INVESTIGATION ON COMPRESSIVE STRENGTHOF CONCRETE WITH PARTIAL REPLACEMENT OF WASTE BY-PRODUCTS

C. S. Unnikrishnan

Lecturer in civil engineering, Maharaja's Technological Institute (Govt Polytechnic College), Thrissur

Abstract- The present study investigates the compressive strength of concrete by partially replacing conventional materials with waste by-products: saw dust ash (SDA), glass powder (GP), and rubber tyre pieces (RTP). This approach aims for cost-effectiveness and reducing the concrete's self-weight. The research examines various replacement percentages of these waste materials and compares their properties with those of normal concrete constituents. Initial replacements include 2%, 4%, and 6% of SDA; 10%, 20%, and 30% of GP; and 2%, 4%, and 6% of RTP. Additionally, combinations of these waste by-products are explored. After conducting proper mix designs, cubes are cast with desired proportions and subjected to compression testing after 7 and 14 days of curing. The obtained test results are analyzed through graph plotting. Notably, the compressive strength increases in cases such as SGR5, SGR13, SGR15, SGR19, and SGR24. The study concludes that SDA replacement should be limited to 4%, GP to 20%, and RTP to 4%.

Keywords- compressive strength, Waste by products, SDA, GP, RTP.

I. Introduction

Concrete stands as the preeminent construction material globally, valued for its unparalleled versatility. Unlike natural stone or steel, which have limited adaptability, concrete can be tailored to meet diverse performance criteria. Its properties are influenced not just by constituent materials, but also by their proportions, mixing techniques, and curing processes. Extensive research in recent years has focused on exploring various reuse methods or concrete. Yet, further investigations are arranted to fully elucidate avenues for maximizing concrete performance.as on the methods of placing and curing the composite. Over recent decades, intensive research studies havebeen carried out to explore all possible reuse methods. Further investigationsare needed to clarify for instance which are the possibilities and means to maximize concrete performance.

II. Problem Description

It's commendable that you're exploring alternatives to mitigate the environmental impact of concrete production. Sawdust ash and recycled waste glass are indeed promising options for reducing pollution and creating more sustainable concrete.

Using sawdust ash as a partial replacement for cement can help decrease the demand for cement, which is a major contributor to carbon dioxide emissions during production. It can also utilize a waste product that might otherwise be disposed of in a less eco-friendly manner. However, it's essential to ensure that the properties of the concrete, such as strength and durability, are not compromised when using sawdust ash.

Similarly, incorporating recycled waste glass into concrete can reduce the need for natural aggregates, conserving natural resources and reducing the energy required for extraction and processing. It can also help alleviate the problem of glass waste accumulation in landfills.

In both cases, thorough research and testing are crucial to ensure that the resulting concrete meets the required standards for strength, durability, and other performance criteria. Additionally, considering the local availability of these waste materials and the feasibility of their large-scale implementation is essential for practical application.

Keep up the good work!

III. Related work

The investigation on the use of sawdust ash (SDA) in concrete reveals promising results, indicating comparable strength to conventional concrete. SDA possesses essential properties, with its significant alkaline nature and high content of important oxides, making it suitable as a pozzolanic material. While the addition of SDA prolongs setting times in ordinary Portland cement (OPC), it remains within recommended ranges. Notably, the compressive strength of concrete increases with higher grades of cement, with early strength development reaching 50-60% of the 28-day strength. Furthermore, the study suggests that SDA concrete can achieve comparable strength to traditional concrete with longer curing periods.

In another study focusing on sandcrete blocks, partial replacement of cement with SDA up to 10% is deemed suitable for non-load bearing walls. SDA's composition meets pozzolan requirements, and its utilization contributes to cost reduction and environmental sustainability. However, an increase in SDA content leads to decreased densities and compressive strengths of sandcrete blocks. Additionally, a research proposal explores the viability of SDA as a partial cement replacement, emphasizing cost-effectiveness and environmental benefits. The proposal recommends a 12% replacement ratio for optimal results.

