The International Journal of Engineering and Science (IJES)
|| Volume || 10 || Issue || 8 || Series I || Pages || PP 52-61 || 2021 ||
ISSN (e): 2319-1813 ISSN (p): 20-24-1805

# Strength Characterization of Periwinkle Shell Polymer Concrete

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**-------------------------------------------------------*ABSTRACT*-------------------------------------------------------**
*Polymer concrete provides several advantages over traditional concrete, some of which have been carefully examined in the past. However, the cost of producing polymer concrete is high, thus this research attempted to minimize the cost of producing polymer concrete by replacing granitic coarse aggregate with periwinkle shell waste. The research implicated that the possibility of utilising waste material in the production of concrete offers a compelling alternative to waste disposal and the preservation of natural resources. To achieve this, the aggregate impact value (AIV) of samples A and B (periwinkle shell) was evaluated and a total of 120.5g of each was examined. To determine the particle size distribution, sieve analysis was performed on 100g of fine aggregate (i.e. river sand) and 5g of periwinkle shell. In addition, three samples of periwinkle polymer concrete cubes and beams were cast, cured, weighed, and crushed to assess the compressive and flexural strength after seven days. 9 samples were thermally tested at temperatures of 50 C, 75 C, and 100 C. From the testing results, the average AIV of the periwinkle shell was discovered to be 58.63 %, indicating a low toughness property and thus unsuitability for road paving application. The polymer concrete's average density was 1510kg/m3, showing a light weight concrete. The polymer concrete's highest 7-day compressive strength was 61N/mm2, its minimum was 59N/mm2, and its highest flexural strength was 5.7N/mm2. The thermal test at 50, 75, and 100 degrees Celsius also demonstrated a steady decline in compressive strength to average values of 51.67, 47.17, and 41.17 N/mm2 respectively. Consequently, based on the findings of the study, periwinkle polymer concrete would perform well in a variety of concrete applications.*

Date of Submission: 06-08-2021 Date of Acceptance: 20-08-2021

## I. BACKGROUND OF STUDY

The common type of concrete comprises of three main ingredients; water, aggregate and cement, which are combined with different ratios depending on the characteristics required
(Cement Concrete and aggregates Australia publications (CCAA), 2015).

Normal concrete has a low tensile strength, brittle, and highly erodible by chemicals and high-velocity water flow. With the demand for less maintenance and longer-lasting infrastructures, this is becoming an increasingly pressing issue in today's society. In the early 1950s, research into a new type of concrete was discovered -polymer concrete (Aravinthan, 2013). Polymer concrete has greater strength, better resilience to external variables, and a shorter cure period.

Polymer concrete became a rapidly increasing topic of research due to its improved characteristics. The sole disadvantage is that it is fairly expensive to manufacture, thus it is only utilized for minor projects such as drainage pipes and coatings over other structural components. Polymer concrete is also frequently utilized for tasks requiring a short curing time, such as bridge rehabilitation. Polymer concrete comes in a variety of forms, depending on the properties required. This paper focuses on the production of epoxy-based periwinkle polymer concrete, which is a relatively new area of study with much to learn about the characteristics and how the specimens will react under various conditions.

Shelter and engineering infrastructure requirements are heavily reliant on the availability of basic building materials at reasonable prices. Cement, which is typically used as a binder and is composed of silicate components, is one of the building materials required. This cement generally produces CO2 during its manufacture, therefore the desire to limit this emission drives research into finding a viable replacement for cement, which leads to the discovery of polymer binders. However, these polymer binders are exceedingly expensive. As a result, the purpose of this research is to determine the efficacy of a local waste material (periwinkle) as a replacement for coarse aggregate in the production of a less expensive polymer concrete.

Environmental pollution can be caused by the use of cement. Climate change has become a big problem owing to global warming. Global warming is caused by the emission of greenhouse gases such as carbon dioxide ($CO_2$) into the atmosphere by many businesses such as the cement industry, therefore the discovery of polymer concrete.

The primary goal of this research is to reduce the cost of producing polymer concrete utilizing waste materials found in Nigeria. The engineering application, waste disposal reduction, and economic element are three main aspects that will influence the replacement of granite with periwinkle in polymer concrete.

The use of periwinkle in polymer concrete is compatible, it could be an alternative to replace the huge demand for granite in the production of polymer concrete used for various purposes (non-renewable resource).

Furthermore, the use of periwinkle in polymer concrete will assist reduce waste disposal and protect the environment.

The high cost of producing polymer concrete will be decreased because periwinkle may be obtained at essentially no cost as opposed to granite, which would necessitate the deployment of complex machinery to ensure its availability from the production stage to the distribution stage.

