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EFFECTS OF OIL BEAN HUSK ASH (OBHA) ON CONCRETE PRODUCED WITH BREADFRUIT HUSK ASH (BHA)

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Abstract

This research work examined the influence of very fine particles of Oil bean husk ash (OBHA) on concrete containing Breadfruit Husk Ash (BHA) as Admixtures on the Slump, Setting time, Compressive, flexural and Splitting tensile strengths of concrete. The fine Aggregate which falls into zone 2 of calibration graph and crushed aggregate of 20 mm maximum size were used. OBHA/BHA/Ordinary Portland Cement (OPC) concrete cubes (150mm x 150mm x 150mm), beams (150mm x 150mm x 700mm) and cylinder (150mm x 300mm) with 0%, 5%, 10%, 15%, 20%, and 30% substitutions of OPC with OBHA/BHA on equal ratio were made, cured and tested at the ages of 3, 7, 14, 21, 28 and 90 days for Compressive, flexural and Split tensile strengths respectively. The water–cement ratio (w/c) was 0.6 and a mix ratio of 1: 2.14: 4.18 were used. The slump test results showed that slump increases with increase in percentage addition of OBHA/BHA. The initial and final setting times increase with increase in OBHA/BHA content. The Compressive, Flexural, and Split Tensile Strength of concrete obtained ranges from (3.65N/mm2 – 29.84N/mm2), (0.50N/mm2 – 3.79N/mm2) and (0.28N/mm2 – 2.06N/mm2) respectively. Compressive, Flexural and splitting tensile strengths results and curves for OBHA/BHA/OPC concrete showed increase in strength as the curing days of concrete increased and also decrease in strength as the OBHA/BHA level increased. The mathematical model used for the prediction of the Compressive, flexural and splitting tensile strength of OBHA/BHA/OPC concrete was created by using the R-Programming Software Application.

Keywords: Breadfruit husk ash, Compressive Strength, Flexural Strength, Mathematical modeling, Oil bean husk Ash, Setting time, Split tensile Strength.

1.0 INTRODUCTION

Concrete is an essential element of civil infrastructure as no other material can match it in terms of resilience, strength, and wide availability, and is therefore the most produced construction material on the planet. Concrete is a composite material composed of cement, aggregates (fine and coarse), water and agro waste ash in a given percentage amounts that harden over time [1].

When aggregate is mixed with dry Portland cement and water, the mixture forms fluid slurry that is easily poured and molded into shape. The cement reacts with the water through a process called concrete hydration that hardens over several hours to form a hard matrix that binds the materials together into a durable stone-like material that has many uses [2]. Aggregates help to reduce shrinkage and heat dissipation during hardening and also contribute to the increase in the mechanical strength of concrete but the fine aggregates serve as the filler to fill the inter-spaces between the coarse aggregates due to their irregular shapes [3].

It is a known fact that concrete is widely used construction material due to its high compressive, flexural, split tensile strength and durability. However, in a relationship with a growing population there will be increase in demand use for concrete. Years by years have passed, concrete also is not left behind in following the revolution as it keeps improving to become a better quality concrete, start with normal concrete (NC), then high strength concrete (HSC), also up until ultra-high strength concrete (UHSC). Usually, HSC consist of a high amount of cement but low with water-cement ratio including highly reactive pozzolanic materials. Researcher [4] ,stated in his paper that HSC must have compressive strength 41 Mpa and greater than that. According to [5] the usage of cement probably contributes towards the high emission of carbon towards the atmosphere. Thus, another alternative should be taken in replacing the amount of cement that will be used in producing concrete. Nowadays, the concrete industry is finding their way to use agro-waste materials since they are abundant, easily found and cost-effective, not only by using these materials could decrease the amount of carbon dioxide but also these materials could improve the concrete materials as general. Researchers[6] in their findings stated that the production of traditional Portland cement, a key ingredient in concrete, is associated with significant environmental impacts, including high energy consumption and substantial Carbon dioxide ($CO_{2)}$ emissions. As a result, there is a growing interest in exploring alternative materials that can partially or fully replace Portland cement in concrete production or act as an admixture to cement.

There has recently been a trend in literatures to allow supplementary materials or by- products to be used as admixtures in concrete production as one way to reduce pollution and environmental disturbances, while offering complementary properties to compensate natural aggregate loss in concrete. Therefore, cement replacements in concrete can be highly beneficial regarding cost, energy efficiency, low permeability, strength and durability [7].

This thesis offers an opportunity to contribute to sustainable construction practices by exploring the potential of agricultural waste products in concrete.

(OBHA) and (BHA) are agro-waste generated from oil bean Husk and Breadfruit husk respectively. Utilizing these by products as admixtures not only addresses waste management issues but also contributes to the development of more sustainable construction materials [8].

Compressive, Flexural and tensile strengths are among the most important mechanical properties of concrete [9]. The value of tensile strength of concrete affects its performance in structures and should be appropriately considered in structural designs [9]. Tensile stresses can also be caused by warping, corrosion of steel, drying shrinkage and temperature gradient [10]. Flexural strength of concrete (modulus of rupture) is an indirect measure of the tensile strength of the unreinforced concrete. It is a measure of the maximum stress on the tension face of an unreinforced concrete beam or slab at the point of failure in bending.

Earlier studies have shown that various agricultural wastes can be used as admixtures in concrete. For instance, Cocoa Pod husk ash, Oil shale ash, rice husk ash (RHA), Palm kernel husk ash and palm oil fuel ash have been successfully used to improve the mechanical properties and durability of concrete [11].

According to [12], the study found out that the use of agricultural waste materials in concrete production has gained attention due to its potential benefits in sustainability and cost reduction. Oil Bean Husk Ash (OBHA) and Breadfruit Husk Ash (BHA) are two such materials that can be used as admixtures in concrete. .

Previous studies found out that RHA is a highly reactive pozzolanic material suitable for use in lime-pozzolana mixes and are often used to blend with Ordinary Portland Cement. Based on the temperature range and the duration of burning of the husk, crystalline and amorphous forms of silica are obtained [13].

Researchers [14], found out that the durability of concrete can be enhanced by the inclusion of these ashes. As overall they can help with the concrete act as filler and also help in the performance in reducing the permeability of concrete, thereby increasing resistance to aggressive environments

Syamsul Bahri in his paper stated that most mineral admixtures have a favorable influence on the strength and durability, the porosity and permeability are one of the biggest factors that affect the durability. The OBHA and BHA in concrete could be active in the deterioration resistance such as alkali – silica reaction. This could affect the strength of the concrete [15].

According to [16], Oil Bean Husk Ash (OBHA) obtained from burning Oil Bean Husk, as an admixture contains silica, which can react with calcium hydroxide released during the hydration of cement to form additional calcium silicate hydrate (C-S-H), the primary strength-giving compound in concrete. Similar to Oil Bean Husk Ash, Breadfruit Husk Ash (BHA) also as an admixture in concrete contains a significant amount of silica [17]. The exact chemical composition can vary based on the burning process and the origin of the husks.

Concrete is a commonly and frequently used construction material, and it is often exposed to different environmental conditions, including exposure to Agricultural by-products like Oil Bean Husk Ash (OBHA) and Breadfruit Husk Ash (BHA) considered to be cementitious materials. However, using OBHA in concrete that already contains BHA can affect Concrete

Consistency quality as the chemical and physical properties of OBHA and BHA may vary depending on the source and processing methods thereby affecting the desired properties of concrete and its performance.

Similarly, the production of conventional concrete may not give the required concrete strength expected during construction. With the incorporation of OBHA and BHA, the expected strength may be achieved. Also, by incorporating them in a concrete matrix, our environment will be safe from dirt which may result to atmospheric pollution.

The aim of the study is to assess the impact or investigate the effects of incorporating Oil Bean Husk Ash (OBHA) on the mechanical properties of concrete containing Breadfruit Husk Ash (BHA). The Objectives are;

i. Developing concrete mixes incorporating varying percentages of Oil Bean Husk Ash and Breadfruit Husk Ash respectively as admixtures (e.g. 0%, 5%, 10%, 15%, 20% and 30% of cement by weight) and comparing these mixes to those with only plain concrete (control). Note: [2.5% OBHA & 2.5% BHA for 5%].

ii. Evaluating the influence of OBHA on the mechanical properties by conducting compressive strength, tensile strength, and flexural strength tests at different curing ages (3, 7, 14, 21, 28 and 90 days) of the concrete samples containing BHA and OBHA.

iii. Determining the variation in workability of the concrete mixes with varying percentages of OBHA content and compared to those mixed with BHA (Slump test).

iv. Determining the variation on initial and final setting times of cement produced with varying percentages of OBHA and BHA comparing these mixes to those with Ordinary Portland cement (control).

v. Developing Mathematical Modelling using R-Programming for optimization and predictions of compressive, flexural and split tensile strengths of OBHA/BHA and Ordinary Portland Cement (OPC) Concrete.

