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DATA-DRIVEN PREDICTION AND NORMALIZATION OF MECHANICAL PROPERTIES IN JUTE FIBER–REINFORCED CONCRETE

PROGNOZOWANIE I NORMALIZACJA WŁAŚCIWOŚCI MECHANICZNYCH BETONU ZBROJONEGO WŁÓKNAMI JUTOWYMI NA PODSTAWIE WYNIKÓW BADAŃ

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Abstract

Using fiber in the concrete is one of the methods to improve its capacity for the load resisting especially for the bending and tensile loading, but this process has two challenges, the first one is the energy usage, the waste gas emission which produced in these fiber's industry, while the second challenge is the increase in the solid waste materials in the land which is include natural plant fiber. The usage of natural fiber instead of these industrial fibers will have a double advantage. This article deals with investigating the effect of using jute fiber on the properties of concrete, also proposing statistical models to predict the compressive strength of concrete by collecting the experimental data from previous experimental work. By using three different models, including the quadrant support vector machine, Integration Linear, and squared exponential Gaussian, and using 80 experimental data points. Based on the obtained results between the proposed models to predict the compressive strength of concrete, SVM provides higher accuracy and efficiency compared to the other proposed models, when the value of the coefficient of determination is higher than the IL, and SEG by 10.98%, and 1.09% respectively.

Keyword: reinforced concrete, jute fiber, modeling, compressive strength

Streszczenie

Zastosowanie włókien w betonie to jedna z metod poprawy jego wytrzymałości na obciążenia, zwłaszcza zginanie i rozciąganie. Proces ten wiąże się z dwoma wyzwaniami. Pierwszym z nich jest zużycie energii i emisja spalin powstających w przemyśle włókienniczym, a drugim – wzrost ilości odpadów stałych w glebie, w tym naturalnych włókien roślinnych. Zastosowanie włókien naturalnych zamiast włókien przemysłowych przyniesie podwójną korzyść. Niniejszy artykuł analizuje wpływ zastosowania włókien jutowych na właściwości betonu, proponując również modele statystyczne do przewidywania wytrzymałości betonu na ściskanie poprzez zebranie danych eksperymentalnych z poprzednich badań laboratoryjnych, z wykorzystaniem trzech różnych modeli, w tym kwadrantowej maszyny wektorów nośnych (SVM), interakcji liniowej (IL) i gaussowskiej radialnej funkcji bazowej (SEG), a także 80 punktów danych eksperymentalnych. Na podstawie uzyskanych wyników pomiędzy proponowanymi modelami przewidywania wytrzymałości betonu na ściskanie SVM zapewnia wyższą dokładność i wydajność w porównaniu z innymi proponowanymi modelami, podczas gdy wartość współczynnika determinacji jest wyższa niż w przypadku IL i SEG, odpowiednio o 10,98% i 1,09%.

Słowa kluczowe: beton zbrojony, włókna jutowe, modelowanie, wytrzymałość na ściskanie

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1. INTRODUCTION

The growing demand for sustainability in the construction sector has motivated researchers particularly in developing countries to explore environmentally responsible alternatives to conventional building materials [1]. Among these materials, concrete and mortar are the most widely used, forming the backbone of modern infrastructure systems due to their versatility, availability, and cost-effectiveness [2].

Concrete, which is the second most consumed material on Earth after water, is composed primarily of a binder (typically Portland cement), water, and aggregates [3]. Globally, its use is estimated at approximately 1.7 m^3 per person per year, reflecting the essential role it plays in construction and urban development [4]. Despite its widespread use and ability to provide sufficient compressive strength for structural applications, conventional concrete suffers from an inherent brittleness, which limits its deformation capacity and resistance to cracking [5, 6]. This mechanical limitation has led researchers to investigate modifications and alternative materials that can enhance its ductility, durability, and overall performance while also reducing environmental impacts.

One of the solutions to improve the ductility of the concrete is the usage of fibers such as steel, glass, carbon, and polypropylene fiber, which change the concrete to reinforced concrete [7-9]. Many researches has been done on the usage of different types of fiber in concrete with various rates [10-13]. Many factors affect the behavior or working of the fiber in the concrete, including fiber forms, mixing proportion, fiber geometry, surface condition of fiber, and curing method [14, 15]. The production process of each type of these fibers will need a high rate of energy and lead to a high rate of greenhouse gas emission into the air [16, 17]. With the population increase, the solid waste materials production including agricultural wastes will increase day by day [18-20]. One of the agricultural wastes is agricultural material that can be able to make fibers [21-23]. The usage of the plant or natural fiber in the construction has long history due to easy availability in the nature and did not required high effort for preparation, low density, renewable, biodegradable and ready available [24-26]. Available fibers which consider as a member in natural fiber groups are bamboo, coconut, sisal, straw, aloe vera fibers, banana, and pine [27-30].

Jute Fiber is obtained from the jute plant, which is low-cost, durable, has high moisture retention capacity, and is biodegradable. The jute fiber during the degradation process will not generate gas or toxic material since it is composed of cellulose [31-34]. Bangladesh is considered the main producer of the jute fiber, which produces more than half of the total jute produced in the world [35-37]. The use of the jute fiber in the concrete will cause an increase in the concrete's ability against tensile stress, flexural stress, fatigue, and thermal shock [38-41].