## II. LITERATURE REVIEW

**Polymer Concrete**

Research into the use of polymer concrete has been seen as early as the 1950's, it was first conducted by the Audit committee institute Ireland ACI committee (Erp, 2014). Polymer concrete can be defined as "concrete in which the binder is an organic polymer; a construction and structural material that is a solidified mixture of macro molecular substance with a mineral aggregate" (the 7th German conference: System Technologies, 2009). Polymer concrete is known for its high strength characteristics, resistance to chemicals and water absorption, is much more durable in comparison to normal concrete and has excellent adhesion properties. As can be seen in Table 1, polymer concrete performs much better in all of the tested characteristics compared to traditional concrete. This makes polymer concrete excellent for use for drainage systems, due to the lack of moisture absorption, and for the use of tanks to hold corrosive materials, due to its chemical abrasion resistance. Although, these characteristics are only applicable for a certain mix of polymer concrete, they can be varied greatly depending on the materials used in the mix.

**Table 1:** Comparison of Mechanical Properties of Polymer Concrete to Normal B30 Concrete

| | Polymer concrete | B30 concrete |
|---|---|---|
| Compressive strength Rc(MPA) | 80-110 | 30 |
| Bending tensile strength Rg(MPA) | 22-35 | 2-4 |
| Splitting tensile strength Rr(MPA) | 8-12 | 1.5-2 |
| Abrasion resistance (cm) | 0.1-0.2 | 0.6 |
| Moisture absorption (mm) | 0 | 4-8 |

**Source:** (Choi, 2012)

Polymer concrete is comprised of three major parts; aggregate, synthetic resin and other additives. The most commonly used resins for polymer concrete include unsaturated polymer resin, methyl methacrylate, epoxy resins, furan resins and polyurethane resins (the 7th German conference: System Technologies, 2009). Aggregate used in the mix is either coarse aggregate, greater than 5mm, or fine aggregate, less than 5 mm (America's Concrete Manufacturer, 2015). The use of polymer concrete is all attributed to its rapid curing, it reaches more than 70% of its final strength within one day of curing which can be seen in Figure 2.1 (Choi, 2012). This particular study was done using polyester resin. However it can be assumed that epoxy resin will cure in the same fashion. This is much quicker than that of normal concrete, which only reaches 20% within the first day of curing (Singh, 2013)

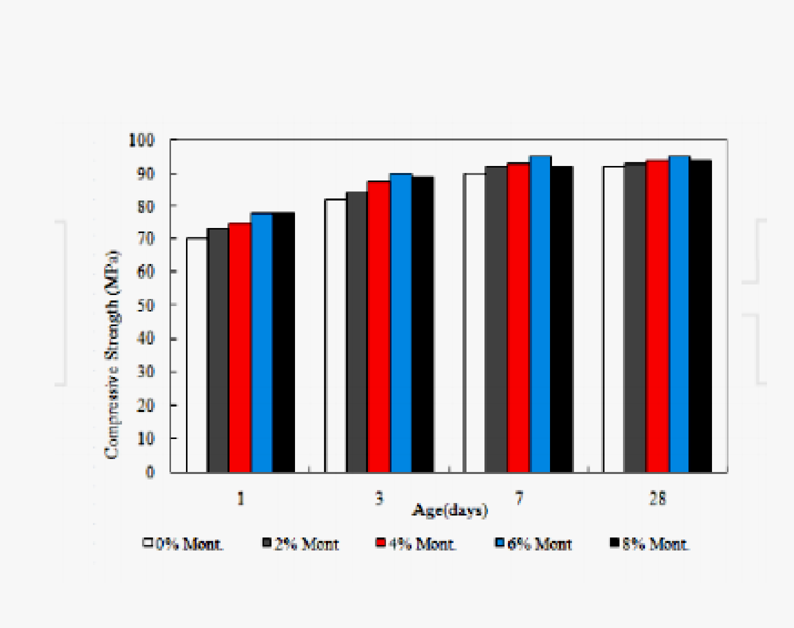


**Figure.1:**Compressive Strength of Concrete over time (Choi, 2012)

Full strength can be reached even quicker if the polymer concrete goes through high temperature curing and is only done if completely necessary. This is due to the curing temperature not having a large effect on the overall strength of the materials, as can be seen in Figure 2 (Choi, 2012). For this project the specimens will be cured at room temperature for 7 days, in that time the samples will have reached full strength. This is also a cost-effective method and would replicate field casting.

