

Properties of concrete modified with waste Low Density Polyethylene and saw dust ash

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Abstract. The increase in industrialization creates need for disposal of large quantity of by-products. To overcome the difficulty of disposal, these by-products can be used as a replacement for raw material. In this concern, non-conventional industrial wastes such as plastic bags, PET bottles, pulverized waste Low Density Polyethylene (LDPE) and biological waste such as saw-dust ash, coconut coir were used as a replacement in concrete. In this project, saw-dust ash and pulverized waste LDPE were introduced as the partial replacement for cement and fine aggregates respectively. 0%, 5%, 10%, 15% and 20% of sand by volume was replaced with LDPE and 0%, 1%, 3%, 5% and 10% of cement by volume was replaced with saw dust ash. Standard cube, cylinder and prism specimens were cast to assess the compressive strength, split tensile strength and flexural strength of modified concrete after 28 days of curing. Optimum percentage of replacement was found by comparing the test results. The mix with 5% of LDPE and 3% of saw dust ash showed a better result among the other mixes.

1. Introduction

Concrete is one of the major materials in construction industry. It has an important role in the economy development of a country due to its consumption in large volumes. Concrete is a composite material which consists of different constituents such as binding materials, water, admixtures and aggregates [1]. Among these, aggregate plays a crucial role, which occupies 60-75% of total concrete volume. Over the past century, concrete based on Portland cement became the product manufactured in highest volume around the world. This concrete possesses highly reliable performance, low cost and versatility. Presently the manufacturing industry facing serious consequences as concrete matrix materials became unsustainable. Huge amount of raw material and energy is consumed for large scale production of Ordinary Portland cement (OPC), which is commonly used as the binder in the manufacture of concrete. Its production not only consumes significant amount of natural resources and energy but also release greenhouse gases. The sources of fine aggregate are natural river sand and quarries which are also not sustainable. Recent researchers studied the possibilities of replacement of conventional constituents in concrete with recycled materials and industrial by-products. This will lead to a sustainable production of concrete with less consumption of natural resources [1-6]. In this study, an attempt was made to produce sustainable concrete by replacing the fine aggregate and cement partially with pulverised waste LDPE and saw dust ash respectively. The optimum percentages of replacement of fine aggregate and cement were found by comparing the rest results.



2. Experimental Investigation

2.1 Specifications of Materials

Ordinary Portland Cement (OPC) of 53 grade was used to prepare the concrete mixes. The physical and chemical properties of OPC are given in the Table 1 and 2 respectively.

Table 1. Chemical composition of OPC

Calcium oxide	62.68%
Silica	20.36%
Alumina	6.87%
Iron oxide	3.67%
Magnesia	1.77%
Sulphuric anhydride	2.24%
Tricalcium silicate	42.57%
Dicalcium silicate	26.33%
Tricalcium aluminate	12%
Tetra calcium alumino-ferrite	2.24%

Table 2. Physical Properties of Cement

Specific gravity of cement	3.13
Consistency	35%
Initial setting time	28 min
Final setting time	60 min

The Coarse aggregate (CA) of hard blue granite of size 20mm aggregates was used to manufacture the concrete. The aggregates were in angular shape. The properties of coarse aggregate are given in the Table 3.

Table 3. Physical Properties of Coarse Aggregate

Specific gravity	2.75
Water absorption	0.9%
Moisture Content	10%
Bulk density	1.66g/cc
Fineness modulus	7.4

Locally available natural river sand was used to manufacture the concrete. The physical and chemical properties of fine aggregate (FA) are given in the Table 4.

Table 4. Physical Properties of Fine Aggregate

Specific gravity	2.68
Water absorption	2.9%
Moisture Content	3%
Bulk density	1.86g/cc
Fineness modulus	3.05

Normal potable water without any impurities is used for preparing of concrete mixes. Saw dust ash (SA) was a heterogeneous mixture of different sized particles generally angular in shape. These particles basically consist of partially burned or unburned wood and bark. Physical and chemical properties of wood ash are given in the Table 5 and 6 respectively.