1.4 **Significance of Study**

The significance of this study lies in its contribution to the understanding of the effects of oil bean husk ash on concrete produced with breadfruit husk ash. The findings of this study will provide valuable insights for Engineers, Architects, and Construction professionals on how to look after concrete structures containing admixtures like OBHA and BHA. This Study offers an opportunity to contribute to sustainable construction practices by exploring the potential of agricultural waste products in concrete. Concrete is a widely used construction material, and its durability is critical to the safety and integrity of structures. Since the quality of OBHA and BHA can vary depending on the source and processing methods, ensuring consistent quality is crucial for achieving reliable concrete performance. The use of agricultural waste materials in concrete production has gained attention due to its potential benefits in sustainability and cost reduction. Oil bean husk ash (OBHA) and breadfruit husk ash (BHA) are two such materials that can be used as admixtures in concrete. By understanding the effects of Oil bean husk ash on concrete produced with breadfruit husk ash, and providing recommendations on optimal proportions of oil bean husk ash and breadfruit husk ash in concrete, this study will contribute to the development of more durable and safer structures. Similarly, by evaluating the impact of OBHA on the mechanical properties of concrete with BHA, you can gain valuable insights into the use of these alternative materials. Also by exploring the synergistic effects of OBHA and BHA in concrete, the study will contribute to the development of eco-friendly construction materials that not only reduce environmental impact but also enhance the performance and longevity of concrete structures. Another significance of this thesis is that a paper will emerge that will be used as an academic tool to help students handle similar or related thesis with confidence.

2.0 MATERIALS AND METHODS

The materials used for this research work are Ordinary Portland cement (OPC), Tap/Fresh Water, Oil Bean Husk Ash (OBHA), Breadfruit Husk Ash (BHA), fine and coarse aggregates.

2.1 Collection and Preparation of OBHA and BHA

The husks of oil bean and Breadfruit seeds were gathered and dried to remove moisture content. The dried husks were burnt in a controlled environment to produce ash. The burnt ashes were allowed to cool before being collected for use. Grinding the Ashes to fine powder was done to ensure it has a similar particle size to that of cement and was sieved to remove any large particles or impurities.

2.2. Collection of Fresh Water Sample

The fresh water used was laboratory water from borehole. The fresh water used was also collected in a quantity that was enough for both batching and curing of the concrete cubes and beams.

2.3 Collection and Grading Of Fine Aggregates

The fine aggregate (sand) used in this project is from a construction site at No. 1 Diobu Avenue in Aba, Abia State passing through 8.00 mm sieve. The grading zone of fine aggregate (sand) was zone 2 as per [18] standard specification. Fine aggregate content is usually 32% to 45% by mass or volume of the total aggregate content.

2.4 Collection and Grading Of Coarse Aggregates

The coarse aggregate used in this project was Crushed granite stone aggregate from quarry at Ishiagu, Ebonyi State, Nigeria passing sieve 20mm but retained on 5.00 mm sieve but conforming to [18] standard specification.

2.5 Collection of Cement

The cement used was Dangote 3X Cement. Dangote 3X is a Portland limestone cement conforming to the Nigerian cement standards [19].

2.6 Batching, Mixing of Samples, Casting, Compaction and Curing of Concrete

Batching of the components of the concrete was by weight and mixing was done with the help of concrete mixer. Required proportion of Ordinary Portland Cement (OPC), BHA, and OBHA were mixed with the fine aggregates, coarse aggregates and water at required proportions. Water was added gradually and the concrete was mixed thoroughly to ensure homogeneity. The initial setting time, workability, slumps, as well as placing the concrete into the concrete cubes/cylinder moulds and concrete beam moulds was carried out. Three different types of concrete specimen were produced in the laboratory. These included; 150mm x 150mm x 150mm cubes, 150mm x 150mm x 700mm concrete prototype beam specimen prescribed according to [20] and 150mm x 300mm cylindrical concrete specimen prescribed according to [21]. After casting, placing, compacting and finishing operation, all specimens were covered with a plastic sheet till de-molding. The specimens were de-molded after 24 hours and immersed in water in a water tank for 3, 7, 14, 21, 28 and 90 days. This was done in accordance with [22]. Once the desired curing period was completed, the specimens were taken out from the curing tank and prepared for test program.

2.7 Mix Design Proportions

One mixture proportion was considered in this research work. Considerations were made on uncrushed maximum aggregate size of 20mm, slump range of 30-60mm, characteristics strength of 25N/mm^2 at 28 days, free water content of 180kg/m^3 and aggregate relative density of 2.6. The mix ratio of [1: 2.14: 4.18] had 34% proportion of fine aggregate corresponding to a free water/cement ratio of 0.60. The mix design was proportioned for target cube strength of 39N/mm^2 and had a Cementitious material content of 300 kg/m^3, a fine aggregate content of 644.3 kg/m^3, a coarse aggregate content of 1250.7 kg/m^3 and a water cementitious ratio of 0.60.

2.8 Slump Test

Slump test was conducted to determine the consistency of plastic concrete and its suitability for detecting changes in workability.

2.9 Compressive Strength Test

For the determination of the Compressive Strength, the concrete cube size measuring 150mm×150mm×150mm in dimension was used. The batching of the concrete moulds was by weight. The concrete was produced using 0, 5, 10, 15, 20, 30% addition of OBHA and BHA respectively on equal basis. The concrete cubes moulds were cleaned and oil was applied and the moulds were filled in layers approximately 50mm thick with the mixed concrete. Each layer of concrete was compacted with not less than 25 strokes using a tamping rod. The cubes were later filled to two third of their height and finally filled completely with the top surface leveled and smoothen with trowel and left for 24 hours to set before being cured at 3, 7, 14, 21, 28 and 90 days. For the Compressive strength test, the total number of concrete cubes cast was one hundred and eight (108). After curing for a specific number of days, the cubes are brought out of water. The mass/weights of the cubes are measured and recorded. For each of the hydration period, three cubes were tested. The cubes are placed on the crushing machine and crushed to determine the failure load.

Then, the average compressive strength is determined using the formula stated below.

$$\sigma = \frac{P}{A}.$$

Where σ =Compressive Strength (N/mm^2), P=Test load (N), A=Area (mm^2).

2.10 Flexural Strength Test

The flexural strength was determined using a beam mould of 150mm x 150mm x 700mm in dimension. The total number of beams cast was one hundred and eight (108). The batching of the concrete moulds was by weight. The concrete was produced using 0, 5, 10, 15, 20, 30% addition of OBHA and BHA respectively on equal basis. The concrete cubes moulds were cleaned and oil was applied and the moulds were filled in layers approximately 50mm thick with the mixed concrete. Each layer of concrete was compacted with not less than 25 strokes using a tamping rod. The cubes were later filled to two third of their height and finally filled completely with the top surface leveled and smoothen with trowel and left for 24 hours to set before being cured at 3, 7, 14, 21, 28 and 90 days. After curing for a specific number of days, the beams are brought out of water and kept moist. The top of the beam as molded is turned to its side and marked as to help with centering in machine. The beams are loaded in the machine and centered on support blocks and loads are applied according to BS 1881 at a given rate of 400kg/minute until rapture occurs. Then, the average Flexural strength or the Modulus of Rupture is determined using the formula stated below.

$R = \frac{PL}{bd^2}$. This is used when the fracture occurs within the middle third of the specimen. Here (a > 200mm) for 150mm beam size or

Where:

R = Modulus of Rupture (N/mm^2)
P = Maximum load applied that causes failure (N)
L = Supported length of beam (mm)
b = Width of specimen (beam) (mm)
d = Failure point depth of specimen (beam) (mm)
a = Line of fracture to the nearest support.

2.11 Split Tensile Strength Test

The Split tensile strength was determined using a cylindrical cube size of 300mm in length or height and 150mm in diameter. The total number of concrete cylinders cast was one hundred and eight (108). In the same manner, the concrete was produced using 0, 5, 10, 15, 20, 30% addition of OBHA and BHA respectively on equal basis. The concrete cubes moulds were cleaned and oil was applied and the moulds were filled in layers approximately 50mm thick with the mixed concrete. Each layer of concrete was compacted with not less than 25 strokes using a tamping rod. The cubes were later filled to two third of their height and finally filled completely with the top surface leveled and smoothen with trowel and left for 24 hours to set before being cured at 3, 7, 14, 21, 28 and 90 days. After curing for a specific number of days, the concrete cylinders are brought out of water and kept moist. Before testing, a line is drawn on the specimen through the diameter of the specimen and the weight and dimensions of the specimen are recorded. The specimen is placed longitudinally on the Universal testing machine. A wooden sheet made of plywood is placed on both sides of the specimen before application of the load and must be aligned according to the marking. Loads are continuously applied in the range of 0.7 to 1.4 MPa/minute until the specimen fails by developing cracks. Then, the Resultant Split Tensile strength is determined using the formula stated below.

$$T = \frac{2P}{\pi DL}.$$

Where:

T =Split Tensile Strength (N/mm^2).

P =Load at which the Specimen breaks (N).

$\pi = \frac{22}{7}$

D = Diameter of specimen (mm).

L = Length of specimen (mm)

2.12 Setting Time Test Using Ordinary Portland Cement (Dangote)

This test was carried out in accordance with the BS 12 (1978) using the Vicat apparatus, OBHA and BHA samples as admixtures respectively. The Vicat apparatus uses two pins, initial and final setting time pins for the determination of initial and final setting time of cement respectively. To carry out this experiment, 80g of water was added to 200g of cement to form cement paste plus 0, 5, 10, 15, 20, 30% addition of OBHA and BHA on equal basis respectively. The paste was then placed on the cup of the Vicat apparatus. Before the placement of the paste on the apparatus, the initial setting pin was fixed on the apparatus for initial setting time. The apparatus is calibrated in millimeters. For the initial setting time, the initial pin was dropped on the paste to 5mm calibration mark on the apparatus. The initial setting time was then recorded starting from the time the water was added to the paste to the time the pin penetrated up to 5mm on the apparatus. Similarly, the final setting time was recorded using the final setting pin. The final setting pin has an inner and outer pin. The final setting pin time was taken when only the inner pin makes a mark on the paste when allowed to drop freely. The final setting time was recorded starting from the time the water was added to the paste to the time the inner pin of the final setting pin makes a mark on the paste.

