Hindawi
Advances in Materials Science and Engineering
Volume 2024, Article ID 9813686, 1 page
https://doi.org/10.1155/2024/9813686

Retraction

Retracted: Effects of Polypropylene Waste Addition as Coarse Aggregates in Concrete: Experimental Characterization and Statistical Analysis

Advances in Materials Science and Engineering

Received 8 January 2024; Accepted 8 January 2024; Published 9 January 2024

This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] D. C. Naveen, K. Naresh, B. S. Keerthi Gowda, M. S. Reddy G, C. D. Prasad, and R. Shanmugam, "Effects of Polypropylene Waste Addition as Coarse Aggregates in Concrete: Experimental Characterization and Statistical Analysis," *Advances in Materials Science and Engineering*, vol. 2022, Article ID 7886722, 11 pages, 2022.

Hindawi
Advances in Materials Science and Engineering
Volume 2022, Article ID 7886722, 11 pages
https://doi.org/10.1155/2022/7886722

Research Article

Effects of Polypropylene Waste Addition as Coarse Aggregates in Concrete: Experimental Characterization and Statistical Analysis

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Received 4 July 2022; Revised 31 July 2022; Accepted 20 September 2022; Published 8 November 2022

Academic Editor: Qian Chen

In recent times, thermoplastic waste materials are being extensively used as fine and coarse aggregates in the concrete mix as an environmentally friendly construction material. This study aims at utilizing polypropylene (PP) as a partial substitute for the conventional coarse aggregates in M30 grade concrete. The different replacement levels of coarse aggregates such as 0%, 20%, 40%, and 60% by weight were used in concrete. Sieve analysis, specific gravity, and water absorption tests were performed in all replacement levels of aggregates. The mechanical (compressive and split tensile tests) tests were conducted after 3, 14, and 28 days. The change in mechanical properties of concrete with the addition of different weight proportions of plastics was studied experimentally. Further, experimental values were predicted using the two-parameter Weibull distribution and artificial neural network (ANN)-based statistical approaches. The Levenberg–Marquardt algorithm was used in predicting the mechanical properties using the ANN. A good correlation was obtained between the experimental and predicted values with an error (%) of less than 10. The decrease in mechanical properties with the increase in replacement levels of coarse aggregates in concrete was observed in both experimental and predicted approaches. This can be attributed to poor bonding between concrete and PP aggregate owing to the development of agglomerations and the hydrophobic nature of PP. However, the strength values of 20% PP-embedded concrete specimens are closer to 0% PP-embedded concrete specimens. Therefore, 20% PP-embedded concrete specimens can be used for primary load-bearing applications to utilize plastic waste and reduce the cost of the component.

1. Introduction

In the past decades, the use of plastics has been widely increased in various applications such as automotive, medical, and housing applications [1–4]. More importantly, their use in packaging and distribution of food for daily usage is high; in that way a large quantity of plastic waste is accumulated all over the world [5, 6]. Larger areas of land are required for storing these several million tons of waste plastics. Even though plastic products are lightweight and easy to design and fabricate, they possess low- or nonbiodegradability. As a result, the disposal of plastic waste causes a considerable threat to humans and animals and is one of the major reasons for environmental pollution, [7]. Therefore, it is important to develop biodegradable plastics [8] or reuse plastic waste for the benefit of different perspectives. Most countries have already started to utilize plastic waste for various applications [9]. In particular, thermoplastic waste materials have been extensively used in energy applications [10] and the construction industry [11].

In recent years, many researchers studied the mechanical properties of thermoplastic waste materials incorporated in concrete structures [12, 13]. Almeshal et al. [14] used polyethylene terephthalate (PET) as a fine aggregate for the partial replacement of sand in concrete. They have investigated the compressive, flexural, and split tensile strength values for different weight substitution levels (0%, 10%, 20%, 30%, 40%, and 50%) of PET-incorporated concrete. A gradual decrease in compressive, flexural, and split tensile strength values with the increase of PET percentage in concrete was found. Ohemang and Ekolu [15] studied the compressive and flexural strength values of different volume fractions of low-density polyethylene (LDPE)-embedded cement mortar. These strength values were compared for different curing ages such as 7, 14, and 28 days. The decrease in strength values with the increase in various proportions of LDPE in cement mortar was found. Also, the increase in strength values with the increase of curing age was reported. In particular, the increase was reported to be higher from the age interval of 7 days to 14 days, compared to those at age intervals of 14 days to 28 days. The decrease in compressive strength with the increase in plastic waste contents and the enhancement in compressive strength with the increase of curing age were also found by several researchers [12, 16, 17].