Moreover, the utilization of SDA in concrete production aligns with efforts to minimize waste and promote sustainable technologies. Reviews suggest that SDA exhibits potential as a cement replacement, urging further research to develop high-strength concrete formulations. Similarly, investigations into incorporating waste materials like crushed glass and waste tires in concrete reveal varying effects on properties such as compressive strength and durability. While rubberized concrete may have reduced strength compared to conventional concrete, there's potential for its use in specialized applications, offering solutions to waste management challenges.

Overall, these studies underscore the importance of exploring alternative materials in construction to address environmental concerns and enhance sustainability The research on utilizing sawdust ash (SDA) in concrete production demonstrates its potential to match the strength of traditional concrete. Noteworthy is SDA's alkaline nature and its significant content of essential oxides, which render it suitable for pozzolanic applications. Although the addition of SDA extends setting times in ordinary Portland cement (OPC), it remains within acceptable limits. Moreover, higher grades of cement correlate with increased concrete compressive strength, with early strength development reaching approximately 50-60% of the 28-day strength. Importantly, the study indicates that SDA concrete can achieve comparable strength to regular concrete with extended curing periods.

In another investigation focusing on sandcrete blocks, findings suggest that replacing up to 10% of cement with SDA is optimal for non-load-bearing walls. SDA's composition meets pozzolan requirements, offering cost savings and environmental benefits. However, increasing SDA content leads to reduced densities and compressive strengths of sandcrete blocks. Additionally, a research proposal examines the feasibility of SDA as a partial cement replacement, emphasizing cost-efficiency and environmental sustainability, and recommending a 12% replacement ratio for optimal results.

Furthermore, the use of SDA in concrete aligns with efforts to minimize waste and promote sustainable practices. Reviews indicate SDA's potential as a cement replacement, urging further exploration to develop high-strength concrete formulations. Similarly, investigations into incorporating waste materials like crushed glass and waste tires reveal diverse effects on properties such as compressive strength and durability. While rubberized concrete may exhibit reduced strength compared to conventional concrete, it holds promise for specialized applications, addressing waste management challenges.

The research on utilizing sawdust ash (SDA) in concrete production demonstrates its potential to match the strength of traditional concrete. Noteworthy is SDA's alkaline nature and its significant content of essential oxides, which render it suitable for pozzolanic applications. Although the addition of SDA extends setting times in ordinary Portland cement (OPC), it remains within acceptable limits. Moreover, higher grades of cement correlate with increased concrete compressive strength, with early strength development reaching approximately

.

IV. Methodology

4.1 Materials

The materials used in the experimental investigation are locally available cement, fine aggregate, coarse aggregate and we also partially replaced some waste by-products like sawdust ash, glass powder, rubber tyre pieces. These materials are tested by considering IS: 2386-1963 Methods of tests for aggregate for concrete.

4.1.1 Cement

Ordinary portland cement of 33 grade has been used in the study. It was procured from a single source and stored. Care has been taken to ensure that the cement of same company and same grade is used throughout the investigation.

4.1.2 Fine aggregate

Fine aggregate Manufactured sand is produced from hard granite stone by crushing. The fine aggregate used was Manufactured sand (M Sand) because it is a substitute of river sand for construction which is cubical shape with grounded edges locally available and it is sieved through 2.36mm sieve and those passing the sieve used for this work.

4.1.3 Coarse aggregate

The coarse aggregate chosen was typically round, well graded natural gravel obtained from the locally available quarries The coarse aggregate used was sieved through 20mm and those passing the sieve is used for this work.

4.1.4 Saw dust ash (SDA)

Saw dust used in this project was of wood which obtained from nearby timber milling factory is airdried and then calcinated into ashes by burning process. The burnt ash Fig.3.1 is then allowed to cool under environmental conditions and then collected into a safe container for material testing. The ash was sieved through 90µ and those passing the sieve were used for this work.

4.1.5 Glass powder

Plain broken windows glass was used for replacement which was supplied from windows glass market. Glass powder as shown in Fig.3.3 is used as a substitute material for fine aggregate in concrete. Before adding in the concrete, the glass was powdered and sieved through 2.36mm sieve and those passing the sieve used for this work.

