounts of 0, 10, 20, 30, and 40% to produce 1:2:4 concrete. Since the addition of WA raises the carbon content in the mix, which necessitates a high-water demand. The test results showed that mixtures with a higher wood ash content need more water to achieve a fair workability. Another author [10] conducted research to see whether saw dust ash could be used as a partial substitute for fly ash in the manufacture of Geopolymer concrete. To generate a cost-effective geopolymer concrete, it is suggested that Fly ash can be partially replaced with Saw dust ash up to 5%.

One more author [11] explored the feasibility of using saw dust ash as a partial cement substitute material and compared the properties of fresh and hardened saw dust ash concrete to Portland cement concrete. It was concluded that the saw dust ash concrete will compete with Portland cement concrete by replacing up to 12% of the cement with saw dust ash. The best way to use Saw Dust Ash as a partial substitute for Ordinary Portland Cement in concrete was explored in this study. The fresh concrete properties, compressive strength, splitting tensile strength and flexural strength of concrete are analysed. Further a statistical evaluation to develop relationship among different properties of concrete were made called regression analysis. It represents the dependent and independent variable in which the dependent variables are expressed in terms of independent variable. The function of relationship is called target function [12]. In this paper the setting time is forecasted by consistency, compacting factor is expressed in terms of slump, compressive strength of cylinder is determined from compressive strength of cube, flexural strength and split tensile strength is predicted from compressive strength of concrete.

Fig. 1 – Burning of saw dust ash

2 Research significance

Sustainability is the important attribute which is the need of the hour to preserve the energy resources as well as to minimize the environmental pollution. Cement production causes maximum contribution to the CO_2 emission to the environment. Since CO_2 emission is one of the main reasons for ozone layer depletion and resulting global warming, it is most welcome to replace any appropriate waste in the place of cement. Saw dust ash is one of the waste materials which is having very high fineness compared to cement. Saw dust ash obtained from open burning satisfies the limits of pozzolanic material. It shows good compressive strength, split tensile strength and flexural strength upto 10% replacement.

3 Experimental program

3.1 Materials

The cement used was ordinary Portland cement (OPC) grade 43 (ESSAR cement) that met the standard codal provision IS 8112-1989 [13] and has a specific gravity of 3.15. The sawdust was collected from the Ambika Timber woods in Thanjavur, Tamilnadu and then converted to ash by open burning in which the temperature was not maintained as constant. Fig.1 depicts the burning procedure. The burnt ash is then allowed to cool for 12 hours in natural conditions. The ash was ground to fine powder and sieved through a 90-micron sieve before being used in concrete. The saw dust ash's average specific gravity was found to be 1.64. The fineness of SDA is found to be 5%. This demonstrates that SDA particles are smaller than cement particles. As a result, it is predicted to have a significant impact on better hydration. The ash has moisture content of 0.41%.

Table 1 – Chemical composition of Saw Dust Ash

Constituents	Saw dust (%)	Cement (%)
Alumina (Al_2O_3)	4.80	20.85
Silica (SiO_2)	79.727	4.78
Calcium (CaO)	8.20	63.06
Iron (Fe_2O_3)	4.45	3.51
Magnesium oxide (Mgo)	2.08	2.32
Sodium (Na_2O)	0.033	0.24
Potassium (K_2O)	0.71	0.55

The coarse aggregate of 20mm size has a specific gravity of 2.71, a water absorption of 0.6 percent, a fineness modulus of 6.81, and a flakiness and elongation index far below 15%. The fine aggregate is river sand that has been sieved at 4.75mm and has a specific gravity of 2.57, moisture content of 14.4%, water absorption of 2.45%, and fineness modulus of 2.51. It is classified as Zone II as per the classification of IS:383- 1970 [14] and has a specific gravity of 2.57, moisture content of 14.4%, water absorption of 2.45 percent, and fineness modulus of 2.51. Chemical composition of saw dust is compared with the composition of cement in Table 1. Saw dust contains maximum silica content of 79.727 %. As per ASTM 618-19 [15] standard the chemical composition of saw dust satisfies the availability of minimum oxide compounds. Summing up all the total oxide components gives the value more than 75% which the minimum criteria [16]. Hence saw dust is identified as a pozzolanic material.

