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# Effects of Slag Contents on Strength Properties of Concrete Grade 25 and 30

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**ABSTRACT**: Emphasis is on the avoidance of waste generation, recycling and reuse of waste, and minimising the adverse impact of disposal on the environment. Therefore, there is need for utilization of this by-product (steel slag) in concrete production in Nigeria as the as the price of natural aggregates (fine and coarse combination) is increasing and also to forestall environmental risk posed by way of steel slag disposal. This study assessed Effects of Slag contents in concrete grade 25 and 30. A total number of One Hundred and Twenty (120) concrete cubes of sizes 150 by 150 by 150mm, and 120 cylindrical concrete samples of sizes 150 by 300 mm were produced. The concrete specimens were cured by immersion in water for maximum of 28 days in order to determine the densities, compressive and split tensile strengths of the concrete in hardened state. The 28 days compressive strengths shows that 50, 75 and 100% NSS-concrete of grade 25 meets the designed target strength of 31.56 N/mm$^2$ while control and 25% NSS-concrete meets the characteristics strengths of 25N/mm$^2$. All slag contents in grade 30 meets the designed target strength of 31.56 N/mm$^2$ and 36.56 N/mm$^2$. The split tensile strengths of the concrete grades increased from 0 to 50% NSS. Based on the findings from this study, NSS could be used up to 100% for concrete production.

**KEYWORDS:**Concrete grade,Compressivestrength, Slag contents, Split tensilestrength.

## I. INTRODUCTION

Concrete is one of the most widely used construction material in the universe. It is a material formed by cement, fine aggregate, coarse aggregate (crushed or uncrushed stone), admixtures (if required) and water [1-3]. The aggregates commonly account for about 75% of the concrete extent and play an enormous function in one of a kind concrete properties. Traditional concrete consists of combinations of sand and gravel, limestone or granite in numerous shapes and sizes as coarse mixture. There's growing hobby in the use of waste materials as an opportunity to aggregate replacements and numerous studies has been made on the use of many exclusive substances as aggregate replacements [4, 5].

Slag is a by-product which is generated during manufacturing of pig iron and steel. The production of slag is by action of various fluxes upon gangue materials within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting company [6]. While producing steel in a manufacturing steel plant, two to four tonnes of wastes (consisting of solid, liquid and gasoline) are generated for each tonne of metal produced. Today, emphasis is on the avoidance of waste generation, recycling and reuse of waste, and minimising the adverse impact of disposal on the environment [7]. Therefore, there is need for the utilization of this by-product (steel slag) in concrete production in Nigeria as the as the price of natural aggregates (fine and coarse combination) is turning into higher and to forestall environmental risk posed by way of steel slag disposal around metal business enterprise.

Gokul et al., [8] examined the use of mild steel slag as a substitute to granite in concrete. It was concluded that compressive strength and the alternative tests confirmed that mild steel slag is advanced to normal aggregates. The 28th day result indicated increment in compressive strength of the concrete from 0% to 60% steel slag, but further reduced at 80% steel slag. However, the strength increased at 100% slag.

Warudkar and Nigade [9] studied the behaviour of replaced crushed stone with steel slag in concrete. The findings concluded that the strength of concrete increased up to 75% steel slag but further decreased after 75%. Hence, the compressive strength witnessed 14% increment with 75% steel slag. The development in strength could be as a result of size, shape and surface texture of steel slag that gives good bonding between the cement paste and particles.

Tran et al., [10] replaced crushed stone with 100% steel slag in high strength concrete with varying grades of concrete. The outcome indicated that the strength of the concrete with steel slag aggregate was similar to that of traditional concrete.

Sharma et al., [11] examined the performance of steel slag in production of concrete. From the outcome, it was found that as the percentage of steel slag increased from 0% to 50%, the strength of concrete increased but further decreased after 50% slag. This is an indication that the optimum substitute was gained at 50% steel slag. Ravikumaret al., [4] also examined the replacement ofcrushed stone with steel slag in concrete.In the study, four concrete of grades and four water cement ratios (0.55w/c, 0.45w/c, 0.37w/c and 0.32w/c) were considered. The end result discovered an increment in compressive strength thereby concluding that the optimum use of steel slagin production of concrete grade 20 $N/mm^2$, 30$N/mm^2$, 40$N/mm^2$ and 50$N/mm^2$ is 60%.