4.1.6 Rubber tyre pieces

For uniformity of the concrete production and convenience, all the tires collected are that of bike. The reason for choosing it is that they can give the required shape and size which is similar to the common natural gravel. For this study, rubber aggregate is prepared by manual cutting and sieved through 20mm IS sieve.

4.2 Material Properties

The properties of all the materials were tested in the laboratory to check whether the sample can be used in the production of concrete. The result obtained from the laboratory is compared with the conventional materials.

4.2.1 Cement Vs SDA

Table 3.4 shows that the material properties of Saw dust ash were tested in the laboratory to check whether the sample is a pozzolan material and can be used in the production of concrete.

Material Properties	Results (Cement)	Results (SDA)	Permissible Limit
Fineness	9%	5%	10%
Specific Gravity	4.76	4.34	Not less than 3.15
Standard Consistency	34%	32%	Around 26 to 34%
Initial Setting Time	45min	45min	Not < 30mins

Table 4.1. Material testing results comparison with cement and SDA

4.2.2 Fine aggregate vs Glass powder

In general, aggregates should be hard and strong, free of undesirable impurities, and chemically stable. Table 3.5 shows the material testing results comparison with fine aggregate and glass powder. The relevant tests to identify the properties of the aggregates were carried out manually. Glass powder is obtained from waste window glass and it is powdered and it is sieved through 2.36mm sieve and passing this sieve is taken for the work.

4.2.3 Coarse aggregate vs Rubber tyre pieces

Aggregates should be round and angular, free of undesirable impurities, and chemically stable. The relevant tests to identify the properties of the aggregates were carried out manually. Rubber tyre of bike is obtained from 25 old market, and it is cut into pieces manually and sieved through 20mm sieve and those passing the sieve used for this work.

4.3 Methodology

The project focuses on studying the compressive strength of concrete when partially replaced with waste by-products such as sawdust ash, glass powder, and rubber tire pieces. Cubes of size 150mm x 150mm x 150mm serve as specimens for casting the concrete. Initially, a control specimen is cast using the standard ratio of ingredients. Subsequently, cubes with single, dual, and triple combinations of waste by-products are cast using different ratios but with the same mix proportions. These cubes undergo compression testing after 14 days of curing to determine their compressive strength, facilitating a comparison with the control specimen. To ensure accurate dimensions and prevent distortion, metal molds are employed, each equipped with a metal base plate to support the mold vertically at 90 degrees. The molds are thinly coated with mold oil to prevent water escape during filling and to avoid concrete adhesion. Thorough mixing of materials is crucial to achieve uniformity in color and consistency. Hand mixing is conducted, with cement and fine aggregate spread out initially, followed by the addition of coarse aggregate and water. Mixing continues until a homogeneous concrete mix is obtained, with water added gradually to achieve the desired consistency. Once mixed, the molds are promptly filled with concrete, poured in three layers with each layer compacted 25 times to expel entrapped air and prevent honeycombing. Compaction is performed manually using a 16mm diameter tamping rod, distributing strokes evenly across the concrete surface. Compaction is critical for air expulsion; especially as lower workability increases the likelihood of air entrapment.

Another study on M25 grade concrete explores the use of scrap tire rubber in various proportions. Slump values decrease with increasing rubber replacement, indicating decreased workability. While compressive strength decreases with higher replacement percentages, rubber concrete still achieves slightly higher compressive strength than conventional concrete. Split tensile strength also increases for 3% rubber replacement, suggesting that scrap tire rubber can be effectively used as an alternate material for coarse aggregate replacement up to 3%.

4.4 Mix Proportions

Data Required for Concrete Mix Design

a) Characteristic compressive strength required in the field at 28 days grade designation - M 25
b) Nominal maximum size of aggregate - 20 mm
c) Shape of CA – Angular
d) Degree of workability required at site - 50-75 mm (slump)
e) Degree of quality control available at site - As per IS:456
f) Type of exposure the structure will be subjected to (as defined in IS: 456) — Mild
g) Type of cement: OPC conforming IS:455

Procedure for Concrete Mix Design of M25 Concrete

Step 1 — Determination of Target Strength

Hemsworth constant for 5% risk factor is 1.65. In this case standard deviation is taken from IS:456 against M 25 is 4.0.

ftarget = fck + 1.65 x S
= 25 + 1.65 x 4.0
= 31.6 N/mm2

Were,
S = standard deviation in N/mm2 = 4 (as per table - 1 of IS 10262- 2009).