Table 2 – Mix proportions

SDA %	W/C Ratio	Cement kg/m^3	SDA kg/m^3	Fine aggregate kg/m^3	Coarse aggregate kg/m^3
0%	0.5	403.02	-	756	1596
5%	0.5	383.04	20.16	756	1596
10%	0.5	362.88	40.32	756	1596
15%	0.5	342.72	60.48	756	1596
20%	0.5	322.56	80.64	756	1596

3.2 Mix proportions and testing details

As per the recommended procedure of Bureau of Indian standards IS:10262-2009 [17], Mix ratio is designed for M20 grade concrete with 1:1.5:3 mix proportion. Design is stipulated for good degree of quality control and mild exposure. The water cement ratio was adopted as 0.5. Totally five mix proportions were derived including control concrete as shown in Table 2. To analyze the fresh concrete properties, the slump cone test, compacting factor test was conducted as per the IS: 7320-1974 [18], IS: 1199-1959 [19]. Concrete cubes of size 150 x 150 x 150mm, cylinders of diameter 150 x 300 mm and 150 x 150 x 500mm prisms were cast to analyze compressive strength, tensile strength and flexural strength of concrete. The concrete cylinder is also tested for compression and split tensile test.

4 Result and Discussion

4.1 Characteristics of saw dust ash

Initial and final setting time of cement depends on the standard consistency of cement paste. Table 3 listed the consistency and setting time values for all design mixes. Due to the addition of saw dust ash there is a notable change in consistency limit. Fig.2 shows the variation of consistency for all mix proportions. Since the size of the saw dust ash is lesser than the size of cement the specific surface area of saw dust ash is high. Large specific area requires additional quantity of cement paste to coat it. Hence the consistency limit increases as the amount of replacement of saw dust ash increases [20]. Fig shows variation of consistency for all proportions. There is no change in the consistency value upto 10% replacement of saw dust ash replacement. Final setting time ranges from 300 to 340 minutes as compared to 290 minutes for plain OPC paste. However, the setting time of replacement paste is within the standard range as per IS:4031-1988 [21]. Linear regression analysis shown in Fig.3 depicted that Eqn (1) and Eqn (2) predicts the initial and final setting time durations from consistency values with regression coefficients of 0.9091 and 0.9377 respectively.

Table 3 – Consistency, Initial setting time and fresh concrete properties

SDA	Consistency limit	Initial setting time	Final setting time	Slump	Compacting factor
%	%	min	min	mm	
0	30	85	225	80	0.9543
5	30	95	240	70	0.8901
10	30	100	245	68	0.8867
15	31	105	255	65	0.8528
20	32	115	260	60	0.8271

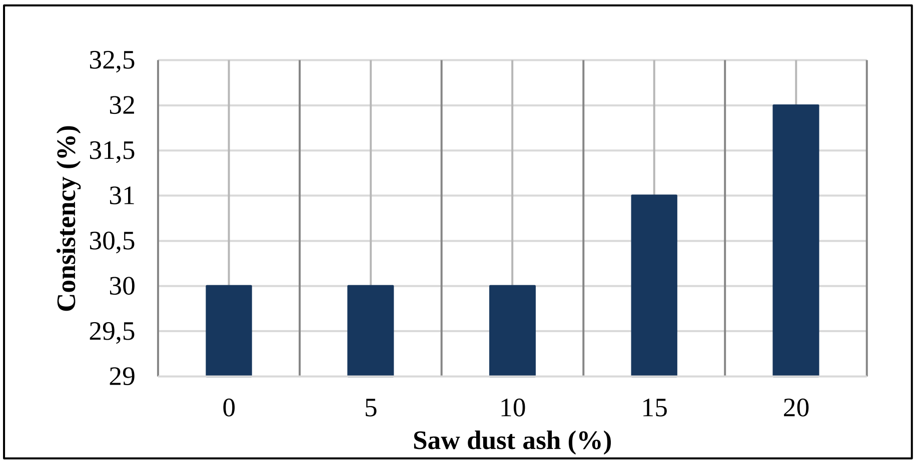

Fig. 2 – Variation in consistency limit

Slump value decreases as the saw dust ash replacement increases. The sawdust ash is finer in size, so it consumes more volume in the aggregate matrix and, hence, requires higher water content and thus decreases the slump value [22]. Fig.4 illustrates the variation of slump and compacting factor for different mix proportions. High silica and calcium content of a pozzolanic material such as saw dush ash requires more water content [23]. At the outset, 35% of slump value decreases in 20% replacement. Compacting factor values reduces from 0.8901 to 0.8271 for the replacement level 5% to 20%. Slump values are used to predict compacting factor values shown in Fig.5 gives a regression coefficient of 0.9878. It depicts that the slump increases the compacting factor also increases. The aggregate to cement ratio decides the increase in compacting factor. When the powder content rises, it acts as a lubricant and increases the compacting factor value.

