

Investigation into the Quality and Suitability of Aggregates Commonly Used In Construction Work Talata Mafara Area Zamfara State, Nigeria

ALYASA'U JAFARU

Civil Engineering Department, Abdu Gusau Polytechnic, Talata Mafara, Zamfara State, Nigeria

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ABSTRACT

This research paper comprises the use of aggregate both fine and coarse aggregate in the production of concrete, which are strong in compressive strength of concrete. The coarse and fine aggregate that posses both physical and mechanical properties in the production of concrete which when in correct proportion give desired strength of the concrete. The mix ratio used was 1:2:4 which is known as pure mixing. 1:2:4 gives 1 head pan of cement with 2 head pan of sharp sand or fine aggregate while 4 head pan for coarse aggregate. After the production of the casted cubes, curing was carried out. The duration of the curing is 7 days. After which the compressive strength test was conducted and the suitability of the sand and gravel materials was determined as GBMC was found to be the best out of the remaining site selected in the strength of concrete generally used in the building construction in the selected area....

Key words: *Compressive strength, Coarse aggregate, fine aggregate, Curing, mechanical properties.*

I. INTRODUCTION

Sand and Gravel (Aggregate) are generally used in construction of building and other structures such as Lintel, Slab, Beam and Column. When concrete is freshly mixed the aggregates are suspended in cement, water, air bubble paste. Selection of types and size gradation of the aggregate depend upon the nature of the aggregate employed, a fairly precise balanced between the amount of fine and coarse aggregate size fraction may have to be maintained to achieve the desire mobility, plasticity and freedom from segregation (Olajide B.T 2013). Presence of aggregate provides an enormous contact area for intimate bond between the paste and the aggregate surfaces. Rigidity of aggregate greatly restrains volume change of the whole mass. Aggregate (sand and gravel) can be classified by their mineral, chemical, and physical properties, aggregate physical properties and direct

result of its mineral and chemical properties, significantly improve the workability of the fresh concrete are contributed by proper choice of aggregate, this improvement is important in the properties of hardened concrete as well, such as properties and pavement slipperiness.

Gravel is a loose aggregation of rock fragments. Gravel is classified by particle size range and includes size classes from granule- to boulder-sized fragments. ISO 14688 grades gravels as fine, medium, and coarse with ranges 2 mm to 6.3 mm to 20 mm to 63 mm. One cubic meter of gravel typically weighs about 1,800 kg (or a cubic yard weighs about 3,000 pounds).

Gravel is an important commercial product, with a number of applications. Many roadways are surfaced with gravel, especially in rural areas where there is little traffic. Globally, far more roads are surfaced with gravel than with concrete or asphalt; Russia alone has over 400,000 km (250,000 mi) of gravel roads. Both sand and small gravel are also important for the manufacture of concrete. Natural gravel has a high hydraulic conductivity, sometimes reaching above 1 cm/s.

Sand is a granular material composed of finely divided rock and mineral particles. Sand has various compositions but is defined by its grain size. Sand grains are smaller than gravel and coarser than silt. Sand can also refer to a textural class of soil or soil type; i.e., a soil containing more than 85 percent sand-sized particles by mass.

The composition of sand varies, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO₂), usually in the form of quartz. The second most common type of sand is calcium carbonate, for example, aragonite, which has mostly been created, over the past half billion years, by various forms of life, like coral and shellfish.

For example, it is the primary form of sand apparent in areas where reefs have dominated the ecosystem for millions of years like the Caribbean. Somewhat more rarely, sand may be composed of calcium sulfate, such as gypsum and selenite, as is found in places like White Sands National Park and Salt Plains National Wildlife Refuge in the U.S.

Sand is a non-renewable resource over human timescales, and sand suitable for making concrete is in high demand. Desert sand, although plentiful, is not suitable for concrete. 50 billion tons of beach sand and fossil sand is used each year for construction.