Islam and Ahmed [42] investigate the usage of jute fiber in concrete at four different rates, including 0, 0.25, 0.5, and 1%, to demonstrate its effect on concrete properties, including compressive strength. According to the obtained result with the increase of the used rate of jute fiber increase compressive strength of the concrete by 0.76, and 3.03% with using 0.5% of jute fiber in 7 and 28 days curing, while when prepared samples have been tested at 91 days, the compressive strength of the modified concrete will be higher than control mix by 17.14% when modified by 0.25%, but the mix that contains 0.5% of jute fiber provide same compressive strength as control mix. Razmi and Mirsayar, [43], used jute fiber in the normal strength concrete with four different rate (0, 0.1, 0.3, and 0.5%), to measure its effect on the compressive strength property which showed that, the usage of the jute fiber provide compressive strength higher than control mix by 40, 36.5% with using jute fiber up to 0.5% at both curing time 7, and 28 days. Asaduzzaman and Islam [44] used jute fiber with five different rates (0, 0.1, 0.2, 0.3, and 0.4%), in the normal strength concrete at three different curing times (7, 14, and 28 days). The compressive strength test result showed that at the seven days curing all the mixed which modified with jute fiber provide compressive strength lower than the control mix, while by 28 days the concrete mixes which modified with 0.1, and 0.2% of jute fiber provide compressive strength higher that the control mix by 5.88, 2.94%. The usage of the jute fiber more than 0.2%, will provide compressive strength lower than control mix. Using 0.3 and 0.4% of jute fiber decrease the compressive strength by 3.03, 5.88%. Ahmad et al. [46] used three different statistical models, including linear regression, non-linear regression, and artificial neural networks, to propose an accurate and efficient model for predicting the compressive strength of mortar modified with different rates of carbon nanotubes, based on 86 data points collected from previous experimental work. Based on the obtained result, the artificial neural network provides higher accuracy and efficiency compared to the other models. Karim et al, [47], investigated the usage of the statistical models to predict the compressive strength of mortar modified with palm oil fuel ash by using three different statistical model including linear regression, non-linear regression, and artificial neural network to propose an accurate and efficient model through the usage of 142 number data which collected from previous experimental work. Based on the obtained result the artificial neural network provide higher accuracy and efficiency compare to the other models. Askari et al. [48] collected 124 experimental data points about the usage of different pozzolanic materials in ultra-high-performance concrete to propose an efficient and accurate statistical model to reduce the time and the cost for predicting the compressive strength of the mixed material. For that reason, three different statistical models have been used, including a support vector machine, an ensemble boosting tree, and an artificial neural network. In this article, ensemble boosting tree provides more accurate and efficient predicted values of compressive strength compared to the other models used. This article deals with the usage of jute fiber in the normal-strength concrete with investigation of the jute effect on the slump, compression, flexural, and tensile strength of concrete based on the collected data from previous experimental work. Lastly, a statistical model is proposed to predict the compressive strength of the concrete modified with jute fiber at different rates.

2. RESEARCH SIGNIFICANT

In this article, instead of the usage of industrial fiber in the concrete, natural fiber will be used, which causes (i) a reduction in the effect of the industrial production on the environment since it causes a reduction in the energy usage and lower waste gas production due to the reduction in the production of industrial fiber. (ii) Can be obtained from nature, which means it can be obtained at a lower cost compared to the other type of fiber, which is produced industrially. (iii) Propose the statistical models with using different form of models (Squared Exponential Gaussian, Quadratic SVM, Interation Linear) to predict the compressive strength of the reinforced concrete with Jute fiber with variable dosages and without trail mx, with choosing the most efficient model according to the obtained value of the assessment tools, (iv) showing the effect of using jute fiber in the properties of concrete such as the slump, flexural, tensile, and compressive strength, with explaining the role of fiber length.

3. RESEARCH METHODOLOGY

At the first step in this article, the experimental data about the usage of the jute fiber with different dosages in the previous experimental work in the literature have been collected with knowing the value of water to cement ratio, cement content, sand content, coarse aggregate content, curing time, and the used rate of fiber. From the collected data, the effect of using Jute fiber on the slump, compressive strength, flexural strength, and tensile strength has been explained. At the final step, the collected data will be statistically analyzed, and randomly divided into two groups of data, one a which is training data, and testing data. The numbers of collected data are 80 data points, with dividing them to two groups: 56 training data, which was used to propose the form of the model, and 24 as testing data, which was used to test the accuracy of the proposed model. The used form of models in this article, are Squared Exponential Gaussian (SEG), Quadratic SVM (Q-SVM), and Interation Linear (IL) as shown in Figure 1. For each models which proposed the value of Coefficient of determination (R^2), mean absolute error (MAE), root mean square error (RMSE) and scatter index (SI), have been found to compare to the other models value with selecting the most efficient and accurate model between proposed models.

