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THE USE OF MUNICIPAL SOLID WASTE ASH AS PARTIAL REPLACEMENT OF QUARRY DUST IN CONCRETE PRODUCTION

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Abstract: *The increasing cost of concrete production calls for cheap and alternate ways of reducing its cost. This includes identifying cheap materials that can substitute fine aggregate, cement or coarse aggregate. This is an experimental research that utilizes an environmental waste, municipal solid waste ash to partially replace quarry dust in concrete production. Quarry dust which is a known material used as fine aggregate in concrete works was replaced with municipal solid waste ash at 5 %, 10 %, 15 %, 20 % , 25%, 30%, 35% and 40 % by weight for concrete grade C-25 mix. The concrete specimens were tested for workability, compressive strength, and water absorption at 7 days, 14 days and 28 days. The results shows that partially replacing quarry dust with MSWA does not improve the strength and workability of concrete but a comparative strength to the control strength can be obtained at 28 days age with 5 % to 15 % replacement which can be used for light concrete works.*

Keywords: *Concrete, Compressive strength, Quarry dust, Municipal solid waste ash*

1. Introduction

Development in urban areas comes with adverse impact on humanity, ranging from traffic congestion to increase waste generation in the society. Waste management has been a problem in the urban areas with the growing population especially in low and middle income countries. Poor collection, poor management, poor disposal and lack of availability of space to dispose or fill with these wastes are on the increase daily in urban areas.

The high cost of treatment or disposal of this waste as well as lack of availability of space to fill with this waste calls for alternate ways of saving the environment from this waste by utilising the waste for other purposes less harmful to the society [1,2]. Landfill with municipal solid waste is not considered as the best option since it can produce methane and can contaminate ground water. Using Municipal Solid Waste Ash (MSWA) also reduces the cost of producing concrete since it will replace one of the expensive material (sand) used in concrete production [3].

Many researchers have come up with ways of utilizing the waste (such as fly ash, silica fume, rice husk ash, etc) generated in the society for construction purposes. One of the most commonly used wastes is the quarry dust generated from quarry sites. Quarry dust is a by-product from the crushing process during quarrying activities. In quarrying, rocks are crushed into various sizes with the dust generated known as quarry dust and it is waste generated from it. It has been used in construction of roads, building materials such as lightweight aggregates, autoclave blocks, tiles and bricks can be manufactured with the use of quarry dust. Many researches have conducted study in different part of the world to know the effects of incorporating quarry dust into concrete production [4,5,6], which has proven a useful material in construction.

Another of the waste generated is the municipal solid waste which its disposal has become an increasing concern due to increase volume of the waste generated daily. Municipal solid wastes are found in many dump sites especially in developing countries. These dump sites have increased rapidly and posing danger to the society which calls for alternate ways of utilizing the waste thereby reducing the danger it poses to the environment. Municipal solid waste ash is the by-product of municipals solid waste which is produced from its combustion. The common method of managing municipal solid waste is by incineration through mass-burning process and refuse-derived fuel process The process whereby metals and glasses are separated from the municipal solid waste before cutting into shreds and then incinerating is termed refuse-derived fuel while mass-burning process involves burning the municipal solid waste as it is dumped or received without any separation [7]. The by-product of the incineration is ash which is known as municipal solid waste ash (MSWA).

Concrete is the most common and widely used building material all over the world with its major constituents being cement, water, coarse and fine aggregate. The cost of producing concrete is much and researchers have done work on ways of reducing the cost of producing concrete [8]. The commonly used fine aggregate for concrete works is river sand which fluctuates in price due to availability in different locations at different seasons. Dredging of rivers for river sand can also pose threat to the environmental. This research studies the properties of concrete produced from partially replacing quarry dust with municipal solid waste ash (MSWA) as fine aggregate for concrete work production.

2. Materials and Methods

2.1 Materials Used

2.1.1 Cement

Portland limestone cement of grade 42.5N which is Dangote brand produced in Nigeria was used throughout the work.

2.1.2 Quarry Dust

The quarry dust which is the by-product of quarry was collected from a quarry site in Nassarawa State of Nigeria and further processing was not done on the sample. It is the fine aggregate used in this work. The particle size analysis graph of the quarry dust used is shown in figure 1

2.1.3 Coarse Aggregate

The coarse aggregate used was clean river gravel which high percentage of it has sizes between 10 mm to 20 mm. The particle size analysis graph of the gravel used is shown in figure 1.

