Effective Use of Ceramic Waste Powder as Partial Replacement of Cement in Establishing Sustainable Concrete

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Abstract: *The most alarming problems of the world today is related to disposal of waste generated in the industry and to find solution of reusing it. The increase of awareness about the environment problems has tremendously contributed to the concerns related with removal of these generated wastes. The ceramic industry inevitable produce wastes, irrespective of improvements introduced in the manufacturing process. The wastes creates a problem in society, requiring a suitable form of arrangement to achieve sustainable development. This study deals with reviewing the usage of ceramic tile wastes in concrete and its effect on fresh and hardened concrete properties. On the other hand, Portland cement concrete industry has full-fledged Every Where in recent years. During the manufacturing of Ordinary Portland Cement (OPC), a large amount of green house is released into the atmosphere causing global warming. It also consumes large amount energy. Hence, it is necessary to find substitute to cement. Therefore, utilization of the ceramic waste powder in various industrial sectors especially the construction industries would help to protect the environment. It is most essential to develop eco-friendly concrete from ceramic waste. This paper presents an experimental study on the properties of concrete containing ceramic wastes. In that the OPC cement has been replaced by ceramic waste powder accordingly in the range of 0%, 10%, 20%, 30% and 40% by weight of M20 and M40 grade concrete. The concrete mixes is been produced and tested for the compressive strength and water absorption at the end of 28 days. Also the cost comparison is been done for the conventional concrete and the concrete with the inclusion of Ceramic Waste Powder for both M20 and M40 grade.*

Keywords: Concrete, Ceramic Industry, Cost, Compressive Strength, Environment, Economical, Water Absorption, Waste

Introduction

The development in the field of concrete technology can decrease the consumption of natural resources, which can be used again and find other options. The process of disposal of waste in to the open soil causes severe impact on environment. By using the replacement materials offers cost reduction, energy savings and few hazards in the environment. The wastes generated from ceramic industry which had been deemed not proper for sale due to various reasons, including dimensional or mechanical defects, or defects in the burning process. Ceramic waste from factories producing construction industry materials has been accumulating on frequently, creating increasingly large piles. Although they are usually chemically inert, the waste accumulates depending upon their size and the environmental control exercised, have a significant visual impact that destroys the quality of the landscape.

In India ceramic production is 100 million ton per year. The tile industry has about 15% to 30% waste material generated from the total production (6). This waste is not recycled in any form at present. However, the ceramic waste is durable, hard and highly resistant to biological, chemical, and physical degradation forces. The properties of these materials make them a good and suitable choice to be used in concrete. Therefore, the replacement of cement in concrete by ceramic wastes represents a tremendous saving of energy and has important environmental benefits. Besides, it will also have a major effect on decreasing concrete costs, since the cost of cement represents more than 45% of the concrete cost (10). The results shows that the use ceramic waste powder as an active addition gives cement with optimistic characteristic as major mechanical strength and the cost-effective advantages.

I. Experimental Materials

The following experimental materials are used in the present research are:

a) Ceramic Waste Powder

The ceramic powder is obtained from the industrial by products or as the solid waste dumped in any major city. As the ceramic in landfill it takes thousands of years to degradable and cause land pollution. So some of not recycled ceramic can be converted into ceramic powder and used as cement replacement. The usage of ceramic waste can be done as in the form of partial cement replacement along with using it as fine or coarse aggregate replacement. Ceramic waste can be used in concrete to improve its strength and other durability factors. Below figure 1 is showing the ceramic waste powder that is been used in this study.

Following given Table 1 shows the properties of ceramic waste powder.

Figure 1 Ceramic Waste Powder

Table 1 Properties on ceramic waste powder

Sr. No.	Parameter	Unit	Result
1	Na_2O	%	1.04
2	MgO	%	2.94
3	Al_2O_3	%	18.30
4	SiO_2	%	62.40
5	K_2O	mg/L	2.48
6	CaO	mg/L	2.05
7	Fe_2O_3	mg/L	10.78

(Source: Modi Laboratory, Ahmedabad, Gujarat)

b) Cement

A cement is the binder materials which is to be used to bind the other ingredients in the concrete. The Ordinary Portland cement (OPC) of 53 grade, confirming characteristics as per IS 12269-1987 is used for making cement concrete mixes for this study.

c) Fine Aggregate

Fine aggregate is the naturally available materials as river sand. Those fractions from 4.75 mm to 150 micron are designated as fine aggregate. Locally available sand, free from silt and organic matters was used. The river sand is be used in combination as fine aggregate conforming to the requirements of IS 383- 1970.

d) Coarse Aggregate

Coarse aggregates are the important constituents in concrete. The fractions from passing from 20 mm sieve to retain on 4.75 mm sieve are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 is being use.

e) Water

Water is an important constituent of concrete as it actually contributes in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water cement ratio used is 0.50 for M20 grade and 0.40 for M40 grade.