The exact definition of sand varies. The scientific Unified Soil Classification System used in engineering and geology corresponds to US Standard Sieves, and defines sand as particles with a diameter of between 0.074 and 4.75 millimeters. By another definition, in terms of particle size as used by geologists, sand particles range in diameter from 0.0625 mm (or $\frac{1}{16}$ mm) to 2 mm. An individual particle in this range size is termed a *sand grain*. Sand grains are between gravel (with particles ranging from 2 mm up to 64 mm by the latter system, and from 4.75 mm up to 75 mm in the former) and silt (particles smaller than 0.0625 mm down to 0.004 mm). The size specification between sand and gravel has remained constant for more than a century, but particle diameters as small as 0.02 mm were considered sand under the Albert Atterberg standard in use during the early 20th century. The grains of sand in Archimedes' *The Sand Reckoner* written around 240 BCE, were 0.02 mm in diameter. A 1938 specification of the United States Department of Agriculture was 0.05 mm. A 1953 engineering standard published by the American Association of State Highway and Transportation Officials set the minimum sand size at 0.074 mm. Sand feels gritty when rubbed between the fingers. Silt, by comparison, feels like flour.

ISO 14688 grades sands as fine, medium, and coarse with ranges 0.063 mm to 0.2 mm to 0.63 mm to 2.0 mm. In the United States, sand is commonly divided into five sub-categories based on size: very fine sand ($\frac{1}{16}$ – $\frac{1}{8}$ mm diameter), fine sand ($\frac{1}{8}$ mm – $\frac{1}{4}$ mm), medium sand ($\frac{1}{4}$ mm – $\frac{1}{2}$ mm), coarse sand ($\frac{1}{2}$ mm – 1 mm), and very coarse sand (1 mm – 2 mm). These sizes are based on the Krumbein phi scale, where size in $\Phi = -\log_2 D$; D being the particle size in mm. On this scale, for sand the value of Φ varies from -1 to +4, with the divisions between sub-categories at whole numbers.

II. LITERATURE REVIEW

2.1 SAND

Sand is one of the most commonly used and an important material in construction. Sand is used as fine aggregate in concrete and used in plastering along with cement. Its also used as a filler materials beneath the tiles. There are various types of Sands currently that can be used in Construction.

Types of Sand Used In Construction

1. River/Natural Sand

River Sand is usually obtained from River Beds and Banks. It is usually very fine in quality and has a white-grey color. River Sand is good for all construction activities like concrete production and plastering as it is well graded. As per the Indian Standard codes, sand used in preparation of concrete and in plastering should ideally confirm to IS-383 Zone-II. Refer the table to understand how Zone classification is given for sand

River Sand is banned in lot of places due to the adverse effects caused to the natural environment. As it is obtained naturally, river sand contains some silt also.

2. Manufactured Sand (M-Sand) & Plaster Sand

Manufactured Sand is manufactured by proper crushing of aggregates into finer materials of required particle size (generally using VSI technology). Since quality control is maintained in the process of preparing manufactured sand, the sand obtained will better confirm to the Zone-II grading standards at all times. They don't have any organic or silt materials.

3. Pit Sand

Pit sand is extracted from Deep pits dug underneath the ground. It usually has a coarser grain size. It is not recommended in construction activities as the particle size is too large.

Guidelines for Selecting Good Sand That Can Be Used For Construction

Sand should have to following main properties to be treated as good for construction use:

Silt Content should be less than 3% by weight (12% by volume in 10 min)

2.2 GRAVEL

THE USES OF GRAVEL IN CONSTRUCTION

Gravel is an excellent building material that provides some outstanding interior design opportunities whilst being incredibly sturdy and reliable. It has become one of the most popular building materials in modern construction, from kitchen surfaces through to paving slabs.

2.3 CEMENT

Cement is a binder substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate

produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material in existence and is behind only water as the planet's most-consumed resource.

Cements used in construction are usually inorganic, often lime or calcium silicate based, which can be characterized as non hydraulic or hydraulic respectively, depending on the ability of the cement to set in the presence of water.

2.3.1 PROPERTIES OF CEMENT

Physical Properties of Cement

Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement. The physical properties of good cement are based on:

- Fineness of cement
- Soundness
- Consistency
- Strength
- Setting time
- Heat of hydration
- Loss of ignition
- Bulk density
- Specific gravity (Relative density)

CHEMICAL PROPERTIES OF CEMENT

The raw materials for cement production are limestone (calcium), sand or clay (silicon), bauxite (aluminum) and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate. Chemical analysis of cement raw materials provides insight into the chemical properties of cement.

1. Tricalcium aluminate (C₃A)

Low content of C₃A makes the cement sulfate-resistant. Gypsum reduces the hydration of C₃A, which liberates a lot of heat in the early stages of hydration. C₃A does not provide any more than a little amount of strength.