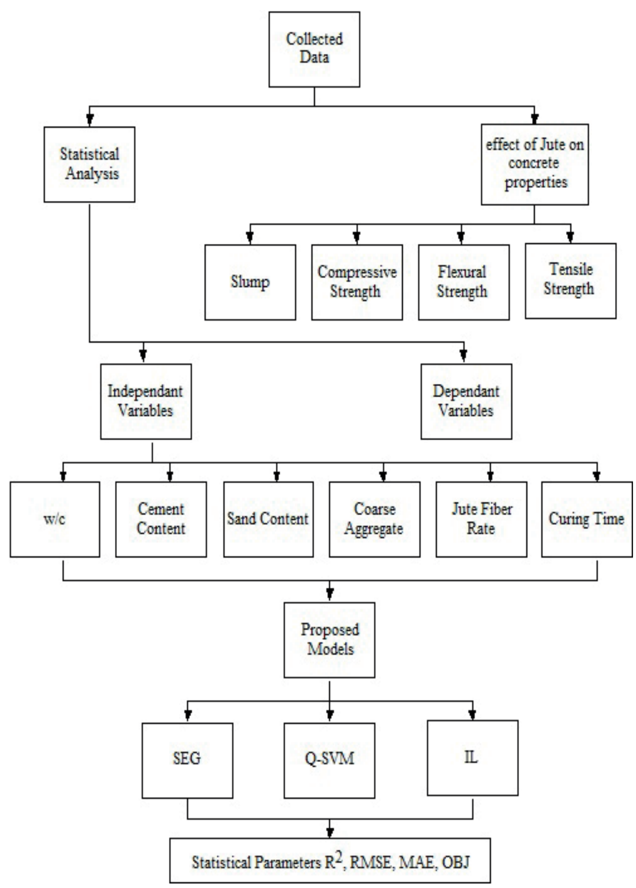

Fig. 1. Research program and methodology

4. EFFECT OF JUTE FIBER ON THE CONCRETE PROPERTIES

4.1. Slump

As explained in Figure 2, with the increase in the jute fiber usage the slump value of the concrete decreases due to the water absorption ability, that effects the mix composition. Islam and Ahmed, [42], used jute fiber with four different rate (0, 0.25, 0.5, and 1%) to investigate their effect on the slump value, when 0.25% of jute fiber has been added to the concrete, the slump value has been decreased by thirty percent compare to the control mix, also when the used rate become 1% the decrease rate become 90%. The changing process in the slump value was the same in the shape and decrease when Asaduzzaman and Islam. [44], used jute fiber in the concrete with five different rates (0, 0.1, 0.2, 0.3, and 0.4%).

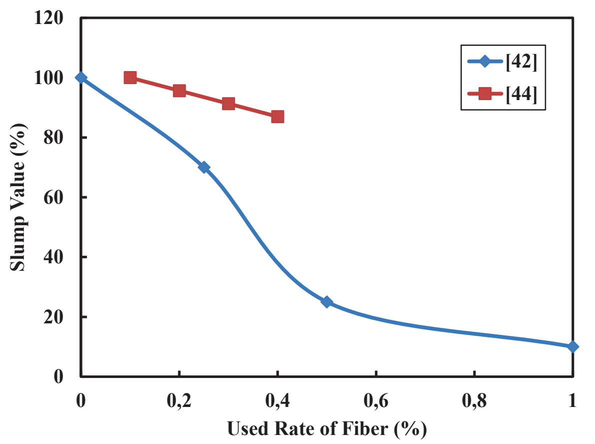

Fig. 2. Slump value based on the used rate of the jute fiber

4.2. Compressive Strength

Based on the collected data from previous experimental work on the effect of jute fiber on the compressive strength of normal strength concrete, which has been expressed in Figure 3, the optimum rate of the jute fiber will be change based on many factors, which are the length, diameter of the fiber, w/c, with many other factors. On the article which is published by Islam and Ahmed, [42], which obtained that when the concrete has been modified with different rate of jute fiber, the usage of 0.25% of jute fiber provide optimum increase in the compressive strength value which is 12.12% higher than control mix compare to the control mix. When Gupta et al. [45], has used jute fiber in the contrete the obtimum usage rate of jute fiber was 0.3% that increase the compressive strength by 12.45% compare to th contro mix, but the optimum rate was 0.5% in the published investigation by Razmi and Mirsayar, [43], with change in the increase rate of compressive strength value compare to the control mix which was 36.91%. The obtained result by Asaduzzaman and Islam [44], were differed from other expressed manuscripts, since by using 0.1% of jute fiber, the increase in the compressive strength was 5.88%.

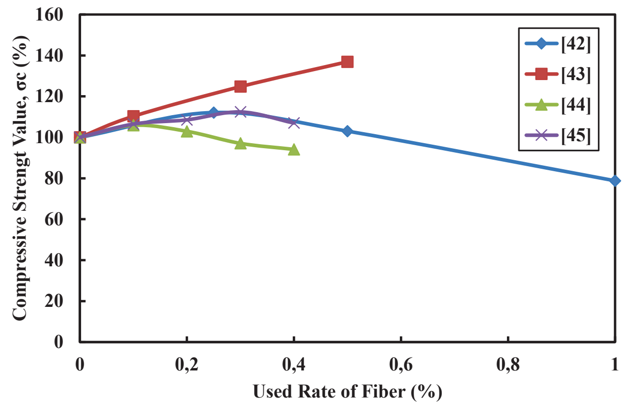

Fig. 3. Compressive strength value based on the used rate of the jute fiber

4.3. Flexural Strength

Due to the role of the fiber as the crack raster in the concrete mix, the concrete is more able to resist the flexural strength when subjected to the bending load. The same result has been obtained compared to the Razmi and Mirsayar [43], when using jute fiber with four different rates, including 0, 10, 30, and 40%. When the control mix does not contain jute fiber, the flexural strength will be 100. When the used rate of jute fiber becomes 0.1% the flexural strength increases by 5.53%. When the used rate of the jute fiber becomes 0.4% the increase rate in the flexural strength becomes 10.31%.

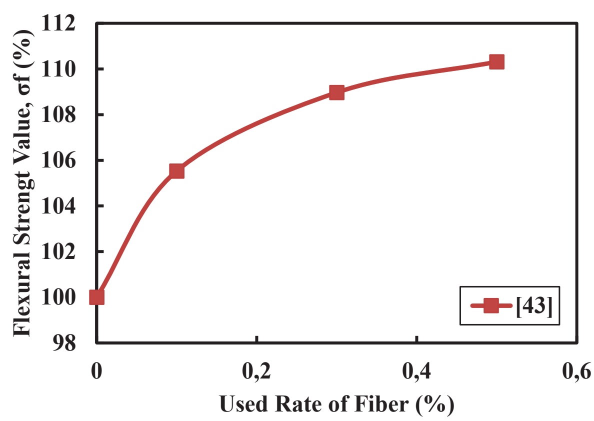

Fig. 4. Flexural strength value based on the used rate of the jute fiber

4.4. Tensile Strength

Fiber, when used in the concrete, increases the bond between the mix composition particles, bridging the crack together, increases the time of the failure due to the lateral or bending stress, but the optimum rate, as shown in Figure 5, will change based on the factor discussed in the previous work. The optimum rate or dosage of the jute fiber were 0.5% where investigated by Razmi and Mirsayar, [43], since increase the tensile strength by 16.95%, but the optimum dosage changes and become 0.1% in the investigation by Asaduzzaman and Islam, [44], and the increase rate in tensile strength become 6.66%, while the optimum dosage become 0.3% in the investigation by Gupta et al. [45], the increase rate in the tensile strength become 58.2%.

