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Mechanical and Microstructural Properties of Concrete Modified with Treated HDPE Plastics and Powdered Rubber Waste

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ABSTRACT : *Today tons of plastics and rubbers are floating across the globe as waste material, due to their low degradability, hence creating environmental and health problems. Utilizing recycled plastic and rubber waste in the production of concrete by partially replacing fine aggregate to form polymer concrete can be considered an alternative strategy for managing these waste materials. This study aims to present an investigation of modified High-Density Polyethylene (HDPE) and Powdered Rubber (PR) with Sodium Hydroxide (NaOH) as a partial replacement for fine aggregate in polymer concrete on its mechanical, durability and microstructural characteristics. The fine aggregate replacement is in the percentages of 0, 5, 10, 15, and 20 by mass. The primary objectives were to achieve an optimal level of HDPE and PR, to evaluate the mechanical and durability properties, to determine the microstructural characteristics using scanning electron microscopy (SEM). The hardened polymer concrete had low compressive strength and split tensile strength with an increase in replacement level achieving strength ranging from 9.4 to 19.9 N/mm² and 1.63 to 2.80 N/mm² respectively, the workability of the polymer concrete also reduced with the increase in replacement level, while the water absorption increased with the increase in replacement levels. The constituents were optimized for six components which includes water, cement, fine-aggregate, HDPE, PR and coarse aggregate to achieve the response variable using Response Surface Method (RSM), an optimal mix was obtained with a compressive strength of 19.9N/mm² with a mix proportion comprising water-cement ratio (0.45), cement (1.000), fine aggregate (0.86), HDPE (0.07), PR (0.07), and coarse aggregate (2.000). The SEM result showed the presence of microcracks and voids at higher replacement levels with a spongy-like C-S-H gel matrix and weak ITZ zone. The study concludes that the modified polymer concrete is suitable for non-structural use, such as pavements, sidewalks, and non-load-bearing walls. By promoting the use of recycled plastic and rubber, this research contributes to sustainable construction practices and environmental conservation.*

KEYWORDS: *Polymer Concrete; High-Density Polyethylene (HDPE); Powdered Rubber (PR); Response Surface Method (RSM); Optimization; Microstructural.*

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1. INTRODUCTION

Concrete, the most widely used construction material globally consumes significant amounts of natural resources and generates environmental impacts. Simultaneously, plastic waste, particularly High-Density Polyethene Plastics (HDPE), and waste rubber from tires contribute to landfill accumulation and pollution. The word "plastic" means substances that have plasticity and accordingly, anything that is formed in a soft state and used in a solid state. Plastics are commonly used substances which play an important role in almost every aspect of our lives. The widespread generation of plastics waste needs proper end-of-life management. Diversity of plastics and rubber applications are related with their specific properties, low density, easy processing, good mechanical properties, good chemical resistance, excellent thermal and electrical insulating properties and low cost (in comparison to other materials) (Eric, A. O. 2014).

Recent advancements in using high-density polyethylene (HDPE) plastics and waste rubber in concrete focus on making construction more sustainable and durable. HDPE, often recycled from waste like plastic bottles, can replace some concrete aggregates, reducing environmental impact. Studies show it improves tensile strength and insulation, but too much can weaken the concrete. Chemical treatments help HDPE concrete resist acids and sulfates better, which is promising for tough conditions. However, there are still challenges, like bonding issues and reduced workability, that need more research. With innovations in recycling and biodegradable plastics, there is a promising effort to reduce environmental impacts and promote sustainability (Eric, A. O. 2014). Despite these benefits, these plastics pose environmental concerns, such as pollution and waste management challenges. Recycling and sustainable alternatives are being explored to address these issues.