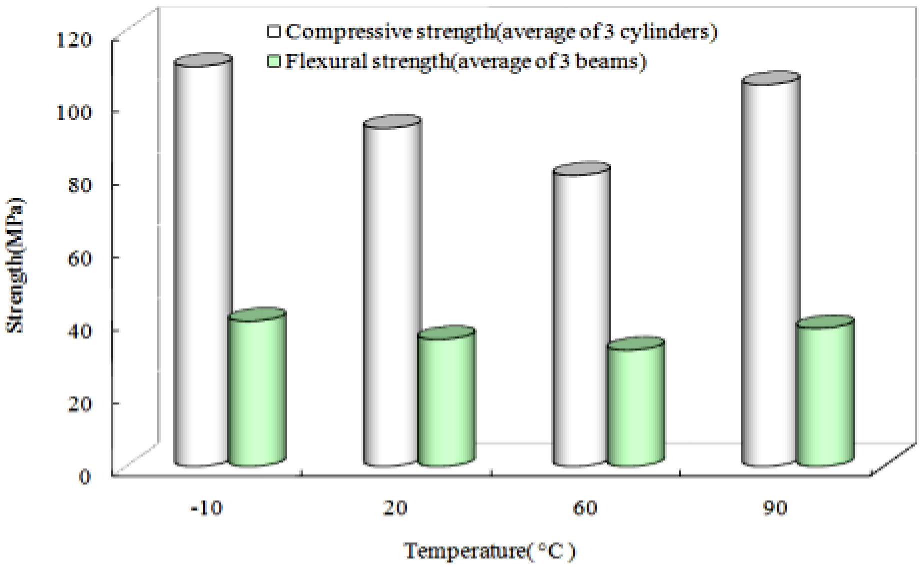


**Figure.2:**The Effect Curing Temperature Has On The Strength Of Concrete (Choi, 2012)

Although Polymer Concrete clearly has better properties than that of normal concrete, the uptake of its use in the construction industry is slow. This is mainly due to the lack of knowledge about the product and the cost. As it is expensive, the mix will need to be optimized before use in major construction projects. The price of polymer concrete is the main issue most constructors have with using the material, and therefore the minimum amount of resin and the cheapest curing option should be taken. Therefore, this study will investigate the suitability of periwinkle as replacement to granite using the optimal resin to filler ratio, with the main focus of the project being on the use of Epoxy Resin in the mix.

## III. METHODS

The various individual constituents used for the production of concrete use for the study and the concrete samples were subjected to various tests, details of those tests are presented are as follows:

1. **Study 1** – consists of the determination of the properties of periwinkle shell as a replacement for aggregate, which include, sieve analysis, specific gravity and water absorption test for periwinkle shell, aggregate impact value, aggregate crushing value.
2. **Study 2** – determination of the compressive and flexural strength of the polymer concrete using periwinkle shell
3. **Study 3** – investigation on the effect of temperature on polymer concrete, which involves heating of some samples from study 2 to a certain temperature before carrying out compressive strength on them to determine the effect of temperature on the compressive strength of the concrete.

## IV. RESULTS AND ANALYSIS OF RESULTS

The results and data of all laboratory tests conducted for this research are presented below.

**Aggregate Impact Value Test Results**

**Table 2 :** Aggregate Impact Value (periwinkle)

| SAMPLES | A | B |
|---|---|---|
| Weight of Material in Mould ($W_1$) | 120.50g | 120.50g |
| Weight of material passing through sieve 2.36mm($W_2$) | 69.60g | 71.70g |
| Weight of material retained on sieve 2.36mm ($W_1 - W_2$) =$W_3$ | 51.80g | 49.70g |
| A.I.V = $\frac{W_2}{W_1} \times \frac{100}{1}$ | 57.76% | 59.5% |
| AVERAGE A.I.V | 58.63% | |

Table 2 shows the aggregate impact values of the periwinkle shell samples. It shows the average aggregate impact value of periwinkle is 58.63%, indicating a weak toughness property (BS 812-112:1990) which may reduce the strength of the concrete unlike the aggregate impact value of granite which falls within the very strong toughness zone. This implies the periwinkle polymer concrete would not be adequate for road surfacing application; however, it may be much adequate for other low impact applications.

Sieve Analysis Test Results

**Table.3:** Sieve Analysis for Fine Aggregate

| Sieve No (mm) | Weight Retained (g) | Weight Passing (g) | % passing |
|---|---|---|---|
| 75 | | | |
| 50 | | | |
| 37.5 | | | |
| 26.5 | | | |
| 20 | | | |
| 14 | | | |
| 10 | | | |
| 8 | | | |
| 5 | | | |
| 3.35 | | 100 | 100 |
| 2 | 6.49 | 93.35 | 93.35 |
| 1.18 | 7.41 | 86.1 | 86.1 |
| 0.6 | 25 | 61.1 | 61.1 |
| 0.425 | 19.9 | 41.2 | 41.2 |
| 0.3 | 14.1 | 27.1 | 27.1 |
| 0.150 | 14.9 | 12.2 | 12.2 |
| 0.075 | 7.2 | 5.0 | 5.0 |
| BASE PAN | 5.0 | 0 | 0 |