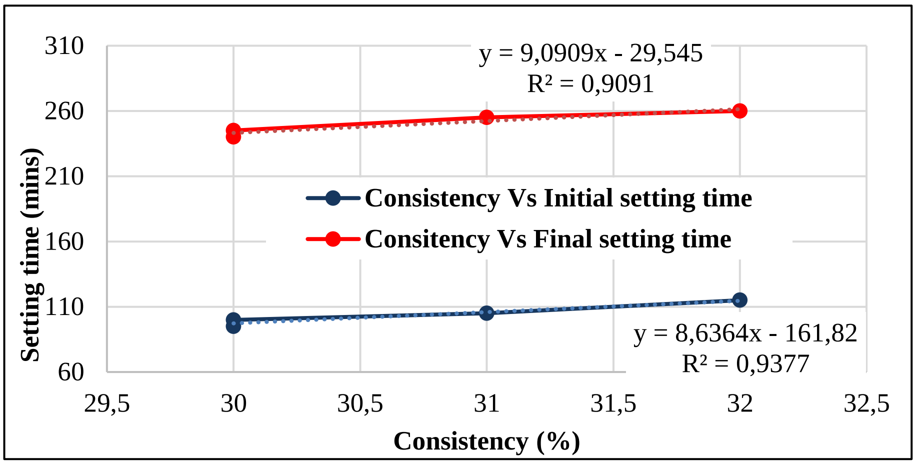

Fig. 3 – Prediction of setting time from consistency values

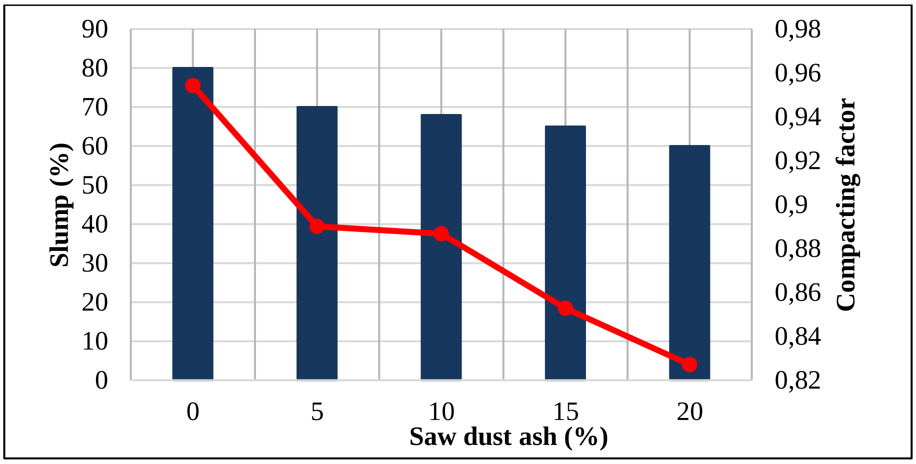

Fig. 4 – Variation of slump and compacting factor

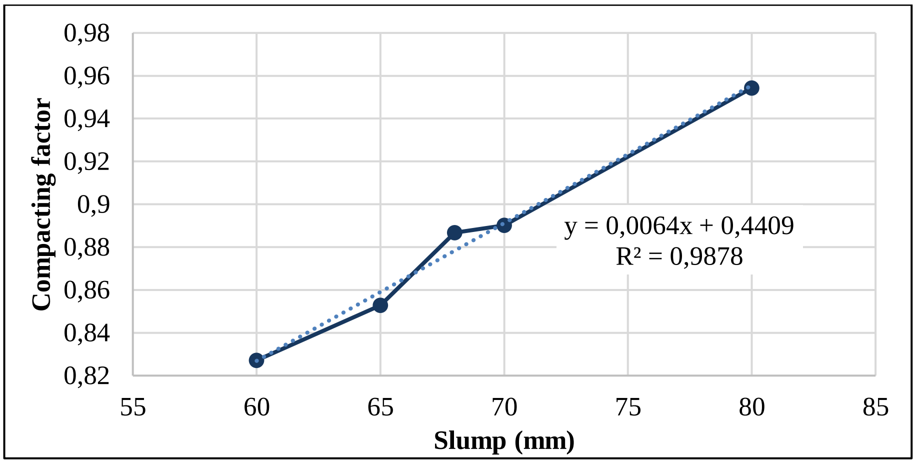

Fig. 5 – Prediction of compacting factor

4.2 Hardened concrete properties

The hardened concrete test such as compressive strength, flexural strength and split tensile strength were tested as per IS: 516 – 1959 [24], IS: 1199-1959[24], SP: 23-1982 [25], IS: 10086-1982 [26]. Table 4 shows the results obtained from different tests. The target mean strength of M20 grade concrete is 26.67 N/mm^2.