The result of the setting time of the Dangote Cement with both OBHA and BHA are recorded accordingly.

2.13 Developing Statistical/Mathematical Modeling Using R-Programming

R- Programming is a versatile language primarily used for statistical computing, data analysis, and graphical representation. It's a popular choice for data scientists, statisticians, and researchers due to its capabilities in data manipulation, visualization, and statistical modeling.

We used two independent variables for Model Formation;

- Percentage of OBHA/BHA: The percentage of cement replaced by OBHA/BHA.

- Curing Age: The age of curing in days.

To model the relationship of Compressive strength, Flexural Strength and Split Tensile Strength with Percentage OBHA/BHA and curing age respectively, we model linear, quadratic and nonlinear and then select the best model.

2.13.1 Model Formulation:

Variables

The variables used in the analysis are defined as follows:

- **Dependent Variable (Y):** Compressive Strength (CS) or Flexural Strength (FS) or Split Tensile Strength (STS) of Concrete Cubes (N/mm^2)
- **Independent Variables (X):** We'll use two independent variables:
- Percentage of OBHA/BHA: The percentage of cement replaced by OBHA/BHA.
- Curing Age: The age of curing in days.

- **x_1:** Amount of OBHA & BHA combined on equal ratio (%) the study considered (0, 5,10,15,20 and 30%)
- **X_2:** The **curing age of cement** refers to number of days during which freshly placed concrete is kept moist to ensure proper hydration of cement, which is essential for strength development and durability. The study considered the following days 3, 7, 14, 21, 28 and 90.

2.13.2 Mathematical Model Formulation for Compressive Strength (CS), Flexural Strength (FS) and Split Tensile Strength (STS).

A possible model form could be:

$$CS = \beta 0 + \beta 1.\ \text{Percentage of OBHA/BHA} + \beta 2.(\text{Percentage of OBHA/BHA})2 + \beta 3.\log(\text{Curing Age}) + \varepsilon$$

$$FS = \beta 0 + \beta 1.\ \text{Percentage of OBHA/BHA} + \beta 2.(\text{Percentage of OBHA/BHA})2 + \beta 3.\log(\text{Curing Age}) + \varepsilon \text{.........}(2.1)$$

$$STS = \beta 0 + \beta 1.\ \text{Percentage of OBHA/BHA} + \beta 2.(\text{Percentage of OBHA/BHA})2 + \beta 3.\log(\text{Curing Age}) + \varepsilon$$

Where:

β_0 = Beta_0: Intercept (Baseline compressive strength or Flexural Strength or Split Tensile Strength).

β_1 =Beta_1: Coefficient for the linear effect of OBHA/BHA percentage.

β_2 =Beta_2: Coefficient for the quadratic effect of OBHA/BHA percentage (to capture the optimal point and subsequent decrease).

β_3 = Beta_3: Coefficient for the logarithmic effect of curing age.

ϵ = Epsilon: Error term.

3.0 RESULTS AND DISCUSSION

3.1 SIEVE ANALYSIS OF FINE AGGREGATES

Table 3.1 below shows the result of the sieve analysis of fine aggregates used. The result shows that the fine aggregate falls into zone 2 of calibration graph which shows that the sand is classified as "moderately coarse sand. According to Indian Standard [23], this type of sand is considered suitable for general-purpose concrete mixes which is crucial for creating a workable, strong, and durable concrete mix. The Sieve analysis determines particle size distribution of fine aggregates which is crucial for assessing material suitability, ensuring quality control in construction projects, and designing concrete mixes which allows Engineers to select appropriate aggregates that meet specific project requirements and achieve desired performance characteristics.

Similarly, Figure 3.1 below shows the Sieve Analysis of Fine Aggregates Graph. The values of D_{10}, D_{30}, and D_{60}, which are the diameters that correspond to the percent finer of 10%, 30%, and 60%, respectively were determined from the grain-size distribution curve. Here, D_{10}=0.27, D_{30}=0.6 and D_{60}=1.1

The values of Coefficient of Uniformity (C_U) of 4.07 and Coefficient of Curvature (C_C) or Coefficient of Gradation of 1.21 were obtained using the following equations:

$$Cu = \frac{D_{60}}{D_{10}} = \frac{1.1}{0.27} = 4.07 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1a)$$

$$C_C = \frac{(D_{30})^2}{D_{60} x D_{10}} = \frac{(0.6)^2}{1.1x0{,}27} = 1.21 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1b)$$

This shows that the fine aggregate is a well graded soil since C_U is greater than 4 and C_C varies between 1 and 3. The values of C_u and C_c are used to classify whether the soil is well-graded or not.

Table 3.1 Result of Sieve Analysis of Fine Aggregates

Standard Sieve size	Mass of sample retained (g)	Mass of sample passing (g)	Percentage retained (g)	Percentage passing (g)
8mm	0.00	250	0.00	100
5mm	15.60	234.40	6.24	93.76
2.36mm	44.30	190.10	17.72	76.04
1.18mm	32.90	157.20	13.16	62.88
600µm	75.05	82.15	30.02	32.86
300µm	54.15	28.00	21.66	11.20
150µm	15.90	12.10	6.36	4.84
Pan	12.10	0.00	4.84	0.00

Standard Sieve size (mm)	Percentage passing (g)
8	100
5	93.76
2.36	76.04
1.18	62.88
0.6	32.86
0.3	11.2
0.15	4.84
Pan	0

Figure 3.1: Fine Aggregate Sieve Analysis Graph

3.2. SLUMP TEST RESULTS

Table 3.2 below shows the slump test results of the concrete having 0%, 5%, 10%, 15%, 20% and 30% of OBHA and BHA Addition combined on equal ratio. It is observed that the slumps were within the assumed slump thereby showing no serious effect. The slump test results showed that slump increases with increase in percentage addition of OBHA and BHA. This flow could be attributed to the fine and spherical particles of OBHA and BHA in contact with cement which is in line with the findings of [24].

Table 3.2: Slump Test Results with various percentages of OBHA and BHA

Mix Ratio	**Addition of OBHA and BHA (%)**	**Height of Slump cone (mm)**	**Height of Concrete after test (mm)**	**SLUMP (mm)**
1 : 2.14 : 4.18	0	300	269	31
1 : 2.14 : 4.18	5	300	266	34
1 : 2.14 : 4.18	10	300	262	38
1 : 2.14 : 4.18	15	300	257.5	42.5
1 : 2.14 : 4.18	20	300	255.2	44.8
1 : 2.14 : 4.18	30	300	253.7	46.3

Figure 3.2 below shows the workability of the fresh OBHA & BHA-Cement Concrete as the percentage of OBHA/BHA is increased from 0 to 30%. It can be observed that concrete became less workable as the percentage of OBHA/BHA increased from 0% to 30%. The Slump increased from 31mm at 0% to 46.3mm at 30% addition levels. This is comparable to the results of [25] and [26]. However, the concrete is still workable and has ease of placement despite the increased slump.

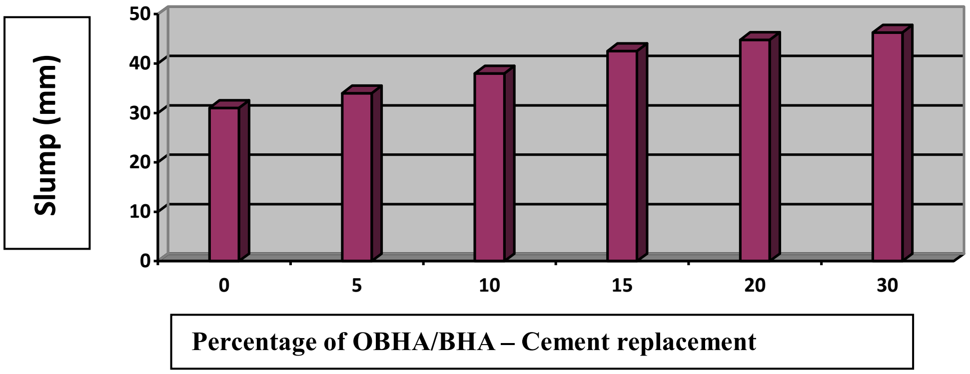


Figure 3.2: Variation in Slump of OBHA/BHA-Cement concrete as percentage replacement varies.

3.3 VARIATION OF SETTING TIMES OF CEMENT WITH PERCENTAGE REPLACEMENT

Table 3.3 below shows the result of the initial and final setting times considered using cement and different percentages of Oil bean husk ash (OBHA) and Breadfruit husk ash (BHA). The initial and final setting times increase with increase in OBHA/BHA content. The reaction between cement and water is exothermic which is defined as the reaction that releases energy by heat. The liberation of heat and evaporation moisture causes the stiffening of the paste and slower heat induced evaporation of water from the cement/OBHA & BHA paste due to its lower cement content [27], and therefore an accelerated increase in the initial setting time of the mixture was observed. Thus, an increase in the setting time was noticeable from 137 minutes (at 5% OBHA/BHA) to 155 minutes (at 15% OBHA/BHA) and the setting time continued to increase until the last proportion as the percentages of OBHA/BHA increased to 30% (165 minutes). Similarly, Figure 3.3 below shows the variation in setting time of OBHA/BHA-Cement as percentage replacement varies. The final setting time also increases as the percentages of OBHA/BHA increase thereby retarding the hydration process. This result is interconnected with the work of [28] and that of [29].

