

Comparative Analysis of the Compressive Strength of Concrete Made from Various Coarse Aggregates

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Abstract

The compressive strength of concrete is a critical parameter that governs the safety and durability of reinforced concrete structures. In Nigeria, the frequent collapse of buildings has been largely attributed to the use of substandard construction materials, particularly poor-quality concrete aggregates. This study presents a comparative analysis of the compressive strength of concrete produced with coarse aggregates obtained from different sources in Nigeria, with the aim of evaluating their suitability for structural applications. Concrete cubes were produced using a constant mix ratio of 1:2:4 (cement: fine aggregate: coarse aggregate), a water–cement ratio of 0.45, and identical cement type, aggregate size, and curing conditions. Three types of coarse aggregates were investigated: granite from Ishiagu quarry (Ebonyi State), limestone (granite) from Okigwe quarry, and local red lump sandstone from Okigwe, Imo State. A total of concrete cubes was cast and cured for 7, 14, 21, and 28 days, after which compressive strength tests were conducted in accordance with relevant British Standards. The results showed that compressive strength increased with curing age for all aggregate types. At 28 days, granite produced the highest average compressive strength of 36.30 N/mm², followed by limestone with 31.56 N/mm², while sandstone recorded the lowest value of 25.18 N/mm². The findings demonstrate that aggregate source significantly influences concrete strength. Granite was found to be the most suitable coarse aggregate for high-strength structural concrete, limestone a viable

alternative, and sandstone unsuitable for applications requiring high characteristic strength. The study provides empirical evidence to guide material selection and promote safer, more durable concrete construction in Nigeria.

1. Introduction

Compressive strength is the most significant mechanical property of concrete and is commonly determined by testing concrete specimens after 28 days of curing. Several factors influence the compressive strength of concrete, including aggregate quality, cement strength, water content, and water–cement ratio [1]. Concrete is a composite material consisting of cement, fine aggregate (sand), coarse aggregate (gravel or granite), and water mixed in prescribed proportions. It remains the most widely used construction material globally, particularly for structural applications. Despite its widespread use, concrete structures account for the majority of collapsed buildings in Nigeria. Recent studies have identified the use of substandard materials, especially poor-quality concrete and aggregates, as a major cause of building failures in the country [2]–[4]. Unsuitable aggregates, including weak, contaminated, and reactive aggregates, have been reported to significantly compromise concrete performance and durability [5]. Similarly, the use of low-quality aggregates has been shown to adversely affect the mechanical performance of asphalt and cement concrete in southwestern Nigeria [6]. Concrete can only achieve acceptable quality and performance when its constituent materials are properly sourced and evaluated. Aggregate quality varies considerably depending on geological formation, geographic location, and environmental conditions [7]. Aggregates typically constitute about 70–80% of the volume of concrete, making their properties critical to concrete strength and durability [8]. Recent research confirms that aggregate characteristics such as strength, surface texture, and mineral composition have a substantial influence on the mechanical and durability properties of concrete [9]. The structural performance of concrete is strongly dependent on aggregate type, size, and source. Even when aggregates appear satisfactory based on basic tests, their performance in concrete may differ, making performance-based evaluation essential [10]. Several recent studies have established that aggregate source significantly affects compressive strength, dimensional stability, and long-term durability of concrete [11]–[13].

The persistent collapse of buildings in Nigeria, with its attendant loss of lives and property, has raised serious concerns among professionals and regulatory bodies. Engineering regulatory authorities have emphasized the need for stricter material quality control and accountability in construction practices [14]. Studies have shown that material-related failures account for a substantial proportion of building collapses in Nigeria [3], [15]. Providing reliable technical information on the performance of aggregates from different local sources is therefore essential for improving construction safety and preventing the use of substandard materials [16].