Step 2 — Selection of water / cement ratio:

IS 456, (page no 20) Maximum water-cement ratio for Mild exposure condition = 0.55

Based on experience, adopt water-cement ratio as 0.49

0.49<0.55, hence OK

Step 3 — Selection of Water Content

IS 10262- 2009,

Maximum water content = 186 Kg (for Nominal maximum size of aggregate — 20 mm)

Estimated water content = 186+ (3/100) x 186 = 191.6 kg /m3

Step 4 — Selection of Cement Content

Water cement ratio = 0.5
Corrected water content = 191.6 kg /m3
Cement content = 383.2 kg/m3
Minimum cement Content for mild exposure condition = 300 kg/m3
383.2 kg/m3 > 300 kg/m3, hence, OK.
As per clause 8.2.4.2 of IS: 456
Maximum cement content = 450 kg/m3.

Step 5: Estimation of Coarse Aggregate proportion

For Nominal maximum size of aggregate = 20 mm,
Zone of fine aggregate = Zone II
And For w/c = 0.5
Volume of coarse aggregate per unit volume of total

aggregate = 0.62
Volume of coarse aggregate per unit volume of total aggregate = 0.62 x 90%
= 0.558
= 1 – 0.558
Volume of fine aggregate
= 0.442

Step 6: Estimation of the mix ingredients
a) Volume of concrete = 1 m3
b) Volume of cement = (Mass of cement / Specific gravity of cement) x (1/1000)
= (383.2/3.15) x (1/1000 = 0.122 m3
c) Volume of water = (Mass of water / Specific gravity of water) x (1/1000) = (191.6/1) x (1/1000) = 0.1916 m3
d) Volume of total aggregates = a – (b + c) = 1 – (0.122 + 0.1916) = 0.6864 m3
e) Mass of coarse aggregates = 0.6864 x 0.558 x 2.84 x 1000 = 1087.75 kg/m3 29
f) Mass of fine aggregates = 0.6864 x 0.442 x 2.64 x 1000 = 800.94 kg/m3

V. Result and Discussion

The waste by-products are mixed in various proportions and are made into concrete blocks. These specimens are tested and the results of the various proportions are compared and the better composition that is obtained are discussed.

% of SDA	**7 Days**	**14 Days**
	(N/mm^2)	**(N/mm^2)**
2%	18.35	22.8
4%	19.2	23.21
6%	16.95	21.45

Table 5.1. Compressive strength of SDA replacement

Table.5.1 shows that the compressive strength of the specimen shows average results while using Saw dust ash alone with composition of 2% 4%, when the composition usage exceeds 6% the compressive strength of the specimen decreases.

% of Glass powder	**7 Days**	**14 Day**
	(N/mm^2)	**(N/mm^2)**
10%	18.9	22.8
20%	18.8	23.25
30%	17.3 7	21.65

Table 5.2. Compressive Strength of GP Replacement

Table.5.2 shows that the compressive strength of the specimen decreases whenexceeds 30%[13]

% of Rubber Tyre pieces	7 Days	14 Days
	(N/mm^2)	(N/mm^2)
2%	18.15	22.35
4%	18.25	22.75
6%	17.37	21.25

Table 5.3. Compressive Strength of RTP Replacement

Table.5.3 shows that the compressive strength of the specimen shows average results while using saw dust ash alone with composition of 2% 4%, when the composition usage exceeds 6% the compressive strength of the specimen decreases.

Name of the specimen	**7 Days**	**14 Days**
	(N/mm^2)	**(N/mm^2)**
SG_1	18.225	22.8
SG_2	18.375	22.7
SG_3	17.65	21.5

Table 5.4. Compressive Strength of SG Replacement

In table 5.4 the compressive strength of the specimen shows average results while using saw dust ash and glass powder with composition of 2% 4%of SDA & 10% 20% of Glass powder when the SDA composition usage exceeds 6% and GP exceeds 30% the compressive strength of the specimen decreases

Name of the specimen	**7 Day**	**14 Days**
	(N/mm^2)	**(N/mm^2)**
GR_1	17.3 5	22.45

Table 5.5. Compressive Strength of GR Replacement

In table 5.5 the compressive strength of the specimen shows average results while using saw dust ash and glass powder with composition of 2% 4%of RTP & 10% 20% of Glass powder when the RTP composition usage exceeds 6% and GP exceeds 30% the compressive strength of the specimen decreases.