2.1.4 Municipal Solid Waste Ash (MSWA)

The municipal solid waste ash (MSWA) was collected at a dump site in Makurdi local government area of Benue State, Nigeria. The ash was obtained from an open burning at the dump site with no further special burning carried out on the collected ash. The particle size analysis graph of the MSWA used is shown in figure 1.

2.2 Methodology

The method used in this research was experimental investigation based with some of the properties of the materials used determined by laboratory experiments. Particle size analysis was conducted on quarry dust, MSWA and gravel used. The specific gravities of the materials used were also determined in the laboratory by experiments. Aggregate impact and crushing test were also carried out on the gravel used. Slump test was carried out on the mortal concrete after which the concrete was used to cast cubes. Compressive strength test and water absorption tests were conducted on the cubes.

2.2.1 Particle Size Analysis Test

The particle size analysis was carried out to determine the particle size gradation of the materials used. The procedure adopted here is given in [9]. This test was conducted on quarry dust, MSWA and gravel.

2.2.2 Specific Gravity Test

The specific gravity test was conducted on the materials used for the experiments according to the procedure given in [10] to determine the ratio of its given mass to equal volume of water. The expression used for this is given as:

$$\text{Specific gravity } (Gs) = \frac{weight\ of\ soil}{weight\ of\ equal\ volume\ of\ water} \quad (1)$$

2.2.3 Mix Proportion

The concrete mix design used is the one according to [11]. The grade of concrete used is C-25 for the 28 days strength. The water-cement ratio of 0.58 was adopted. Table 4 present the summary of mix design at different proportions of replacement. The mix ratio of approximately 1:2:4 (cement into fine aggregate into coarse aggregate ratio) was used with the fine aggregate (quarry dust) partially replaced at certain percent during the experiments.

2.2.4 Slump Test

Slump test was carried out on the fresh concrete for each concrete mixture using metallic slump mould. This test was used to determine the workability of the fresh concrete and the procedure followed is that obtained in [12]. The slump value is the different between the highest subsided concrete height to the height of the slump mould. The result for slump test is presented in table 5.

2.2.5 Compressive Strength Test

From each concrete mixture, concrete cubes of size 150 mm × 150 mm × 150 mm were casted for determining the compressive strength of the concrete. The test was conducted according to the procedures in [Ref], cured by immersion in water and crushed at 7 days, 14 days, 21 days and 28 days in order to determine the compressive strength according to [13]. Table 6, 7, and 8 present the result of the compressive strength test at ages 7, 14 and 28 days respectively.

2.2.6 Water Absorption Test

Water absorption test was conducted on all the cubes at all ages during the experiment. The dry weight of the casted cubes was measured immediately after removing from mould and the weight of casted cubes immediately after curing in water was measured at 7 days, 14 days, 21 days and 28 days of age. For each concrete cube casted and at each age of crushing, the percentage of water absorption was measured. Percentage absorption by weight is given by equation (2).

$$\text{Percentage absorption by weight} = \frac{W_2 - W_1}{W_1} \times 100 \qquad (2)$$

where W_1 = weight of dry specimen in g

W_2 = weight of specimen submerged in water and wiped with cloth in g

3. Results

3.1 Particle size analysis

The results of the sieve analysis (particle size distribution curve) for the materials used are presented in figure 1.