Anifowoseet al., [12] compared compressive strength of Ikirun and Osogbo slag on concrete grade 20. The study concluded that Nigerian slag can successfully be used as a partial replacement of coarse aggregate (crushed stone) in production of concrete grade 20 (structural concrete).

Adedokunet al., [13]opined that slump and compacting factor values decreased the workability of concrete withincreased in steel slag contents, while increment of water cement ratio improved the functionality of concrete. The compressive strength of the concrete increased up to 60 % substitute of granite with steel slag, due higher specific gravity of the slag contrast to that of granite.

Khafagaet al., [14] opined that the optimum steel slag aggregates as substitute of crushed stone to achieve better split tensile strength was obtained at 66.67% of steel slag. Qurisheeet al., [15] additionally concluded that concrete with 40% alternative of crushed stone with steel slag can also provide extra tensile strength. However, the outcome of the experiment performed by Kothai and Malathy [16] indicated that split tensile strength for steel slag concrete was just like traditional concrete.

Sharma et al., [11] concluded that the most appropriate splitting tensile strength was observed at 50% steel slag via weight of crushed stone. Ravikumaret al., [4] observed that split tensile strength of steel slag concrete with optimum replacements in concrete grade 20 $N/mm^2$,30 $N/mm^2$, 40$N/mm^2$and50$N/mm^2$ is 60% steel slag. This trend is likewise just like outcome of Subramani and Ravi [17].

Adedokunet al., [18] investigated the sustainability of Ife Steel Slag (INS) on the split and flexural strengths of concrete.Adoption of 40% INS would be sustainable for mix ratio 1:2:4 concrete productions thereby reducing environmental pollution.

Anifowoseet al., [5] evaluated the influence of Water Cement Ratios on the Optimum use of Prism Nigerian Slag (PNS) in Concrete. The study concluded that 60% PNS would produce a concrete of high compressive and split tensile strengths than traditional concrete for mix ratio 1:2:4.

## II. MATERIALS AND METHODS

### MATERIALS

Dangote cement brands of 42.5R which conforms to NIS 444-1 [19]; Water that conforms to NIS 554 [20]; river sand that pass through sieve 5.0 mm and crushed stone of 12.5 mm maximum size were used for production of concrete specimens. Steel slags were collected from steel slag from Ife Iron and Steel Nig. Ltd., Ife, Nigeria. The slags were broken and allowed to pass through British Standard sieve 13.2 mm and retained on sieve 5.0 mm. the physical properties of the materials used are as presented in Table 1.

**Table 1: Physical properties of aggregates used**

| Parameters | Materials | | |
|---|---|---|---|
| | Fine Aggregate | Granite | Slag |
| Fineness modulus | 2.8 | | |
| water absorption | | 0.6 | 2.4 |
| specific gravity | 2.66 | 2.68 | 2.76 |
| Aggregate Impact Value | | 12.5 | 7.3 |
| Aggregate Crushing Value | | 24.6 | 23.0 |
| Los Angeles Abrasion Value | | 19.7 | 23.5 |

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## METHODS

This research was limited to assessment of Nigerian Steel Slag (NSS) as substitute of coarse aggregate (crushed stone) in concrete grade 25 and 30 production. The contents of steel slag used to replace granite were 25, 50, 75 and 100%. Concrete mix proportioning for the concrete grades (25 and 30) was done in accordance with COREN Mix Design Manual [21]. The mix design was used to achieve characteristics strengths of 25N/mm$^2$ and target strength of 31.56 N/mm$^2$ for concrete grade 25 while characteristics strengths of 30N/mm$^2$ and target strength of 36.56 N/mm$^2$ was designed for concrete grade 30. A total number of One Hundred and Twenty (120) concrete cubes of sizes 150 by 150 by 150mm, and 120 cylindrical concrete samples of sizes 150 by 300 mm were produced. The concrete specimens were cured by immersion in water for 7, 14, 21 and 28 days. At the end of each curing ages, the densities of the cubes were determined while compressive and split tensile strengths were determined on the concrete cubes and cylindrical concrete, respectively.

