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EVALUATION OF RECYCED CONCRETE AGGREGATES (RCA) AS SUSTAINABLE CONSTRUCTION MATERIALS TO CURTAIL FRESH AGGREATES EXPLOITATIONS IN BORNO

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Abstract: *Compressive strength and modulus of elasticity of masonry are significant parameters when considering structural masonry design. Hollow sandcrete blocks masonry were evaluated experimentally which are made from recycled concrete aggregates (RCA) for compression until failure which were conducted in accordance with BS EN1052 1:199. Properties of structural units and the mortar were also determined. Results shows that the mean compressive strength of the mortar, clay bricks units and concrete blocks units are 4,2N/mm², 63.0 N/mm² and 12.8N/mm²² respectively. The characteristic compressive strength of masonry made of clay brick is 11.2N/mm² and that made of concrete block is 7.2N/mm². The failure of the masonry tested in compression was due to development of tensile cracks parallel to the axis of the loading. Modulus of elasticity of masonry was close to 10000fk which is a formula given by Eurocode6.its evident that recycled concrete aggregates are useful in manufacturing of some masonry structures and should be exploited for maximum benefits instead of land filling demolition debris and using natural aggregate.*

Keywords: *Aggregates, Concrete RCA, Sustainability Recycling.*

INTRODUCTION

Recycle is the process of converting waste materials into re-usable materials or object to prevent waste of potentially useful materials and hence reduce the consumption of fresh raw materials and enhancing sustainability.

Recycled aggregate is produced as a result of crushing graded particles processed from materials, the materials that have been use in construction. One of the most common phenomena in developed and developing countries as well is the demolition of structures, such as building and traffic infrastructure, and substituting with new ones. The main reason for these situation is the need for expansion, deterioration of old structures, change of purpose, rearrangement of city plan, natural disasters (earthquake, flood and fire). The most common method of managing this material has been through its disposal in landfills. (ChaitradipSakar *et al.,* 2018). This doesn't induce economic strain but also post great environmental impact. Using recycled demolished concrete as an alternative aggregate in structural concrete is gaining popularity as a viable and sustainable solution.

The study aims to undertake compressive strength analysis of recycled concrete, natural aggregate concrete and explore the potential replacement of certain percentage of sand in the mixture of concrete and study their properties. The addition of certain portion of recycled aggregate instead of natural aggregate (sand) into the mixture, producing the recycled concrete which can conserve energy and materials for concrete production.

To evaluate the compressive strength and sustainability of recycled concrete aggregate (RCA) for construction The demolition of concrete structures has made concrete debris the largest portion of the waste. With landfills becoming scarce, the need to recycle demolition debris is becoming increasingly relevant. Producing and reusing RCA will reduce landfill waste and minimizing the production and transportation of natural aggregates. Aggregates which is used in concrete in large proportion plays a significant role in any kind of concrete structures. Use of recycled aggregates reduces construction cost and is more environmentally sustainable as against uncontrolled exploitation of virgin aggregates. Globally in the last few decades, abandoned concrete has been used as coarse aggregates to produce concrete with promising performance.

The compressive strength and splitting tensile strength of concrete made with recycled coarse aggregates depends on the mix proportion on the mix proportion. In general, the strength of recycled concrete can be 10 -25 % lower than that of conventional concrete made with natural coarse aggregates

With the ever increasing awareness on the environment and the need for sustainable use of nature's scares resources has resulted in the need to practice sustainability in all its ramifications thus, the need to look at the sustainable way of virgin aggregates exploitation and curtail landfilling of recycled concrete aggregates in the state.

Besides. It saves cost as getting the recycled aggregate is less expensive than exploration of virgin aggregates. Recycled aggregate can be used for various functions, it is suitable for use in construction projects, landscaping and in home improvement application

SCOPE OF THE STUDY

This project will identify physical properties of recycled aggregate concrete and the advantages and disadvantages that these properties have on re-use application. It will identify how RAC is produced and how it is specified in construction. This project will identify the availability of natural aggregate; and include three case study in which RCA would be reused.

All the investigation involve are using experimental or test conducted in the concrete laboratory. The laboratory work is to observe and to execute the method obtain from literature review. The investigation of the study is mainly during the 7, 14, 21 days of production of the concrete cube

LITERATURE REVIEW

Concrete is a composite material that consists of cement fine aggregate, course aggregate and water. The strength and fire resistance of concrete mainly depends on course aggregate which is facing a severe problem of scarcity due to several reasons. Many investigations by researchers have been reported on the replacement of coarse aggregate with recycled aggregates. The mechanical properties of such recycled aggregate concrete at high temperatures are still being investigated. The followings are some of the important ant parameters that are reviewed with a view of obtaining a good quality.