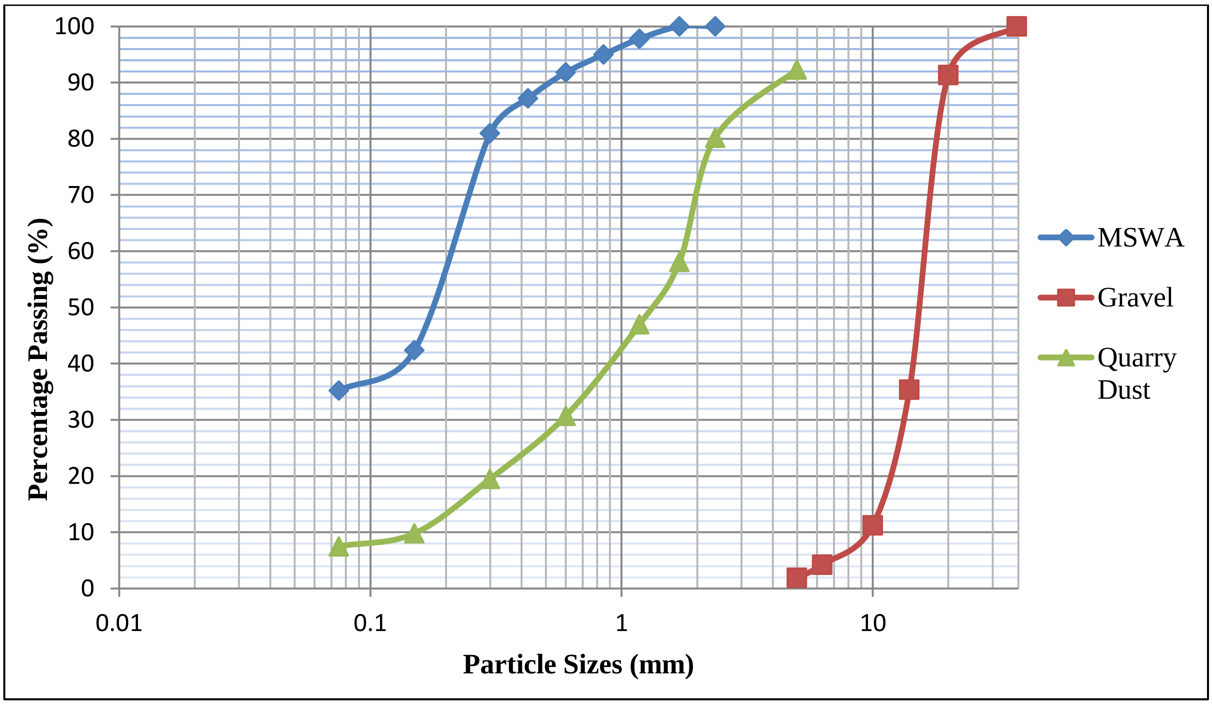

Figure 1: Particle size analysis chart for Municipal Solid waste ash, grave and quarry dust

3.2 Specific gravity

The specific gravity of quarry dust, gravel and MSWA are presented in table 1, 2, and 3 with summary of mix proportion presented in table 4.

Table 1: Average specific gravity of quarry dust

	1	2	3
Weight of flask, W_1 in g	36.27	36.35	36.37
Weight of flask + Water, W_2 in g	109.22	109.34	109.04
Weight of flask + Quarry dust, W_3 in g	94.13	91.80	99.82
Weight of flask + Quarry dust + Water, W_4 in g	114.55	143.14	147.55
$W_3 - W_1$	57.86	55.45	63.45
$W_2 - W_1$	72.95	72.99	72.67
$W_4 - W_3$	50.42	51.34	47.73
$G_s = \frac{W_3 - W_1}{(W_2 - W_1) - (W_4 - W_3)}$	2.57	2.56	2.54
Mean G_s	**2.56**		

Table 2: Average specific gravity of gravel

	1	2
Weight of flask, W_1 in g	595	595
Weight of flask + Water, W_2 in g	1619	1619
Weight of flask + Quarry dust, W_3 in g	1093	1095
Weight of flask + Quarry dust + Water, W_4 in g	1930	1931
$W_3 - W_1$	498	500
$W_2 - W_1$	1024	1024
$W_4 - W_3$	837	836
$G_s = \frac{W_3 - W_1}{(W_2 - W_1) - (W_4 - W_3)}$	2.66	2.66
Mean G_s	**2.66**	

Table 3: Average specific Gravity of MSWA

	1	2	3
Weight of flask, W_1 in g	36.27	36.35	36.37
Weight of flask + Water, W_2 in g	107.22	109.34	109.04
Weight of flask + Quarry dust, W_3 in g	57.48	58.83	58.39
Weight of flask + Quarry dust + Water, W_4 in g	119.10	119.52	119.18
$W_3 - W_1$	21.21	22.48	22.02
$W_2 - W_1$	72.95	72.99	72.67
$W_4 - W_3$	61.62	60.69	60.79
$G_s = \frac{W_3 - W_1}{(W_2 - W_1) - (W_4 - W_3)}$	1.87	1.83	1.85
Mean G_s	**1.85**		

