Journal of Advanced Zoology
*ISSN: 0253-7214*
*Volume* **45** *Issue* **3** **Year 2024** *Page* **156:162**

# Evaluation Of Mechanical Properties Of Concrete With Jute Fiber

**Dr. Atul Prakashchandra Khatri[1*], Dr. Srikanth Ramvath[2], Abdul Ahad[3], D. V. Tanuja[4], Shrikant Sarjerao Bobade[5], Dr M. Durga[6]**

*[1*]Associate Professor, Department of Civil Engineering, Marathwada Mitra Mandal's Institute of Technology, Lohgaon, Pune-411047, Maharashtra, India*
*[2]Associate Professor, Department of Civil Engineering, Chaitanya Deemed to be University, Hyderbad-500075, Telangana, India*
*[3]Research Scholar, Department of Civil Engineering, Faculty of Engineering & Technology, Jamia Millia Islamia, New Delhi, India.*
*[4]Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.*
*[5]Assistant Professor, Department of Civil Engineering, SVPM's College of Engineering, Malegaon Bk. Tal-Baramati, Pune-413115, Maharashtra, India.*
*[6]Associate Professor, Department of Civil Engineering, KG Reddy College of Engineering and Technology, Moinabad Mandal, Hyderabad, Telangana-500075, India.*

***Corresponding Author:** *Dr. Atul Prakashchandra Khatri*
**Associate Professor, Department of Civil Engineering, Marathwada Mitra Mandal's Institute of Technology, Lohgaon, Pune-411047, Maharashtra, India*

### *Abstract*

Concrete, a globally used construction material, lacks tensile strength without reinforcement. Researchers explore novel materials to enhance reliability and sustainability. Notably, concrete contains significant carbon due to cement use. Recent research indicates jute fiber's (JF) potential to enhance concrete's mechanical strength and reduce carbon emissions. This study analyzes JF's application in mechanical properties and environmental impact, addressing a literature gap. Experiments added JF at varying percentages (0%, 0.10%, 0.25%, 0.50%, 0.75%) and conducted tests in fresh and hardened states (slump, CS, STS, FS, WA). Embodied carbon (EC) ratios were computed. Results show JF reduces environmental impact, with optimal proportions (e.g., 0.10% JF) enhancing CS, STS, and FS. Response Surface Methodology (RSM) created a model for JF effects. The study identifies potential benefits for advancing concrete through JF utilization.

***Keywords:** jute fiber; compressive strength; split tensile strength; flexural strength; embodied carbon; eco-strength efficiency; water absorption; response surface methodology; optimization*

## 1. Introduction

Despite its widespread usage in construction, concrete has drawbacks such as poor tension strength, fissure susceptibility, and limited fracture strain capacity. Fiber-reinforced concrete (FRC) is thought to be a workable way to improve the material's brittleness and tensile strength. Concrete components can be reinforced with a variety of fibers, both organic and inorganic; the choice of fiber depends on characteristics like as composition, length, and flexibility. Thin fibers, particularly microfibers with widths of microns, efficiently lessen plastic shrinkage cracks by lowering permeability and leaking. Although they are pricey and stiff, studies mostly concentrate on steel, carbon, glass, and propylene fibers [1]. In emerging nations, composites made of natural fiber-reinforced cement are becoming more affordable options for building construction. Natural fibers are being more and more used in reinforcing materials because of their capacity to decompose and environmental sustainability. They are inexpensive, strong, recyclable, and safe for the environment. Bio composites—especially those made with natural fibers—have taken the role of synthetic polymers in a number of industries, including the automotive, construction, and aviation sectors. It has been demonstrated that adding coconut, sugarcane bagasse, Roselle, sisal, hemp, and jute to concrete composites improves their compressive and tensile strength. The addition of roselle fiber strengthened the cement matrix, making it less brittle and more ductile [2].

Natural fibers included in cement-based materials serve as fissure arrestors, halting the spread of fractures and averting disastrous consequences. Improved tensile strength and flexibility are achieved in building materials made with continuous fiber reinforcement. According to research that has already been done, jute fiber (JF) in concrete shows a lot of potential for a variety of uses, such as affordable building materials, gypsum-based walls, and lightweight roofing. For industrial machinery basic structures, this method works effectively. Using natural fibers in cement composites is an eco-friendly and adaptable option for a range of building uses [3]. Because they are abundant, affordable, and made from annual plants, jute fibers (JF) have gained interest as a potential substitute in concrete composites. Their structural adaptability, wide availability, and antimicrobial qualities render them appropriate for a range of uses, especially as reinforcements in laminated and bionic composites. Jute textiles are perfect for outdoor use because of their antimicrobial, shielding properties against UV rays, and pentagonal or hexagonal cross patterns. Because of its exceptional mechanical qualities, jute textiles are used in many different sectors and satisfy both structural and budgetary requirements.