Tom *et al.,* (2015) attempted to improve the quality of recycled aggregate by two step mixing approach (TSMA) and analyzed the micro structure of recycled aggregate concrete produced from TSMA. The research concluded that the water absorption of recycled coarse aggregate decreased with the increase in size of coarse aggregate. The higher water absorption of 10mm than 20mm size recycled aggregate was attributed to the higher adhered mortar. The Tam *et al.,* (2015) compared the performance of concrete made with normal mixing approach (NMA) and (TSMA) by studying its compressive strength at 7, 14, 21, 28, and 56 days.

Bara *et al.,* (2016) studied the mechanical properties of recycled aggregate concrete by varying the degree of saturation of the aggregate. The recycled aggregate was used in dry, semi-saturated and saturated conditions. The Bara *et al.,* (2016) reported that the strength of recycled aggregate was almost same as that of conventional concrete. They conducted that the semi-saturated recycled aggregate performed better than the dry and completely saturated aggregate.

Amnon Katz *et al.* (2013) studied the mechanical properties of recycled aggregate concrete by replacing 100% virgin aggregate with recycled aggregates. The recycled aggregate was crushed at different ages to study their properties such as bulk specific gravity, bulk density, absorption and adhered cement percentage. A comparative study was made between the mechanical properties of recycled aggregate concrete and granite aggregate concrete. The Amnon Katz *et al.,* (2013) reported that the properties of recycled aggregate were independent of the crushing age. A compressive reduction of about 25% with ordinary Portland cement and a reduction of 30 to 40% with while Portland cement was reported at the same water cement ratio.

Poon *et al.,* (2004) investigated the properties of fresh and hardened recycled aggregate concrete in air dried (AD), oven dried (OD) and saturated surface dry (SSD) condition. The poon *et al.,* (2020) reported lesser values of bulk density and strength and higher values of water absorption and porosity for recycled aggregate compared to granite aggregate. The mechanical properties of three different mixes were also discussed with the replacement ratio of 20%, 50% and 100%. These properties were compared with 100% crushed granite aggregate concrete. No significant loss in slump and compressive strength was observed between the crushed granite aggregate concrete and recycled aggregate concrete when aggregate were used in AD and SSD condition.

Padmini*et al.,* (2019) investigated the properties of recycled aggregate concrete by extracting these aggregate from three different grades (M15, M25, M35) of parent concrete. The influence of the different of parent concretes on the properties of recycled aggregate concretes on the discussed. Each grade of parent concrete was made with three different size of aggregate such as 10mm, 20mm and 40mm. The recycled aggregate was prepared from these nine types of parent concrete and the same sized aggregate were stacked together to use in the present study. The padmini *et al.,* (2009) observed that the water absorption of recycled aggregate increased with the increase in grade of parent concrete and decreased with increase in size of recycled aggregate. The bulk density also followed the same trend as that of water absorption. They also concluded that the target strength increased with the increase in size of aggregate.

Sami *et al.,* (2009) investigated the effect of quality of recycled aggregate on strength properties of recycled aggregate concrete. The recycled aggregate concrete was collected from two sources (i) crushed concreted cube of strength 30Mpa and 50Mpa from laboratory. The toughness, soundness, compressive strength and the tensile strength were discussed. The Semi *et al.,* (2019) reported that the toughness value was well within the limits suitable for structural concrete irrespective of the origin of recycle aggregate. They concluded that the compressive and tensile strengths of recycled aggregate concrete made with aggregate concrete.

Safiuddin*et al.,* (2020) conducted experiments to emphasize the effects of recycled coarse aggregate on fresh and hardened properties of high workability concrete.

The specific gravity and bulk density of recycled aggregate were lower and water absorption, moisture content, angularity number and impact value were higher than that of natural aggregate. The natural was substitute by recycled aggregate in percentages of 30, 50, 70 and 100%. The safiuddin*el al.,* (2019) reported that the compressive strength of recycled aggregate concrete was comparable to that of the natural aggregate concrete at all replacement levels excepts for 100%

replacement. The reduction in compressive strength at 28days for 100% replacement was reported as 12.2%. this lower strength loss of recycled aggregate concrete may attribute to the better interfacial bond due to rough surface of recycled aggregate and more than natural aggregate concrete.

