

Gundu M., Abhaysinha S. (2021). *Experimental study on the performance of concrete mix with paper waste, waste plastic, quarry dust, and fly ash. Journal of Engineering Sciences, Vol. 8(1), pp. H1–H7, doi: 10.21272/jes.2021.8(1).h1*

Experimental Study on the Performance of Concrete Mix with Paper Waste, Waste Plastic, Quarry Dust, and Fly Ash

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Article info:

Received:

January 17, 2021

The final version received:

April 27, 2021

Accepted for publication:

May 2, 2021

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Abstract. In recent years, concrete in the construction industry has rapidly increased worldwide, including developing countries like India. The raw materials required to produce such a quantity require huge depletion of natural resources. On the other hand, disposal of paper waste, fly ash, and plastic waste is one of the biggest problems faced by many countries, including India, the amount of waste collected and recycled is less compared to disposal quantity. The use of these wastes in concrete reduces the disposal of waste in nature. In this experiment work, the use of these wastes in the concrete has been studied. Preliminary tests like specific gravity, fineness modulus, and water absorption have been carried out on the materials. Various mix designs are prepared by partial replacement of cement with fly ash and paper pulp, and sand is completely replaced with the quarry dust, and coarse aggregate is replaced with shredded plastic waste to create sustainable concrete. A comparative study on the properties like slump cone, the weight of the cubes, compressive strength and split tensile strength, and feasibility of such concrete has been carried out. Results indicated that the weight of cubes started to decrease with the addition of waste. Compressive strength and split tensile strength show that the strength started to fall with the addition of plastic. The cost of concrete decreased with the addition of waste. 5 % of plastic waste in concrete and 3 % of paper pulp, and 5 % of fly ash is considered the optimal replacement percentage.

Keywords: slump cone, split tensile, compressive strength, fly ash, quarry dust, plastic waste, paper waste.

1 Introduction

Concrete is one of the major and widely used materials in the construction industry all over the world. From a study, developing countries have been consuming around 400 million concrete, and the quantity of consumption is expected to increase in the coming decades. The raw materials used for concrete like sand, coarse aggregate, and cement are taken from the Earth's core, depleting each year. Many countries face another fundamental problem with solid waste disposal, which causes a significant threat to the environment and human health.

Plastic waste is one of the solid wastes which causing a great threat to the environment and ecology. A study report on India from CPCB (Central Pollution Control Board) of 2018–2019 shows around 3,360,043 metric tonnes per annum (Roughly around 9200 metric tonnes per day), and among the total collected, only 60 % is recycled, and the remaining are disposed or incineration which ultimately causing pollution to the environment. To reduce this

disposal or incineration we can use these materials in the construction.

Another major solid waste is paper waste, and it is the 3rd biggest polluter of the environment. To meet the demand of industry million trees are cut down, which resulting in global warming. According to a study to meet the demand of India 3 million tonnes of paper waste is collected, which is only 20 % of the total production the remaining end's up as landfill or incinerated.

Fly ash is the waste residue of the thermal power plant which ends up as a landfill. Quarry dust is generated during the crushing process of aggregate in the quarry. Many researchers have tried to study the properties of this waste in concrete as a replacement for cement and the results are quite acceptable. In this study, the use of these materials in the concrete and study of their properties and feasibility of the concrete has been discussed.

