Impact of Cement Replacement Partially by Mosaic powder on Compressive Strength of Concrete

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Abstract: Mosaic tile is considered as one of the most popular tiles used as finishing material in different parts of the buildings, especially, for floor finishing. During the process of the manufactured mosaic tile, a huge volume of sludge waste has been produced in the stage of polishing and has the effect towards the environment, so it can be reused as a partial replacement of cement for economical purpose. The mosaic sludge can be improved to the mosaic powder through the process of normally drying and sieving. In this paper, an experiment has been conducted to investigate the behavior of compression strength of the concrete by replacing cement with the mosaic tile dust (MTD) by the rate of 5%, 10%, 15%, 20%, 25% and 30%. For this purpose, an experimental program was carried out in which fourteen mixes with different combinations of mosaic tile dust in two different groups of different w/c ratio of 0.45 and 0.55 respectively. The samples are tested and compared with the conventional concrete to find out whether the compressive strength increases or decreases with increasing the rate of replacing the cement by mosaic tile dust (MTD) by the above ratios.

Keywords: Concrete Cube Sample, Mosaic Tile Dust, Compressive Strength, Workability

1. Introduction

Concrete is arguably the most important building material, playing a basic role in all building structures. Its virtue lies in its versatility, durability and fire resistant. Concrete can be used for all standard buildings, both single storey and multistorey and for containment and retaining structures and bridges as discussed by MacGinley and Choo (1990). The concrete technology researchers are continuously trying to improve concrete design to reach higher concrete strength and at the same time reduce the consumption of the resources by finding new alternatives. Nowadays a large amount of mosaic tile sludge in building construction is generated during polishing the tile surface, which makes around totally dirty. This study presents the solution for the environmental problem by collecting the waste and drying it to reproduce powder, which is used as a partially cement replacement in the concrete. Recently, many researches were carried out in order to use ceramic and marble tile waste as a partial replacement or mixture material in the concrete in order to improve concrete design.

Ceramic Tile Waste

The studies conducted by Sukesh et al. (2012) and Torgal et al. (2011) have done their research about the partial replacement of cement in concrete by using of waste materials like ceramic waste. They have found that the concrete with partial cement replacement by ceramic powder has minor

strength loss possess increase durability performance. Manogna and Lakshmi (2015) and Raval et al. (2013) have investigated that using ceramic waste as a partially replacement of cement up to 30% by weight of cement increases the compressive strength of concrete but further replacement of cement with tile powder decreases the compressive strength gradually. However, Anwar *et al.* (2015) concludes that when the ceramic waste powder is replaced by up to 30% by weight of cement without affecting compressive strength of concrete, but further replacement of cement with ceramic waste powder decreases the compressive strength, this result has also been reported by Patel et al. (2014).

Marble Tile Waste

Pal et al. (2016), Vijaya et al. (2016), Raju et al. (2016), Shirule et al. (2012), Singh et al. (2015), Sahu (2016), Kumar and Kumar (2015) have discovered that the compressive strength of concrete increases up to 10% replacement of cement by marble dust powder and further increasing of percentage of marble dust powder leads to decreasing in compressive strength of concrete. Nonetheless, Singh and Bansal (2015), Anwar et al. (2015) and Gurumoorthy (2014) have investigated that the most suitable and optimum percentage replacement of marble dust in concrete is almost 12%, 20% and 25% respectively. Further, any addition of waste marble dust the compressive strength is decreased.

The purpose of this paper is to find the compressive strength of concrete while replacing the mosaic tile dust (MTD) with different proportions in concrete based on experimental investigations and comparing the characteristic strength at the two water cement ratios, namely, of 0.45 and 0.55.

The outline of this paper is as follow. The experimental materials are presented in Section 2. Section 3 shows the mix design and considered variables. Sections 4 and 5 introduce the experimental methodology and the discussion respectively, while a concluding summary is presented in Section 6.

2. Experimental Materials

2.1 **Cement**

Ordinary Portland Cement (OPC) was used for the entire experimental mixes of the study. The chemical and physical properties of the cement are shown in Tables 1 and 2 respectively, which are conformed to IQ.S 5/1984 Standard for Ordinary Portland Cement. The specific gravity of the cement is 3.14.

