Utilization of Sawdust as Sustainable Construction Material

Kiran Devi, Nana Lida, Taba Teyi, Puyam Bicker Singh, Kaushal Sharma, and Neeraj Saini

Abstract The large-scale mining of natural materials like sand, for use in infrastructure projects, in emerging countries like India is creating a threat to the environment. As a result, it becomes necessary for researchers to investigate the use of industrial by-products instead of natural materials in order to safeguard the environment. This research looked into the effectiveness of utilizing sawdust to partially substitute river sand in concrete, which could help to minimize both environmental issues and construction costs. Sawdust is a waste product that, when burnt, emits a large amount of carbon dioxide, polluting the environment. The direct dumping of wood waste is damaging to the environment, forcing waste management strategies to be developed. The use of sawdust by replacing fine aggregates can be helpful to the construction industries in terms of economic and environmental aspects. In the present study, sawdust was used as partial substitution to fine aggregates by 0, 5, 10, 15 and 20% to investigate its effect on compressive strength, density, dynamic elastic modulus and water absorption of concrete at different curing ages. The non-destructive tests were also conducted on the concrete specimens. The economic analysis of sawdust was also carried out. The use of saw dust as a sand replacement resulted in inferior performance in several aspects when compared to normal concrete. However, using waste as a sand replacement increased the performance in terms of economic and environmental factors.

Keywords Cement concrete · Sawdust · Compressive strength · Density · Economic analysis

K. Devi (✉) · N. Lida · T. Teyi · P. B. Singh · K. Sharma · N. Saini
Department of Civil Engineering, Faculty of Engineering and Technology, Shree Guru Gobind Singh Tricentenary University, Gurugram, Haryana 122505, India
e-mail: kiranbimbhra@gmail.com

K. Sharma
e-mail: kaushal@sgtuniversity.org

N. Saini
e-mail: drneeraj.fet@sgtuniversity.org

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1 Introduction

The most popular building material is concrete. Durability and environmental safety are also essential considerations in the building process. Aggregates are one of the most important ingredients of concrete production, and growing demand of building industry has resulted in rapid depletion of natural resources. Every year, about 11 billion tonnes of natural aggregates are taken from riverbeds all around the world [1]. Several countries have imposed limitations in recent years to prevent the negative environmental impacts of sand mining from rivers. As a result of these rules, researchers and construction companies are looking for alternate aggregate from different industries [1, 2].

Because wood is utilized in so many businesses and is so engrained in our daily lives, there is a huge amount of sawdust and other recovered wood available. The majority of sawdust is produced by timber industries all over the world. Sawdust is a by-product of sawing wood into standard sizes. It's made out of wood chips or loose particles. The particle size is determined by the type of wood used to make sawdust, as well as the size of the saw teeth. During milling procedures, roughly 10 to 13% of the overall content of the log is converted to sawdust, depending on the average width of the blade, the thickness of the timber sawed, and the sawing method [2, 3]. Sawdust is produced in large quantities as industrial waste that must be appropriately disposed of in the environment. Sawdust is primarily disposed of in landfills. Furthermore, open sawdust dumping has the potential to cause serious health problems. When sawdust is burned off, it causes pollution and other environmental problems in developing countries. As a result, proper sawdust use remains a big concern, endangering the ecosystem and environment even more [2, 3]. The substitution of sawdust for sand reduced the workability and hardened density significantly [4–6]. The use of sawdust powder and powdered granulated blast slag in mortar mixtures increased strength while lowering cost [7]. Siddique et al. [6] reported that sawdust powder at 5% has comparable strength afterward strength declined.

The current study investigates the effects of sawdust powder as a fractional substitution to sand on the hardened properties of different concrete mixtures. The correlation between compressive strength and density was derived. The goal of the study was to examine the feasibility of sawdust powder in different concrete mixtures in terms of fresh, hardened, and cost aspects.

2 Materials and Methods

2.1 Material

The ordinary Portland cement of 43 grade, which meets the Indian Standards specification, was used in the concrete mixtures [8]. Table 1 shows the physical parameters of cement. In this study, fine sand and gravel of 10 and 20 mm size were employed,

Table 1 Physical properties of cement

Property	Consistency	IST	FST	Soundness	Specific gravity	Fineness
Value	28.5	175	265	4	3.1	5%

Table 2 Physical properties of aggregates

Property	Aggregates	Type	Fineness modulus	Zone	Specific gravity	Bulk density (loose), kg/m^3	Bulk density (compacted), kg/m^3
Values	Fine aggregates	Natural coarse sand	3.15	II	2.62	1646	1824
	Coarse aggregates (10 mm)	Crushed aggregates	6.0	–	2.67	1480	1700
	Coarse aggregates (20 mm)	Crushed aggregates	6.8	–	2.65	1410	1550

Table 3 Mix designation of concrete mixtures

Sr. No.	1	2	3	4	5
Mix designation	SD0	SD5	SD10	SD15	SD20
Sawdust powder (%)	0	5	10	15	20

and physical aggregate properties are listed in Table 2 [9]. Throughout the trial, only tap water was utilized. Sawdust powder is made from hardwoods and softwoods. It was sun-dried and stored in waterproof bags. Before using in concrete mixtures, sawdust powder was sieved through 1.18 mm sieve. The sawdust powder had a specific gravity of 1.6 and water absorption of 1.6%.