2 Literature Review

Shyam and Drishya [1] studied concrete properties by replacing fine aggregate with plastic waste. High-density polyethylene (HDPE) is replaced with M Sand at 5, 10, 15, and 20 %, and results show 5 % replacement as the optimum percentage of replacement. Pooja et al. [2] has carried out a study on concrete behavior by replacing fine aggregate with plastic waste. Mixes are prepared by replacing plastic waste at 15, 20, and 30 % in fine aggregate. The results show that the concrete strength has increased up to 15 %, and further strength has decreased. Kalapad et al. [3] had carried a study to reduce paper waste. To obtain a proper mix design, tests like specific gravity, initial and final setting time, sieve analysis, and bulking of sand on materials. Tests like slump cone on fresh concrete and compressive strength on hardened concrete. The test results found that the paper waste replacement with cement at 10 % shows maximum strength and by addition of the wastepaper sludge, there is a slight reduction in the workability. Ilakkiya et al. [4] had carried out a study to use paper waste in concrete. Various properties of the concrete had been studied. The test results had concluded that 10 % of paper waste shown an acceptable strength property. Ahmad et al. [5] had done an experimental study by replacing cement with paper sludge ash as 5, 10, 15, and 20 %. Different tests had performed, and test results show 5 % of replacement as the optimum mix for the M25 grade of concrete. Bhargavi et al. [6] had studied the use of wastepaper sludge in the concrete. Wastepaper sludge is partially replaced with cement, 4 mixes are prepared for M30.

Moreover, the test results shows suggest that 4 % of replaced concrete can be used as a structural element. Balwaik et al. [7] prepared samples by replacing cement with paper pulp at 0, 5, 10, 15, and 20 %, and a comparative study with the conventional concrete was done. The percentage of water absorption of the concrete has increased. This is due to the increased percentage of the paper pulp that had been noticed. Khandelwal [8] had suggested that 4 % of replacement of the shredded plastic with sand shown better results of the compressive strength and flexural strength. Dhaarani et al. [9] studied the concrete properties by replacing coarse aggregate with plastic, and the test results show 10 % as the optimum mix for modified concrete. Khajuria and Sharma [10] had carried an investigation on the properties of the concrete by replacing natural coarse aggregate with plastic at 0, 2.5, 5.0, 7.5, and 10 %. The test results show 2.5 % of replacement as the suitable replacement for the concrete. Minhas and Jain [11] had carried a review paper on the use of plastic waste in concrete and observed a significant increase in the strength properties with plastic waste like PET in concrete.

This literature review aims to study the various research work carried out on paper and plastic waste. The literature review concludes that both paper and plastic waste can be used in concrete, but the combined effect of these materials needs to be studied. This experimental work is to study the combined effect of these materials in concrete.

3 Research Methodology

3.1 Research objectives

The research objectives are as follows:

- to prepare various mix designs for partial replacement of paper waste, plastic waste, fly ash, crush sand;
- to investigate the properties of the concrete by replacing the cement with fly ash (5 %), paper waste (3 %), sand with quarry waste, and plastic waste (0, 5, 10, and 15 %) in the coarse aggregate;
- to carry out a comparative analysis of test results with the conventional concrete;
- to carry out the techno feasibility study on the plastic paper concrete;
- to recommend the optimum percentage of the replacements in the concrete.

3.2 Methodology

The following flow of methodology is followed in the present experimental work (Figure 1).