AGGREGATE

The term "aggregate" is used to described the gravel, crushed stone and other similar materials which are mixed with cement and water to make concrete. As aggregate form the bulk of volume of concrete, the selection for suitable aggregate is important. Gravel sand and crushed stone, such as a granite basal and other hardener types of limes stone and sand are used in aggregate. Aggregate containing organic materials makes poor concrete (Dordi, 1995). The types of aggregate used in producing concrete are fine and coarse aggregate.

Aggregates are widely used as a base material for foundations and as an ingredient in Portland cement concrete and asphalt concrete. While geological classification of aggregates given insight into the properties of the material the suitability of a specific source of aggregates for a particular application requires testing and evaluation.

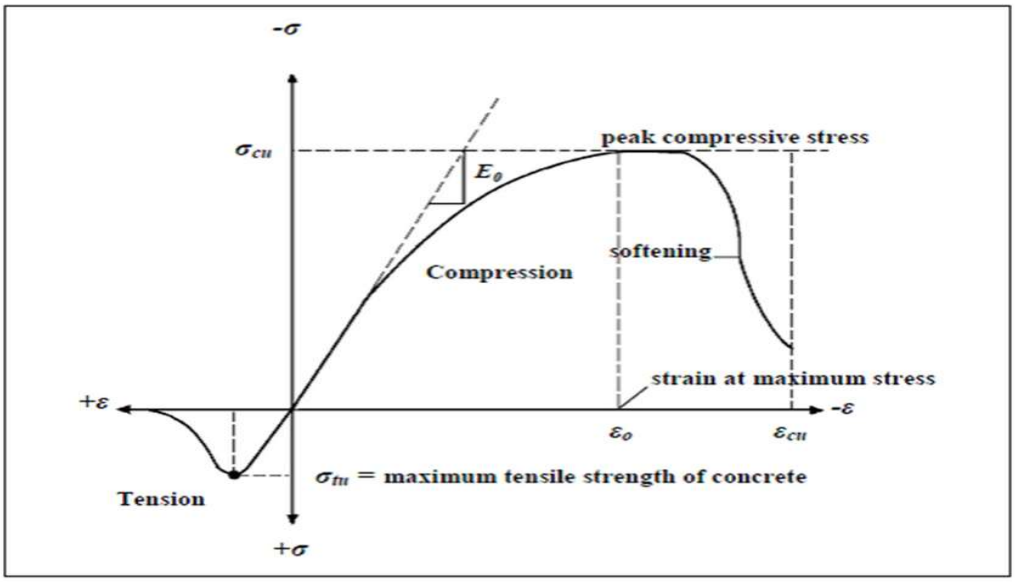

Fig 1: shows a Typical strain –stress curve for a concrete block.

COMPACTION

Concrete should be thoroughly compacted during the operation of placing and worked round reinforcement or embedded fixtures and into corners of the form work. If the concrete is in adequately compacted by rodding tamping, vibration, rolling or pressure air voids will remain in hardened concrete. These void are in excess of those due to water that is not needed for hydration. Compaction may be carried out manually or by mechanical vibration which ever method, it is necessary to ensure that the concrete is fully compacted.

Xie*et al.,* (2022) presented the preparation technology of high strength self-compacting concrete (SCC) containing u33333ltrapulverise fly ash (UPFA) and super plasticizer (SP). Various parameters of concrete were selected namely good workability high mechanical properties and high durability and SCC was developed.

Khatib (2018) investigated the properties of self-compacting concrete prepared by adding fly ash (FA). FA was used as a replacement for Portland cement (PC). PC was replaced 0 – 80% by fly ash.

Table 1: Shows Small Specimen Size for Testing the Compressive Strength of Masonry

FACE SIZE UNIT			HEIGHTS	Thickness
I (mm)	Hu(mm)	length	>5hu	>tu
<300	<150	>(2xIu)	>3hu	
>300	>150	<(1.5xIu)		?3

CURING

Curing of concrete is pre-requisite for the hydration of the cement content. For a given concrete the amount and rate of hydration and the physical make-up of the hydration product depended on the time, moisture, temperature and history. Generally, the longer the period during which concrete is kept in water the greater its final strength provided there are no impurities in the water. Plastic shrinkage normally occurs while concrete is still wet. Preventing rapid drying of the surface of concrete and adopting good curing practices are some of the precautions against plastic shrinkage cracking (Sivakumar and Manu, 2017). 3The most effective technique of overcoming plastic shrinkage cracking is by preventing the loss of water from the concrete surface by extended curing. The concrete curing duration also affects the development of shrinkage cracking (Sharon Huo and Ling, 2020).