II. Experimental Methodology

The following mix designs were used in the present research work:

a) Mix Design for Concrete

A mix of M20 and M40 grade concrete was designed as per IS 10262:2009 and the same was used to prepare the test samples. Material requirement for 1m^3 conventional concrete and concrete with inclusion of ceramic waste powder is shown in Table 2 and Table 3.

Table 2 Material requirement for 1m^3 of M20 grade Concrete

Concrete Mixes	Design Mix for M20 grade Concrete (By Weight)				
	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Ceramic Waste Powder (kg)	W/C Ratio
A1 Control Mix	383.00	729.70	1173.03	0.00	0.50
B1 (10% CWP)	344.70	729.70	1173.03	38.30	0.50
B2 (20% CWP)	306.40	729.70	1173.03	76.60	0.50
B3 (30% CWP)	268.10	729.70	1173.03	114.90	0.50
B4 (40% CWP)	229.80	729.70	1173.03	153.20	0.5

Table 3 Material requirement for 1m^3 of M40 grade concrete

Concrete Mixes	Design Mix for M40 grade Concrete (By Weight)				
	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Ceramic Waste Powder (kg)	W/C Ratio
C1 Control Mix	479.00	660.99	1155.78	0.00	0.40
D1 (10% CWP)	431.10	660.99	1155.78	47.90	0.40
D2 (20% CWP)	383.20	660.99	1155.78	95.80	0.40
D3 (30% CWP)	335.30	660.99	1155.78	143.70	0.40
D4 (40% CWP)	287.40	660.99	1155.78	191.60	0.40

a) Compressive Strength Test (IS 512: 1956)

Compressive Strength test was conducted on 150mm x 150mm x 150mm cubes. Concrete specimens were removed from curing tank and cleaned. In the Compressive testing machine, the load is applied at a constant rate on 2000 kN capacity compression testing machine up to failure. The load is increased until the specimen fails and the maximum load is recorded. The compression test are carried out at 7, 14 and 28 days. For strength computation, the average load of three specimens was reported as the cube compressive strength. Following figure 2 shows the setup for compressive strength testing machine.

Figure 2 Setup of compressive strength testing of concrete specimen

b) Water Absorption (IS 2185 Part 1:2005)

Concrete blocks shall be completely immersed in clean water at room temperature for 24 hours. The blocks shall then be removed from the water and allowed to drain, visible surface water being removed with a damp cloth, the saturated and surface dry blocks immediately weighed. After weighing all Concrete blocks shall be dried in a ventilated oven at 100 to 115^{0}C for not less than 24 hours. Following figure 3 shows the water absorption test for concrete.

Figure 3 Water absorption test for concrete

III. Results and Discussion

The result and discussion are the present research are as follows:

a) **Compressive Strength test**

The compressive strength of ceramic waste powder based concrete was investigated in this study. Following Table 4 shows compressive strength results of conventional mix and ceramic waste powder based concrete of M20 grade in different proportions.