On the other hand, Rubber production worldwide especially in Africa, primarily natural rubber from Hevea brasiliensis, plays a significant but non-dominant role in global supply, contributing 5–7% of world output, with West and Central Africa leading (R. Loffman, 2023). Historically, rubber was tapped from wild sources like Funtumia elastica and Landolphia vines during the late 19th-century boom (1890–1913), driven by demand for bicycles and automobiles (R. Dumett. 1971) Countries like Côte d'Ivoire, Nigeria, Liberia, and Cameroon are key producers, with Côte d'Ivoire leading at 1.7 million metric tons in 2023, accounting for 73% of Africa's output. Colonial-era production, notably in the Congo Free State, relied on forced labor, causing demographic collapses (J. Stengers et al. 1985). The increase of non-biodegradable HDPE plastic and rubber waste poses environmental hazards, thereby becoming overcrowded and expensive for waste disposal, attempts must be made to minimize the quantities of materials that are delivered to these landfills (Eric, A. O. 2014). The benefits of this recycling can be economically advantageous. Today tons of plastic and rubbers are floating all over the globe as a waste material, which is proving hazardous to the environments. Management and safe disposal of these wastes have become a compulsion to keep the environment clean and healthy. Utilization of these waste as construction material is considered one of the possible solutions towards green and healthy environment (M. Sulyman et al. 2016).

Moreover, in recent years, researchers and engineers have become interested in replacing/substituting some constitutes of concrete with waste materials to affect the strength of the concrete in a positive way. These include: agricultural waste, industrial waste such as furnace slags, car tires and other waste materials. Such applications have been considered as alternative strategies for the management of waste materials in the developing world.

This study aims to explore the possibility of using these polymer wastes such as HDPE plastics and Powdered Rubber (PR) wastes as sustainable components in Concrete by determining the properties of the modified polymer concrete. The objective was to evaluate Material characterization, to determine the optimal replacement levels of HDPE and PR as partial replacement for fine aggregates in polymer concrete, to evaluate the mechanical properties (compressive strength, split tensile strength and workability) and durability properties (water absorption) of polymer concrete incorporating HDPE and PR, and to analyze the microstructural characteristics of the modified polymer concrete using scanning Electron Microscopy (SEM).

1.1 Importance of Optimizing Mechanical and Durability Properties

The mechanical properties of concrete, including compressive strength, split tensile strength, and workability, are critical for structural integrity. Studies indicate that HDPE and PR when used as fine aggregate replacements, can reduce concrete's compressive strength due to their lower stiffness compared to natural sand (Z. Z. Ismail et al. 2008). However, these materials can enhance ductility and impact resistance, making them suitable for specific applications such as pavements or non-load-bearing elements (B. S. Thomas and R. C. Gupta. 2016). Optimizing the proportion and particle size of HDPE and rubber aggregates is crucial to achieving a balance between strength and flexibility, ensuring that the concrete meets design standards while leveraging the lightweight nature of these materials (A. A. Mohammed, et al. 2018)

Durability properties, such as resistance to water absorption, freeze-thaw cycles, and chemical attack, determine the long-term performance of concrete structures. HDPE plastic, with its inherent chemical inertness, can improve resistance to aggressive environments, but its hydrophobic nature may weaken the bond with cement paste, potentially increasing permeability (L. Gu and T. Ozbakkaloglu, 2016). Similarly, rubber can enhance thermal insulation and crack resistance but may compromise water resistance if not properly integrated (E. Ganjian, et al. 2009). Optimizing the mix design, including the use of additives or surface treatments for these waste materials, it is vital in enhancing durability, ensuring that concrete with HDPE and rubber aggregates withstands environmental stresses over time (F. Pacheco-Torgal, et al. 2012).

Optimizing the mechanical and durability properties of concrete with HDPE and rubber is critical for promoting sustainable construction practices. This approach reduces reliance on natural resources, mitigates waste disposal issues, and aligns with global sustainability objectives, such as the United Nations' Sustainable Development Goals (United Nations, 2015). Furthermore, achieving reliable performance ensures that such concrete can be used in practical applications.