Name of the specimen	**7 Days**	**14 Days**
	(N/mm²)	**(N/mm²)**
RS_1	18.15	22.8
RS_2	18.55	23.3
RS_3	17.25	21.35

Table 5.6. Compressive Strength of SR Replacement

In table 5.6 the compressive strength of the specimen shows average results while using saw dust ash and glass powder with composition of 2% 4%of RTP & 2% 4% of SDA when the RTP composition

Name of the specimen	7 Days	14 Days
	(N/mm2)	(N/mm2)
SGR 1	17.65	21.9
SGR 2	18.1	22.75
SGR 3	18.7	22.45
SGR_4	17.05	22.1
SGR_5	18.7	23
SGR_6	17.1	21.5
SGR_7	16.95	20
SGR_8	16	21.5
SGR_9	17.5	18.5

Table 5.7 Compressive strength results of Set-1

Name of the specimen	**7 Days**	**14 Days**
	(N/mm²)	**(N/mm²)**
SGR_{10}	16.5	21.5
SGR_{11}	19.1	23.2
SGR_{12}	17.8	20.9
SGR_{13}	18.9	23.7
SGR_{14}	16.2	20
SGR_{15}	19.2	23.6
SGR_{16}	16.5	19.6
SGR_{17}	17.1	21.0
SGR_{18}	17.4	19.2

Table 5.8. Compressive strength results of Set-2

In table 5.8 the compressive strength of the specimen shows average results in many cases and while adding the combinations of GP & RTP by keeping the SDA as 4% shows the increase in compressive strength and whenSDA & RTP exceeds 6% it shows decrease in compressive strength

Name of the specimen	**7 Days**	**14 Days**
	(N/mm²)	**(N/mm²)**
SGR_{19}	19.5	23.6
SGR_{20}	17.5	22.1
SGR_{21}	16.2	19.5
SGR_{22}	16.9	19.2
SGR_{23}	17.1	21
SGR_{24}	19.7	23.5
SGR_{25}	17.1	19.7
SGR_{26}	16.5	20.5
SGR_{27}	17.6	21.2

Table 5.9. Compressive strength results of Set-3

Table 5.9 shows that the compressive strength of the specimen showsaverage results in many cases and while adding the combinations of GP & RTP by keeping the SDA as 6% shows the increase in compressive strength and when RTP exceeds 6% it shows decrease in compressive strength.

VI. Conclusion

In summary, the study reveals that the optimal replacements for achieving maximum compressive strength were found to be 4% for sawdust ash (SDA), 20% for glass powder (GP), and 4% for rubber tire pieces (RTP). Further combinations of these materials showed that the highest strength was obtained for the combination of SG2, GR2, and RS2. Notably, compositions such as SGR 5, SGR 13, SGR 15, SGR 19, and SGR 24 demonstrated average to good results. The increase in concrete strength can be attributed to the pozzolanic reaction of SDA and the cementitious products formed during cement hydration. The angular nature of glass particles promotes enhanced bonding with the cement paste, leading to increased compressive strength. However, an increase in rubber tire pieces content weakens the cement paste bonding, resulting in decreased strength due to increased voids in the concrete matrix. Optimizing the percentage of rubber tire pieces minimizes voids and maximizes concrete bonding, while a higher percentage of glass powder enhances bonding and strength due to its high silica content and angular particle structure. Therefore, it's crucial to balance the replacement percentages of waste by-products to achieve optimal concrete properties.