MATERIALS AND METHOD

MATERIALS

CEMENT

Ordinary Portland cement (OPC) was use in this research. The cement brands were made by Dangote Cement. Cement Portland, cements are hydraulic cement that is they set and harden by reacting with water to form a paste. The paste is usually composed of Portland cement, water and entrapped air or purposely entrained air. The paste ordinarily constitutes about 25% to 40% of the total volume of concrete. Cement production process are generally distinguished into wet process semi-wet process, semi-dry and lopal process and dry process. A cement is a binder material 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 together. Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete mortar, stucco and non-specialty ground. It was developed from other types of hydraulic lime stone.

FINE AGGREGATE

The fine aggregate used in this research was naturally occurring clean river sand obtained from local suppliers, fine and coarse. Fine aggregate consists of natural or manufactured sand with particles size ranging up to 10mm. fine aggregates generally consist of natural sand or crushed stone with most particles passing through a $^{3}/_{8}$-inch sieve. Coarse aggregates are any particles greater than 0.19 inch, but generally range between $^{3}/_{8}$ and 1.5 inches in diameter. The fine aggregates to be investigated in this study is to begin as raw sand which is strip mined by excavators and loader into haulers. Aggregate can be used as a surface application for projects ranging from horse stalls to pathways. Aggregate are essential components of concrete. They act as inert material in concrete.

COARSE AGGREGATE

The3 coarse aggregate used in this research was crushed granite which was also obtained from a local supplier. Coarse aggregate is those with particles retained on the 1.25mm sieve and ranging up to 150mm. the most commonly used maximum aggregate size is 20mm. since aggregate make up about 60% to 75% of the total volume of concrete, their selection is important. Aggregate should consist of particles with adequate strength and resistance to exposure conditions and should not contain materials that will cause deterioration of the concrete Aggregate is mixed with cement to form concrete that is used to lay foundation of a road or even a roof in a building.

WATER

Water should be clear and free from impurities (sulphates and chlorine). For any particular set of materials and condition of curing, the strength of hardened concrete is determi33ned by the amount of water, but in the concrete. The advantages of adjusting the water cement ratio are:

- Increased compressive and flexural strength.
- Lower permeability thus increased water tightness and lower absorption.
- Increased resistance to weathering
- Less volume changes from wetting and drying
- Reduced shrinkage cracking tendencies.
-

CONCRETE MIX DESIGN

Concrete mix design is defined as the process of selecting suitable ingredients of concrete and determines their relative proportions with the objective of producing concrete of certain minimum strength and durability as economically as possible.

Concrete mix design consists of selecting the correct proportion of cement, fine and coarse aggregates and water, which on combination and through mixing produces concrete having the specified properties. Natural gravel and sand are usually dry or dredged from a pit river, lake or sea bed. Naturally occurring concrete aggregates are a mixture of rocks and minerals

ESULTS AND DISCUSSIONS

RECYCLING OF CONCRETE

Recycling of concrete involves breaking, removing and crushing concrete from an existing old structure/building into a specific size and quantity/Production of recycled concretes b begins at the demolition site. Broken concrete in large size are called concrete rubbles. the concrete rubble is thereafter crushed into materials with specific size and quality is known as recycled aggregates and are use as fresh aggregates

The following tests would be conducted for the recycled concrete which includes:

- Unit weight
- Specific gravity
- Absorption capacity
- F.M value
- Compressive strength test.

The following materials are required for the processing and manufacturing of the cubesL

A) for natural aggregate concrete
   i. Cement
   ii. Fine sand
   iii. Coarse aggregate (granite)

iv. Water

B) For recycled aggregate concrete
   i. Cement
   ii. Recycled sand (retained at 2.36 B. S sieve)
   iii. Recycled coarse aggregate retained at

C) For recycled aggregate concrete with replaced percentage
   i. Cement
   ii. Recycled sand
   iii. Coarse aggregate
   iv. Water

CEMENT

Cement is a binder, a substance used for construction that sets, harden and adheres to other materials to bind them together. Ordinary Portland cement was used in this work, the brand used for casting the cubes Dangote cement the cement was obtained in the market from a local distributor. The cement is a hydraulic cement, it has the character of hardening and setting under water.