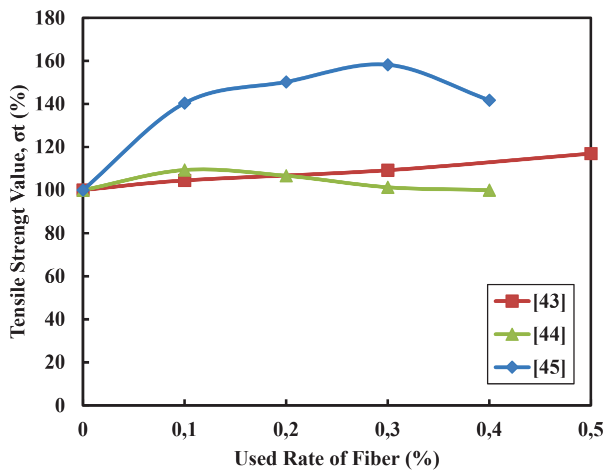

Fig. 5. Tensile strength value based on the used rate of the jute fiber

4.5. Effect of fiber length on compressive strength of modified concrete

Based on the obtained result as expressed in the Figure. 6, when Islam and Ahmed, [42], used jute fiber in the concrete by four different rate with two different length, in both length using 0.25% of jute fiber provide optimum increase in the compressive strength compare to the control mix while when the fiber length was 10 cm, the increase rate in the compressive strength was higher compare to the used fiber when its length is 20 cm. Opposite result obtained by Asaduzzaman and Islam, [44]. When jute fiber was used at four different rates with two different lengths. In both sets of jute fiber usage, the optimum rate was 0.1% but the increase rate in the compressive strength compared to the control mix was higher when the fiber length was 25 cm compared to the jute fiber with a 20 cm length.

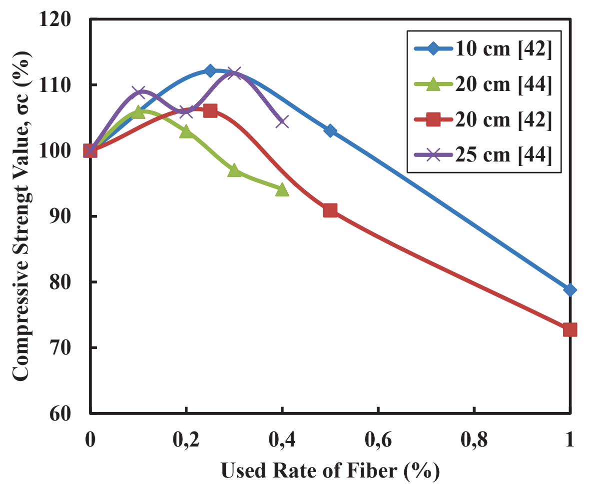

Fig. 6. Compressive strength value based on the used fiber length

5. DATA COLLECTION AND STATISTICAL ANALYSIS:

5.1. Data Collections

The collected data from previous experimental work are as expressed in Table 1.

Table 1. The collected data from previous experimental work

References	w/c	Cement Content (kg/m³)	Sand Content (kg/m³)	Coarse Aggregate (kg/m³)	Fiber rate (%)	Curing Time (Days)	Compressive Strength (MPa)
[42]	0.42	467.4	595.1	999.1	0	7	26
	0.42	467.4	595.1	999.1	0.25	7	27
	0.42	467.4	595.1	999.1	0.5	7	28
	0.42	467.4	595.1	999.1	1	7	24
	0.42	467.4	595.1	999.1	0	7	26
	0.42	467.4	595.1	999.1	0.25	7	27
	0.42	467.4	595.1	999.1	0.5	7	22
	0.42	467.4	595.1	999.1	1	7	18
	0.42	467.4	595.1	999.1	0	28	33
	0.42	467.4	595.1	999.1	0.25	28	37
	0.42	467.4	595.1	999.1	0.5	28	34

References	w/c	Cement Content (kg/m^3)	Sand Content (kg/m^3)	Coarse Aggregate (kg/m^3)	Fiber rate (%)	Curing Time (Days)	Compressive Strength (MPa)
[42]	0.42	467.4	595.1	999.1	1	28	26
	0.42	467.4	595.1	999.1	0	28	33
	0.42	467.4	595.1	999.1	0.25	28	35
	0.42	467.4	595.1	999.1	0.5	28	30
	0.42	467.4	595.1	999.1	1	28	24
	0.42	467.4	595.1	999.1	0	91	35
	0.42	467.4	595.1	999.1	0.25	91	41
	0.42	467.4	595.1	999.1	0.5	91	35
	0.42	467.4	595.1	999.1	1	91	30
	0.42	467.4	595.1	999.1	0	91	35
	0.42	467.4	595.1	999.1	0.25	91	36
	0.42	467.4	595.1	999.1	0.5	91	34
	0.42	467.4	595.1	999.1	1	91	25
[43]	0.46	350	972	862	0	7	35
	0.46	350	972	862	0.1	7	40
	0.46	350	972	862	0.3	7	43
	0.46	350	972	862	0.5	7	49
	0.46	350	972	862	0	28	41
	0.46	350	972	862	0.1	28	45
	0.46	350	972	862	0.3	28	51
	0.46	350	972	862	0.5	28	56
[44]	0.44	405	755	1000	0	7	31
	0.44	405	755	1000	0.1	7	31
	0.44	405	755	1000	0.2	7	31
	0.44	405	755	1000	0.3	7	27
	0.44	405	755	1000	0.4	7	26
	0.44	405	755	1000	0	14	33
	0.44	405	755	1000	0.1	14	33
	0.44	405	755	1000	0.2	14	33
	0.44	405	755	1000	0.3	14	32
	0.44	405	755	1000	0.4	14	31
	0.44	405	755	1000	0	28	34
	0.44	405	755	1000	0.1	28	36
	0.44	405	755	1000	0.2	28	35
	0.44	405	755	1000	0.3	28	33
	0.44	405	755	1000	0.4	28	32
	0.44	405	755	1000	0	7	31