Consequently, this study investigates the compressive strength of concrete produced using coarse aggregates obtained from different quarry sources in Nigeria. By maintaining constant mix proportions, cement type, aggregate size, and curing conditions, the study aims to isolate and evaluate the influence of aggregate source on concrete strength and contribute to improved material selection for structural concrete applications

1.2. Statement of the problem

The rising cost of building materials has increased the demand for alternative and locally sourced construction materials to reduce transportation and importation costs. However, the frequent collapse of buildings in Nigeria, accompanied by loss of lives and property, has become a major

national concern. Recent investigations indicate that poor-quality construction materials account for a significant proportion of building failures in the country [3], [15]. Despite this, empirical data on the comparative strength performance of concrete made with aggregates from different Nigerian sources remains limited. This lack of reliable performance data often leads to the indiscriminate use of substandard aggregates. Therefore, this study seeks to provide additional empirical evidence on the compressive strength of concrete made from various locally sourced coarse aggregates.

1.3. Aim and objectives of the study

The main aim of this study is to comparatively analyze the compressive strength of concrete made from various coarse aggregates.

The specific objectives are to:

1. Assemble coarse aggregate samples from selected sources
2. Cast concrete cubes using each aggregate sample.
3. Conduct concrete cube crushing tests after specified curing periods.
4. Compare the compressive strength results obtained for each aggregate type.
5. Make recommendations on the most suitable aggregate for structural concrete based on the findings.

1.4. Scope of the study

This study is centered on comparative analysis of the compressive strength of concrete made with granite from ishiagu quarry in Ebonyi state, granite from Okigwe quarry and Okigwe local red lump stone in Imo state.

1.5. Significance of the study

In this study, the researcher centered on the comparative analysis of the strength of concrete made from various aggregate. Therefore, this study will be immense benefits to all the public and private building engineers in Nigeria. This study will be of immense benefit to other researchers who intend to know more on this study and can also be used by non-researchers to build more on their research work. This study contributes to knowledge and could serve as a guide for other study.

The benefits of this research include:

1. Improved understanding of the effects of different coarse aggregates on the compressive strength of concrete.
2. Improved design of concrete mixes for specific applications.
3. Improved cost-effectiveness of concrete mixes.
4. Improved safety of concrete structures.
5. Improved durability of concrete structures.

2. Literature Review

2.1 Introduction

This chapter presents a review of relevant literature related to the comparative analysis of the compressive strength of concrete produced using different aggregates. It examines concepts, material properties, and findings from recent studies to establish the current state of knowledge

and identify research gaps relevant to aggregate performance and concrete strength, particularly within the Nigerian construction context.

2.2 Concrete Properties

Concrete is a composite material made up of fine and coarse aggregates bound together by a cement–water paste, forming a rock-like mass after hydration [17]. Cement serves as the binder that holds the aggregates together through chemical reactions with water. Concrete is characteristically strong in compression but weak in tension; hence, steel reinforcement is introduced to provide tensile strength, resulting in reinforced concrete [18].

Recent studies indicate that the strength of concrete is influenced by several interrelated factors, including the water–cement ratio, aggregate type and quality, surface texture of aggregates, cement composition, curing age, cement fineness, and the degree of hydration [19], [20]. Concrete strength generally increases with decreasing water–cement ratio and with increasing curing age, provided adequate curing conditions are maintained [21]. Once a concrete mix design is selected, it is essential to maintain consistency throughout construction operations, as variations in mix proportions can adversely affect structural performance [22].

2.2.1 Properties and Effects of Cement on Concrete

a) Chemical Composition of Cement

The chemical composition of Portland cement significantly influences the strength and durability of concrete. Modern standards specify acceptable limits for cement compounds such as calcium oxide (CaO), silica (SiO₂), alumina (Al₂O₃), iron oxide (Fe₂O₃), magnesia (MgO), and sulphur trioxide (SO₃), as these constituents affect setting time, strength development, and soundness [23]. Compliance with these requirements ensures uniform performance and minimizes deleterious reactions in hardened concrete.

b) Physical Properties of Cement

The physical properties of cement including fineness, soundness, compressive strength, and setting time play a critical role in concrete performance [24]. Cement fineness affects the rate of hydration, early strength development, workability, and bleeding characteristics of fresh concrete. Finer cement particles increase the surface area available for hydration, leading to faster strength gain but potentially higher water demand [25].