2.2 Aggregates

2.2.1 Course Aggregate

In the investigation the crushed gravel is used, which is available locally. In order to obtain the densest possible concrete, the existing gravel was separated by sieve analysis and remixed by desired amount according to the specification for having the most well graded course aggregate. The sieve analysis was carried out for the whole required quantity so as to be fitted with the standard specification ASTM-C33 (2003) for coarse aggregate, see Table 3 and Figure 1. The specific gravity and Fineness Modulus of the course aggregate is 2.72 and 2.15 respectively.

Table 1: Chemical properties of cement (OPC)

Chemical requirements	IQ.S 5/1984 Standard for Ordinary Portland Cement	
	Limitation	Test Results
Lime saturation coefficient %	0.66-1.02	1.0
Magnesium Oxide (as MgO)%	≤5	3.6
Sulfate content (as SO3) %	2.5 if C3A ≤ 5	2.2
	2.8 if C3A ≥5	
Loss of ignition (as LOI)%	≤4.0	3.5
Non soluble substance %	≤ 1.5	0.8

Table 2: Physical properties of cement (OPC)

Physical Requirements	IQ.S 5/1984 Standard for Ordinary Portland Cement	
	Limitation	Test Result
Fineness (Blaine) kg/m^2	≥230	343
-Initial setting time minute	≥45	150
-Final setting time hour	≤10	3:20
Soundness (expansion) %	≤ 0.8	0.2
Compressive strength is not less than (MN/m^2)	≥15.0	35.7
	≥ 23.0	46.0

Table 3: Grading of Coarse Aggregate with ASTM-C33 (2003) limits

No.	Sieve No. (mm)	% Passing	ASTM C33 Limits
1	12.5	100	100
2	9.5	90	85-100
3	4.75	20	10 – 300
4	2.36	5	0 - 10
5	1.18	0	0 - 5
Fineness Modulus	2.15		
Specific Gravity	2.72		

