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# COMPRESSIVE AND FLEXURAL STRENGTH OF CONCRETE BLENDED WITH MUNICIPAL SOLID WASTE ASH AND MICROSILICA

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## KeyWords
Compressive Strength, Flexural Strength, Microsilica, Municipal Solid Waste Incinerator Ash (MSWI Ash), Particle Packing Method.

## ABSTRACT
This Study investigated the effects of Municipal Solid Waste Incinerator (MSWI) Ash and microsilica on the compressive and flexural strength of medium strength concrete. Samples of four water-cement ratios (0.35, 0.40, 0.45 and 0.5) were prepared to achieve concrete grades of 40, 35, 30 and 25 respectively using the particle packing method of mix design. The supplementary cementitious materials (MSWI ash and microsilica) were implemented as partial substitutes for cement in percentages of 5, 10, 15, 20 and 25. Compressive strength and flexural strength tests were implemented on all prepared hardened concrete samples after 7 days, 14 days, 28 days curing and 28 days curing respectively. Also, the workability of the concrete was determined through slump test implemented on freshly prepared concrete samples. The workability test results were consistent with the requirements of BS 1881 Part 102: 1990. The compressive strength results showed that for all grades of concrete samples tested, the replacement of cement with a combination of MSWI ash and microsilica resulted in reduction of compressive strength at various replacement levels compared to the reference samples. However, strength increments were observed at 10% replacement levels, compared to the reference samples for all concrete grades. Similar trend was observed for flexural strength development. However, the flexural strength increment was observed for 15% cement replacement for grade 35 concrete samples. Therefore, optimum content of MSWI ash and microsilica as partial replacements for cement was obtained at 10% replacement levels as obtained from the compressive and flexural strengths tests carried out in the study.

## 1.0 INTRODUCTION

In recent time, nations across the globe are resolving environmental problems associated with wastes through conversion of waste into useful materials. Municipal solid waste “MSW” (locally called refuse) is collected and burnt in an incinerator and the by-products of the combustion process are collected. The ash obtained typically accounts for about 80% of the by-products in the municipal solid waste incinerator (MSWI) plant. The incineration of municipal solid waste has important benefits as it can reduce the volume and the mass of the waste by 85% and 75%, respectively [1]. Recently, various researches have been going on using municipal solid waste in order to add economic value to waste product. These municipal solid wastes (MSW) which is widely known as refuse refer to the stream of all solid wastes generated in a community except for industrial and agricultural waste. Generally, these include discarded durable and nonmiscellaneous inorganic debris and sludge and the ashes generated by sewage treatment plants and demolition debris including household hazardous wastes [2]. Studies have confirmed the feasibility of using municipal solid waste incinerator (MSWI) ash as a replacement for fine aggregates in concrete mixes to produce useful concrete products [3,4].

Silica fume, otherwise known as microsilica has been implemented as cementitious material in the production of concrete. This research work is to combine municipal solid waste incinerator (MSWI) ash and micro-silica to produce concrete that can be used to build infrastructural elements made with reinforced concrete. Microsilica is a powdery and very fine dust obtained from exhaust-gas of ferrosilicon and silicon smelting furnaces and used in concrete to promote the compressive strength of concrete. Microsilica is introduced into concrete mix due to its fineness and pozzolanic ability in producing a denser cement formation. During the hydration of cement, pozzolanic reaction takes place between microsilica particle and calcium hydroxide as a result, it reduces the quantity of calcium hydroxide and increases the total product of hydration. When it is rightly incorporated it reduces the permeability and increases the strength, hence produces a more durable concrete. A little amount of micro-silica can be significant in a concrete mix, a good example being in the range of 5 to 10% by weight of the cement. The limestone cement concrete with small percentage of micro-silica shall give good performance for Freeze-thaw condition, reinforcement protection, and sulphate resistance and reduced aggregate reactivity [5]. [6] observed that silica fume increases the strength of concrete by 25%. Silica fume is much cheaper than cement therefore it is very important from economic point of view. Also, [7] concluded that the addition of silica fume to concrete increases the strength more than 17% due to their pozzolanic properties and reduces the permeability of concrete. [8] observed that silica fume has been recognized as a pozzolanic admixture that is it effective in enhancing mechanical properties to a great extent. An addition of silica dust to concrete improves the durability of the concrete and also protects the embedded steel from corrosion.

However, there exists a significant dearth in research carried out investigating the combined effects of MSWI ash and microsilica on the strength performance of medium strength concrete. Therefore, this research carried out to examine the performance of medium strength concrete using municipal solid waste incinerator ash and microsilica as a partial replacement for cement. Also, to determine the economic importance, suitability for design and safety of using MSWI ash and microsilica as partial replacement for cement for medium strength concrete grades of 25 to 40.

This research study is important as it solves the negative impact associated with MSW in our environment and further reduce the amount of cement usage in concrete production which emits so much carbon content into the environment. Also, in Nigeria, waste recycling programme and good campaign management and disposal method of municipal solid waste (MSW) are ongoing but with little practical implementation, the popular method generally observed here in Nigeria is that of uncontrolled combustion of MSW but there are still adverse effects on public health and the environment. Therefore, a viable solution to the disposal problem would be the use of municipal solid waste incinerator ash (MSWI ash) with combination of micro-silica for Civil Engineering applications such as raw materials in producing concrete, concrete blocks, pavement blocks, Kerb’s stone and for other usages.

## 2.0 MATERIALS AND METHODS

The materials used for this research work include MSWI ash, Micro-silica, limestone cement, fine aggregate (sharp river sand), coarse aggregate (granite stones), superplasticizer and water.