1.2 Synergistic Effects of HDPE and Rubber Powder

The combined use of HDPE and PR in concrete introduces synergistic effects that can be leveraged to tailor concrete properties. HDPE's rigidity complements the elasticity of rubber powder, potentially balancing strength and ductility (M. K. Batayneh, et al. 2008). For instance, HDPE can enhance the structural integrity of lightweight concrete, while rubber powder improves energy dissipation under dynamic loading. The framework hypothesizes that optimal replacement ratios (typically 5–20% for HDPE and 10–30% for rubber powder, based on literature) can achieve a balance between sustainability and performance (A. Siddika, et al. 2019).

II. MATERIALS AND METHOD

The material constituents, their mix and the manufacturing process are important factors that determine the strength of the concrete. The materials that were used for this experiment are noted below:

HDPE plastics: These are waste plastics having identification code "2" that were gotten form refuse sites. HDPE are widely used in the manufacturing industry due to its own high strength to density ratio, durability, impact resistance and resistance to many chemicals. The sorted-out waste products were cleaned from dirt and shredded into particle size of 3 – 5mm using an Industrial single or dual shaft shredder.

Plate 1. HDPE plastics waste

Plate 2. Powdered rubber waste

Rubbers: Rubber which has become an essential material in the production industry due to its flexibility, strength and durability. It serves as a major component in an automobile. These rubbers were also sorted from mechanic workshops; automobile waste tires were used for this research. They were cleaned form dirt and shredded onto powdered size of 0.75 – 1mm using an Industrial single or dual shaft shredder. The specific gravity of PR gotten to be 3.142.

Cement: Ordinary Portland Cement (OPC) is suitable for normal concrete and many activities in the construction industry. To make OPC, raw materials like lime, silica, alumina, and iron oxide are used to manufacture Portland cement, a mixture of limestone and clay is heated until it almost fuses, and, then, the clinker is ground into a fine powder (M.Tawfik, 2006). An OPC such as Dangote cement available at local market was used for this research; having a specific gravity of 3.14 and grade 42.5N.

Sodium Hydroxide: Sodium Hydroxide (NaOH) which is a highly corrosive white crystal, highly soluble in water and absorbs moistures and carbon dioxide from the atmosphere. NaOH was used in this research to remove surface contaminants and create an abrasive surface on the waste rubber and plastics to enable interfacial bonding between these aggregates and cement binder. 16 moles were used during the laboratory research.

Plate 3: Sodium Hydroxide

Aggregates: Both fine and coarse aggregates were used in the mix. The fine aggregate consisted of river sand passing through a 4.75 mm sieve, while the coarse aggregate comprised crushed granite with a maximum size of 20 mm. The aggregates were analyzed to ensure compliance with BS EN 933-1:2012 requirements for particle size distribution. The fine aggregate had a specific gravity of 2.61, The result shows that the fine aggregate specific gravity falls within the recommended range of 2.4 to 3.0 (Sanusi A, et al. 2020).

2.1 Preparation and mixing

HDPE and PR aggregate were soaked in a 16-molar concertation of NaOH solution for 4hrs to enable removal of surface contaminant and enhance an abrasive surface, the aggregates were cleaned with clean water to remove excessive NaOH and air dried at room temperature for 48hrs. The other raw materials were mixed according to a 1:1:2 mix design ratio prepared in accordance to the Department of Environmental (DOE) method of mix design. In this research, the fine aggregate was partially replaced with HDPE and PR (at replacement of 100% fine aggregate, 95:5%, 90:10%, 85:15% and 80:20%) with water – cement ratio of 0.45. The mixing was homogenous to ensure proper coating of the aggregates with cement binder. After which the freshly mixed polymer concrete was poured in a 150 mm cube mould for compressive test and a 100 x 200 mm cylindrical mould for split tensile test, the concrete was compacted in layers of 25 blows with a tamping rod for each layer. The cast concrete was surface dressed and tagged for identification after which the samples were air dried for 24hrs. The samples were removed from the mould, allowed to be air dried for 2hrs and immersed inside a curing tank for 7 and 28 days for hydration occurrence to enhance strength gain.