2.2 Mix Proportions

The cement concrete specimens were cast by varying the quantities of sawdust powder and fine aggregate. The mix proportions for different concrete mixtures are detailed in Table 3.

After 28 days of water curing, the cube compressive test on concrete samples was performed in a compressive machine according to IS specification [10]. At 28 days, the density of concrete samples was assessed. The rebound hammer and ultrasonic pulse velocity tests were carried out in accordance with IS:13,311-1992 [11, 12]. The amount of water absorbed by concrete samples was measured.

3 Results and Discussion

3.1 Density

The effect of sawdust powder on the density of hardened concrete has been illustrated in Fig. 1. The density of hardened concrete, on the other hand, gradually falls as the level of sawdust replacement increases, as shown in Fig. 1. The reduction in density of hardened concrete may be due to the lower specific gravity of sawdust particles [2]. At 28 days, sawdust at 5, 10, 15, and 20% reduced density by 7.5, 10.7, 13.7, and 21.2% respectively, as illustrated in Fig. 1(b).

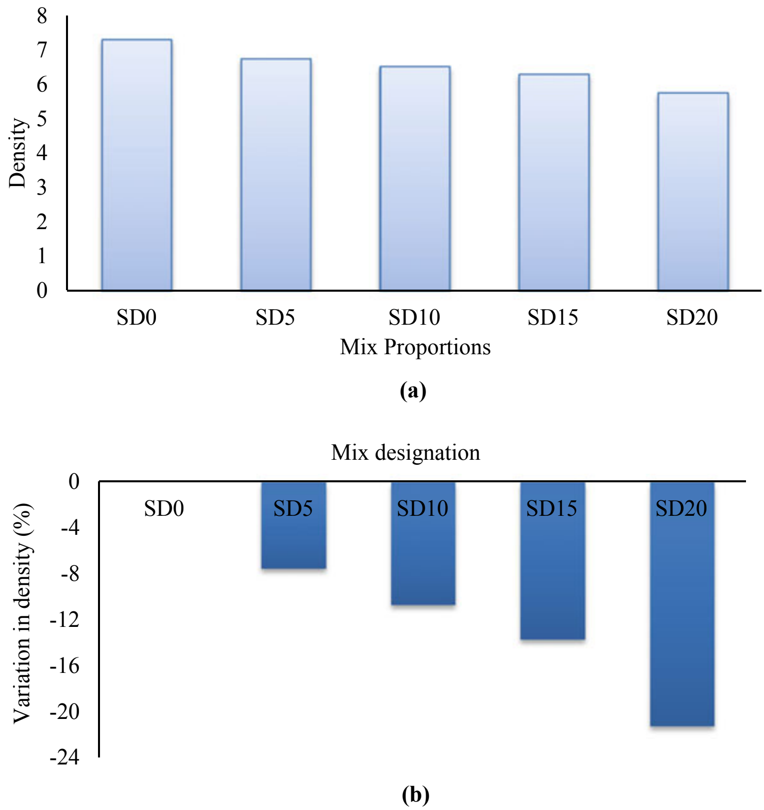

Fig. 1 **a** Variation of density in different concrete mixtures **b** Percent variation in density

3.2 Compressive Strength

The variation in compressive strength of concrete containing substantial quantities of sawdust has been depicted in Fig. 2 (a) and (b). The addition of sawdust to concrete mixes has been demonstrated to lower their strength, as illustrated in Fig. 2(a), maybe due to high porosity and water absorption capacity of sawdust powder which results in insufficient water for the hydration process. The hydration process got delayed in the presence of sawdust powder [13]. The decrease in strength gain with increased sawdust powder may be due to different chemical compositions, consequently leads to poor binding in matrix. The incorporation of sawdust powder reduced strength due