References	w/c	Cement Content (kg/m³)	Sand Content (kg/m³)	Coarse Aggregate (kg/m³)	Fiber rate (%)	Curing Time (Days)	Compressive Strength (MPa)
[44]	0.44	405	755	1000	0.1	7	30
	0.44	405	755	1000	0.2	7	28
	0.44	405	755	1000	0.3	7	27
	0.44	405	755	1000	0.4	7	26
	0.44	405	755	1000	0	14	33
	0.44	405	755	1000	0.1	14	32
	0.44	405	755	1000	0.2	14	32
	0.44	405	755	1000	0.3	14	31
	0.44	405	755	1000	0.4	14	30
	0.44	405	755	1000	0	28	34
	0.44	405	755	1000	0.1	28	37
	0.44	405	755	1000	0.2	28	36
	0.44	405	755	1000	0.3	28	38
	0.44	405	755	1000	0.4	28	36
[45]	0.379	566	565	999	0	7	21
	0.383	566	565	999	0.1	7	25
	0.385	566	565	999	0.2	7	26
	0.39	566	565	999	0.3	7	26
	0.392	566	565	999	0.4	7	26
	0.381	566	565	999	0.1	7	23
	0.385	566	565	999	0.2	7	24
	0.39	566	565	999	0.3	7	25
	0.393	566	565	999	0.4	7	24
	0.379	566	565	999	0	28	37
	0.383	566	565	999	0.1	28	39
	0.385	566	565	999	0.2	28	40
	0.39	566	565	999	0.3	28	41
	0.392	566	565	999	0.4	28	39
	0.381	566	565	999	0.1	28	37
	0.385	566	565	999	0.2	28	38
	0.39	566	565	999	0.3	28	39
	0.393	566	565	999	0.4	28	38

5.2. Statistical Analyses

For the collected data as expressed in the Table 1, histogram distribution has been drawn for each independent parameters including, w/c, cement content, sand content, coarse aggregate content, used rate of fiber, curing time as shown in Figures 7, 9, 11, 13, 15, 17, also the scatter relation between each independent parameters lonely has been drawn with dependent parameters (compressive strength) as shown in Figures 8, 10, 12, 14, 16, 18.