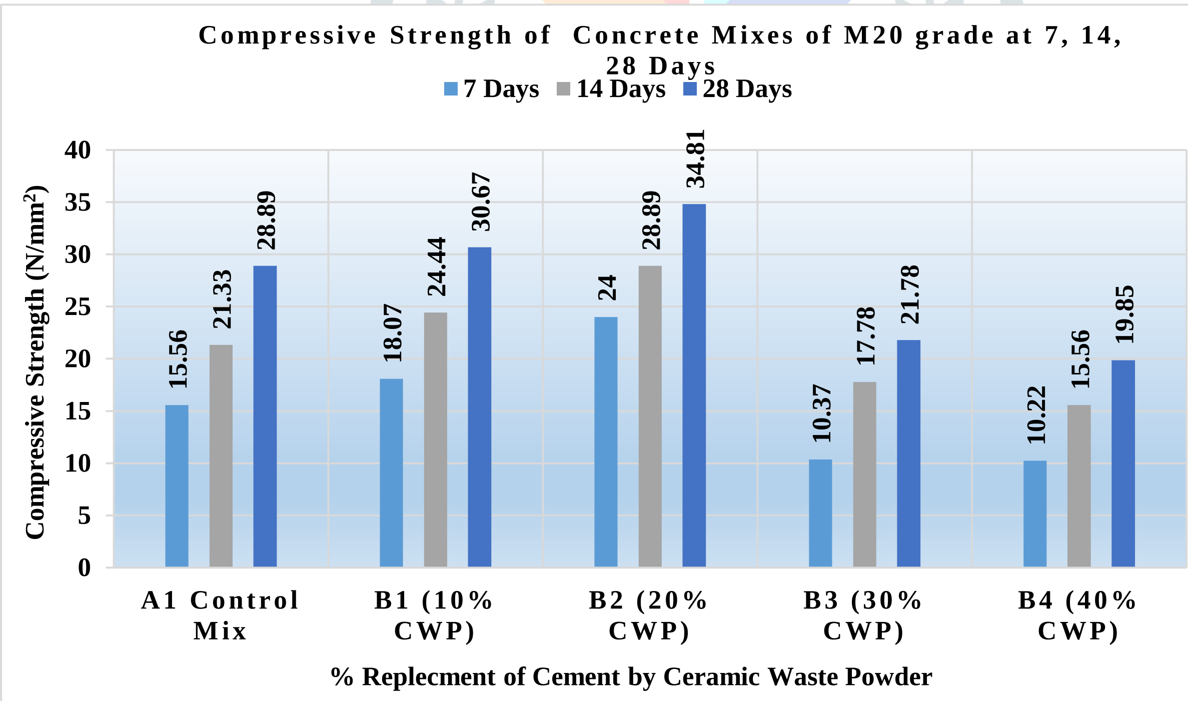
Table 4 Compressive strength of different concrete mixes of M20 grade

Concrete Mixes	Compressive Strength (N/mm^2)			% Change in Compressive Strength		
	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
A1 Control Mix	15.56	21.33	28.89	0	0	0
B1 (10% CWP)	18.07	24.44	30.67	(+)16.13	(+)14.58	(+) 6.16
B2 (20% CWP)	24.00	28.89	34.81	(+) 54.24	(+) 35.44	(+) 20.49
B3 (30% CWP)	10.37	17.78	21.78	(-) 33.35	(-) 16.64	(-) 24.61
B4 (40% CWP)	10.22	15.56	19.85	(-) 34.31	(-) 27.05	(-) 31.29

Following figure 4 shows the results of compressive strength of control mix and Ceramic Waste Powder based Concrete mixes in different proportions at 7 days, 14 days and 28 days.

Figure 4 % Replacement of cement by ceramic waste powder V/S compressive strength (N/mm^2) in different proportion of concrete of M20 grade

From above figures 4 the compressive strength of concrete mixes is increased as the days past. The compressive strength is increased with the increase in proportions of ceramic waste powder in concrete up to 20% and after that compressive strength is decreasing.



Following Table 5 shows compressive strength results of conventional mix and ceramic waste powder based concrete of M40 grade in different proportions.

Table 5 Compressive strength of different concrete mixes of M40 grade

Concrete Mix	Compressive Strength (N/mm²)			% Change in Compressive Strength		
	7 Days	14 Days	28 Days	7 Days	14 Days	28 Days
C1 Control Mix	28.30	35.11	48.89	0	0	0
D1 (10% CWP)	35.56	47.11	54.37	(+) 25.65	(+) 34.17	(+)11.20
D2 (20% CWP)	27.56	38.67	50.07	(-) 02.61	(+)10.13	(+) 02.41
D3 (30% CWP)	20.89	24.44	37.78	(-) 26.18	(-) 30.39	(-) 22.72
D4 (40% CWP)	17.33	21.78	34.07	(-) 38.76	(-) 37.96	(-) 30.31

Following figure 5 shows the results of compressive strength of control mix and ceramic waste powder based concrete mixes in different proportions at 7 days, 14 days and 28 days.