Jute and sisal fibers have better mechanical qualities than those of coconut and sugarcane fibers, as shown by materials that have been reinforced with these fibers. According to research, jute fibers have a density seven times lower than that of steel fibers and a tensile strength between 250 and 300 MPa, which makes them useful for a variety of applications. Studies on cementitious composites that take into account continuous and extended jute fibers show benefits in terms of strength, resistance to external forces, and resistance to cracks. Variables including fiber type, amount, and infill affect the characteristics of natural fiber-reinforced concrete (NFRC). Sufficient fiber content and ideal conditions are essential for NFRC operation. While there is disagreement about the use of jute fiber (JF) and issues with corrosion and thermal expansion when using steel fibers in concrete, JF's environmental effect is taken into account throughout the whole processing and cultivation cycle. Since jute can be grown in a variety of climates and requires less pesticides, it is typically considered an environmentally beneficial crop. Concerns regarding the long-term structural integrity of jute fibers are raised by the possibility of their deterioration over time as a result of alkaline assault, moisture exposure, and microbes in concrete settings. The evaluation of JF's environmental effect takes into account several elements, including farming techniques, energy sources, transportation, and processing techniques, all of which contribute to the fiber's reputation as being reasonably ecologically benign. JF's carbon footprint is calculated using the embodied carbon factor from the literature that is currently accessible [4].

According to a prior study by Ahmed Jawad et al. [4], adding Jute Fiber (JF) increased the fibrous surface area of the concrete, which decreased its fluidity and increased its abrasiveness. The study discovered that adding 2% JF increased the maximum mechanical strength to the greatest extent possible, with the biggest gains occurring in the areas of split tensile strength (STS), flexural strength (FS), and compressive strength (CS). But mechanical qualities deteriorated after a 2% point. By influencing density, water absorption, drying shrinkage, and resilience to acidic conditions, JF inclusion enhanced durability qualities. Increased JF content was shown to be positively correlated with lower slump in newly mixed concrete in another investigation conducted by Muhammad S. Islam et al. [5].

According to a prior study by Ahmed Jawad et al. [4], adding Jute Fiber (JF) increased the fibrous surface area of the concrete, which decreased its fluidity and increased its abrasiveness. The study discovered that adding 2% JF increased the maximum mechanical strength to the greatest extent possible, with the biggest gains occurring in the areas of split tensile strength (STS), flexural strength (FS), and compressive strength (CS). But mechanical qualities deteriorated after a 2% point. By influencing density, water absorption, drying shrinkage, and resilience to acidic conditions, JF inclusion enhanced durability qualities. Increased JF content was shown to be positively correlated with lower slump in newly mixed concrete in another investigation conducted by Muhammad S. Islam et al. [5].

## 2. Materials and Experimental Methods

### *2.1. Materials*

The main material used in the experiment was ordinary Portland cement (OPC), which ensured that the binders met ASTM C150M-15 criteria. Jute was procured from local sources, highlighting its essential function in the formulation of concrete. The acquired jute was evaluated in accordance with supplier guidelines to verify its appropriateness for concrete manufacturing. To improve the quality of reinforced concrete, it is important to keep an eye on the growth of jute within the concrete and assess its structural soundness. Jute and concrete bonding at its best increases component strength. A local vendor was used to purchase micro silica, and after conveyance, the density and pertinent properties of the material were evaluated. The results of the study showed a relationship between the characteristics of the material, its reduced capacity to absorb water, and its enhanced capacity to absorb water by materials of particular particle sizes. While fine aggregate was readily accessible locally, coarse material was purchased from a merchant in the vicinity. To satisfy water requirements in the production of self-consolidating concrete, a Polycarboxylate superplasticizer (SP) with a density of 1200 kg/m$^3$ was purchased from nearby vendors. Jute and superplasticizers were cross-matched in an effort to find any possibly dangerous chemical components. Table 1 provides a thorough breakdown of Jute Fiber (JF) composition.

