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DEVELOPMENT AND EVALUATION OF DURABILITY AND STRENGTH PERFORMANCE OF RUBBER LATEX-MODIFIED CONCRETE

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Abstract: Portland cement concrete has been used in construction because of its durability and cost-effectiveness. Due to various drawbacks of Portland cement concrete, such as weak flexural strength, low tensile strength, porosity, durability, etc., there has been an increase in interest in using natural latex rubber (NRL) in the development of high-performance concrete in recent years. In order to overcome the constraints of conventional concrete, the purpose of this research is to experimentally study the use of natural rubber latex in concrete by adding a small percentage of natural rubber latex to the concrete mixture to reduce the limitations of conventional concrete. The natural rubber latex would be included in the concrete as a polymer additive. When compared to plain concrete, adding rubber latex to the mix has been shown to improve the mechanical properties of concrete, such as compressive strength, tensile strength, and flexural strength. The optimum NRL inclusion of 2% in plain concrete has improved the mechanical properties. Therefore, the project's primary goal of improving plain concrete's structural properties has been achieved.

Keywords: durability, strength, workability, natural rubber latex, concrete

1.0 INTRODUCTION

In construction, Portland cement concrete has been used because of its durability and cost-effectiveness. According to Neville and Brooks (1987), concrete is used more frequently than all other building materials combined and has a variety of desirable uses, including tunnels, buildings, sewage systems, roads, tanks, concrete bridges, and buildings. Despite the foregoing, concrete does not necessarily perform as well as we would like. This is due to the long-term aging impact of concrete, which is caused by the cement matrix's drying out and resulting in decreased strength. Also, differential shrinkage caused by the presence of wet and dry concrete could result in cracking. Structures with these flaws have a shorter lifespan, which raises maintenance and repair costs. Additionally, over the course of their existence, concrete structures are typically subjected to a variety of environmental factors. As a result, concrete constructions may degrade and deteriorate, which may have an impact on how long they last.

Numerous studies have indicated that the corrosion of the steel reinforcement in plain concrete caused by the ingress of chloride has been proven to be the primary factor in the degrading process (Zornoza et al., 2009; Costa and Appleton, 1999). In fact, the construction sector incurs a significant annual cost as a result of the premature deterioration of RC structures, which leads to several critical repair and rehabilitation issues. The following categories can be used to group the primary effects: The first issue is the financial and economic impact resulting from the reconstruction or repair of specific components, or possibly the entire structure (Virmani, 2002). In general, structural restoration is quite expensive, and for marine and waterfront structures, it is significantly more expensive and time-consuming due to the presence of water and challenges in accessing the damaged area. The second issue is the safety of concrete structures as a result of the presence of cold joints between old and fresh concrete. A growing and carefully regulated corrosion of reinforcement is not only a technical and economic problem but also a very serious environmental and sustainability concern that has led to a fast-growing number of new large concrete constructions being produced.

In recent years, there has been an increasing interest in the use of latex rubber to make high-performance concrete due to several limitations in Portland cement concrete, such as poor flexural strength, low tensile strength, low chemical resistance, etc. These limitations make concrete vulnerable to seismic forces, chemical attacks from hostile environments, and other factors and have become a problem with significant ramifications for the economy, the environment, and public safety. This supports the necessity of creating high-performance concrete with proper ingredient selection and rationing to create a composite primarily distinguished by its developed strength, porosity, and durability.

Using natural rubber latex-concrete composites to change the cementitious matrix by minimizing the microcracks and closing the pores is one technique to improve the concrete microstructure. Polymer latex has reportedly been used more frequently in cementitious materials to increase a variety of properties, including durability, adhesiveness, mechanical strength, toughness, and crack resistance, according to studies by Zhang and Kong (2014) and Lu et al. (2017). Another study by Bala and Ismail (2012) shows that the natural rubber latex modification significantly improves the plain concrete from porous to an impermeable and denser microstructure by forming a lining of latex film across voids, pores, and microcracks.