## III. RESULTS AND DISCUSSION

### SLUMP

The results (Figures 1 and 2) shows that, as the slag contents in the fresh concrete mix increased, the fresh concrete became less workable. The reduction in slump height is witnessed by fresh concrete grade 25 and concrete grade 30. However, slump height of grade 30 is lower to that of grade 25. The behaviour in slump height reduction corresponds to the previous findings byQurisheeet al., [15],Anifowoseet al., [22], Anifowoseet al., [23], Anifowoseet al., [12], Adedokunet al., [18], Anifowoseet al., [5] and Adedokunet al., [13]. This was as a result of the water absorption capacity and surface texture of the NSS.

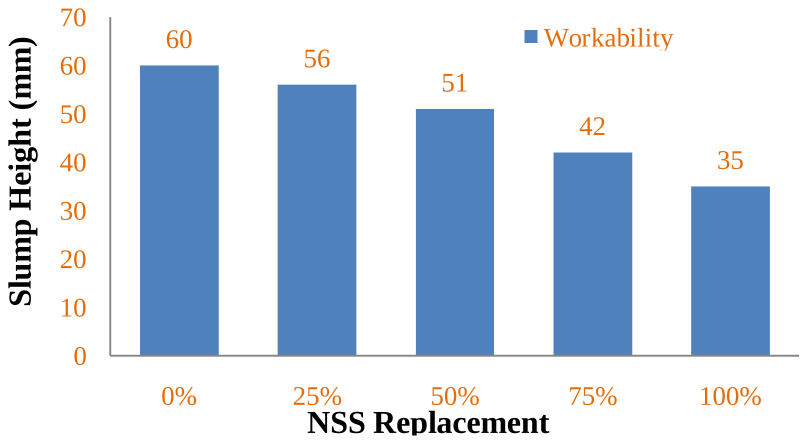


**Figure 1: Slump of Concrete Grade 25**

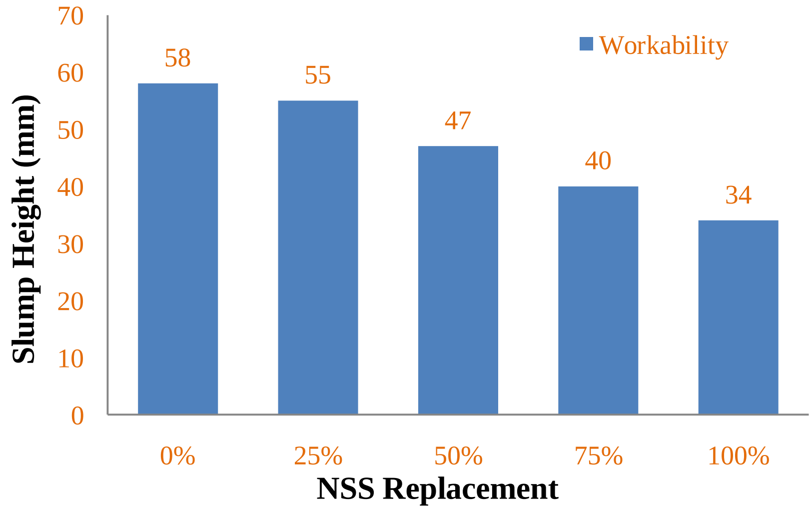


**Figure 2: Slump of Concrete Grade 30**

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**DENSITY**

The density values for concrete grade 25 (Figure 3) ranged from 2352 - 2336 kg/m$^3$, 2330 - 2349 kg/m$^3$, 2480 - 2491 kg/m$^3$, and 2486 - 2491 kg/m$^3$, for 7, 14, 21 and 28 days respectively. While density values for concrete grade 30 (Figure 4) ranged from 2342 - 2355 kg/m$^3$, 2354 - 2380 kg/m$^3$, 2485 - 2496 kg/m$^3$, and 2490 - 2501 kg/m$^3$, for 7, 14, 21 and 28 days respectively. At seven days (for concrete grade 25), as the NSS percentages increased from 0% to 50% NSS, the density values also increased but further reduced after 50% NSS. Hence, the 14 days curing age witnessed