International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 3, Number 3, September 2018
http://www.casirmediapublishing.com

# ANALYSIS AND COMPARISON OF STRENGTHS AND WORKABILITY OF VIRGIN AND RECYCLED CONCRETE CUBES

**Gana A.J & Oladapo E.P.**

Department of Civil Engineering, Collage of Science and Engineering
Landmark University, Omu-Aran, Kwara state
**Emails:** doctorgana@yahoo.com, phildebo123@gmail.com

## ABSTRACT

This study access the reduction and use of rubble concrete cubes from concrete laboratories, to ensure sustainability which is environmental friendly by concrete recycling which involves the comparison of the strength and workability of virgin and the recycled concrete. Data from developed countries have been obtained and all over developing countries but this report examine the data from North central region of Nigeria specifically Omu Aran, head quarter of Irepodun local government area, Kwara state, Nigeria. Both constructive and destructive tests such as cubes crushing test and Schmidt hammer test are carried out. The slump value for virgin concrete is 280mm and for recycled concrete is 285mm. partially compacted virgin concrete is 11.3kg, fully compacted virgin concrete is 12.5kg and partially compacted recycled concrete is 11.0kg, fully compacted recycled concrete is 12.3kg. Result shows that recycled concrete possess more compressive strength compared to virgin concrete and both are workable as recycled concrete consumes more water to attain desired workability. This study is limited to compressive strength, recommendation for further research is required on the comparison of the flexural strength and workability of virgin and the recycled concrete.

***Keywords: Strength, workability, virgin, recycled, concrete, cubes.***

## INTRODUCTION

Materials used in Engineering which ranges from steel to composites and many more are basically employed because of their performance and easy accessibility for engineering works. In time past, the performance was initially analyzed based on the technological development without so much concern for the impact on the environment. Engineering performance of materials are no longer analyzed and measured on account of technological specifications alone, but also on the basis of their effect on the environment (NJEM, 2005). In recent years, the effect on the environment is just as important as the scientific requirements to ascertain the performance of the material. In Canada, the Canadian Environmental Protection Act, 1999 (CEPA 1999) is the primary element of the legislative framework for protecting the Canadian environment and human health. In Canada, each level of government has powers to protect the environment. (Napier, 2016. Therefore, materials performance in Engineering projects is now determined based on the sustainability, that is;

1. It should be obtainable whenever it is needed for use.
2. Require the minimum time or resources necessary for efficiency and effectiveness.

3. Its effect throughout the lifespan of the design must not lead to an undesirable state.
4. Can be produced as residue-free as possible, i.e. produced poor in waste. Also has a future, multi material reuse at a high technical level that is as complete and ecologically meaningful as possible (NJEM, 2005).

One of the most efficient ways to ensure sustainability is by a process called Recycling, it involves the act of processing used or abandoned materials (waste) for use in creating new products. Construction industry produces huge deposition of materials (construction and demolition materials) year in year out. Construction and demolition (C&D) waste is a central component of the solid waste stream, amounting to roughly 25 percent of total solid waste nationally (LeBlanc, 2016), re use of construction and demolition materials is a major concern to ensure sustainability all over the world, this materials are divided into two groups; the inert and non-inert. The inert materials includes broken concrete, tiles, rock and sands. The non-inert materials includes timber, plastic, steel and so on. The largest part of C&D material is concrete, which encompasses around 40 to 50 percent of C&D generated material (LeBlanc, 2016). Like it was stated earlier, recycling is one of the prominent and vital ways of reducing waste compilation (in this case, unused construction and demolition materials being dumped).

For inert materials, it serves as filling material for conversion of wastelands into land suitable for construction works. Most construction and demolition waste currently generated in the U.S. is lawfully destined for disposal in landfills regulated under Code of Federal Regulations (CFR) 40, subtitles D and C (Napier, 2016). The only problem with this is that the left over concrete take up space as a non-biodegradable material (Braen, Recycled concrete aggregate, 2016). Moreover, recycling has been the dominant course of successive event and ideas occurring in present times. In recent years, professionals have learned that recycling old concrete is actually beneficial for everyone involved – including the environment (Braen, Recycled concrete aggregate, 2016). Many countries are giving infrastructural laws relaxation for increasing the use of recycled aggregate (from broken concrete), the application of recycled aggregate has been started in a large number of construction projects of many European, American, Russian and Asian countries (sonawane). Recycled concretes are in two forms:
(1) Recycled concrete Aggregate (RCA)
(2) The remaining portion is referred to as Fine recycled concrete Aggregate.

According to (Mayuri Wijayasundara, 2017), the use of recycled concrete aggregate replacing natural aggregate (NA) to produce concrete has gained importance in the last decades, mainly due to the advantages associated, with it such as:

(1) Opening up the possibility to provide a sustainable end use to the concrete waste (CW) in the construction and demolition (C&D) waste stream

(2) Providing a solution to NA scarcity and/or having to source NA from long-distance sources

(3) Conservation of natural resources.

Considering these advantages, several investigations have been carried out recently to explore the use of recycled concrete aggregate as a constituent material in concrete (RCA-C) and to determine the level of performance/applications of the resultant concrete, referred to as recycled aggregate concrete (RAC). More specifically, use of recycled concrete aggregate in structural concrete.

## Statement of Problem

It is necessary to conduct practical test and see how feasible concrete recycling really is, if the resources required for the process is not extravagant and the property of the recycled concrete cube is worth it and this involves checking the performance of the recycled concrete against that of the virgin concrete cube (freshly made). This project and research work focus on obtaining and discovering benefits and advantages of recycled concrete cube to virgin concrete cube and vice versa in the north central region of Nigeria, specifically, Omu-Aran, Kwara state, Nigeria by comparing the strength and workability of the recycled concrete cube and virgin concrete cube.

## Aim and Objectives

The aim of this study is to analyse and compare the strengths and workability of virgin and recycled concretes cube. The objectives is as follow:

1. Determine the potential of recycled concrete cube by comparing the strength and workability of the recycled concrete cube and virgin concrete cube.
2. Explain the differences in the workability and strength of recycled concrete cube and virgin concrete cube.
3. Spread detail extensive knowledge of the potential of recycled concrete cube to the general public.
4. Obtain the compacting factors and slump values for recycled and virgin concrete cube to analyse their workability.

## Scope of Study

This study of comparison of strengths and workability of recycled and virgin concrete cube involves determining the properties and behaviour of the stipulated materials. Test will be carried out to obtain this qualities and behaviour, which includes;

Compressive strength of recycled concrete cube
Compressive strength of virgin concrete cube
Effect of cement mix ratio
Effect of Curing days (7, 21, 28)
Size of aggregate
Type of aggregate used
The test will be carried out in civil Engineering laboratory of Landmark University, Omu Aran, Kwara state.

### Justification or Significance of Study

Construction and Demolition materials possess serious environmental problem in Nigeria, used concrete test cube contributing massively to this. Maximizing waste produce C&D materials (concrete test cube) in order to reduce enormous use of virgin concrete which has resulted in the increase of cost of the constituent materials due to high demand. Recycled concrete cube will serve as a means of using the waste, which ensure preservation of the environment and serves as an alternative to the use of virgin concrete for construction

## LITERATURE REVIEW

### Background of Study

**Figure 2.1 Disposed Concrete (Braen, 2015).**

When concrete cubes, pavements and structures are torn down or excavated, the rubble becomes waste. This is, unless, the concrete is taken to a recycling plant. In an effort to reduce the amount of raw materials needed to produce stone aggregate, industry experts have realized the value in breathing new life into old concrete. The materials are thoroughly screened in order to remove any metal, scrap or other impurities. It is then crushed down to a smaller aggregate size so that it can be repurposed for other construction and landscaping purposes (Braen, 2015). The reprocessed concrete is known as Recycled concrete. The challenge with recycling is to combine strict environmental controls with cost-efficient method to make recycling an economically viable proposition. Materials such as asphalt, concrete, brick and natural stone from infrastructure and building demolition can be both an environmentally responsible resource and a cost-effective option to virgin rock material production. Recycled aggregate can replace or supplement many of the materials currently used in construction around the world. The right preparation is a cornerstone of successful recycling. This demands thorough understanding of the materials and processes in order to ensure a quality end product and avoid damage to equipment. Concrete can be processed using crushing and screening to produce cement bonded base course, aggregate materials for new concrete production or high-quality trench fillers/drainage course material (Construction, 2017).

## Common Use of Recycled Concrete

A typical demolition job will result in quite a bit of concrete. This salvaged concrete can then be crushed, recycled and reused in other projects. According to Dtwreckit (2017):

### (1) Road base

Before a road can be paved, a structural foundation has to be laid. Recycled aggregate concrete is an ideal material for this use. A road base is both the most accepted use of recycled concrete recognized by the Department of Transportation and simplest use of the material.

### (2) Ready Mix Concrete

By mixing cement with sand and water, a new material can be formed that's ready to be poured and formed into a new structure. While this use for recycled concrete hasn't been widely adopted yet, more and more recyclers are attempting it. In many ways, ready mix concrete is a similar use for concrete aggregate as new asphalt pavement, which replaces virgin aggregate with recycled materials. The ready mix is used for construction of structural members such as columns, retaining wall etc.

### (3) Soil stabilization

In construction projects or environmental rehabilitations, soil stabilization is often necessary in order to improve the load bearing capabilities of slopes in the area. Recycled concrete aggregate can be added to the soil in addition to fly ash to stabilize it. This also enables the slope to withstand water erosion. In many cases, concrete can be recycled on-site and reused in this manner on the same project.

**(4) Pipe bedding**
Similarly to acting as a base layer for road construction, recycled concrete can also be used as the bed for underground utilities. Again, recycled aggregate is an alternative for virgin aggregate and much more cost effective in most cases.

**(5) Landscaping**
With a little creativity, recycled concrete can be reused as landscape features to improve the look of a home or commercial building. Anything from crushed aggregate to large boulders has been added to landscaping. These can be purely ornamental or serve a purpose such as a retaining wall, erosion structure or underpass abutment. The uses of recycle concrete are nearly limitless and this material often offers a cheaper alternative without sacrificing quality.