Several researchers used analytical models to predict the flexural and split tensile strength values using compressive strength values [14, 18]. Moreover, many researchers are also used artificial neural network (ANN) methods to solve complex problems in the area of concrete technology [19–22]. Onyelow et al. [23] compared the compressive strength values of 28 days of post-cured Fly Ash-embedded concrete specimens using genetic programming (GP), evolutionary polynomial regression (EPR), and three different ANN (backpropagation, gradually reduced gradient, and genetic algorithm) methods. It was found that the compressive strength values of the GP model had the least accuracy of 81%, the EPR model had a moderate accuracy of 90%, and all ANN models had almost the same accuracy of approximately 94%. Rezazadeh Eidgahee et al. [24] employed different machine learning methods (ANN, GP, and group method of data handling (GMDH)) in predicting the dynamic modulus of hot mix asphalt. It was reported that the accuracy of the ANN model is higher based on higher correlation coefficient values greater than 0.98, compared with GP and GMDH models.

In general, there is a tendency for strength values to be scattered due to the possibility of operator and instrument errors. In particular, the occurrence of errors during the manufacturing of the component is high. Statistical studies are useful to capture the scatter in strength values [25, 26]. However, very limited researchers employed statistical approaches to predict the strength values for different weight proportions of plastic waste embedded in concrete or cement mortars [15, 27]. In this study, the two-parameter Weibull distribution is used to predict the compressive and split tensile strength values for different weight proportions of polypropylene plastic waste-embedded concrete. A good correlation was obtained between the predicted and experimental results. The ANN strategy is also adopted to predict the compression and split tensile strength values of polypropylene plastic waste embedded in cement concrete specimens.

2. Materials and Methods

2.1. Materials. In this study, materials such as cement, sand as fine aggregate, and recycled polypropylene as coarse aggregate are used. The material specifications for cement, fine aggregate, coarse aggregate, and admixtures are discussed. Sieve analysis was done for sand and coarse aggregate to test their suitability for use in concrete.

2.1.1. Cement. In this study, ordinary Portland cement (OPC) of 53 grade was used for casting cubes and cylinders for all concrete mixes. The cement was of uniform color, i.e., grey with a light greenish shade and was free from any hard lumps. The specific gravity (SG) of cement was carried out as per IS 2386 (Part 3)-1963 using equation (1), as given in Table 1. The summary of the various tests conducted on cement is given in Table 2, and the obtained values are closer to standard values.

$$\frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)\, x\, 0.79}. \tag{1}$$

2.1.2. Fine Aggregates. The sand used for the experimental program was locally procured and conformed to Indian Standard Specifications IS: 383–1970. The sand was first sieved through a 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. The properties of the fine aggregate used in the experimental work are given in Table 3. The aggregates were sieved through a set of sieves as shown in Figure 1(a) to obtain the sieve analysis and the same is presented in Table 3. The fine aggregates belonged to grading zone III.

2.1.3. Coarse Aggregates. The recycled polypropylene was used as coarse aggregate in this study. These aggregates were tested as per Indian Standard specifications IS: 383–1970. The results of the sieve analysis of recycled polypropylene are given in Table 4 and Figure 1(b).

2.2. Specimen Fabrication. Before manufacturing the specimens, the mix design was determined for M30 grade concrete based on the degree of workability and quality control, specific gravity, etc. The specific gravity of cement, sand (fine aggregate), and recycled polypropylene (coarse aggregate) was determined as 3.01, 2.61, and 2.65, respectively. Mixture ratios such as cement: fine aggregate: coarse aggregate: water were used for manufacturing the specimens, by weight as 1 : 1.09 : 2.29 : 0.38, respectively. Fabricated cubic and cylindrical specimens for compression and split tensile tests are shown in Figure 2.

Table 1: Specific gravity of cement.