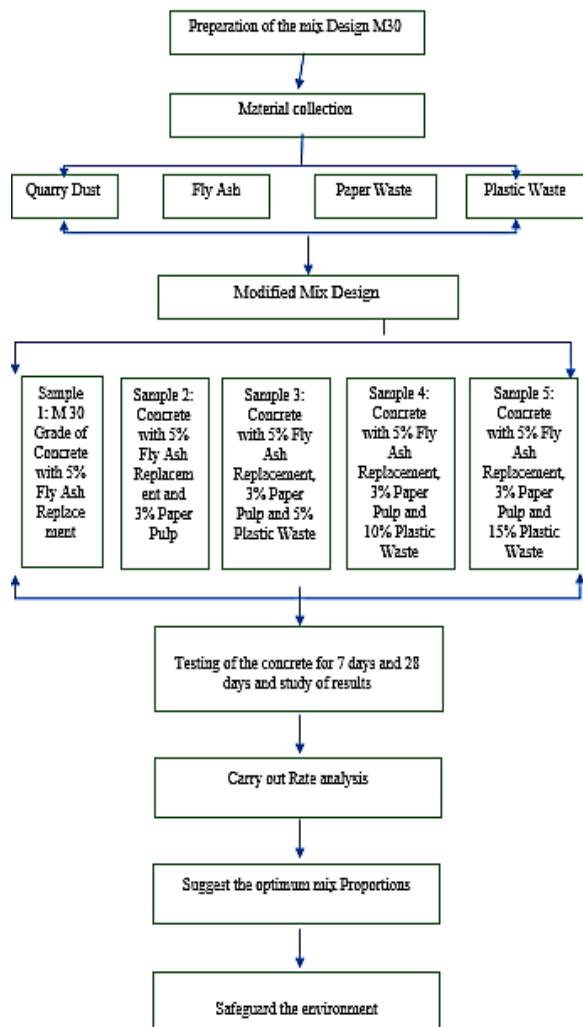


Figure 1 – Flow chart of the methodology

3.3 Materials and methods

The plastic waste (polypropylene plastic waste), paper waste, fly ash, quarry dust was collected from the plastic waste shredding site, local book manufacturer and printing press, stone crusher site in Dist. Warangal, Telangana. Fly ash from the nearby thermal power plant. The basic tests on the materials are conducted as per IS Codes.

Physical properties of the quarry dust are presented in Table 1, other components of the mix – Table 2.

Table 1 – Physical properties of the quarry dust

Sr. No	Property	Obtained Value
1	Specific gravity	2.57
2	Surface texture	Rough
3	Water absorption	0.30
4	Fineness modulus	2.80

Table 2 – Physical properties of other components of mix

Sr. No	Property	Obtained Value
1	Specific gravity of cement	3.15
2	Fineness of cement %	4
3	Specific gravity of 20 mm aggregate	2.68
4	Specific gravity of plastic	0.905
5	Admixture	Kuna plast PC 30

3.4 Mix design of the concrete mix

The mix design for concrete preparation is selecting the right proportion of each material to obtain the required properties like strength, workability, and economical. M30 grade of concrete is selected as this concrete can be used in different structure components (Table 3).

Mix design was prepared for specimen by replacing cement with 5 % fly ash, 3 % paper pulp, coarse aggregate with plastic waste by 5, 10, and 15 %. The combination of the mix design is as follows.

Sample 1 – cement is replaced with 5 % fly ash. Sand is replaced with quarry dust.

Sample 2 – cement is replaced with 5 % fly ash and 3 % paper pulp. Sand is replaced with quarry dust.

Sample 3 – cement is replaced with 5 % fly ash and 3 % paper pulp. Sand is replaced with quarry dust. Coarse aggregate is replaced with 5 % shredded plastic.

Sample 4 – cement is replaced with 5 % fly ash and 3 % paper pulp. Sand is replaced with quarry dust. Coarse aggregate is replaced with 10 % shredded plastic.

Sample 5 – cement is replaced with 5 % fly ash and 3 % paper pulp. Sand is replaced with quarry dust. Coarse aggregate is replaced with 15 % shredded plastic.

Table 3 – Mix design of M30

Sample 1		
Material	Quantity, kg	Ratio
Cement	399	1
Fly ash	21	0.053
Paper pulp	0	0
Quarry dust	675	1.692
Coarse aggregate	1137	2.850
Shredded plastic	0	0
Water	201	0.504
Admixture	2.1	0.005
Sample 2		
Material	Quantity	Ratio
Cement	386.4	0.968
Fly ash	21	0.053
Paper pulp	12.6	0.032
Quarry dust	675	1.692
Coarse aggregate	1137	2.850
Shredded plastic	0	0
Water	201	0.504
Admixture	2.1	0.005
Sample 3		
Material	Quantity	Ratio
Cement	386.4	0.968
Fly ash	21	0.053
Paper pulp	12.6	0.032
Quarry dust	675	1.692
Coarse aggregate	1137	2.850
Shredded plastic	19	0.048
Water	200	0.501
Admixture	2.1	0.005
Sample 4		
Material	Quantity	Ratio
Cement	399	1
Fly ash	21	0.053
Paper pulp	12.6	0.032
Quarry dust	675	1.692
Coarse aggregate	1137	2.850
Shredded plastic	39	0.098
Water	200	0.501
Admixture	2.1	0.005
Sample 5		
Material	Quantity	Ratio
Cement	399	1
Fly ash	21	0.053
Paper pulp	12.6	0.032
Quarry dust	675	1.692
Coarse aggregate	1137	2.850
Shredded plastic	58	0.145
Water	199	0.499
Admixture	2.1	0.005