Standard consistency tests are used to determine the optimum water content required to produce a homogeneous cement paste suitable for concrete production [26]. Compressive strength tests on cement mortar cubes are also conducted to assess cement quality and conformity with regulatory standards for structural use [27].

2.2.2 Concrete Materials

The proportions of constituent materials in concrete largely determine its strength, durability, and workability. Fresh concrete is a plastic mass that can be moulded into desired shapes, which accounts for its versatility as a construction material [28]. Aggregates (fine and coarse) typically constitute about 70–80% of the total concrete volume, while cement paste and entrapped air occupy the remaining volume [29].

Concrete is generally composed of cement, aggregates, water, and admixtures (when required). Each component performs a specific function, and improper proportioning of any constituent can adversely affect concrete quality [30].

2.2.3 Aggregates

Aggregates include natural sand, gravel, and crushed stone used in concrete production. They form the bulk of concrete and significantly influence its mechanical and durability properties [31]. Aggregates are not entirely inert; their physical, thermal, and chemical characteristics affect concrete strength, shrinkage, creep, and resistance to environmental degradation [32].

Clean aggregates should be free from excessive clay, silt, organic matter, salts, and other impurities that could interfere with cement hydration or weaken the aggregate paste bond [33]. Sound aggregates must also be dimensionally stable and resistant to weathering under temperature and moisture variations [34]. Proper selection and grading of aggregates ensure a dense concrete matrix with minimal voids and improved strength performance [35].

2.2.4 Water

Water plays a crucial role in concrete production by initiating cement hydration and facilitating mixing, placing, compaction, and curing. Mixing and curing water should be potable or free from harmful impurities such as organic matter, acids, and excessive salts [36]. Poor-quality water can adversely affect setting time, strength development, and long-term durability of concrete [37].

The water–cement ratio is a critical parameter governing concrete strength and durability. Lower water–cement ratios generally produce higher-strength concrete when adequate compaction and curing are ensured [38]. Improper water management during mixing and curing can result in reduced strength, cracking, and eventual structural failure [39].

2.2.5 Admixtures

Admixtures are materials added to concrete to modify its properties for specific applications or construction conditions. Common admixtures include accelerators, retarders, plasticizers, superplasticizers, and air-entraining agents [40]. When properly used, admixtures can improve workability, strength, durability, and resistance to environmental effects without compromising concrete quality [41]. However, admixtures are not substituting for good workmanship or proper mix design. Their effects must be evaluated through laboratory testing before use in practice to ensure compatibility with other concrete constituents [42].

Recent studies have shown that aggregate source significantly influences the compressive strength of concrete. Experimental investigations reveal that gravel and crushed stone from different geological locations produce varying strength characteristics, even under identical mix proportions [43], [44].

2.2.6 Materials for Aggregates

Aggregate materials are used in concrete to improve strength, reduce shrinkage and creep, enhance durability, and lower production costs. Natural and recycled materials such as crushed rock, gravel, recycled concrete, and industrial by-products may be used, provided they meet standard quality requirements [45].

Key aggregate characteristics include cleanliness, hardness, grading, particle shape, surface texture, chemical inertness, availability, and cost. These properties collectively influence concrete workability, strength, and durability [46].

2.2.7 Grading of Aggregates

Aggregate grading determines the amount of cement paste required to produce workable and durable concrete. Well-graded aggregates reduce void content and minimize cement demand,

leading to improved strength and economy [47]. Sieve analysis is commonly used to evaluate aggregate grading, ensuring compliance with standard specifications for concrete production [48]. Aggregates may be supplied as single-sized (divided) or combined (all-in) aggregates. Proper grading of either form can produce high-quality concrete when correctly proportioned [49].