Table 4: Summary of mix proportion

MSWA (%)	Cement (kg)	Quarry Dust (kg)	MSWA (kg)	Gravel (kg)
0	12.70	23.02	0.00	40.69
5	12.70	21.87	1.15	40.69
10	12.70	20.72	2.30	40.69
15	12.70	19.57	3.45	40.69
20	12.70	18.42	4.60	40.69
25	12.70	17.27	5.76	40.69
30	12.70	16.11	6.91	40.69
35	12.70	14.96	8.06	40.69
40	12.70	13.81	9.20	40.69

3.3 Slump Result

The slump for various replacement percentages is presented in table 5

Table 5: Slump test results at various % of MSWA

Percentage replacement of MSWA (%)	Actual water/binder Ratio	Slump (mm)
0	0.57	62
5	0.61	48
10	0.68	48
15	0.75	52
20	0.87	45
25	1.02	48
30	1.17	40
35	1.47	47
40	1.70	46

3.4 Compressive strength test result

The compressive strength test results for various replacement of MSWA at ages 7 days, 14 days and 28 days are given in tables 6, 7, and 8 respectively. A summary graph is presented in figure 2.

Table 6: Average compressive strength of cubes at age 7 days

Percentage replacement of MSWA (%)	Average Weight (g)	Average Failure Load (kN)	Average Compressive strength (N/mm^2)
0	8174	470	20.88
5	8100	465	20.67
10	7973	443	19.69
15	7894	338	15.02
20	7826	223	9.91
25	7593	177	7.87
30	7376	132	5.88
35	7199	112	4.98
40	7036	86	3.82

Table 7: Average compressive strength of cubes at age 14 days

Percentage replacement of MSWA (%)	Average Weight (g)	Average Failure Load (kN)	Average Compressive strength (N/mm^2)
0	8117	510	22.67
5	8113	472	21.00
10	8002	457	20.31
15	7958	365	16.20
20	7924	272	12.09
25	7699	226	10.04
30	7613	170	7.56
35	7361	147	6.53
40	7122	118	5.24

Table 8: Average compressive strength of cubes at age 28 days

Percentage replacement of MSWA (%)	Average Weight (g)	Average Failure Load (kN)	Average Compressive strength (N/mm^2)
0	8169	589	25.18
5	8114	550	24.44
10	7874	510	22.89
15	7938	440	19.56
20	7973	380	16.89
25	7767	272	12.07
30	7573	255	11.33
35	7312	224	9.93
40	7060	190	8.44