2.2. Mix proportion

The constituents were used in different fractions to determine mixture proportions that would yield the targeted compressive strength at the test age of 28 days. Table 1 shows the compositions HDPE, PR wastes and fine aggregate concrete mixes based on their mass using water – cement ratio of 0.45.

2.3. Optimization

To obtain an optimal mix to give desired strength, HDPE and PR aggregates were optimized with a statistical approach known as Response Surface methodology (RSM) using a statistical software called Minitab to achieve an optimal value, it provides a robust, user friendly and statistically grounded framework for developing sustainable, lightweight, and durable concrete. RSM procedure integrates experimental design, multivariate modeling, and multi-objective optimization to balance mechanical performance, and physical properties, addressing the growing need for waste products in construction materials (Aliyu et al.2021). The methodology employs a two-factor Central Composite Design (CCD) with face-centered axial points (α = 1), generating 15

Table 1: Mix Proportions of Concrete Incorporating HDPE plastics and Powered Rubber

S/N.	Points (%)	Water (kg)	Cement (kg)	Fine Aggregates (kg)	HDPE (kg)	Rubber (kg)	Coarse Aggregate (Kg)	Water-Cement Ratio
1	0	0.842	1.87	2.08	-	-	3.91	0.45
2	5	0.842	1.87	1.984	0.052	0.052	3.91	0.45
3	10	0.842	1.87	1.872	0.104	0.104	3.91	0.45
4	15	0.842	1.87	1.776	0.156	0.156	3.91	0.45
5	20	0.842	1.87	1.664	0.208	0.208	3.91	0.45

experimental runs to fit a full quadratic response surface model (D. C. Montgomery, 2020). A worksheet/spreadsheet was created with the mix design and result values gotten from the laboratory experiment. These values were grouped into two, an Input variables and response variables. RSM is particularly useful for optimizing responses based on multiple input variables. Minitab provides tools for fitting models to the data, visualizing response surfaces, and identifying optimal conditions. This helps in finding the best settings for the factors to achieve desired outcomes, which is crucial in various fields such as manufacturing, quality control, and product development. Minitab offers robust statistical tools for analyzing the results of DOE. The software provides comprehensive ANOVA tables, regression analysis, and diagnostic plots, which help in understanding the significance of factors and interactions.

RSM models visualization using graphical optimization led to the understanding the influence of HPDE and Powdered Rubber contents on concrete compressive strength. The overall goals in numerical optimization were to maximize compressive strength.

III. RESULT AND DISCUSSION

3.1 Particle Distribution

The particle size distribution of fine aggregate and powdered rubber was used to determine their suitability for concrete production. The results show the percentage passing through various sieve sizes, ranging from clay-sized particles to large coarse aggregates. A graphical representation of the particle size distribution shows fine aggregate and Powdered rubber samples had few or no particles within the clay or silt ranges (0.001–0.099 mm), indicating a lack of finer particles that could increase water demand and decrease workability. Majority of the particle's sizes fell within the sand range (0.03–2.00 mm). For rubber, 36.47% passed the 0.6 mm sieve, while 100% passed the 4.75 mm sieve, while that of Fine aggregate, 23.47% passed the 0.6mm sieve.

3.2 Slump test

The Slump test of concrete in accordance to BS EN 12350-2, was carried out with the help of a conical cone open at both ends. The slump cone filled at intervals with concrete and compacted in layers, after which it was lifted up and the resulting height of concrete spread over the surface shows the degree of fluidity, workability, and consistency of the concrete mix. Generally, the slump height decreased as the percentage replacement of fine aggregate with waste polymer content increased. A more drastic decrease in the slump was observed with 20% polymer replacement which was 51mm. further increase in the polymer waste content will yield no slump as observed from the results obtained for the 15% and 20% polymer waste replacement respectively, which indicates difficulty to which the concrete flows. This means that more water is required to make the concrete workable as HDPE and PR increased in the mix. This trend is due to the fact that the addition of waste polymer content obstructs the flow and reduces the workability of the concrete (C. Prahallada et al. 2013).

Table 2: Workability of Polymer Concrete.