**Table 1.** Constituents of Jute fiber.

| S. NO. | Constituents | Percentage (%) |
|---|---|---|
| 1 | α-Cellulose | 60.00 |
| 2 | Lignin | 12.00 |
| 3 | Hemicellulose | 22.00 |
| 4 | Fatty and waxy matter | 1.00 |
| 5 | Nitrogenous matter (as protein) | 1.00 |
| 6 | Miscellaneous | 3.00 |
| 7 | Mineral matter (ash) | 1.00 |

### *2.2. RSM and Mix Proportioning*

The concrete under investigation complied with ACI 211.1-91 requirements for jute-free controlled samples. Response surface methods (RSM) and Design Expert 13 software were used to illustrate the effect of varying jute quantities as an independent variable on the dependent variables by including them into the compounds. Implementing Mix Design was made easier by RSM manipulation within the software's best design selection. There were several composite formulas made, with jute content varying from 0% to 0.75%. Relevant to the investigation were freshly mixed and cured concrete studies, which included collapse cone assessments, water absorption (WA), embodied carbon (EC), split tensile strength (STS), flexural strength (FS), compressive strength (CS), and eco-strength efficiency (ESE). While RSM produced a variety of mixes with varying JF proportions, the mixture's consistent ingredients were micro silica, gravel, fine sand.

## 3. Results and Discussion

### *3.1. Fresh Characteristic*

Slump Flow

Concrete slump flow was examined between mixes that included Jute Fiber (JF) and the control mix that did not. The control mix had a slump flow value of 85 mm and demonstrated great flowability with 0% JF. Nevertheless, the flowability of concrete was negatively impacted by the addition of JF. The addition of 0.25%

JF reduced slump flow by 22.3%, whereas the addition of 0.10% JF reduced flowability by 10.5%. Additionally, compared to the control mix, the addition of 0.50% JF resulted in a 41.1% decrease in concrete flow. With 0.75% JF, the largest reduction was seen, leading to a 54.11% drop in slump flow as compared to the control mix. JF's hygroscopic properties and propensity to absorb water led to a reduction in slump flow. Slump flow was also shown to be reduced by cement paste and JF having a good connection and cohesiveness. With regard for ideal inclusion percentages, prior research, including those conducted by S. Islam et al. [5] and Rakibul Hasan et al. [6], supports the finding that the addition of JF to concrete tends to reduce flowability.

## *3.2. Mechanical Properties*

### 3.2.1. Compressive Strength

When Jute Fiber (JF) is not present, the control group's Compressive Strength (CS) is 59 MPa. JF introduction exhibits a positive association with CS, reaching an optimal value beyond which additional accumulation results in a decrease in the strength of the concrete. The best percentage in this combination is achieved by adding 0.25% JF, which raises CS by 3.38% after adding 0.10% JF, which improves CS by 6.77%. Above this threshold, JF content increases (e.g., to 0.50%) cause a 3.39% reduction in strength in comparison to the control group. An 11.86% decrease in strength is seen when comparing the highest JF concentration of 0.75% to the control. According to the study, the ideal JF addition for improved CS is 0.10%; adding more than this reduces the strength of the concrete. A 15% improvement in CS was shown in earlier study by Mohammad H. Elgawish et al. [7] with 0.25% to 0.50% JF, but Islam and Ahmed discovered a little strength boost with 0.50% JF. A high JF percentage reduces the strength of concrete by causing agglomeration and clustering, which create voids and interfere with the cement hydration process.

### 3.2.2. Split Tensile Strength

The Split Tensile Strength (STS) of the control sample is around 5.62 MPa. There is a slight increase in STS when Jute Fiber (JF) is added to concrete. The strength grows by 6.91% when 0.10% JF is added, and by 3.21% when 0.25% JF is added, STS reaches its maximum strength. On the other hand, adding 0.50% JF causes a 1.4% modest reduction in strength, while adding a further 0.75% JF causes a 10.29% reduction in STS. According to the study, the ideal JF addition to maximize STS is 0.25%. Previous studies by Elgawish and Zakaria found that concrete's STS is improved by 0.10–0.50% JF with a length of 10–20 mm. In a similar vein, Tiezhi Zhang et al.'s study indicates that JF fiber with a length of 18 ± 2 mm and a percentage range between 0.25% and 0.50% is ideal for optimizing concrete stiffness. Because JF and the cementitious matrix adhere better to one another, JF increases toughness by allowing concrete to bend under tensile loads, improving ductility, and promoting STS [8].