Table 5. Physical Properties of saw dust ash

Specific Gravity	2.57
Fineness	6.0%
Colour	Grey
Density	1472 kg/m ³

Table 6. Chemical composition of saw dust ash

Silicon dioxide (SiO ₂) %	31.00
Aluminum oxide (Al ₂ O ₃) %	14.40
Iron oxide (Fe ₂ O ₃) %	6.90
Calcium oxide (CaO) %	12.60
Magnesium oxide (MgO) %	0.69
Potassium Oxide (K ₂ O) %	1.57
Loss of Ignition	34.30
Moisture content %	1.60
Alkalis %	0.89

Pulverized waste LDPE was used as a substitute for fine aggregate. The physical properties of LDPE are given in the Table 7.

Table 7. Physical Properties of LDPE

Tensile Strength	0.20 - 0.40 N/mm ²
Notched Impact Strength	No break
Thermal Coefficient of Expansion	100 - 220 x 10 ⁻⁶
Max. Continued Use Temperature	65 °C (149 °F)
Melting Point	110 °C (230 °F)
Glass Transition Temperature	-125 °C (-193 °F)
Density	0.910 - 0.940 kg/m ³

2.2 Tests conducted

Workability of the freshly prepared mix was assessed by conducting slump cone test. The variation in density of the concrete was assessed by weighing the hardened concrete specimens of each mixes. The strength characteristics of the mixes were assessed by conducting compressive strength, split tensile strength and flexural strength tests.

2.3 Mix Proportions

In this research, a concrete mix of grade M325 with the characteristic compressive strength of 25 N/mm² was used. The proportion of the constituents was designed to conform to Indian standards [10,11] and obtained a ratio of 1:1:2 with water to cement ratio 0.50. The conventional mix was then modified by adding various fractions of LDPE and saw dust ash. 25 mixes were prepared and the details of mixes are given in the Table 8.

Table 8. Mix Proportions

Mix id	LDPE (%)	S.A (%)	F.A (kg/m ³)	CEMENT (kg/m ³)	C.A (kg/m ³)	LDPE (kg/m ³)	SA (kg/m ³)
0-0	0	0	493	493	1030.14	0	0
0-1	0	1	493	488.07	1030.14	0	4.38
0-3	0	3	493	478.21	1030.14	0	13.16
0-5	0	5	493	468.35	1030.14	0	21.93
0-10	0	10	493	443.7	1030.14	0	43.87
5-0	5	0	468.35	493	1030.14	14.29	0
5-1	5	1	468.35	488.07	1030.14	14.29	4.38
5-3	5	3	468.35	478.21	1030.14	14.29	13.16
5-5	5	5	468.35	468.35	1030.14	14.29	21.93
5-10	5	10	468.35	443.7	1030.14	14.29	43.87
10-0	10	0	443.7	493	1030.14	28.59	0
10-1	10	1	443.7	488.07	1030.14	28.59	4.38
10-3	10	3	443.7	478.21	1030.14	28.59	13.16
10-5	10	5	443.7	468.35	1030.14	28.59	21.93
10-10	10	10	443.7	443.7	1030.14	28.59	43.87
15-0	15	0	419.05	493	1030.14	42.89	0
15-1	15	1	419.05	488.07	1030.14	42.89	4.38
15-3	15	3	419.05	478.21	1030.14	42.89	13.16
15-5	15	5	419.05	468.35	1030.14	42.89	21.93
15-10	15	10	419.05	443.7	1030.14	42.89	43.87
20-0	20	0	394.4	493	1030.14	57.18	0
20-1	20	1	394.4	488.07	1030.14	57.18	4.38
20-3	20	3	394.4	478.21	1030.14	57.18	13.16
20-5	20	5	394.4	468.35	1030.14	57.18	21.93
20-10	20	10	394.4	443.7	1030.14	57.18	43.87

3. Results and discussions

3.1 Workability of mixes

Slump test was conducted for each mix and the results are tabulated in the Table 9. From the test results it was observed that, the slump value is getting reduced as the percentage of LDPE is increased in the concrete. The addition of saw dust ash also leads to the reduction in slump. This shows the decrease in workability of modified concrete mixes compared to the conventional mix. This is due to the hydrophobic nature of the LDPE and saw dust ash.

