

TAMARIND GUM BIOPOLYMER FOR CONCRETE ENHANCEMENT: EVALUATING A NATURAL SOLUTION FOR IMPROVED PERFORMANCE

Shailendra Pandurang Banne^{1*}, Pratima Vitthal Kalokhe²

^{1, 2}Department of Civil Engineering, Pimpri Chinchwad College of Engineering, Nigdi, Pune 411044, India.

¹<https://orcid.org/0000-0001-5626-5508> , ²<https://orcid.org/0009-0009-1981-0218>

Email: *bannemtech@gmail.com, pratima.kalokhe@pccoepune.org

ARTICLE INFO

Article History

Received on: February 26, 2026

Reviewed on: March 20, 2026

Accepted on: May 10, 2026

Published on: June 30, 2026

Keywords:

Tamarind Gum Biopolymer,
Compressive Strength,
Linear Regression (LR),
Multilayer Perceptron (MLP),
Flexural Strength,
Split Tensile Strength,
Durability,
Microstructural Analysis.

ABSTRACT

This study explores the use of tamarind gum biopolymer (TGB) as a sustainable additive in concrete, with a focus on workability, strength, and durability. TGB considerably improves concrete performance by increasing hydration, decreasing microcracking, and encouraging a denser microstructure at an optimum dosage of 0.2% by weight of cement. Slump cone and flow table tests show that 0.2% TGB provides a balanced combination of workability and strength. Tests of strength revealed gains in split tensile strength (20% at 7 days, 21.21% at 28 days), flexural strength (7.81% at 7 days, 10.83% at 28 days), and compressive strength (10.78% at 7 days, 11.13% at 28 days). Incorporating 0.2% TGB into concrete significantly enhances its durability by reducing chloride ion penetration, indicating improved performance in aggressive environments. A comparison of linear regression and MLP-based ANN models demonstrated that the MLP provided more accurate predictions of 28-day concrete compressive strength from 7-day results, effectively capturing nonlinear relationships. XRD analysis reveals that incorporating 0.2% TGB enhances hydrogen and carbon bonding in concrete, significantly improving its flexural strength, durability, and resistance to cracking and environmental stress. SEM analysis revealed the formation of C–H bonds, indicating effective integration of tamarind gum biopolymer and its role in enhancing the microstructure of concrete.



Copyright ©2026 by authors and Galileo Institute of Technology and Education of the Amazon (ITEGAM). This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

I. INTRODUCTION

A developing field that fits with the demand for eco-friendly substitutes for conventional chemical additives and the increased focus on sustainable building practices is the use of biopolymers in concrete. Tamarind Gum, known for its thickening, binding, and water-retaining properties, offers several potential benefits when used as an additive in concrete. Because it is readily accessible, renewable, and biodegradable, it is a desirable alternative for lowering the environmental impact of building materials. By methodically assessing the impact of tamarind gum biopolymer (TGB) at different concentrations on the workability, strength, and durability of concrete, this study aims to close that gap. Now a days many researchers working on incorporating biopolymers into concrete to enhance its mechanical properties and durability, offering sustainable solutions for the construction industry.

1.1 STUDIES ON THE ROLE OF BIOPOLYMERS IN CONCRETE

Xanthan gum: Compressive strength and chlorine ion penetration are investigated in relation to self-compacting concrete's (SCC) rheology. The resistance and durability of SCC were accurately predicted by a backpropagation neural network model, with xanthan gum serving as the critical component [1]. The viscosifying effect of xanthan gum on cement slurry for use in cementing oil wells is the focus of this research. Experimental results showed that xanthan gum improved the slurry's pumpability by increasing its compressive strength, thickening time, and rheology. Consistent with xanthan gum's capacity to lessen cementing operation failure, results showed an increase in compressive strength with time [2].

For the purpose of improving concrete slabs, this study investigates a biopolymer-modified cementitious repair material (CXT) that consists of xanthan gum, tartaric acid powder, and Portland cement. The mechanical properties, load-bearing capacity, and structural integrity of recovered concrete are enhanced by CXT, according to testing. Rebuilding concrete infrastructure could be made possible by CXT due to its environmental benefits and cost-effectiveness, according to the article [3].

Tamarind Kernel Powder: The purpose of this experiment is to examine how incorporating tamarind kernel powder (TKP) into cement changes its characteristics. Slump cone tests for workability and split tensile tests for compressive strength are the primary aims of the investigation. The purpose of the findings is to assess the efficacy of TKP in enhancing the performance of cement [4]. The research paper explores into the topic of tamarind seed powder and its bonding and gelling properties in relation to food and medicine. We talk about the structural, rheological, and physical characteristics of tamarind seed powder as well as its hydration behaviour and its uses. This research provides novel insights for several industries, including construction, by demonstrating the many potential uses of tamarind seeds in both food and non-food production [5]. Research into the effectiveness of tamarind powder and fly ash in enhancing HPC is taking place in this project.

For workability, strength, and durability, the study substitute's fly ash for portland cement in varying proportions and tamarind powder for some sand. Compressive, split tensile, and flexural strengths of modified concrete are higher than those of regular concrete, according to experimental results [6]. In order to improve sustainability, this study investigates using Date Seed (DS) and Tamarind Seed (TS) in place of some fine particles in M25 grade concrete. Control-conformant concrete can be created by substituting fine particles for the 10% DS and 1.5% TS. But after this, concrete's mechanical properties deteriorate due to replenishment [7]. This research looks at the possibility of improving the quality of concrete by adding tamarind kernel powder to it. Powdered tamarind kernels, at concentrations ranging from 0% to 3%, improve the flexural strength and load-bearing capacity of reinforced concrete beams.

The addition of tamarind kernel powder to concrete makes it more stable than regular concrete [8]. The usage of tamarind kernel powder (TKP) as an addition in concrete at different percentages (0% to 0.75%) by cement weight is examined in this study. The compressive and split tensile strengths of concrete cubes and cylinders were evaluated. The findings demonstrated that adding TKP enhanced the concrete's strength characteristics [9]. This study explores the use of tamarind kernel powder, a bio-waste material, as an admixture in concrete, with additions ranging from 0.25% to 1.25% of cement weight. The results suggest that adding up to 1% tamarind kernel powder enhances concrete strength without negatively affecting workability or fresh concrete qualities. This addition improves concrete performance, as confirmed by non-destructive tests, making it a sustainable substitute [10].

Guar gum: Guar gum, an environmentally friendly additive, affects concrete mechanical properties in this investigation. Guar gum can replace up to 0.8% of cement to improve compressive and tensile strengths, although higher water-to-cement ratios lower strengths. Guar gum generates threads between concrete particles, modifying its shape, according to SEM [11]. The application of natural biopolymer additives (guar gum, sodium alginate, and Kathira) to increase concrete's resistance to scouring is investigated in this work. The findings demonstrate that these additions lessen concrete shrinkage and improve the mechanical qualities (compressive, tensile, and flexural strength). Additionally, all three biopolymers increase scouring resistance [12]. The effects of guar gum and arabic gum on the moisture and strength of concrete were studied. Research shows that a combination of 0.5% arabic gum and 0.75% guar gum increases compressive strength, but that using too much gum can diminish its advantages. Without increasing the price, these bio-waste components enhance concrete [13].

Cellulose: In order to improve the performance of carbonation-cured OPC-slag composites, this research investigates the utilization of nanocellulose and polydopamine. Microporosity is reduced and nano porosity is enhanced by both biopolymers, and the degree of binder reaction is raised. Adding 0.05 weight percent of nanocellulose or polydopamine increases flexural strength by 66% and early compressive strength by 35%, respectively [14]. With different percentages (0.5%, 1%, 1.5%, and 2%) added to the mix, the application of cellulose fibers in structural concrete is examined in this work. According to the findings, compressive strength increases up to 1% cellulose fiber before declining. In general, cellulose fiber concrete mixes improve performance and strength, but excessive amounts decrease effectiveness [15]. This study found that cellulose nanocrystals (CNC) improve cement/fly ash paste mechanical characteristics, especially when dosed higher. CNC enhances hydration products, gel pores, and transition pores and speeds up hydration, according to study. The findings suggest CNC could improve fly ash/cement composites for building [16].

Arabic gum and Other Biopolymers: In order to restore columns damaged by tidal flooding, this effort created bio-polymer modified concrete utilizing Gracilaria sp., Moringa oleifera, and honey (GMH). After 14 months of monitoring, the modified columns compressive strength increased by 92.34% to 32.37 MPa. The study highlights the potential for GMH-based biopolymer concrete to increase durability and sustainability in maritime environments [17]. The combined effects of superplasticizers (SP) and biopolymer viscosity-modifying admixtures (BVMA) on the rheological characteristics of cement pastes are examined in this work. The findings showed that when combined, BVMA increased viscosity and SP via regulating hydration and setting times, improving compressive strength. The results of the study show that when combined with SP, BVMA shows a lot of promise as a viscosity modifier in cement-based composites [18].

This study examines the application of alginate, a natural polymer generated from marine brown seaweed, in concrete, emphasizing its advantages in enhancing durability and sustainability. Alginate is a naturally occurring hydrogel that helps fix carbon dioxide, stabilize soil, and increase heat capacity. The study highlights how alginate might improve the properties of green concrete for environmentally friendly building [19]. The application of Gum Arabic (GA) derived from Acacia Senegal trees as a superplasticizer in self-compacting concrete is examined in this work. With an ideal dosage of 8% by weight of cement at water-powder ratios of 1.0, 0.9, and 0.8, the study discovered that GA enhances the rheology of concrete. For self-compacting concrete, GA is suggested as an efficient and environmentally friendly superplasticizer [20].