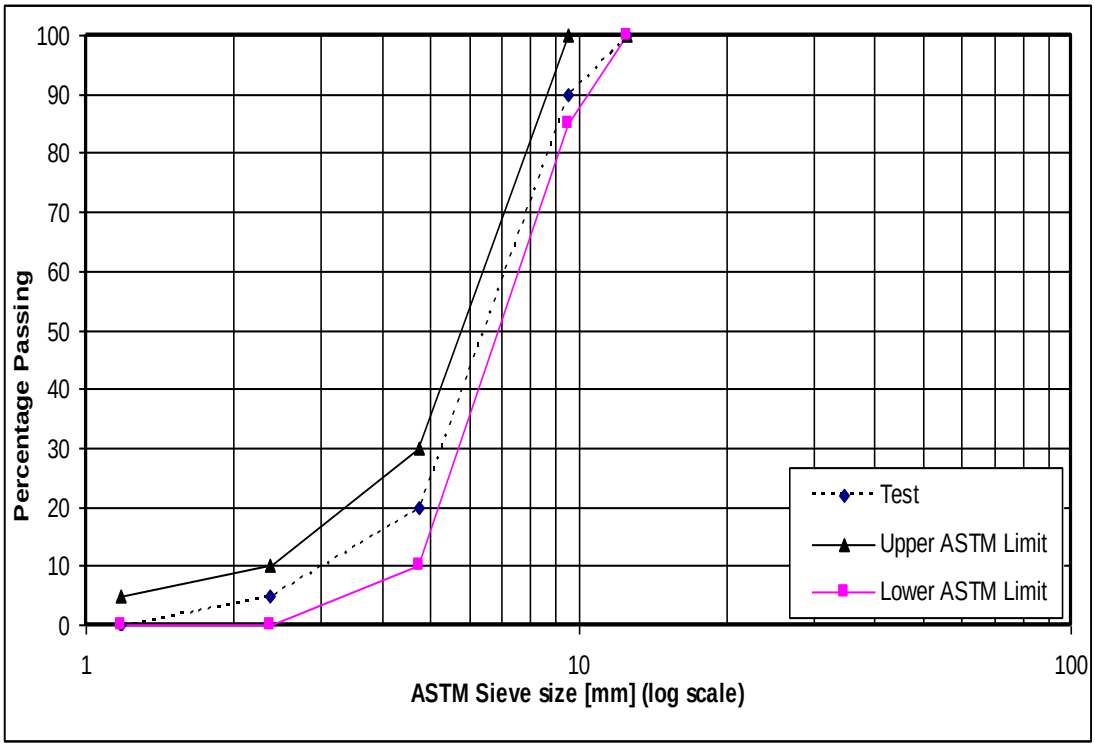


Figure 1: Grading curve for the coarse aggregate with ASTM-C33 (2003) limits

2.2.2 Fine Aggregates

The locally available river natural sand has been used as fine aggregate in this study. To get the most dense concrete, the existing sand was separated by sieve analysis and remixed by the desired amount for having well-graded fine aggregate according to ASTM-C33 (2003) standard

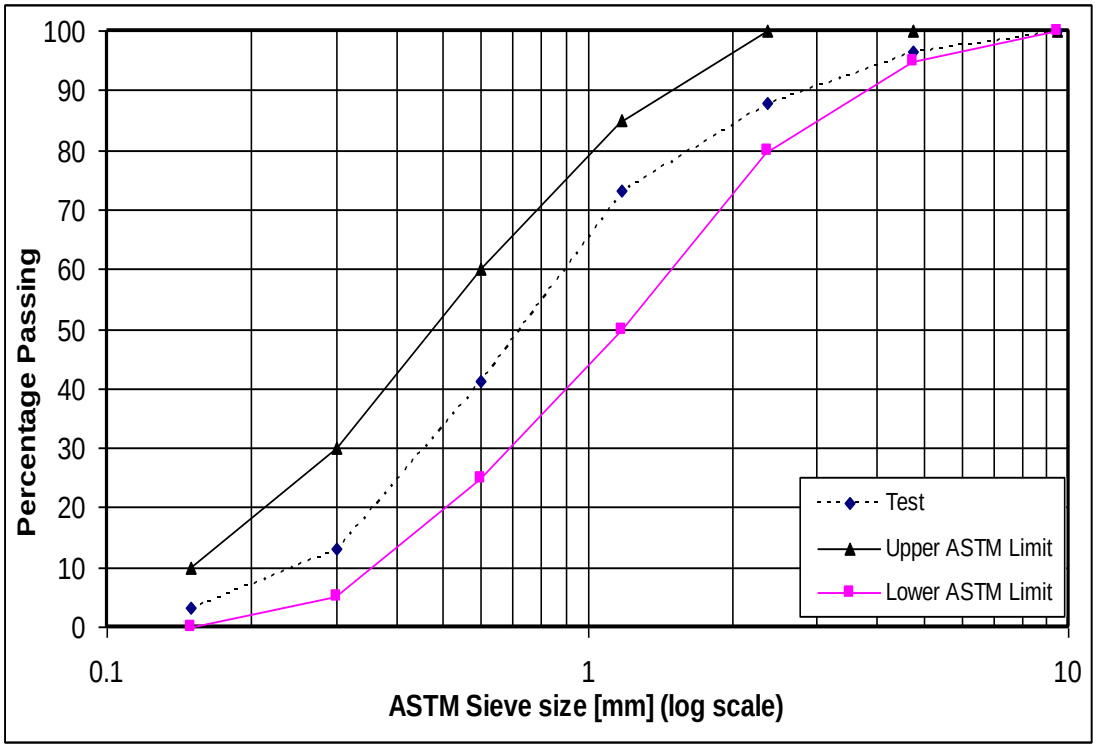
specification for fine aggregate (see Table 4 and Figure 2, for more information). The specific gravity of sand is 2.66 and fineness modulus is 4.66.

2.3 Water

Water is an important component of concrete since it works in the chemical reaction with cement and it aids to from the strength giving cement gel. In the investigation tap water is used for mixing and curing. The quality of water was observed carefully, it was free from organic materials and oil.