### 3.2.3. Flexural Strength

The Flexural Strength (FS) of the control mix is 4.76 MPa. When 0.10% Jute Fiber (JF) is added, FS rises by 9.63%, while strength improves by 5.88% when 0.25% JF is added. On the other hand, FS decreases when 0.25% JF is added to the mixture as opposed to 0.10% JF, suggesting that 0.10% is the ideal amount. JF addition results in FS increases that are negligible and almost identical to the control mix. Comparing the JF content to 0.75%, FS is 6.95% lower than in the control group. By improving the ductility of concrete and permitting more deformation before collapse, the addition of JF increases flexural capacity. In the cement matrix, fibers interconnect to distribute loads uniformly and offer resistance, increasing FS. A stronger link between the cementitious material and JF promotes cohesion and load transmission, which raises FS even further. Except for 10 mm fiber at 0.50%, the study by Islam and Ahmed [5] indicates that the inclusion of JF did not considerably enhance the stiffness of concrete beams. There was a 6.0% increase in the modulus of rupture when 10 mm fiber was used at 0.50%. All examined fiber concentrations (0.25%, 0.50%, and 1.00%) showed a decreasing trend in the modulus of rupture at a 20 mm fiber length. Regardless of fiber aspect ratios, the combination of 1.0% JF had a negative impact on the modulus of rupture.

## 4. Analysis of Variance Using RSM

Jute's effect on the fresh and hardened properties of concrete is evaluated and predicted using the Response Surface Methodology (RSM) model. The experimental data set was subjected to a multiple regression analysis for RSM. According to the anticipated model, the ANOVA was conducted using the optimal design approach. At a significance threshold of 0.05, the statistical measures of Sum of Squares (SS), model F-values, and p-value are displayed [9]. Each component's statistical significance is ascertained using p-values that fall between 0.05 and 0.01. These numbers show that there is a positive correlation between the observed and predicted values. The input factor's model p-values of 0.005 are shown by the ANOVA findings of our investigation. The slump, CS, STS, FS, WA, EC, and concrete's ESE after 28 days of curing are represented by the F-values of the RSM-generated model created by design expert software. The aforementioned figures are, in order, 18,295.35, 108.90, 55.29, 34.60, 1827.77, 9.685 × 106, and 148.03. This highlights how significant the final models are. The F value and absence of Fits are also used to evaluate the model's validity and efficacy. A little amount of data volatility around the model fit is suggested by the lack of Fits [10].

A prediction model's accuracy and dependability may be assessed using statistics, specifically the coefficient of determination (R2). One way to gauge how closely the fitted model matches the observed data is to look at the R2 coefficient. The statistic assesses how well the model and the data match each other. The percentage of the dependent variable's fluctuation that can be ascribed to the independent variables is expressed as an R-squared value [11].

This numerical value usually fluctuates between zero and one. A better model performance is often indicated by a higher R-squared value. After 28 days following the casting process, the study produced R-square values of 0.9997, 0.9732, 0.9485, 0.9202, 0.9973, 0.999, and 0.9801 for slump, CS, STS, FS, WA, EC, and ESE, respectively. The high determination coefficient values led to the conclusion that the models had a very good fit to the data. Furthermore, it is deemed inadequate if there is a 30% discrepancy between the modified and predicted R-squared values. The signal-to-noise ratio requires a minimum threshold of 4 and depends on the accuracy level being sufficient [12]. The results obtained for Adequate Precision after the 28th day of the curing procedure were reported in the current study as follows: 291.9249, 28.5585, 21.1222, 17.1756, 90.8653, 7414.069, and 32.8631, respectively.

In this study, a number of criteria were examined, including flowability, FS, WA, EC, ESE, CS test, and STS test. 28 days after casting, the data were gathered, and graphs showing actual values vs predicted values were used for analysis. The discovery that the data points clustered along the line that produced the best alignment suggests that the models' predictions about the responses are coherent. In plots that compare actual and projected values, the degree of conformity between the data points and the line of best fit indicates how similar the expected and observed results are [13].

### *4.1. Impacts of Jute Fiber on Concrete's Fresh Properties*

Slump Flow

The slump values response variable's ANOVA findings. Since the quadratic strategy produced the best match to the data from the flowability evaluation, it was chosen. The model's F-value of 18,295.35 illustrates its statistical significance. There is a very little possibility (0.01%) that an F-value of this size will be obtained from random fluctuation alone. The probability of this happening is really low. If the p-values are less than 0.0500, then it is possible to deduce that a substantial portion of value is covered by the model terms. Variables A and A2 provide a substantial contribution to the model under the conditions specified. Model terms that have values greater than 0.1000 are not taken into account since they are deemed trivial.