Sl. no.	Observations	Values obtained			
		Trial 1	Trial 2	Trial 3	Average
1.	Weight of the specific gravity bottle (W_1), g	35.8	35.8	35.8	35.80
2.	Weight of bottle + 1/3rd filled cement (W_2), g	53.8	53.6	53.8	53.73
3.	Weight of bottle + 1/3rd filled cement + kerosene (W_3), g	89.4	89.3	89.4	89.37
4.	Weight of bottle + kerosene (W_4), g	76.2	76.2	76.2	76.20
5.	Specific gravity	3.0	3.02	3.0	3.01

Table 2: Various tests conducted on cement.

S. no	Characteristics	Values obtained	Standard values
1.	Normal consistency	33%	25%–35%
2.	Initial setting time	38 minutes	Not be less than 30 minutes
3.	Final setting time	260 minutes	Not be greater than 600 minutes
4.	Fineness	4.8%	<10%
5.	Specific gravity	3.01	Around 3.15

Table 3: Sieve analysis of fine aggregates.

Sieve size (mm)	Weight retained (g)	Cumulative weight retained (g)	Cumulative % retained	% Passing
4.75	0	0	0	100
2.36	13	13	2.6	97.4
1.18	57.3	70.3	14.06	85.94
0.6	135.7	206	41.2	58.8
0.3	246.5	452.5	90.5	9.5
0.15	43.7	496.2	99.24	0.76
<0.15	3.8	500	100	0

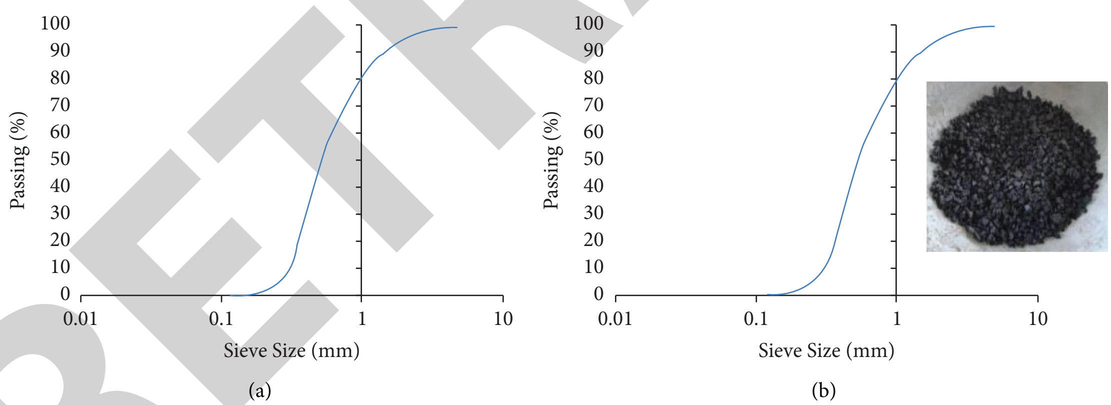

Figure 1: Sieve analysis of fine (a) and coarse (b) aggregates.

Table 4: Sieve analysis of recycled polypropylene as coarse aggregates.

Sieve size (mm)	Weight retained (g)	Cumulative weight retained (g)	Cumulative % retained	% Passing
4.75	175	175	35	65
2.36	110	285	57	43
1.18	102	387	77.4	22.6
0.6	76	463	92.6	7.4
0.3	24	487	97.4	2.6
0.15	8	495	99	1
<0.15	5	500	100	0

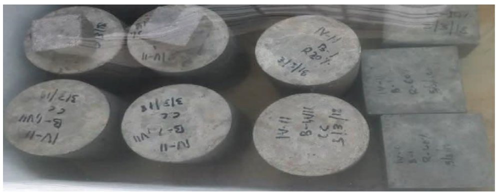

Figure 2: Fabricated cubic and cylindrical specimens.

2.3. Experimental Details

2.3.1. Compressive Strength of Concrete. Compression tests were performed as per IS 516–1999 standard on different weight proportions of polypropylene-embedded concrete cubic specimens. Three different specimens were tested in each combination. The dimensions of the specimens such as length, width, and thickness used for compression tests were 150 mm × 150 mm × 150 mm, respectively. The specimens were submerged in clean fresh water for the duration of 3, 14, and 28 days before testing and kept in a dry place so that the water is drained well to get better results. The compressive load is applied on the specimen using the universal testing machine, as shown in Figure 3(a). The load is gradually applied until it fails. The compressive strength of the specimen was calculated using equation (2), it is given by

$$F_c = \frac{P}{A}, \tag{2}$$

where F_c is the compressive strength, P is the ultimate load, and A is the area of the specimen which is 150 mm × 150 mm.