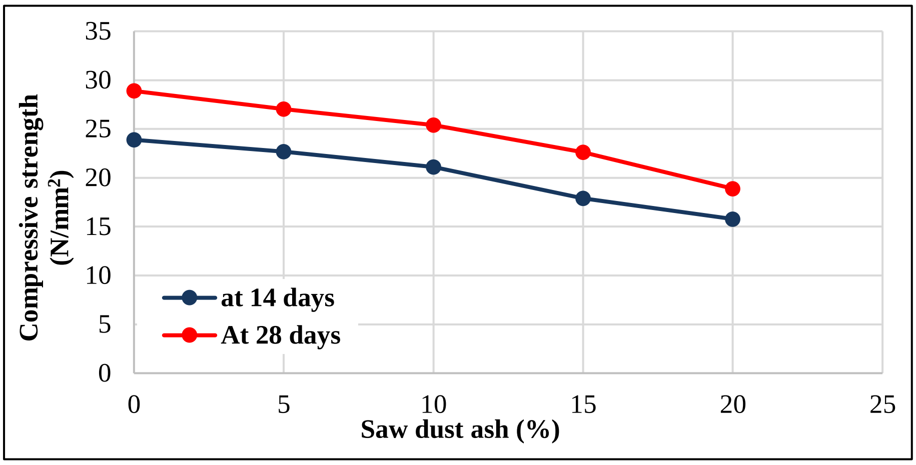

Fig. 6 – Compressive strength at 14 and 28 days

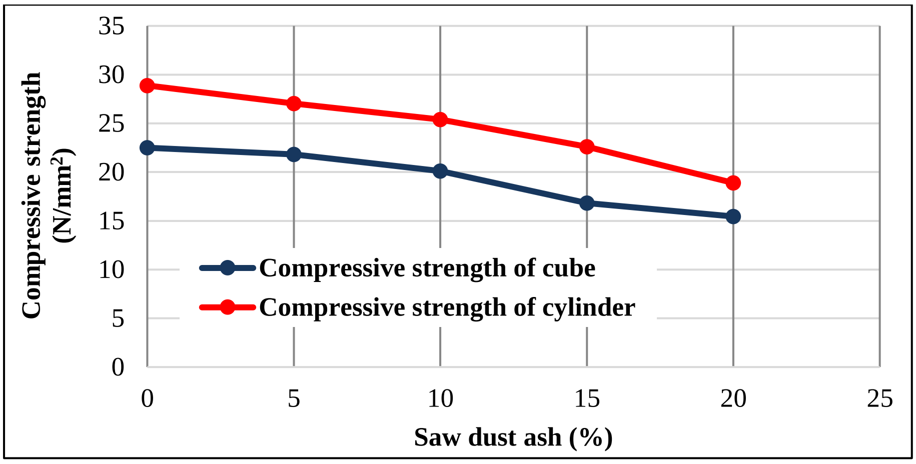

Fig. 7 – Comparison between compressive strength of cubes and cylinders

Table 4 – Hardened concrete properties

SDA	Compressive strength on cube (N/mm^2)		Compressive strength on cylinder (N/mm^2)	Flexural strength (N/mm^2)	Split tensile strength (N/mm^2)
	14 days	28 days	28 days	28 days	28 days
0%	23.89	28.89	22.5	3.552	2.62
5%	22.67	27.02	21.81	3.392	2.33
10%	21.11	25.41	20.11	3.2	2.19
15%	17.89	22.61	16.84	2.84	1.98
20%	15.78	18.89	15.45	2.76	1.63