This study tests biopolymers such giant kelp extract, locust bean gums, almond, and tragacanth as viscosity-modifying admixtures (VMAs) in cement-based composites. Pre-dispersion procedures affect rheology, with welan gum, giant kelp extract, and guar gum performing well. This biopolymer increased paste stability but hindered early strength growth [21]. An overview of the effects of incorporating biopolymers into mortar and concrete is given in this paper, with particular attention paid to increases in workability, compressive strength, and water retention. Chitosan, xanthan gum, guar gum, lignosulfonate, and cellulose ethers are examples of biopolymers that improve physical characteristics and lessen heavy metal leaching. Biopolymer-based concrete and mortar are more environmentally friendly and long-lasting [22]. This work examines silica-lignin hybrid materials as cement composite admixtures, demonstrating that they are classified as I-class hybrid materials due to their weak physical interactions between constituents.

Rheological properties were enhanced by the inclusion of these bio-admixtures; the greatest outcomes were shown at a silica-lignin ratio of 5:1, which increased compressive strength while preserving enough flexibility. Higher silica content had the opposite impact from higher lignin content, which decreased mechanical characteristics [23]. The usage of κ -carrageenan and thermo-reversible animal gelatin as substitute binders for temperature-controlled 3D concrete printing is investigated in this work. According to the study, these biopolymers have good buildability and appropriate rheological characteristics, with notable increases in yield stress after cooling. The research highlights the potential for more sustainable concrete printing with reduced reliance on cementitious materials [24]. The application of biopolymers in mortar and concrete is examined critically in this work, with an emphasis on how they affect the materials mechanical, physical, and durability properties. It highlights the advantages of resin-based biopolymer composites by contrasting conventional concrete, polymer concrete, and biopolymer concrete. The purpose of the publication is to advance knowledge and offer insightful information for upcoming studies and uses of biopolymer concrete [25].

Partially replacing cement in environmentally friendly concrete with ceramic waste powder (CWP) and rice husk ash (RHA) is the focus of this investigation. By substituting 20% CWP and 10% RHA for the cement, the compressive strength increased by 14%, the tensile strength by 28%, and the flexural strength by 19%. In addition to improving concrete's properties, recycling these by-products helps lessen landfill waste and its harmful impacts on the environment [26]. In order to reduce lead (Pb) leachability, this study investigates the use of biopolymers (xanthan gum, guar gum, and chitosan) to encapsulate CRT glass waste in concrete. The resultant composites demonstrated a notable decrease in lead leachability and a 30% increase in compressive strength, both of which were much below hazardous waste requirements. This strategy provides a long-term way to lessen the problems associated with CRT waste [27]. A unique concrete composite was tested using six natural polymers as binders, and each one's compression strength was assessed. Composites based on gelatin exhibited the maximum compression strength (59.6 MPa), but those based on chitosan and κ -carrageenan demonstrated lower strengths.

The study found that because of their better mechanical properties, gelatine-based composites are most suited for use in building [28]. The study measures the long-term compressive strength of polymer concrete composites with different types of fine fillers for a period of up to 9.5 years following preparation. The results showed that fly ash composites in particular had excellent durability and significant strength improvements over time. These findings disprove the notion that strength training is only effective over the short term [29]. This research aims to promote sustainability and recycling by investigating the feasibility of making concrete with marble powder instead of cement. After 28 days, the results were the greatest when 10% to 15% marble powder was used instead of cement to increase the compressive and tensile strengths. Future building applications may face challenges due to mechanical quality degrading as replacement numbers increase [30]. The effects of aluminosilicate pozzolanic wastes (FCCW and MK) on cured Portland cement paste are investigated in this study. It finds that FCCW strengthens the material under compression and speeds up the hydration process.

By combining FCCW with MK at a 1:1 ratio, microstructure is enhanced and portlandite production is decreased. The compressive strength was higher in the composite binder mixture that contained 9% cement as opposed to the prior one [31]. In order to improve the mechanical properties and longevity of concrete, this research investigates the possibility of adding calcined kaolin (CK) and gum Arabic (GA). There is an 8.94% improvement in compressive strength with 0.8% GA and no discernible decrease in strength when using up to 20% CK in place of cement, according to the results. The results of the durability tests showed that 0.6% GA produced the highest compressive strength [32]. The effects of calcined kaolin (CK) and gum Arabic (GA) on the workability, setting time, and mechanical performance of concrete are investigated in this study. The results show that 20% CK is optimal for increasing compressive strength, and that 0.8% GA is optimal for improving mechanical properties and workability. Electron microscopy and X-ray fluorescence analysis confirm the materials' beneficial chemical interactions and surface contour [33].

Starch: The effects of adding starches and their derivatives to concrete mixes on hydration, creep, and compressive strength were investigated. According to preliminary findings, compressive strength rose by 4.9% with cassava starch and 5.3% with 1% maize starch. Additionally, the starch additions improved the hydration and creep characteristics [34]. This study examined how adding starches from cassava (CA) and maize (MS) affected the concrete's strength, oxygen permeability, and absorptivity. The results showed that adding 0.5% and 1.0% CA and 1.5% with MS enhanced compressive strength by 2.7% and 3.8%, respectively. Furthermore, concrete with starch admixtures outperformed control samples, exhibiting lower oxygen absorptivity and permeability [35].

It studied how adding cassava flour to Portland pozzolanic cement influenced fresh and cured concrete. Cassava flour increased compressive, split tensile and flexural strengths. Strength and durability were better with 3% cassava flour. The effects of adding 0%, 0.5%, 1%, and 1.5% maize starch biopolymer to concrete were tested. The results showed that 0.5% starch enhanced slump 25%, fresh density 2.5%, compressive strength 50%, splitting tensile strength 50%, and flexural strength 26%. For concrete enhancement, 0.5% starch worked best [36]. This study studied the effects of raw starch and aquagels on moisture content, shrinkage, and strength in lightweight concrete made from wheat, maize, and high amylose corn starches. Starch-based lightweight concrete had lower compressive strength than perlite-based concrete, although smaller, spherical aquagels increased density and strength.

Extruded aquagels and hydrated raw starch combinations shrank and cracked [37]. This study examined the use of potato starch (PS) as a natural ingredient in concrete at several percentages (0% to 2% of cement weight). According to the data, compressive strength was enhanced by adding 1.2% PS, with 1:2:4 and 1:3:6 mix ratios performing best. By enhancing workability, setting time, and concrete strength, PS offered an affordable and ecologically friendly alternative to durable concrete [38]. This study combined xanthan gum and cassava starch to generate a bio-admixture that increased the bonding strength of cement-based goods. By decreasing porosity and increasing bonding capacity, the ideal xanthan gum ratio increased compressive strength by 16.6%. Additionally, the bio-admixture strengthened the starch's hydrophilic properties, which increased cement mortar's workability and durability [39]. This work explores the use of bio-based polymers, such as acacia gum, cassava starch, and triumfetta pandurate gum, to modify the rheological properties of cementitious systems. While cassava starch had no influence on plastic viscosity and only marginally decreased yield stress, acacia gum was shown to function similarly to superplasticizers based on polycarboxylate.

Combining triumfetta pendrata gum with plasticizing polymers considerably improved the thixotropy of cement pastes [40]. When added to concrete at a rate of 1%, maize starch enhances workability and raises density and compressive strength, according to this study. However, density and compressive strength decrease with additional starch concentration. In addition to improving the properties of concrete, corn starch is an affordable substitute for chemical admixtures [41]. This study presents an innovative method for improving concrete performance by integrating tamarind gum, a naturally sourced biopolymer, as a sustainable additive. Tamarind gum presents a biodegradable and sustainable alternative to conventional admixtures, which has not been thoroughly investigated within concrete technology. This experimental study offers novel insights into the influence of this biopolymer on essential mechanical parameters, including compressive strength, tensile strength, and flexural behaviour. This research integrates traditional material science with sustainable innovation.

II. MATERIALS AND METHODOLOGY

II.1 CEMENT

The usual OPC 53 cement grade is used. The physical properties of the cement, determined by the standard operating procedure, are in accordance with the requirements of IS 12269: 1989. Table 1 displays the physical properties of cement.

Table 1: Physical Properties of cement.

Sr. No.	Property	Value
1	Setting time (initial)	36 Min
2	Setting time (final)	289 Min
3	Consistency of cement	35%
4	Specific gravity	2.69
5	Fineness	4.2%

Source: Authors, (2026).

II.2 FINE AGGREGATE

Sand that was easily accessible locally and that complied with IS 383-1970's requirement by passing through a 4.75 mm sieve was employed. Table 2 displays the fine aggregate's physical properties.

Table 2: Physical Properties of Fine Aggregate.

Sr. No.	Property	Value
1	Specific gravity	2.60
2	Water absorption	3.78%
3	Fineness modulus	2.65%

Source: Authors, (2026).

II.3 COARSE AGGREGATE

Locally available aggregate was processed through a 20 mm sieve and retained on a 4.75 mm sieve, per IS383-1970s recommendations. Table 3 shows the physical characteristics of a coarse aggregate.

Table 3: Physical Properties of Coarse Aggregate.

Sr. No.	Property	Value
1	Specific gravity	2.67
2	Water absorption	1.01%
3	Fineness modulus	3.2%

Source: Authors, (2026).

II.4 TAMARIND GUM BIOPOLYMER

A natural addition to concrete, tamarind gum biopolymer is made from tamarind seeds and enhances workability, strength, and durability. It improves bonding, lowers water requirements, and lessens the likelihood of shrinkage and cracking. Tamarind gum provides a sustainable substitute for artificial additives in concrete because it is an environmentally benign and biodegradable substance. The tamarind fruits were purchased from a local Indian store. The gum was extracted from the tamarind pulp by boiling it, and the resulting gum powder was filtered and dried under close supervision before being used. The required amount of tamarind gum by weight of cement was prepared independently and allowed to cool to room temperature before being mixed with the concrete. Figure 1 shows the tamarind gum biopolymer. Table 4 shows the physical properties of tamarind gum biopolymer.



Figure 1: Tamarind Gum Biopolymer.

Source: Authors, (2026).

Table 4: Physical Properties of tamarind gum biopolymer (TGB).