Notre Dame engineering professor Yahya Kurama says, because concrete has a huge carbon footprint that's a problem for the environment. "It's very intensive in terms of its demands on energy, water, land space, everything." Producing concrete accounts for 5 percent of the world's annual human generated $CO_2$ emissions. In the U.S., it is along with other demolished building materials takes up nearly half of all landfill space. To reduce such harm, the industry has concentrated on things like reducing new concrete production and finding new uses for concrete by products. In the United States, recycled concrete is used in sidewalks and roads, but not for load-bearing structures. Kurama and his team, along with scientists from the University of Texas at Tyler and New Mexico State University, set out to determine whether it was strong and durable enough to be used to construct buildings. "Currently there's a lot more supply of recycled concrete aggregates than demand," he pointed out. "What we're trying to do is bring up the demand and at the same time generate the engineering background that these materials can be used in a higher-level application" (Celeste, 2016).

## Conditions That Influence Concrete Strength

Concrete strength is affected by many factors, such as quality of raw materials, water/cement ratio, coarse/fine aggregate ratio, age of concrete, compaction of concrete, temperature, relative humidity and curing of concrete. According to Theconstructor website (2017):

**1. Quality of Raw Materials:**

**Cement:** Provided the cement conforms with the appropriate standard and it has been stored correctly (i.e. in dry conditions), it should be suitable for use in concrete.

**Aggregates:** Quality of aggregates, its size, shape, texture, strength etc determines the strength of concrete. The presence of salts (chlorides and sulphates), silt and clay also reduces the strength of concrete. **Water:** frequently the quality of the water is covered by a clause stating "..the water should be fit for drinking..". This criterion though is not absolute and reference should be made to respective codes for testing of water construction purpose.

**2. Water / Cement Ratio:**

The relation between water cement ratio and strength of concrete is shown in the plot as shown below:

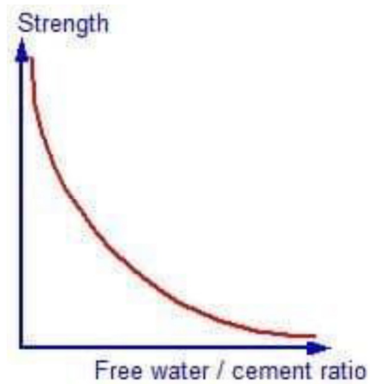



**Figure 2.2 Strength, Water Cement Ratio Slope (Constructor, 2017).**

The higher the water/cement ratio, the greater the initial spacing between the cement grains and the greater the volume of residual voids not filled by hydration products. There is one thing missing on the graph. For a given cement content, the workability of the concrete is reduced if the water/cement ratio is reduced. A lower water cement ratio means less water, or more cement and lower workability. However if the workability becomes too low the concrete becomes difficult to compact and the strength reduces. For a given set of materials and environment conditions, the strength at any age depends only on the water-cement ratio, providing full compaction can be achieved.

**3. Coarse / fine aggregate ratio:**

Following points should be noted for coarse/fine aggregate ratio:

i. If the proportion of fines is increased in relation to the coarse aggregate, the overall aggregate surface area will increase.

ii. If the surface area of the aggregate has increased, the water demand will also increase.

iii. Assuming the water demand has increased, the water cement ratio will increase.

iv. Since the water cement ratio has increased, the compressive strength will decrease.

**4. Aggregate / Cement Ratio:**

Following points must be noted for aggregate cement ratio:

i. If the volume remains the same and the proportion of cement in relation to that of sand is increased the surface area of the solid will increase.

ii. If the surface area of the solids has increased, the water demand will stay the same for the constant workability.

iii. Assuming an increase in cement content for no increase in water demand, the water cement ratio will decrease.

iv. If the water cement ratio reduces, the strength of the concrete will increase.

The influence of cement content on workability and strength is an important one to remember and can be summarized as follows:

i. For a given workability an increase in the proportion of cement in a mix has little effect on the water demand and results in a reduction in the water/cement ratio.

ii. The reduction in water/cement ratio leads to an increase in strength of concrete.

iii. Therefore, for a given workability an increase in the cement content results in an increase in strength of concrete.

**5. Age of concrete:**

The degree of hydration is synonymous with the age of concrete provided the concrete has not been allowed to dry out or the temperature is too low.

In theory, provided the concrete is not allowed to dry out, then it wil always be increasing albeit at an ever reducing rate. For convenience and for most precycled aggregate concretetical applications, it is generally accepted that the majority of the strength has been achieved by 28 days.

**6. Compaction of concrete:**

Any entrapped air resulting from inadequate compaction of the plastic concrete will lead to a reduction in strength. If there was 10% trapped air in the concrete, the strength will fall down in the range of 30 to 40%.

**7. Temperature:** The rate of hydration reaction is temperature dependent. If the temperature increases the reaction also increases. This means that the concrete kept at higher temperature will gain strength more quickly than a similar concrete kept at a lower temperature. However, the final strength of the concrete kept at the higher temperature will be lower. This is because the physical form of the hardened cement paste is less well structured and more porous when hydration proceeds at faster rate.

This is an important point to remember because temperature has a similar but more pronounced detrimental effect on permeability of the concrete.

**8. Relative humidity:**

If the concrete is allowed to dry out, the hydration reaction will stop. The hydration reaction cannot proceed without moisture.

**9. Curing:**

It should be clear from what has been said above that the detrimental effects of storage of concrete in a dry environment can be reduced if the concrete is adequately cured to prevent excessive moisture loss.

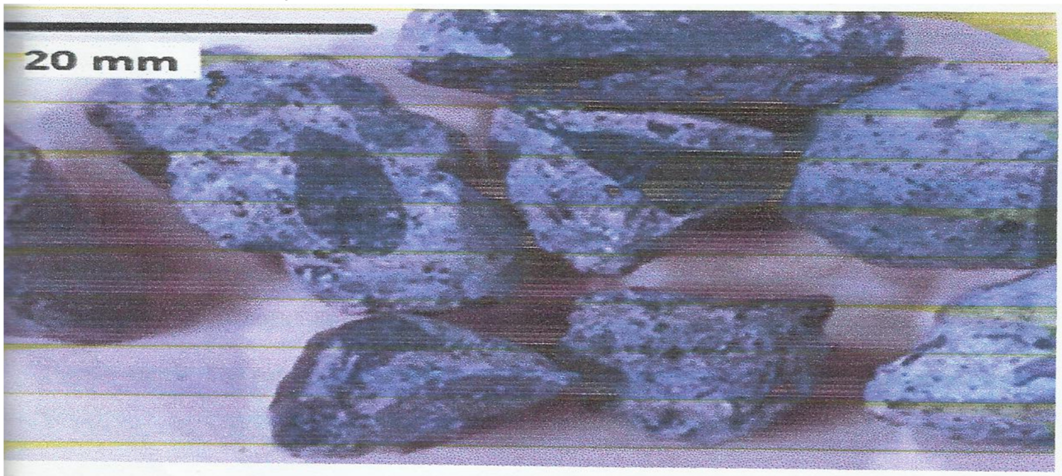
**10. Weather condition:**

Increased water temperature, either at mixing stage or during curing, increase the speed of strength gain of concrete. In colder climates, outer concrete is exposed to freeze-thaw cycles which are damaging. Freeze-thaw deterioration is a serious threat to concrete durability. All materials expand and shrink with changes in temperature and moisture content. Excessive contraction can cause concrete to crack. The cracks in concrete then allow moisture to penetrate and the cruel cycle of deterioration starts (blog.ofbusiness.com, 2016).

## Properties of Concrete Containing Recycled Concrete Aggregate of Preserved Quality

The study focuses on evaluating recycled concrete aggregate (RCA) of high quality produced through a protocol that preserves the original properties of the concrete to be recycled. The depletion of virgin aggregate sources has become a widespread issue. This has brought forth a need for an alternate aggregate source. In recent years, research into recycling concrete has gained considerable attention. Through continuous cycles of rehabilitation, renovation, and demolition, there has been an accumulation of concrete waste. Recycled concrete aggregate also has an effect on the fresh properties of concrete. The greater angularity, surface roughness, absorption and porosity contribute to the decrease in workability of fresh recycled concrete aggregate concrete. The rapid loss in workability can be attributed to the increase in fines during the mixing process. As the mixing drum continues to rotate the residual mortar in recycled concrete aggregate can be broken down or chipped away to create more fines. Recycled concrete aggregate can be broken down or chipped away to create more fines (M. Safiuddin, 2011). An interfacial transition zone (ITZ) exists in concrete consisting of virgin aggregate which is known as a weak plane within the matrix of the concrete. This zone contains a slightly higher water-to-cement ratio (w/c) than the rest of the concrete (K.L. Scrivener, 2004). Concrete incorporating recycled concrete aggregate has two interfacial transition zones: one between the original aggregate and the residual mortar and one between the recycled concrete aggregate and the fresh paste (Ryu, 2002). A two stage mixing approach (TSMA) has been used to improve the interfacial transition zone between recycled concrete aggregate and the new cement paste. The TSMA, developed by Tam, Gao and Tam divided the mixing process into two stages where half the mixing water is mixed first with the aggregates, and the second half is added after with the rest of the ingredients (V.W. Tam, 2005).