2.2.8 Classification of Aggregate

Mineral aggregate was used as inert filler in cement concrete. The aggregate is not inert filler and its physical, thermal and chemical properties influence the performance of the concrete to a great extent. The aggregate is cheaper than cement and thus it is cheaper to use as much quantity of aggregate and as little of cement as possible, but economy alone is not the reason for using aggregate in the concrete.

a. Based on Source

I. Natural Aggregate: These are obtained by crushing from quarries of igneous, sedimentary or metamorphic rocks. Gravels and sand reduced to their present size by the natural agencies also fall in this category. The most widely used aggregate are from igneous origin. Aggregates obtained from pits or dredged from river, creek or sea are most often not clean enough or well graded to suit the quality requirement. There are various rock types when crushed are suitable for used as aggregates. These include; 1. Limestone: Are sedimentary rocks chiefly composed of calcium carbonate. The harder and denser types particularly the carboniferous types are suitable for concrete. Less hard types are unsatisfactory.

Igneous rocks: The most common are the granites, basalts aplite and gabbros. Granitic aggregates are commonly used because they are hard, tough and dense and are excellent in bonding with cement.

Metamorphic rocks: They have variable characteristics. Marbles and quartzite's are usually massive, dense and adequately tough thus provide good aggregates. However, schists and slates are often thinly laminated and are therefore unsuitable.

Other rocks such as shale, sandstones etc. are rarely available. Shale's are poor aggregates because they are weak, soft and absorptive. In sandstones, imperfect cementation of constituent grains makes some sandstone friable and very porous thus unsatisfactory aggregates. Since natural aggregates are formed by geological processes or by crushing rock, their many properties depend on the properties of the parent rock e.g. chemical and mineral composition, petrology, specific gravity, hardness, strength, pore structure, color etc. these properties have a considerable influence on the quality of fresh and hardened concrete.

II. Artificial Aggregates

Artificial aggregates are manufactured primarily from industrial by-products, waste materials, or processed natural materials. These aggregates are commonly used in lightweight or heavyweight concrete applications, particularly where the utilization of industrial waste materials offers economic or environmental benefits [50]. Most artificial aggregates are lightweight in nature and are produced to meet specific performance requirements.

Recent studies indicate that artificial aggregates such as blast furnace slag, sintered fly ash, and recycled glass aggregates are derived from industrial processes and can be successfully

incorporated into concrete when properly processed [51]. Broken bricks, commonly referred to as brick bats, are also classified as artificial aggregates and are mainly suitable for mass concreting applications such as foundation bases rather than reinforced concrete works due to their lower strength characteristics [52].

Blast furnace slag aggregates are produced through controlled cooling of molten slag followed by crushing. The resulting dense and durable particles are commonly used in precast concrete products. Typical blast furnace slag aggregates possess specific gravity values ranging between 2.0 and 2.8 and bulk densities between 1100 and 1300 kg/m³, depending on processing conditions [40].

b) Classification Based on Density

Heavyweight Aggregates

Heavyweight aggregates are characterized by specific gravity values of 4.0 and above. Common examples include scrap iron, steel shot, ilmenite, magnetite, and barite. These aggregates are primarily used in concrete applications requiring high density, such as radiation shielding in nuclear facilities and counterweight structures [53]. Heavyweight concrete typically has densities exceeding 3600 kg/m³, while concrete produced with steel shots may attain densities of up to 7000 kg/m³ [54]. Recent studies confirm that such aggregates significantly enhance concrete density and radiation attenuation capacity without compromising structural integrity when properly designed [55].

Lightweight Aggregates

Lightweight aggregates are used to produce low-density concrete, which offers advantages such as reduced dead load and improved thermal insulation. These aggregates typically have specific gravity values below 2.6 and oven-dry densities ranging from 500 to 2000 kg/m³ [56]. The reduced density results from internal air voids within the aggregate particles, which also increase porosity. Most artificial aggregates fall into this category, including sintered pulverized fuel ash (PFA) and foamed slag. Natural lightweight aggregates such as pumice are volcanic in origin and are available in limited geographic locations. Although lightweight aggregates reduce concrete density, they generally produce lower compressive strength compared to normal-weight aggregates and exhibit higher creep and shrinkage values [57]. The strength performance of lightweight aggregate concrete depends largely on aggregate type, source, grading, and the use of lightweight or natural fine aggregates [58].