3.2 Density of hardened concrete

The hardened cube specimens of each mixes were weighed to calculate the density of modified mixes. The results are tabulated in the Table 9. It was observed that the density was constantly reduced by the addition of LDPE. It was further reduced due to the addition of saw dust ash. This is also attributed to the hydrophobic nature of LDPE and saw dust ash.

3.3 Compressive strength

Standard cube specimens of size 150mm×150mm×150mm was tested conforming to Indian standards [6], in the compression testing machine and the results are tabulated in the Table 9.

Table 9. Test results

Mix ID	Slump (cm)	Density (kg/m ³)	Compressive strength (N/mm ²)	Split tensile strength (N/mm ²)	Flexural strength (N/mm ²)
0-0	10	2464	34.82	3.52	4
0-1	11.5	2428	32.45	3.56	5.25
0-3	12	2448	33.93	3.35	5
0-5	12	2384	33.63	3.5	5
0-10	12	2440	33.36	3.30	5.2
5-0	15	2400	38.06	3.42	6.5
5-1	10	2312	38.28	3.20	4.75
5-3	7.5	2372	37.53	3.28	5.0
5-5	7.5	2292	38.38	3.05	2.75
5-10	7.5	2336	34.12	3.00	2.5
10-0	9.0	2288	35.27	3.33	6.5
10-1	6.5	2360	34.04	3.19	6.5
10-3	5.5	2268	29.99	3.16	2.5
10-5	4.5	2332	28.06	2.67	3.75
10-10	4.5	2288	24.03	2.69	3.5
15-0	4.25	2204	27.47	2.43	5.5
15-1	3.5	2188	22.04	3.2	4.75
15-3	3.5	2268	26.76	2.37	5.5
15-5	2	2236	27.74	2.65	3.25
15-10	1.5	2216	22.20	2.52	2.25
20-0	3.5	2203	25.22	2.33	5.0
20-1	3	2132	27.95	3.08	4.75
20-3	2.75	2240	22.05	2.34	4.25
20-5	2.75	2204	21.03	2.59	2.75
20-10	2.75	2200	27.91	3.26	2.5

It was observed that the compressive strength of the mixes was getting reduced compared to the conventional mix by the addition of LDPE and it was further reduced by the addition of saw dust ash. This also attributed to the hydrophobic nature of LDPE and saw dust ash because of which matrix formed by the binder and fine aggregate will be weak. The weaker bond between the binder and aggregates lead to the decrease in the compressive strength of mix. The variation of compressive strength is represented in the figures 1,2,3,4 and 5.