4 Results

4.1 Test conducted on specimens

4.1.1 Slump cone test

A slump cone test was performed for each sample to know the workability of the modified concrete. Initially, the slump value started increasing till sampling 3, and further, the slump started decreasing (Figures 2–3, Table 4).



Figure 2 – cylinders testing

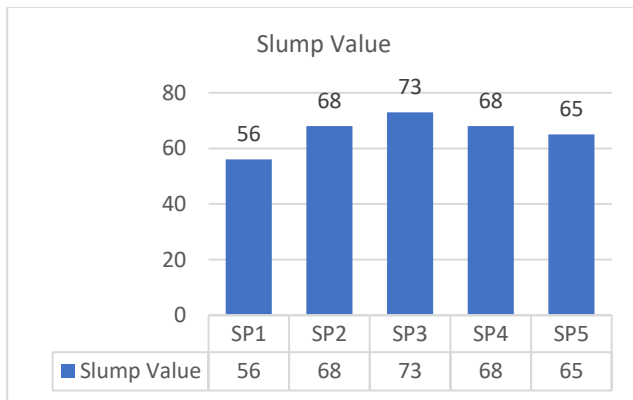


Figure 3 – Slump cone test values

Table 4 – Slump values and placing conditions

Degree of workability	Slump, mm	Placing conditions
Very low	< 25	Blinding concrete; shallow concrete sections; pavement using pavers
Low	25–75	Mass concrete; lightly reinforced sections slabs; columns, beams, walls, floors; hand placed pavements; canal lining; strip footings
Medium	50–100	Heavily reinforced sections in slabs, beams, walls columns slip formwork; pumped concrete
High	75–100	Trench fill; in-situ piling tremie
Very high	100–150	concrete

Slump values from the test results fall under the medium workability range, which concludes that this modified concrete can be used for manually compacted flat slabs and beams.

Specimens were prepared with proper precaution and quantity as mentioned in the above mix design. Cubes of sizes 150 mm x 150 mm x 150 mm, and cylinder of size height 300 mm and diameter 150 mm were prepared by mixing the materials according to the given proportions for replacement of 5 % fly ash and 3 % paper pulp to cement, and sand is completely replaced with the quarry dust, coarse aggregate is replaced with 5, 10, and 15 % of the shredded plastic. A total of 300 cubes and 10 cylinders were cast, including 6 cubes and 2 cylinders for each percent replacement of every 3 cubes for 7 days and 28 days of testing and 2 cylinders for 28 days of each replacement.

4.1.2 Cube weight

After 24 hours of the specimen cast, the specimens were unmolded, and weights of 3 cubes were noted. It was observed that the weight of the samples started decreasing with the increase in the plastic content in the concrete (Figure 5).

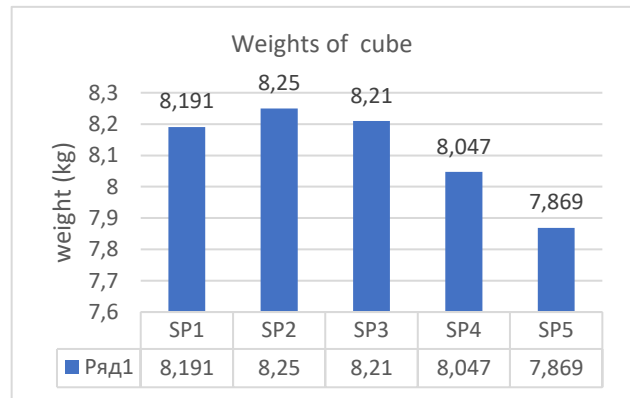


Figure 4 – Weights of the cubes

4.1.3 Compressive strength test

After the curing periods of 7 days and 28 days, the samples were taken out of the curing tank allowed for the drying process. Then the samples were placed in the automatic compression testing machine. The load was applied according to the is code. The peak load at which the specimen fails has been noted to interpret the results (Figure 5).