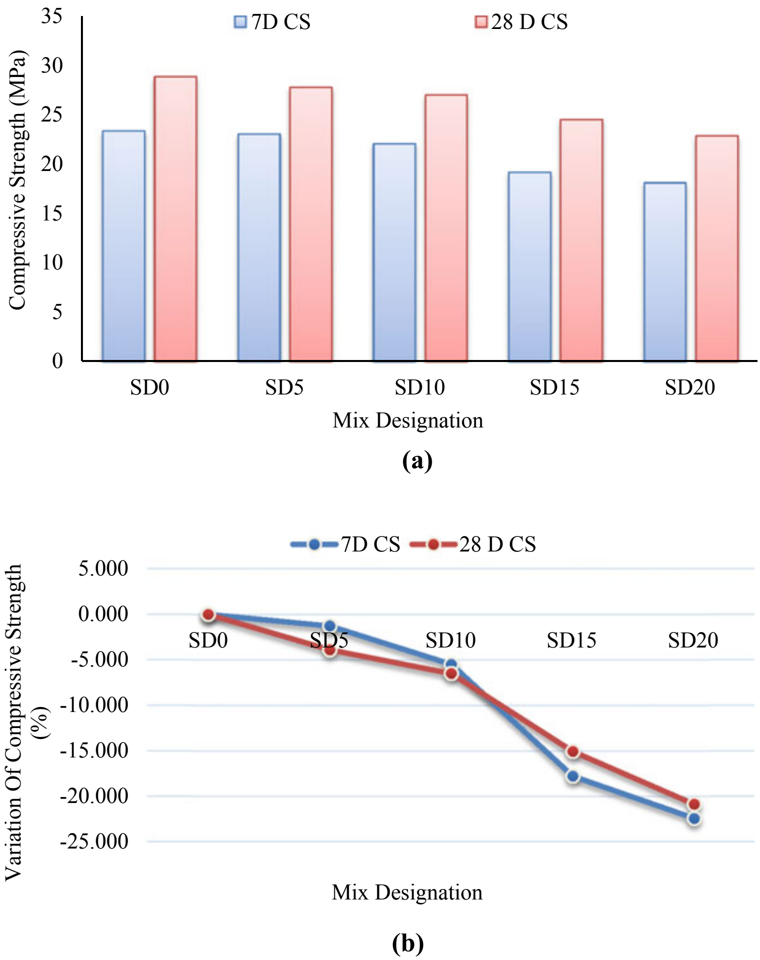

Fig. 2 **a** Variation of compressive strength of concrete **b** Percentage variation of compressive strength of concrete

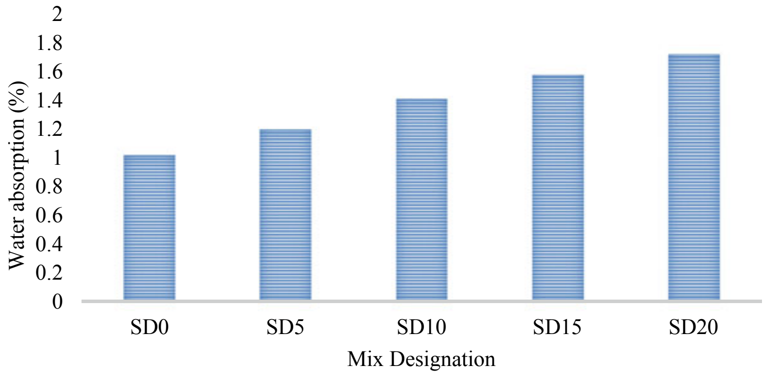

Fig. 3 Variation in water absorption of concrete

to weak interfacial transition zones (ITZ) between aggregates and cement paste [6]. The maximum reduction in compressive strength was 22 & 21% and the minimum reduction was 1 & 4% at 7 and 28 days of water curing as depicted in Fig. 2(b).

3.3 Water Absorption

The addition of sawdust powder in concrete mixtures increased the water absorption as shown in Fig. 3. The increase in water absorption value compared to the reference mix may be due to its high absorption capacity [14]. The maximum water absorption was at 20% substitution.

3.4 Non-destructive Test

The non-destructive testing of different concrete mixtures was carried out using rebound hammer and ultrasonic pulse velocity. The velocity and dynamic elastic modulus of elasticity were increased with the inclusion of sawdust powder as shown in Table 4. The UPV value indicates the good quality of concrete. The compressive strength calculated from the rebound hammer has been illustrated in Fig. 4.

3.5 Correlation Between Compressive Strength and Density

The correlation between compressive strength and density of hardened concrete was derived with a good correlation coefficient as shown in Fig. 5.

