# EVALUATION OF CONCRETE'S PROPERTIES USING DIFFERENT COARSE AGGREGATE SIZES

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## ABSTRACT

This study reported on the evaluation of some concrete's properties using different coarse aggregate sizes. This has become imperative because coarse aggregate contains the largest portion of materials used in concrete and determining its optimum performance in concrete can be helpful for professionals in the construction industry. An experimental research design was adopted, which produced thirty (30) concrete specimens, made up of eighteen (18) cube mould of 100 mm x 100 mm x 100mm and twelve (12) beam mould of size 500 mm x 100 mm x 100 mm. The specimens were cured and tested at 7 days, 14 days, and 28 days respectively. The results revealed that the optimum compressive strength of 19.0 mm aggregate sized concrete was 6.12% higher than the 12.5 mm aggregate sized concrete at 28 days of curing duration. Also, the optimum flexural strength of 12.5 mm aggregate sized concrete was 14.0% higher than the 19.0 mm aggregate sized concrete at 28 days of curing duration. This suggest that 12.5 mm aggregate sizes should be used in the construction of structural members that transmit their loading in flexure and 19.0 mm aggregate sizes are best suitable for compression structural members for optimum structural performance.

**Keywords:** Aggregate, compressive strength, concrete, flexural strength
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## INTRODUCTION

According to Akinwonmi and Seckley [1] concrete is a synthetic construction material made by mixing of cement, fine aggregates, coarse aggregate and water in the proper proportions and it is also a well-known heterogeneous mix of cement, water and aggregates. According to Neville [2], concrete has a highly heterogeneous and complex structure with large range of particles sizes. Concrete strength is governed by aggregate sizes, type and source [3 - 6]. Compressive strength is the most significant mechanical property of concrete. It is obtained by measuring concrete specimen after curing for 28 days. Some of the factors that influence the concrete strength include aggregate quality, cement strength, water content and water/cement ratio [7].

The compressive strength of concrete depends on water-cement ratio, degree of compaction, aggregate-cement ratio, the bond between mortar and aggregate, grading, shape, strength and aggregate sizes [8]. In ordinary structural concrete, the aggregates occupy 70 to 80% of the volume of hardened concrete, and occupy more than 90% of asphalt cement concrete [6]. The universality in the use of concrete is hinged on the invaluable strength properties of the cementitious product, although in many practical cases other characteristics such as durability, permeability and workability are also equally important [9].

Flexural strength which is also called the Modulus of Rupture (MR) or Bending Strength is defined as the stress in a material just before it yields in a flexure test. It represents the highest stress experienced within the material at its moment of yield [10].

Flexural strength or modulus of rupture (MR) is about 10% to 20% of the compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and concrete mix design. The standard test methods are ASTM C78 [11] (third-point loading) or ASTM C293 [12] (center-point loading). The MR determined by third-point loading is usually lower than the MR determined by the center-point loading, sometimes by as much as 15% [13].

Aggregates can be classified as fine or coarse depending on the particle size distribution [14]. Fine aggregates are generally natural sand or soil collected from the riverbank and is graded from particle of 5 mm in size down to the finest particles but excluding dust. Neville [15] holds that coarse aggregates are natural gravel or crushed stone usually larger than 5 mm [16]. Mishuk et al [17] holds that perhaps a maximum size of 80 mm coarse aggregates can be used for concrete. Fowler and Quiroga [18] reported that aggregates are expected to have important effects on the properties of concrete since they occupy 70-80% of it. Aggregates and paste are the major factors that affect the strength of concrete [19].

The properties of aggregate also greatly affect the durability and structural performance of concrete as aggregate with undesirable properties cannot produce strong concrete [15]. Also, Aitcin [20] highlighted that although an excess of coarse aggregate could decrease drying shrinkage, it will increase the number of micro-cracks within the paste. Aggregates are a very significant constituent in concrete since they give body to the concrete, reduce shrinkage and affect economy.

Studies have shown that the basic reason for coarse aggregates is to provide bulk to the concrete, as economic filler which is much cheaper than cement. Other studies have shown that aggregates provide volume stability and durability of the resulting concrete [21]. It is imperative that a constituent with such a high proportion would affect the strength of concrete.

The required amount of cement paste is dependent upon the amount of void space that must be filled and the total surface area that must be covered. When the particles are of uniform size the spacing is the greatest, but when a range of sizes is used the void spaces are filled and the paste requirement is lowered. The more these voids are filled, the less workable the concrete becomes, therefore, a compromise between workability and economy is necessary. Many authors like Golterman *et al*. [22]; Johansen and Hammer [23] found out that uniformly distributed mixtures produce better workability than gap-graded mixtures. Uniformly distributed mixtures generally lead to higher packing resulting in concrete with higher density and less permeability [22]. Uniformly distributed mixtures require less paste, thus decreasing bleeding, creep, and shrinkage [24].

It is not necessarily true that aggregate whose properties all appear satisfactory will always make good concrete, and this is why the performance criterion of aggregate in concrete has to be the determining factor. Since aggregates in concrete are important in its strength formation, its research on the various sizes cannot be over emphasized and its effects on the concrete's properties may give insights to its best usage for optimum performance in the construction industry. This necessitated the research on the evaluation of concrete's properties using different aggregate sizes.