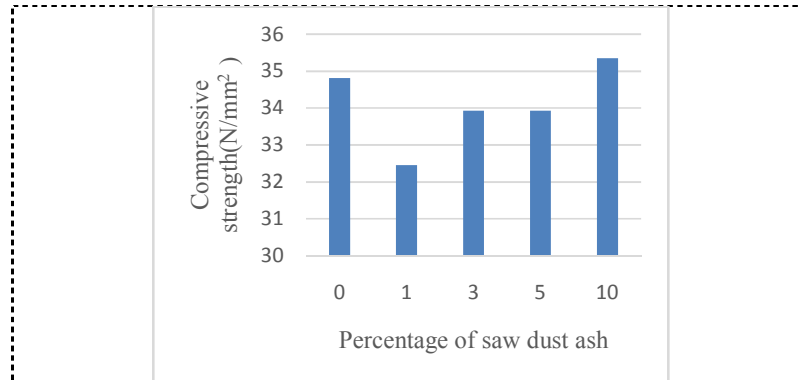


Figure 1. Variation of compressive strength of mix with 0% LDPE

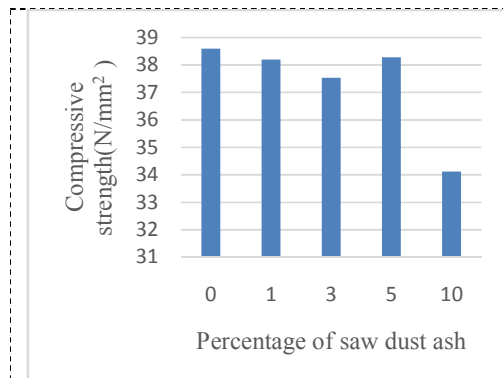


Figure 2. Variation of compressive strength of mix with 5% LDPE

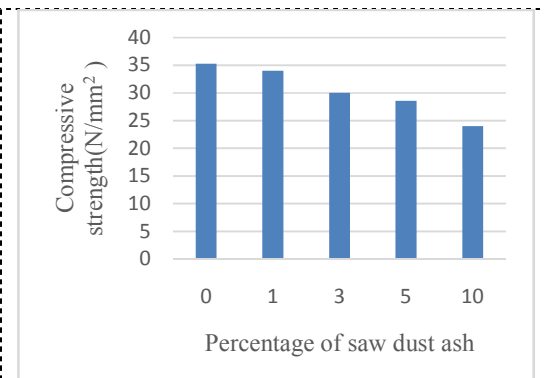


Figure 3. Variation of compressive strength of mix with 10% LDPE

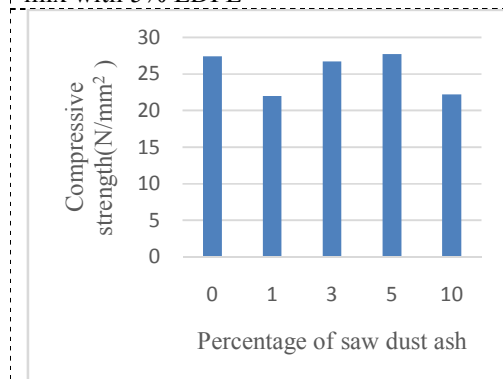


Figure 4. Variation of compressive strength of mix with 15% LDPE

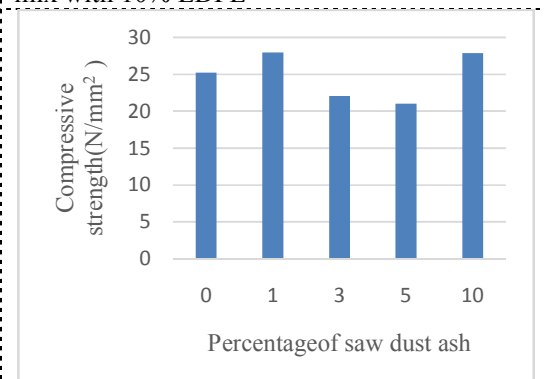


Figure 5. Variation of compressive strength of mix with 20% LDPE

3.4 Split tensile strength test

To assess the tensile nature of the modified mixes, standard cylinder specimens were tested conforming to the Indian standards [7]. The results are tabulated in the table 8. It was observed that, split tensile strength was also reduced compared to the conventional mix, as the percentage of substitutes was increased. This effect is also attributed to the hydrophobic nature of LDPE and saw dust ash. The variation of split tensile strength is represented in the figures 6,7,8,9 and 10.