reduction in density value after 25% NSS while 21 and 28 days density value increased with increase in slag contents. The grade 30 concrete results also show similar trend in terms of curing age and slag contents substitute to that of concrete grade 25. Hence, the density values of concrete grade 30 are higher than the values of concrete grade 25. The nature of increment in concrete density value with respect to curing age corresponds to the previous study by Raheem et al., [24], Odeyemiet al., [25], Anifowoseet al., [22] and Anifowoseet al., [12]. Hence, the density of both concrete grade fell within 2000 to 2600 kg/m$^3$ for normal weight concrete [26, 5].

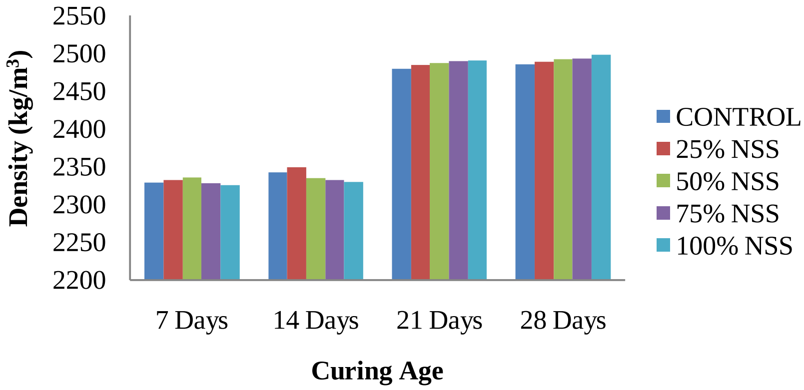


**Figure 3: Density of Concrete Grade 25**

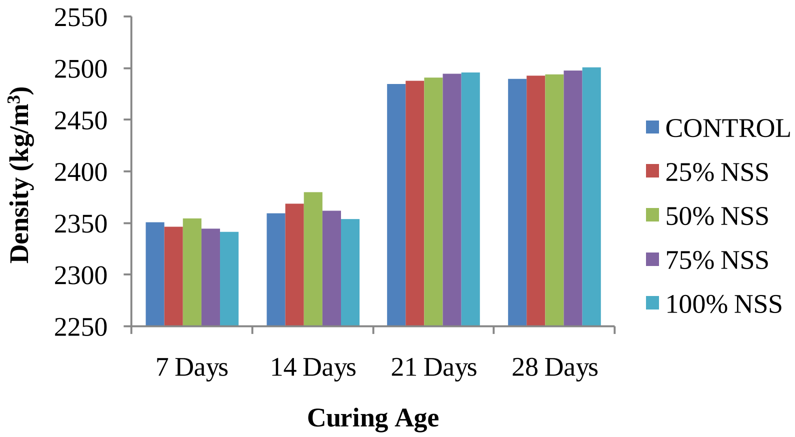


**Figure 4: Density of Concrete Grade 30**

**COMPRESSIVE STRENGTH**

The strengths of concrete grade 25 (Figure 5) ranged from 17.67 – 18.31 N/mm$^2$, 18.73 - 19.21 N/mm$^2$, 22.31 – 25.24 N/mm$^2$, and 28.07 – 31.82 N/mm$^2$, for 7, 14, 21 and 28 days respectively. While strengths of concrete grade 30 (Figure 6) ranged from 21.61 – 22.18 N/mm$^2$, 23.03 – 23.61 N/mm$^2$, 27.15 – 30.31 N/mm$^2$, and 34.00 – 37.31 N/mm$^2$ for 7, 14, 21 and 28 days respectively. At 7 and 14 days (for concrete grade 25), as the NSS percentages increased from 0% to 50% NSS, the strengths also increased but declined after 50% NSS. Hence, 21 and 28 dayscompressive strengths increased with increase in NSS contents.