Plate 3.1 (a) MSW before incineration Plate 3.1(b) MSW after incineration.

## 2.1 Experimental Procedures

The detailed experimental procedures for the various laboratory tests carried out in the study are presented in this section. These includes procedures for determination of physical/chemical properties of materials, properties of concrete in the fresh and hardened states

The materials (coarse aggregate and fine aggregate) were air dried and oven dried in the laboratory for 24 hours.

The sample mixes prepared went through various laboratory tests for concrete like slump test on fresh concrete for workability test and compressive strength test and flexural strength test on hardened concrete samples. The slump test was implemented in accordance to BS 1881: Part 102: 1990. Compressive strength and flexural strength tests were implemented following BS 1881: Part 108: 1983 and ASTMC 293.

Sieve analysis, bulk density and specific gravity determination test were carried out according to following standards (Sieve analysis BS 812 Part 103.1 (1985), BS 1377:1975 Standards (BS 812 Part 2: 1995) on aggregates to determine their particle size distribution, bulk density and specific gravity. The standard consistency and soundness test were carried out following BS 4550 Part 3 sections 3:5:1985. Semi quantitative techniques of chemical composition of MSWI ash was carried out following ASTM C150 standard.



## 2.2 Concrete Mix Design

The Particle Packing Method (PPM) mix was adopted in this research. The mix design method was selected as the method incorporates finer particles to reduce voids in concrete. In the course of designing a concrete mix with admirable properties such as workability, segregation resistance and less voids, maximum size of coarse aggregates is limited to 10mm. The three proportions of coarse and fine aggregates applied are as follows; 60:40, 55:45 and 52:48 for coarse and fine aggregates respectively. Hence, the computation of compacted bulk density and specific gravity of concrete aggregates were carried out. The properties of coarse and fine aggregates that produced the least amount of void volume were utilized.

The bulk density of the blended mixture was selected proportionately of (52 and 48) was weighed in the laboratory and packing density (PD) and void content (VC) were calculated using equations 2.1 and 2.2 respectively in accordance with ASTM C29 or EN 1097-3; 1998.

$$\text{Packing Density} = \sum \frac{Bulk\ \ density\ \ \times weig\,ht\ fraction}{speci\,fic\ \ gravity} \qquad 2.1$$

$$\text{Void Content} = 1 - \sum \frac{Bulk\ \ density\ \ x\ weig\,ht\ fraction}{specific\ \ gravity} \qquad 2.2$$

The total packing density (PD) obtained by mixing different sized coarse aggregate and fine aggregate is used to compute the voids content (VC) of the mixture using equation 2.3.

Voids content (VC) = 1- P.D 2.3

The paste which is made of (cementations material and water) is designed to fill the voids and provide the desired workability. Hence excess pastes of 10% were assumed to allow the coating of aggregates. The primary paste volume can be computed via the equation below

$$V_p = V_{exp} \ + V_{void} \qquad 2.4$$

Where $V_p$ = Total primary volume paste, $V_{exp}$ = Excess paste volume, $V_{void}$ = Void volume of the compacting aggregate blend in concrete.

### 2.2.1 Mix design procedure

The mix design procedure is outlined below.

i. Aggregate grading (determination of void content in compacted aggregate combination).
ii. Computation of packing density.
iii. Calculation of primary paste volume.
iv. Calculation of aggregate volume = 1 - total voids content.
v. Calculation of total solid volume of aggregate $= \sum \frac{weight\ fraction\ \ of\ aggregate}{specific\ \ gravity}$ 2.5
vi. Calculation of aggregate weight $= \frac{volume\ \ of\ aggre\ gate}{Total\ \ solid\ \ volume\ \ of\ \ aggrgate} \times weight\ fraction \times 1000$ 2.6
vii. Calculation of cement content.

Table 2.1 below captures the summary of the mix proportions of the different concrete mix prepared for the test as obtained from the implementation of the mix design computation outlined above.

**Table 2.1 Mix Proportions for Concrete Grade 25, 30, 35 and 40**

| % replacement of cement | Concrete Grades | W/C | Free water [kg/m$^3$] | Cement [kg/m$^3$] | Micro-silica [kg/m$^3$] | MSWI Ash [kg/m$^3$] | Fine Aggregate [kg/m$^3$] | Coarse Aggregate [kg/m$^3$] |
|---|---|---|---|---|---|---|---|---|
| 0 | Grade 25 | 0.5 | 208.25 | 416.5 | 0 | 0 | 696.46 | 1068.43 |
| 5 | 1:1.67:2.57 | | | 395.68 | 10.4125 | 10.4125 | | |
| 10 | | | | 374.85 | 20.825 | 20.825 | | |
| 15 | | | | 354.025 | 31.238 | 31.238 | | |
| 20 | | | | 333.2 | 41.65 | 41.65 | | |
| 25 | | | | 312.375 | 52.063 | 52.063 | | |
| 0 | Grade 30 | 0.45 | 199.64 | 443.64 | 0 | 0 | 696.46 | 1068.44 |
| 5 | 1:1.9:2.1 | | | 421.458 | 22.182 | 11.091 | | |
| 10 | | | | 399.276 | 44.364 | 22.182 | | |
| 15 | | | | 377.094 | 66.546 | 33.273 | | |
| 20 | | | | 354.912 | 88.728 | 44.364 | | |
| 25 | | | | 332.73 | 110.91 | 55.455 | | |
| 0 | Grade 35 | 0.4 | 189.82 | 474.55 | 0 | 0 | 697.03 | 1070.33 |
| 5 | 1:1.47:2.26 | | | 450.823 | 11.864 | 11.864 | | |
| 10 | | | | 427.095 | 23.728 | 23.728 | | |
| 15 | | | | 403.368 | 35.592 | 35.592 | | |
| 20 | | | | 379.64 | 47.455 | 47.455 | | |
| 25 | | | | 355.913 | 59.319 | 59.319 | | |
| 0 | Grade 40 | 0.35 | 178.54 | 510.1 | 0 | 0 | 704.36 | 1068.42 |
| 5 | 1:1.37:2.10 | | | 484.595 | 12.753 | 12.753 | | |
| 10 | | | | 459.09 | 25.505 | 25.505 | | |
| 15 | | | | 433.585 | 38.258 | 38.258 | | |
| 20 | | | | 408.08 | 51.01 | 51.01 | | |