International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 3, Number 3, September 2018
http://www.casirmediapublishing.com




This Figure 2.3 sample Of Recycled Concrete Aggregate with Preserved Quality Produced in the Study (Jonathan Andal, 2016)

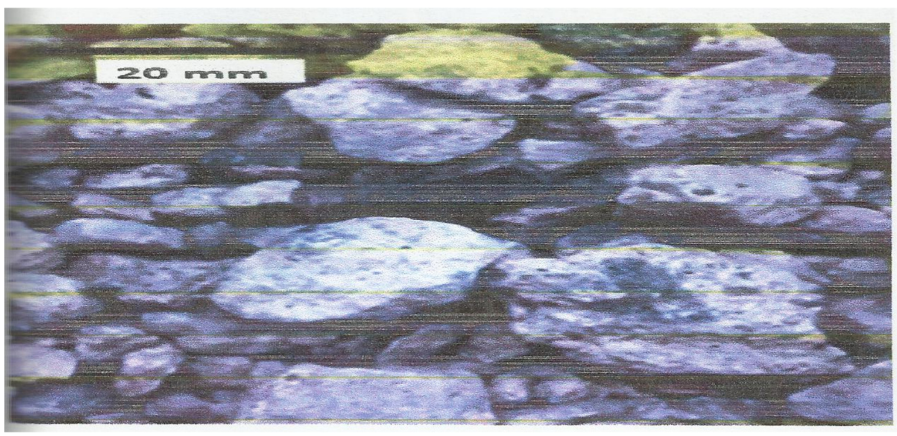



Figure 2.4: A Close-Up Of The Preserved-Quality Recycled Concrete Aggregate Produced (Jonathan Andal, 2016

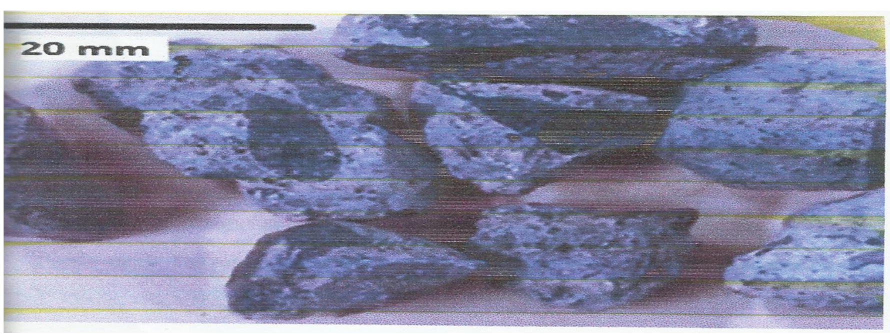



**Figure 2.5: A Close – Up of the Commercial Recycled Concrete Aggregate in the Study (Jonathan Andal,** 2016)

## Compressive Strength

A comparison between the effects of recycled concrete aggregate with preserved quality and commercial recycled concrete aggregate was performed using the results of the c2 concrete. The use of commercial recycled concrete aggregate further decreased the compressive strength. This can be attributed to the lower quality of residual mortar surrounding the original aggregate, as indicated by micro-deval and residual mortar tests presented earlier. The use of 30% ground granulated blast-furnace slag showed no measurable effect on the compressive strength. The compressive strength results of 15-mpa and f1-concrete incorporating recycled concrete aggregate with preserved quality are listed in tables 8 and 9. The samples in each category passed the 28-day requirements of 15 mpa and 30 mpa, respectively. Both classes of concrete exhibited a decrease in compressive strength with the increase in the amount of recycled concrete aggregate replacement. while the use of 100% recycled concrete aggregate resulted in some reduction in the strength, the use of 30% recycled concrete aggregate as partial replacement of coarse aggregate

The main objective of the study was to find out if the quality of concrete containing coarse recycled concrete aggregate can be enhanced by adopting certain procedure or protocol that aims at producing recycled concrete aggregate of high quality. To achieve this objective, the fresh, hardened, and durability properties of concrete incorporating two types of recycled concrete aggregate, a commercial recycled concrete aggregate and an recycled concrete aggregate produced using the adopted protocol were evaluated and compared to control concrete with virgin aggregate. The preserved-quality recycled concrete aggregate used here was produced using the adopted quality control protocol. The results and analysis have indicated that the recycled concrete aggregate with preserved quality performed better compared to the commercial recycled concrete aggregate in all tests. A comparison between the effects of preserved-quality recycled concrete aggregate and commercial recycled concrete aggregate on different properties of c2 concrete. The commercial recycled concrete aggregate proved to produce concrete of lower strength compared to the recycled concrete aggregate with preserved quality. This was evident since the concrete with 100% commercial recycled concrete aggregate did not satisfy the 32 mpa requirement after 28 days. The samples containing recycled concrete aggregate with preserved quality also experienced less drying shrinkage and less variability. At a 100% replacement, concrete with commercial recycled concrete aggregate exhibited 12% more drying shrinkage than concrete with preserved-quality recycled concrete aggregate. Through visual inspection and the mass loss results of the salt scaling test, it was evident that concrete with commercial recycled concrete aggregate exhibited more scaling compared to concrete containing recycled concrete aggregate with preserved quality. Compares the mass loss of the concrete

samples containing commercial recycled concrete aggregate to those containing recycled concrete aggregate with preserved quality after 50 freeze-thaw cycles. A one-tailed t-test was performed on the results obtained for both types of recycled concrete aggregates to confirm whether or not the difference between performance of commercial recycled concrete aggregate and preserved-quality recycled concrete aggregate is statistically different. The p values reported confirm that preserved-quality recycled concrete aggregate produced concrete of significantly better properties compared to commercial recycled concrete aggregate except for splitting tensile strength where the results were not significantly different. In addition, the results showed that a 30% replacement of recycled concrete aggregate with preserved quality produced concrete that was comparable to that produced with virgin aggregate. It is feasible to enhance the protocol used to produce recycled concrete aggregate. For instance, separating the returned-to-plant concrete based on air-entrainment would produce recycled concrete aggregate with an increased resistance to salt scaling (Jonathan Andal, 2016). In general, according to Jonathan Andal (2016) one can argue that possible reasons for the enhanced performance of preserved-quality recycled concrete aggregate compared to commercial recycled concrete aggregate are:
(1) lower amount of adhered mortar in preserved quality recycled concrete aggregate compared to commercial recycled concrete aggregate, and/or
(2) Mortar of better quality in preserved recycled concrete aggregate. In terms of amount of residual mortar, the results of the residual mortar test showed no significant difference between mass losses of the two recycled concrete aggregates after 10 cycles. Visual inspection after 10 cycles showed both.
The following conclusions are drawn based on the findings of this study according toJonathan Andal (2016) :

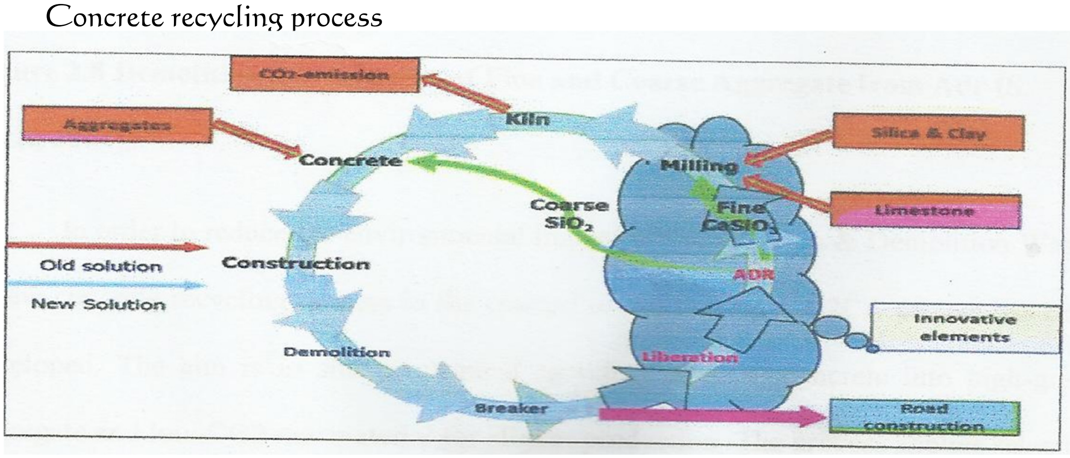
1. A recycled concrete aggregate production protocol that preserves the original quality of the returned concrete was adopted and found to produce recycled concrete aggregate of higher quality than commercially available recycled concrete aggregate. The main elements of the protocol were to separate returned concrete based on strength and eliminate or minimize the addition of water while discharging the returned concrete from the transit mixers.
2. The slump retention results indicated that it is feasible to produce recycled concrete aggregate-concrete of adequate workability and workability retention.
3. Compressive strength tests indicated that an increase in the amount of recycled concrete aggregate in the mix resulted in a decrease in compressive strength. However, concrete made with preserved-quality recycled concrete aggregate showed higher strength when compared to the same grade of concrete containing commercial recycled concrete aggregate. The same conclusion applies to splitting tensile strength.

4. Drying shrinkage testing showed that an increase in the amount of recycled concrete aggregate resulted in an increase in drying shrinkage. Concrete with commercial recycled concrete aggregate experienced significantly more shrinkage compared to concrete with preserved-quality recycled concrete aggregate. The addition of 30% ground granulated blast-furnace slag had a minimal effect on drying shrinkage.
5. All salt scaling concrete samples which contained the right amount of entrained air were able to satisfy the 0.8 kg/m2 mass loss requirement. However, an increase in the amount of recycled concrete aggregate increased salt scaling. Concrete with commercial recycled concrete aggregate samples exhibited significantly more mass loss compared to concrete containing preserved-quality recycled concrete aggregate. Page | 21
6. Commercial recycled concrete aggregate similar to that used in this study is best suited for use in applications with no stringent requirement for drying shrinkage and salt scaling.
7. Using preserved-quality recycled concrete aggregate at 30% partial replacement of coarse aggregate was found to produce concrete of performance similar to that of concrete with virgin aggregates.