Normal-Weight Aggregates

Normal-weight aggregates are commonly obtained from natural sources such as granite, basalt, gravel, and limestone. These aggregates typically have specific gravity values ranging from 2.55 to 2.75 and produce concrete densities between 22.5 and 24.5 kN/m³, depending on mix proportions [59]. Normal-weight aggregates are widely used in structural concrete and must comply with standard requirements governing strength, grading, and durability [60].

c) Classification Based on Particle Size

Concrete is produced using aggregate particles that span a wide range of sizes, typically with maximum sizes between 10 mm and 50 mm, with 20 mm being common for structural concrete. Aggregate particle size distribution, known as grading, plays a crucial role in concrete strength and workability [61].

Low-quality concrete may be produced using all-in aggregates containing a full range of particle sizes, while high-quality concrete is typically manufactured using separately graded fine and coarse aggregates divided at the 4.75 mm sieve size [62].

Coarse Aggregate

Aggregates predominantly retained on a 4.75 mm sieve are classified as coarse aggregates. The size of coarse aggregate generally ranges from 5 mm to 150 mm. For normal reinforced concrete structures such as beams and columns, the maximum aggregate size is usually limited to 25 mm, while mass concrete applications may use aggregate sizes up to 150 mm [63].

Fine Aggregate (Sand)

Fine aggregates consist of particles passing through a 4.75 mm sieve and retained predominantly on a 75 μm sieve. River sand is the most commonly used fine aggregate due to its smooth texture and good workability. Crushed rock fines may also be used; however, they often produce a harsher concrete finish compared to river sand [64].

d) Classification Based on Shape and Surface Texture

The shape and surface texture of aggregates significantly influence the properties of both fresh and hardened concrete. Aggregate shape affects workability due to differences in surface area, which determine the amount of cement paste required for adequate lubrication [65].

Aggregates with spherical, cubical, or irregular shapes generally improve strength and workability, whereas flat, elongated, or needle-shaped particles reduce load-carrying capacity and are more susceptible to breakage [66]. Surface texture classifications include smooth, granular, rough, crystalline, and honeycombed. Rough-textured aggregates enhance the bond between cement paste and aggregates, improving strength, although they may reduce workability [67].

e) Classification Based on Unit Weight

Aggregates may also be classified based on unit weight and specific gravity. Normal-weight aggregates typically possess specific gravity values between 2.5 and 2.7 with bulk densities of 1520–1680 kg/m^3 . Heavyweight aggregates exceed these values, while lightweight aggregates have specific gravity values below 2.5 and bulk densities less than 1120 kg/m^3 [68]. This classification is essential for selecting aggregates suitable for specific structural and functional concrete applications.

3. Material and Method

3.1 Material Selection

The materials for this research were carefully selected and it includes ordinary Portland cement brand prevalent in the Nigerian market, sharp river sand, coarse aggregates i.e., Granite from Ishiagu quarry in Ebonyi state, granite from Okigwe quarry (Limestone), Okigwe red lump stone (Sand stone) and water.

3.1.1 Cement

Ordinary Portland cement was used in this research. It was supplied in a 25kg bag and was collected in an accredited depot. This is to ensure that the sample collected is a true representative of what was produced from the factory.

3.1.2 Aggregates

Two sets of Aggregates were used for this project

Fine aggregate

Clean sharp sand from Ota-mmiri River in Owerri, the capital city of Imo state was used for this research. It was sun dried and sieved using the 4.75mm BS sieve to remove debris and attain homogeneity of the particles before use.

Coarse aggregate

The coarse aggregates (granite, limestone, sandstone) that was used for this research were gotten from the local market here in Owerri, Imo state. Virtual inspection was carried out to make sure they are free from impurities.

3.1.3 Water

Water is a very important requirement in concrete production. Borehole water near civil engineering laboratory in Imo state university, Owerri was used for mixing concrete and washing of specimen.

3.2 Compressive Strength Test

The aim of this research is to determine the compressive strength of concrete made with various coarse aggregates.