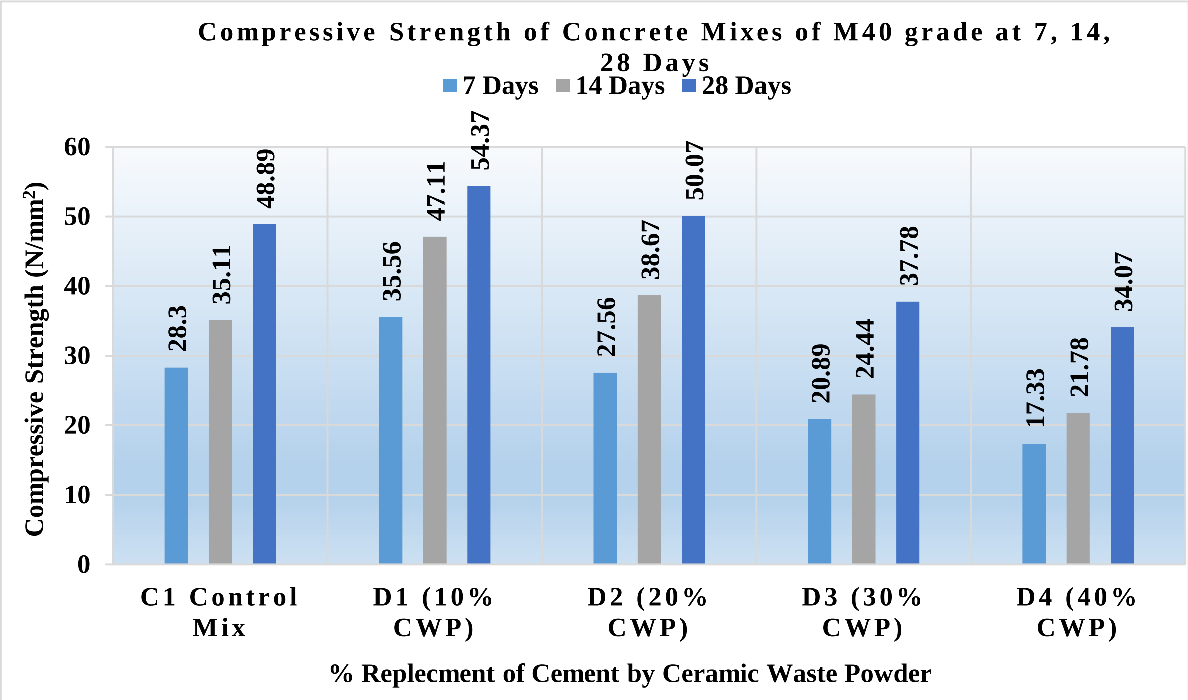


Figure 5 % Replacement of cement by ceramic waste powder V/S compressive strength (N/mm²) in different proportion of concrete of M40 grade

From above figures 5 the compressive strength of concrete mixes is increased as the days past. The compressive strength is increased with the increase in proportions of ceramic waste powder in concrete up to 20% compared to standard nix and after that compressive strength is decreasing.

b) Water Absorption

In this study, Water absorption of ceramic waste powder based concrete was investigated. Following Table 6 shows water absorption results of control mix and ceramic waste powder based concrete with different proportions

Table 6 Water absorption of different concrete mixes of M20 grade

Concrete Mixes	Water Absorption (%) at 28 days
A1 Control Mix	2.43
B1 (10% CWP)	2.21
B2 (20% CWP)	2.00
B3 (30% CWP)	2.31
B4 (40% CWP)	2.49

Following figure 6 shows the water absorption of concrete mixes of M20 grade control mix and ceramic waste powder based concrete in different proportions at 28 days.