## Review of Performance of Recycled Aggregate Concrete Based on a New Concrete Recycling Technology

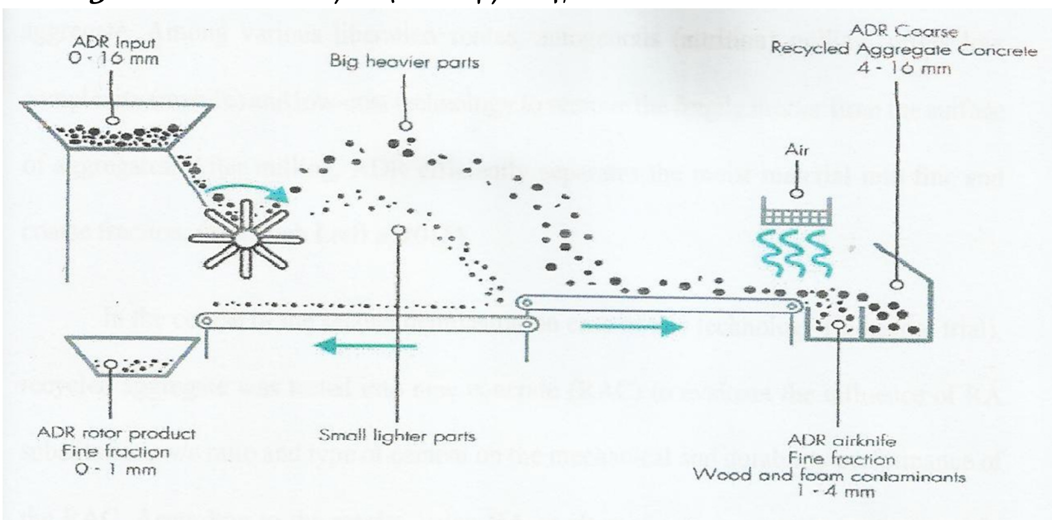
By recycling part of the concrete fraction of C&DW into high-quality construction materials like aggregate and cement for new concrete, it is possible to take advantage of the surplus of waste. There has been vast research to solve associated problems with End of Life (EOL) concrete (S. Ismail, 2013). However, it should be noticed that due to the low price of concrete also the overall cost of the recycling process, the implemented concrete recycling route should be economically beneficial and environmentally sustainable. A new technology of concrete recycling called C2CA (Concrete to Cement and Aggregate) aims at a cost-effective system approach for recycling high-volume EOL concrete streams into prime-grade aggregates and cement (S. Lotfi, 2014).

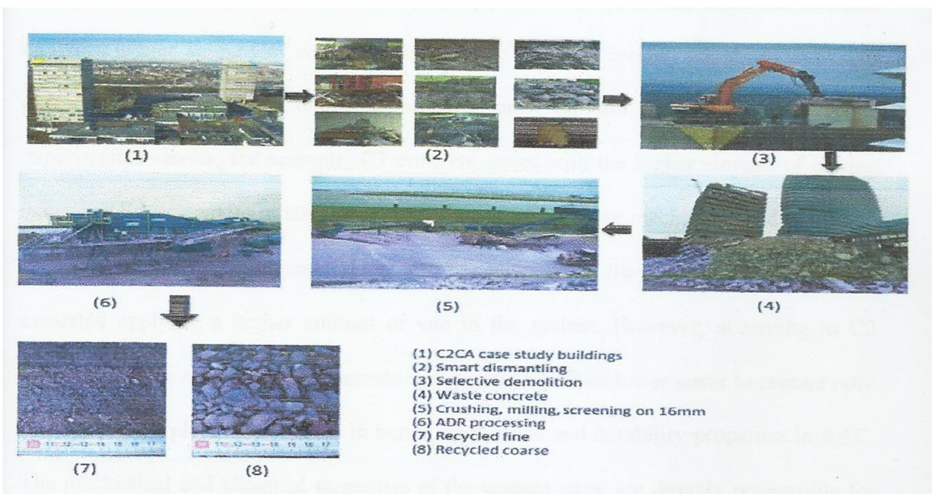
Concrete recycling process



International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 3, Number 3, September 2018
http://www.casirmediapublishing.com

Figure 2.6 concrete Cycle (S. Lotfi, 2014)




aggregate. Among various liberation routes, autogenous (attrition) milling, offers low complexity (mobile) and low-cost technology to remove the fragile mortar from the surface of aggregates. After milling, ADR efficiently separates the moist material into fine and coarse fraction. (Somayeh Lotfi a, 2015). In the course of the second demonstration case of this technology (industrial trial), recycled aggregate was tested into new concrete (RAC) to evaluate the influence of RA substitution, w/c ratio and type of cement on the mechanical and durability performance of the RAC. According to the results, using RA as alternative aggregate in concrete might increase the overall porosity of concrete compared to the reference concrete. Besides, applying higher amount of w/c by increasing the effective mixing water induces more porosity to the system that makes the situation more difficult. As it is observed in the experimental results, for example, C1 concrete series with the higher amount of mixing water and lower amount of strength shows in most cases worse mechanical and durability properties than the C2 concrete series. On the other hand, the adverse effect of RA is escalated applying a higher amount of w/c in the system. However, according to C2 concrete results, modifying the concrete mix design, based on lower water to cement ratio and using superplasticizer, results in better mechanical and durability properties in RAC. The mechanical and chemical properties of the cement paste are directly responsible for higher resistance of concrete under exposure to aggressive conditions. Thus, all durability properties can be influenced by the choice of cement and the amount of mixing water in the concrete mixture. Based on the C2CA concrete test program and the current situation in European standards and regulations it is concluded that RA is a suitable alternative to natural coarse aggregates for a significant share of concrete applications including structural applications. Replacing more than 50% if the coarse aggregate with recycled concrete (Somayeh Lotfi a, 2015)

## Review of Methodology for the Integrated Assessment on the Use of Recycled Concrete Aggregate Replacing Natural Aggregate in Structural Concrete

Acknowledging the potential of recycled concrete aggregate to be used as an alternative aggregate product and its endorsement through various research findings, the position on producing recycled aggregate concrete and its use in structural applications, against the conventional practice of using natural aggregate concrete is considered worthy of investigation. The aim of this study is to develop a methodology for an integrated assessment of the financial, social and environmental performance of recycled aggregate concrete compared to the existing use of natural aggregate concrete, so that a complete and a comprehensive comparison can be made. (Mayuri Wijayasundara, 2017). Factors evaluated in methodology for the integrated assessment on the use of recycled concrete aggregate replacing natural aggregate in structural concrete, according to Mayuri Wijayasundara (2017):

**1. Risks to public health**

The main difference in processes that would occur due to the Project Case is the increase of the concrete recycling operation and the reduction of natural aggregate quarrying and processing, assuming that the waste management operation at the demolition site does not change. Therefore, the risks to public health due to the Project Case can mainly be discussed from the perspective of incremental change due to concrete crushing and handling instead of natural aggregate rock quarrying, crushing and handling. The ultrafine particles resulting from concrete crushing, and fine dust clouds resulting in concrete crushing are considered more hazardous and penetrating than that resulting from natural aggregate rock. Exposure decay profiles have shown up to five times higher respiratory deposition compared to a typical car journey within 10 m of the source, while dustrespirators were found to remove half of the total particles. A comparison of dust generated with concrete recycling to natural aggregate rock crushing was not present in the literature. Equally, it is noted that explosives and chemicals containing heavy metals and hazardous compounds are required in quarrying and blasting operations, which imposes significant risks to occupational and public health. These two effects (incremental effect due to crushing concrete compared to natural aggregate rock and effect due to usage of explosives and chemicals in natural aggregate extraction) have limited information available for aquantitative evaluation.

**2. Employment creation/reduction**

The additional work generated in the RMC industry and concrete recycling industries due to manufacturing of a new product is considered to be negligible without detailed knowledge on work sharing and management possibilities, and considering the magnitude of change. The impact on the transport market is considered to be negligible, as transportation services for bulk materials are considered a commodity, and moving from the Base Case to the Project Case results in change in transportation requirements than a significant additional demand. With the reduction of quantities, underutilisation of resources is expected to occur in the natural aggregate quarrying and processing industries. Looking at the cost structure of the aggregate quarrying industry for 2012 to 2013, the depreciation amounted to 4.2%; while purchases including cartage, chemicals, cutting blades and explosives, amounted to 37.3%. Though the industry is capital intensive, the variable cost of production seems to be quite significant. When quarrying is avoided, the existing industry will be affected by reduction of production capacity, and hence will have underutilised capacity affecting their cost structure. It is argued that this would not result in social implications due to industry decline or employment reduction, based on the following grounds. Firstly, with the depreciation amounting to only 4.2%, and the variable cost of production being significant, the industry would be able to absorb and adjust to the effects of asset underutilisation with relative ease. Secondly, with the Project Case, there is a need to increase capacity for recycling of concrete waste, which has a similar process to aggregate processing. Assuming asset specificity in the natural aggregate processing industry to be negligible, intra-industry collaboration could result in matching of underutilised capacity in the natural aggregate processing industry to extra capacity required in the concrete recycling industry. Employment reduction in the natural aggregate processing industry can be assumed to offset the employment created in the concrete recycling industry, on the basis that the skills can be matched.

**3. Increase of knowledge capital due to education/technology transfer**

The Project Case is expected to result in novel practices employing novel practices and new technology in the areas of recycling concrete to produce recycled concrete aggregate as a constituent material, quality control of recycled concrete aggregate as a constituent material and production of recycled aggregate concrete. However, the innovation required for this considering the approach proposed in this paper (to use existing facilities and minimal change to existing processes) is identified by less significant, considering that the modifications are required for adaptation at commercial-scale, rather than technology innovations. However, further advancement of technology, knowledge capital and industry practices could be foreseen with other novel approaches to use recycled concrete aggregate in concrete where significant changes in the processes and technology are concerned, such as the use of material refinement techniques to reduce residual mortar in recycled concrete aggregate which have not been considered for the research. Under the current context, the social impact due to the use of current approach in terms of innovation is regarded as marginal.

In evaluating the use of recycled concrete aggregate replacing natural aggregate to use in structural concrete, the importance of the use of a framework and methodology to employ an integrated approach become evident. This is mainly due to the fact that evaluation of individual dimensions provide mixed outcomes, while interlinks remain among the dimensions. In order to converge a multi-disciplinary evaluation to provide a representative and conclusive result, cost-benefit analysis is suggested in this paper, with specific identification of the concept and framework to finally evaluate net present value as the main indicator. The following conclusions are made according to Mayuri Wijayasundara (2017):

1. In comparing the use of recycled concrete aggregate to manufacture recycled aggregate concrete, against the use of natural aggregate to produce natural aggregate concrete for structural concrete, the conclusions on material performance, environmental benefits and financial viability of the studies conducted so far do not make the choice of production of recycled aggregate concrete obvious with a significant advantage. The adaptation measures required for recycled aggregate concrete as a product using a recycled material seems to have a trade-off and the associated benefits, if existing are often identified to be marginal, when individual dimensions evaluated above are concerned.