Sr. No.	Property	Value/Range	Details
1	Appearance	Light brown powder	Depends on processing method
2	Moisture Content	3 – 5%	Determined by GPC
3	Solubility in Hot Water	>90%	At ~80°C, forms viscous solution
4	pH (1% solution)	6.0 – 7.5	Near neutral, suitable for most cement environments

Source: Authors, (2026).

II.5 WATER

For curing and casting, potable water that complies with IS 456-2000 was utilized.

II.6 MIX DESIGN

The concrete mix was designed as per standard guidelines to achieve the desired workability and strength parameters for experimental evaluation. The detailed mix proportions of the control concrete are presented in Table 5. This base mix served as the control for comparison with tamarind gum biopolymer-modified mixes in subsequent trials.

Table 5: Concrete Mix Design.

Sr. No.	Constituents	Concrete [kg/m ³]
1	Cement	353
2	Sand	825
3	Coarse aggregate	1126
4	Water	163
5	w/c ratio	0.46

Source: Authors, (2026).

This research aims to analyse the physical and mechanical properties of the resulting concrete mix, including compressive strength, tensile strength, flexural strength, and durability aspects.

II.7 CONCRETE MIXING

By adding tamarind gum biopolymer to a mix design that includes cement (353 kg/m³), sand (825 kg/m³), coarse aggregate (1126 kg/m³), and water (163 kg/m³), while keeping the water-to-cement (w/c) ratio at 0.46, this study examines the impact of the biopolymer on the characteristics of concrete. The mixing process involved thorough blending of dry materials, followed by the uniform dispersion of the biopolymer and controlled addition of water. Figure 2 shows the addition of TGB while preparing the concrete. Table 6 shows the mix sample name and % dose of TGB.



Figure 2: Addition of TGB during preparation of concrete.
Source: Authors, (2026).

Table 6: Details of sample name and % of TGB dose.

Sr. No.	Concrete Sample Name	Details
1	M1	Conventional concrete only
2	M2	Concrete with 0.1% TGB
3	M3	Concrete with 0.2% TGB
4	M4	Concrete with 0.3% TGB

Source: Authors, (2026).

II.8 METHODOLOGY

The experimental study was conducted in a systematic manner to investigate the influence of tamarind gum biopolymer on the mechanical properties and microstructure of concrete. Figure 3 shows the flow chart of methodology of the present study.

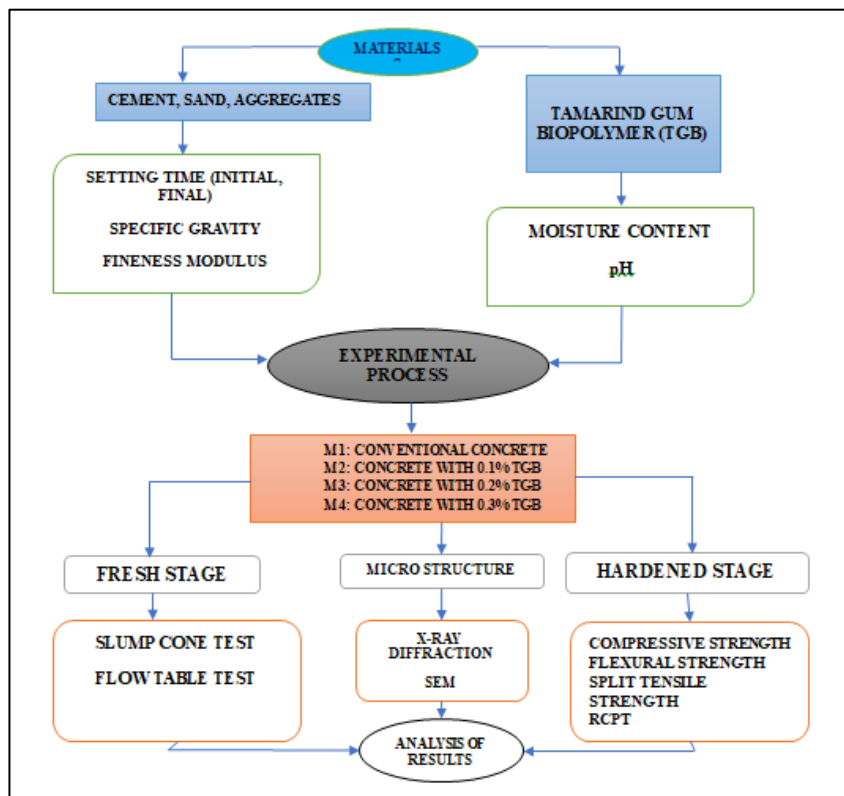


Figure 3: Flow chart of methodology.
Source: Authors, (2026).

III. RESULTS AND DISCUSSION

The analysis for both the freshly mixed concrete and the hardened form are discussed in this section. These assessments encompass the workability, compressive strength, flexural strength, split tensile strength, durability characteristics along with microstructural analysis that were obtained from our experimental analysis:

III.1 SLUMP CONE TEST

The workability of concrete mixes containing varying dosages of Tamarind Gum Biopolymer (TGB) was evaluated using the Slump Cone Test. The conventional concrete mix (M1) maintained a consistent slump of 125 mm, indicating high workability. However, with the incremental addition of TGB, a noticeable reduction in slump was observed. At 0.1% TGB dosage (M2), the slump value decreased to 110 mm, followed by 100 mm at 0.2% (M3), and 90 mm at 0.3% (M4). This decline in slump suggests that the inclusion of TGB reduces the flowability of the mix. The decrease in workability can be attributed to the hydrophilic nature of the biopolymer, which tends to absorb and retain water within its structure, thereby reducing the free water available for lubrication between aggregates. Despite this reduction, the workability remained within acceptable limits, particularly at lower dosages, making TGB a viable additive without significantly compromising fresh concrete behaviour. The variation in the slump value of concrete using TGB is displayed in figure 4. Figure 5 shows the experimental photos of slump cone test.

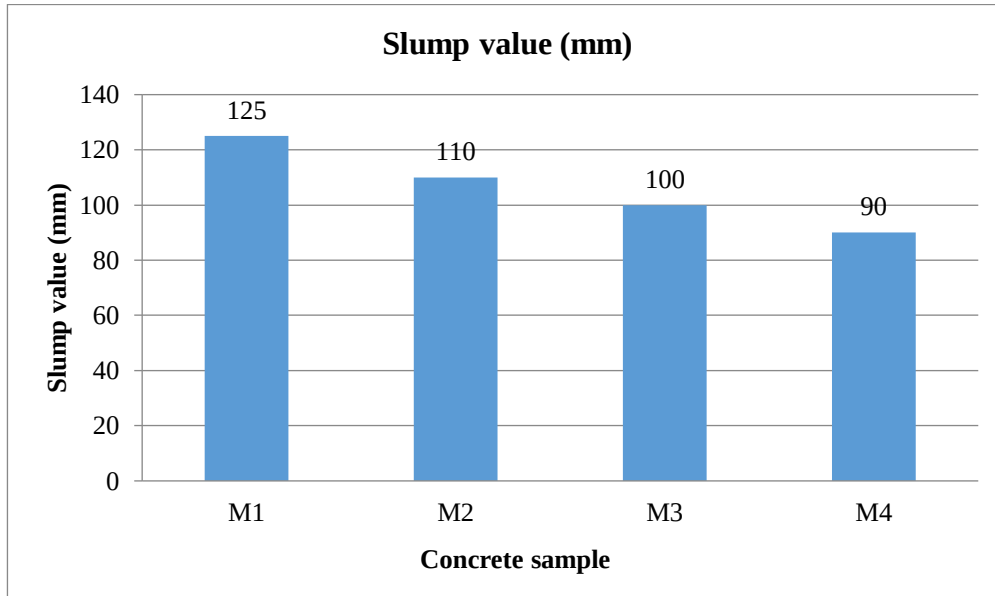


Figure 4: Results of slump cone test.

Source: Authors, (2026).



Figure 5: Slump Cone Test Performance.

Source: Authors, (2026).

III.2 FLOW TABLE TEST:

The flow table test was conducted to further assess the workability and flowability of concrete containing varying dosages of tamarind gum biopolymer (TGB). The control mix, representing conventional concrete, maintained a consistent flow table diameter of 51 mm across all observations. However, with the inclusion of TGB at increasing dosages, a gradual decrease in flow diameter was observed. Specifically, the mix with 0.1% TGB exhibited a flow diameter of 50 mm, followed by 49 mm at 0.2%, and 48 mm at 0.3%. This reduction in flow diameter with increasing biopolymer content is indicative of a decline in the plasticity and flowability of the concrete mix. At lower concentrations, the effect is minimum and still within practical working limits, making TGB a viable additive for enhancing performance without significantly compromising workability. Figure 6 and 7 displays the results of flow table test and photograph of experiment in the lab.

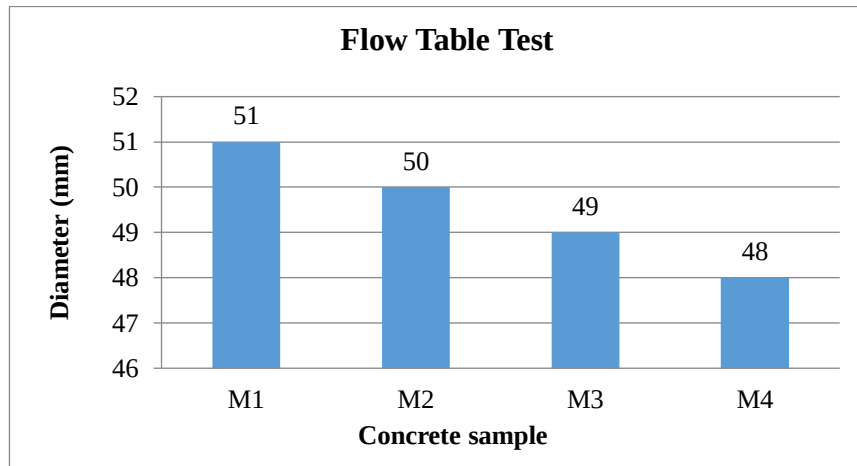


Figure 6: Results of Flow Table Test.