Type I cement: contains up to 3.5% SO₃ (in cement having more than 8% C₃A)

Type II cement: contains up to 3% SO₃ (in cement having less than 8% C₃A)

2. Ferrite (C₄AF)

Ferrite is a fluxing agent. It reduces the melting temperature of the raw materials in the kiln from 3,000°F to 2,600°F. Though it hydrates rapidly, it does not contribute much to the strength of the cement.

3. Magnesia (MgO)

The manufacturing process of Portland cement uses magnesia as a raw material in dry process plants. An excess amount of magnesia may make the cement

unsound and expansive, but a little amount of it can add strength to the cement. Production of MgO-based cement also causes less CO₂ emission. All cement is limited to a content of 6% MgO.

4. Sulphur trioxide

Sulfur trioxide in excess amount can make cement unsound.

5. Iron oxide/ Ferric oxide

Aside from adding strength and hardness, iron oxide or ferric oxide is mainly responsible for the color of the cement.

6. Alkalis

The amounts of potassium oxide (K₂O) and sodium oxide (Na₂O) determine the alkali content of the cement. Cement containing large amounts of alkali can cause some difficulty in regulating the setting time of cement. Low alkali cement, when used with calcium chloride in concrete, can cause discoloration. In slag-lime cement, ground granulated blast furnace slag is not hydraulic on its own but is "activated" by addition of alkalis. There is an optional limit in total alkali content of 0.60%, calculated by the equation Na₂O + 0.658 K₂O.

2.5 WATER

Water is

an inorganic, transparent, tasteless, odorless, and nearly colorless chemical substance, which is the main constituent of Earth's hydrosphere and the fluids of all known living organisms (in which it acts as a solvent). It is vital for all known forms of life, even though it provides no calories or organic nutrients. Its chemical formula is H₂O, meaning that each of its molecules contains one oxygen and two hydrogen atoms, connected by covalent bonds. Two hydrogen atoms are attached to one oxygen atom at an angle of 104.45°.

"Water" is the name of the liquid state of H₂O at standard ambient temperature and pressure. It forms precipitation in the form of rain and aerosols in the form of fog. Clouds are formed from suspended droplets of water and ice, its solid state. When finely divided, crystalline ice may precipitate in the form of snow. The gaseous state of water is steam or water vapor. Water covers 71% of the Earth's surface, mostly in seas and oceans.

Small portions of water occur as groundwater (1.7%), in the glaciers and the ice caps of Antarctica and Greenland (1.7%), and in the air as vapor, clouds (formed of ice and liquid water suspended in air), and precipitation (0.001%).

Water plays an important role in the world economy. Approximately 70% of the freshwater used by humans goes to agriculture.^[6] Fishing in salt and fresh water bodies is a major source of food for many parts of the world. Much of the long-distance

trade of commodities (such as oil, natural gas, and manufactured products) is transported by boats through seas, rivers, lakes, and canals. Large quantities of water, ice, and steam are used for cooling and heating, in industry and homes. Water is an excellent solvent for a wide variety of substances both mineral and organic; as such it is widely used in industrial processes, and in cooking and washing. Water, ice and snow are also central to many sports and other forms of entertainment, such as swimming, pleasure boating, boat racing, surfing, sport fishing, diving, ice skating and skiing.

III. METHODOLOGY

3.1 BASIC EXPERIMENT FOR THE STUDY

3.1.1 MOLD ACQUISITION

Plastic or steel concrete cube molds are used to form specimens for concrete compressive strength testing. They can also be used as sample containers in the determination of mortar set times as indicated in ASTM C403 and AASHTO T 197.

* Plastic Concrete Cube Mold, 150x150mm is a one-piece mold made of rugged plastic with reinforced construction. It allows for easy specimen removal.

* Steel Concrete Cube Mold, 6x6 in molds specimens for strength testing or used as a container to hold test samples. It allows easy assembly and demolding.

3.1.2 MIX DESIGN

Concrete mix design

* **A binder:** cement, which hardens in the presence of water;

* **Water:** it is required for the cement to harden and in order to lay it. However, care is necessary as too much water reduces the strength and durability of the concrete.

* **Aggregate:** it varies in size from sand to gravel, which forms the "skeleton" of the concrete.

* And, when required, **additives:** they modify the properties of the concrete depending on their nature. To formulate a concrete, it is firstly necessary to select:

* The type of aggregate (the stones) and the size of the particles

* Then the type of cement (there is a large variety of types of cement with different characteristics and performances - in general 350 Kg of cement for 1m³ of concrete)

* Then the amount of water (generally between 130 and 150 Litres for 1m³ of concrete)

* And lastly, if required, the amount of additives (a few Kilograms for 1m³ of concrete).