2.3.2. Split Tensile Strength of Concrete. It is difficult to investigate the direct tensile strength of concrete; however, often, researchers are performed flexural or split tensile tests to estimate the direct tensile strength. A split tensile test for different weight proportions of polypropylene-embedded concrete specimens was performed as per IS 516–1999 standard. Three different specimens were tested in each combination. The dimensions of concrete cylindrical specimens such as a diameter of 150 mm and a length of 300 mm. The cylindrical specimens were placed horizontally between the loading surfaces of a compression testing machine, as shown in Figure 3(b) and the load is applied until the failure of the cylinder along the vertical diameter. The splitting tensile strength of specimens is calculated using equation (3), it is given by

$$F_t = \frac{2P}{\pi l d}, \tag{3}$$

where l and d are the length and diameter of the specimen, respectively.

3. Results and Discussion

3.1. Mechanical Properties. The average compressive and split strength values for different curing ages of concrete/polypropylene specimens are shown in Figures 3 and 4, respectively. It is clear from the figure that the strength values increase with the increase in curing ages of 3 to 28 days. The increase in strength values between 14 and 28 days is relatively less compared to 3 and 28 days. This can be attributed to an increase in physical, chemical, and mechanical bonding of the microstructure of concrete specimens, which strengthens the specimen. Therefore, it is essential to postcure the concrete specimen for a minimum of two weeks. An enhancement in compressive strength with the increase in curing age of concrete specimens was also found by numerous researchers [12, 16, 17].

However, the decrease in strength values is observed with the increase in different weight percentages of polypropylene in the concrete. However, the strength values of 20% PP-embedded concrete specimens are closer to 0% PP-embedded concrete specimens. Therefore, specimens of 20% PP-embedded concrete specimens are recommended for primary load-bearing applications, whereas 40% and 60% PP-embedded concrete specimens are recommended for secondary load-bearing applications. The trend of the curves matches well with the literature [28–30]; in their studies, they have reported the decrease in compressive strength of concrete with the increase in plastic substitution. Thetwo main factors which restrict the improvement of compressive strength, at higher weight percentages (40% and 60%) of PP embedded in concrete specimens, are (i) poor bonding between PP aggregate and concrete due to the development of agglomerations, (ii) the hydrophobic nature of PP aggregate that decreases the rate of hydration [31]. A similar kind of decrease in strength values with the addition of higher weight percentages of waste materials in the concrete is found in these articles [9, 14, 32].

The trend of split tensile strength values seen in Figure 4 is similar to compressive strength values. Similar kinds of results are reported elsewhere [33]. As expected, from Figures 4 and 5, the compressive strength values are significantly higher in all specimens tested at different curing ages compared to split tensile strength values. A similar kind of trend is found elsewhere [34]. From equations (2) and (3), the applied direction of loading is the main reason for the difference between the values in these two tests [24]. The compressive strength of concrete is always higher for a concrete specimen as it withstands axially directed pushing force until it reaches its maximum force, after that the specimen is crushed, as shown in Figure 3(a). However, the failure response of the specimen subjected to the split tensile test is the transverse shear, as shown in Figure 3(b). Numerous researchers [35–37] have reported experimentally and theoretically that the compressive strength value of the cubic concrete specimen is several times higher than that of the split tensile strength.

3.2. Prediction of Compressive and Split Tensile Strength Values Using Two-Parameter Weibull Distribution. In this section, the procedure for predicting the compression and split tensile strength values are discussed using the two-parameter Weibull analysis. The compressive ($\overline{\sigma_C}$) and split tensile strength ($\overline{\sigma_{ST}}$) values can be written in terms of scale parameter (α), shape parameter (β), and gamma function (Γ) using equations (4) and (5), respectively [20, 38].

(a) (b)

Figure 3: (a) Compression test setup. (b) Split tensile test setup.