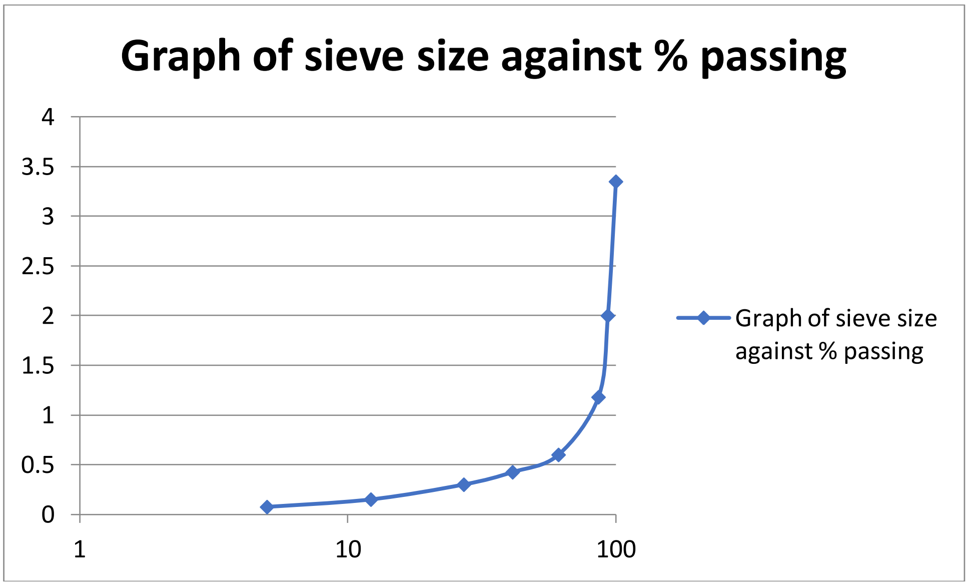


**Figure 3:** Particle Size Distribution for Sand

The sieve analysis result presented in Table 3 and Figure 2 above gives an indication of particle size distribution of the fine aggregate and the gradation which shows from the graph that it is a uniform gradation. The curve on the gradation graph is very steep, and occupies a small range of the aggregate.

**Table.4:** Sieve Analysis for Periwinkle Shell

| Sieve No (mm) | Weight Retained (g) | Weight Passing (g) | % passing |
|---|---|---|---|
| 75 | | | |
| 50 | | | |
| 37.5 | | | |
| 26.5 | | | |
| 20 | | | |
| 14 | 1.895 | 3.105 | 62 |
| 10 | 3.045 | 0.06 | 1.2 |
| 8 | 0.035 | 0.025 | 0.5 |
| 5 | 0.010 | 0.015 | 0.3 |
| Base Pan | 0.015 | 0 | 0 |

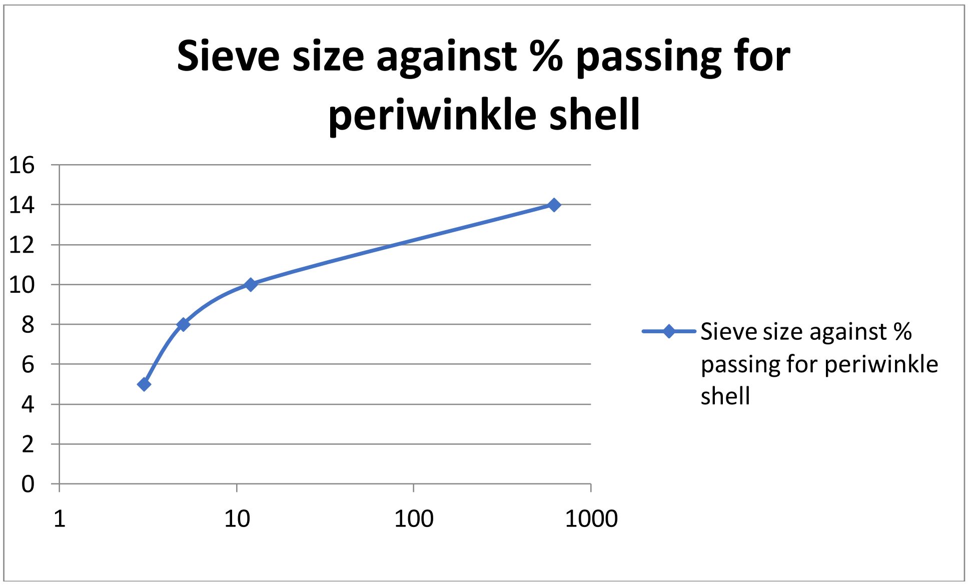


**Figure4:** Grain Size Distribution

Table 4 and Figure 3 above shows the particle size distribution for periwinkle shell and the graph shows the type of grading which is an open gradation. From the result, the particle size ranges between 10 – 20 mm, with about 62% of the sample being retained on the 10mm sieve.