Fig.6 shows the variation of compressive strength at 14 and 28 days. Decreasing trend of compressive strength was observed at each dosage of SDA percentage. SDA possess very low pozzolanic reaction, low rate of hydration and low

Calcium oxide content [27]. The control concrete specimen (0% cement replacement) achieves a compressive strength of 28.89 N/mm2 at 28 days. It was greater than expected value as the mix design for concrete. The results predict that the compressive strength of concrete decreases due to the addition of saw dust ash. Even though 5% of saw dust ash has reached the target value of compressive strength. 20% replacement of saw dust ash gives the lowest 28-day strength value of 18.89 N/mm2. However, the long-term compressive strength showed as considerable rate of increment in compressive strength [28]. In addition, the compressive strength of cylinder is lower than the compressive strength of cube specimens. Fig.7 depicts the compressive strength of cubes and cylinders. The percentage of reduction is in the range of 18% to 25% compared to cube specimens. Size of the cylinder specimen occupies more volume which is subjected to more stress than larger specimen resulting in lesser strength [29].

It was also observed that compressive strength continued to increase with age. A regression analysis was made to predict equivalent compressive strength of cylindrical specimens from the compressive strength values of cube specimens (Fig.8) given in Eq (1).

$$f_{cy} = 0.7702 f_{cu} + 0.4239 \tag{1}$$

where f_{cy} is the compressive strength of cylindrical specimens and f_{cu} is the compressive strength of cube specimens. Eq (1) refers to a linear equation which yields 0.9598 as regression coefficient.