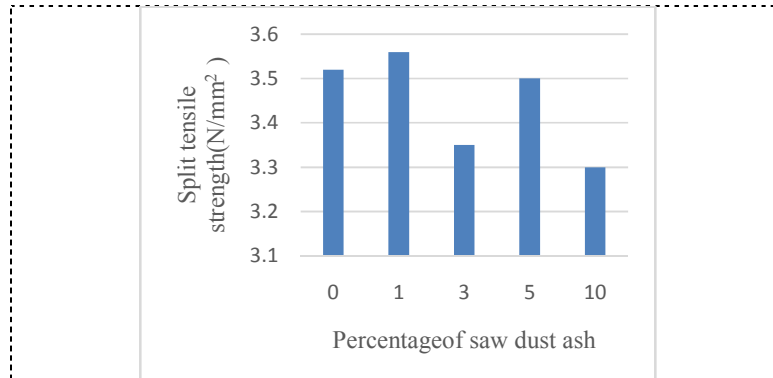


Figure 6. Variation of Split tensile strength of mix with 0% LDPE

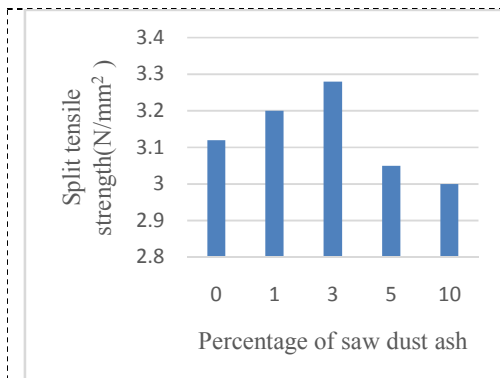


Figure 7. Variation of Split tensile strength of mix with 5% LDPE

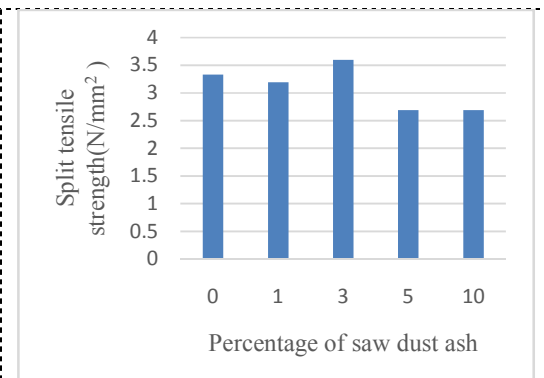


Figure 8. Variation of Split tensile strength of mix with 10% LDPE

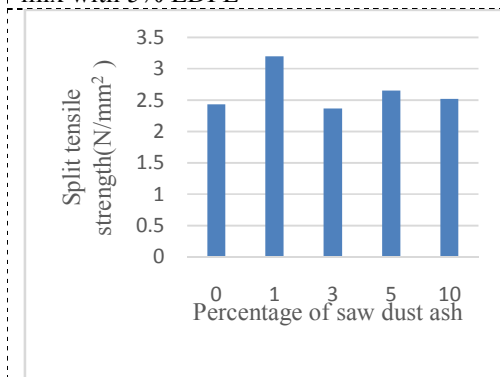


Figure 9. Variation of Split tensile strength of mix with 15% LDPE

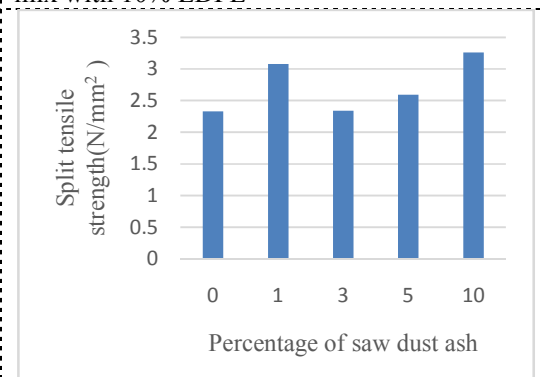


Figure 10. Variation of Split tensile strength of mix with 20% LDPE

3.5 Flexural strength

Standard prism specimens were tested for flexure conforming to the Indian standards [6], to assess the flexural strength of the modified mixes. Reduction in the flexural strength compared to the conventional mix was observed with increase in the percentage of LDPE and it was further decreased due to the addition of saw dust ash. The variations of flexural strength with increase in the percentages of LDPE and saw dust ash are given in the figures 11,12,13,14 and 15. The reduction in flexural strength is also attributed to the hydrophobic nature of the substitutes.