Table 3.3: **Initial and Final Setting Time Test using Ordinary Portland Cement.**

Amount of Cement (%)	**Amount of OBHA & BHA (%) combined on equal ratio**	**Initial Setting time (Minutes)**	**Final Setting time (Minutes)**
100	0	122	183
95	5	137	227
90	10	145	239
85	15	155	255
80	20	160	265
70	30	165	275

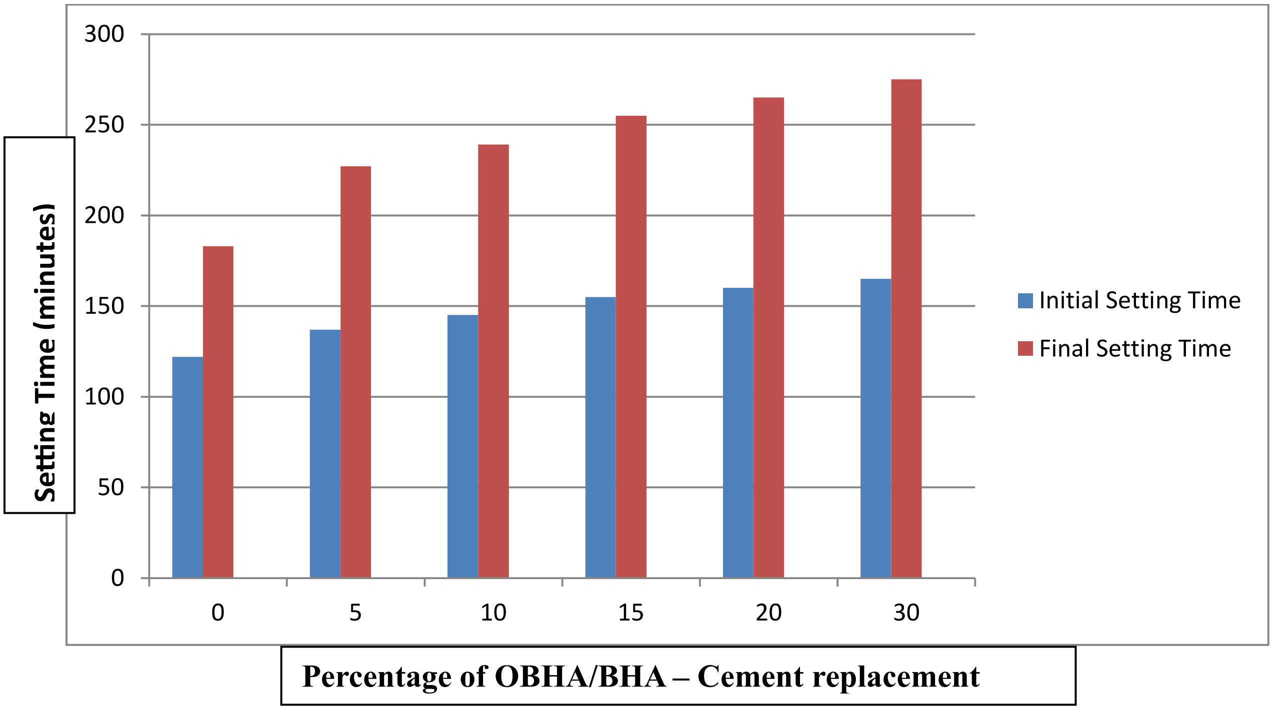


Figure 3.3: Variation in setting time of OBHA/BHA-Cement as percentage replacement varies.

3.4 Average Compressive Strength of Concrete Cubes (N/mm^2) with various percentages of OBHA and BHA

Table 3.4 below showed the results of the average compressive strength tests of OBHA & BHA concrete cubes of mix ratio (1 : 2.14 : 4.18), and water cement ratio of 0.60. The Compressive Strength value ranges from (3.65N/mm^2 – 29.84N/mm^2). The result of the average compressive strength of concrete produced for all mix increases with age at curing and decreases as the OBHA/BHA content increases. The best compressive strength result was obtained with the percentages of cement replaced by 5% OBHA/BHA and it decreased significantly as the percentages of OBHA/BHA increased. In fact, the strength showed remarkable increase with ageing, with highest compressive strength encountered in the 90 days; which may be due to retention of water with the structural frame of the mixture thereby allowing better hydration.

Table- 3.4: Average Compressive Strength of Concrete Cubes (N/mm^2) with various percentages of OBHA and BHA

Amount of Cement (OPC) (%)	Amount of OBHA & BHA combined on equal ratio (%)	Design strength (N/mm^2)	Design strength (N/mm^2)	Design strength (N/mm^2)	Design strength (N/mm^2)	Design strength (N/mm^2)	Design strength (N/mm^2)
		3 Days	**7 Days**	**14 Days**	**21 Days**	**28 Days**	**90 Days**
100	0	10.36	11.66	19.52	22.46	26.04	29.84
95	5	6.86	8.48	15.92	18.38	23.13	28.27
90	10	6.13	7.81	14.35	16.34	20.75	25.51
85	15	4.96	6.76	13.06	14.93	19.03	23.46
80	20	4.60	6.42	12.65	14.79	17.46	20.31
70	30	3.65	5.56	11.90	13.10	16.64	20.47

Similarly, Figure 3.4 below shows the Compressive Strength curve for OPC/OBHA & BHA which shows increase in strength as the curing days of concrete increase and decrease in strength as the OBHA/BHA level increases.

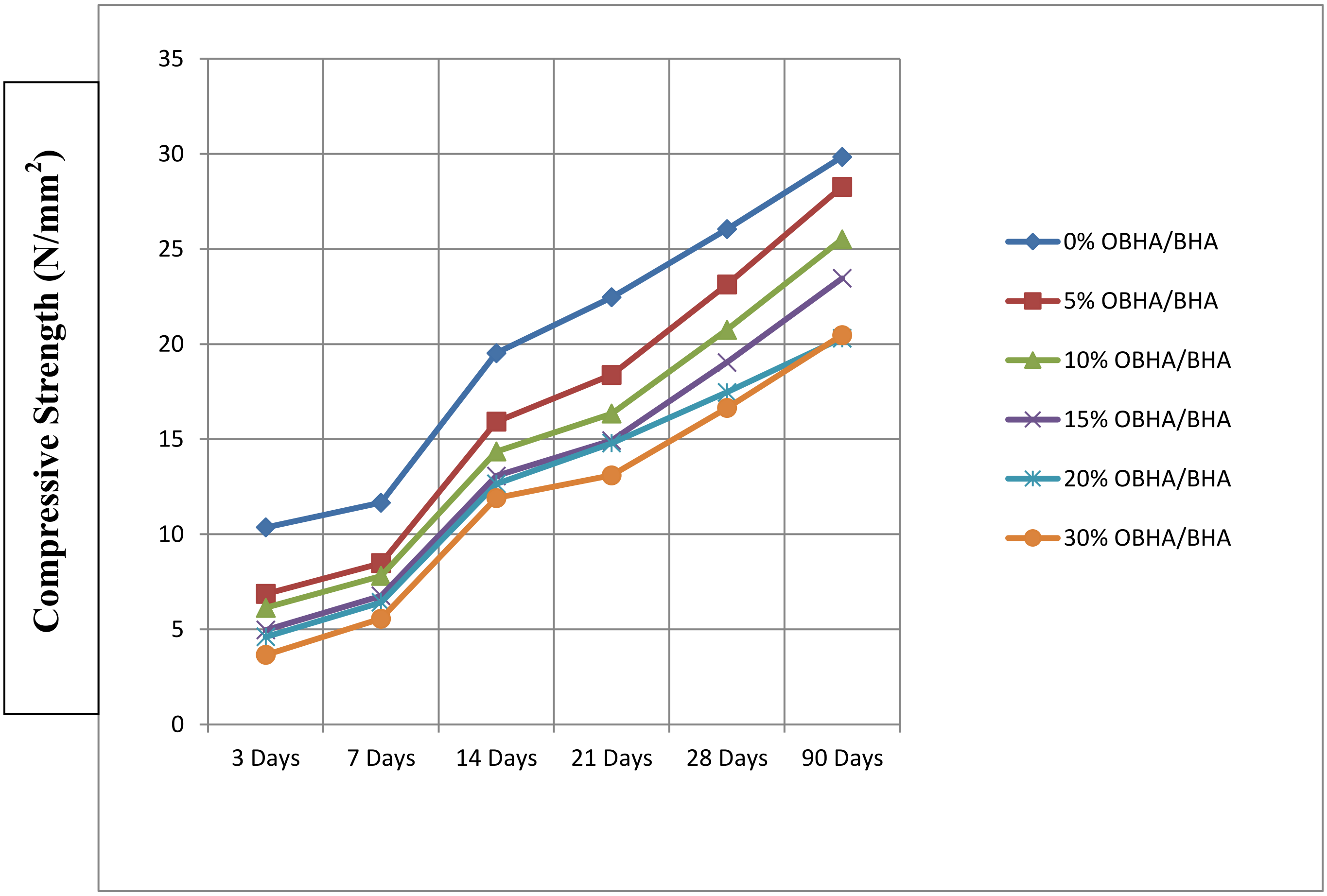


Fig. 3.4: Compressive Strength Development of concrete mixes with varying percentage addition of OBHA/BHA cured in water (1: 2.14: 4.18/0.60).

3.5. Statistical/Mathematical Model Analysis for the Compressive Strength of Cement/OBHA & BHA Concrete.

Preliminary observations from Compressive strength data;

i. Compressive strength increases with age at curing**:** This suggests a positive correlation with curing age, likely a non-linear one (e.g., rapid increase initially, then a slower gain, eventually levelling off).

ii. Compressive strength decreases as OBHA/BHA content increases: This indicates a negative correlation with the percentage of OBHA/BHA replacement.

iii. Best compressive strength at 5% OBHA/BHA replacement: This suggests an optimal point, implying that a simple linear decrease might not fully capture the behaviour across all percentages. It could be a quadratic relationship where the strength initially increases (or maintains well) with low percentages and then drops more significantly with higher percentages.

iv. Highest compressive strength at 90 days**:** This confirms the age-dependent strength gain.

