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Effect of Using Different Substitutes as Partial Replacement of Cement & Aggregate on the Strength of Concrete

Rewa Bochare

Assistant Professor (Sr. Grade), Department of Civil Engineering, Prestige Institute of Engineering, Management & Research, Indore 452010, Madhya Pradesh, India

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Abstract – *Concrete is a conglomerate of cement, sand, aggregate and water, mixed in a specific proportion to achieve the requisite strength. With the rapid urbanization in the past decade, the demand for concrete as a construction material has increased considerably. This has resulted in the dearth of raw materials like cement and aggregate. This paper studies the effect on or variation in the strength of concrete when a certain amount of cement is replacement with fly-ash, marble powder or a certain amount of sand is substituted by Manufactured (M) sand, or coarse aggregate by concrete waste. Tests were performed on M20 concrete and 28 days strength was assessed using a Compression Testing Machine. The partial replacement of concrete & aggregate was varied in terms of quantity and it was found that the use of marble powder, fly-ash and M-sand furnished extra strength to the concrete. Also concrete waste gave satisfactory strength and may be perceived as a feasible option from economic point of view.*

Key Words: Concrete, Strength, M-sand, partial replacement, marble powder, fly-ash

1. INTRODUCTION

Concrete's versatility, durability, sustainability, and economy have made it the world's most widely used construction material. About four tons of concrete are produced per person per year worldwide and about 1.7 tons per person in the United States (Shanmugapriya et al 2017). The term concrete refers to a mixture of aggregates, usually sand, and either gravel or crushed stone, held together by a binder of cementations. The paste is typically made up of Portland cement and water and may also contain supplementary cementing materials (SCMs), such as fly ash or slag cement, and chemical admixtures. Understanding the fundamentals of concrete is necessary to produce quality concrete.

1.1 Partial Replacement of Cement & Sand

Most commonly Portland cement is associated with the general term "concrete." A range of materials can be used as the cement in concrete. Other cementations materials such as fly ash and slag cement are sometimes added to Portland Pozzolona cement and become a part of the binder for the aggregate.

The raw materials needed for the manufacturing of cement are obtained from nature. Also the process of obtaining cement from cement plants involves huge amount of resources. Thus tremendous demand of cement in the past has led to rise in the prices of cement thereby making the construction projects costlier. Thus the need of the hour is to find substitute materials which may be used in place of cement without compromising on the desired strength of concrete.

Also river beds have served as a natural source of sand for centuries together. But over exploitation of this natural resource has led to ecological imbalance and associated hazards. Thus recently manufacturing of sand has been taken up, which is supplied to concrete producers. This study explores the use of this M-sand and concrete waste in making of concrete.

1.2 Substitutes Tested

In the present study, two different materials have been used to replace the quantity of cement partially, namely: fly-ash, and Marble Powder and Concrete waste. Also the two materials used to replace sand were M-Sand (Manufactured sand), and concrete waste. The concrete waste was used by crushing into fine powder, the leftover broken cubes subjected to Compression Testing Machine in the laboratory. The concrete mix was designed for testing of M20 concrete cubes. The performance of Fly-Ash has been explored extensively in this past, but the fly-ash for this project was locally procured to check for the adequacy. Marble Powder was procured locally too, which is waste from the marble cutting industry. Concrete waste is generally found in construction waste, demolition waste, production waste and waste returned in ready-mix trucks. The reuse of concrete could help generate a reduction in landfill usage, less exploitation of natural resources and reduced transportation costs.

By using waste, recycled and by-product materials in the production of concrete blocks, the problems of cost and resource availability can be overcome. Furthermore, environmental pollution problems that arise from the manufacture of such materials can be minimized. Benefits also come in terms of reduced disposal costs.

2. METHODOLOGY

Mix proportioning is generally carried out for a particular compressive strength requirements ensuring that fresh concrete of the mix proportioned to possess adequate workability for placement without segregation and bleeding while attaining a dense state. There are several methods available for concrete mix design but in this study Indian Standard Recommended Method of concrete mix design (IS 10262:2009) was used. After obtaining the mix, three cubes for standard M20 mix were casted. Then 5% of the quantity of cement was replaced once with marble powder, concrete was mixed in the laboratory and three cubes were casted. Then this replacement was increased to 10% and three cubes were casted. Lastly this replacement quantity was increased to 15% and the standard concrete cubes were casted. The three batches of three cubes each were kept for curing. The 28 days strength was assessed for the 5%, 10% and 15% replacement batch each and was compared to that of the standard M20 batch (no replacement).