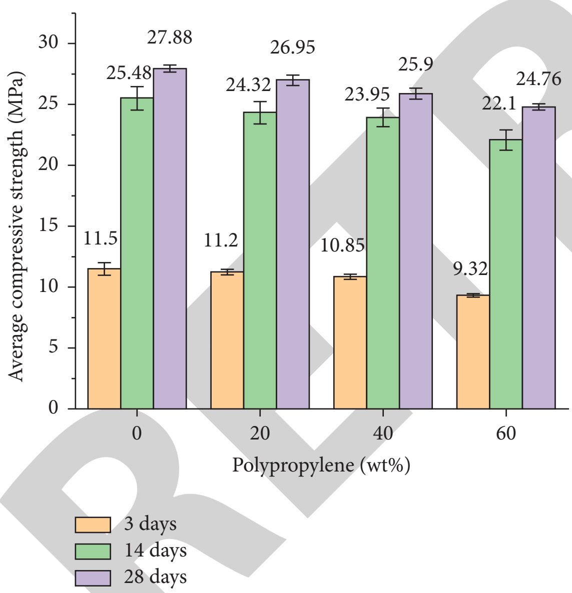

Figure 4: Effect of polypropylene addition in concrete on the compressive strength for different curing ages.

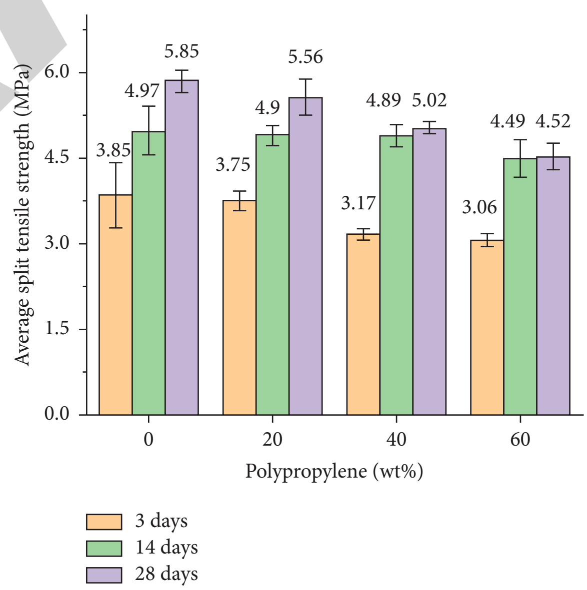

Figure 5: Effect of polypropylene addition in concrete on the split tensile strength for different curing ages.

$$\overline{\sigma_C} = \alpha_C \, \Gamma_C\left(1 + \frac{1}{\beta_C}\right), \quad (4)$$

$$\overline{\sigma_{ST}} = \alpha_{ST} \, \Gamma_{ST}\left(1 + \frac{1}{\beta_{ST}}\right). \quad (5)$$

The subscript 'C' denotes the compressive strength and 'ST' denotes the split tensile strength. The scale parameter is the characteristic strength and the shape parameter is the Weibull modulus. These parameters can be determined by using equation (6) [39, 40].

$$\ln\left(\ln\left(\frac{1}{(1-F)}\right)\right) = \beta \quad \ln \left(\overline{\sigma}\right) - \beta \ln(\alpha), \quad (6)$$

where F is the cumulative failure probability $= (i - 0.3)/n + 0.4$ [41, 42]; i is the current test number which varies from 1 to 3 as three specimens are tested for