VII. References

1. Adaway.M, Y.Wang(2015) Recycled glass as partial replacement for fine aggregate in structural concrete. Electronic Journal of Structural Engineering.pp.116-122.
2. Divya Bhavana Tadepalli, Anandram.K Srinivas.M Srikanth.P (2016) Testing of Strength Parameters When coarse aggregate is replaced with Scrap Tyre Rubber in Concrete. International Journal of Innovative Research In Science Engineering and Technology. Vol.5, Issue 4. pp.4830-4835
3. Iqbal Malik.M,.Muzafar Bashir, Sajad Ahmad, Tabish Tariq, Umar Choudary(2013) in Study of concrete involving use of waste glass as partial replacement of fine aggregate. IOSR Journal of Engineering, Vol.3, pp.8-13
4. IS: 2386-1963 Methods of tests for aggregate for concrete. (1-9 parts)
5. IS: 383-1970 Specifications for fine & coarse aggregate from natural sources for concrete
6. IS: 2250-1981 Compressive strength test for cement mortar cubes.
7. IS: 456-2000, Plain and Reinforced concrete – Code of Practice- Bureau of Indian Standards, New Delhi.
8. IS:10262-2009 Guidelines for Concrete Mix Design – Bureau of IndianStandards, New Delhi.
9. Kotresh.K.M.et.al, Mesfin Getahun Belachew (2014) – Study on waste tyre rubber as concrete aggregates. International Journal of Scientific Engineering and Technology.Vol. 3,pp 433-436
10. Mamery Adama Serifou.et.al,(2017) made experiment on Effect of Association Natural-Recycling Aggregates (Crushed Glass and Waste Tire) on Mechanical Properties of the Concrete. International journal of materials science and applications. Vol. 6, No.1, 2017, pp. 28-31.
11. Mannava Anusha, T.Ram Prasanna Reddy (2016) Replacement of fine aggregate with glass powder in high performance concrete. International Journal of Advanced Technology and Innovative Research.Vol. 08,pp.2967-2973
12. Marthong.C (2012) Sawdust ash as Partial Replacement of cement in concrete. International Journal of Engineering Research andApplications Vol.2, pp.1980-1985
13. Obilade.I.O. (2014) Uses of saw dust ash as Partial Replacement for Cement for Concrete. International Journal of Engineering ScienceInvention.Vol 3.pp.36-40
14. Partha saika, Owais Mushtaq, A.Arunya(2016) Experimental study of replacement of course aggregate by rubber chips in concrete. Int.J.Chem.Sci,pp. 386-392
15. Praveen Kumar.S, Boobalan S.C (2013) Impact of Saw Dust and Crushed Waste Glass in the Properties of Sandcrete Blocks
16. Raheem A.A and Sulaiman. O.K(2013) Sawdust ash as Partial Replacement for cement in the Production of Sandcrete hollow blocks. . International Journal of Engineering Research and Applications Vol.2, pp.713-721

17. Rahul Mahla, Er.R.P.Mahla, Hisar(2015) on Partial replacement ofcoarse aggregate by waste tires in Cement concrete. International Journal of Technical Research.Vol.4,pp. 95-98
18. Ratod Vinod Kumar and Shiva Rama Krishna.M (2016) A Case Study on Partial Replacement of cement by SawDust Ash in Concrete. International Journal Of Science and Research,Vol. 5,pp. 275
19. Sajjad Ali Mangi,Norwati Jamaluddin, Wan Ibrahim.M.H, Noridah Mohamed, Samiullah Sohu (2017) Utilization of Saw dust ash as Cement Replacement for the Concrete Production. International Journal of Scientific Engineering and Technology.Vol. 3,pp 125-131
20. Vijaya Sekhar Reddy, P.Sumalatha, M.Madhuri, K.Ashalatha (2015) Incorporation of waste glass powder as partial replacement of fine aggregate in cement concrete International Journal of Scientific & Engineering research,Vol. 6, pp.405-409.
21. Arasu, Naveen, and J. Robinson. "Experimental analysis of waste foundry sand in partial replacement of fine aggregate in concrete." *International Journal of Chemtech Research* 10, no. 8 (2017): 605-622.
22. Arasu, Naveen, M. Muhammed Rafsal, and OR Surya Kumar. "Experimental investigation of high performance concrete by partial replacement of fine aggregate by construction demolition waste." *International Journal of Scientific & Engineering Research* 9, no. 3 (2018).