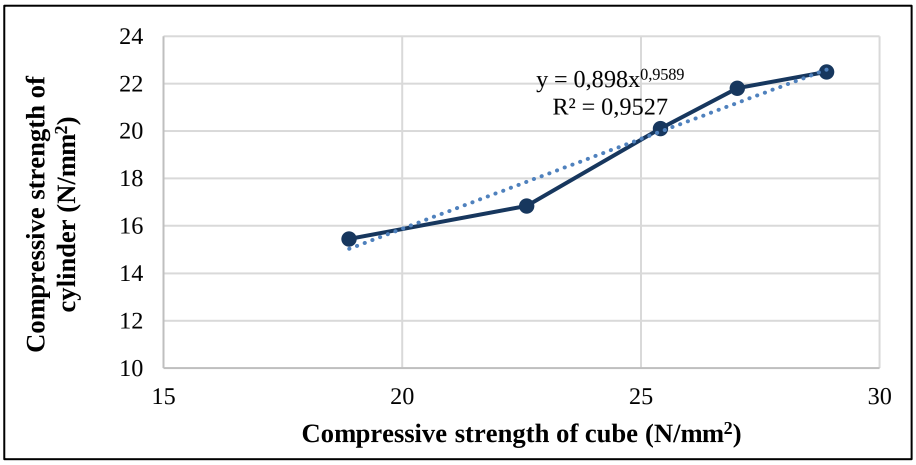

Fig. 8 – Prediction of compressive strength of cylinder

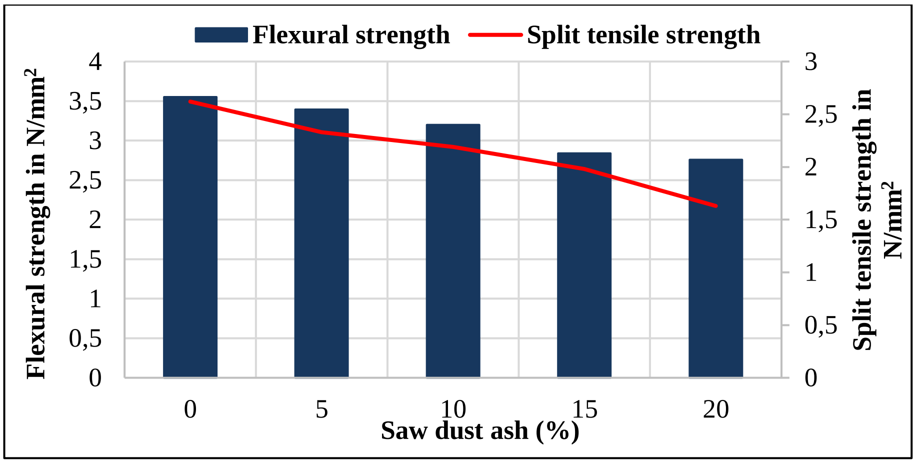

Fig. 9 – Flexural strength and split tensile strength

Fig. 9 represents variation of flexural strength and split tensile strength. Flexural strength of saw dust ash concrete reduces from 3.39 to 2.76 N/mm^2 for each replacement. Split tensile strength of concrete decreases from 2.33 to 1.63 N/mm^2 for each replacement. Figures 10 and 11 demonstrate how the compressive strength of a concrete cube can be used to estimate flexural and split tensile strength. Eq (2) depicts the relationship between flexural and compressive intensity based on the regression analysis. The relationship between split tensile strength and compressive strength is expressed by Eq (3). To determine flexural strength of concrete, Eq (4) and Eq (5) prove similar equations suggested by ACI code [30, 31]. Similar equations for predicting split tensile strength of concrete have already been obtained by the author Neville [31] and ACI code [32].

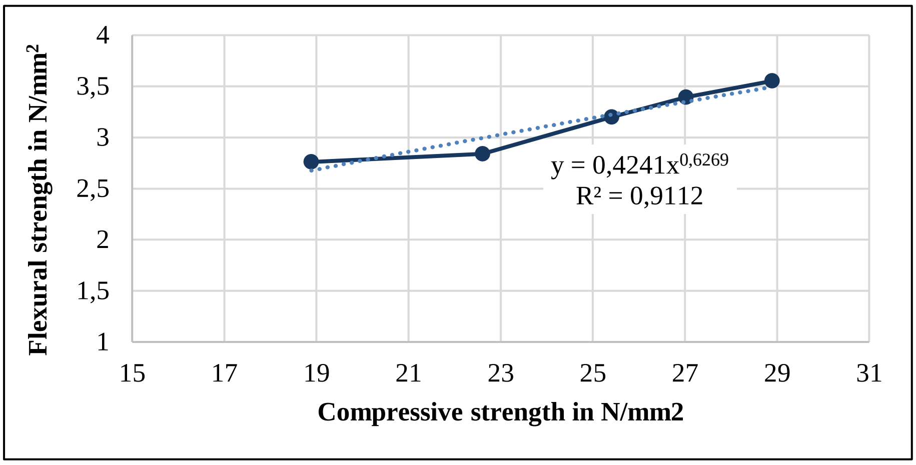

Fig. 10 – Prediction of Flexural strength

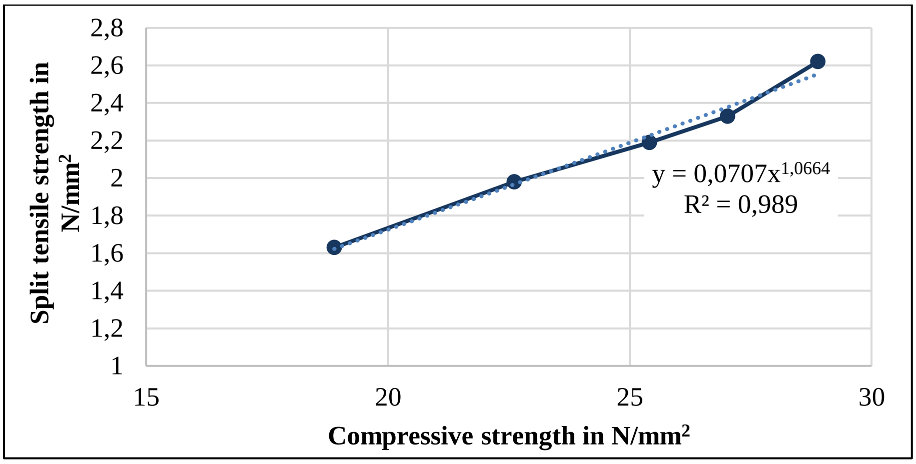

Fig. 11 – Prediction of split tensile strength

Regression coefficient $R^2 = 0.9112$ $$f_{fs} = 0.4241 f_c^{\,0.6269} \quad (2)$$