Source: Authors, (2026).



Figure 7: Flow Table Test Performance.

Source: Authors, (2026).

III.3 COMPRESSIVE STRENGTH:

The standard IS 516:1959 describes concrete cube compression testing procedures. Compressive tests are conducted on a compression testing machine (CTM) after curing in water for 7 and 28 days.

III.3.1 Compressive Strength of 7 Days:

The early compressive strength of concrete incorporating tamarind gum biopolymer (TGB) was evaluated after 7 days of curing. The conventional concrete exhibited a consistent compressive strength of 21.89 N/mm² across all dosage levels, at 0.1% TGB, the compressive strength increased slightly to 23.26 N/mm², At 0.2% TGB, the strength further increased to 24.25 N/mm² and a significant decline in compressive strength was observed at 0.3% TGB, dropping to 12.5 N/mm². These results indicate that while low to moderate dosages (0.1%–0.2%) of tamarind gum biopolymer can enhance early compressive strength, higher concentrations may hinder performance. Figure 8 shows the graphical representation of compressive strength for 7 days.

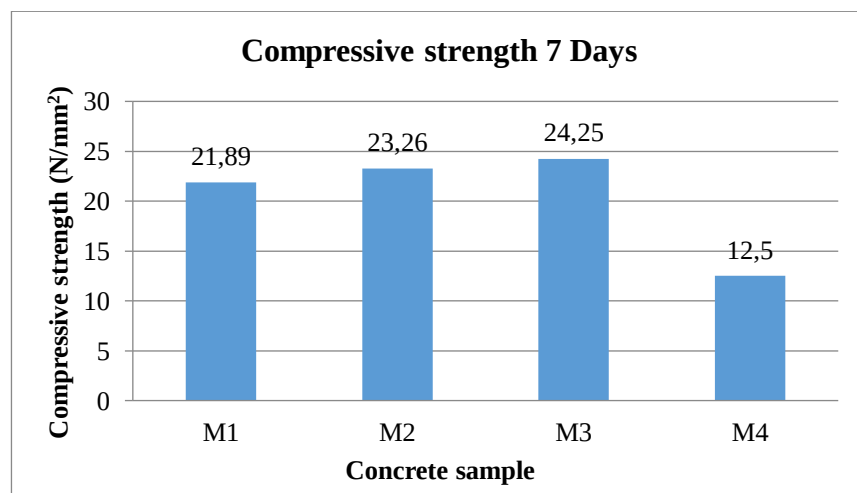


Figure 8: Compressive strength of concrete for 7 days

Source: Authors, (2026).

III.3.2 Compressive Strength of 28 Days:

The 28-day compressive strength of concrete mixes containing varying percentages of tamarind gum biopolymer (TGB) was assessed to determine the long-term mechanical performance of the modified concrete. At a 0.1% dosage, the compressive strength of TGB concrete was 34.1 N/mm². At 0.2% TGB, a notable increase in compressive strength to 38.12 N/mm² was observed, significantly outperforming the conventional mix. Conversely, at 0.3% TGB, the compressive strength dropped sharply to 20.16 N/mm², far below the reference value. This decline suggests that excessive biopolymer content may hinder proper cement hydration and introduce porosity, leading to reduced strength. The hydrophilic nature of TGB at higher concentrations may result in water retention that delays or disrupts the hydration process.

The results demonstrate that an optimum dosage of 0.2% TGB can significantly improve the long-term compressive strength of concrete. The incorporation of tamarind gum biopolymer (TGB) at a dosage of 0.2% by weight of cement significantly enhanced the performance of concrete in terms of its mechanical properties. Specifically, the 7-day compressive strength showed an increase of 10.78%, indicating that the biopolymer positively influenced early strength development. The 28-day compressive strength demonstrated a substantial increase of 11.13% compared to the conventional concrete mix. This gain reflects the long-term benefits of TGB in sustaining hydration, improving matrix densification, and reducing internal porosity. Figure 9 shows the graphical representation of compressive strength for 28 days and figure 10 depicts the cube testing under CTM.

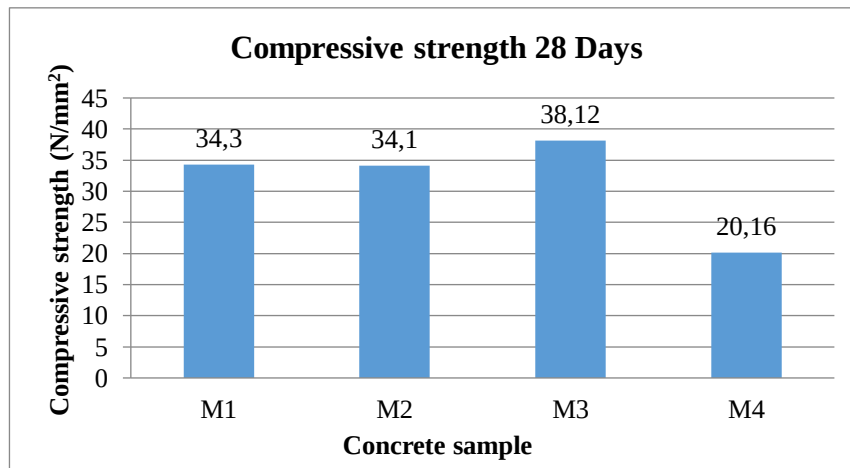


Figure 9: Compressive strength of concrete for 28 days.
Source: Authors, (2026).



Figure 10: Cube Testing in CTM.
Source: Authors, (2026).

III.3.3 Modeling of Compressive Strength Using LR-LSM, and MLP

a) Linear Regression (LR) and Least Squares Method (LSM)

To establish a predictive relationship between 7-day and 28-day compressive strengths of concrete, a simple linear regression model was developed. The model assumes a linear dependence of the 28-day strength (y) on the 7-day strength (x) and is defined by the equation 1:

$$Y = mx + c \quad \text{Equation 1}$$

Where:

- y = 28-day compressive strength (N/mm²)
- x = 7-day compressive strength (N/mm²)
- m = slope of the regression line
- c = y-intercept

Using the Least Squares Method (LSM), the values of m and c were computed based on the minimization of the squared differences between the predicted and actual values. The below equation 2 shows that resulting equation.

$$Y = 1.446x + 1.57 \quad \text{Equation 2}$$

This model indicates that, on average, for every 1 N/mm² increase in 7-day compressive strength, the 28-day strength increases by approximately 1.446 N/mm².

b) MLP Model Equation

To predict the 28-day compressive strength of concrete from its 7-day strength, a **Multilayer Perceptron (MLP)** model was developed. The MLP model is particularly well-suited for capturing the nonlinear relationships that govern strength development in concrete. The MLP model can be represented by the following equations 3 as hidden layer output and equation 4 as final output.

Given input x (7-day strength), the prediction $\hat{y}$ (28-day strength) is:

1. Hidden layer output:

$$h_i = \text{ReLU}(w_i x + b_i) \quad \text{Equation 3}$$

2. Final output:

$$\hat{y} = \sum_{i=1}^4 W_i h_i + b_{\text{output}} \quad \text{Equation 4}$$

Where:

- W_i and b_i are the weights and biases of the input to the hidden layer.
- V_i and c are the weights and bias of the hidden layer to output.
- ReLU is defined as: $\text{ReLU}(z) = \max\{f_0(z), 0, z\}$

So the four hidden neurons are:

$$h_1 = \text{ReLU}(-0.0019995 \cdot x - 0.7536)$$

$$h_2 = \text{ReLU}(1.2841 \cdot x - 0.4593)$$

$$h_3 = \text{ReLU}(0.2646 \cdot x - 1.2103)$$

$$h_4 = \text{ReLU}(0.4960 \cdot x + 1.0800)$$

The final output (predicted 28-day compressive strength) is calculated as a **weighted sum** of the activated hidden neurons using equation 5.

$$\hat{y} = 0.0002023 \cdot h_1 + 0.7367 \cdot h_2 - 0.8383 \cdot h_3 + 1.3495 \cdot h_4 + 0.9865 \quad \text{Equation 5}$$

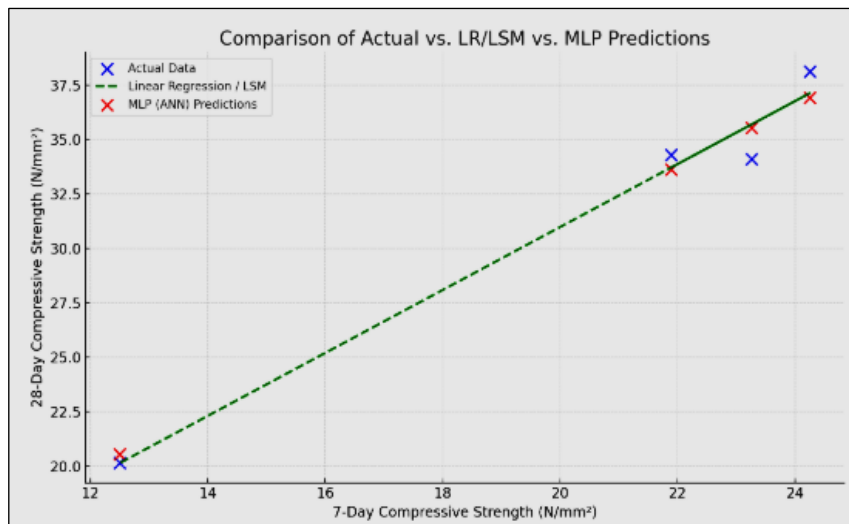


Figure 11: Comparison of Actual vs LR/LSM vs MPL Predictions.

Source: Authors, (2026).