4.1.4 Tensile strength test

The specimens were taken for testing after 28 days of curing and the specimen is allowed for the drying process. Then the specimen was placed in the automatic compression testing machine and the load is applied till the specimen fails and the results were noted for the interpretation (Figures 5–6).

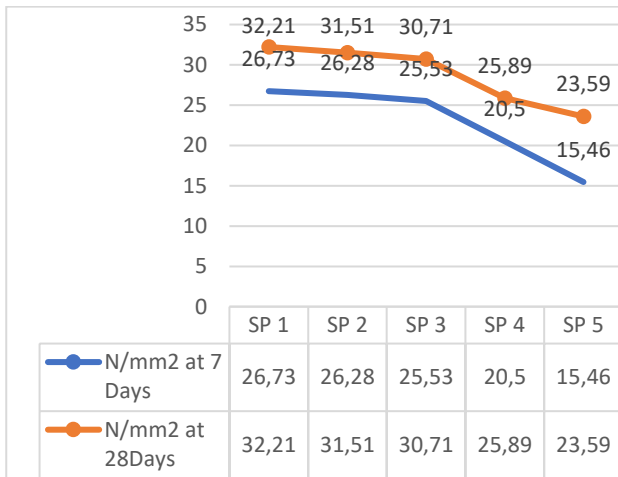


Figure 5 – Compressive strength test results

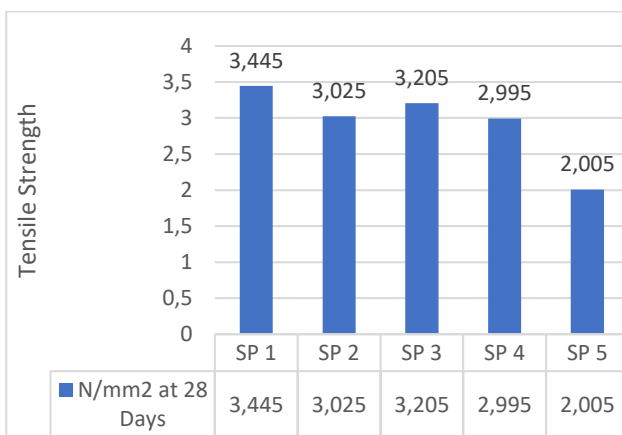


Figure 6 – Split tensile strength results

4.2 Rate analysis

The rate of the materials is collected from the suppliers from Pune, Maharashtra, to carry out the rate analysis for the M30 grade of concrete (Table 5). A comparative analysis is done with the conventional concrete and the modified concrete to replace fly ash, paper pulp, quarry dust, and paper waste.

Table 5 – Normal concrete rate analysis

Material	Unit	Quantity	Price	Total cost
Cement	kg	420	6	2520.00
Sand	–	0.687	2826.8	1942.01
20 mm aggregate	–	1.137	777.38	883.88
water	lit	201	0.5	100.50
Admixture	lit	2.1	110	231.00
Total Cost				5677.39

Rate analysis is carried out on the samples with the addition of plastic waste, fly ash, paper waste, and quarry dust in various proportions (Figures 7–11).