Similar exercise was carried out for fly-ash but the replacement percentages were 15%, 20% and 25%.

The percentages of replacement of natural sand by M-sand were 5%, 10% and 15%.

Concrete waste was used to replace 100% quantity of aggregate and 50% the quantity of sand. The calculated quantities for all these replacement percentages have been given in Table 1.

Table -1: Quantity of replacement of substitutes

Substitute	Replacing	Original Qty. (KG)	Replaced Qty. (KG)
Fly-Ash	Cement	4.08	0.612, 0.816, 1.02
Marble Powder	Cement	4.08	0.240, 0.408, 0.612
M-sand	Sand	6.12	0.360, 0.612, 0.918
Concrete Waste	Sand & Aggregate	6.12, 12.24	2.04 & 14.28

Figure 1 : Casting of Concrete moulds in lab.

3. RESULTS

Upon casting the cubes, as mentioned in the methodology above, and curing the cubes for 28 days, their strength was checked in a Compression Testing Machine.

The results that were obtained for each substitute are being represented here in tabular form from Table 2 to Table 5.

Table -2: Strength results for fly-ash replacement

S.No.	Material	Weight (gm)	Load (KN)	Density (gm/cm^3)	Strength (N/mm^2)
1	Standard Cement (100%)	8410	482	2.49	21.42
2	Fly ash (15%)	8500	642	2.51	28.53
3	Fly ash (20%)	8570	436	2.53	19.37
4	Fly ash (25%)	8650	429	2.56	19.06

Table -3: Strength results for Marble Powder replacement

S.No.	Material	Weight (gm)	Load (KN)	Density (gm/cm^3)	Strength (N/mm^2)
1	Standard Cement (100%)	8410	458	2.49	20.35
2	Marble Powder (5%)	8630	382	2.55	16.97
3	Marble Powder (10%)	8800	607	2.60	26.97
4	Marble Powder (15%)	9005	625	2.66	27.77

Table -4: Strength results for M-sand replacement

S.No.	Material	Weight (gm)	Load (KN)	Density (gm/cm^3)	Strength (N/mm^2)
1	Standard Cement (100%)	8410	458	2.49	20.35
2	M-sand (5%)	8660	792	2.56	35.20
3	M-sand (10%)	8940	656	2.64	29.15
4	M-sand (15%)	8800	862	2.60	38.31

Table -5: Strength results for Concrete Waste replacement

S.No.	Material	Weight (gm)	Load (KN)	Density (gm/cm^3)	Strength (N/mm^2)
1	Standard Cement (100%)	8410	458	2.49	20.35
2	Waste of Material (7-days)	8250	454	2.44	20.17
3	Waste of Material (14-days)	8290	458	2.45	20.22
4	Waste of Material (28-days)	8680	514	2.57	22.858

The strength expected from the cubes of M20 concrete after curing for 28 days in water is at least 20 N/mm^2. The strengths obtained in all the above cases have been reported in the last column of all the Tables from 2 to 5.

Also 7 days and 14 days cube strength was checked for the concrete samples made using concrete waste as a partial replacement of sand and full replacement of coarse aggregate.

4. CONCLUSIONS

After studying the results obtained the following conclusions were arrived at:

1) Use of fly-ash as a partial replacement of cement gave satisfactory results in providing the desired strength of concrete at 15% replacement. However there was a reduction in strength values for 20% and 25% replacement.

2) Use of marble powder as a partial replacement of cement yielded poor strength at 5% replacement. However higher strength was achieved at 10% and 15% replacement.

3) Extremely high strength was achieved at 5%, 10% and 15% replacement of sand using M-sand as a partial substitute.

4) Satisfactory results in strength of cubes were observed when concrete waste was used as 100% replacement of aggregates and 50% replacement of sand.

5) M-sand was observed to carry huge amount of dust which made the handling and working difficult while concrete mixing.

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