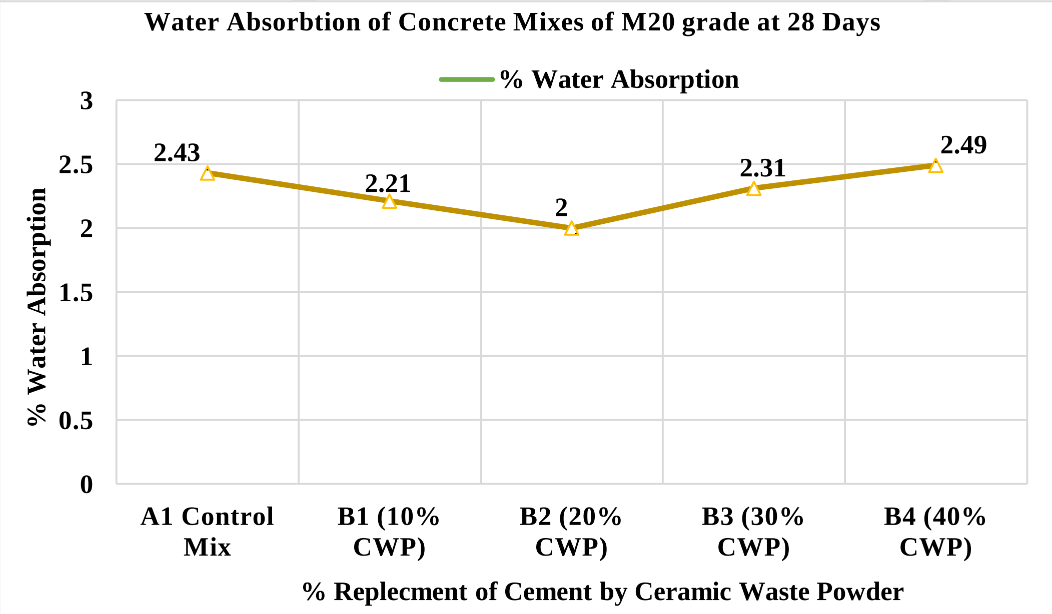


Figure 6 % Water absorption in different proportion of concrete of M20 grade

From above figure 6 the concrete mixes percentage of water absorption was decreased with the increase of ceramic waste powder content up to 20% after that percentage of water absorption was increased with the increase of ceramic waste powder content in concrete.

Table 7 shows water absorption results of control mix and ceramic waste powder based concrete with different proportions of M40 grade.

Table 7 Water absorption of different concrete mixes of M40 grade

Concrete Mixes	Water Absorption (%) at 28 days
C1 Control Mix	2.35
D1 (10% CWP)	2.20
D2 (20% CWP)	2.23
D3 (30% CWP)	2.38
D4 (40% CWP)	2.42

Following figure 7 shows the water absorption of concrete mixes of M40 grade Control mix and ceramic waste powder based concrete in different proportions at 28 days.

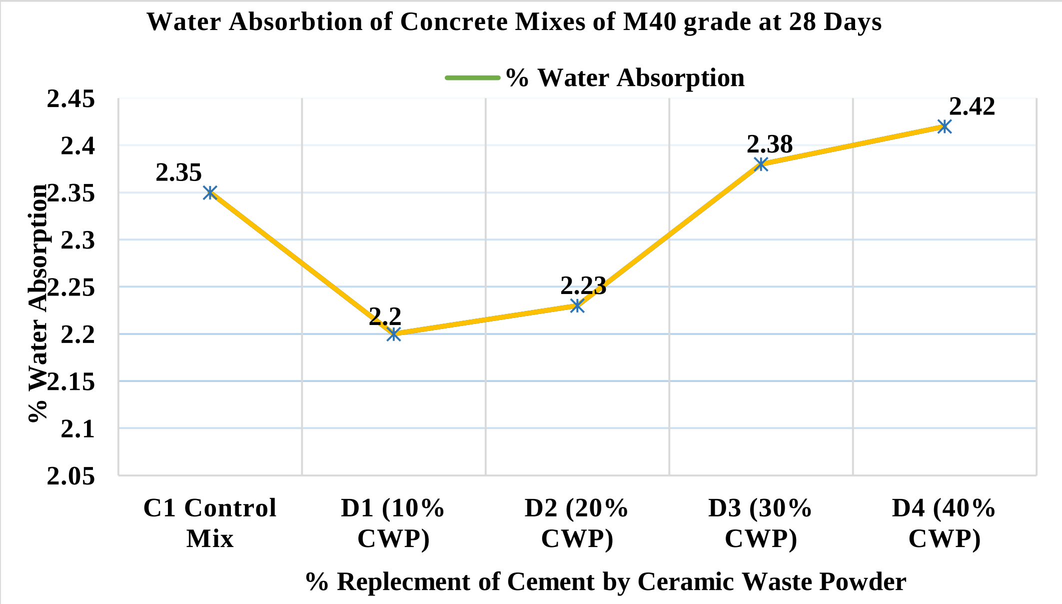


Figure 7 % Water absorption in different proportion of concrete of M20 grade

From above figure 7 the concrete mixes percentage of water absorption was decreased with the increase of ceramic waste powder content up to 10% after that percentage of water absorption was increased with the increase of ceramic waste powder content in concrete and % water absorption is near to the control mix for D3 mix.

c) Cost Analysis

Following Table 8 shows the cost of materials and Table 9 shows the total cost of concrete mixes of grade M20 for 1 m^3.