2 A comprehensive, integrated evaluation methodology covering all concerned dimensions using the principles of sustainable development is suggested in this paper. The methodology uses cost-benefit analysis to amalgamate individual dimensions required for evaluation and suggests considering the financial, direct environmental, indirect environmental and social dimensions for the assessment. The result of cost-benefit analysis would be in terms of net present value, which reflects the benefits to society with the implementation of the initiative of using recycled concrete aggregate in concrete. The alternative use of recycled concrete

aggregate to manufacture recycled aggregate concrete is defined as the Project Case and the as-is situation is defined as the Base Case in this study.

3 The concept, framework and methodology presented in this paper elaborate evaluation of the Project Case incorporating:

i. The internalised impact in terms of incremental financial cost/cost saving in producing a unit volume of recycled aggregate concrete. The financial implications are proposed to be assessed by estimating the incremental price of recycled aggregate concrete compared to natural aggregate concrete to the construction contractor. The incremental cost approach and the use of process-based costing is suggested to evaluate the incremental costs of production of recycled concrete aggregate as a constituent material in concrete and recycled aggregate concrete as opposed to crushed concrete used as a road-base material and natural aggregate concrete, respectively.

ii. The external cost directly attributable to the production of recycled aggregate concrete, incorporating the life cycle impacts of producing recycled aggregate concrete. The direct environmental implications are to be estimated by evaluating the incremental EE of recycled aggregate concrete as opposed to natural aggregate concrete, using the I-O-based hybrid analysis and then converting this result to a monetary value to reflect the cost/benefit to society.

iii. The external cost which arises as a result of the change within the concerned system boundary giving rise to indirect environmental and social implications. The key indirect environmental implications include the effect of avoided landfilling, natural aggregate extraction and the net effect of avoided transportation.

## Environmental Impacts of Recycling Concrete, Coming from Construction and Demolition Waste

### 1. Landfill Sites are reduced

Waste is disposed of in the landfills which causes a number of environmental problems. Not everything that is dumped in landfills is biodegradable. Even waste that takes a long time to decompose will cause environmental problems as it can emit gases or by-products that are really harmful to the environment and the people working around landfills. Choosing to recycle materials like paper, cardboard, metal, plastic, etc., means you are keeping them away from landfills (norcalcompactors.net, 2017).

### 2. Energy Consumption is Minimized

Recycling materials requires energy, however, it is a lot less compared to what is required to manufacture new products altogether. Making recycled plastic products requires less energy and resources as compared to making new plastic products for example (norcalcompactors.net, 2017).

**3. Pollution is reduced:**When you dump waste in landfills, it will start emitting gases when it begins to rot. You would be familiar with a foul smell that is usually found near landfills. These gases pollute the environment and attract insects, flies and bugs. When you recycle the waste instead of sending it to the landfills, you are directly reducing the pollution that occurs as a result of landfill. Further, recycling various products leads to less carbon emissions, reducing the carbon footprint that product (norcalcompactors.net, 2017).

**4. Saves Money**

Recycling and using recycled goods will help you save money. For example, you can recycle vegetable and fruit waste, grass and leaves to make compost. Additionally, you can sell your recyclable waste to recycling companies. This means recycling can definitely put some money in your pockets when you don't opt to dispose of it in the traditional polluting way (norcalcompactors.net, 2017).

## Utilization of Recycled Demolition Concrete

Regardless of the replacement ratio, recycled aggregate concrete (RAC) had a satisfactory performance, which did not differ significantly from the performance of control concrete in this experimental research. However, for this to be fulfilled, it is necessary to use quality recycled concrete coarse aggregate and to follow the specific rules for design and production of this new concrete type. Durability, reliability and adequate in service performance of these reused waste materials over the stipulated design life of designed structures are of paramount importance to structural designers. The production technics of recycled aggregate, the mixture proportion, the physical property, the durability, the basic mechanical behaviour and the structural performance of recycled aggregate concrete are mainly investigated. The results indicate that it is feasible to reuse waste concrete and the recycled aggregate concrete which can be adopted in both self-bearing members and load-bearing members in civil engineering Concrete is the main material used in construction in the Gulf Cooperation Council (GCC). Therefore, it makes economic and environmental sense to use recycled materials in the making of new concrete for different applications.

i) The idea of reusing the waste material is very exciting and encouraging specially when it will be helpful in minimizing destruction to earth's crust and green forest cover by virtue of reduced mining (R. Praba Rajathi, 2014).

ii) Protection of environment from the demolition concrete waste (R. Praba Rajathi, 2014).

International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 3, Number 3, September 2018
http://www.casirmediapublishing.com

# METHODOLOGY

## Study Area

The location of this study is Landmark University Omu-Aran which is situated at the north central Nigeria region and concrete cube from Landmark University concrete Laboratory within the location were used in the production of recycled concrete specifically the concrete laboratory.

## Material Sourcing

Cement, fine aggregates and coarse aggregates were all obtained from the Omu-Aran community; the source of water is underground borehole water. Rubble concrete from concrete laboratory in Landmark University was obtained for the production of recycled concrete to be used for test in this study. Portland cement was used to serve as the binder. The cement conforms to the appropriate standard and it has been stored correctly (i.e. in dry conditions), it is therefore suitable for use in concrete.

Aggregate: Fine and Coarse aggregate used were natural. . Specifications of natural Aggregates used for fresh or virgin concrete were according to BS 882 1992.

## Mix Design

The mix design of 1:3:6 was used for the experiment to produce both concretes (Recycled and Virgin concrete)

Figure 3.1 Student Mixing Concrete

## Experimental Test Procedure

The Aggregate test required includes Grain size analysis test procedures according to BS 810-103. 1989, Density determination test procedures according to BS 810-2 1985 were carried out, Concrete test required include slump cone test procedures according to BS 1881-102 1983, cube crushing test procedures according to BS 1881-116 1983.

### Rebound Hammer Test

Rebound hammer test was done to find out the compressive strength of concrete by using rebound hammer as per IS: 13311 (Part 2) – 1992 (Khan, 2012). The rebound of an elastic mass depends on the hardness of the surface against which its mass strikes (Khan, 2012). When the plunger of the rebound hammer was pressed against the surface of the concrete, the pring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete (Khan, 2012). The surface hardness and therefore the rebound was taken to be related to the compressive strength of the concrete (Khan, 2012). The rebound value was read from a graduated scale and was designated as the rebound number or rebound index (Khan, 2012). The compressive strength can be read directly from the graph provided on the body of the hammer (Khan, 2012).

### Compaction Factor Test

#### Aim

To study the workability of concrete.

#### Theory

The test is sufficiently sensitive to enable difference in work ability arising from the initial process in the hydration of cement to be measured. Each test, therefore should be carried out at a constant time interval after the mixing is completed, if strictly comparable results are to be obtained. Convenient time for releasing the concrete from the upper hopper has been found to be two minutes after the completion of mixing. (Constructor, 2017)

### Concrete Slump Test

#### Aim

Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work.

#### Theory

Concrete slump test was carried out from batch to batch to check the uniform quality of concrete during construction. The slump test is the most simple workability test for concrete, involves low cost and provides immediate results (Constructor, 2017). Generally concrete slump value is used to find the workability, which indicates watercement ratio, but there are various factors including properties of materials, mixing methods, dosage, admixtures etc. also affect the concrete slump value (Constructor, 2017).

## Factors which influence the concrete slump test:

Material properties like chemistry, fineness, particle size distribution, moisture content and temperature of cementitious materials (Constructor, 2017). Size, texture, combined grading, cleanliness and moisture content of the aggregates, Chemical admixtures dosage, type, combination, interaction, sequence of addition and its effectiveness, Air content of concrete, Concrete batching, mixing and transporting methods and equipment, Temperature of the concrete, Sampling of concrete, slump-testing technique and the condition of test equipment, The amount of free water in the concrete, and Time since mixing of concrete at the time of testing. (Constructor, 2017)

## Cube Crushing Test

Compressive strength of concrete cube test provides an idea about all the characteristics of concrete. By this single test one can that whether Concreting has been done properly or not. Concrete compressive strength for general construction varies from 15 MPa (2200 psi) to 30 MPa (4400 psi) and higher in commercial and industrial structures (Constructor, 2017). Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc (Constructor, 2017). Test for compressive strength is carried out either on cube or cylinder. Various standard codes recommends concrete cylinder or concrete cube as the standard specimen for the test. American Society for Testing Materials ASTM C39/C39M provides Standard .

Test Method for Compressive Strength of Cylindrical Concrete Specimens (Constructor, 2017).

These specimens were tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete (Constructor, 2017).

## Method of Analysis

Statistical method of analysis using the SPSS application and excel spreadsheet application is used, data and result obtained were recorded in tables.

## Curing Method

Ponding Method

This is the best method of curing. It is suitable for curing horizontal surfaces such as floors, roof slabs, road and air field pavements (Suryakanta, 2014). The horizontal top surfaces of beams can also be ponded. After placing the concrete, its exposed surface is first covered with moist hessian or canvas (Suryakanta, 2014). After 24 hours, these covers are removed and small ponds of clay or sand are built across and along the pavements. The area is thus divided into a number of rectangles. The water is filled between the ponds. The filling of water in these ponds is done twice or thrice a day, depending upon the atmospheric conditions (Suryakanta, 2014). Though this method is very efficient, the water requirement is very heavy. Ponds easily break and water flows out. After curing it is difficult to clean the clay (Suryakanta, 2014).

## RESULT AND ANALYSIS

This involves the data and result obtained when test on workability and compression of both virgin and recycled concrete are carried out such as slump cone, cube crushing test, Schmidt hammer test and compacting factor test.

### *Workability*

This is the easiness to which a material (concrete) can be used in construction. Test to determine this property includes slump cone test and compacting factor test.

### Slump Cone Test

Figure 4.1 Concrete Slump For Slump Cone Test
The height of the slump cone apparatus = 300mm
The height of the virgin concrete slump = 280mm
The height of the recycled concrete slump = 285mm
Slump obtained for virgin concrete and recycled concrete is true slump

## Compacting Factor Test

Figure 4.2: Student Performing Compacting Factor Test With Compacting Factor Apparatus.