Samples	Slump value (mm)
X1= 100% Fine Agg	153
X2= 95% Fine Agg + 2.5% PR + 2.5% HDPE	95
X3= 90% Fine Agg + 5% PR + 5% HDPE	65
X4= 85% Fine Agg + 7.5% PR + 7.5% HDPE	58
X5= 80% Fine Agg + 10% PR + 10% HDPE	51

Table 3:Compressive Strength test for Polymer Concrete

S/No.	Mix ID (%)	Age (days)	Sample 1 (Mpa)	Sample 2 (Mpa)	Sample 3 (Mpa)	Mean ± SD (Mpa)
1	0	7	19.6	20.6	18.8	19.7 ± 0.9
		28	23.8	24.9	26.7	25.1 ± 1.5
2	5	7	12.3	14.9	10.8	12.7 ± 2.1
		28	19.9	18.4	17.3	18.5 ± 1.3
3	10	7	10.2	9.5	11.2	10.3 ± 0.9
		28	13.6	14.5	11.2	13.1 ± 1.7
4	15	7	10.6	11.0	12.3	11.3 ± 0.9
		28	12.2	11.6	11.4	11.7 ± 0.4
5	20	7	11.1	11.2	12.2	11.5 ± 0.6
		28	9.4	9.4	9.8	9.5 ± 0.2

3.2 Density of Polymer Concrete

Concrete density is a critical parameter that reflects the compactness and quality of the mix. It directly influences strength, durability, and structural performance. The density of concrete cubes depends on factors such as aggregate type, water-cement ratio, compaction method and curing conditions. The bulk density of the sample cubes ranged from 2251.26 to 2513.78 kg/m³, with an average of 2375.11kg/m³ and a standard deviation of 83.71 kg/m³, whereas the control samples had a density range of 2498.96 to 2527.26 kg/m³. The density values of the sample cubes fall within the range of 2200–2400 kg/m³ for normal weight concrete reported in (Density of Concrete) and was also noted in (Matthias B, et al. 2025). This research shows that incorporating PR and HDPE plastics in concrete significantly affects its density.

3.3 Water Absorption

Water absorption tests were conducted on all samples, The results of the water absorption test at 28 days, indicate variations in moisture absorption across different sample compositions. The mean moisture absorption values range from approximately 0.92% to 6.59%.

$$\text{Water Absorption} = \frac{B-A}{A} \times 100\,\%$$

A = Weight Before, B = Weight After

It was noticed the water absorbed by the concrete samples increased with the increase Polymer content replacement when compared with the control sample. This is due to higher plastic and rubber content that causes interfacial spaces in the concrete and as evaporation occurs, voids are formed, thus increases the absorption value (R. Baboo et al. 2012).

3.4 Compressive Strength Test

Compressive strength tests were conducted on all cube samples with size of 150 x 150 x 150mm using an ELE Compressive Strength Testing Machine. It was observed that the compressive strength increased with increasing curing age for all replacements levels, a trend similar to that of the control mix. However, the incorporation of waste polymer content in the concrete lowers the compressive strength of the hardened concrete and further increment in replacement level reduces the compressive strength of the hardened concrete. The reduction in compressive strength as a result of increasing replacement with waste polymer content is caused due to the weak bonds between cement paste and the waste polymer materials and also the hydrophobic nature of polymers which restricts hydration of cement (Zainab Z. Ismail. et al. 2008). However, the treatment of HDPE plastic and PR with NaOH solution did not give the concrete a significant compressive strength gain when compared with results from other researcher incorporating untreated polymer content in concrete as partial or fully replacement, but further research using different moles of NaOH or different chemicals used for treating polymers may lead to strength gain in hardened polymer concrete. The compressive strength test on the control concrete cubes yielded an average of 25.102N/mm², whereas the modified polymer concrete mixtures, detailed in Table 3 achieved a maximum average strength of 18.501N/mm², corresponding to the following proportions (X_i) of components: water-cement ratio (0.450), cement (1.000), fine aggregate (0.95), HDPE (0.025), Powdered rubber (0.025), and coarse aggregate (2.000), respectively.