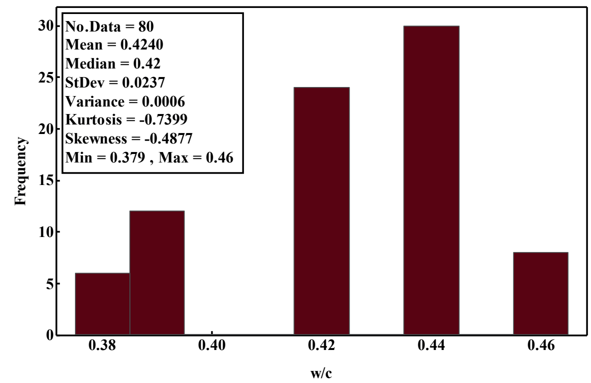

Fig. 7. Histogram distribution of w/c

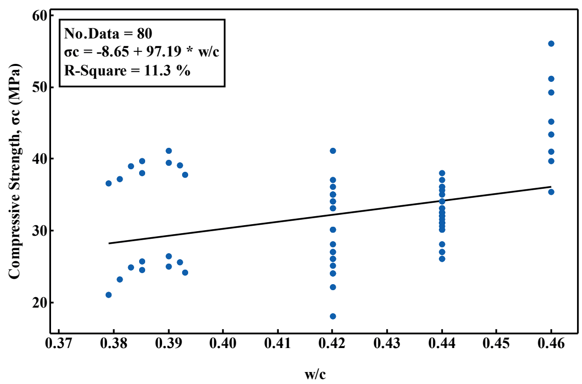

Fig. 8. Scatter relation between w/c and compressive strength

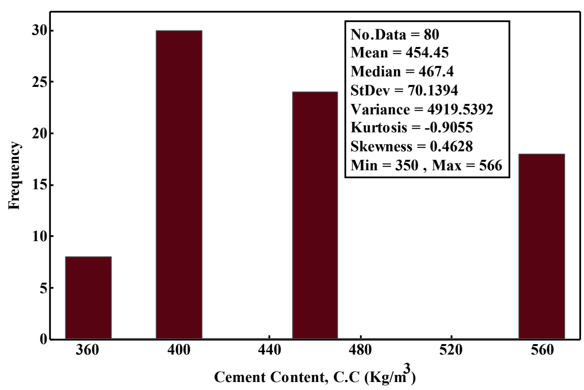

Fig. 9. Histogram distribution of cement content

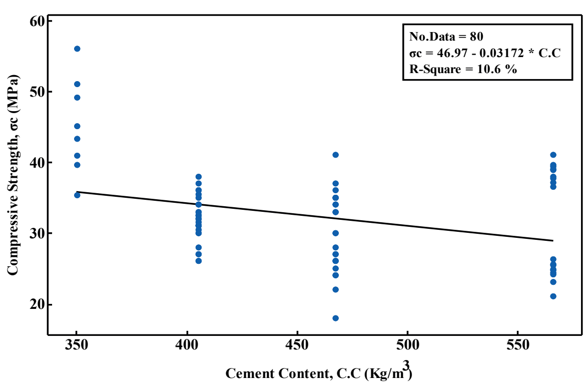

Fig. 10. Scatter relation between cement content and compressive strength

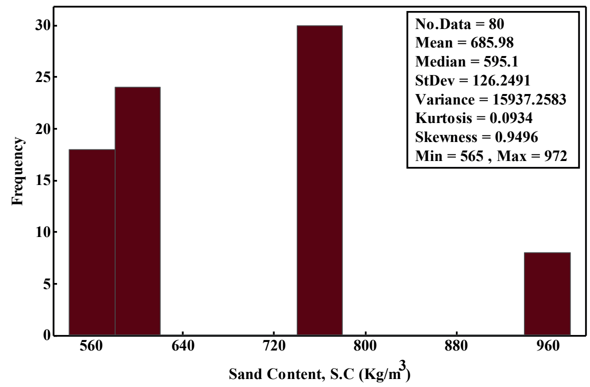

Fig. 11. Histogram distribution of sand content

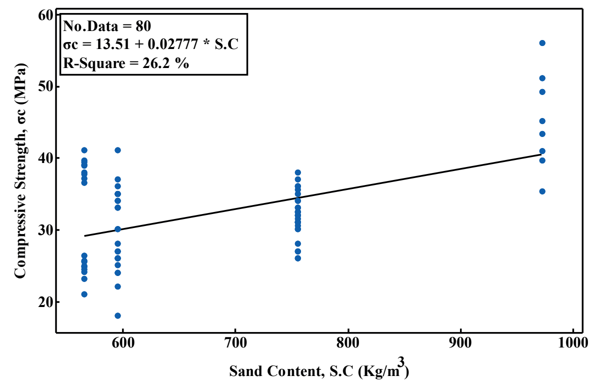

Fig. 12. Scatter relation between sand content and compressive strength

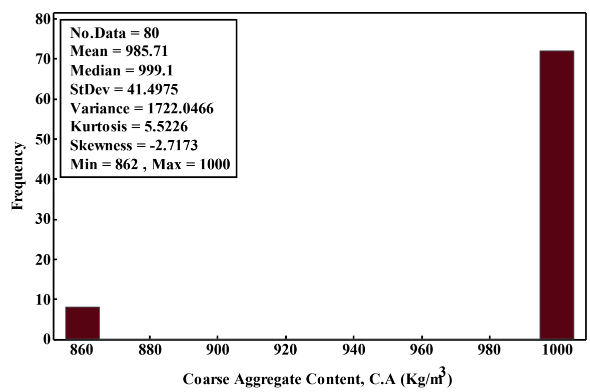

Fig. 13. Histogram distribution of coarse aggregate content

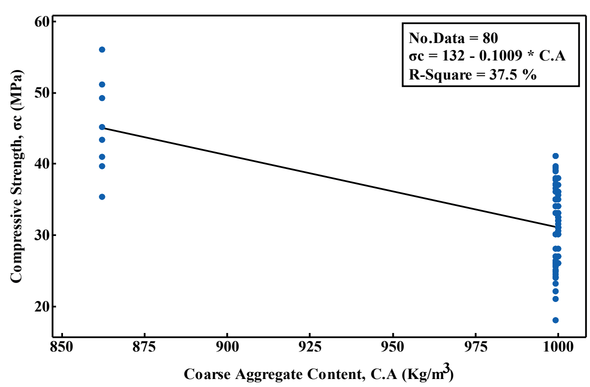

Fig. 14. Scatter relation between coarse aggregate and compressive strength

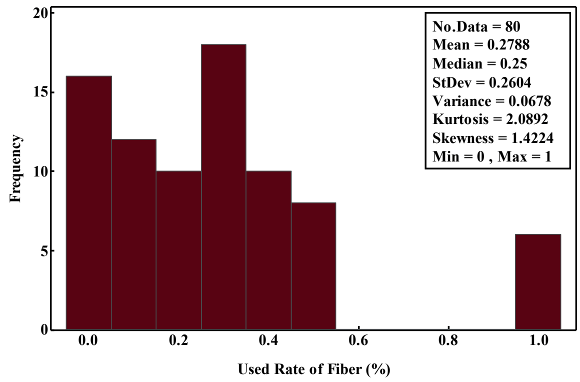

Fig. 15. Histogram distribution of used ratio of fiber

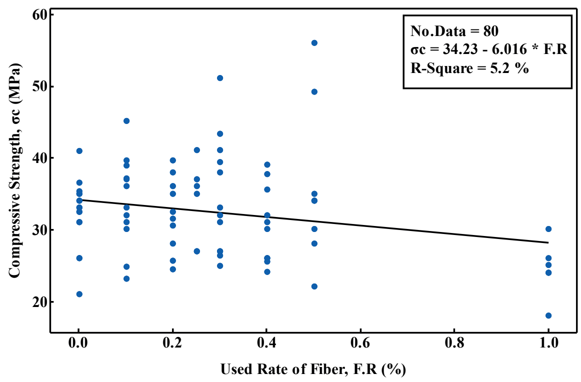

Fig. 16. Scatter relation between used rate of fiber and compressive strength

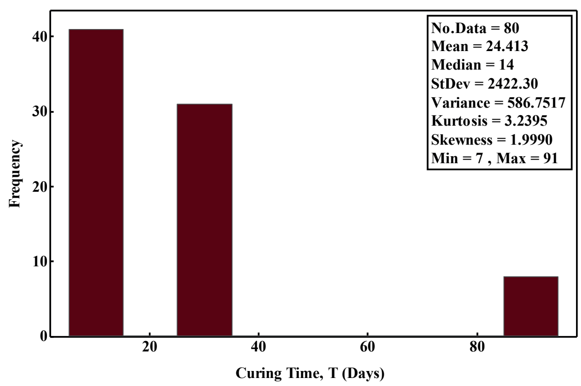

Fig. 17. Histogram distribution of curing time

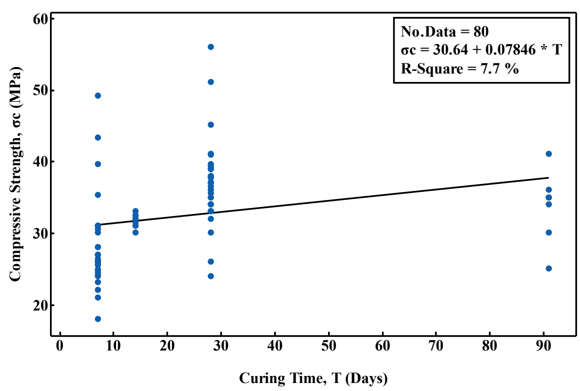

Fig. 18. Scatter relation between curing time and compressive strength

5.3. Modeling

Since the relation between independent parameters lonely with dependent parameters were not with adequate accuracy and efficiency, all the independent parameters have been used in the form of one model to create the relation with dependent parameter as expressed in the following section.

5.3.1. Squared Exponential Gaussian

The Squared Exponential Gaussian, also known as the Radial Basis Function (RBF) kernel, is widely used in statistical modeling and machine learning, particularly within Gaussian Processes (GPs). It is a type of covariance function that assumes that points closer in input space have more similar output values.

This kernel assumes infinitely differentiable functions, making it suitable for modeling very smooth processes. It is commonly used in applications such as time series forecasting, regression, and spatial statistics. However, one of its limitations is that it can be overly smooth and may not perform well when modeling functions with high variability or discontinuities [49].

In practice, the Squared Exponential Gaussian is valued for its mathematical convenience and strong prior assumptions about function smoothness. It is often contrasted with other kernels such as the Matérn kernel, which allows for rougher functions and offers more flexibility in some real-world scenarios [50].

5.3.2. Integration Linear

Linear interaction refers to the inclusion of interaction terms in a linear model to capture the effect of two or more variables acting together on a response. In a basic linear regression, the assumption is that each predictor contributes independently to the outcome. However, when variables interact, the effect of one variable depends on the level of another. This is modeled by adding a product term to the equation [51].