| | | | |
|---|---|---|---|
| 25 | 382.575 | 63.763 | 63.763 |

A control mix having 100% cement was prepared and the cement was replaced in varying proportions of 5%, 10%, 15%, 20% and 25% with Micro-silica + MSWI Ash for each water binder ratio. The concrete was mixed in the laboratory, slump test was carried out on fresh concrete and total numbers of 216 cubes of size 150 x 150 x 150mm concrete cubes and 48 beams of size 500 x 100 x 100mm were cast, cured for 7, 21, 28 days and various tests were carried out to determine the compressive and flexural strength of concrete.

## 2.3 Compressive Strength Test (BS 1881: Part 108: 1983)

The compressive strength of concrete were obtained after the cubes (150mm x 150mm x 150mm) had achieved the required age in accordance with BS 1881:Part108:1983 and BS EN12390-3-2009 procedures. The load was applied steadily till failure occurred and highest load reached was recorded.
The compressive strength is calculated from the equation 2.7 below:

$$f_c = \frac{faiure\ \ load}{cross\ \ sectional\ \ area} = \frac{P}{A} \qquad 2.7$$

Where: $f_c$ = compressive strength, P = failure load, A = cross sectional area of cube.

## 2.4 Flexural Strength Test

Flexural Strength test carried out on specimen of beam size 100mm x 100mm x 500mm by using three (3) points loading universal compression machine. The beams were tested at the end of 28 days curing age at a constant strain until they failed due to bending stress. Flexural load was determined without considering the deflection of the beam specimen. Flexural strength is computed using equation 2.8 below.

$$F_s = \frac{3FL}{2WD^2} \qquad 2.8$$

Where $F_s$ = Flexural strength, F = failure load, L = length of beam, W = Width of beam, D = Depth of beam.

## 3.0 RESULTS AND DISCUSSION

This section presents the results and discussion of the results obtained from experimental tests carried out on the physical and mechanical properties of the concrete specimens in the laboratory. The results are analyzed with the help of graphs and tables and are discussed accordingly.

## 3.1 Chemical Composition of MSWI Ash

The chemical constituents or composition of municipal solid waste incinerator ashes was determined by semi-quantitative technique at an accuracy level as high as 15-20% specification according to ASTM C150 and the result is summarized in Table 3.1. The result of this analysis shows that MSWI Ashes contains hydraulic oxide of (17.3% $SiO_2$, 4.67% $Al_2O_3$, and 4.13% $Fe_2O_3$) in lower quantities which are acceptable for effective hydration reactions.

**Table 3.1: Chemical Composition of MSWI Ash**

| Constituent | MSWI Ash (mass %) |
|---|---|
| Silicon oxide ($SiO_2$) | 17.3 – 21.4 |
| Calcium oxide (CaO) | 19.2 – 27.5 |
| Iron oxide ($Fe_2O_3$) | 4.13 – 10.3 |
| Magnesium oxide (MgO) | 6.04 – 12.4 |
| Potassium oxide ($K_2O$) | 0.81 – 1.20 |
| Aluminium oxide ($Al_2O_3$) | 4.67 – 5.48 |
| Sodium oxide ($Na_2O$) | 3.6 – 4.38 |
| Sulphate oxide ($SO_3$) | 2.23 – 3.55 |
| Zinc oxide (ZnO) | 1.69 – 4.21 |

## 3.2 Particle Size Distribution of Materials

In this study, sieve analysis was carried out on the MSWI ash and the aggregates and the particle size distribution obtained are presented in Figure 3.1 to Figure 3.3 shown below. From the figures, the size distributions of the materials are within acceptable range. From these results the coefficient of uniformity, coefficient of concavity Cc for both fine and coarse aggregates were computed to be 3.4286 and 0.7202 for fine aggregates and 1.6177 and 1.1071 for coarse aggregates. These results presented in Figure 3.1 to Figure 3.3, below shows that the materials are uniformly graded according to BS812 part 3; 1985. Hence fine and coarse aggregates exhibit good coefficient of uniformity and of concavity and satisfied ASHTTO classification of Cu>4 and 1<Cc<3 for the aggregates.