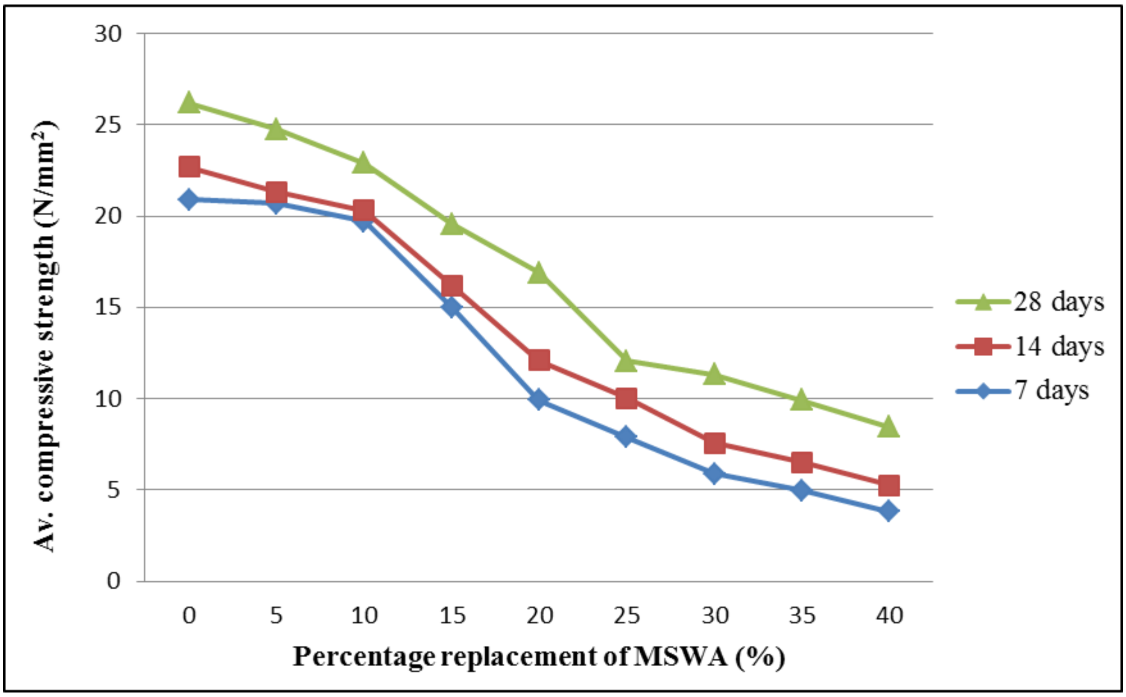

Figure 2: Av. Compressive strength of Cubes at different ages and % of MSWA

3.5 Water absorption test result

Table 9: Percentage of water absorption rate at 7 days

Percentage replacement of MSWA (%)	Av. Weight (g)	Av. Weight (g)	Percentage absorption (%)
0	8130	8194	0.79
5	8100	8157	0.70
10	7951	8014	0.79
15	7894	7947	0.67
20	7843	7906	0.80
25	7593	7668	0.99
30	7460	7521	0.82
35	7199	7256	0.79
40	7129	7180	0.72

Table 10: Percentage of water absorption rate at 14 days

Percentage replacement of MSWA (%)	Av. Weight (g)	Av. Weight (g)	Percentage absorption (%)
0	8061	8128	0.83
5	8010	8076	0.82
10	8010	8075	0.81
15	7958	8014	0.70
20	7916	7993	0.97
25	7699	7801	1.32
30	7632	7708	1.00
35	7361	7429	0.92
40	7181	7239	0.81

Table 11: Percentage of water absorption rate at 28 days

Percentage replacement of MSWA (%)	Av. Weight (g)	Av. Weight (g)	Percentage absorption (%)
0	8149	8224	0.92
5	7901	7974	0.92
10	7901	7970	0.87
15	7938	7998	0.76
20	7922	8024	1.29
25	7767	7891	1.60
30	7564	7662	1.30
35	7312	7408	1.31
40	7023	7076	1.22

4. Discussion of Results

Figure 1 shows the particle size distribution curve for quarry dust, MSWA and gravel used for the experiments. The graph shows that the three materials used are well graded.
Table 1, 2 and 3 shows the average specific gravity of quarry dust, gravel and MSWA respectively which shows that the specific gravity of MSWA is lower than that of quarry dust used with a difference of 0.71.
Table 5 shows the slump obtained throughout the experiments which are true slump and the water/cement ratio increased as the percentage of MSWA increases, the workability of the concrete decreases which suggests that as the percentage replacement of ash increases, the water needed in the mix also increases.
Table 6, 7 and 8 shows the compressive cube strength of various mixes at age 7, 14 and 28 days respectively. It shows a reduction in strength as percentage of replacement of quarry dust with MSWA increases from 5 % to 40 %. It suggests that for light concrete work, MSWA can be used to replace quarry dust up to 15 % replacement maximum. Graphical presentation of the strength behaviour of the concrete cubes at various percentage replacements and at different ages are shown in figure 2.
Table 9, 10 and 11 shows the percentage water absorption which increases at increase in MSWA replacement.

5. Conclusion

The tests results obtained from partially replacing quarry dust with MSWA in concrete work can lead to the following conclusion:

1. The partial replacement of quarry dust with MSWA did not improve the compressive strength of concrete.
2. The actual replacement of quarry dust with MSWA that can be comparatively adequate for light concrete works is 5 % to 15 %.
3. The workability of quarry dust concrete partially replaced with MSWA decreases with increase in MSWA percentage.
4. The specific gravity of MSWA is less than that of quarry dust.

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