**Compressive Strength Results**

**Table.5**: Compressive Test Result for Periwinkle Polymer Concrete

| Sample ID | Curing Age (days) | Crushing Load (KN) | Crushing strength (N/mm$^2$) | Average (N/mm$^2$) |
|---|---|---|---|---|
| A | 7days | 590 | 59 | 60 |
| B | | 600 | 60 | |
| C | | 610 | 61 | |

**Table.6:** Compressive Strength Results of Polymer Concrete Used As Control

| Sample ID | Curing Age (days) | Crushing Load (KN) | Crushing strength (N/ mm$^2$) | Average (N/ mm$^2$) |
|---|---|---|---|---|
| A | 7days | 925 | 92.5 | 92 |
| B | | 920 | 92 | |
| C | | 915 | 91.5 | |

Source;(Choi 2012)

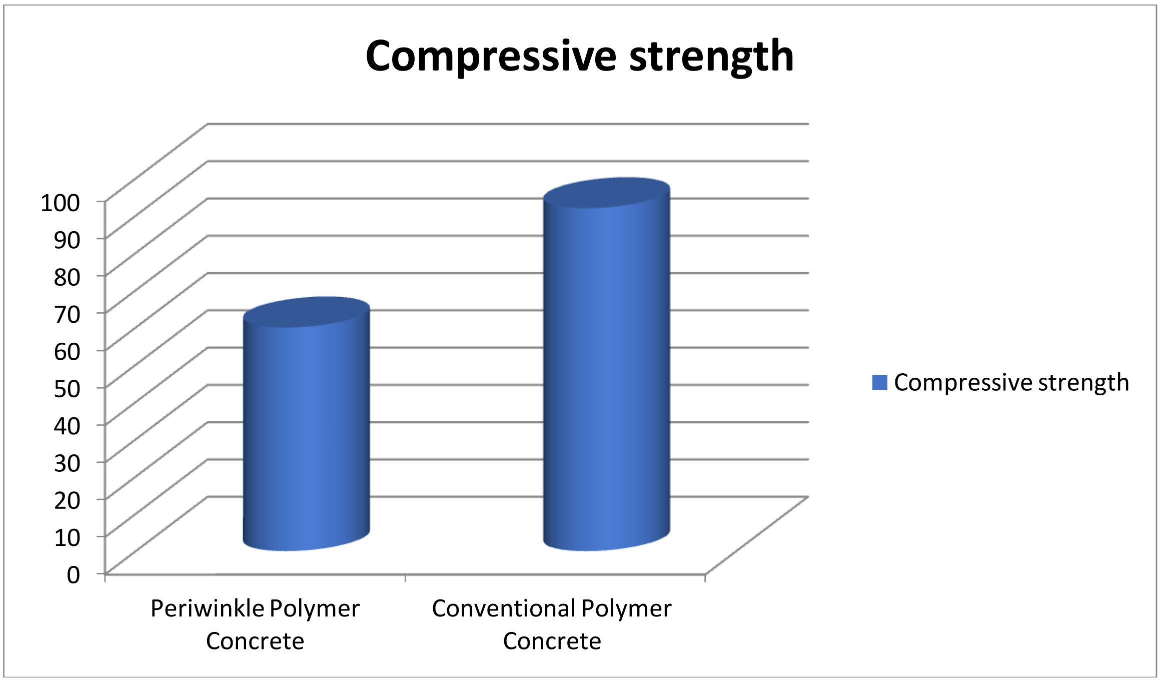


**Figure5:** A Chart Comparing Compressive Strength of Periwinkle Polymer Concrete To Conventional Polymer Concrete

Table 6 shows the compressive strength obtained for periwinkle polymer concrete which was found to be 60N/mm$^2$which is about 34% lower than that obtained by Choi (2012)as shown in Table 4.6. However this falls within the strong concrete category which finds useful application in various engineering works.