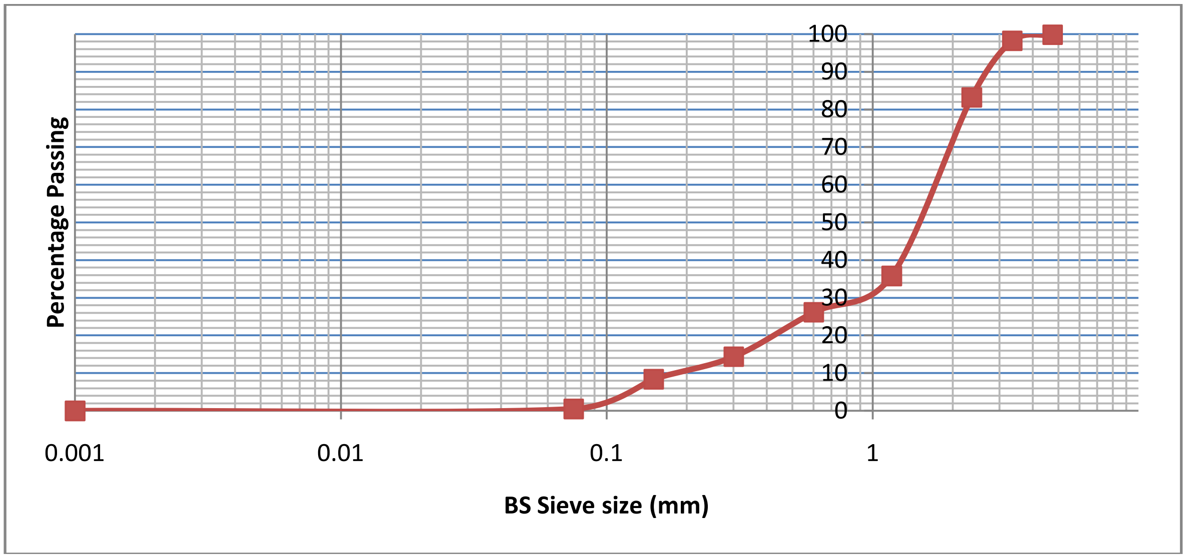


Figure 3.1 Particle Size Distribution of MSWI Ash

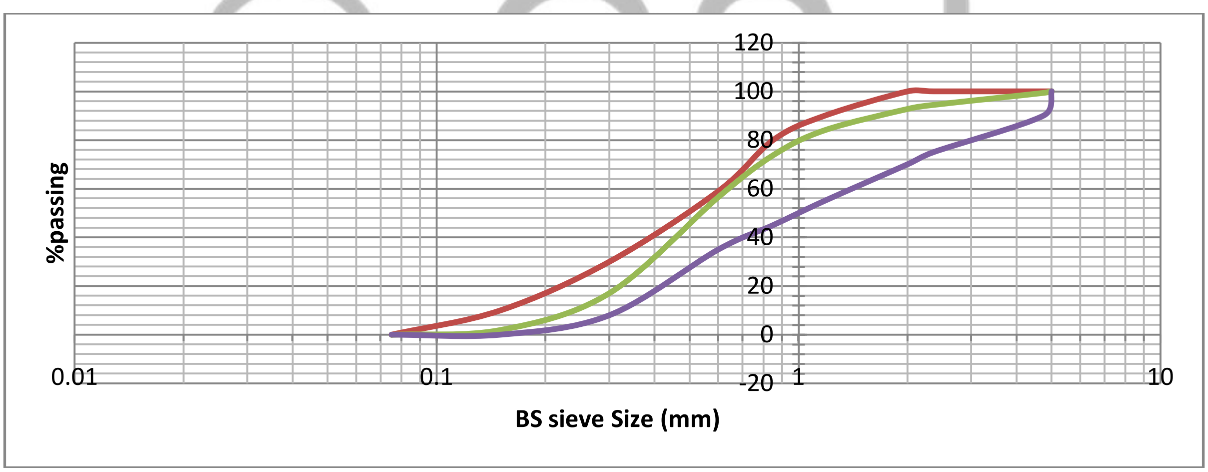


Figure 3.2 Particle Size Distribution for Fine Aggregates in Envelop

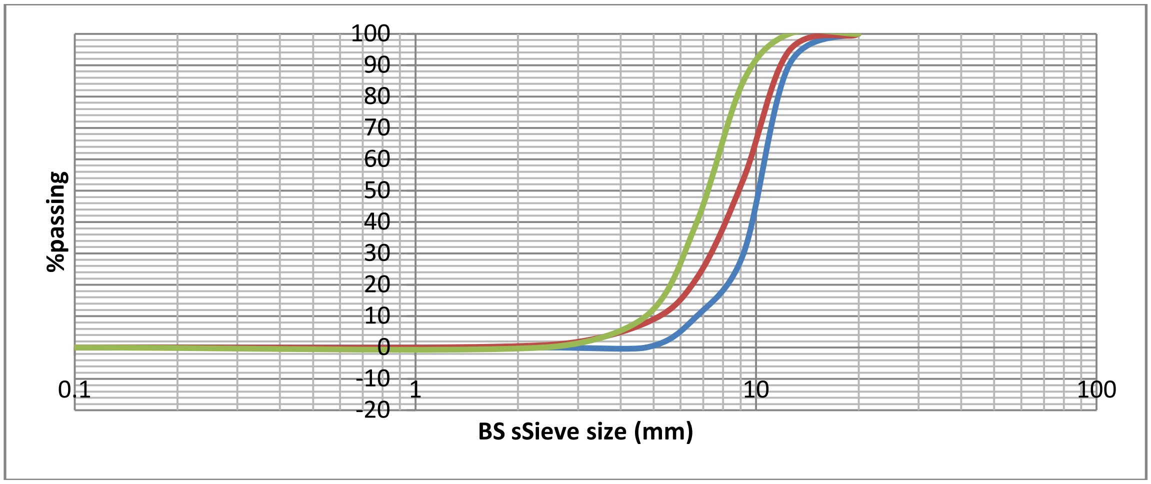


Figure 3.3 Particle Size Distribution for Coarse Aggregate in Envelope.

### 3.3 Workability and Compacting Factor Result

The workability measure and the compacting Factor tests results are presented in Table 3.2 below. It shows that the slump values range from 44 to 90. The compacting factor progresses from 0.81 to 0.91 as the percentage replacement of MSWI Ash + Micro-silica increases from 0 to 25 respectively for all the grades of concrete used in this study and their respective workability begins to decrease with respect to percentage increase of MSWI Ash + Micro-silica. However, the results satisfied the conditions in BS1881 Part 102:1990. The slump values are plotted and presented in Figure 3.4.