The usefulness of the concrete depends greatly on its compressive strength and this is influenced by several factors. The compressive strength of concrete cubes at 7, 14, 21 and 28 days was determined in accordance to BS 1881: part 116. Twelve cubes were crushed after each curing duration; four samples for each. The compressive strength value were recorded and the average taken for each specimen.

3.2.1 Apparatus

- Compressive strength testing machine
- Tamping rod
- Hand trowel
- Curing tank
- Oil (for greasing interior of the cubes)
- 150mm x 150mm concrete cube molds
- Shovel
- Scoop

3.2.2 Procedure

1. The fine and coarse aggregates were washed and sun-dried to remove some deleterious materials.
2. The cement, fine aggregate, coarse aggregate were measured in a ratio of 1:2:4
3. The fine aggregate and cement were mixed thoroughly thereafter, the coarse aggregate was poured into the mixture and they were mixed thoroughly.
4. The required quantity of water was gotten using the water cement ratio and thereafter poured into the mixture.
5. A trowel was used to pour the fresh concrete into the 150mm x 150mm concrete cube mould

and was compacted with a tamping rod; it was done in three stages. Each of the specimen was placed in four parts labelled G1, G2, G3, G4, L1, L2, L3, L4, S1, S2, S3, S4 with the above representing concrete produced with granite, limestone and sandstone respectively.

6. The casted specimens were removed from the mould after it has set for 24hours and the cubes were cured by fully immersing them in water with the aid of a curing tank in accordance to BS 1881: part 111.

7. The specimens were inserted into a curing tank and allowed to cure for 7 days, 14 days, 21 days and 28 days.

8. 3 samples of each specimen cube were removed from the curing tank and allowed to dry for 24 hours after 7 days, 14 days, 21 days and 28 days respectively before subjecting it to crushing.

9. The specimen samples were subjected to crushing with the aid of a compressive strength testing machine.

10. The value of the load at which the test cube failed was recorded and used to calculate the compressive strength at each curing age. The compressive strength of the specimens was obtained for each curing age, recorded and tabulated.

The compressive strength = P/A

Where P = Failure load (N)

A = Cross Sectional Area (mm²).

4. Results and Discussion

In this experiment, the following materials are used:

1. Cement Type – Ordinary Portland Cement (OPC).
2. Water Cement Ratio – 0.45
3. Mix Ratio – 1:2:4

Table 4.1 Result of compressive strength test of Granite

CURING DURATION (DAYS)	AREA OF CUBE (mm ²)	CRUSHING FORCE (KN)	COMPRESSIVE STRENGTH (N/mm ²)	AVERAGE COMPRESSIVE STRENGTH (N/mm ²)
7 DAYS	22,500	280	12.44	12.37
	22,500	275	12.22	
	22,500	280	12.44	
14 DAYS	22,500	420	18.67	19.56
	22,500	450	20.00	
	22,500	450	20.00	
21 DAYS	22,500	650	28.89	28.15
	22,500	600	26.67	
	22,500	650	28.89	
28 DAYS	22,500	800	35.56	36.30
	22,500	800	35.56	
	22,500	850	37.78	

SOURCE: Laboratory Test

Table 4.2 Result of compressive strength test of Limestone

CURING DURATION (DAYS)	AREA OF CUBE (mm²)	CRUSHING FORCE (KN)	COMPRESSIVE STRENGTH (N/mm²)	AVERAGE COMPRESSIVE STRENGTH (N/mm²)
7 DAYS	22,500	200	8.89	8.89
	22,500	180	8.00	
	22,500	220	9.78	
14 DAYS	22,500	370	16.44	15.85
	22,500	350	15.56	
	22,500	350	15.56	
21 DAYS	22,500	520	23.11	23.26
	22,500	550	24.44	
	22,500	500	22.22	
28 DAYS	22,500	710	31.56	31.56
	22,500	700	31.11	
	22,500	720	32.00	