**Flexural Strength Test Result**

**Table.7:** Flexural Strength of Periwinkle Polymer Concrete

| Sample ID | Curing Age (days) | Failure Load (KN) | Surface Area (mm$^2$) | Flexural strength (N/ mm$^2$) | Average (N/ mm$^2$) |
|---|---|---|---|---|---|
| A | 7days | 18 | 50000 | 5.4 | 5.6 |
| B | | 19 | | 5.7 | |
| C | | 19 | | 5.7 | |

**Table 8:** Theoretical Flexural Strength Results of Polymer Concrete Used As Control

| Sample ID | Curing Age (days) | Failure Load (KN) | Surface Area (mm$^2$) | Flexural strength (N/ mm$^2$) | Average1 (N/ mm$^2$) |
|---|---|---|---|---|---|
| A | 7days | 40 | 50000 | 12 | 12.1 |
| B | | 40 | | 12 | |
| C | | 41 | | 12.3 | |

Source;*(Choi 2012)*

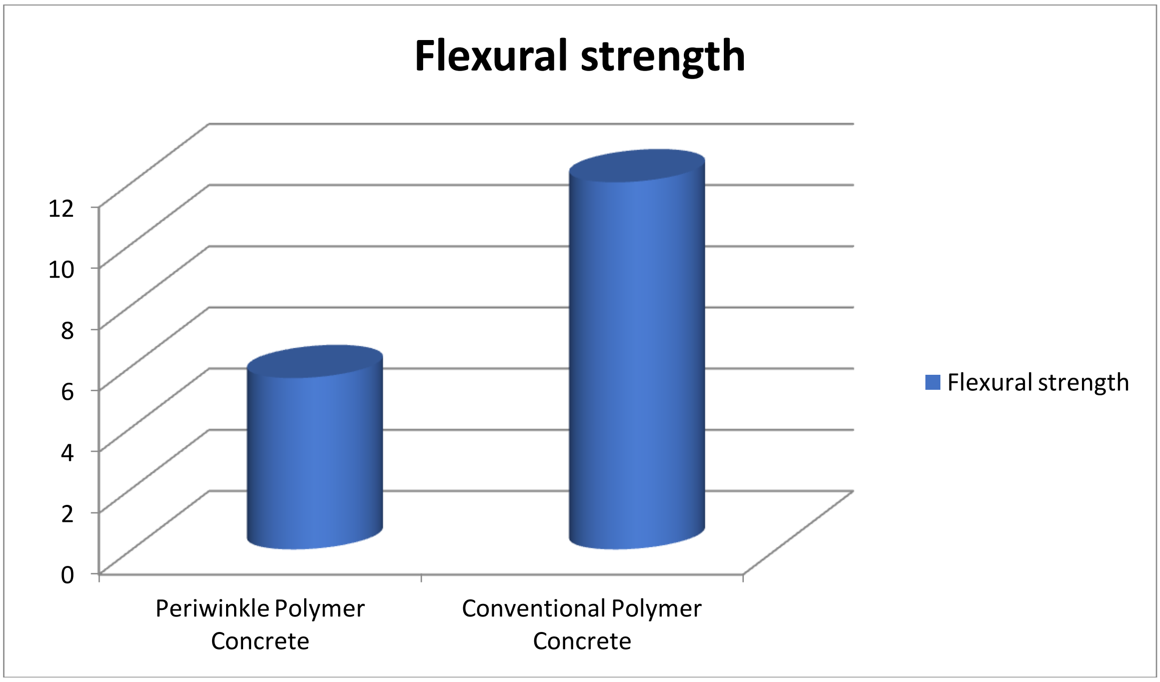


**Figure7:** A Chart Comparing Flexural Strength of Periwinkle Polymer Concrete To Conventional Polymer Concrete

Table .8 shows the flexural strength obtained for periwinkle polymer concrete which was found to be 5.6N/mm$^2$. This is a 54% reduction in flexural strength when compared to the granitic polymer concrete test conducted by Choi (2012). However, this high difference may be due to the hand mixing procedure, which is does not yield a thorough mixing when compared to an automated machine mixer.

**Thermal Testing Result**

**Table.9:** Thermal Test Results for Periwinkle Concrete

| Sample ID | temperature (℃) | Failure Load (KN) | Compressive strength (N/mm$^2$) | Average (N/mm$^2$) |
|---|---|---|---|---|
| A | | 525 | 52.5 | |
| B | 50 | 515 | 51.5 | 51.67 |
| C | | 510 | 51 | |
| A | | 480 | 48 | |
| B | 75 | 470 | 47 | 47.17 |
| C | | 465 | 46.5 | |
| A | | 420 | 42 | |
| B | 100 | 415 | 41.5 | 41.17 |
| C | | 400 | 40 | |