The study employed a quantitative, experimental research design to investigate the relationship between a set of independent variables and a continuous dependent variable. The primary analytical techniques are multiple linear regression and Polynomial Regression. The dataset for this analysis was Average Compressive Strength of Concrete Cubes (N/mm^2) with various percentages of OBHA and BHA. Using R-Programming Software language version 4.5.1 with the tidy verse, broom, ggpubr, caret, grid Extra, nls2 and nls tools libraries, create the data set based on the Average Compressive Strength of Concrete Cubes obtained after loading the required packages.

Variables

The variables used in the analysis are defined as follows:

- **Dependent Variable (Y):** Compressive Strength of Concrete Cubes (N/mm^2)

Independent Variables (X): We'll use two independent variables:

- Percentage of OBHA/BHA: The percentage of cement replaced by OBHA/BHA.
- Curing Age: The age of curing in days.

- **x_1:** Amount of OBHA & BHA combined on equal ratio (%) the study considered (0, 5,10,15,20 and 30%)
- **X_2:** The **curing age of cement** refers to number of days during which freshly placed concrete is kept moist to ensure proper hydration of cement, which is essential for strength development and durability. The study considered the following days 3, 7, 14,21, 28 and 90.

For the Regression Analysis, we model linear, quadratic and non linear and select the best model for analysis.

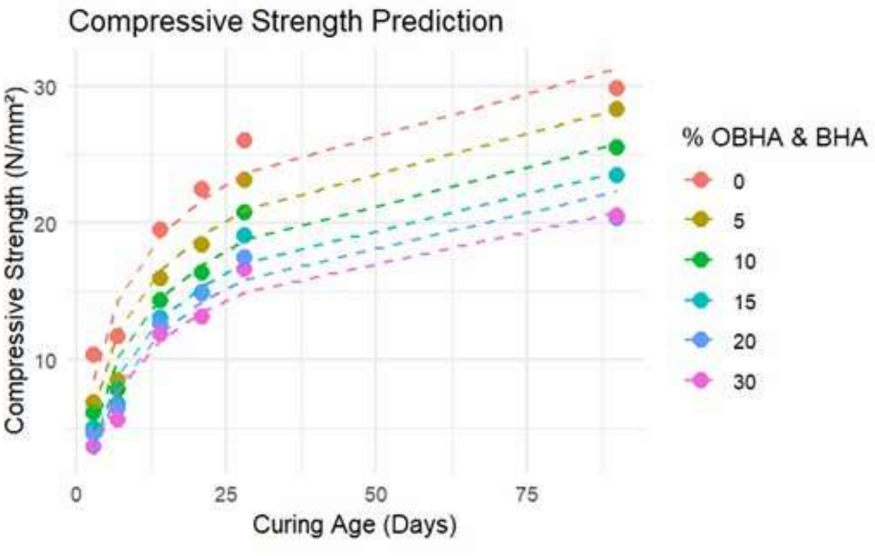
Model Evaluation

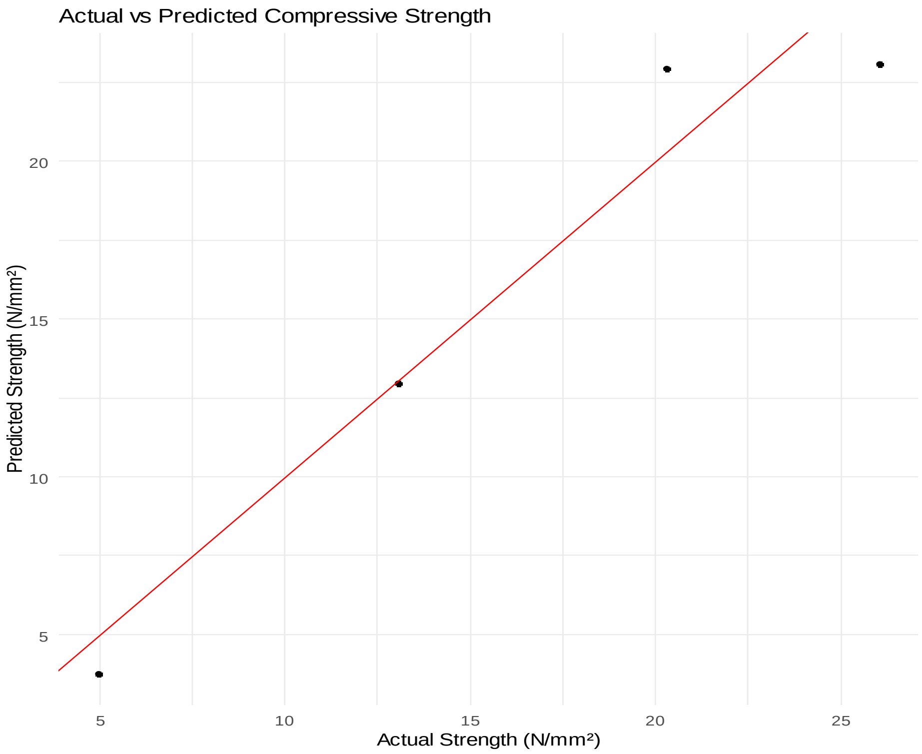
The performance of both the linear and polynomial regression models was evaluated and compared using the following metrics on the **test set**:

a. **R-squared (R^2):** The proportion of variance in the dependent variable that is predictable from the independent variables.
b. **Adjusted R-squared:** A modified version of R^2 that adjusts for the number of predictors in the model, providing a more reliable metric for comparing models with different numbers of features.
c. **Root Mean Squared Error (RMSE):** The square root of the average of squared differences between predicted and actual values. It is in the same units as the dependent variable and is a key measure of prediction error.

A higher R-squared/Adjusted R-squared and a lower RMSE indicate a better model fit.

Akaike Information Criterion (AIC), and graphical residual analysis. The exponential model was compared against the linear and polynomial models to assess whether the non-linear formulation provided a more accurate and parsimonious description of the strength–curing age relationship. Using R-Programming Software language we arrived at the following:





Optimization Result

	OBHA/BHA Percent	Curing Age	Strength
1	5	90	28.25905

Interpretation:

- The optimal mix for maximum compressive strength is:
  - 5% OBHA/BHA replacement
  - 90 days curing
  - Predicted strength: 28.26 N/mm²
- This aligns with the experimental result where 5% replacement yielded the highest strength.

The R-based regression model effectively captures the relationship between OBHA/BHA content, curing age, and compressive strength. The model shows:

- A strong fit with high predictive accuracy.
- Compressive strength increases with curing age due to prolonged hydration.
- Strength decreases with higher OBHA/BHA content, likely due to dilution of

cementitious material.

- Optimal performance is achieved at 5% OBHA/BHA replacement and 90 days curing, making it the most efficient mix for structural applications

3.6 Average Flexural Strength of Concrete Cubes (N/mm^2) with various percentages of OBHA and BHA.

Table 3.6 below showed the results of the average flexural strength tests of OBHA & BHA concrete cubes of mix ratio (1 : 2.14 : 4.18), and water cement ratio of 0.60. The Flexural Strength value ranges from (0.50N/mm^2 - 3.79N/mm^2). The result of the average flexural strength of concrete produced for all mix increases with age at curing and decreases as the OBHA/BHA content increases. The best flexural strength result was obtained with the percentages of cement replaced by 5% OBHA/BHA and it decreased significantly as the percentage of OBHA/BHA increased. In fact, the strength showed remarkable increase with ageing, with highest flexural strength encountered in the 90 days; which may be due to retention of water with the structural frame of the mixture thereby allowing better hydration.

Table- 3.6: Average Flexural Strength of Concrete Cubes (N/mm^2) with various percentages of OBHA and BHA.

Amount of Cement	Amount of OBHA & BHA (%) combined on equal ratio	Design strength (N/mm^2)	Design strength (N/mm^2)	Design strength (N/mm^2)	Design strength (N/mm^2)	Design strength (N/mm^2)	Design strength (N/mm^2)
		3 Days	**7 Days**	**14 Days**	**21 Days**	**28 Days**	**90 Days**
100	0	1.42	1.76	2.87	3.19	3.49	3.79
95	5	0.94	1.28	2.34	2.61	3.10	3.59
90	10	0.84	1.18	2.11	2.32	2.78	3.24
85	15	0.68	1.02	1.92	2.12	2.55	2.98
80	20	0.63	0.97	1.86	2.10	2.34	2.58
70	30	0.50	0.84	1.75	1.86	2.23	2.60

Correspondingly, Figure 3.6 below shows the Flexural Strength curve for OPC/OBHA & BHA concrete which is used to determine the concrete's ability to resist cracking and failure when subjected to bending forces. It provides crucial data for structural design, quality control, and material selection in construction, ensuring that concrete beams, slabs, and pavements can withstand applied loads without deforming or breaking. This measurement is critical for predicting a structure's durability, performance, and longevity. The curve in this study shows increase in strength as the curing days of concrete increase and decrease in strength as the OBHA/BHA level increases. This is in conformity with the research of [30].