SOURCE: Laboratory Test

Table 4.3 Result of compressive strength test of Sandstone

CURING DURATION (DAYS)	AREA OF CUBE (mm²)	CRUSHING FORCE (KN)	COMPRESSIVE STRENGTH (N/mm²)	AVERAGE COMPRESSIVE STRENGTH (N/mm²)
7 DAYS	22,500	100	4.44	5.48
	22,500	120	5.33	
	22,500	150	6.67	
14 DAYS	22,500	250	11.11	11.41
	22,500	250	11.11	
	22,500	270	12.00	
21 DAYS	22,500	380	16.89	17.78
	22,500	400	17.78	
	22,500	420	18.67	
28 DAYS	22,500	550	24.44	25.18
	22,500	580	25.78	
	22,500	570	25.33	

SOURCE: Laboratory Test

Below is the graph of compressive strength (N/mm²) against curing duration (days)

X-axis: Curing Duration (7, 14, 21, and 28 days)

Y-axis: Compressive Strength (N/mm²)

Three curves representing:

Granite

Limestone

Sandstone

Figure 1

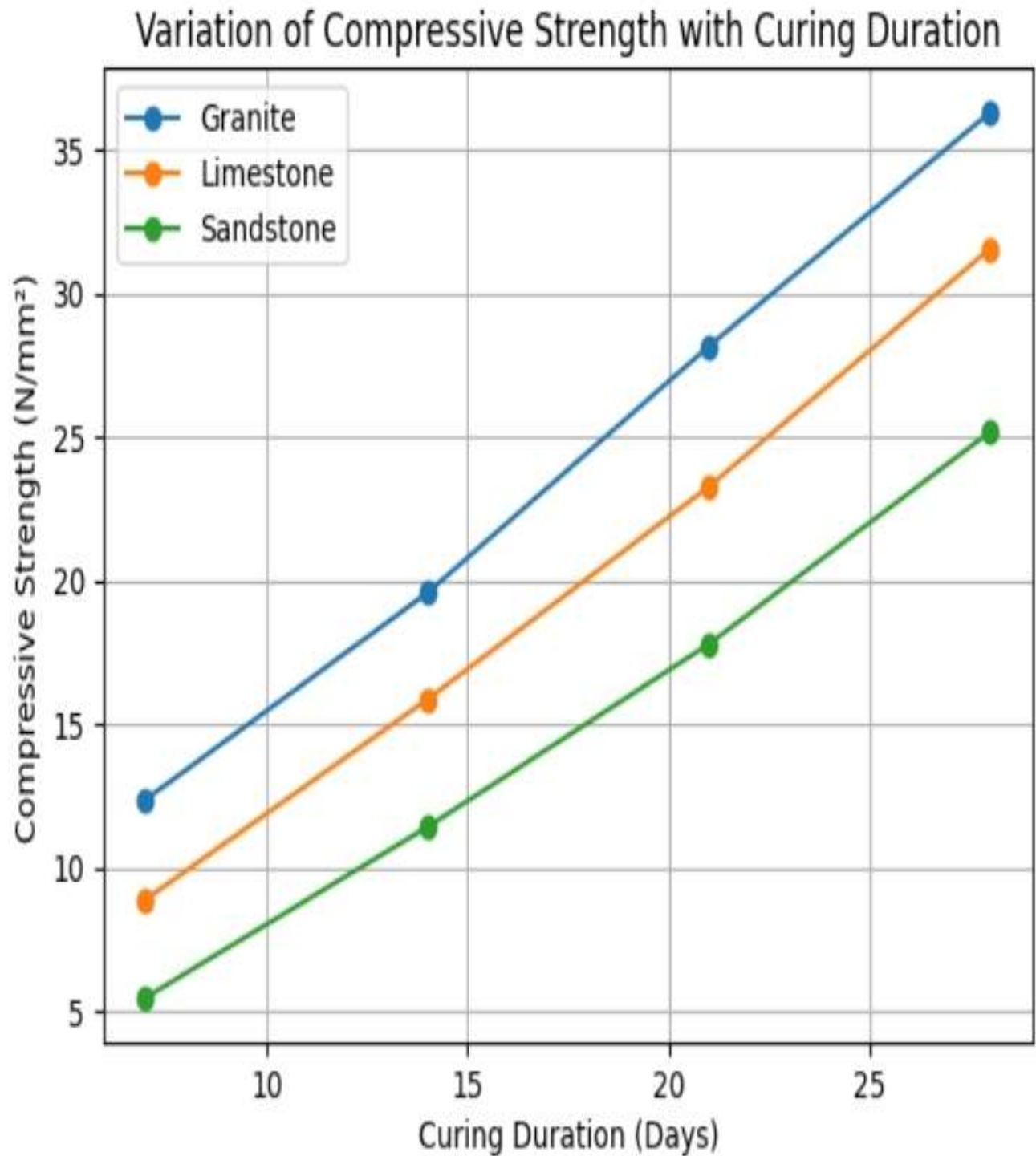


Figure 1. shows the variation of compressive strength with curing duration for concrete produced using granite, limestone, and sandstone as coarse aggregates. The compressive strength of all concrete samples increased with curing age from 7 to 28 days. Concrete produced with granite exhibited the highest compressive strength at all curing durations, while sandstone showed the

lowest strength values.

Discussion

From the result of compressive strength test presented in table 4.1 - 4.3, it is observed that the strength of concrete increases with respect to curing duration and also with respect to the type of coarse aggregate. The result of the test and laboratory experiment of this project has shown that the comparison of the compressive strength of concrete made with various coarse aggregates; granite, limestone, sandstone differs substantially in all curing duration.

From the result in table 4.1, granite have an average compressive strength of 12.37 N/mm^2 for 7 days, 19.56 N/mm^2 for 14 days, 28.15 N/mm^2 for 21 days and 36.30 N/mm^2 for 28 days of curing respectively.

From the result in table 4.2, limestone have an average compressive strength of 8.89 N/mm^2 for 7 days, 15.85 N/mm^2 for 14 days, 23.26 N/mm^2 for 21 days and 31.56 N/mm^2 for 28 days of curing respectively.