## MATERIALS AND METHODS

The material used includes Dangote Portland cement of grade 42.5, fine aggregate, coarse aggregate (sizes 19.0 mm and 12.5 mm) which were obtained from a dealer along Oluku, Benin City and water. The tools include steel moulds of 100 mm x 100 mm x 100 mm size and 50 mm x 100 mm x 100 mm, shovel and head pans. Eighteen (18) moulds of dimensions 100 mm x 100 mm x 100 mm and twelve (12) beam moulds of dimension 500 mm x 100 mm x 100 mm concrete specimen was produced according to BS 1881: Part 124 [25] methodology. These concrete specimens were prepared using grade 20 concrete at the Civil/ Structural Engineering Laboratory at the University of Benin, Benin City, Nigeria. Flexural and compressive tests were carried out on the specimens for 7 days, 14 days, and 28 days curing interval.

The centre point flexural test method was used to obtain their various flexural strengths according to BS EN 12390–5 [26] methodology. The BS EN 12390–3 [27] methodology was used for the compressive strength test. Other tests such as particle size distribution test for the fine aggregates, fineness modulus of the fine aggregate, density and specific gravity test were carried out before concreting.

### Sieve analysis

Sieve analyses were carried out in accordance with ASTM C136 [28] methodology. The result of the sieve analysis of the fine aggregate, shown in Figure 1 falls within zone 3 which makes it suitable for concrete.

### Fineness modulus of sand

Fineness modulus was carried out according to BS EN 12620-1 [29] methodology. Fineness modulus for the fine aggregate was 2.24mm. This falls into the category of fine sand which is between 2.2 mm and 2.6 mm.

### Specific gravity of aggregate

The specific gravity was carried out according to ASTM C127 [30] methodology. The result obtained for the fine aggregate is 2.63, the specific gravity for 19.0 mm and 12.5 mm aggregates were 2.52 and 2.61 respectively. These fall within the required standards for concrete making.

### Densities of 12.5 mm and 19.0 mm aggregate concrete

The densities of the 12.5 mm and 19.0 mm aggregate sized concrete was carried out according to ASTM C642 [31] methodology and the results were presented in Table 1. The average densities increased as the aggregate sizes decreased for the various curing duration. The increase of density may be due to the reduced air pores present in smaller sized aggregate [2].

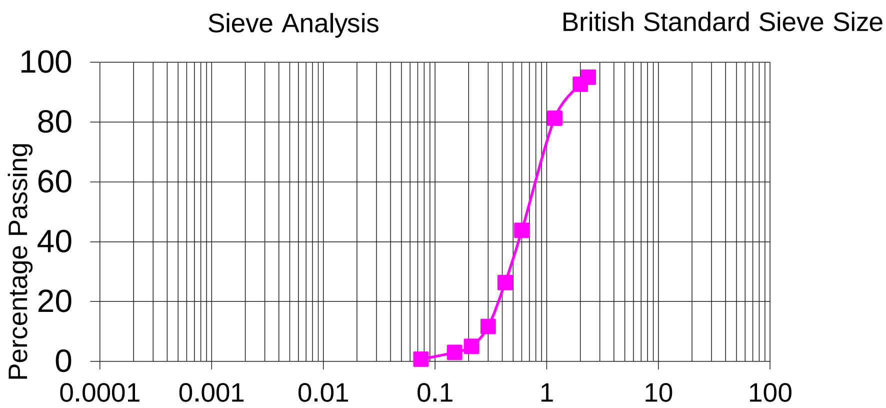


**Figure 1**: Particle size distribution of fine aggregate

**Table 1**: Density of binary blended concrete for RHA pozzolans

| Age of curing (days) | Average densities (Kg/m$^3$) | | | |
|---|---|---|---|---|
| | 12.5mm aggregate sized concrete cube | 19.0mm aggregate sized concrete cube | 12.5mm aggregate sized concrete beam | 19.0mm aggregate sized concrete beam |
| 7 | 2403 | 2393 | 2782 | 2596 |
| 14 | 2447 | 2433 | 2782 | 2640 |
| 28 | 2457 | 2526 | 2857 | 2630 |