For example, in social sciences, the effect of education on income might depend on gender. Without modeling this interaction, we risk oversimplifying complex relationships. Including interaction terms helps improve model accuracy and interpretability in such contexts [52].

5.3.3. Quadratic Support Vector Machine

A Quadratic Support Vector Machine (QSVM) is a type of Support Vector Machine (SVM) that uses a quadratic kernel to separate data that is not linearly separable. Unlike linear SVMs, which draw a straight hyperplane, QSVMs project input data into a higher-dimensional space using a second-degree polynomial kernel, allowing for more flexible decision boundaries. This method is particularly effective in complex classification problems where the relationship between features is nonlinear. The kernel function, often written as $K(x, y) = (x^T y + c)^2$, helps the SVM to identify curved boundaries in the feature space, increasing classification accuracy in various applications, such as image recognition and bioinformatics [53, 54].

5.3.4. Assessment tools for proposed modeling

The following parameter is taken while comparing the results for the above modeling:

$$R^2 = 1 - \frac{\sum(Yi - Yp)^2}{\sum(Yi - Mean)^2} \quad (1)$$

$$RMSE = \sqrt{\frac{\sum(Yi - Yp)^2}{\boldsymbol{N}}} \quad (2)$$

$$\boldsymbol{SI} = \frac{RMSE}{Mean} \cdot 100 \quad (3)$$

$$MAE = \frac{\sum(Yi - Yp)}{n} \quad (4)$$

Based on the used statistical parameters, the higher R^2 value will be more desirable and the model with $SI > 0.3$ will consider as bad performance while $0.2 < SI < 0.3$ consider acceptable performance and $0.1 < SI < 0.2$ consider excellent performance but if $0 < SI < 0.1$ will measure as great performance [55-57].

6. RESULT AND DISCUSSIONS

6.1. Squared Exponential Gaussian (SEG)

Due to the usage of the algorithm, by using collected data, the model has been proposed as black box system, based on the proposed models for the testing data which has been separated randomly on the collected data set, the value of the compressive strength or each measured compressive strength have been predicted. The scatter relation between measured and predicted compressive strength using squared exponential Gaussian models as in the Figure 19. The measured value of the coefficient of determination in the model was 0.9.

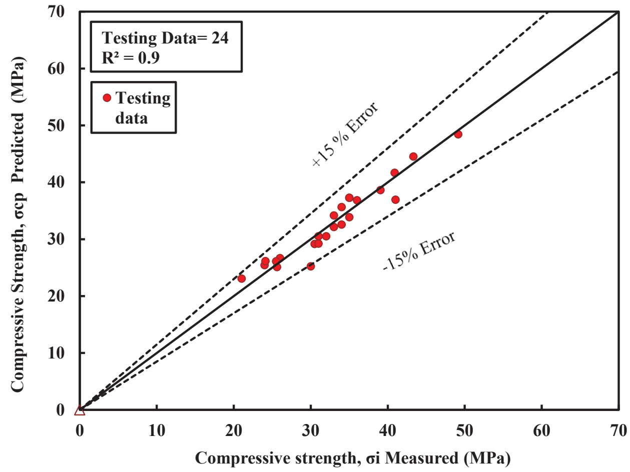

Fig. 19. Correlation between measured and predicted compressive strength using SEG

6.2. Integration Linear (IL)

With the previous model, two other algorithm have been used, to chose most efficient and accurate model. By using collected data, the model has been proposed as black box system, based on the proposed models for the testing data which has been separated randomly on the collected data set, the value of the compressive strength or each measured compressive strength have been predicted. The scatter relation between measured and predicted compressive strength using Integration Linear models as in the Figure 20. The measured value of the coefficient of determination in the model was 0.9.