Table 4 UPV and dynamic elastic modulus of concrete mixtures

Mix no.	Elastic modulus (GPa)	Ultrasonic pulse velocity (m/sec)
SD0	6.98	3073
SD5	7.31	3214
SD10	7.60	3343
SD15	7.96	3502
SD20	8.55	3763

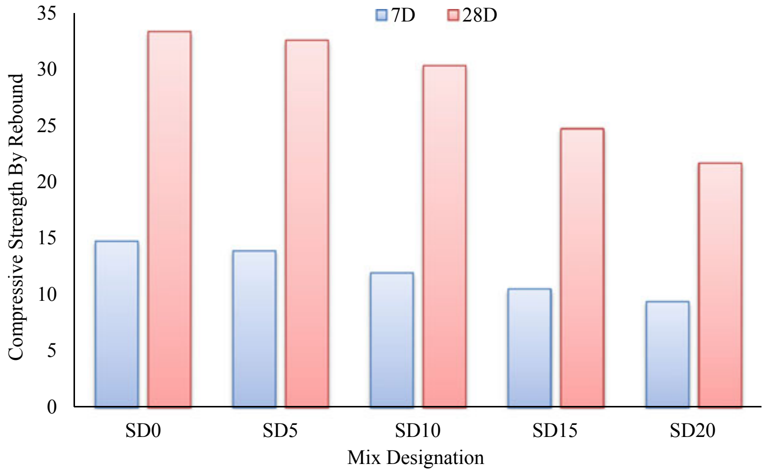

Fig. 4 Variation of compressive strength of concrete by rebound number

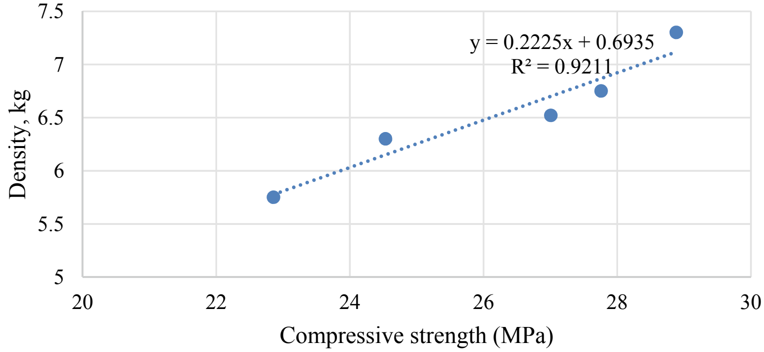

Fig. 5 Correlation between strength and density

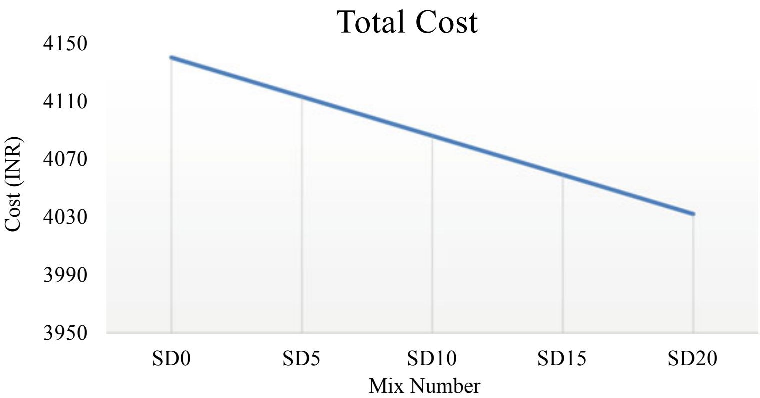

Fig. 6 Cost analysis of concrete mixtures

3.6 Cost

Figure 6 depicts the cost analysis of several sawdust-based concrete compositions. The addition of sawdust powder to concrete mixtures lowered construction costs. The cost of the production of concrete specimens incorporating sawdust at 0, 5, 10, 15, and 20% was INR 4140, INR 4113, INR 4086, INR 4059, and INR 4032, respectively. With 20% sawdust powder, the greatest cost reduction of 3% was obtained.

The cost of cement, sand, and aggregates were all considered while computing the total cost of concrete. Because sawdust was acquired as a free resource from a sawmill and used as a better alternative to landfilling or utilizing it as a cooking fuel in rural regions, the cost of sawdust has no bearing on this cost estimate. By restricting the use of natural resources, minimizing the volume of waste material, and lowering CO_2 emissions, proper sawdust utilization in concrete can help to save the environment.

4 Conclusion

In the present study, sawdust powder was utilized in the different concrete mixtures to investigate its effect on the different properties. The incorporation of sawdust powder in concrete reduced the density, strength, and cost of concrete. The reduction in density, compressive strength, and cost varied from 7–21, 4–22, and 3% with the different percentages of sawdust powder. The maximum increase in water absorption was at 20% sawdust powder. A good correlation between compressive strength and density was derived with a high correlation of 0.92. The sawdust concrete has lower strength that can be used where lower strength is required. Since sawdust concrete has a lower density, therefore it can be used where a lower structural load is required.

Since sawdust is a waste product with no other purpose or resale value, its new application as a construction material has the potential to remove a large volume of industrial waste from landfills.

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