### *4.2. Impact of Jute Fiber on the Mechanical Properties of Concrete*

#### 4.2.1. Compressive Strength

The ANOVA results for the Variable Response 28-day CS (Compressive Strength) indicate that the cubic model is the most suitable for the CS dataset. The F-value of 108.90 signifies the statistical significance of the model, with a mere 0.01% chance that such a high F-value could result from random fluctuations. Model terms A, A2, and A3 are statistically significant, as their p-values are less than 0.0500. Values exceeding 0.1000 for model terms suggest their lack of statistically significant impact on the result. Model reduction proves beneficial for enhancing a model's overall quality when a substantial fraction of its terms is deemed unimportant, excluding those necessary for preserving hierarchy. This occurs by eliminating terms vital to maintaining hierarchical systems. Using an equation with encoded variables facilitates predicting a result for a specific level of each component. In many cases, a component's value of +1 indicates higher levels, while -1 denotes lower levels of the same component. The significance of components can be ranked using the factor coefficients of the encoded equation.

#### 4.2.2. Split Tensile Strength

The ANOVA results for the Variable Response STS (Split Tensile Strength) on day 28 indicate that the cubic model offers the best fit for STS in concrete. The Model F-value, calculated at 55.29, indicates the model's statistical significance, with only a 0.01% chance of obtaining such a value due to random fluctuations. Values above 0.1000 for model terms suggest their lack of statistically significant impact on the result. Model reduction is a beneficial strategy to enhance the overall efficacy of a model by eliminating unnecessary terms, preserving hierarchy. The elimination of non-essential terms contributes to a streamlined hierarchical structure. Equations with variable codes can predict outcomes for varying component levels, where +1 represents higher levels, and -1 represents lower levels, following the traditional method.

### 4.2.3. Flexural Strength

The ANOVA test results for FS (Flexural Strength) on Day 28 reveal that the cubic model is the most fitting. The model's statistical significance is confirmed by a low probability (0.01%), indicating a minimal chance of obtaining a similar F-value by random variation. The importance of model terms is highlighted by their p-values, with A, A2, and A3 being the most significant variables. In cases where model terms are non-significant, indicated by values above 0.1000, model reduction can enhance its quality by eliminating extraneous terms. Equations expressed in terms of coded variables (+1 and -1 representing higher and lower concentrations) facilitate predicting outcomes for specific component values. Comparative effects of elements are determined by evaluating factor coefficients associated with each ingredient in the coded equation.

### *4.3. Impact of Jute Fiber on Sustainability*

### 4.3.1. Embodied Carbon

The ANOVA results for the Variable Response EC (Embodied Carbon) indicate that the cubic model is the most suitable, with an F-value of 9,684,954.96, demonstrating the model's statistical significance. The probability of obtaining such a large F-value by random fluctuation is extremely low (0.01%). Statistically significant model terms (A, A2, and A3) have p-values below 0.0500, while terms with values above 0.1000 are considered negligible. Model reduction, eliminating unnecessary terms while preserving hierarchy, can enhance the overall quality of the model. Predictions for the response can be obtained using a coded factor equation, with precision depending on specific concentrations of each component. The upper and lower bounds of components are represented by +1 and -1, respectively, providing default values for their respective levels.

### 4.3.2. Eco-Strength Efficiency

The ANOVA results for the Variable Response ESE (Eco-Strength Efficiency) indicate that the cubic model is the optimal model, with an F-statistic value of 148.03, highlighting the model's statistical significance. The probability of obtaining such a large F-value by chance alone is extremely low (0.01%). Model terms (A, A2, and A3) are considered significant if their p-values are less than 0.0500. Model reduction, eliminating unnecessary terms while preserving hierarchy, can be beneficial in improving the model's performance. If a model term's value is greater than 0.1000, it is considered non-significant. Applying model reduction techniques can enhance the model's overall quality by eliminating superfluous terms. The equation can predict the outcome of a response by considering specific concentrations of each encoded component. For categorical variables, the highest tier is typically assigned a numerical value of 1, and the lowest tier is assigned a numerical value of -1.