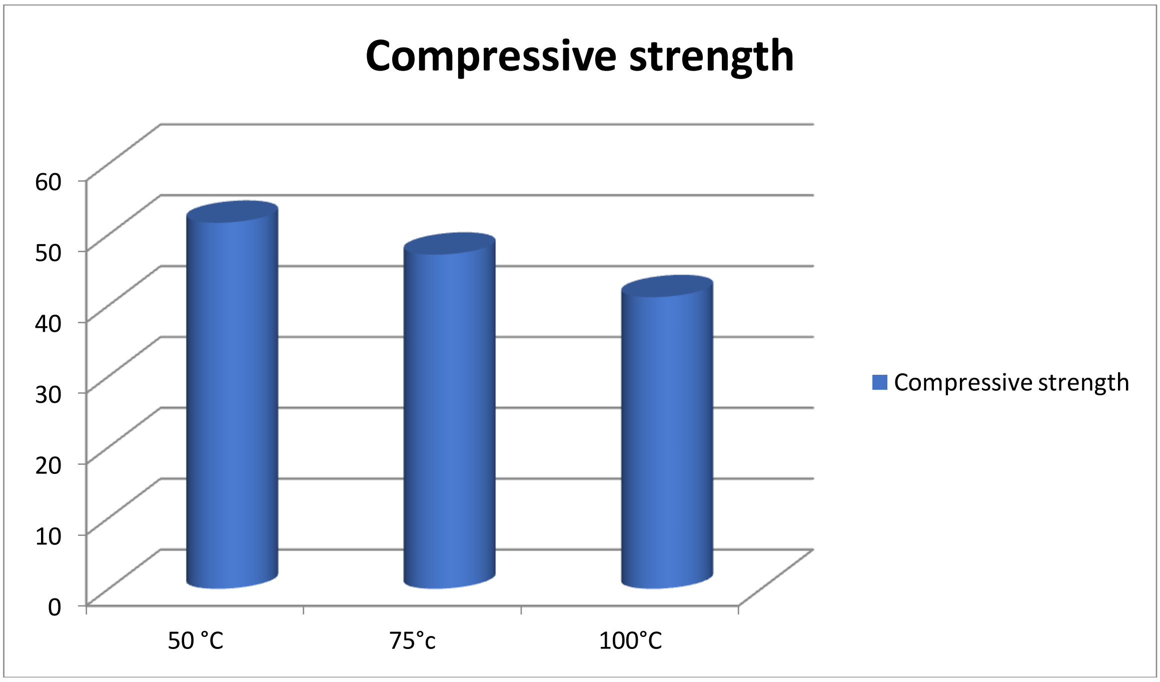


**Figure8: A** Chart Showing Reduction in Strength to Increasing Temperature

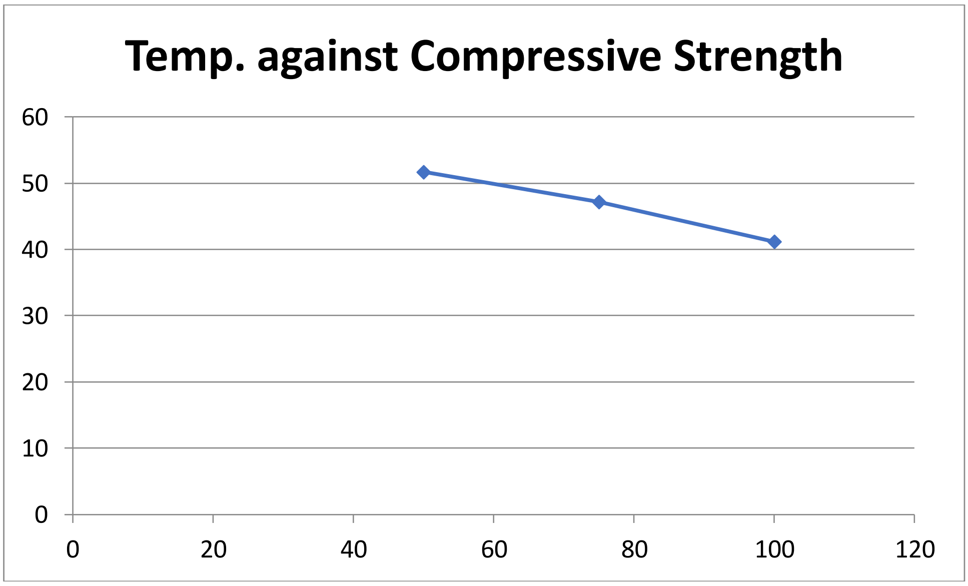


**Figure9:** A Graph Showing Reduction in Strength to Increasing Temperature

Table 9 shows the results from the thermal test carried out at various temperatures; Figures 8 and 9 show the reduction in strength of periwinkle polymer concrete to increasing temperature which follows the same trend for conventional polymer concrete. The compressive strength decreases progressively from 51.67 to 41.17 N/mm$^2$ when heated at temperatures between 50 to 100 ºC.