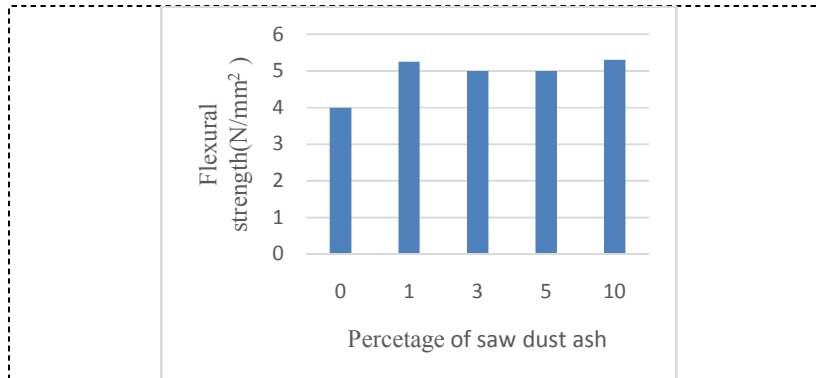


Figure 11. Variation of Flexural tensile strength of mix with 0% LDPE

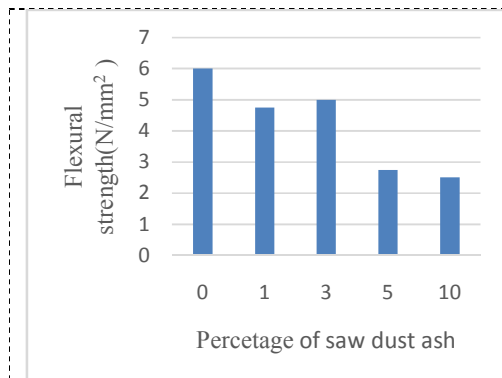


Figure 12. Variation of Flexural tensile strength of mix with 5% LDPE

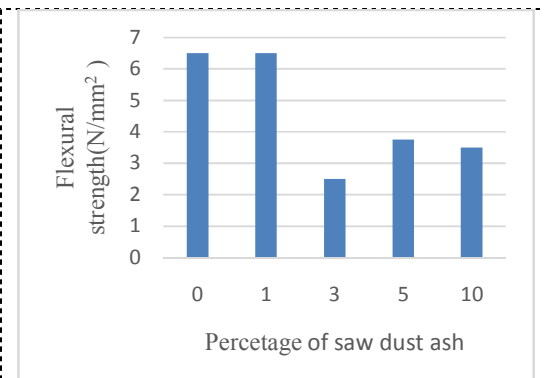


Figure 13. Variation of Flexural tensile strength of mix with 10% LDPE

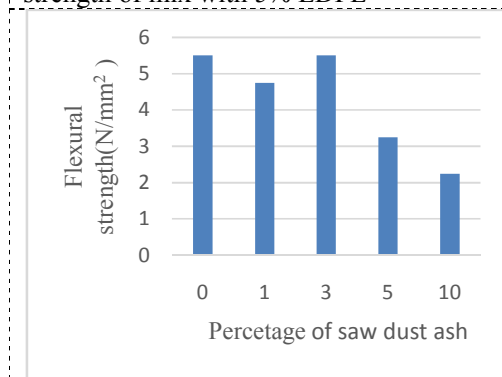


Figure 14. Variation of Flexural tensile strength of mix with 15% LDPE

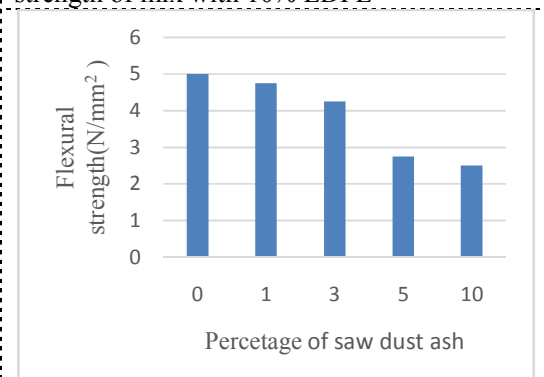


Figure 15. Variation of Flexural tensile strength of mix with 20% LDPE

4. Conclusions

- From the test results, it was observed that, the workability of the modified mixes were decreasing as the percentage of LDPE and saw dust ash increased in the mix. Due to the hydrophobic nature of LDPE and saw dust ash, less water will be absorbed for the preparation of matrix which will lead to the formation of dry mixes.
- It was observed that the density of modified mixes was less compared to the conventional mix. This is due to the addition of low density materials as substitutes for the conventional materials.

- The compressive strength, split tensile strength and flexural strength of the mixes were getting reduced compared to the conventional mix by the addition of LDPE and those were further reduced by the addition of saw dust ash. This also attributed to the hydrophobic nature of LDPE and saw dust ash because of which matrix formed by the binder and fine aggregate will be weak. The weaker bond between the binder and aggregates lead to the decrease in the strength of mix.
- The mix with 5% of LDPE and 3% of saw dust ash showed a better result among the other mixes. This can be considered as the optimum ratio of LDPE and saw dust ash to achieve the targeted properties.

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