Natural rubber latex is a natural polymer latex that can be used to effectively modify cement composites, promoting sustainable construction practices. It is obtained from renewable and locally available resources. The word "latex" simply refers to a polymer with a liquid that is based on water. Latex is another name for the organic polymers that are dispersed during the mixing of the concrete. One of the agricultural goods (cash crops) that Nigeria and West Africa have historically been recognized for is natural rubber.

Conventional concrete is anticipated to become more impermeable, water-resistant, and durable at the ideal degree of natural rubber latex inclusion. This could be very helpful in decreasing chemical attacks on concrete in hostile environments. Since adding a tiny amount of natural rubber latex to a concrete mixture could enhance properties like flexural strength, tensile strength, porosity, and durability of concrete, the goal of this research is to experimentally investigate natural rubber latex in relation to concrete. The natural rubber latex would be included in the concrete as a polymer admixture.

2.0 MATERIALS AND METHODS

2.1 MATERIALS

The materials used in this research study were locally sourced in Cross River State. They were chosen based on previous research and survey results. The materials included the following: cement (32.5R), fine aggregate (river sand), coarse aggregate (5–25 mm granite), portable water, and natural rubber latex.

2.1.1 Cement

Ordinary Portland cement following BS 1377 was used in the experimental study.

2.1.2 Fine aggregate

The fine aggregate used in this experimental investigation was obtained from a nearby river.

2.1.3 Coarse aggregate

Crushed granite aggregate was used in this experiment, and the diameter was 5–25 mm and was free from organic matter.

2.1.4 Water

Portable water was used in this experiment for casting and curing cubes; this water was gotten from the laboratory.

2.1.5 Rubber latex:

The rubber latex was extracted locally from a rubber tree.

2.2 METHODS

The entire experimental investigation was divided into phases:

In phase I, a sieve analysis test to determine the proportion of aggregate to be used for the mix design was conducted.

In phase II, the mix design for conventional and rubberized concrete was established.

In phase III, different samples with different parameters for compressive strength, tensile strength, and flexural strength were prepared.

In phase IV, tests were conducted on different samples with different parameters to determine the compressive strength, tensile strength, and flexural strength of the concrete.

2.2.1. Selection of concrete grade

The selection of concrete grade was important in this research. In this respect, the research only concentrated on grade 20 to reflect the distinctions in strength from various types of grade.

2.2.2 Concrete mix design

The design was crucial in determining the quantity of materials used in grade C20. The strength of concrete mix is defined as characteristic strength based on statistical analysis and is estimated to be ±5% strength based on test results. In light of this characteristic's strength, cubes made from a concrete mix should be generally stronger.

2.2.3 Raw materials

Aggregate used consisted of fine aggregate, coarse aggregate, sand, cement, portable water, natural rubber latex.

2.2.4 Measuring and mixing of concrete

The weight measurement method was applied when mixing raw materials such as cement, aggregates, natural rubber latex, and water. This method required strong quality control.

2.3 Testing

The following tests were conducted in this research study

i. Compressive strength
ii. Split tensile strength
iii. Flexural strength

2.3.1 Compressive strength test

The compressive test is the most common test conducted on hardened concrete. The cubes of size 100 x 100 x 100mm were prepared using a mold according to standard specifications. The test cubes were cast and placed in a curing tank for 28 days. The compressive strength was determined by dividing the ultimate applied load by the cross-sectional area of the cube.

Compressive Strength $f = P/A$

Where, P = cube compression load

A = Area of the cube

2.3.2 Split tensile strength

The split tensile strength test is an indirect test for the split tensile strength of concrete. The tensile strength of concrete can be obtained indirectly by subjecting the concrete cylinder to the action of a compressive force along two opposite ends of the base plate of a compression testing machine. Cylindrical specimens of 100 mm diameter and 200mm length were cast and placed in a curing tank for 28 days.