**Table 3.2: Slump and Compacting Factor Result**

| Concrete Grade | % Replacement of Micro Silica + MSWI Ash | Slump (mm) | Compacting Factor |
|---|---|---|---|
| G25 | 0 | 85 | 0.89 |
| | 10 | 75 | 0.88 |
| | 15 | 63 | 0.83 |
| | 20 | 52 | 0.85 |
| | 25 | 45 | 0.91 |
| G30 | 0 | 80 | 0.82 |
| | 10 | 73 | 0.83 |
| | 15 | 62 | 0.85 |
| | 20 | 55 | 0.81 |
| | 25 | 44 | 0.88 |
| G35 | 0 | 90 | 0.88 |
| | 10 | 85 | 0.87 |
| | 15 | 74 | 0.85 |
| | 20 | 65 | 0.82 |
| | 25 | 55 | 0.83 |
| G40 | 0 | 86 | 0.84 |
| | 10 | 74 | 0.82 |
| | 15 | 63 | 0.81 |
| | 20 | 55 | 0.85 |
| | 25 | 45 | 0.87 |

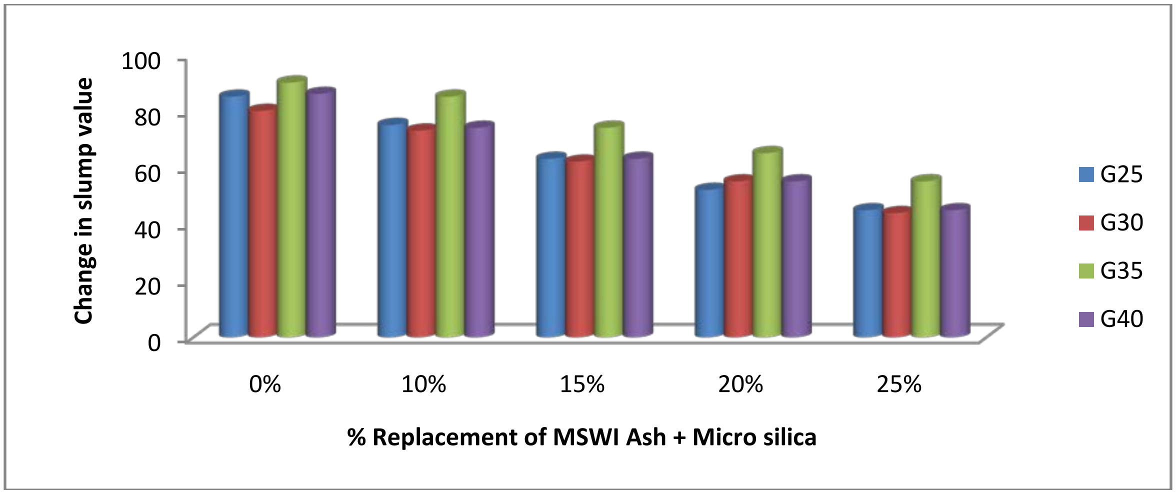


**Figure 3.4 Slump value versus % replacement of MSWI Ash +Micro-silica**

## 3.4 Compressive Strength

The results of the compressive strength tests carried out on all grades of concrete blended with MSWI ash and the control samples are presented in Table 3.3 below. Also, the results are plotted against percentage replacement of cement and presented in Figures 3.5 to 3.8.

**Table 3.3: Experimental Values of Compressive Strength for Various Duration of Wet Curing of Concrete Made with MSWI Ash + Microsilica**

| Grade | W/C | Percentage replacement of MSWI Ash + Microsilica | 7 Days Compressive Strength (N/mm2) | 21 Days Compressive Strength (N/mm2) | 28 Days Compressive Strength (N/mm2) |
|---|---|---|---|---|---|
| G25 | 0.50 | 0 | 34.70 | 38.67 | 46.14 |
| | | 5 | 34.0 | 37.04 | 45.15 |
| 1:1.67:2.57 | | 10 | 35.85 | 42.97 | 47.17 |
| | | 15 | 30.07 | 38.29 | 41.64 |
| | | 20 | 27.93 | 33.70 | 38.81 |
| | | 25 | 24.59 | 30.15 | 33.85 |
| G30 | 0.45 | 0 | 32.63 | 37.03 | 42.07 |
| | | 5 | 32.11 | 33.63 | 39.11 |
| 1:1.57:2.42 | | 10 | 33.63 | 39.11 | 45.48 |
| | | 15 | 30.96 | 36.44 | 41.48 |
| | | 20 | 29.91 | 33.63 | 38.97 |
| | | 25 | 28.44 | 30.81 | 38.74 |
| G35 | 0.40 | 0 | 35.48 | 37.92 | 47.76 |
| | | 5 | 36.04 | 36.12 | 46.74 |
| 1:1.47:2.26 | | 10 | 38.36 | 40.30 | 50.30 |
| | | 15 | 31.85 | 35.85 | 43.44 |
| | | 20 | 27.09 | 33.44 | 41.33 |
| | | 25 | 25.85 | 29.33 | 35.41 |
| G40 | 0.35 | 0 | 41.03 | 43.59 | 52.77 |

| | | | | |
|---|---|---|---|---|
| | 5 | 40.15 | 43.34 | 50.34 |
| 1:1.37:2.10 | 10 | 44.84 | 46.67 | 60.52 |
| | 15 | 32.59 | 37.63 | 44.74 |
| | 20 | 31.07 | 35.57 | 42.66 |
| | 25 | 26.96 | 32.89 | 37.04 |