One cubic metre of concrete weighs 2.5 Tones.

Typically, 1m³ of concrete is made up of 350Kg of cement, 700Kg of sand, 1,200Kg of chippings and 150 Litres of water.

The mix design process can either be conducted on the basis of charts or experimentally. These methods are based on achieving the maximum density of concrete.

Approximate proportions of constituents in a conventional concrete

Constituent	Water	Air	Aggregate	Cement
Volume (%)	14-22	1-6	7-14	60-78
Weight (%)	5-9	-	9-18	63-85

This composition is then optimized and adjusted on the basis of compression tests conducted on test specimens.

The water content must be kept as low as possible, compatible with the workability and hydration of the concrete. The proportion of cement has a direct influence on the mechanical strength. The water/cement (w/c) ratio must be between 0.35 and 0.5.

3.1.3 BATCHING AND MIXING

Batching

Batching is the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Traditionally

batching is done by volume but most specifications require that batching be done by mass rather than volume.

Mixing

The mixing operation consists of rotation or stirring, the objective being to coat the surface the all aggregate particles with cement paste, and to blind all the ingredients of the concrete into a uniform mass; this uniformity must not be disturbed by the process of discharging from the mixer.

3.1.4 CONCRETE SLUMP TEST

Concrete Slump Test is a measurement of concrete's workability, or fluidity. It's an indirect measurement of concrete consistency or stiffness. A slump test is a method used to determine the consistency of concrete. The consistency, or stiffness, indicates how much water has been used in the mix. The stiffness of the concrete mix should be matched to the requirements for the finished product quality. The concrete slump test is used for the measurement of a property of fresh concrete. The test is an empirical test that measures the workability of fresh concrete. More specifically, it measures concrete consistency between batches. The test is popular due to the simplicity of apparatus used and simple procedure.

PRINCIPLE OF SLUMP TEST

The slump test result is a measure of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete which then gives an idea about the workability condition of concrete mix.

SLUMP TEST APPARATUS

- Slump cone,
- Scale for measurement,
- Tempering rod (steel)

PROCEDURE OF CONCRETE SLUMP TEST

1. The mold for the concrete slump test is a frustum of a cone, 300 mm (12 in) of height. The base is 200 mm (8in) in diameter and it has a smaller opening at the top of 100 mm (4 in).
2. The base was placed on a smooth surface and the container was filled with concrete in three layers, whose workability is to be tested.
3. Each layer was tamped 25 times with a standard 16 mm (5/8 in) diameter steel rod, rounded at the end.
4. When the mold was completely filled with concrete, the top surface was struck off (leveled with mould top opening) by means of screening and rolling motion of the tempering rod.
5. The mould must be firmly held against its base during the entire operation so that it could not move due to the pouring of concrete and this can be done by means of handles or foot - rests brazed to the mold.
6. Immediately after filling was completed and the concrete is leveled, the cone was slowly and carefully lifted vertically, an unsupported concrete now slumped.
7. The decrease in the height of the center of the slumped concrete is called slump.
8. The slump was measured by placing the cone just besides the slump concrete and the tempering rod was placed over the cone so that it should also come over the area of slumped concrete.

9. The decrease in height of concrete to that of mold was noted with scale. (Usually measured to the nearest 5 mm (1/4 in).

3.1.5 CASTING OF CONCRETE PROCEDURE FOR CASTING

1. The standard cube moulds 6 Nos. were thoroughly cleaned and all nuts/bolts were tightened properly.
2. Oil was applied to all contact surface of mould.
3. Size of mould was normally from the mixing spot while concreting.
4. The random sample from the mixing spot was taken while concreting.
5. The cubes were filled with concrete in 3 layers.
6. Each layer was compacted with 35 Nos. of stroke by tamping rod.
7. The top surface was finished by trowel after completion of last layer.
8. The moulds were covered by damp hessian cloth immediately to prevent loss of water.
9. Each specimen was taken from various locations of proposed concreting.
10. After 24 hours, specimens were removed out of mould.
11. While removing, care was taken to avoid breaking of edges.
12. Coding was put on cubes by maker, which was self-explanatory showing site name, concrete location, building number and date of casting.
13. The specimens were submerged in clean fresh water for curing till the time of testing (i.e. after 7 days).