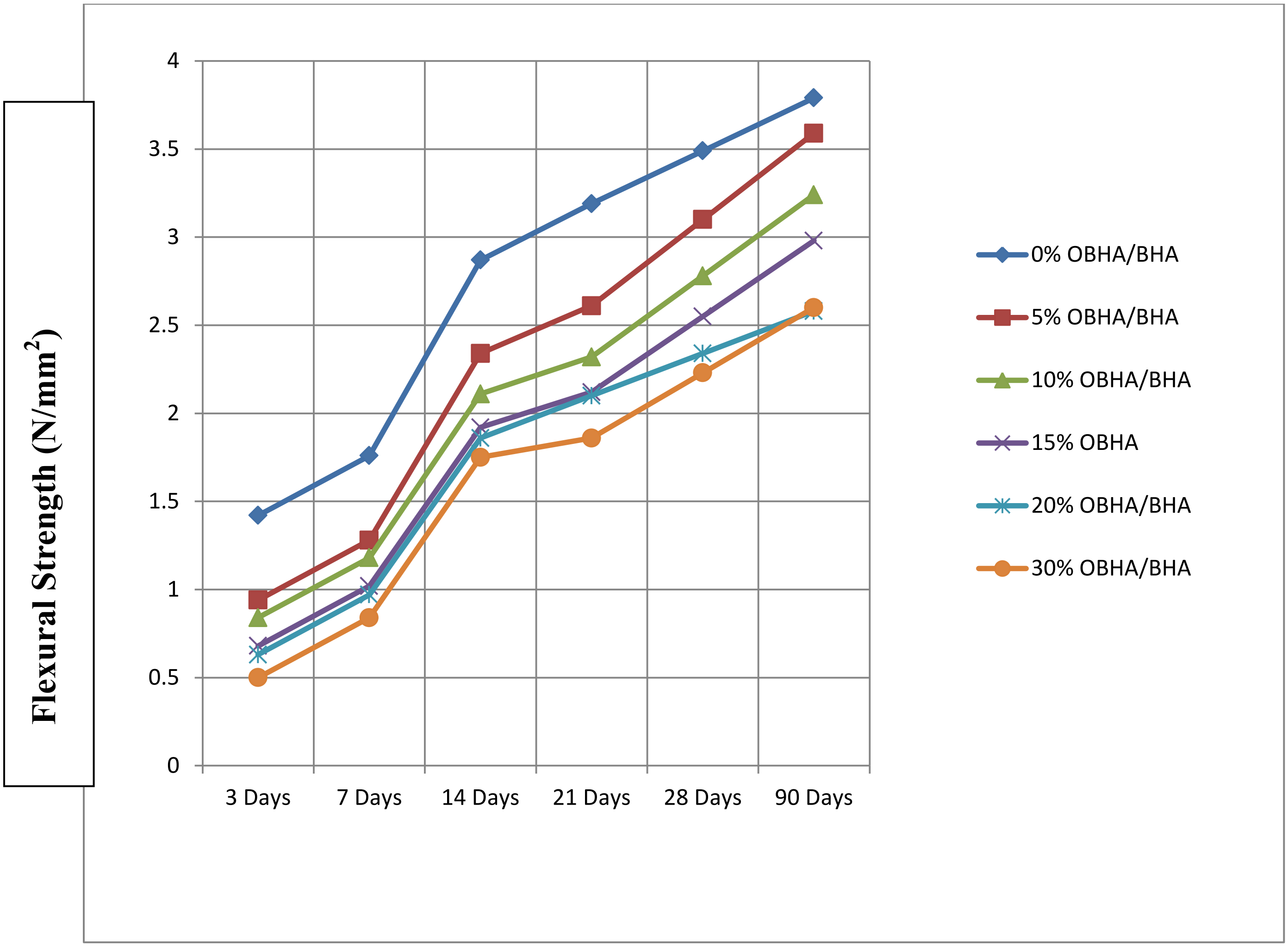


Fig. 3.6: Flexural Strength Development of concrete mixes with varying percentage addition of OBHA/BHA cured in water (1: 2.14: 4.18/0.60).

Statistical/Mathematical Model Analysis for the Flexural Strength of Cement/OBHA & BHA Concrete.

Preliminary Observations from Flexural Strength Data (OBHA & BHA Concrete)

1. Flexural Strength Increases with Curing Age

- At every replacement level (0% to 30%), the flexural strength consistently increased from 3 days to 90 days.
- This suggests continued hydration over time, especially beneficial with the pozzolanic activity of OBHA and BHA.

2. Flexural Strength Decreases with Higher OBHA/BHA Content.

- As the percentage of cement replaced by OBHA/BHA increases, the average flexural strength decreases.
- This trend is seen at all curing ages**.**

- The likely reason is the lower cementitious content, leading to reduced binding potential and delayed pozzolanic reaction.

3. Best Performance at 5% Replacement

- The highest flexural strength for any curing age (e.g., 3.59 N/mm² at 90 days) occurred with a 5% replacement level.
- Beyond 5%, strength started to reduce significantly, implying an optimal substitution point for flexural strength.

4. 90-Day Strength is the Peak

- At all mix levels, 90 days produced the maximum strength values.
- This suggests long-term strength development due to better hydration and possible latent pozzolanic activity of OBHA and BHA.

5. Water Retention & Hydration

- As you noted, the retained water within the structural framework likely helped promote better long-term hydration, which enhanced strength over time.
- The high water–cement ratio (0.60) may have contributed to prolonged availability of water for continued reactions.

Mathematical Model Formulation:

Considering these observations, a multiple regression model would be suitable. We'll use two independent variables:

- Percentage of OBHA/BHA: The percentage of cement replaced by OBHA/BHA.
- Curing Age: The age of curing in days.

Since the relationship with Percentage of OBHA/BHA is not simply linear (due to the optimal 5% point), we might consider a quadratic term for it. The relationship with Curing Age is also non- linear, often modeled with logarithmic or power functions, or even as a polynomial. Given the "remarkable increase with aging, with highest flexural strength encountered in the 90 days," a logarithmic or square root transformation of age, or a polynomial up to a certain degree, could be explored.

Interpretation:

- At 5% OBHA/BHA, predicted flexural strength at 28 days is 2.88 N/mm².
- At 10%, it drops to 2.59 N/mm².
- At 15%, it further drops to 2.34 N/mm².
- This confirms the experimental observation that Flexural strength decreases with increasing OBHA/BHA replacement.

Optimization Result

	OBHA/BHA Percent	Curing Age	Strength
1	0	90	3.997141

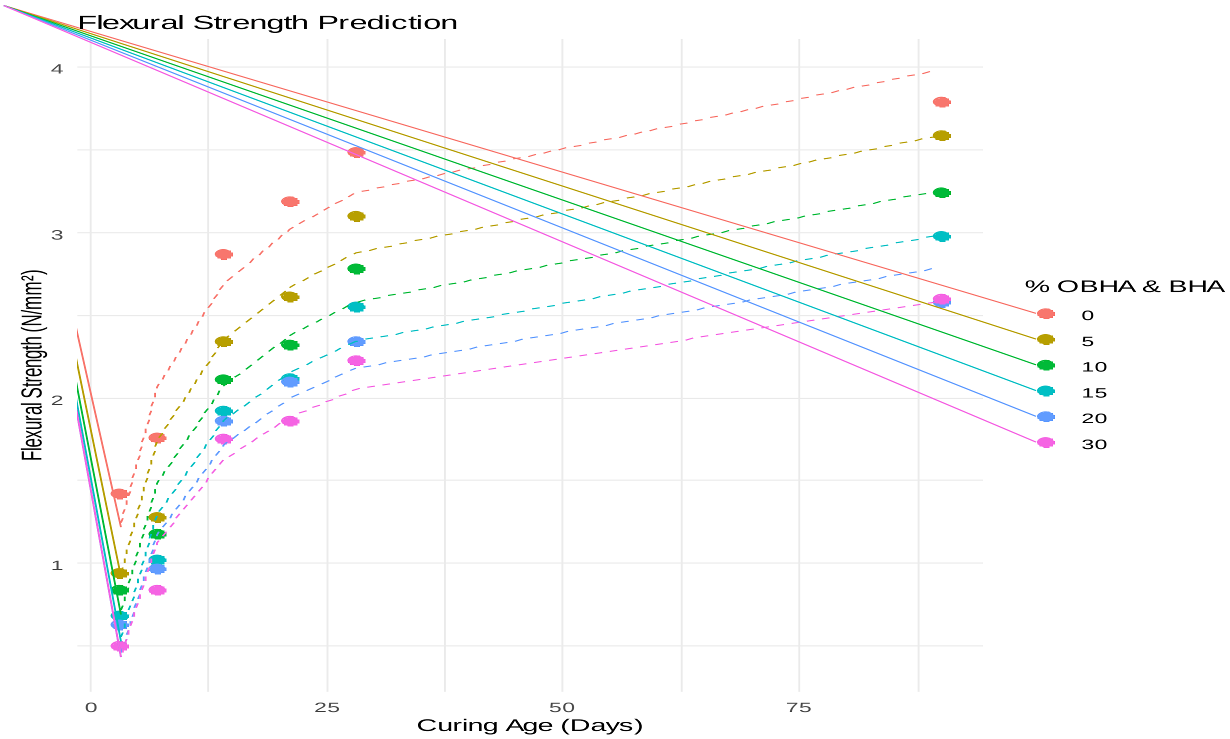
Interpretation:

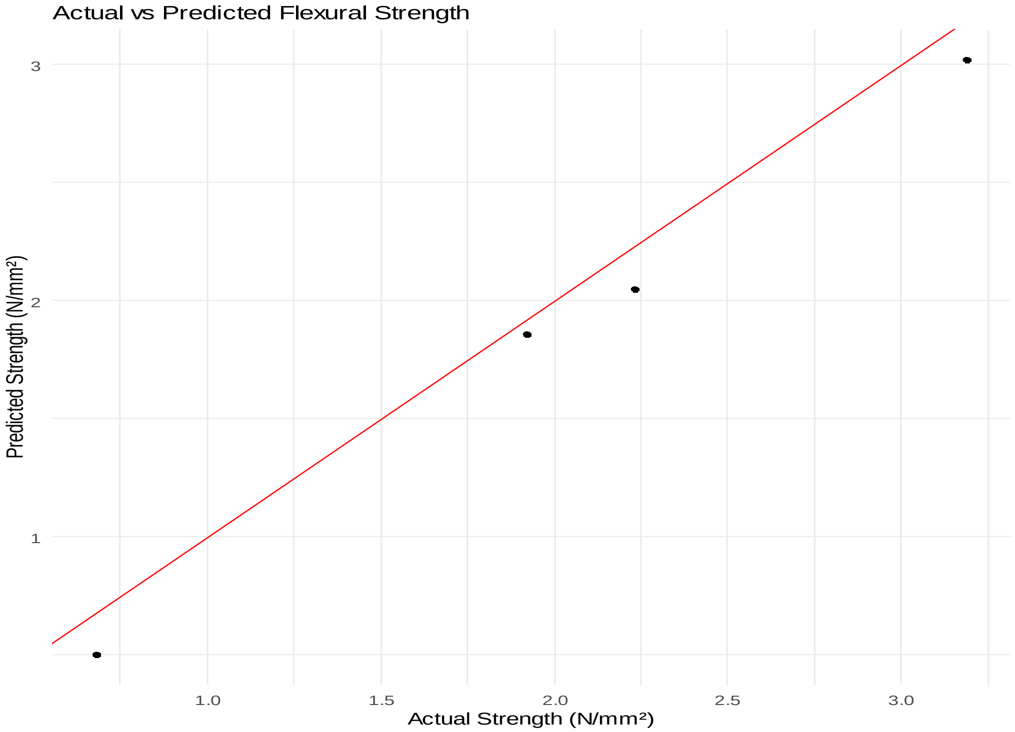
The optimal mix for flexural strength is:

- 5% OBHA/BHA replacement
- 90 days curing
- Predicted strength: 3.997 **N/mm²**

The R-based model for flexural strength prediction demonstrates:

- Strong predictive power with high R².
- Flexural strength increases with curing age, due to enhanced hydration.
- Strength decreases with increasing OBHA/BHA content, confirming dilution effects.
- Optimal performance is achieved at 5% OBHA/BHA replacement and 90 days curing, making it
- ideal for structural applications requiring flexural durability.





3.7 Average Split Tensile Strength of Concrete Cubes (N/mm^2) with various percentages of OBHA and BHA.

Table 3.7 below showed the results of the average Split tensile strength tests of OBHA & BHA concrete cubes of mix ratio (1 : 2.14 : 4.18), and water cement ratio of 0.60. The Split tensile Strength value ranges from (0.28N/mm^2 - 2.06N/mm^2). The result of the average Split tensile strength of concrete produced for all mix increases with age at curing and decreases as the OBHA/BHA content increases. The best split tensile strength result was obtained with the percentages of cement replaced by 5% OBHA/BHA and it decreased considerably as the percentage of OBHA/BHA increased. In fact, the strength showed remarkable increase with ageing, with highest split tensile strength encountered in the 90 days; which may be due to retention of water with the structural frame of the mixture thereby allowing better hydration.

Table- 3.7: Average Split Tensile Strength of Concrete Cubes (N/mm^2) with various percentages of OBHA and BHA.

Amount of Cement (%)	Amount of OBHA & BHA (%) combined on equal ratio	Design strength (N/mm^2) 3 Days	Design strength (N/mm^2) 7 Days	Design strength (N/mm^2) 14 Days	Design strength (N/mm^2) 21 Days	Design strength (N/mm^2) 28 Days	Design strength (N/mm^2) 90 Days
100	0	0.80	0.83	1.39	1.59	1.69	2.06
95	5	0.53	0.60	1.13	1.30	1.50	1.95
90	10	0.47	0.55	1.02	1.16	1.35	1.76
85	15	0.38	0.48	0.93	1.06	1.24	1.62
80	20	0.35	0.46	0.90	1.05	1.13	1.40
70	30	0.28	0.39	0.84	0.93	1.08	1.41

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Respectively, Figure 3.7 below shows the Split tensile Strength curve for OPC/OBHA & BHA which illustrates how the stress applied to a cylindrical concrete specimen, which causes it to split along its vertical diameter, relates to the resulting displacement or strain. This curve, is typically load-transversal displacement or stress-displacement, and it provides information on the post-peak behavior of fiber-reinforced concrete, though it doesn't fully capture the material's true post-crack behavior. In our case, the study shows increase in strength as the curing days of concrete increase and decrease in strength as the OBHA/BHA level increases. This is in compliance with the research of [30].

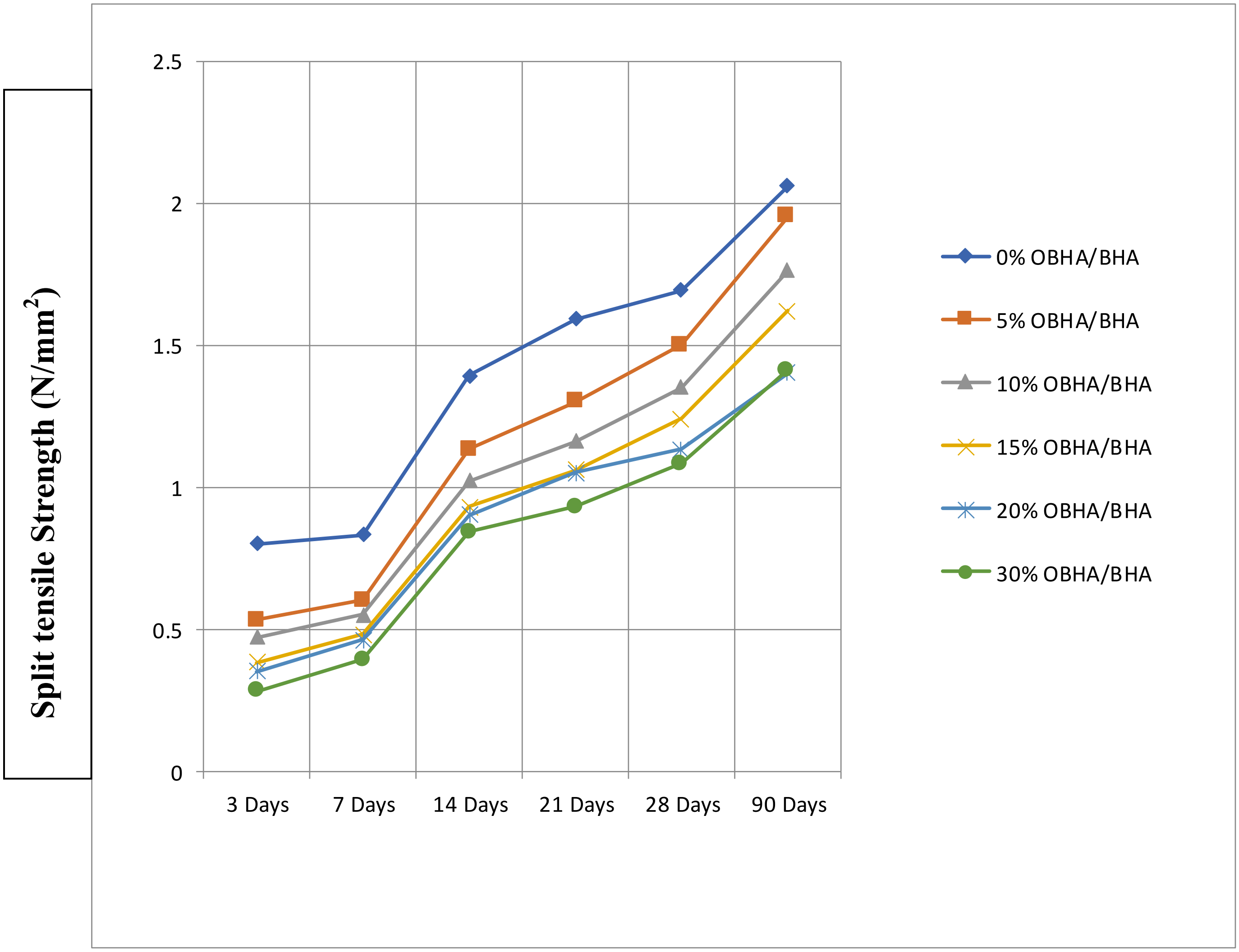


Fig. 3.7: Split tensile Strength Development of concrete mixes with varying percentage addition of OBHA/BHA cured in water (1: 2.14: 4.18/0.60).

Statistical/Mathematical Model Analysis for the Split Tensile Strength of Cement/OBHA & BHA Concrete.