Weight of would = 7.9kg
Partially compacted virgin concrete = 19.2kg
Fully compacted virgin concrete = 20.4kg
Partially compacted recycled concrete = 18.9kg
Fully compacted recycled concrete = 20.2kg

Figure 4.3 Compacted Concrete in Cylindrical Mould of Compacting Factor Apparatus

## Compressive Strength

Compressive test was carried out on a total of 12 specimen for each experiment (Schmidt hammer, cube crushing test) carried out, spread across the curing periods, 7,14,21 and 28 days. The test carried out are Schmidt hammer test and cube crushing test.

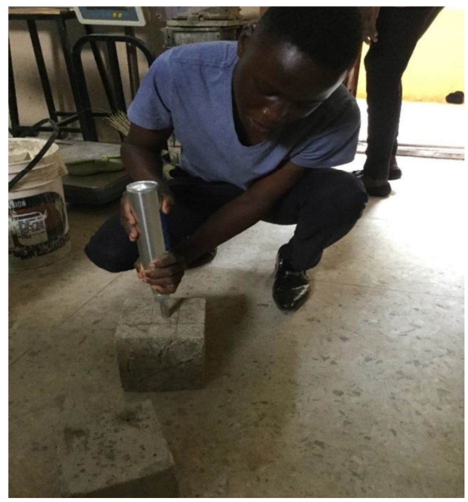
## Schmidt Hammer

Fc = $PA$

Fc = compressive strength in mega-Pascal

P = maximum load at failure in kilo-newton

A = area of the specimen on which the compressive force acts on the specimen



International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 3, Number 3, September 2018
http://www.casirmediapublishing.com

Figure 4.4 Student Exerting Plunger On Six Different Points On Concrete Cube With Schmidt Hammer.

## Cube Crushing Test

Figure 4.5 Student Performing Cube Crushing Test With Compressive Machine.

Table 4.1 Result for Virgin Concrete Cube Compressive Value as Corresponding With
CuringDays.

| VIRGINCONCRETE | 7 days | 14 days | 21 days | 28 days |
|---|---|---|---|---|
| F1 (N/MM2) | 6.04 | 10.2 | 10.4 | 28.7 |
| F2 (N/MM2) | 10.6 | 12.4 | 13.2 | 25.6 |
| F3 (N/MM2) | 10.5 | 14.9 | 9.73 | 26.9 |
| Mean (N/MM2) | 9.05 | 12.5 | 11.11 | 27.07 |

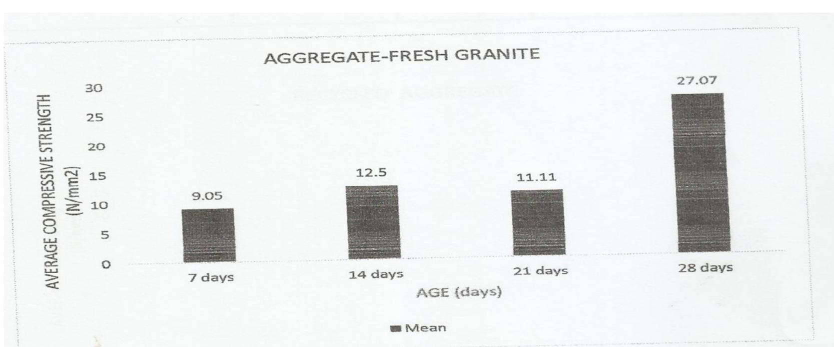



Figure 4.6 Graph of Virgin Concrete Cube Compressive Value Against Curing Days.

The figure above shows average compressive strength attained by virgin concrete cube at various curing days. The compressive strength increases as the curing days increases except for 21 days. At 28 days the concrete cube possess the highest compressive strength in the figure.

Table 4.2 Result for Recycled Concrete Cube Compressive Value as Corresponding With Curing Days.

| RECYCLED CONCRETE | 7 days | 14 days | 21 days | 28 days |
|---|---|---|---|---|
| RC1 (N/MM2) | 8.36 | 11.38 | 16.13 | 30.4 |
| RC2 (N/MM2) | 10.9 | 12.8 | 12.84 | 29.91 |
| RC3 (N/MM2) | 12.58 | 14.9 | 11.91 | 23.5 |
| Mean (N/MM2) | 10.61 | 13.03 | 13.63 | 27.94 |

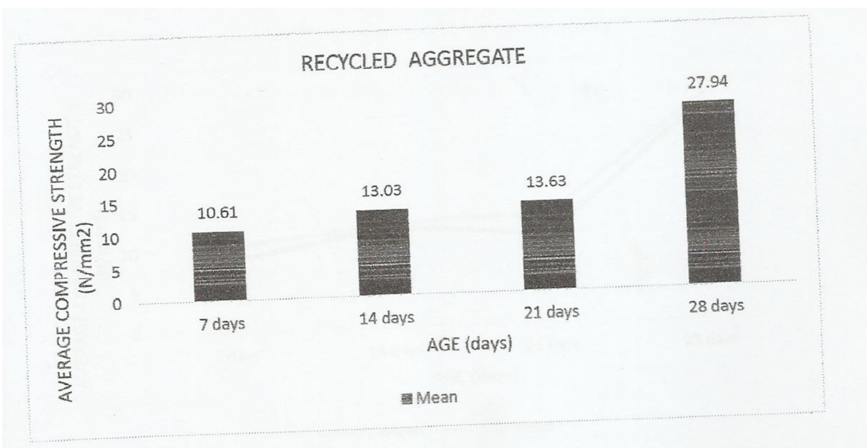



Figure 4.7 Graph of Recycled Concrete cube Compressive Value Against Curing Days.

The figure above shows the compressive value attained by the concrete cube (specimen) at different curing days, the value increase as the number of days increases because it acquire more compressive strength. At 28 days the concrete cube possess the highest compressive strength in the figure.

Table 4.3 Result for Average Compressive Strength of Virgin and Recycled Concrete cube.

| VIRGIN CONCRETE | 7 days | 14 days | 21 days | 28 days |
|---|---|---|---|---|
| FC-Mean (N/MM2) | 9.05 | 12.5 | 11.11 | 27.07 |
| RECYCLED CONCRETE | 7 days | 14 days | 21 days | 28 days |
| RC-Mean (N/MM2) | 10.61 | 13.03 | 13.63 | 27.94 |

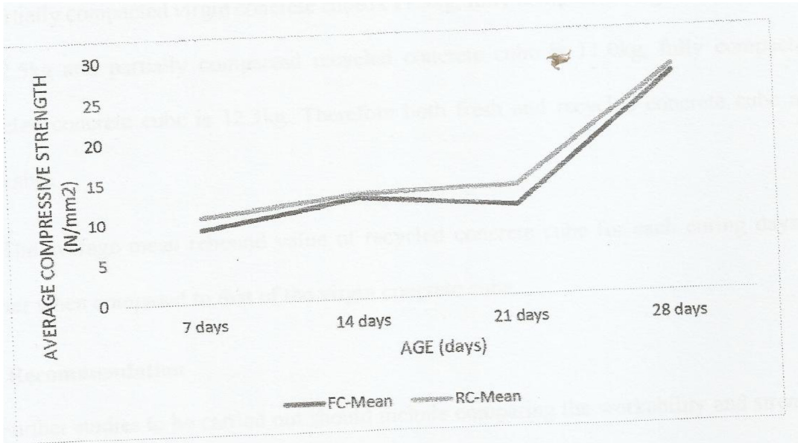



Figure 4.8 Graph Showing the Comparison between Average Compressive Strength of Virgin and Recycled Concrete cube.

The figure above shows the comparison of average compressive strength of recycled concrete cube and virgin concrete cube in respect to the curing days. At every curing days the figure shows that the compressive strength is slightly greater than virgin concrete cube.

## CONCLUSION

1. The slump value for virgin concrete cube is 280mm and for recycled concrete Can be is 285mm .They both attain true slump characteristics which shows that they are workable.
2. The recycled concrete cube mix consumes more water than virgin concrete cube in other to attain the desired workability of the mix.
3. Recycled concrete cube possess higher compressive strength than Virgin concrete cube as shown in Figure 4.8.
4. Partially compacted virgin concrete cube is 11.3kg, fully compacted virgin concrete cube is 12.5kg and partially compacted recycled concrete cube is 11.0kg, fully compacted recycled concrete cube is 12.3kg. Therefore both fresh and recycled concrete cube are workable.
5. The average mean rebound value of recycled concrete cube for each curing days is higher when compared to that of the virgin concrete cube.

## RECOMMENDATION

1. Further studies to be carried out should include comparing the workability and strength of virgin and recycled concrete cube across different mix ratio.
2. I recommend that other forms of curing should be investigated to determine the strength and workability for virgin and recycled concrete cube for each type.

3. Construction companies should make use of recycled concrete cube for construction of structural elements which possess desired property and reduce waste.

## REFERENCES

(2016,7,8).Retrieved from blog. of business.com: http://blog.ofbusiness.com/guide/factors -that-affect-concretes-durability/

(2017, 10, 13). Retrieved from norcalcompactors.net: http://www.norcalcompactors.net /positive-effect-recycling-environmental-economic-front/

Braen, D. (2015, 04 22). *The Definitive Guide to Using RCA in Your Next Construction Project*, pg. 2.

Braen, D. (2016). *Recycled concrete aggregate.* Haledon, New Jersey: Braen Stone Company. pg 15.

Celeste, E. (2016). *Recycled Concrete's Time Has Come. pg.2*

Commission, E. (2014). Communication Form the Commission to the European Parliament, theCouncil, the European Economic and Social Committee and the Committee ofthe Regions on Resource Efficiency Opportunities in the Building Sector.