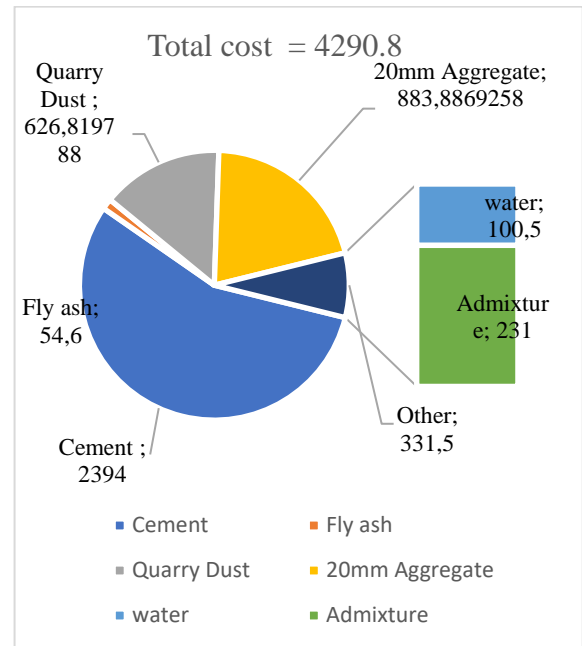


Figure 7 – cost graph of sample 1

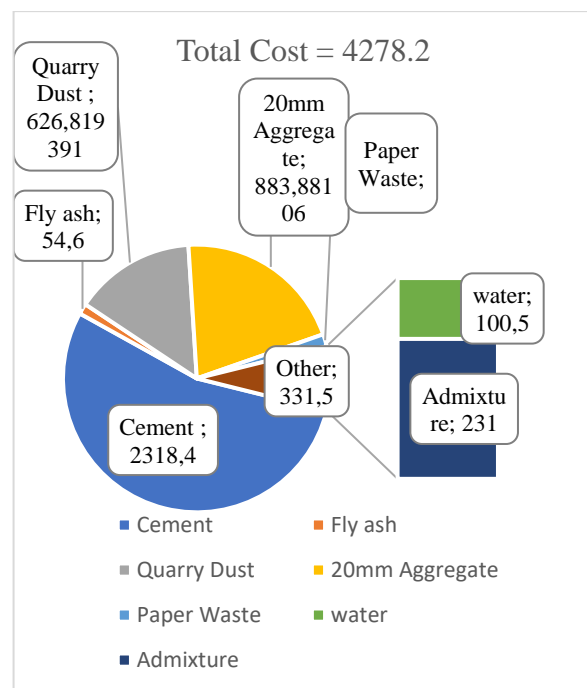


Figure 8 – Cost graph of sample 2

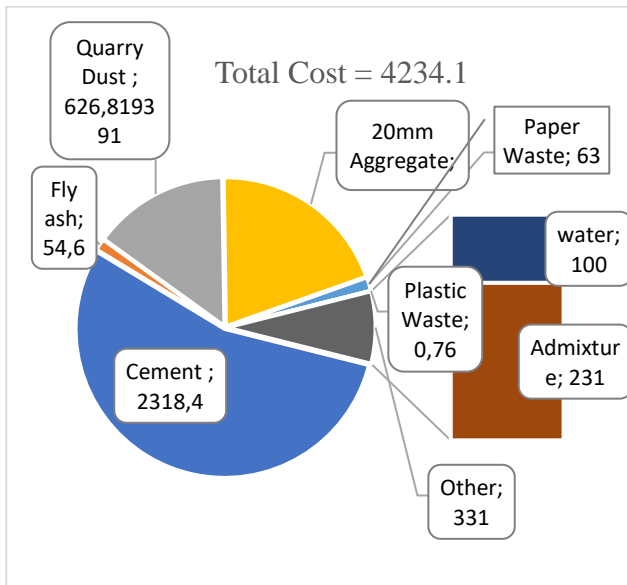


Figure 9 – Cost graph of sample 3

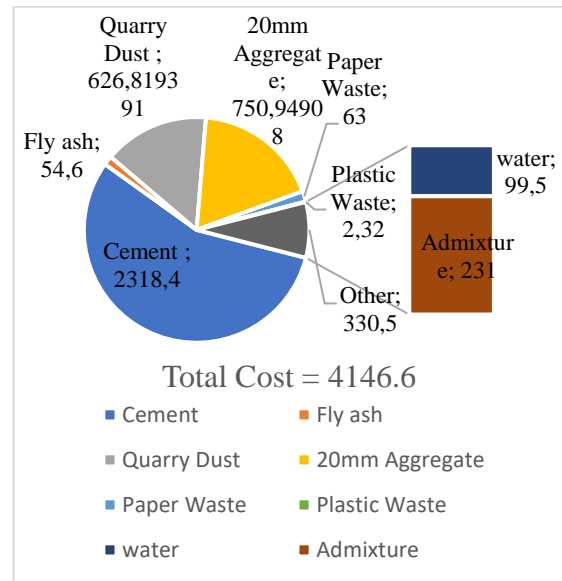


Figure 11 – Cost graph of sample 5

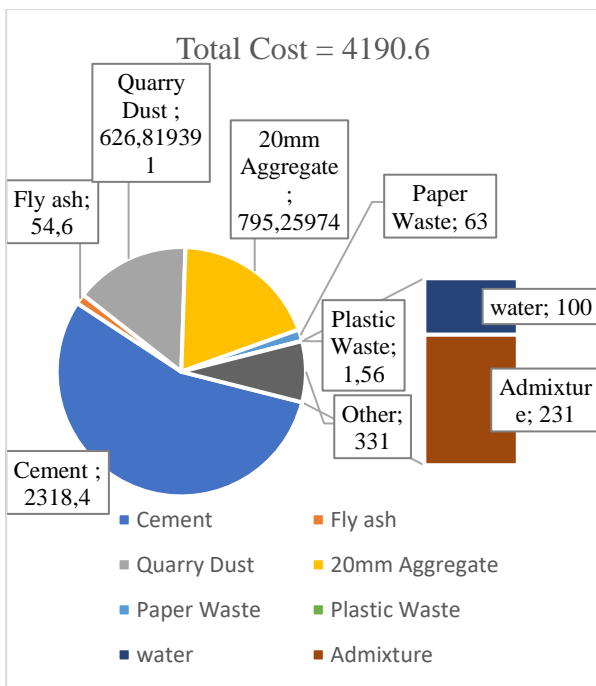


Figure 10 – Cost graph of sample 4

5 Discussion

The test results on the modified concrete are as follows. Initially, the weight of the cube for sample 1 with fly ash is 8.191. With the addition of paper pulp, the weight has increased to 8.25. With the addition of the plastic in the concrete, the weight of the cubes decreased to 8.210, 8.047, and 7.869.

Compressive strength test results after 28 days are as follows: 32.21, 31.51, 30.71, 25.89, and 23.59, indicates that with the addition of plastic, the strength of concrete decreases as mentioned by Shyam and Drishya [1].

The split strength indicates that with the addition of paper pulp, the strength drops initially, and with the addition of plastic waste, the strength of concrete increases till 5 % addition and a further increase in plastic, strength started to drop. The cost of the normal concrete is 5677.4, and with the addition of plastic waste, paper waste, quarry dust, and fly ash, the cost of concrete 4290.8, 4278.2, 4234.1, 4190.6, and 4146.5, which indicates a decrease in the cost of the concrete.

6 Conclusions

From the tests and results on plastic waste, paper waste, fly ash, and quarry dust in concrete, the following conclusion is drawn.

The compressive strength of concrete started to decrease with the addition of plastic waste. This may be due to the flaky and elongated shape of plastic. The weight of the concrete decreases with the addition of paper and plastic waste. The cost of concrete reduces with the use of the wastes. The split tensile strength initially decreases, and with the addition of plastic, the strength increases.

Based on the study results, fly ash of 5 %, paper pulp of 3 %, and plastic waste of 5 % can be used in producing concrete. These wastes can be used to reduce natural resources.

Since the presence of paper waste in concrete, we cannot use this concrete in the water logging area. It can be used by providing a waterproofing coating.

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