Split tensile strength = ${}^{2p}/_{\pi LD}$

Where, P is the compressive load on the cylinder

L is the length of the cylinder

D is the diameter of the cylinder

2.3.3 Flexural strength

Flexural strength is also known as the modulus of rupture," which is the maximum tensile or compressive stress at rupture. Beams were cast and placed in a curing tank for 28 days. The beam size was 100 x 100 x 500mm.

Module of rupture $\sigma = \frac{3PL}{2bd^2}$

Where,

P = load in N applied to the specimen

L = length of the support span (mm)

B = width in mm of the specimen

D = depth in mm of the specimen

2.4 Test procedure

Specimens were cast. To obtain a uniform consistency, the concrete was thoroughly mixed in a pan. Specimens were well compacted using vibrators. The specimens were demolished after 24 hours of casting, and the specimens were cured for 3–28 days. The calculated proportions of the mix were mixed in a dry state, and the natural rubber latex was added as an admixture along with water. Cubes are tested for workability using the slump test and strength at 28 days.

3.0 RESULTS AND DISCUSSION

3.1 Slump test

The test was conducted by using a slump flow cone that was filled up with fresh concrete and lifted up vertically to allow the fresh concrete to flow on a flat surface. After 30 seconds, the slump was measured, and the result is shown in Table 3.1.

Table 3.1: Slump Test

S/N	Addition of natural rubber latex (%)	Slump (mm)
1	0	20
2	1	18
3	2	16
4	3	13

Based on Table 3.1, all test results for Slump flow indicate that the utilization of natural rubber latex does not affect the slump flow of concrete. The values of slump decrease with an increase in the addition of latex, as shown in Figure 3.1, but the concrete matrix with latex inclusion had more flow during compaction.

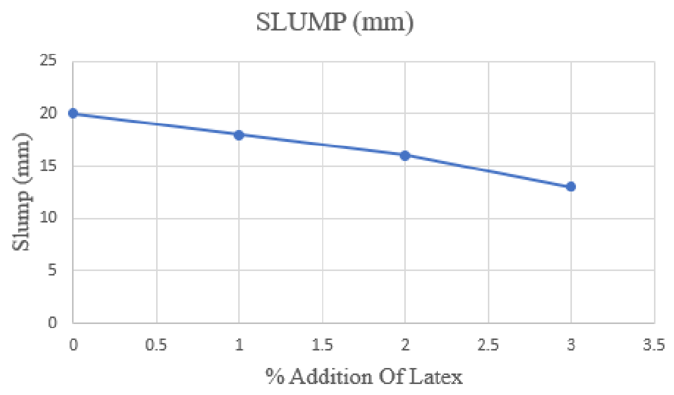

Figure 3.1: Slump at various % of addition of NRL

3.2 Compressive strength

The compressive strength test was conducted by testing the specimen with a dimension of 100 x 100 x 100 mm^3 with the universal testing machine, and the maximum load was used to calculate the strength. The results are presented in Table 3.2.

Table 3.2: Compressive Strength Test (N/mm^2)

Days	0% Latex	1% Latex	2% Latex	3% Latex
3	10.12	10.24	10.54	10.31
7	16.45	16.64	17.13	16.75
14	22.77	23.04	23.72	23.20
28	25.05	25.34	26.09	25.52

With the increase in latex/water ratio, compressive strength increases in comparison with the control mix, as shown in Figure 3.2 for up to 2% replacement. The highest values of compressive strength for concrete with latex is at 2% before starting to decrease.

Table 3.2 and Figure 3.2 give the average compressive strength of the latex concrete in 3, 7, 14, and 28 days. It could be seen that the higher the dosage of latex, the higher the strength.