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Concrete grade 30 results shows similar trends to concrete grade 25 in terms of curing age and NSS contents. Hence, compressive strengths of concrete 25 and 30 increased with increase in curing age. This corresponds to previous findings by Ravikumaret al., [4], Anifowoseet al., [22], Adedokunet al., [6], Anifowoseet al., [12] and Anifowoseet al., [5].
The 28 days compressive strengths indicated that 50, 75 and 100% NSS-concrete of grade 25 meets the designed target strength of 31.56 N/mm$^2$ while control and 25% NSS-concrete meets the characteristics strengths of 25N/mm$^2$. Nonetheless, all granite replacements (25, 50, 75 and 100% NSS) in grade 30 meets the designed target strength of 36.56 N/mm$^2$. Hence, the intending use and economical factor of concrete will determine the percentage of NSS to be used as all percentage meets the characteristics strengths of grade 25 and 30.

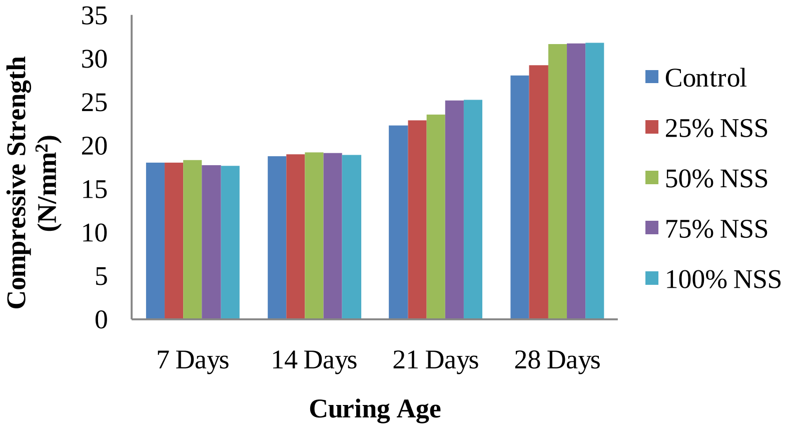


**Figure 5: Compressive Strength of Concrete Grade 25**

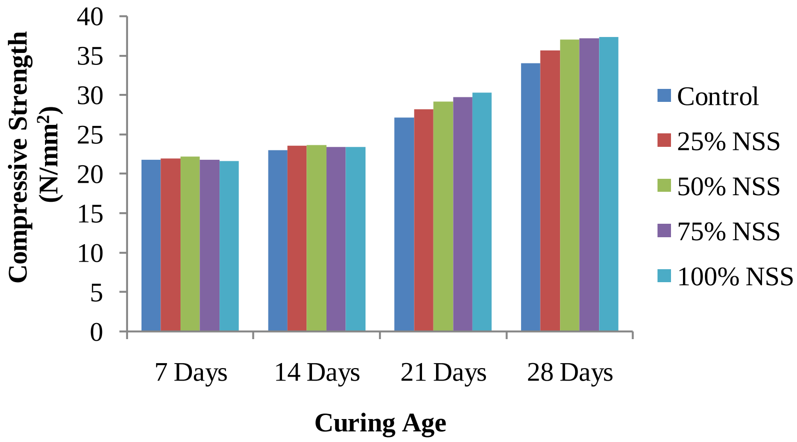


**Figure 6: Compressive Strength of Concrete Grade 30**

**SPLIT TENSILE STRENGTH**

The split tensile strength of concrete grade 25 ranged from 2.41 – 2.74 N/mm$^2$, 2.63 – 3.12 N/mm$^2$, 3.57 – 4.28 N/mm$^2$, and 4.15 – 5.11 N/mm$^2$, for 7, 14, 21 and 28 days respectively (Figure 7). While split tensile strengths of concrete grade 30 ranged from 2.52 – 2.83 N/mm$^2$, 2.81 – 3.98 N/mm$^2$, 4.45 – 5.17 N/mm$^2$, and 5.11 – 6.13 N/mm$^2$ for 7, 14, 21 and 28 days respectively (Figure 8). The split tensile strength of the concrete increased from 0 to 50% NSS. Hence, the strengths later decreased after 50% NSS for 7, 14, 21 and 28 days. The split tensile strength of concrete grade 30 results shows similar trends to concrete grade 25 in terms of NSS contents and curing age. Hence, compressive strengths of concrete 25 and 30 increased with increase in curing age. This trends corresponds to previous findings by Subramani and Ravi [17], Thangaselvi [27], Qurisheeet al., [15], Ravikumaret al., [4], Adedokunet al., [18] and Anifowoseet al., [5].