Table 8 Cost of materials

Materials	Cost Rs/kg
Cement	6.20
Fine Aggregate	0.60
Coarse Aggregate	0.80
Carbon black powder	0.25

Table 9 Total cost of different concrete mixes of M20 grade for 1 m^3

Concrete Mixes	Total Cost Rs/m^3	% Change on Total cost
A1 Control Mix	3750.84	0
B1 (10% CWP)	3522.96	(-) 6.07
B2 (20% CWP)	3295.07	(-) 12.15
B3 (30% CWP)	3067.19	(-) 18.23
B4 (40% CWP)	2839.30	(-) 24.30

Following figure 8 shows the cost analysis of control mix and ceramic waste powder based concrete mixes of M20 grade in different proportion for 1 m^3 cement concrete.

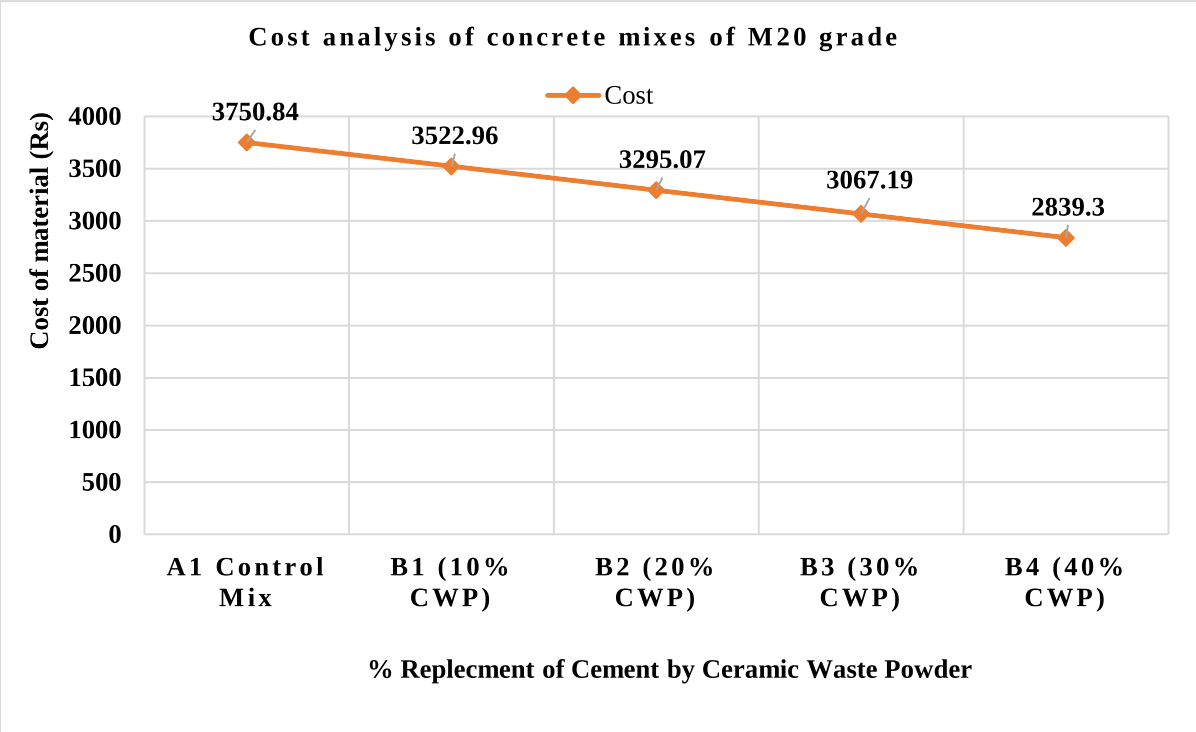


Figure 8 Total cost of 1 m^3 concrete mixes of M20 grade

From above figure 8, it can be said that ceramic waste powder based concrete mixes in different proportion have lesser rates to compare to control mix for 1 m^3. Rates of ceramic waste powder based concrete decrease with increases of ceramic waste powder content compared to control mix.