**Density of Periwinkle Concrete Cubes**

**Table10:** Density Result for Periwinkle Concrete Cubes

| Sample ID | Weight (kg) | Volume (m$^3$) | Density (kg/m$^3$) | Average (kg/m$^3$) |
|---|---|---|---|---|
| A | 1.530 | 0.001 | 1530 | |
| B | 1.505 | 0.001 | 1505 | 1510 |
| C | 1.495 | 0.001 | 1495 | |

Table 10 above shows the density of the cubes, which indicates that the cubes falls within the range o light weight concrete (1500-2000) kg/m$^3$

## V. CONCLUSION

Based on the investigation and experimental results obtained, it can be seen that periwinkle polymer concrete falls in the category of C60 concrete which is a strong commercial grade concrete mix most commonly used in the construction of structural and support beams, footings and foundations, road works and in agricultural use. Periwinkle polymer concrete was also found to be in the class of light weight concrete. There exists a high potential for the use of periwinkle shell as coarse aggregates in the manufacture of polymer concrete.

Although the compressive and flexural strength investigation shows that periwinkle polymer concrete has lower strength (61N/mm$^2$) when compared to the granitic polymer concrete strength (92.5N/mm$^2$) previously investigated, the periwinkle polymer concrete still remains in the strong class category of concrete.

Results from the thermal investigation shows that the strength of periwinkle polymer concrete reduces (51.6 – 41.17 N/mm$^2$) with increase in temperature (50 – 100 ºC), which follows the normal trend of reduction of strength of polymer concrete.

The study revealed that periwinkle polymer concrete would perform well in many concrete applications.

## VI. RECOMMENDATIONS

Based on the investigation and experimental results, the following recommendations are made

1. Periwinkle polymer concrete is recommended for lightweight concrete components.
2. This concrete can be used in rural areas and places where periwinkle is abundant and may also be used where conventional aggregate are costly.
3. For better performance of this type of concrete, Comparative study of other mix ratios should be investigated.
4. Other wastes should be investigated to check for suitability as aggregates in polymer concrete.

## REFERENCES

[1]. Adewuyi, A. P., and T. Adegoke (2008).Exploratory Study of Periwinkle Shells as Coarse
[2]. Aggregates in Concrete Works.ARPN Journal of Engineering and Applied Sciences, 3(6):1-5.
[3]. Agbede, Olufemi Isaac and Joel Manasseh (2009).Suitability of Periwinkle Shell as Partial Replacement for River Gravel in Concrete. Leonardo Electronic Journal of Practices and Technologies, Issue 15, July-December, p. 59-66.
[4]. America's Concrete Manufacturer, 2015. Aggregates. [Online] Available at: http://www.cement.org/cement-concrete-basics/concrete materials/aggregates [Accessed 16 May 2017].
[5]. Aravinthan, L. a., 2013. Comparative assessment of polymer concrete with different types of resin, s.l.: s.n.
[6]. Aravinthan, L. a., 2013. Effect of Fly Ash on the Behaviour of Polymer Concrete with Different Types of Resin. Materials and Designs, Volume 51, pp. 175-181.
[7]. Balogun, L. A. (1993). ―Periwinkle shells and palm kernel shells as concrete aggregates.
[8]. In proceedings of the third international conference on structural Engineering Analysis and modeling, Kumasi Ghana. pp. 533-543
[9]. Beredugo, Y. O. (1984). Periwinkle shells as concrete aggregate. Nigeria Building and Road Research Institute Technical Publication, 2:4 – 9.
[10]. BS (812-112) :1990. Testing aggregates. Method for determination of aggregate impact value (AIV) Craft, R. a. S. a., 2004. Properties of Polymer Concrete using Fly Ash. Journal of Material in Civil Engineering, Volume 16, pp. 15-19.
[11]. Choi, G. H. T. a. E. S., 2012. Time Dependent Behavior of Polymer Concrete Using Unsaturated Polyester Resin. In: s.l.:Intech, pp. 228-256.
[12]. Erp, F. a. M. a. A. a. V., 2014. Design of Epoxy Based Polymer Concrete Matrix for Composite Railway Sleeper, s.l.: s.n. 118
[13]. Falade, F. (1995). An investigation of Periwinkle shells as coarse aggregate in concrete.Building and Environment, 30 (4): 573 – 577
[14]. Kazmierczac, G. a. M. a., 2004. Study of the Modulus of Elasticity of polymer concrete compounds and comparative assessment of polymer concrete and portland cement concrete. Cement and Concrete Research, Volume 34, pp. 20912095.119
[15]. Lar B, Wiebe V, Paolo P, Alexander P. (2009) 7th German Conference on Multiagent Systems Technologies, MATES 2009
[16]. Singh, B. a. C. a., 2013. Mechanical Properties of Polymer Concrete.

Elamah, D. "Strength Characterization of Periwinkle Shell Polymer Concrete." *The International Journal of Engineering and Science (IJES)*, 10(08), (2021): pp. 52-61.