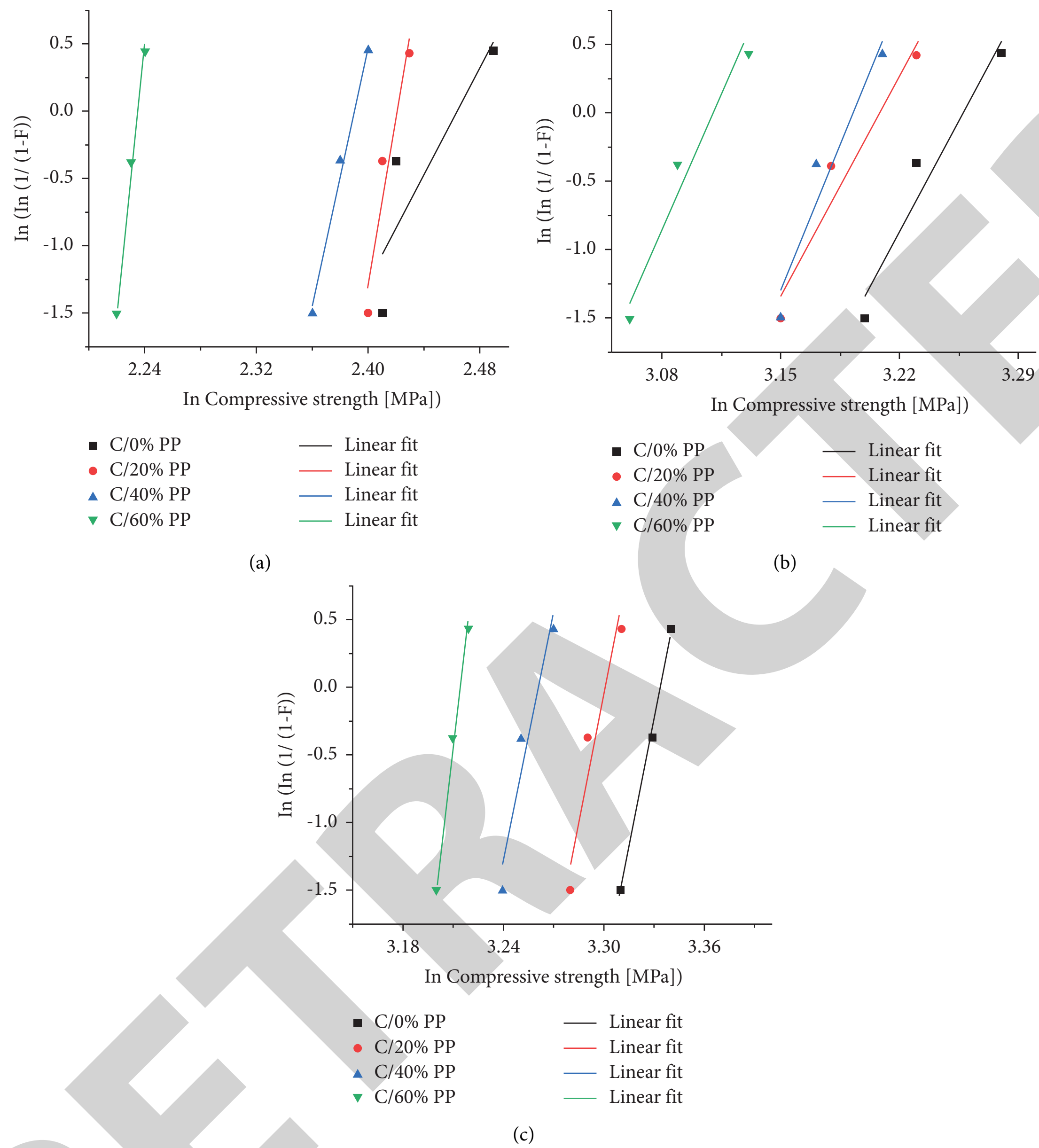

Figure 6: Compressive strength distributions for different curing ages of concrete specimens: (a) 3 days, (b) 14 days, and (c) 28 days.

each mixture of polypropylene-embedded concrete; n is the total number of specimens tested in each set which is equal to 3. $\overline{\sigma}$ is the experimental compressive or split tensile strength. $\Gamma(1 + (1/\beta))$ corresponding to β value is used in the gamma function data sheet.

The variability of compressive strength values for different curing ages such as 3, 14, and 28 days can be seen in Figures 6(a)–6(c), respectively. These are linear regression lines plotted using equation (6). Black, red, blue, and green color lines indicate the strength values for different weight contents of polypropylene such as 0, 20, 40, and 60%, respectively, embedded concrete specimens. Similarly, the scatter in split tensile strength values for the same curing ages of specimens are given in Figures 7(a)–7(c).

Tables 5 and 6 show the scale parameter, shape parameter, and gamma function values for the compressive and split tensile strength values of PP-embedded concrete specimens for different curing ages, respectively. The comparison of the predicted and experimental compressive and split tensile strength values are given in Table 7. It is clear from the table that the percentage of deviation of the predicted strength values from the experimental results is less than 5%. The decrease in compressive and split tensile strength values with the increase in PP content in concrete is observed in both predicted and experimental results.