Following Table 10 shows the total cost of concrete mixes of grade M40 for 1 m^3.

Table 10 Total cost of different concrete mixes of M40 grade for 1 m^3

Concrete Mixes	Total Cost Rs/m^3	% Change on Total cost
C1 Control Mix	4291.02	0
D1 (10% CWP)	4006.01	(-) 6.64
D2 (20% CWP)	3721.01	(-) 13.28
D3 (30% CWP)	3436.00	(-) 19.92
D4 (40% CWP)	3151.00	(-) 26.56

Following figure 9 shows the cost analysis of control mix and ceramic waste powder based concrete mixes of M40 grade in different proportion for 1 m^3 concrete.

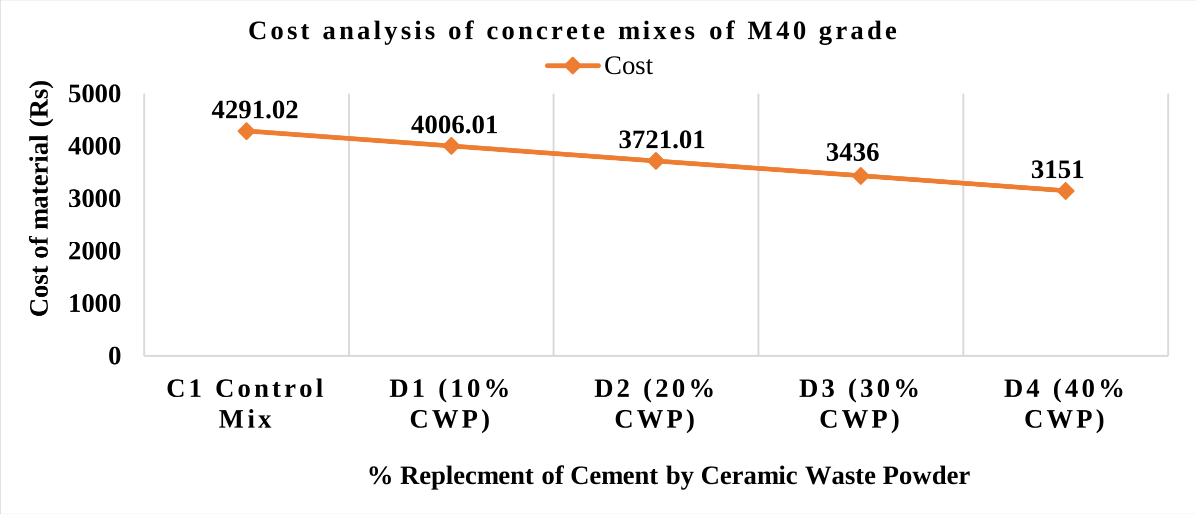


Figure 9 Total cost of 1 m^3 concrete mixes of M40 grade

From above figure 9, it can be said that ceramic waste powder based concrete mixes in different proportion have lesser rates to compare to control mix for 1 m^3. Rates of ceramic waste powder based concrete decrease with increases of ceramic waste powder content compared to control mix.

IV. Conclusion

Based on investigations, research concerning compressive strength, water absorption and cost analysis for control mix and ceramic waste powder based concrete in different proportions, the following conclusions are carried out for various parameters:

1. The compressive strength shows an increase in nature up to 20% replacement (B2 Mix) and then it started to decrease in M20 grade of concrete.
2. Where as in M40 grade of concrete, the compressive strength showing an optimum results at 10% replacement (D1 mix) and then it started to decrease. Although the strength at 20% replacement (D2 mix) is higher than the control mix.
3. The increased compressive strength results show that it can be utilized to make concrete sustainable and cost benefited as well.
4. The water absorption of M20 grade concrete shows a minimum value at 20% replacement (B2 mix) compare to all mixes.
5. In M40 grade of concrete the water absorption is minimum at 10% replacement (D1 mix) and after that it started to increase.
6. As the ceramic waste powder is almost freely available compare to cement, the cost of the concrete is decreasing as the %age replacement is increasing.
7. Also at the optimum compressive strength, the cost calculation shows that approximately 13% of total cost can be saved by replacing ceramic waste powder with cement.
8. Thus by adopting replacement method, the problems such as waste disposal crisis can be handled or overcome. It also draw attention towards the high value application of such waste.

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