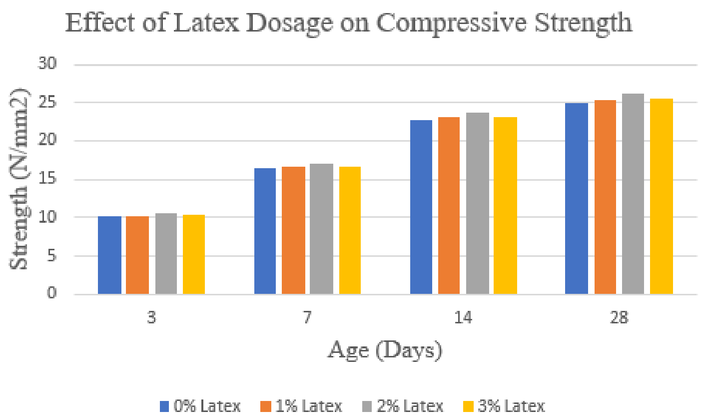

Figure 3.2: Effect of latex dosage on compressive strength

3.3 Flexural strength

The flexural strength tests were carried out using a beam (100 x 100 x 500mm) supported at 50mm to the edge with a 400mm clear span. The results after 3, 7, 14, and 28 days are presented in Table 3.3. It also shows that as the Latex dosage increases, the flexural strength increases.

Table 3.3: Flexural Strength Test (N/mm^2)

Days	0% Latex	1% Latex	2% Latex	3% Latex
3	1.92	2.23	2.64	2.16
7	3.11	3.62	4.28	3.52
14	4.31	5.01	5.93	4.87
28	4.74	5.51	6.52	5.36

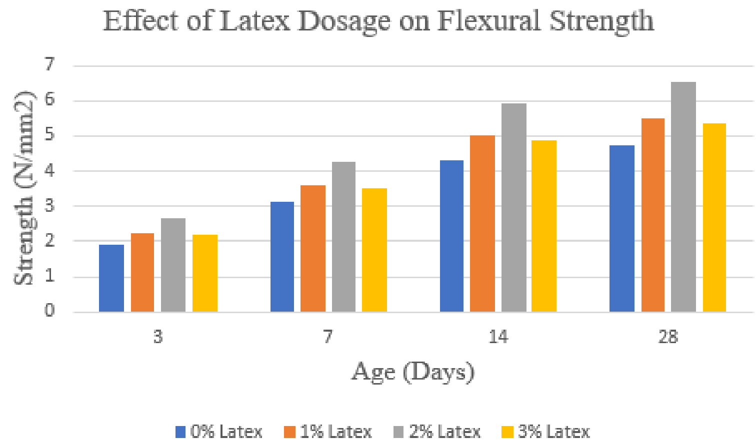

Figure 3.3a: Effect of latex dosage on flexural strength

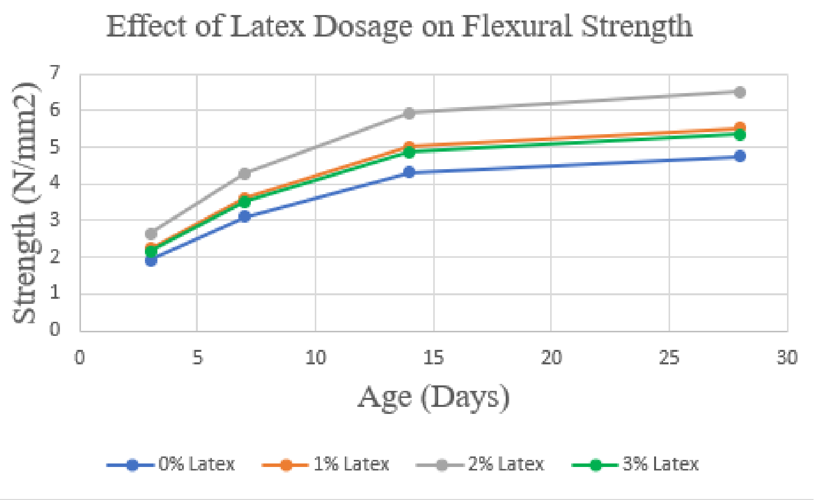

Figure 3.3b: Effect of latex dosage on flexural strength

Figures 3.3a and 3.3b show the effect of latex with different percentages of latex addition on the flexural strength of the concrete. It can be seen that the flexural strength of the concrete slightly increases with an increase in the percentage addition of latex, up to 2%, before starting to drop.