Regression coefficient R^2=0.979 $$f_t = 0.707 f_c^{\,0.69} \quad (3)$$

ACI 318 R-95 [29] $$f_{fs} = 0.62 f_c^{\,0.5} \quad (4)$$

ACI 363R-92 [30] $$f_{fs} = 0.94 f_c^{\,0.5} \quad (5)$$

Neville (1995) [31] $$f_t = 0.23 f_c^{\,0.67} \quad (6)$$

ACI 363R-92 $$f_t = 0.634 f_c^{\,0.5} \quad (7)$$

ACI 363R-92 $$f_t = 0.94 f_c^{\,0.5} \quad (8)$$

ACI 318R-99 [32] $$f_t = 0.59 f_c^{\,0.5} \quad (9)$$

where f_{fs} is the flexural strength of concrete, f_t represents split tensile strength of concrete and fc represents compressive strength of concrete. The weakening is caused by a lack of bonding and a delay in the hydration process. The implication is that the concrete with up to 10% cement replacement can be used for most concrete works such as structural members in buildings.

5 Conclusion

Saw dust ash is a pozzolanic material since it is having more than 70% of oxide components. The ash contains calcium oxide which would be comparable with that of OPC Due to large surface area the consistency limit is more and setting hours is high as well. The workability of the SDA concrete decreased when higher amount of cement was replaced by the saw dust ash. Hence higher amount of water would be required to improve the workability of the concrete when the percentage of the saw dust ash is higher.

Compressive strength results show that 5%replacement reaches the required target strength. At 10% replacement it starts decreasing. The strength goes on decreasing for further replacements. Similar effect was observed in the split tensile strength and flexural strength. Ordinary Portland cement has typical flexural strength values of 3.552 N/mm^2 for M20 grade of concrete. The 10% replacement mix attain a flexural strength of 3.20 N/mm^2. Also based on split tensile test that a cement replacement of up to 10% with saw dust ash attained 2.19 N/mm^2. The regression analysis concluded that the flexural strength and split tensile strength can be accurately predicted from the compressive strength values.

REFERENCES

[1]- M.S. Imbabi, C. Carrigan, S. McKenna, Trends and developments in green cement and concrete technology. Int. J. Sust. Built Env., 1(2) (2012) 194-216. doi:10.1016/j.ijsbe.2013.05.001.

[2]- M.C.G. Juenger, F. Winnefeld, J.L. Provis, J.H. Ideker, Advances in alternative cementitious binders. Cem. Concr. Res., 41(12) (2011) 1232-1243. doi:10.1016/j.cemconres.2010.11.012.

[3]- P.K. Mehta, H. Meryman, Tools for reducing carbon emissions due to cement consumption. Structure, 1(1) (2009) 11-15.

[4]- C. Vijayaprabha, D. Brindha, A. Siva, Durability performance of copper slag concrete admixed with polypropylene fiber. J. Struct. Eng, 43(6) (2017) 1-5.

[5]- V. Chakrawarthi, B. Darmar, A. Elangovan, Copper slag concrete admixed with polypropylene fibres. Građevinar, 68(02.) (2016) 95-104. doi:10.14256/JCE.1211.2015.

[6]- J. Sun, J. Feng, Z. Chen, Effect of ferronickel slag as fine aggregate on properties of concrete. Constr. Build. Mater., 206 (2019) 201-209. doi:10.1016/j.conbuildmat.2019.01.187.

[7]- W. Ahmed, R.A. Khushnood, S.A. Memon, S. Ahmad, W.L. Baloch, M. Usman, Effective use of sawdust for the production of eco-friendly and thermal-energy efficient normal weight and lightweight concretes with tailored fracture properties. J. Cleaner Prod., 184 (2018) 1016-1027. doi:10.1016/j.jclepro.2018.03.009.

[8]- C. Marthong, Sawdust ash (SDA) as partial replacement of cement. Int. J. Eng. Res. Appl., 2(4) (2012) 1980-1985.