Construction, S. (2017, 10 12). Retrieved from Sandvik Construction: http://construction.sandvik.com/application/recycling/. pg.2

Constructor. (2017, 10 12). *https://theconstructor.org/concrete/factors-affecting-strength-of-concrete/6220/*. Retrieved from https://theconstructor.org: https://theconstructor.org/concrete/factors-affecting-strength-of-concrete/6220/

*dtwreckit*. (2017, 10 12). Retrieved from dtwreckit web site: http://dtwreckit.com/blog/posts/view/25/uses-of-recycled-concrete-aggregate

Jonathan Andal, M. S. (2016). Properties of concrete containing recycled concrete aggregate. *Construction and Building Materials*, 842-855.

K.L. Scrivener, A. C. (2004, 12). The Interfacial Transition Zone Between Cement Paste and Aggregate, Interface Sci. pp. 411–421.

Khan, S. (2012, December 18). *https://www.engineeringcivil.com/rebound-hammer-test.html*. Retrieved from https://engineeringcivil.com: https://www.engineeringcivil.com/rebound-hammer-test.html

LeBlanc, R. ( 2016). *The Importance of Concrete Recycling.*

López, G. I. (2016, 08 12). Grain size analysis. p. 1.

M. Safiuddin, U. A. (2011, 6 19). Use of recycled concrete aggregate in concrete. pp. 796–810.

Mayuri Wijayasundara, P. M. (2017). Methodology for the integrated assessment on the use of recycled. *Journal of Cleaner Production*, 321-334.

Mayuri Wijayasundara, P. M. (2017). Methodology for the integrated assessment on the use of recycled. *Journal of Cleaner Production*, 321-334.

Napier, T. (2016). *CONSTRUCTION WASTE MANAGEMENT.* Washington, DC: National institute of building sciences.

NJEM. (2005). 35.

R. Praba Rajathi, e. a. (2014). Utilization of Recycled Demolition Concrete. *International Journal Of Engineering And Computer Science*, 3.

Ryu, J. (2002, 20 21 ). Improvement on strength and impermeability of recycled concrete made from crushed concrete coarse aggregate, J. Mater. Sci. Lett. . pp. 1565–1567.

S. Ismail, M. R. (2013). Engineering properties of treated recycled concrete aggregate (RCA) for structural applications, Constr. Build. Mater. 44. pp. 464–476. S. Lotfi, J. D. (2014). Mechanical recycling of EOL concrete into high-grade aggregates, Resour. Conserv. Recycl. 87 . pp. 117–125.

Somayeh Lotfi a, M. E. (2015). Construction and Building Materials. *Performance of recycled aggregate concrete based on a new concrete*, 243–256.

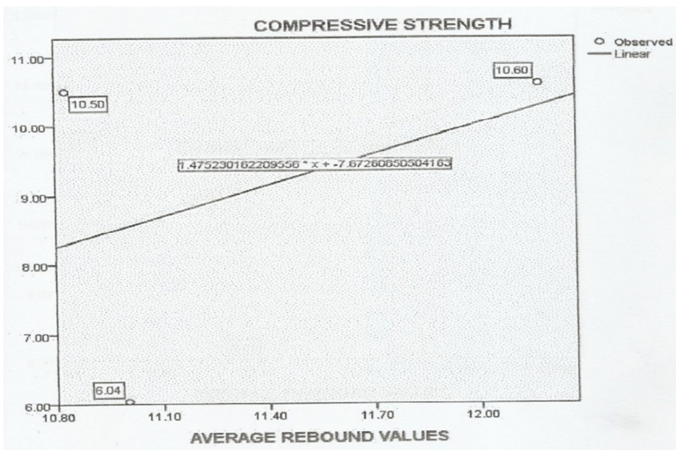
sonawane, T. R. (n.d.). use of recycled aggregate concrete. *IOSR Journal of mechanical and Civil Engineering*, 8.

Suryakanta. (2014, May 16). *http://civilblog.org/2014/05/16/6-methods-of-curing-of-concrete/*. Retrieved from http://civilblog.org: http://civilblog.org/2014/05/16/6-methods-of-curing-of-concrete/

V.W. Tam, X. G. (2005, 6). Microstructural analysis of recycled aggregate concrete produced from two-stage mixing approach, Cem. Concr. Res. 35 . pp. 1195–1203.

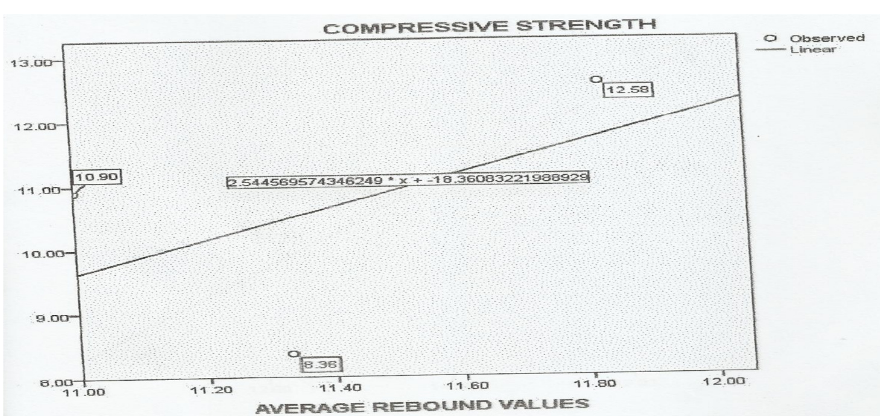
# APPENDIX A
# REGRESSION ANALYSIS
## 7 DAYS VIRGIN CONCRETE CUBE
### Model Summary and Parameter Estimates
Dependent Variable: COMPRESSIVE STRENGTH

| Equation | Model Summary | | | | | Parameter Estimates | |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Linear | .171 | .206 | 1 | 1 | .729 | -7.673 | 1.475 |




## 7 DAYS RECYCLED CONCRETE CUBE
### Model Summary and Parameter Estimates
Dependent Variable: COMPRESSIVE STRENGTH

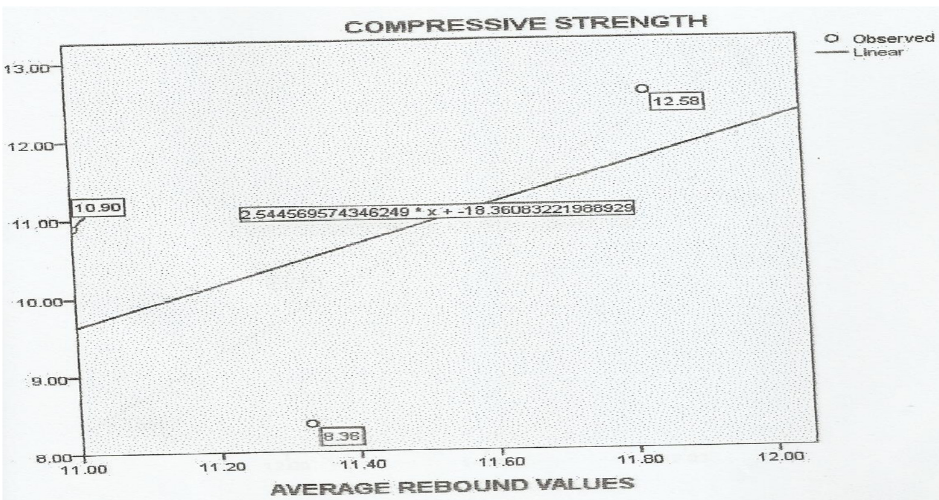
| Equation | Model Summary | | | | | Parameter Estimates | |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Linear | .251 | .334 | 1 | 1 | .666 | -18.361 | 2.545 |



International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 3, Number 3, September 2018
http://www.casirmediapublishing.com

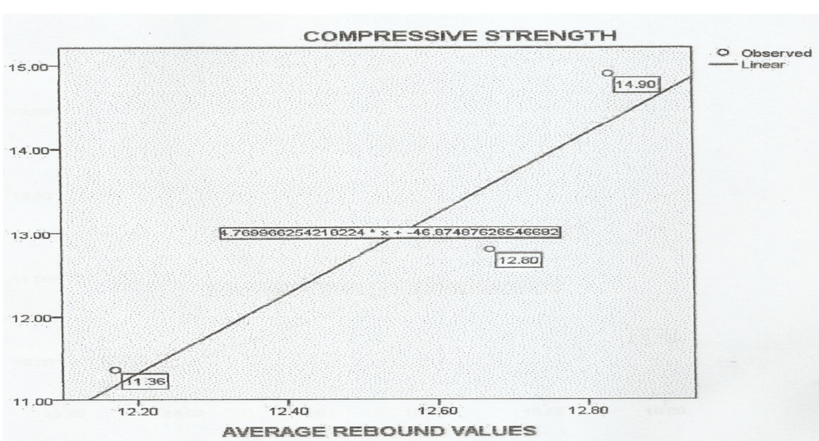
**Model Summary and Parameter Estimates**
Dependent Variable: COMPRESSIVE STRENGTH

| Equation | | Model Summary | | | | | Parameter Estimates |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Linear | .895 | 8.491 | 1 | 1 | .210 | 3.392 | .692 |




14 DAYS RECYCLED CONCRETE CUBE
**Model Summary and Parameter Estimates**
Dependent Variable: COMPRESSIVE STRENGTH

| Equation | | Model Summary | | | | | Parameter Estimates |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Linear | .851 | 5.711 | 1 | 1 | .252 | -46.875 | 4.770 |

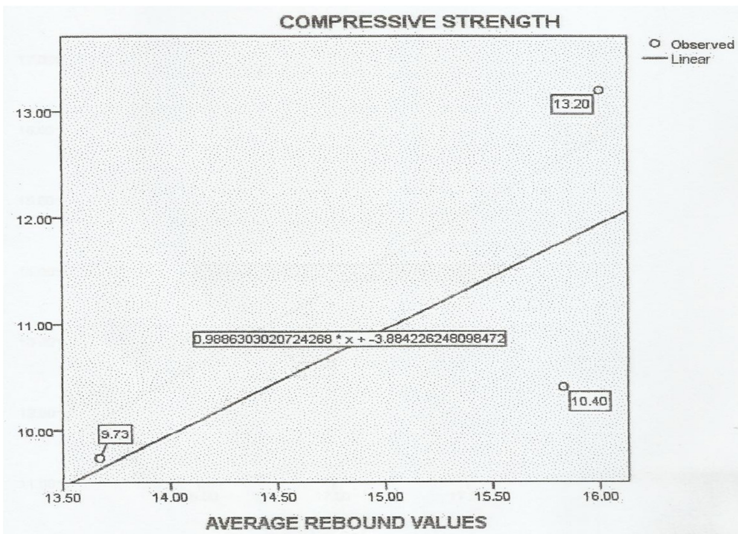


21 DAYS VIRGIN CONCRETE CUBE

**Model Summary and Parameter Estimates**

Dependent Variable: COMPRESSIVE STRENGTH

| Equation | | Model Summary | | | | | Parameter Estimates |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Linear | .487 | .948 | 1 | 1 | .508 | -3.884 | .989 |