Figure 11 shows that, LR and LSM provide a useful baseline; the MLP model significantly improves prediction accuracy, especially in cases with nonlinear strength gain behaviour. Given its flexibility and accuracy, the MLP model proves to be a promising tool for estimation of concrete compressive strength in practical engineering applications.

III.4 FLEXURAL STRENGTH:

The flexural strength of concrete was determined in accordance with IS 516:1959. Beam specimens of standard size were tested at 7 days using a flexural testing machine with a two-point loading setup.

III.4.1 Flexural Strength of 7 days:

The 7-day flexural strength increased with dosage up to 0.2%, reaching a maximum of 2.62 N/mm² before declining to 1.60 N/mm² at 0.3% dosage. Compared to conventional concrete, the modified mix showed enhanced performance at 0.1% and 0.2% dosages, but a significant reduction was observed at 0.3%. Figure 12 shows the variation in flexural strength of concrete with different dosages of TGB.

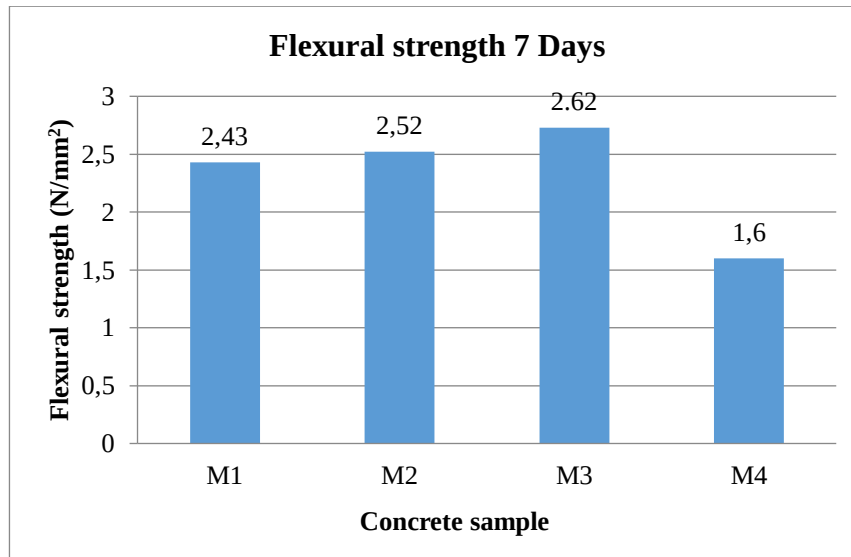


Figure 12: Flexural Strength of concrete for 7 days.
Source: Authors, (2026).

III.4.2 Flexural Strength of 28 Days:

At 28 days, the flexural strength peaked at 4.5 N/mm² for the 0.2% dosage, exceeding the conventional concrete strength of 4.06 N/mm². Dosages of 0.1% and 0.2% both demonstrated improved flexural performance compared to conventional concrete, while the 0.3% dosage resulted in a notable decrease to 2.8 N/mm². The results indicate that an optimal dosage exists around 0.2%, beyond which the flexural strength diminishes significantly. Figure 13 shows the results of compressive strength for 28 days.

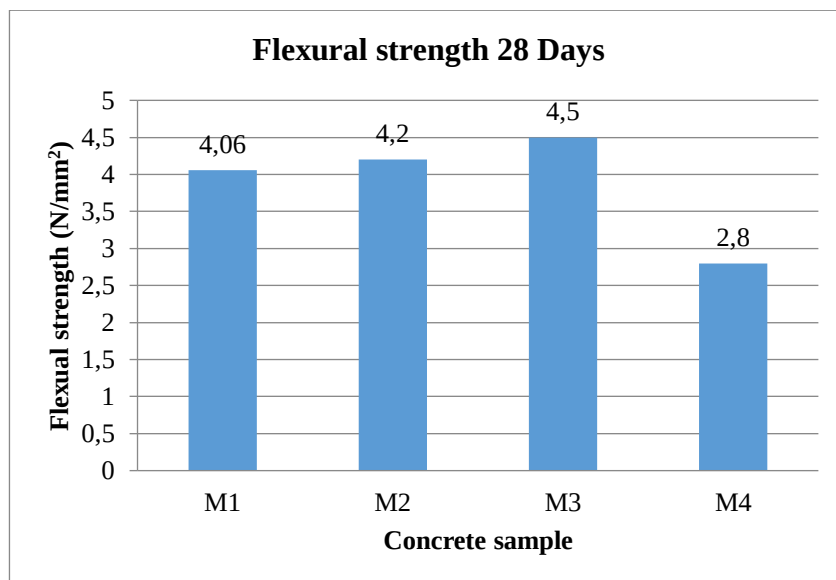


Figure 13: Flexural Strength of concrete for 28 days.
Source: Authors, (2026).

The inclusion of 0.2% tamarind gum biopolymer (TGB) by weight of cement resulted in a notable enhancement of the flexural strength of concrete. Specifically, the flexural strength increased by 7.81% at 7 days and 10.83% at 28 days compared to conventional concrete. TGB contributes to improved interfacial bonding between the cement matrix and aggregates, which plays a crucial role in resisting tensile stresses and minimizing crack formation. These results underscore the potential of tamarind gum biopolymer as an eco-friendly and sustainable additive for producing concrete with superior flexural performance and long-term durability. Figure 14 shows the casting of concrete specimens using tamarind gum biopolymer (TGB) at the mixing and molding stage along with beam testing.



Figure 14: Preparation of concrete specimens in the laboratory.
Source: Authors, (2026).

III.5 SPLIT TENSILE STRENGTH:

The split tensile strength of concrete specimens was evaluated at two different curing intervals—7 days and 28 days, to determine the influence of varying dosage levels of an additive on performance, in comparison with conventional concrete.

III.5.1 Split Tensile Strength of 7 Days:

As shown in Figure 15, the split tensile strength at 7 days increased with dosage up to 0.2%, followed by a decline at 0.3%. The specimen with 0.2% dosage achieved the highest tensile strength of 2.4 N/mm², compared to 2.2 N/mm² at 0.1% and 1.74 N/mm² at 0.3%. In contrast, the strength of conventional concrete remained constant at 2 N/mm² across all dosages. This suggests that a 0.2% dosage provides optimum early-age tensile strength enhancement.

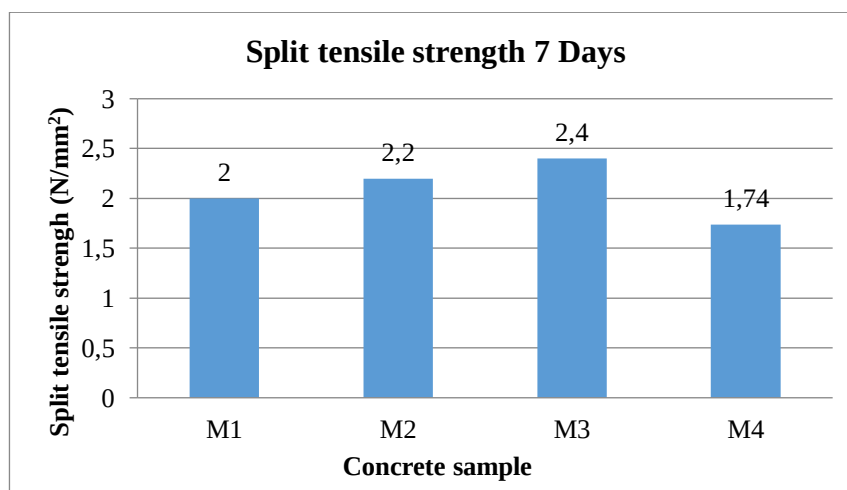


Figure 15: Split tensile strength of concrete for 7 days.
Source: Authors, (2026).

III.5.2 Split Tensile Strength of 28 Days:

Figure 16 presents the 28-day results. Similar to the 7-day trend, the specimen with a 0.2% dosage showed the highest strength of 4 N/mm², outperforming both the 0.1% (3.6 N/mm²) and 0.3% (2.9 N/mm²) dosages. Again, the conventional concrete maintained a consistent strength of 3.3 N/mm². These results highlight that a 0.2% dosage not only enhances early strength but also contributes significantly to long-term tensile performance. Figure 17 shows the split tensile strength determination under CTM.

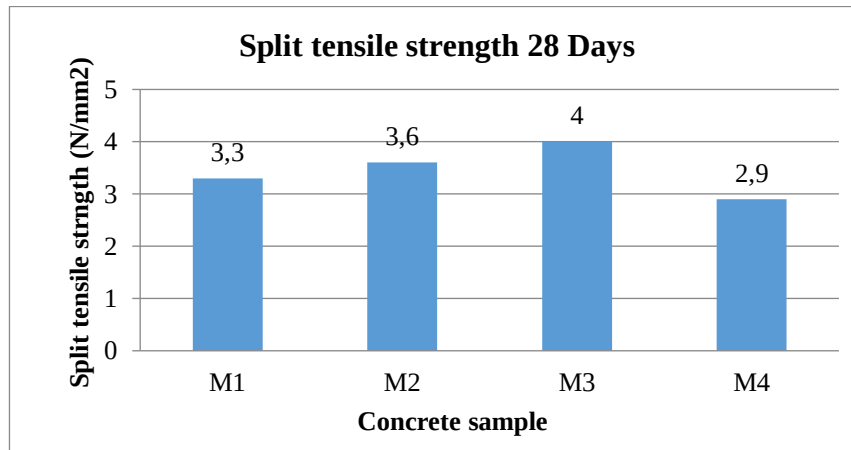


Figure 16: Split tensile strength of concrete for 28 days.
Source: Authors, (2026).



Figure 17: Split tensile strength determination under CTM.
Source: Authors, (2026).