3.5 Split Tensile test

Split Tensile Strength test was performed in accordance to BS EN 12390-6 guidelines. 10 concrete cylinders with size of 100mm x 200mm were cast and cured for 28 days at room temperature. A compression testing machine of 3000 KN capacity was used to determine the split tensile strength for these polymer concrete samples, as shown in Table 4. The mode of failure on the concrete samples was a vertical crack developed along the diameter of the cylindrical specimen, aligned with the loading axis, Hence the tensile stresses exceeded the sample's tensile strength, initiating a crack that propagates through the center.

The decrease in the split tensile values is associated with increase in polymer content replacement due to the weak bonding and hydrophobic nature of plastics and rubbers are the crucial reasons for the decrease in split tensile strength values of the concrete samples. The treatment of NaOH had an insignificant effect in the bonding of these polymers with cement paste, therefore making the interfacial bonding a weak zone. Sanding coating the polymer aggregates were found to affect the concrete spilt tensile strength in a positive way (SN Abbas et al. 2010.)

Table 4: Split tensile Strength test for Polymer Concrete.

S/N	Split tensile strength 1 (N/mm²)	Split tensile strength 2 (N/mm²)	Average (N/mm²)
1	3.884	3.761	3.823
2	2.801	2.580	2.691
3	2.390	2.187	2.289
4	1.716	1.999	1.858
5	1.926	1.631	1.779

S/N	Split tensile strength 1 (N/mm²)	Split tensile strength 2 (N/mm²)	Average (N/mm²)
1	3.884	3.761	3.823
2	2.801	2.580	2.691
3	2.390	2.187	2.289
4	1.716	1.999	1.858
5	1.926	1.631	1.779

3.6 Microstructural Analysis of Polymer Concrete

The microstructural characteristics of hardened polymer concrete were examined using Scanning Electron Microscopy (SEM), the sample X1 (100% fine aggregate) and X5 (80% fine aggregate) were used for specimen for this test. The experimental result shows that sample X5 has the weakest strength on compressive strength and stiffness properties when compared to other polymer concrete mixtures. This samples were scanned with SEM using high-resolution images to investigate topographical information such as surface micro-cracks, voids, particle arrangement and bonds. The SEM micrograph shows that the polymer concrete exhibited a dense and irregular particle morphology, with very visible voids and cracks on the polymer concrete sample.

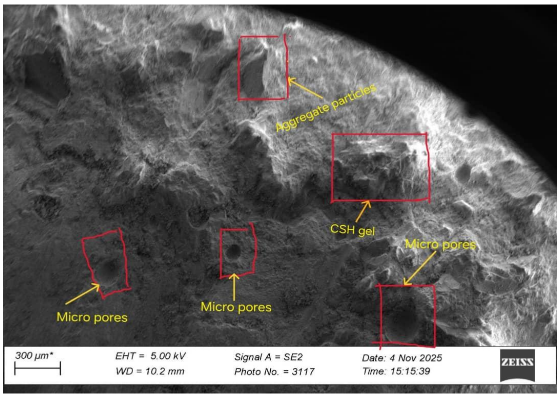

Fig.4: SEM micrograph for X1 (0% replacement)

The matrix–aggregate interface appeared not too strongly bonded. Compared to traditional concretes, capillary pores were particularly evident, therefore aligning with the high-water absorption result.

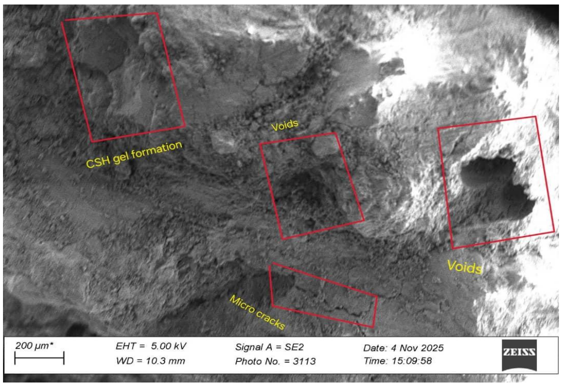

Fig.5: SEM micrograph for X5 (20% replacement)