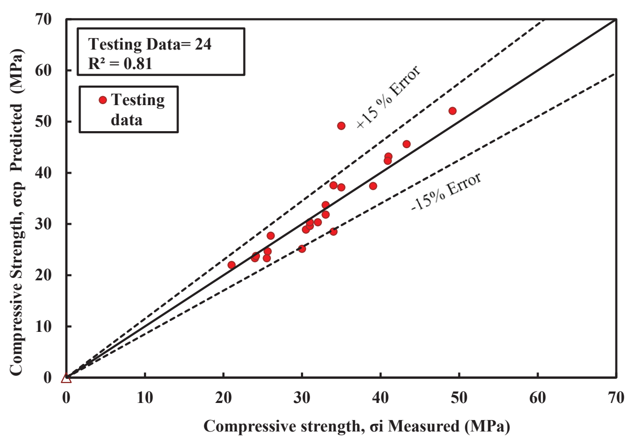

Fig. 20. Correlation between measured and predicted compressive strength using IL

6.3. Quadratic Support Vector Machine (QSVM)

As the third models, this form also has been used to propose model with high accuracy and efficiency. The scatter relation between measured and predicted compressive strength using Integration Linear models as in the Figure 21. The measured value of the coefficient of determination in the model was

0.91 which make it to be most attractive, accuracy, and efficiency model based on the value of coefficient of determination.

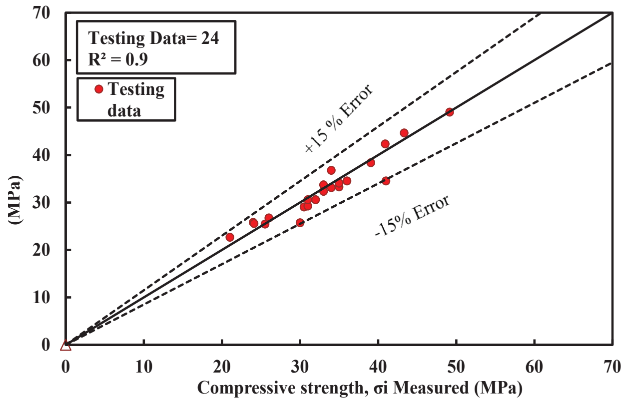

Fig. 21. Correlation between measured and predicted compressive strength using QSVM

6.4. Model Comparisons

Based on the obtained result as expressed in the Table 2, quadratic support vector machine model provide higher accuracy com pare to the Integration Linear, and Squared Exponential Gaussian since the value of coefficient of determination higher that the coefficient of determination in IL, and SEG by 10.98, and 1.09% respectively, the value of root mean square error (RMSE) in QSVM lower than the RMSE in IL, and SEG by 42.25% and 2.91, also value of mean absolute error (MAE) in QSVM lower than the RMSE in IL, and SEG by 30.34, and 10.9%

Table 2. Statistical assessment tools value for different proposed models

Models	IL Testing	SEG Testing	QSVM Testing
R^2 (%)	0.81	0.9	0.91
RMSE (MPa)	3.03	2.192	2.13
MAE (MPa)	1.89	1.609	1.45

7. CONCLUSIONS

After reviewing the previous experimental work on the usage of jute fiber in the concrete, and investigating their effect on the properties of concrete, by proposing different statistical models to predict the compressive strength of concrete, the following conclusions have been drawn:

1. The incorporation of jute fiber into concrete consistently led to a reduction in workability, with the magnitude of this decrease intensifying as fiber content increased. This behaviour is primarily attributed to the high surface area and hydrophilic nature of jute fibers, which promote increased water demand and internal friction within the mix. These findings underscore the necessity for appropriate adjustments in mix design when natural fibers are utilized, particularly in applications where flow ability is critical.
2. The results indicate that jute fiber enhances the compressive strength of concrete up to an optimum dosage, beyond which further increases in fiber content adversely affect strength development. The reduction in strength at higher fiber dosages may be associated with fiber clustering, inadequate dispersion, and the formation of micro-voids. Notably, the optimal fiber content is mix-dependent, varying according to parameters such as water–cement ratio, aggregate characteristics, and fiber geometry. This highlights the importance of conducting mix-specific optimization studies to maximize the mechanical benefits of natural fiber inclusion.
3. Among the evaluated predictive models, the Support Vector Machine (SVM) exhibited superior accuracy and generalization capability for estimating the compressive strength of jute fiber–reinforced concrete. The SVM model achieved a higher coefficient of determination relative to the IL and SEG models by 10.98% and 1.09%, respectively. These outcomes affirm the robustness of SVM for modeling nonlinear relationships in concrete performance and suggest its potential applicability in broader predictive frameworks for sustainable construction materials.
4. The findings indicate that jute fiber–reinforced concrete, when used at optimal dosages, is suitable for various non-structural and semi-structural applications, such as paving blocks, panels, and partition elements where improved toughness is required. The successful use of the SVM model further provides a practical tool for optimizing mix proportions, supporting the broader use of natural fibers as a sustainable and cost-effective alternative in concrete production.

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Research involving human/animal participants
This article does not contain ant studies involving animals human participants performed by any of the authors.