III.6 RAPID CHLORIDE PENETRATION TEST (RCPT):

The Rapid Chloride Penetration Test (RCPT) was conducted in accordance with ASTM C1202 to assess the resistance of concrete to chloride ion penetration. This test is critical for evaluating the durability performance of concrete. Conventional Concrete, with an average charge passed of 3816 coulombs, falls under the category of Moderate Chloride Ion Penetrability. Concrete with 0.2% TGB, with an average charge of 1966.18 coulombs, is classified under Low Chloride Ion Penetrability. The incorporation of 0.2% TGB significantly reduced the charge passed, indicating a notable improvement in resistance to chloride ion penetration. This implies that the modified concrete mix is more durable and suitable for aggressive environments, such as coastal or de-icing salt exposure zones. The reduction from 3816 to 1966.18 coulombs represents a nearly 48.5% improvement in performance. This suggests that the use of TGB at an optimal dosage could enhance the long-term durability and service life of concrete structures. Table 7 and 8 shows the results of RCP on conventional concrete and concrete with 0.2% TGB. Table 9 shows the comparison of chloride ion penetrability between conventional concrete and concrete with 0.2% TGB using RCPT. Figure 18 depicts the RCPT apparatus to determine the durability of concrete.

Table 7: Results of RCPT on Conventional Concrete.

RCPT on Conventional Concrete						
V	C1(ma)	C2(ma)	C3(ma)	Temp1°C	Temp2°C	Temp3°C
0	0	0	0	0	0	0
59.9	125	120	115	39.1	40.1	51
59.9	123	118	112	45.3	47	65.5
59.9	120	115	109	52	54.2	79.4
59.9	116	112	106	58.7	59.7	93.3
59.9	113	110	103	64.7	64.9	99.3
59.8	110	107	100	71.4	69.3	100.3
59.8	107	104	97	77.5	73.3	100.3
59.8	104	101	94	84.2	73.1	100.1
59.8	100	99	91	90.5	77.2	100.7
59.8	97	96	88	95.3	81.1	99.5
59.9	94	93	86	98.8	85.1	92.4
59.9	91	90	83	99.5	97	99.5

Source: Authors, (2026).

Table 8: Results of RCPT Test on Concrete with 0.2% TGB.

RCPT on Concrete with 0.2% TGB						
V	C1(ma)	C2(ma)	C3(ma)	Temp1°C	Temp2°C	Temp3°C
0	0	0	0	0	0	0
59.9	105	194.4	169.2	39.1	40.1	51
59.9	102	189.0	183.6	45.3	47	65.5
59.9	99	181.8	180	52	54.2	79.4
59.9	96	176.4	174.6	58.7	59.7	93.3
59.9	94	170	196.2	64.7	64.9	99.3
59.8	92	165.6	163.8	71.4	69.3	100.3
59.8	90	161.0	154.8	77.5	73.3	100.3
59.8	88	156.6	151.2	84.2	73.1	100.1
59.8	85	151.2	147.6	90.5	77.2	100.7
59.8	82	145.8	144	95.3	81.1	99.5
59.9	79	142.2	140.4	98.8	85.1	92.4
59.9	80	131.4	198.0	99.5	97	99.5

Source: Authors, (2026).

Table 9: Comparison of Chloride Ion Penetrability between Conventional Concrete and Concrete with 0.2% TGB using RCPT.

Conventional Concrete	Concrete with 0.2% TGB
Q1	3750
Q2	3825
Q3	3873
Average	3816

Source: Authors, (2026).



Figure 18: RCPT Apparatus.

Source: Authors, (2026).

III.7 MICROSTRUCTURAL ANALYSIS

III.7.1 XRD Analysis:

Hydrogen (46.20%) Likely forms part of the molecular structure of the biopolymer, contributing to hydrophilic properties and helping to modify the water retention and workability of the concrete. The hydrogen content of the tamarind gum biopolymer in concrete indicates it has a hydrophilic nature (able to bond with water). This can improve the workability of the concrete mix, allowing easier placement and compaction without requiring excessive water. Oxygen (32.30%) plays a key role in the hydrophilic nature of the biopolymer and may interact with water molecules, affecting hydration and potentially forming hydrogen bonds with the cement compounds. Calcium (13.50%) contribute to interactions with calcium hydroxide ($\text{Ca}(\text{OH})_2$) in the concrete, potentially improving the binding properties and the hydration process. The oxygen and calcium components in tamarind gum biopolymer may interact with cement hydrates, potentially improving the bonding between the cement paste and the aggregates. This could lead to improved compressive strength and tensile strength. Carbon (8.50%) may be part of the organic structure of the biopolymer, influencing the plasticity and flexibility of the concrete. The carbon from the biopolymer could contribute to enhancing the flexural strength by providing some plasticity and reducing brittleness.

This means that concrete with tamarind gum biopolymer might perform better under tensile stress and flexural loading than conventional concrete. The presence of tamarind gum biopolymer could delay hydration slightly, as biopolymers can act as retarders. However, this effect is likely minimum if the polymer is added in small amounts. The retardation could be beneficial in terms of workability and control over setting times, especially in hot climates. The hydrogen and oxygen content can improve the water retention capacity of the concrete, reducing the risk of drying shrinkage. This would help mitigate cracking due to water evaporation during curing. Tamarind gum biopolymer often have binding properties that can fill the pores within the concrete matrix, reducing its porosity and making the concrete less permeable to water, chemicals, and aggressive agents. The added carbon may help improve the flexibility of the concrete, making it more resistant to cracking under temperature fluctuations (thermal cycles), moisture variations, and external physical impacts. The reduced permeability and improved crack resistance would enhance the concrete's durability. Tamarind gum biopolymer can be a beneficial additive to concrete, especially in applications where improved durability, workability, and resistance to environmental factors are needed. It's a natural, eco-friendly option that enhances concrete's mechanical properties and performance over time. Figure 19 and 20 shows the XRD results and elemental composition of conventional concrete respectively. Similarly figure 21 and 22 depicts the XRD results and elemental composition of concrete with 0.2% TGB.

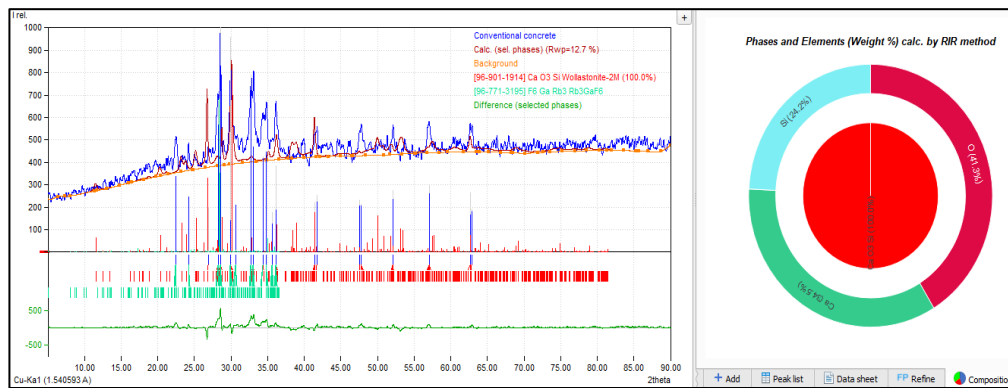


Figure 19: Intensity vs. 2θ curve in XRD analysis of conventional concrete.

Source: Authors, (2026).

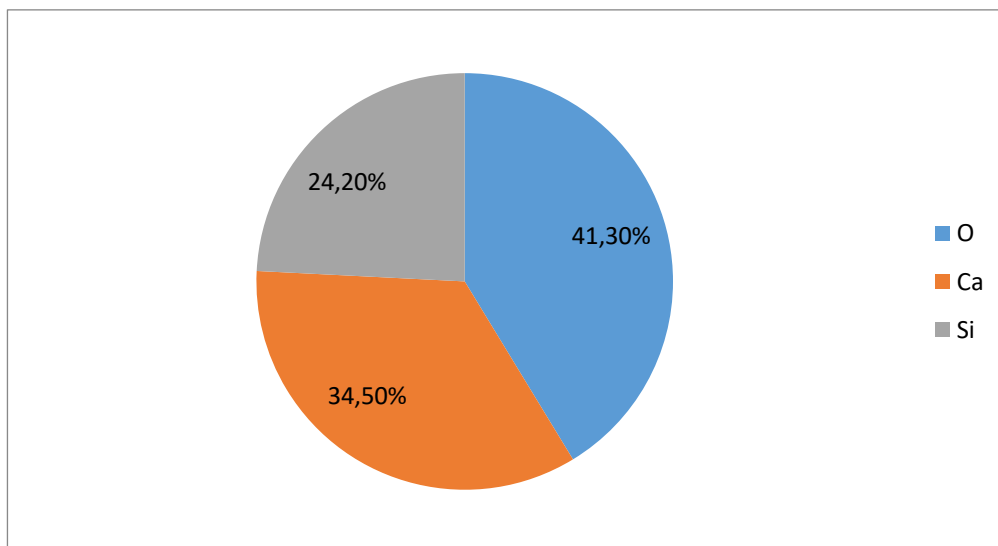


Figure 20: Elemental composition of conventional concrete.

Source: Authors, (2026).

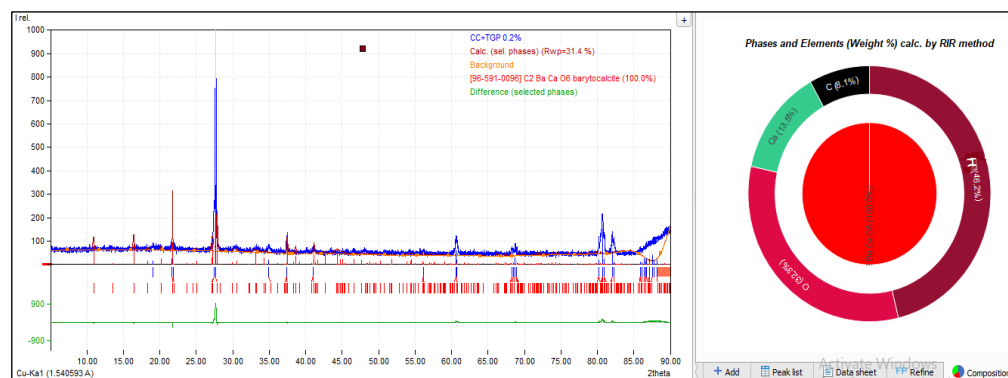


Figure 21: Intensity vs. 2θ curve in XRD analysis of concrete with 0.2% TGB.