From the result in table 4.3, sandstone have an average compressive strength of 5.48 N/mm^2 for 7 days, 11.41 N/mm^2 for 14 days, 17.78 N/mm^2 for 21 days and 25.18 N/mm^2 for 28 days of curing respectively.

The results have shown that concrete increased in compressive strength with respect to curing duration.

5. Conclusion and recommendation

The result of the test and laboratory experiment of this project has shown that the comparison of the compressive strength of concrete made with various coarse aggregate; Granite, Limestone, Sandstone differs substantially in all curing duration (7, 14, 21, 28 days). After the experiment and analysis, granite came first with an average compressive strength of 36.30 N/mm^2 for 28 days. This is followed by limestone with an average compressive strength of 31.56 N/mm^2 for 28 days. Sandstone comes last with an average compressive strength of 25.18 N/mm^2 for 28 days.

5.1. Recommendation

Based on the results and analysis the followings are recommended

1. I hereby recommend that for a massive reinforced concrete project in Civil Engineering that requires a high value of compressive strength, or a high characteristics strength of concrete, f_{cu} of up to 30 N/mm^2 , Granite is highly recommended using the mix ratio of 1:2:4
2. I recommend Limestone for any massive construction project that requires high characteristics strength of concrete, f_{cu} of 30 N/mm^2 as a close alternative of Granite. Limestone has an average compressive strength of 31.56 N/mm^2 for a concrete mix ratio of 1:2:4 with 28 days curing duration, making it a close substitute as far as massive construction work is concerned.
3. However, I do not recommend Sandstone coarse aggregate for any massive reinforced concrete construction projects because of its low value of characteristics strength of concrete f_{cu} of 25.18 N/mm^2 despite the strong mix ratio of 1:2:4 that was used at an optimum curing duration of 28 days in the laboratory tests. Therefore, it can be used in any projects that do not require high f_{cu} . Since granite has the highest compressive strength, the government should make it more available for the masses.

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