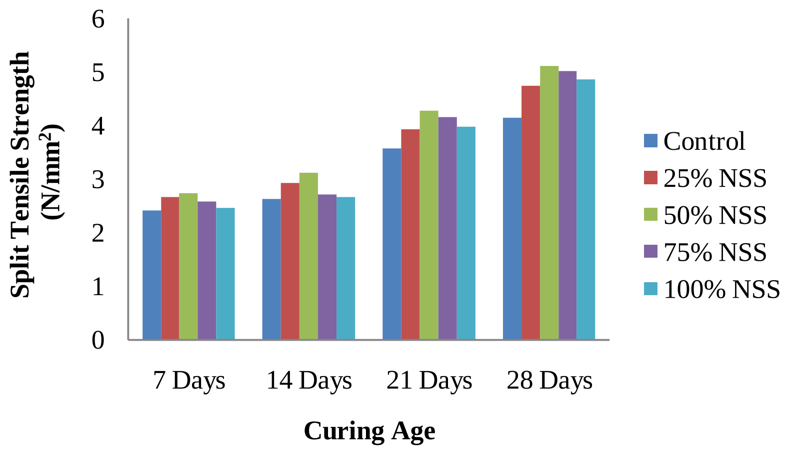


**Figure 7: NSS-Splitting Strength of Concrete Grade 25**

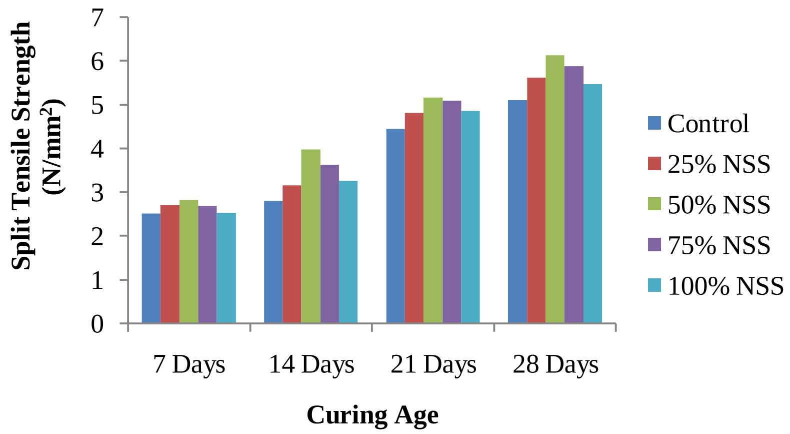


**Figure 8: NSS-Splitting Strength of Concrete Grade 30**

## IV. CONCLUSION

Slag contents for production of concrete grade 25 and 30 was assessed. The fresh concrete of grade 25 and 30 mix witnessed reduction in slump height due to increase in slag contents. The 28 days compressive strengths shows that 50, 75 and 100% NSS-concrete of grade 25 meets the designed target strength of 31.56 N/mm$^2$ while control and 25% NSS-concrete meets the characteristics strengths of 25N/mm$^2$. Nonetheless, all granite replacements (25, 50, 75 and 100% NSS) in grade 30 meets the designed target strength of 36.56 N/mm$^2$. The split tensile strengths of the concrete grades increased from 0 to 50% NSS. Hence, the strengths later decreased after 50% NSS for 7, 14, 21 and 28 days. NSS could be used up to 100% for concrete production based on the outputs of the compressive strengths. Thus, the intending use and economical factor of concrete will determine the percentage of NSS to be used as all percentage meets the characteristics strengths of grade 25 and 30.

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