Source: Authors, (2026).

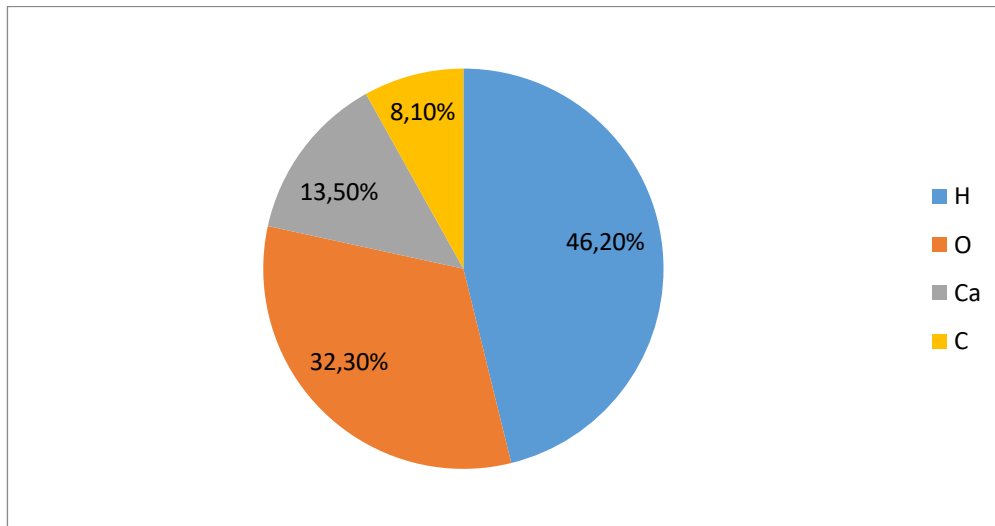


Figure 22: Elemental composition of concrete with 0.2% TGB.

Source: Authors, (2026).

III.7.2 Scanning Electron Microscopy (SEM):

The microstructural changes in concrete caused by the addition of tamarind gum biopolymer were much enhanced by the SEM study. Compared to the control mix, the micrographs showed that the changed concrete had a denser and more refined matrix. Specifically, the biopolymer-modified samples showed clear characteristics associated with C-H linkages. This indicates that the organic molecular chains formed from tamarind gum have been effectively integrated into the cementitious matrix. The existence of carbon-hydrogen bonding suggests that the biopolymer's polysaccharide components interact with hydration products, which could enhance the matrix's integrity. The improved mechanical performance and decreased porosity seen in later testing are probably caused by these changes to the microstructure. Tamarind gum biopolymer has the potential to help create environmentally friendly and highly functional concrete by forming organic-inorganic interactions that lend credence to the idea that it can fill pores and serve as a natural binder. Figure 23 shows the SEM images of conventional concrete and concrete with 0.2% TGB dose.

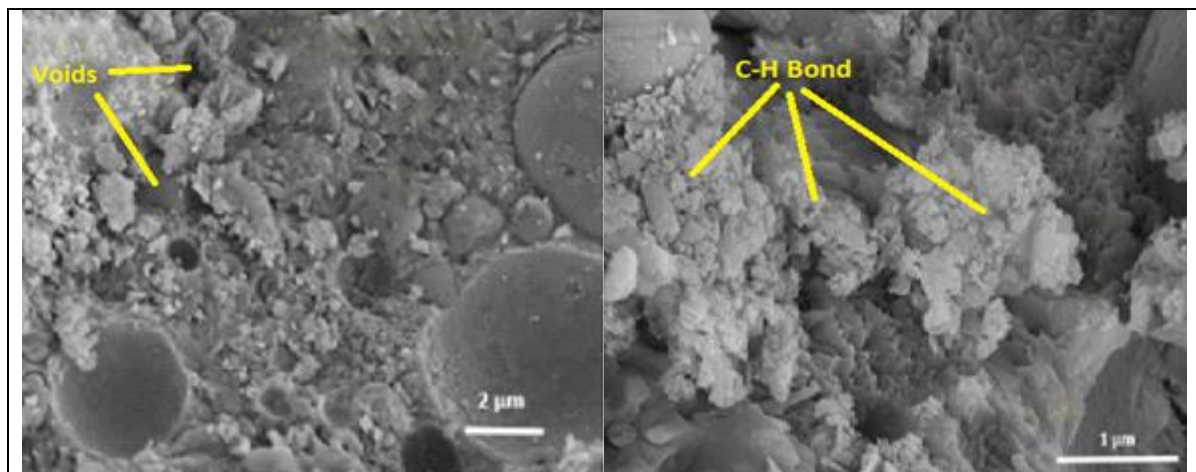


Figure 23: SEM images of a) Conventional Concrete b) Concrete with 0.2% TGB dose.

Source: Authors, (2026).

IV. CONCLUSIONS

- The application of tamarind gum biopolymer (TGB) as a concrete additive is examined in this study, which demonstrates its beneficial impacts on workability, strength, and durability. When added to concrete at an optimum dose of 0.2% by weight of cement, tamarind gum biopolymer improves workability, strength, and durability.
- The slump cone test indicates that tamarind gum biopolymer (TGB) reduces concrete workability due to its water-absorbing and thickening effects. While conventional concrete shows a 125 mm slump, increasing TGB levels reduce it to 110 mm (0.1%), 100 mm (0.2%), and 90 mm (0.3%). An optimal 0.2% dosage offers a good balance between workability and stability.
- The flow table test reveals that increasing tamarind gum biopolymer (TGB) reduces concrete flowability due to its water-absorbing and viscosity-enhancing properties. While 0.2% TGB offers the best balance between workability and stability, it shows potential as a natural additive for improving concrete performance.
- Concrete performance was greatly enhanced by adding 0.2% tamarind gum biopolymer (TGB) by weight of cement, which increased the concrete's 7-day and 28-day compressive strengths by 10.78% and 11.13%, respectively.
- MLP model outperforms LR and LSM, offering a more accurate and flexible approach for estimating concrete compressive strength, particularly in cases with nonlinear strength gain behaviour.

- The inclusion of 0.2% tamarind gum biopolymer (TGB) by weight of cement significantly enhanced concrete flexural strength, with increases of 7.81% at 7 days and 10.83% at 28 days. This improvement is attributed to improved hydration, bonding, and reduced micro-cracks, highlighting TGB as a promising natural additive for stronger, more durable concrete.
- Concrete's split tensile strength increased by 20% after 7 days and 21.21% after 28 days when 0.2% tamarind gum biopolymer (TGB) by weight of cement was added. TGB is a sustainable and efficient additive for increasing the tensile performance because it improves bonding, decreases cracking, and improves hydration.
- The addition of 0.2% TGB enhances concrete durability by significantly improving its resistance to chloride ion penetration.
- The elemental composition of tamarind gum biopolymer, particularly its high hydrogen and oxygen content, enhances the hydrophilic behaviour of the mix, improving water retention, workability, and reducing shrinkage-related cracking.
- The presence of C–H bonds in the SEM analysis confirms the successful integration of tamarind gum biopolymer into the cement matrix, contributing to improved microstructural density and potential performance enhancement.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Shailendra Pandurang Banne, Pratima Vitthal Kalokhe.

Methodology: Shailendra Pandurang Banne, Pratima Vitthal Kalokhe.

Investigation: Shailendra Pandurang Banne, Pratima Vitthal Kalokhe.

Discussion of results: Shailendra Pandurang Banne, Pratima Vitthal Kalokhe.

Writing – Original Draft: Shailendra Pandurang Banne, Pratima Vitthal Kalokhe.

Writing – Review and Editing: Shailendra Pandurang Banne, Pratima Vitthal Kalokhe.

Resources: Shailendra Pandurang Banne, Pratima Vitthal Kalokhe.

Supervision: Shailendra Pandurang Banne, Pratima Vitthal Kalokhe.

Approval of the final text: Shailendra Pandurang Banne, Pratima Vitthal Kalokhe.