3.1.6 COMPRESSIVE STRENGTH OF CONCRETE

Compressive strength is the capacity of material or structure to resist or withstand under compression. The Compressive strength of a material is determined by the ability of the material to resist failure in the form cracks and fissure.

In this test, the push force applied on the both faces of concrete specimen and the maximum compression that concrete bears without failure was noted

The test was carried out using (150x150x150)mm concrete cubes on a Universal testing machine or compressive testing machine.

PROCEDURE

1. The prepared concrete mix was placed in the steel cube mould for casting.
2. Once it sets, after 24 hours the concrete cube was removed from the mould.
3. The test specimens were kept submerged underwater for stipulated time.

4. As mentioned earlier, the specimen must be kept in water for 7 or 14 or 28 days and for every 7 days the water was changed.
5. It was ensured that concrete specimen was well dried before placing it on the UTM.
6. Weight of samples was noted in order to proceed with testing which must not be less than 8.1Kg.
7. Testing specimens were placed in the space between bearing surfaces.
8. Care was taken to prevent the existence of any loose material or grit on the metal plates of machine or specimen block.
9. The concrete cubes were placed on bearing plate and aligned properly with the center of thrust in the testing machine plates.
10. The loading was applied axially on specimen without any shock and increased at the rate of 140kg/sq cm/min till the specimen collapsed.
11. Due to the constant application of load, the specimen started cracking at a point & final breakdown of the specimen was noted.

IV. RESULTS

Table 4.0 COMPRESSIVE STRNGTH OF CUBES CORED FOR 7 DAYS USING IMMERSION METHOD OF CURING

SAMPLE	CUBE ID	DATE OF CAST.	CURIN G PEROIU D (days)	DATE OF TEST.	W (Kg)	CUBE SIZE (mm x mm x mm)	DENS. OF CUBE (Kg/m ³)	A (mm ²)	LOAD AT FAILURE (KN)	COMP. STENG. (N/mm ²)	AVR. COMP. STREN. (N/mm ²)
BOBO SAND AND REC ROCK GRAVEL	BBRR 1	19/4/21	7	27/4/21	7.96	150x150 x150	2358.52	22500	375	16.7	17.0
	BBRR 2	19/4/21	7	27/4/21	7.68	150x150 x150	2275.56	22500	390	17.3	
	BBRR 3	19/4/21	7	27/4/21	7.65	150x150 x150	2266.67	22500	380	16.9	
GADA BABBA AND MOTHER CAT GRAVEL	GBMC 1	19/4/21	7	27/4/21	7.53	150x150 x150	2231.11	22500	520	23.1	20.1
	GBMC 2	19/4/21	7	27/4/21	7.90	150x150 x150	2340.74	22500	330	15.6	
	GBMC 3	19/4/21	7	27/4/21	7.84	150x150 x150	2322.96	22500	485	21.6	
MAKERA SAND AND CGC GRAVEL	MCGC 1	19/4/21	7	27/4/21	8.04	150x150 x150	2382.22	22500	480	21.3	19.5
	MCGC 2	19/4/21	7	27/4/21	7.79	150x150 x150	2308.15	22500	340	15.1	
	MCGC 3	19/4/21	7	27/4/21	7.47	150x150 x150	2213.33	22500	495	22.0	

The compressive strength of the concrete cube test provides an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not.

Compressive strength achieved by concrete at 7 days is about 65% and at 14 days is about 90% of the target strength.

Average compressive strength of the concrete cube made with Bobo sand and Rec rock gravel = 17.0N/mm² (at 7 days)

Average compressive strength of the concrete cube made with Gada babba sand and mother cat gravel = 20.1N/ mm² (at 7 days) and,

Average compressive strength of the concrete cube made with makera sand and CGC gravel = 19.5N/ mm² (at 7 days)

Compressive Strength of Concrete at Various Ages

The strength of concrete increases with age. The table below shows the strength of concrete at different ages in comparison with the strength at 7 days after casting.

Age	Strength percent
1 day	16%
3 days	40%
7 days	65%

Compressive Strength of Different Grades of Concrete at 7 Days

Grade of Concrete	Minimum compressive strength N/mm ² at 7 days
M15	10
M20	13.5
M25	17
M30	20
M35	23.5
M40	27
M45	30

V. CONCLUSION

In conclusion, the Compressive strength of concrete shown above indicate that GBMC is the best and suitable sand and gravel to be use in talata mafara compared to MCGC and BBRR.

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