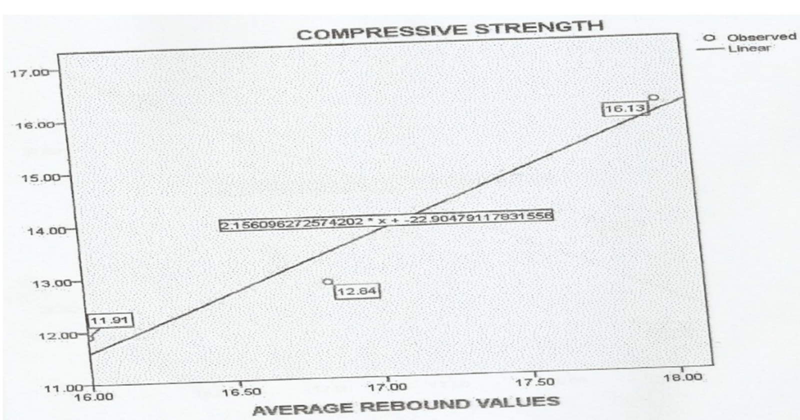



21 DAYS RECYCLED CONCRETE CUBE

**Model Summary and Parameter Estimates**

Dependent Variable: COMPRESSIVE STRENGTH

| Equation | Model Summary | | | | | | Parameter Estimates |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Linear | .955 | 21.076 | 1 | 1 | .137 | -22.905 | 2.156 |



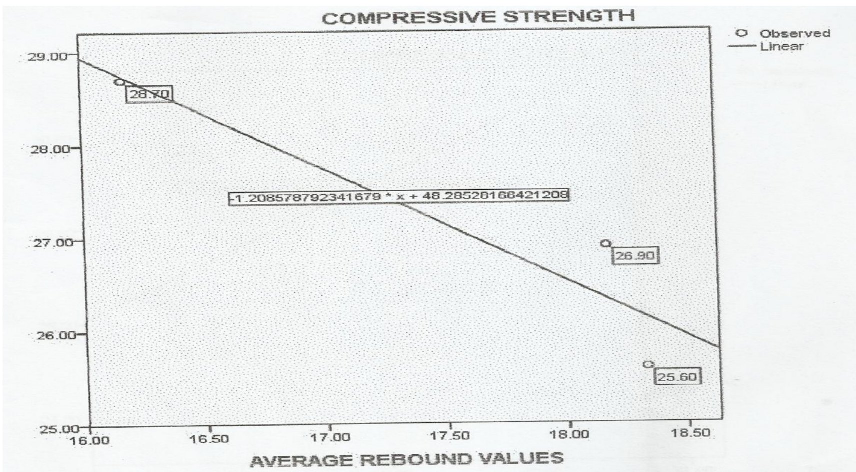
International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 3, Number 3, September 2018
http://www.casirmediapublishing.com

28 DAYS VIRGIN CONCRETE CUBE

**Model Summary and Parameter Estimates**

Dependent Variable: COMPRESSIVE STRENGTH

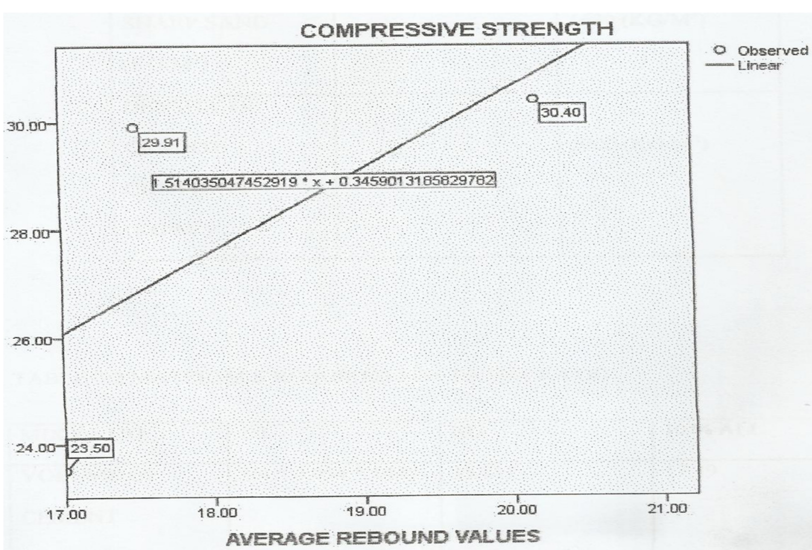
| Equation | Model Summary | | | | | Parameter Estimates | |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Linear | .873 | 6.880 | 1 | 1 | .232 | 48.285 | -1.209 |




28 DAYS RECYCLED CONCRETE CUBE **Model Summary and Parameter Estimates**

Dependent Variable: COMPRESSIVE STRENGTH

| Equation | Model Summary | | | | | Parameter Estimates | |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Linear | .449 | .815 | 1 | 1 | .532 | .346 | 1.514 |



# APPENDIX B
## QUANTITY OF MATERIALS

| | | |
|---|---|---|
| VOLUME OF MOLD (m3) | | 0.003375 M3 |
| 16 MOLDS REQUIRED PER MIX RATIO (m3) | 16 * 0.003375 | 0.054 M3 |
| DENSITY OF CEMENT (KG/M3) | | 1440 (KG/M3) |
| DENSITY OF SHARP SAND (KG/M3) | | 1680 (KG/M3) |
| DENSITY OF GRANITE CHIPPINGS (KG/M3) | | 2700 (KG/M3) |

TABLE 3.2 MATERIALS REQUIRED FOR 1:3 MIX RATIO

| MIX RATIO | 1:3 | KG | 10 % ALL |
|---|---|---|---|
| VOLUME OF CEMENT NEEDED | 1/4 * 0.054 * 1440 | 15.811 | 17.39 |
| VOLUME OF RECYCLED AGGREGATE NEEDED | 3/4 * 0.054 * 1680 | 55.339 | 60.87 |
| WATER REQUIRED | 17.39 * 0.8 | - | 13.91 |

TABLE 3.3 MATERIALS REQUIRED FOR 1:3:6 MIX RATIO

| MIX RATIO | 1:3:6 | KG | 10 % ALL |
|---|---|---|---|
| VOLUME OF CEMENT NEEDED | 1/10 * 0.054 * 1440 | 7.776 | 12.65 |
| VOLUME OF GRANITE NEEDED | 3/10 * 0.054 * 2650 | 42.93 | 35.58 |
| VOLUME OF SHARP SAND NEEDED | 6/10 * 0.054 * 1680 | 54.432 | 44.27 |
| WATER REQUIRED | | 12.65 * 0.8 | 10.12 |

International Journal of Science and Advanced Innovative Research
ISSN: 2536-7315 (Print) 2536-7323 (Online)
Volume 3, Number 3, September 2018
http://www.casirmediapublishing.com

Table 4.1 Result for Virgin concrete rebound value as corresponding with curing days

| VIRGIN CONCRETE | 7 DAYS | | | 14 DAYS | | | 21 DAYS | | | 28 DAYS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | 13 | 12 | 13 | 10 | 20 | 14 | 14 | 13 | 18 | 20 | 17 |
| 2 | 10 | 12 | 10 | 10 | 12 | 15 | 20 | 12 | 15 | 16 | 14 | 20 |
| 3 | 11 | 13 | 10 | 11 | 12 | 17 | 11 | 14 | 15 | 16 | 18 | 17 |
| 4 | 10 | 11 | 11 | 10 | 11 | 18 | 16 | 16 | 11 | 15 | 21 | 14 |
| 5 | 12 | 12 | 11 | 11 | 11 | 15 | 18 | 18 | 16 | 16 | 18 | 19 |
| 6 | 10 | 12 | 11 | 10 | 15 | 16 | 16 | 22 | 12 | 16 | 19 | 22 |
| AVERAGE | 11 | 12.167 | 10.83 | 10.83 | 11.83 | 16.83 | 15.83 | 16 | 13.67 | 16.17 | 18.33 | 18.17 |
| MEAN AVERAGE | 11.33 | | | 13.17 | | | 15.17 | | | 17.56 | | |

Table 4.2 Result for Recycled concrete rebound value as corresponding with curing days

| RECYCLED | 7 DAYS | | | 14 DAYS | | | | 21 DAYS | | 28 DAYS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 13 | 13 | 12 | 11 | 11 | 14 | 15 | 16 | 20 | 14 | 16 |
| 2 | 10 | 10 | 12 | 10 | 10 | 11 | 16 | 19 | 16 | 18 | 18 | 16 |
| 3 | 12 | 11 | 12 | 14 | 11 | 13 | 21 | 17 | 18 | 21 | 19 | 18 |
| 4 | 12 | 12 | 11 | 12 | 12 | 13 | 22 | 16 | 16 | 22 | 18 | 16 |
| 5 | 10 | 10 | 11 | 12 | 17 | 12 | 20 | 16 | 16 | 22 | 16 | 21 |
| 6 | 12 | 10 | 12 | 13 | 15 | 17 | 15 | 18 | 14 | 18 | 20 | 15 |
| AVERAGE | 11.333 | 11 | 11.83 | 12.17 | 12.67 | 12.83 | 18 | 16.83 | 16 | 20.17 | 17.5 | 17 |
| MEAN AVERAGE | | 11.39 | | 12.56 | | | | 16.94 | | 18.22 | | |