[9]- M. Abdullahi, Characteristics of wood ash/OPC concrete. Leonardo Elec. J. Prac. Tech., 8 (2006) 9-16.

[10]- T. Praveen Kumar, C. Sudheesh, S. Sasi Kumar, Strength Characteristics of Saw Dust Ash Based Geo polymer Concrete. Int J ChemTech Res, 8(2) (2015) 738-745.

[11]- Ratod Vinod Kumar, M.S.R. Krishna, A Case Study on Partial Replacement of Cement by Saw Dust Ash in Concrete. Int.l J. Sci. Res., 5(6) (2016) 275-280.

[12]- C. Vijayaprabha, Evaluation of long term compressive strength of concrete made with copper slag and polypropylene fiber. J. Struct. Eng, 441 (2020) 441-448.

[13]- I. BIS, IS 8112:2013. Specification for 43 grade ordinary Portland cement, Bureau of Indian Standards, New Delhi, India. (2013).

[14]- I. BIS, IS 383- 1970. Specification for coarse and fine aggregates from natural sources for concrete, Bureau of Indian Standards, New Delhi, India. (1970).

[15]- A. ASTM, ASTM C618-19 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. ASTM International, West Conshohocken, PA, (2018).

[16]- C. Vijayaprabha, D. Brindha, Investigation on cyclic behaviour of FRC beams incorporating copper slag as sustainable waste. J. Mat. Eng. Str. «JMES», 7(2) (2020) 293-306.

[17]- BIS, IS:10262-1982 : Recommended Guidelines for Concrete Mix Design Tile, Bureau of Indian Standards, New Delhi, India. (1999).

[18]- BIS, IS 7320-1974, specification for concrete slump test apparatus, Bureau of Indian Standards, New Delhi, India.

[19]- BIS, IS: 1199-1959, Method of sampling and analysis Bureau of Indian Standards, New Delhi, India.

[20]- A.U. Elinwa, Y.A. Mahmood, Ash from timber waste as cement replacement material. Cem. Concr. Compos., 24(2) (2002) 219-222. doi:10.1016/S0958-9465(01)00039-7.

[21]- BIS, IS 4031-1988, Methods of physical tests for hydraulic cement Bureau of Indian Standards, New Delhi, India.

[22]- A. Muneer, B.A. Mempn, M. Oad, Impact of Cement Replacement by Sawdust Ash on Workability and Compressive Strength of Concrete. Quaid-E-Awam University Research Journal of Engineering, Science & Technology, Nawabshah., 18(1) (2020) 43-50.

[23]- A. Raheem, B. Olasunkanmi, C. Folorunso, Saw dust ash as partial replacement for cement in concrete. Organization, technology & management in construction: an international journal, 4(2) (2012) 474-480. doi:10.5592/otmcj.2012.2.3.

[24]- BIS, IS 516-1959: Method of Tests for Strength of Concrete, Bureau of Indian Standards, New Delhi, India. (1959).

[25]- I. SP23, Handbook on concrete mixes. Bureau of Indian Standards, New Delhi, (1982).

[26]- BIS, IS 10086-1982 : Specification for moulds for use in tests of cement and concrete. Bureau of Indian Standards, New Delhi, India, (2008).

[27]- F.F. Udoeyo, H. Inyang, D.T. Young, E.E. Oparadu, Potential of Wood Waste Ash as an Additive in Concrete. J. Mater. Civ. Eng., 18(4) (2006) 605-611. doi:10.1061/(ASCE)0899-1561(2006)18:4(605).

[28]- M. Tokyay, M. Özdemir, Specimen shape and size effect on the compressive strength of higher strength concrete. Cem. Concr. Res., 27(8) (1997) 1281-1289. doi:10.1016/S0008-8846(97)00104-X.

[29]- A. Committee. Building code requirements for structural concrete (ACI 318-95) and commentary (ACI 318R-95). American Concrete Institute. (1995.

[30]- A. Committee. 363R-92, State-of-the-art report on high-strength concrete. American Concrete Institute. (1997.

[31]- A.M. Neville, Properties of concrete. Vol. 4. Longman London, 1995.

[32]- A. Committee. Building code requirements for structural concrete:(ACI 318-99); and commentary (ACI 318R-99). American Concrete Institute. (1999.