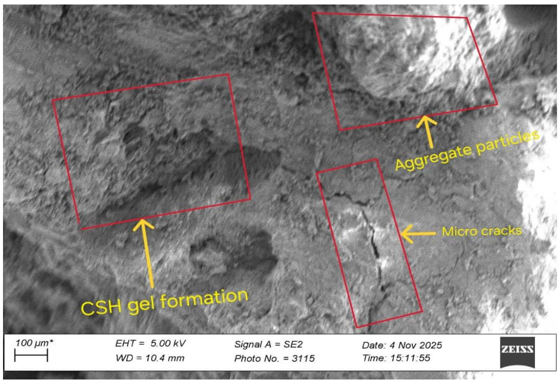

Fig.6: SEM micrograph for X5 (20% replacement)

In addition, the micrographs for the control sample showed a relatively smooth and compact surface texture, further supporting the material's high ultrasonic pulse velocity and rebound hardness values. The densification of the microstructure is considered a key factor in the superior compressive and split tensile strengths achieved by the specimens. In the SEM micrographs, aggregate particles, and interfacial transition zones (ITZ) were clearly identified and labeled. The dark areas represent the pores and microcavities observed in the micrograph, ranging from small micropores to larger voids near particle–matrix interfaces. Localized separations like the microcracks around some random spots suggest weak interfacial bonding. The SEM micrograph of sample X5 (20% replacement) confirms that HDPE and Rubber contributed to a more porous binder phase through the formation of microcracks and large voids, hence leading to the low compressive strength and high-water absorption ratio.

3.7 Optimization result of Polymer Concrete

RSM predicted the influence of HDPE and PR quantities with other aggregate and cement as independent variables on compressive strength responses. It covered optimization aspect by obtaining the optimum values of compressive strength. RSM design has the capacity to ascertain linear interaction and quadratic influences of the independent variables on properties of concrete (T.F. Awolusi, et al. 2018). The research optimized the combined outcomes of these factors to minimize or maximize desired outputs. The result gotten from the compressive test was computed into the Response surface software (Minitab) for analysis and optimization.

Table 5: **Model summary of the compressive strength test**

S	R^2	R^2 (adj)	R^2 (pred)
1.11	93.17%	90.62%	84.64%

The compressive strength model in Table 5, has a value of R^2 = 93.17% indicating its fitness for use as a model for predicting the compressive strength of the mixtures and thus for optimization computations. The values of R^2 and R^2 adj which is high estimated as 93.17% and 90.62% respectively, shows the competence of the model. The F-value and P-value are observed in to be the crucial parameters in evaluating the model significance (M.M. Abdulredha, et al 2020). The coefficients of determination coupled with statistical tests showed that the model was capable of explaining different options in the response. Acceptable range of fit of the model exists between the normal probability and the externally studentized residuals as shown in Fig.7, a linear relationship is considerably

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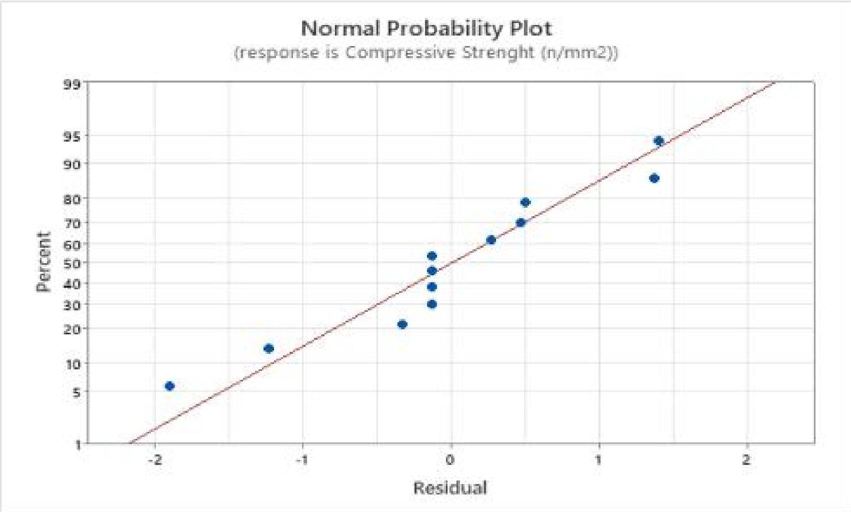