## RESULTS AND DISCUSSION

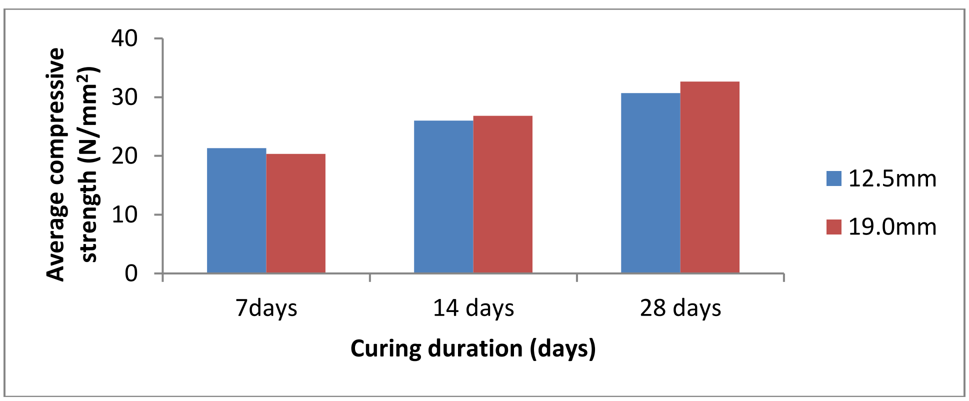


**Figure 2:** Compressive strength of 12 mm and 19 mm aggregate concrete

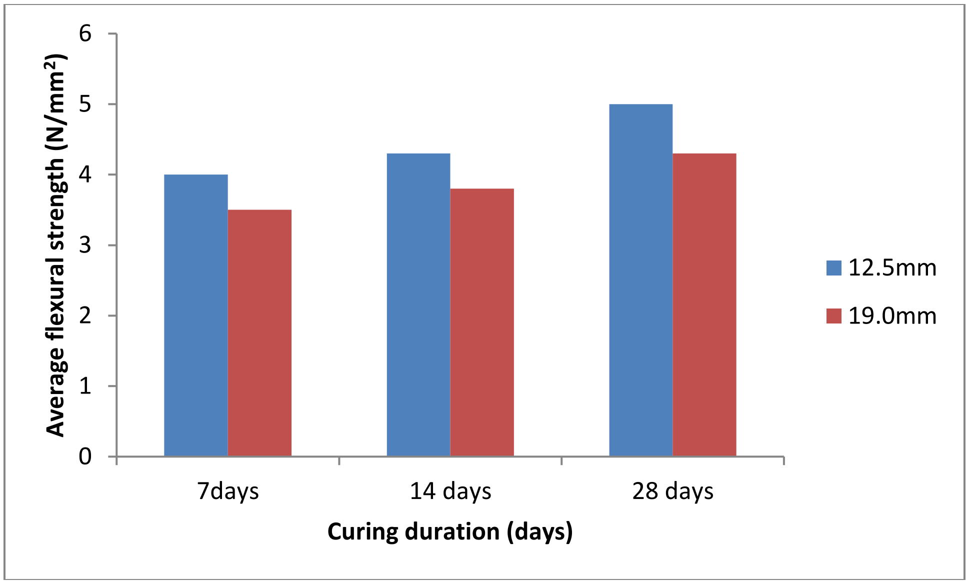


**Figure 3:** Flexural strength of 12 mm and 19 mm aggregate concrete

**Slump test**

The slump test was carried out according to BS 1881: 102 [32] methodology. The average slumps for concrete made with 19.0 mm and 12.5 mm aggregate were 46.33 mm and 39.33 mm respectively. It was observed that there was an increase in the workability of the concrete as the aggregate sizes increased. This observation was corroborated by Obi [35].

**Effect of coarse aggregate sizes on the compressive strength of concrete**

Figure 2 presents the results for the compressive strength of concrete using 12.5 mm and 19.0 mm aggregate when cured for 7 days, 14 days and 28 days respectively. There was a progressive increase in compressive strength as the aggregate sizes were increasing for the various curing duration. The optimum compressive strength of 19.0 mm aggregate sized concrete was 6.12 % higher than the 12.5 mm aggregate sized concrete at 28 days of curing duration. These may be due to the smaller surface area to be wetted per unit mass on the larger aggregate sized concrete which leads to a lower cement/water ratio and improved strength. This was collaborated by Vilane and Sabelo [33].

**Effect of coarse aggregate sizes on the flexural strength of concrete**

Figure 3 presents the results for the flexural strength of concrete using 12.5 mm and 19.0 mm aggregate when cured for 7 days, 14 days and 28 days respectively. There was a progressive decrease in flexural strength as the aggregate sizes were increasing for the various curing duration. The optimum flexural strength of 12.5 mm aggregate sized concrete was 14.0% higher than the 19.0 mm aggregate sized concrete at 28 days of curing duration. These decreases may be due to the larger surface area to be wetted per unit mass, leading to a higher water cement/ratio and lower strength because of the more aggregate content present in the 12.5 mm aggregate sized concrete than the 19.0 mm aggregate sized concrete [19, 34].

## CONCLUSION

The findings from the study reveal that:

1. The workability increases with increase in aggregate sizes for all curing duration.
2. The density of the aggregate sized concrete decreased as the aggregate sizes increased.
3. The optimum compressive strength of 19.0 mm aggregate sized concrete was 6.12% higher than the 12.5 mm aggregate sized concrete at 28 days of curing duration.
4. The optimum flexural strength of 12.5 mm aggregate sized concrete was 14.0% higher than the 19.0 mm aggregate sized concrete at 28 days of curing duration.
5. The 12.5 mm aggregate is better used in flexure than the 19.0 mm aggregate size.
6. Based on the findings from this study, it is suggested that 12.5 mm aggregate should be used in the construction of structural members that transmit their loading in flexure and 19.0 mm aggregate will be best suitable for compression structural members.

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