Table 4: Grading of Fine Aggregate with ASTM-C33 (2003) limits

No.	Sieve No. (mm)	% Passing	ASTM C33 Limits
1	9.50	100	100
2	4.75	96.5	90-100
3	2.36	87.7	75-100
4	1.18	73.2	55-90
5	0.6	41.2	35-59
6	0.3	13.1	8-30
7	0.15	3.2	0-10
Fineness Modulus	4.15		
Specific Gravity	2.66		



Figure

Figure 2: Grading curve for the fine aggregate with ASTM-C33 (2003) limits

3. Mix Design and Considered Variables

One variable, cement replacement partially by mosaic powder, was selected to investigate its effect on compressive strength of concrete in two different w/c ratios (0.45 and 0.55) as shown in Tables 5 and 6 with their mix design.

Table 5: Mix design w/c =0.45 for 12 liter of concrete batch

All units in gram		Ratio of MTD to the original required cement (3600g)						
		0%	5%	10%	15%	20%	25%	30%
Materials	Cement	3600	3420	3240	3060	2880	2700	2520
	MTD	0	180	360	540	720	900	1080
	Water	1620	1620	1620	1620	1620	1620	1620
	Gravel	14837	14815	14794	14772	14751	14730	14708
	Sand	9891	9877	9862	9848	9834	9820	9805
Total		29948	29913	29877	29841	29805	29770	29734

Table 6: Mix design w/c =0.55 for 12 liter of concrete batch

All units in gram		Ratio of MTD to the original required cement (3600g)						
		0%	5%	10%	15%	20%	25%	30%
Materials	Cement	4800	4560	4320	4080	3840	3600	3360
	MTD	0	240	480	720	960	1200	1440
	Water	2640	2640	2640	2640	2640	2640	2640
	Gravel	12569	12540	12512	12483	12455	12426	12397
	Sand	8379	8360	8341	8322	8303	8284	8265
Total		28389	28341	28293	28246	28198	28150	28102

4. Experimental Methodology

In this experiment the mosaic tile dust (MTD), which was used as a partially cement replacement was evaluated. In the investigation two groups of mixes were used with the two w/c ratios of 0.45 and 0.55. Each group of mixes contains seven batches 0%, 5%, 10%, 15%, 20%, 25% and 30% of original required cement replaced by mosaic tile dust (MTD). For each of the batches 3 cubes were casted. After 24 hours the cubes were demoulded and placed in the water tank for the curing purpose for 28 days, then all specimens were tested for compressive strength and the results which were recorded eventually.

5. Discussion

After all specimens were tested for compressive strength, the results are shown in Table 7, and for more clarity the results are also shown in Figure 3, which represents compressive strength vs. rate of mosaic tile dust (MTD) used instead of Ordinary Portland Cement. It is observed that the compressive strength of the specimens without replacing any amount of MTD with cement are 23.05MPa and 33.39MPa for w/c of 0.55 and 0.45 respectively. However, the compressive strengths for both w/c of 0.55 and 0.45 peaked with replacing cement by only 5% of mosaic tile dust (MTD), and the compressive of 28.38MPa and 35.32MPa are recorded. This increasing of compressive strength are due to the filler like behavior of the mosaic tile dust (MTD), which cooperates in the filling of the voids, resulting more densifying concrete and make a bit stronger concrete as compared to the conventional concrete.

Beyond the 10% replacement of mosaic tile dust (MTD) to 30%, which is the maximum amount of using MTD, the compressive strength starts declining steadily with the rest of increasing mosaic tile dust (MTD). In other words, the compressive strength decreases by 10%, 6%, 4%, 23.6% for 15%, 20%, 25% and 30% replacement of cement by MTD respectively for the w/c= 0.55. Whereas, the rate of decreasing in compressive strength are 21%, 13%, 13.65%, 24% for 15%, 20%, 25%, 30% replacement of cement by MTD respectively for w/c=0.45. That is because the growing level of the partial replacement of mosaic tile dust (MTD) decreases the workability and results the loss of well compacting and increasing the voids. In the same time, the material works as filler when the

material is used instead of cement, the percent of cementitious medium drops and the bond between the whole matrixes will reduce, leading to decreasing the compressive strength. In conclusion, we can see that the best rate of using mosaic tile dust (MTD) as a partial replacement of Ordinary Portland Cement is about 5% for both w/c of 0.55 and 0.45, as shown in Figure 7.