Fig. 7: Normal Probability Plot

observed in this Fig.7. This observation confirms that the constructed model is normally distributed capable of predicting the experimental findings. It is reported that a good model should be normally distributed ((M.M. Abdulredha, et al 2020). Optimization computations indicated that incorporating HDPE and PR into concrete mixes can yield compressive strengths ranging from 9.4 N/mm² to 19.9 N/mm. Specifically, a mix proportion comprising water-cement ratio (0.45), cement (1.000), fine aggregate (0.86), HDPE (0.07), PR (0.07), and coarse aggregate (2.000) achieved an average compressive strength of 19.90 N/mm². This finding demonstrates the viability of using HDPE and PR in polymer concrete production, potentially reducing the reliance on fine aggregates, leading to savings on the use conventional materials and increasing incorporating waste polymer into concrete production for sustainability. However, it's important to note that incorporating HDPE and PR results in a decrease in compressive strength in polymer concrete compared to conventional concrete. Therefore, such mixes are more suitable for non-structural applications where low strengths are needed.

IV. CONCLUSION AND RECOMMENDATIONS

This study investigated the potential of modified High-Density Polyethene plastics and Powdered Rubber in concrete as an alternative material for sustainable construction The aim of this research was to evaluate the effect of these modified polymers on the mechanical and microstructural effect of concrete. From the results and discussion, the following conclusions were drawn:

i. The sieve analysis results show high a percentage passing from sieve size of 600microns for fine aggregate and powdered rubber.

ii. The workability of polymer concrete was reduced with the addition of HDPE and Powdered rubber at different replacement levels, as indicated by the decrease in slump values from 152mm at 0% to 53mm at 20% replacement.

iii. The compressive strength and split tensile strength decreased with the increase in replacement levels. At a 5% replacement, the high strength was achieved. The compressive strength of HDPE Rubber-based polymer concrete also increased with curing age from 7 to 28 days.

iv. The optimal replacement level using RSM approach was at 5% replacement predicting compressive strength of 19.90 N/mm^2.

v. Density of the polymer concrete samples decreased with the increase in replacement levels ranging from 2251.26 kg/m^3 at 20% to 2513.78 kg/m^3 at 5%. This is due to the low density of HDPE plastics and rubbers when compared to the density of fine aggregates. The density falls within the density range of 2200 - 2400 kg/m^3 for normal traditional concrete.

vi. The water absorption ratio also increased at higher replacement levels, ranging from 0.92 – 3.90%.

vii. SEM showed a scattered C-S-H gel matrix with a spongy look; it also captured micro cracks, voids and pores at different areas of the polymer concrete samples. The C-S-H gel matrix shows weak bonding between cement binder and the aggregates within the concrete sample. Although the SEM showed densification and compactness within the sample, but with a thread line of microcracks and pores, which results in samples exhibiting high porosity and low strength.

RECOMMENDATIONS:

This study recommends the use of modified HDPE and powdered rubber in concrete in pavements, block stones, interlocks for walkways and other areas that withstand little or no loads acting on them and allow water seepage. Further Research on Mechanical Performance Future studies should explore ways to enhance the compressive strength of modified HDPE and powdered rubber concrete through additives such as pozzolans, fiber reinforcements, or supplementary cementitious materials like silica fume or fly ash and the addition of superplasticizers for increase an in workability. Further surface treatment such has sand coating of HDPE and PR to improve the hydrophilic nature that enable stronger bonds between cement-aggregate matrix to improve the strength performance and durability.

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