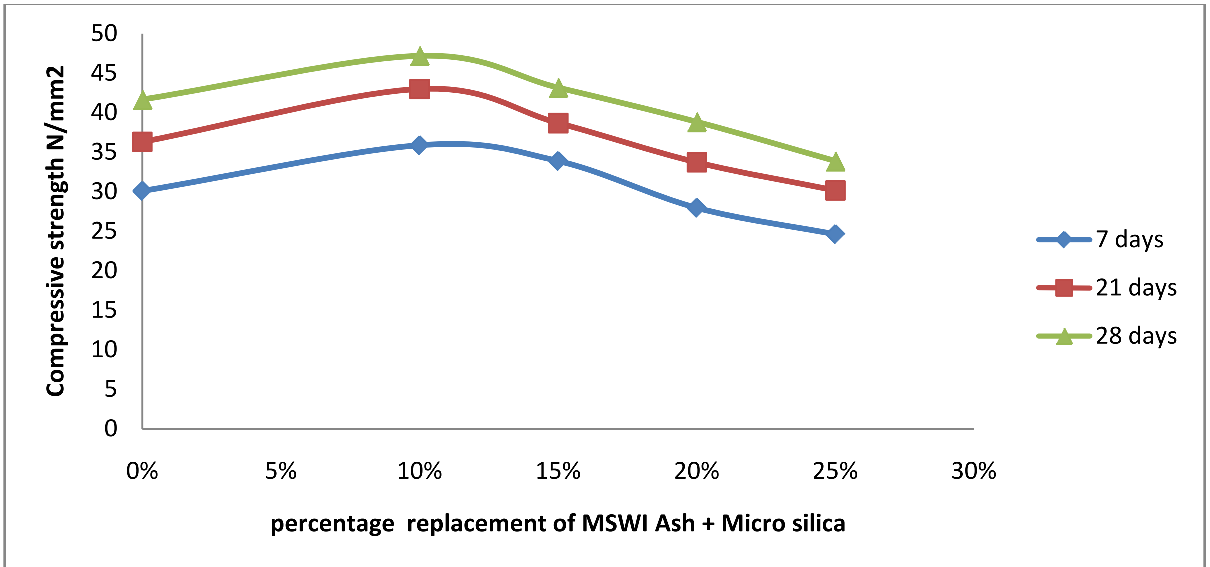


**Figure 3.5 Variation of Compressive Strength of Concrete G25 with % replacement of MSWI Ash and micro-silica**

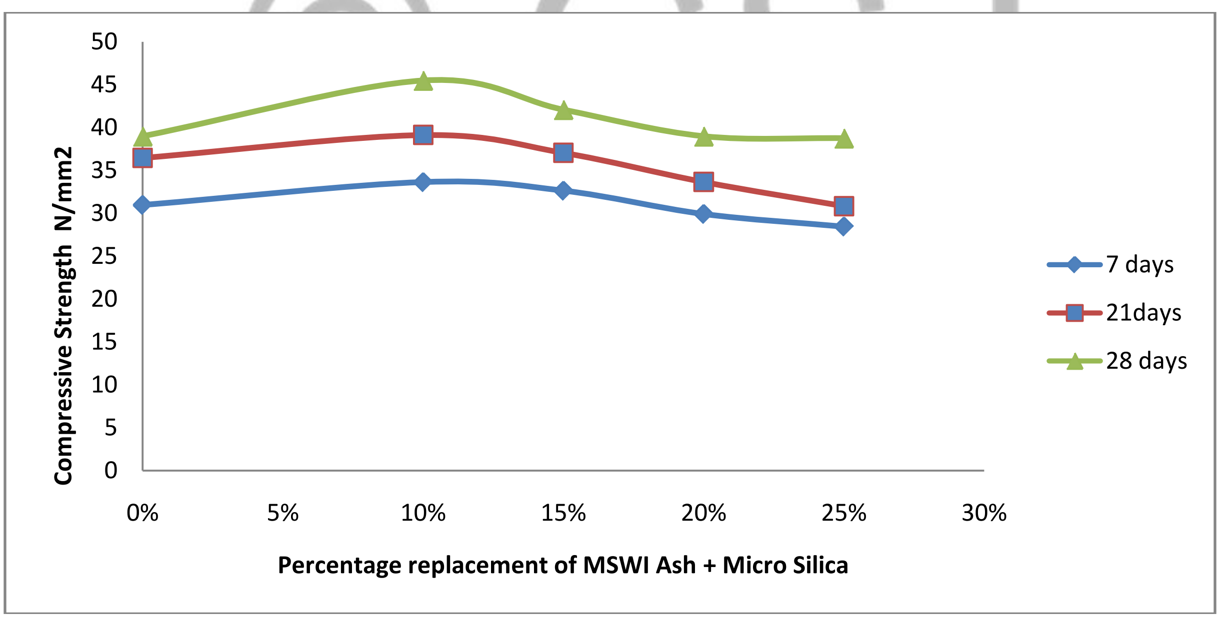


**Figure 3.6: Variation in Compressive Strength of Concrete G30 with % replacement of MSWI Ash and micro-silica**

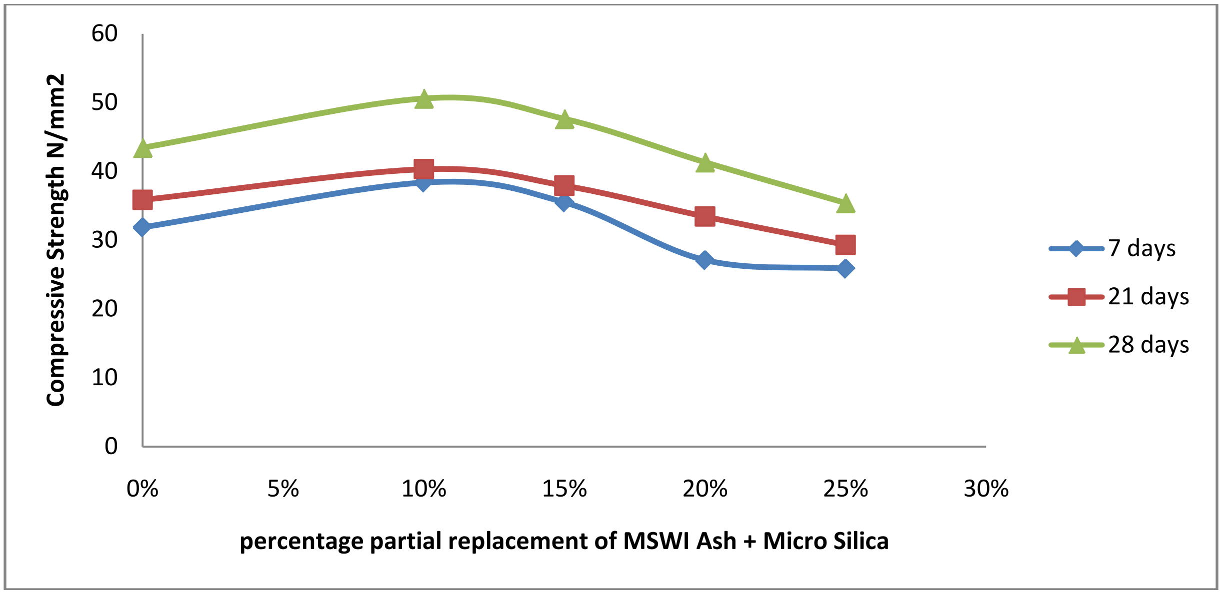


**Figure 3.7: Variation in Compressive Strength of Concrete G35 with % replacement of MSWI Ash and micro-silica**

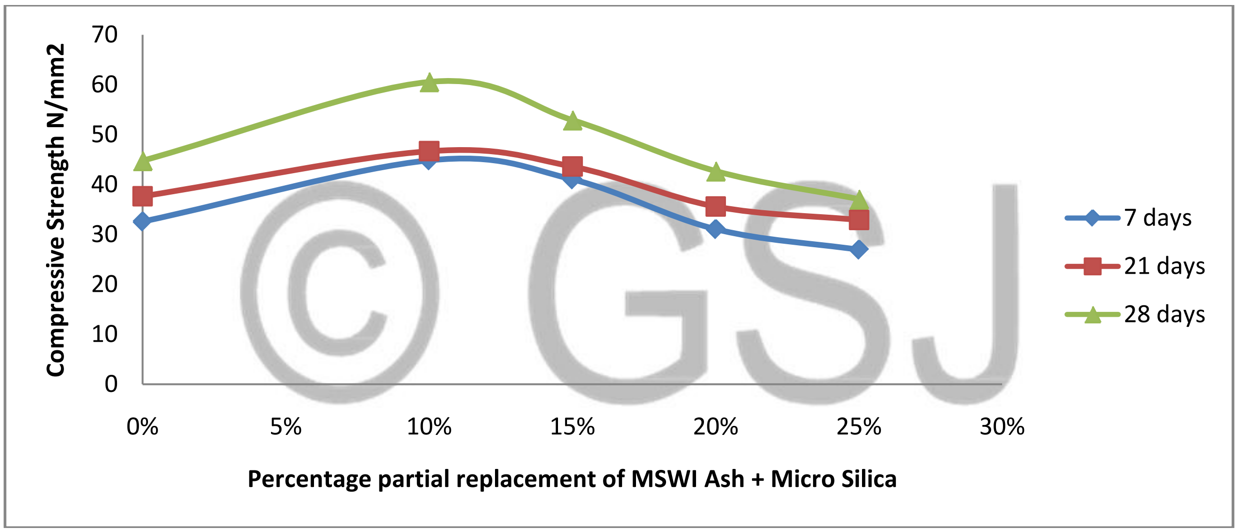


**Figure 3.8 Variation in Compressive Strength of Concrete G40 with % replacement of MSWI Ash and micro-silica**

From Figures 3.5 to 3.8 and Summary Table 3.3 above it is observed that the compressive strength begins to increase with increase in replacement of MSWI Ash and Micro-silica content from 5 to 10% then start dropping gradually in strength due to increase of $SiO_2$, $Al_2O$, and $Fe_2O_3$ in MSWI Ash +Micro-silica. Based on the result of this study, 5% and 10% partial replacement of MSWI Ash and Micro-silica would be recommended for medium strength concrete production in accordance to BS 8110; 1997.

## 3.5 Flexural Strength

The result of the flexural strength of the concrete as obtained from the flexural strength test implemented after 28 days of wet curing are presented in Table 3.4 below. Also presented in Figure 4.9 is the plot of the flexural strength values against the replacement values of cement. From the results, it is observed that the flexural strength of the concrete samples increase as the percentage replacement increases up to 10% and begins to drop upon increment in the replacement levels for all grades of concrete. However, at 15% replacement levels, the flexural strengths were greater than those of the control samples. Optimum increment in flexural strength were however, observed for cement replacement level of 10%.