The absolute volume (i.e. it specifically means the actual space occupied with granular solids like cement and aggregate) of cementing materials is usually between 7% to 15% and the water between 14% and 21% respectively.

FINE AGGREGATE

Fine aggregate is defined as rock particles with diameter less than 4.75mm, usually called sand, fine aggregate generally consist of natural sand and crushed stone. The fine aggregate used in this research was naturally occurring, clean river sand. a representative sample was taken and sieve analysis was conducted to determine the percentage passing, BS test sieve which was used to carry out our mix for casting of the concrete cube.

COARSE AGGREGATE

Coarse Aggregate is the portion of concrete which is made up of the larger stone embedded in the mix. Concrete contain three ingredients; water, cement, and aggregate. The coarse aggregate used in this research work was crushed granite, which was also obtained from a local supplier. The most commonly used minimum aggregate size is 20mm. Aggregate should contain materials that will not cause deterioration of concrete. A continues gradation of particles size is desirable for efficient use of the paste.

WATER

Water should be clear and free from any impurity for any particle set of materials and condition of curing the strength of hardened concrete is determined by the amount of water cement ratio.

RECYCLED COARSE AGGREGATE

The recycled coarse aggregate was gotten from the laboratory i.e. crushed concrete cube in the laboratory which we crushed them using mortar and pestle and carryout sieve analysis. The aggregate pass through MM sieve and retained at the aggregate was washed to make it clean from dirties and also dry under normal room temperature.

RECYCLED SAND

Recycled sand was also gotten from the laboratory. Concrete cubes and sandcrete blocks were being crushed and sieved using MM sieve. It was and allowed to dried under normal temperature of the room. While the recycled aggregate in the concrete with replaced sand was gotten from a demolished site. It was crushed, sieved and also was led so as to get rid of the leaves, stick and other materials which can affect the strength of the concrete.

PROCEDURE FOR CASTING CONCRETE CUBES

1. Batching is making of the constituent materials
2. Dry mix
3. Wet mix
4. Placing
5. Compacting
6. Firming
7. Demolding after 24 hours
8. Immersion in curing tank

1. Clean the concrete cube mold and apply oil in the inner part of the mold.
2. Take an amount of the sample from the mix, while concreting, pour concrete in the cube in 3 layer.
3. Compact each layer with 25 number of strokes with the tamping rod.
4. Finish the top surface trowel after compacting of the proposed concreting.
5. Each specimen should be taken from different location of the proposed concreting.
6. After 24 hours, remove the specimen from the mold.
7. While removing, take care to avoid breaking of the edges.
8. Code the cube with point or marker.
9. Submerged the specimen in clean fresh water until the time testing.
10. Test 3 specimen for 7 days, 3 specimens for 14 days, and 3 specimens for 21 days curing.
11. Write the details of the cube and the data clearly. TABLE 3.0 SHOWS COMPRESSSIVE STRENGTH OF CONCRETE BLOCK UNITS

specimens	Failure load (KN)	Compressive strength N/mm²	Mean compressive strength N/mm²
A	475	10.8	12.8
B	508	11.5	
C	637	14.5	

Table 2: shows the concrete blocks compressive strength

TYPE OF PRISM	Dimensions	Compressive strength	Characteristic compressive strength
Concrete blocks rectangular wallets	**670 x 98 x 690** **670 x 98 x6885** **670 x 98 x 68586**	**7.0** **9.3** **9.78.7**	**7.2**

CONCLUSION

The compressive strength of masonry unit is 12.8 N/mm² while the compressive strength of mortar was 4.2 N/mm² where it shows that the compressive strength of the mortar determined experimentally fulfills the requirement of its definitions while the compressive strength of mortar was 4.2 N/mm² .it is suggested that the testing modulus of elasticity of masonry strains in transverse direction should be measured in order to determine the poison ratio of masonry. The failure loads of the mortar were in the range between 39.5KN and 45.9KN while the area of the applied load was 1000mm² and the mean compressive strength of the mortar was 4.2 N/mm² where the range was 4.0 and 4.3 N/mm².

The evaluation of the RCA is becoming increasingly a very good option for sustainability and environmental friendliness. The prerequisites engineering properties of both RCA and virgin aggregates was examined to showcase the benefits of each viz viz the existing exigencies of scares natural resources. The observation and analysis of data from experiment was carried out on the concrete cubes with recycled sand (i.e. some percentage replacement) is stronger than the recycled concrete cube with recycled sand and recycled coarse aggregate.

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