VI. REFERENCES

- [1] A. Masoumi, R. Farokhzad, and S. H. Ghasemi, "The Role of Xanthan Gum in Predicting Durability Properties of Self-Compacting Concrete (SCC) in Mix Designs," *Buildings*, vol. 13, no. 10, 2023, doi: 10.3390/buildings13102605.
- [2] C. Khan, I. A. Gopang, and G. Abbas, "Optimizing Wellbore Integrity: Xanthan Gum Contribution To Cement Slurry Performance," *Int. Res. J. Mod. Eng. Technol. Sci.*, no. 10, pp. 671–675, 2023, doi: 10.56726/irjmets45109.
- [3] A. Valli S and R. Kumar M S, "Effectiveness of Xanthan Gum-based composite in repairing cracks in reinforced concrete structures," *Mater. Res. Express*, vol. 11, no. 9, p. 095701, 2024, doi: 10.1088/2053-1591/ad719d.
- [4] C. Chandak, T. Saxena, G. Scholar, B. I. T. Durg, C. Engineering, and B. I. T. Durg, "COMPRESSIVE STRENGTH OF CONCRETE WHEN TAMARIND KERNEL POWDER IS USED AS AN ADDITIVE," pp. 41–45, 2018.
- [5] S. Venkatraman, K. Kiruthiga, and B. Kaviya, "Development of Plain cement Mortar mixed with Tamrind Kernel Powder," no. 9, pp. 1598–1600, 2019, doi: 10.35940/ijtee.I3334.0789S319.
- [6] N. V. S. M. E and A. F. Ash, "Study on Effects of Fly-Ash and Tamarind Kernel Powder in Concrete," vol. 7, no. 01, pp. 282–284, 2018.
- [7] S. C. Sarathkumar, "Experimental investigation on concrete with partial replacement of fine aggregate by date and tamarind seed," vol. 8, no. 1, pp. 45–52.
- [8] R. Vinothini and V. S. Tamilarasan, "INTERNATIONAL JOURNAL OF ADVANCES IN ENGINEERING RESEARCH FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE BEAM USING TAMARIND KERNEL POWDER AS AN ADMIXTURE," *Int. J. Adv. Eng. Res.* 2016, no. 11, pp. 56–61, 2016.
- [9] J. Abhishek and A. S. Pasar, "Studies on Strength Properties of Concrete with the Addition of Tamarind kernel powder as an Additive," no. May, pp. 812–814, 2019.
- [10] S. Venkatraman, "Study on strength parameters of plain cement concrete added with tamarind kernel powder," vol. 22, no. January 2020, pp. 843–850, 2021, doi: 10.1002/suco.201900578.
- [11] T. Radvand and V. Toufigh, "Properties of concrete containing Guar gum," *Eur. J. Environ. Civ. Eng.*, vol. 26, no. 7, pp. 2736–2752, 2022, doi: 10.1080/19648189.2020.1767217.
- [12] M. R. Atash Beik et al., "Using Biopolymers as Anti-Washout Admixtures under Water Concreting," *Buildings*, vol. 14, no. 4, 2024, doi: 10.3390/buildings14041140.
- [13] S. Venkatraman and V. Ramasamy, "Hydration Effect of Gum Arabic and Guar Gum Powder on Strength Parameters of Concrete," *Caribb. J. Sci.*, vol. 53, no. 2, pp. 124–133, 2019.
- [14] R. I. Khan, M. Intesarul, W. Ashraf, and S. Shah, "Role of biopolymers in enhancing multiscale characteristics of carbonation-cured cementitious composites," *Cem. Concr. Compos.*, vol. 134, no. September, p. 104766, 2022, doi: 10.1016/j.cemconcomp.2022.104766.
- [15] S. Awasthi and P. Tiwari, "International Journal of Research Publication and Reviews Strength and Flexural Behaviour of Cellulose Fiber Concrete," vol. 2, no. 11, pp. 262–266, 2021.
- [16] H. Feng, Y. Su, A. Guo, Z. Yu, Z. Guo, and F. Ash, "Mechanical properties of cellulose nanocrystal modified cement / fly ash pastes under various water / binder ratios," *Constr. Build. Mater.*, vol. 447, no. August, p. 138213, 2024, doi: 10.1016/j.conbuildmat.2024.138213.
- [17] R. M. I. R. Susilorini, I. Iskandar, and B. Santosa, "Long-Term Durability of Bio-Polymer Modified Concrete in Tidal Flooding Prone Area: A Challenge of Sustainable Concrete Materials," *Sustain.*, vol. 14, no. 3, 2022, doi: 10.3390/su14031565.

- [18] N. Ortiz-Álvarez, J. Lizarazo-Marriaga, P. F. B. Brandão, Y. Santos-Panqueva, and J. Carrillo, "Rheological properties of cement-based materials using a biopolymer viscosity modifying admixture (BVMA) under different dispersion conditions," *Cem. Concr. Compos.*, vol. 124, no. September, 2021, doi: 10.1016/j.cemconcomp.2021.104224.
- [19] V. Murugappan and A. Muthadhi, "Studies on the influence of alginate as a natural polymer in mechanical and long-lasting properties of concrete – A review," *Mater. Today Proc.*, vol. 65, no. April, pp. 839–845, 2022, doi: 10.1016/j.matpr.2022.03.424.
- [20] S. O. Abuodha, C. M. Athman, and T. Nyomboi, "Use of gum Arabic as a superplasticizer in self- compacting concrete," *Int. J. Innov. Sci. Mod. Eng.*, vol. 5, no. 4, pp. 8–13, 2018.
- [21] J. V. González-Aviña, M. Hosseinpoor, A. Yahia, and A. Durán-Herrera, "New biopolymers as viscosity-modifying admixtures to improve the rheological properties of cement-based materials," *Cem. Concr. Compos.*, vol. 146, no. September 2023, 2024, doi: 10.1016/j.cemconcomp.2023.105409.
- [22] M. Olivia, H. Jingga, N. Toni, and G. Wibisono, "Biopolymers to improve physical properties and leaching characteristics of mortar and concrete: A review," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 345, no. 1, 2018, doi: 10.1088/1757-899X/345/1/012028.
- [23] A. Ślosarczyk, I. Kłapiszewska, P. Jedrzejczak, L. Kłapiszewski, and T. Jesionowski, "Biopolymer-based hybrids as effective admixtures for cement composites," *Polymers (Basel)*, vol. 12, no. 5, 2020, doi: 10.3390/POLYM12051180.
- [24] J. Christ, A. Perrot, L. M. Ottosen, and H. Koss, "Rheological characterization of temperature-sensitive biopolymer-bound 3D printing concrete," *Constr. Build. Mater.*, vol. 411, no. December, p. 134337, 2024, doi: 10.1016/j.conbuildmat.2023.134337.
- [25] P. D. Aher, Y. D. Patil, S. M. Waysal, and A. M. Bhoi, "Critical review on biopolymer composites used in concrete," *Mater. Today Proc.*, no. xxxx, pp. 10–15, 2023, doi: 10.1016/j.matpr.2023.07.212.
- [26] W. W. El-Nadoury, "Eco-friendly concrete using by-products as partial replacement of cement," *Front. Mater.*, vol. 9, no. October, pp. 1–11, 2022, doi: 10.3389/fmats.2022.1043037.
- [27] D. Kim, I. G. Petrisor, and T. F. Yen, "Evaluation of biopolymer-modified concrete systems for disposal of cathode ray tube glass," *J. Air Waste Manag. Assoc.*, vol. 55, no. 7, pp. 961–969, 2005, doi: 10.1080/10473289.2005.10464682.
- [28] J. Christ, T. Engelsens, E. E. Thybring, L. M. Ottosen, and H. Koss, "Screening of natural polymers as binder in concrete composites," *Constr. Build. Mater.*, vol. 441, no. July, p. 137405, 2024, doi: 10.1016/j.conbuildmat.2024.137405.
- [29] J. J. Sokołowska, "Long-Term Compressive Strength of Polymer Concrete-like Composites with Various Fillers," pp. 9–11, 2020.
- [30] M. M. Abbas and R. Muntean, "Marble Powder as a Sustainable Cement Replacement: A Review of Mechanical Properties," *Sustain.*, vol. 17, no. 2, pp. 1–28, 2025, doi: 10.3390/su17020736.
- [31] V. Antonovič, D. Sikarskas, R. Boris, A. Kudžma, J. Malaiškienė, and R. Stonys, "A Study on the Microstructure and Mechanical Properties of Portland Cement Incorporating Aluminosilicate Waste," *Materials (Basel)*, vol. 17, no. 2, 2024, doi: 10.3390/ma17020354.
- [32] G. Frichnes, M. Mouanda, and J. N. Thuo, "Gum Arabic as an Admixture in Modified Concrete Mixed with Calcined Kaolin Gum Arabic as an Admixture in Modified Concrete Mixed with Calcined Kaolin," no. June, 2022, doi: 10.28991/CEJ-2022-08-05-010.
- [33] G. Frichnes, M. Mouanda, S. O. Abuodha, and J. N. Thuo, "Structural Performance of Concrete mixed with Gum Arabic as a Biopolymer Admixture and Calcined Kaolin as a Partial Replacement for Cement," no. November, 2021, doi: 10.14445/23488352/IJCE-V8I11P106.
- [34] A. Akindahunsi, W. Schmidt, and S. E. Iyuke, "The Influence of Starches on some Properties of Concrete Developing of self-cooling concrete pavers View project," no. July 2014, 2013.
- [35] A. A. Akindahunsi and H. C. Uzoegbo, "Strength and Durability Properties of Concrete with Starch Admixture," *Int. J. Concr. Struct. Mater.*, vol. 9, no. 3, pp. 323–335, 2015, doi: 10.1007/s40069-015-0103-x.
- [36] W. Abbas and H. Mohsen, "Properties and Behavior of Starch Biopolymer Concrete," *Eng. Technol. J.*, vol. 38, no. 10A, pp. 1414–1420, 2020, doi: 10.30684/etj.v38i10a.365.
- [37] G. M. Glenn, G. M. Gray, W. J. Orts, and D. W. Wood, "Starch-based lightweight concrete: Effect of starch source, processing method, and aggregate geometry," *Ind. Crops Prod.*, vol. 9, no. 2, pp. 133–144, 1999, doi: 10.1016/S0926-6690(98)00024-7.
- [38] C. Nwa-David, "Performance of potato starch admixture on fresh and hardened behaviours of concrete at varied mix design ratios," *Eng. Technol. J.*, vol. 0, no. 0, pp. 1–8, 2024, doi: 10.30684/etj.2024.145272.1654.
- [39] P. Selvakumar and V. Kumarasamy, "Investigation on microstructural and compressive strength characteristics of a novel bio-admixture comprising Cassava Starch-Xanthan gum with cement mortar for building application," *Rev. Mater.*, vol. 29, no. 1, 2024, doi: 10.1590/1517-7076-RMAT-2023-0331.
- [40] W. Schmidt, I. L. Tchegnina Ngassam, K. A. Olonade, R. Mbugua, and H. C. Kühne, "Plant based chemical admixtures – potentials and effects on the performance of cementitious materials," *RILEM Tech. Lett.*, vol. 3, no. 2018, pp. 124–128, 2018, doi: 10.21809/rilemtechlett.2018.83.
- [41] S. M. Abd, Q. Y. Hamood, A. S. Khamees, and Z. H. Ali, "Effect of Using Corn Starch As Concrete Admixture," *Int. J. Engg. Res. Sci. Tech*, vol. 5, no. 3, 2016.