**Table 3.4: Flexural Strength Results of Tested Samples**

| % Replacement for G25 to G40 | Water Cement Ratio | Concrete Grades | Average Flexural Strength [N/mm2] |
|---|---|---|---|
| 0 | 0.5 | G25 | 5.25 |
| 5 | | | 7.5 |
| 10 | | | 8.49 |
| 15 | | | 7.5 |
| 20 | | | 5.25 |
| 25 | | | 3.25 |
| 0 | 0.45 | G30 | 7.5 |
| 5 | | | 7.27 |
| 10 | | | 9 |
| 15 | | | 8 |
| 20 | | | 7.5 |
| 25 | | | 5.25 |
| 0 | 0.40 | G35 | 7.6 |
| 5 | | | 8.49 |
| 10 | | | 8 |
| 15 | | | 9.25 |
| 20 | | | 7.25 |
| 25 | | | 7.5 |
| 0 | 0.35 | G40 | 9 |
| 5 | | | 7.5 |
| 10 | | | 10.89 |
| 15 | | | 8.25 |
| 20 | | | 7.5 |
| 25 | | | 6.67 |

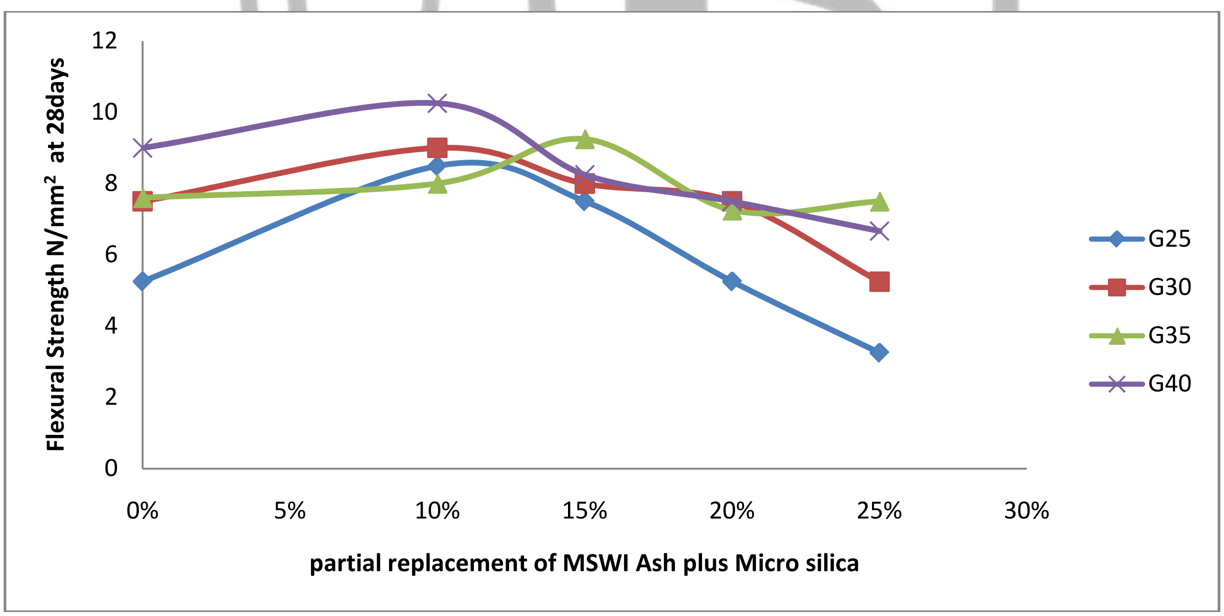


Figure 3.9 Flexural Strength Versus % Replacement of MSWI Ash + Micro-silica

## Conclusion

Compressive and flexural strength of concrete mixed with MSWI Ash and microsilica as partial replacement of cement have been examined in this study. From the results analysis and discussion of the results in this work the following conclusions are drawn.

i. The mass and volume of the municipal solid waste (MSW) was reduced to about 85% and 75%, respectively after it has been incinerated in the Kiln of Civil Engineering Department of Rivers State University. The results from by semi-quantitative technique at an accuracy level as high as 15-20% shows that MSWI Ashes contains hydraulic oxide of 17.3 % $SiO_2$, 4.67 % $Al_2O_3$ and 4.13% $Fe_2O_3$ in lower quantities.

ii. The workability test results show that the workability reduces as the percentage replacement of the MSWI Ash plus Micro-silica increases.

iii. The compressive strength test results show that, the compressive strength improves when MSWI Ash plus Micro silica are replaced in less or equal to 10% of cement in comparison to the control mixes (0% cement partial replacement) but compressive strength drops gradually when MSWI Ash plus Micro silica are placed in more proportion than 10% because of the hydraulic oxide ($SiO_2$, $Al_2O$, and $FeO_3$) contained in MSWI Ash.

iv. The flexural test results shown at 10% peak point an average flexural strength of 8.4N/mm$^2$, 9N/mm$^2$, 9.25N/mm$^2$ and 10.89 N/mm$^2$ for concrete Grades G25, G30, G35 and G40 respectively at partial replacement levels of 5, 10, 15, 20 and 25% of MSWI ash + Micro-silica for cement.

From the findings of this research work 5 to 10% of partial replacement of MSWI Ash combined with Micro-silica are recommended to be utilized for concrete works of grade G25 to G40 of the concrete used in this study. This is premised on the compressive strengths of 42.07N/mm$^2$, 47.17N/mm$^2$, 50.30N/mm$^2$ and 60.52N/mm$^2$ at 28days respectively and flexural strength of 8.4N/mm$^2$, 9N/mm$^2$, 9.25N/mm$^2$ and 10.89 N/mm$^2$ respectively obtained for the different grades of concrete. Also, further studies are recommended to be carried out in this research area to find out durability and splitting Tensile strength of MSWI ash and Micro-silica concrete.

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