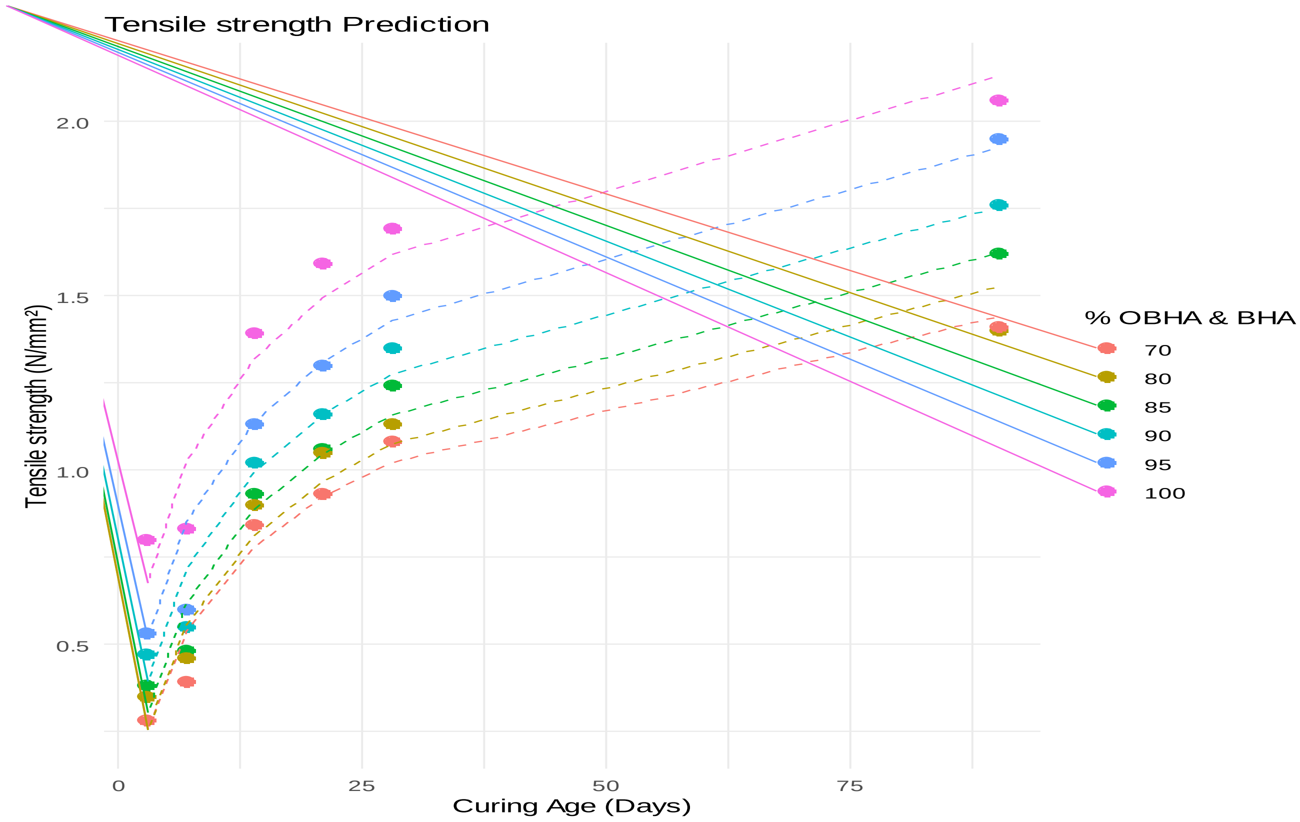
Preliminary observations from the data:

- The average Split tensile strength of concrete produced for all mixes increases with age at curing.
- The average Split tensile strength of concrete decreases as the OBHA/BHA content increases.
- The best split tensile strength result was obtained when 5% of the cement was replaced by OBHA/BHA.
- The split tensile strength decreased considerably as the percentage of OBHA/BHA increased beyond 5%.
- The strength showed a remarkable increase with aging, with the highest split tensile strength observed at 90 days, possibly due to water retention within the mixture's structural frame, allowing for better hydration.
- The Split tensile strength values ranged from 0.28 N/mm² to 2.06 N/mm².

Model Fit and Accuracy

The model demonstrates excellent predictive capability with:

- High R-squared value (0.9594)**:** Indicates that 95.94% of the variability in split tensile strength is explained by the model
- Low RMSE (0.0348 N/mm²)**:** The average prediction error is very small compared to the range of strength values (0.28-2.06 N/mm²)
- Coefficients of Linear and quadratic terms for cement percentage are statistically significant (p-values < 0.01), confirming the importance of each term in the model. Linear and quadratic terms for log(age) and interaction term between cement percentage and log(age) to account for how the effect of cement percentage might change with curing age were not significant



The actual vs. predicted plot as shown below shows points closely clustered around the 45-degree line, confirming good predictive accuracy. The example predictions demonstrate practical utility:

- For 92% cement at 28 days, the model predicts 1.329 N/mm²
- To achieve 1.5 N/mm² at 28 days, the model recommends 93.6% cement content

Practical Implications

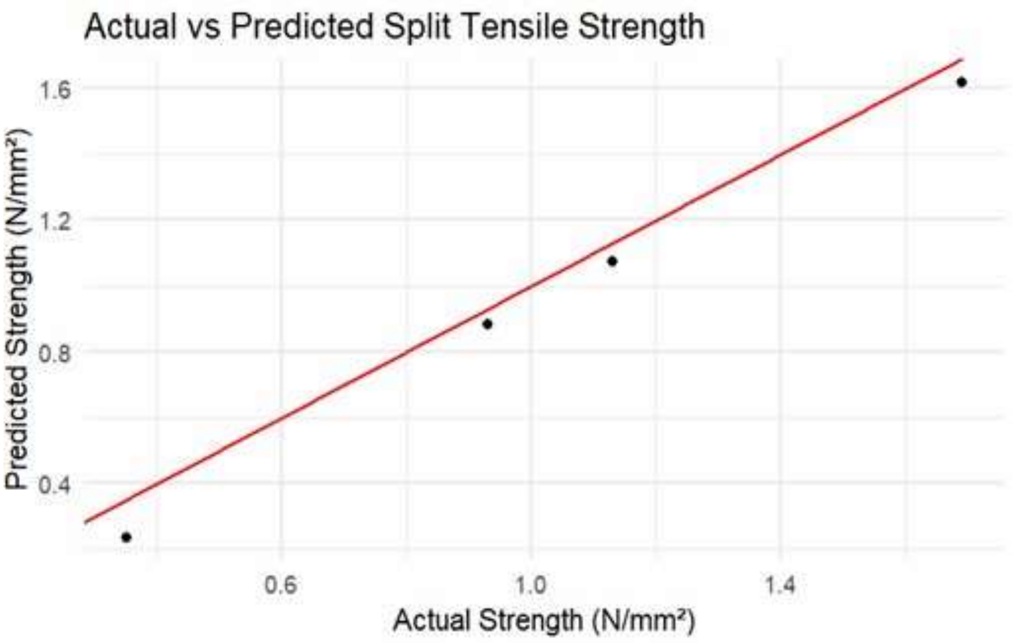
1. Strength Development**:**

- The model confirms that strength increases with curing time, with the most rapid gains in the first 7-14 days
- The logarithmic relationship suggests diminishing returns with extended curing

Material Efficiency**:**

- The concave relationship suggests there's a point where increasing cement content yields diminishing strength returns
- This helps balance material costs with performance requirement.

Visualize actual vs predicted



The developed model successfully captures the complex relationships between cement content, curing age, and split tensile strength. It provides both accurate predictions and practical optimization capabilities for concrete mix design. The excellent statistical metrics and logical coefficient signs confirm the model's validity for the tested conditions. This tool can significantly aid in material optimization for OBHA/BHA concrete applications.

5.0 CONCLUSION

In conclusion, we can say that;

i. The strength development in the concrete produced increases with the increase in the hydration period.
ii. The higher the setting time, the lower the strength of concrete produced.
iii. Curing is very important in concrete so as to ensure the complete hydration of cement.
iv. The strength development in concrete depends on the percentage chemical composition of cement and other materials in the Concrete.
v. The use of agricultural waste products like Oil bean husk ash and Breadfruit husk ash in concrete production is part of a growing interest in sustainable materials. These materials can potentially improve certain properties of concrete while also providing an environmentally friendly disposal method for agricultural waste. Therefore, utilizing agricultural waste like

OBHA and BHA in concrete production is environmentally beneficial, reducing the carbon footprint of cement manufacturing by lowering the clinker content and promoting recycling.

vi. The combination of Oil bean husk ash and Breadfruit husk ash in concrete has the potential to create a more sustainable and cost-effective construction material. However, it is crucial to optimize the mix design and thoroughly test the concrete to ensure it meets the required standards for structural applications.

vii. The inclusion of ash affects the workability of the concrete mix. Ash particles are generally finer than cement particles, which can increase the water demand for achieving the desired consistency. This might require adjustments in the mix design, such as increasing the water content or using water-reducing admixtures.

viii. Based on the Compressive, Flexural and split tensile strength tests performed, it is discovered that the incorporation of OBHA/BHA in concrete can influence the strength of the concrete. Therefore, the optimal replacement levels need to be determined thoroughly. Typically, small replacement percentages (e.g., 5-10%) might enhance strength due to pozzolanic action, while larger proportions could reduce strength if the ash content is too high and affects the cement matrix negatively.

ix. Also the Pozzolanic reaction of OBHA and BHA reduces the permeability of concrete, thereby enhancing its resistance to sulphate attack, alkali-silica reaction, and chloride penetration.

x. Economically, both OBHA and BHA are typically low-cost materials, which can reduce the overall cost of concrete production. This is particularly beneficial in South Eastern regions in Nigeria where these agricultural wasters are abundant.

xi. The R-based regression model effectively captures the relationship between OBHA/BHA content, curing age, and compressive strength. The model shows:

Based on the results so far, it will be good to say that the use of Oil Bean Husk Ash and Breadfruit Husk Ash in concrete is a promising area of research that aligns with sustainable construction practices, therefore, OBHA/BHA has effect on the concrete and the optimal replacement levels needs to be determined thoroughly as larger proportions could reduce strength if the ash content is too high and affects the cement matrix negatively.

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