## 5. Conclusions

The present work employed statistical models like Response Surface Methodology (RSM) and computational elements to examine the effects of jute fiber (JF) on the mechanical, fresh, and environmental characteristics of concrete. The following are the study's main conclusions:

1. Optimal Percentage of Jute Fiber: Based on scientific research, the best and most desired outcomes for concrete that has been mixed with JF are obtained when the concrete has a 0.10% JF content. Concrete's fresh and hardened characteristics do not show positive impacts over this proportion.
2. Statistical Significance: The use of forecast models based on p-values yielded statistically significant outcomes, which made a substantial contribution to the assessment of the mechanical characteristics of carbon fiber-reinforced concrete, both fresh and hardened.
3. Coefficients of Determination (R-squared): They are 0.9997, 0.9732, 0.9485, 0.9202, 0.9973, 0.999, and 0.9801 for slump flow, concrete's compressive strength (CS), split tensile strength (STS), water absorption (WA), embodied carbon (EC), and eco-strength efficiency (ESE), in that order.
4. Features of Slump: The lowest slump flow was seen at a JF percentage of 0.75%, and the maximum slump was noted at 0%. The build-up of JF in the concrete was the reason given for the reduction in slump flow of new concrete.
5. Mechanical Properties: The highest CS, STS, and Flexural Strength (FS), measured 63 MPa, 6.01 MPa, and 5.22 MPa, respectively, when 0.10% JF was included into the concrete.
6. Maximized Results: The investigation yielded optimal results for a number of characteristics, such as slump, concrete's CS, STS, WA, EC, and ESE. For these replies, the corresponding desirability level was determined to be 0.994.

7. Prognostication Formulas: By adding various percentages of JF, the derived equations may be used to forecast the characteristics of concrete with effectiveness.

These results provide important new information about how to optimize and forecast the characteristics of concrete by carefully using jute fiber.

## References

1. Rocha, D.L.; Júnior, L.U.D.T.; Marvila, M.T.; Pereira, E.C.; Souza, D.; de Azevedo, A.R.G. A Review of the Use of Natural Fibers in Cement Composites: Concepts, Applications and Brazilian History. Polymers 2022, 14, 2043.
2. Hussien, N.T.; Oan, A.F. The use of sugarcane wastes in concrete. J. Eng. Appl. Sci. 2022, 69, 31.
3. Juarez, C.A.; Fajardo, G.; Monroy, S.; Duran-Herrera, A.; Valdez, P.; Magniont, C. Comparative study between natural and PVA fibers to reduce plastic shrinkage cracking in cement-based composite. Constr. Build. Mater. 2015, 91, 164–170.
4. Ahmad, J.; Arbili, M.M.; Majdi, A.; Althoey, F.; Deifalla, A.F. Performance of concrete reinforced with jute fibers (natural fibers): A review. J. Eng. Fibers Fabr. 2022, 17, 15589250221121871.
5. Islam, M.S.; Ahmed, S.J. Influence of jute fiber on concrete properties. Constr. Build. Mater. 2018, 189, 768–776.
6. Hasan, R.; Sobuz, H.R.; Akid, A.S.M.; Awall, R.; Houda, M.; Saha, A.; Meraz, M.; Islam, S.; Sutan, N.M. Eco-friendly selfconsolidating concrete production with reinforcing jute fiber. J. Build. Eng. 2023, 63, 105519.
7. Elgawish, M.H.; Zakaria, M.A. The effectiveness of intensive versus standard physical therapy for motor progress in children with spastic cerebral palsy. Egypt. Rheumatol. Rehabil. 2015, 42, 1–6.
8. Zhang, T.; Yin, Y.; Gong, Y.; Wang, L. Mechanical properties of jute fiber-reinforced high-strength concrete. Struct. Concr. 2020, 21,703–712.
9. Song, H.; Liu, J.; He, K.; Ahmad, W. A comprehensive overview of jute fiber reinforced cementitious composites. Case Stud. Constr. Mater. 2021, 15, e00724.
10. Nassar, A.; Thom, N.; Parry, T. Optimizing the mix design of cold bitumen emulsion mixtures using response surface methodology. Constr. Build. Mater. 2016, 104, 216–229.
11. Cushman, B.R. Energy Consumption Energy Type Nutrition Research. 2017, pp. 1–12. Available online: http://www.dartmouth.edu/~cushman/books/Numbers/Chap1-Materials.pdf (accessed on 27 June 2023).
12. Abdulkadir, B.; Mohammed, I. Rsm Analysis and Study on the 6 Months Compressive Strength Development and Shrinkage
13. Behaviour of High-Volume Fly Ash Rubberized ECC (HVFA-RECC). Int. J. Adv. Res. Eng. Technol. 2020, 11, 965–980.