3.4 Split tensile strength

Likewise, the split tensile test was carried out to determine the tensile strength of the latex modified concrete. The results after 3, 7, 14, and 28 days are presented in Table 3.4. It also shows that as the Latex dosage increases, the split strength increases. There was a rise in the value of the tensile strength from the control to the highest value at 2% latex addition in the conventional concrete. This can be deduced to be because of the film, which envelops the concrete and increases its tensile properties.

Table 3.4: Split Tensile Strength (N/mm^2)

Days	0% Latex	1% Latex	2% Latex	3% Latex
3	1.72	2.51	2.94	2.85
7	2.80	4.01	4.78	4.63
14	3.87	5.65	6.62	6.41
28	4.26	6.21	7.28	7.05

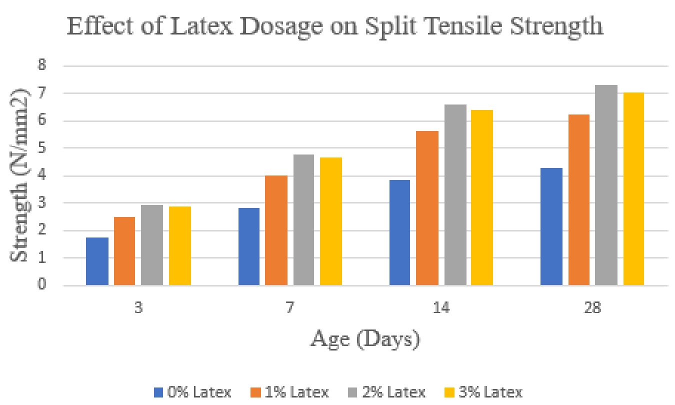

Figure 3.4a: Effect of latex dosage on split tensile strength

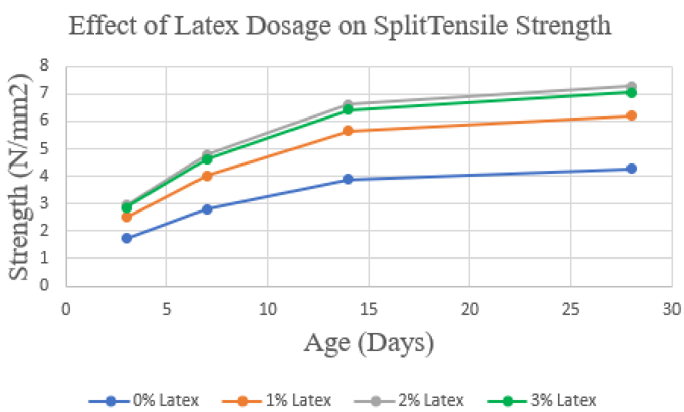

Figure 3.4b: Effect of latex dosage on split tensile strength

Figures 3.4a and 3.4b show the effect of latex with different percentages of latex addition on the split tensile strength of the concrete. It can be seen that the split tensile strength of the concrete increases with an increase in the percentage addition of latex, up to 2% before starting to drop.

4.0 CONCLUSIONS

The following conclusions were drawn from this experimental work:

1. Natural rubber latex can be used as an admixture because of its high plasticity and impermeable nature.
2. The slump test result showed good workability and consistency.
3. The strength development in natural rubber latex is similar to that of conventional concrete.
4. The addition of natural rubber latex increases the strength of conventional concrete.

5.0 RECOMMENDATIONS

From the research work, the following recommendations were made:

1. Research should be carried out for other grades of concrete.
2. Natural rubber latex should be added to the percentage of cement used for the mixing of concrete.
3. Rubber latex should be used when in liquid form to allow for easy dissolving when mixing.

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