Table 7. The effect of cement replacement by various amount of MTD

MTD%	Compressive strength (MPa) for w/c 0.55	Compressive strength(MPa) for w/c 0.45
0%	23.05	33.39
5%	28.38	35.32
10%	24.62	33.56
15%	21.93	31.34
20%	21.68	29.09
25%	20.93	28.83
30%	17.60	25.34

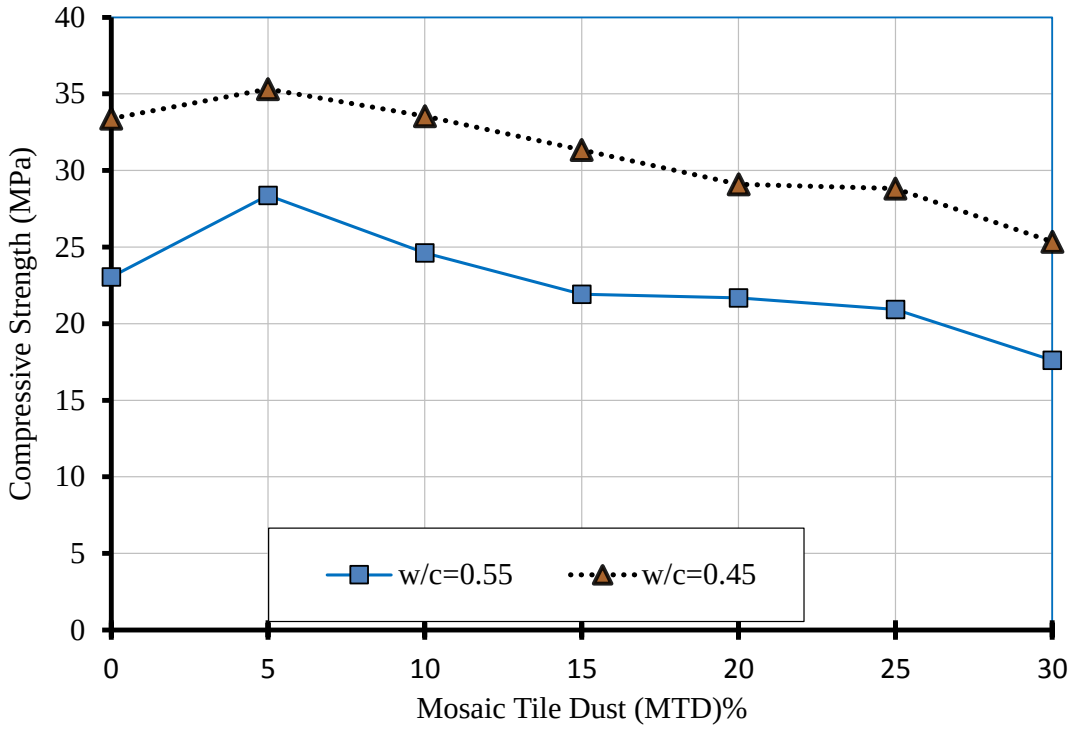


Figure 3: The effect of cement replaced by various level MTD

6. Conclusion

The purpose of this research was mainly to find out and compare the compressive strength of normal concrete with cement replacement partially by mosaic tile dust (MTD) at the water cement

ratios of 0.55 and 0.45 for better fruitful replacement. Based on experimental investigations of the compressive strength of concrete, the following observations are drawn:

1. Compressive strength of concrete increases up to 10% of partial replacement of cement with mosaic tile dust (MTD).
2. Compressive strength of concrete decreases when the replacement level increased from 10% to 15%, 20%, 25% and 30% by weight of cement.
3. The optimum percentage for replacement of cement with mosaic tile dust (MTD) with cement is almost 5%.
4. Utilization of mosaic tile dust (MTD) as a partial replacement of cement has another benefit in terms of environment and economy because cement industry is one of the main sources of CO2 to the atmosphere, and the mosaic tile dust (MTD) could be obtained without cost.
5. The workability decreases with increasing percentage of mosaic tile dust (MTD) replacement of cement in the mixes.

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