3.3. Prediction of Compressive and Split Tensile Strength Values Using the ANN Model. The ANN is a family of massively parallel architectures that are capable of learning and predicting the results. The basic strategy for developing a neural network-based model for material behavior is to train

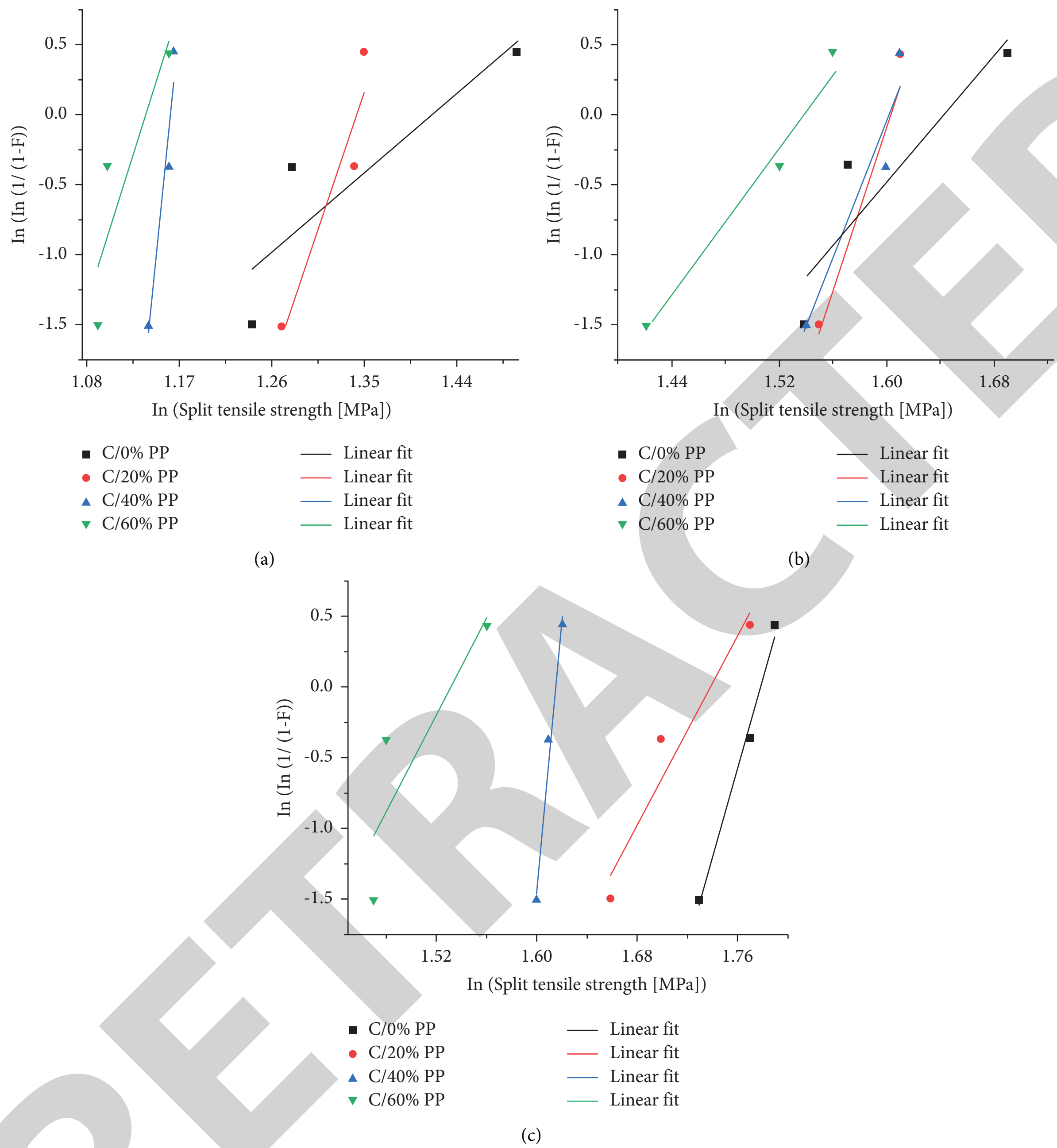

Figure 7: Split tensile strength distributions for different curing ages of concrete specimens: (a) 3 days, (b) 14 days, and (c) 28 days.

a neural network on the results of a series of experiments using that material [43]. If the experimental results contain relevant information about the material behavior, then the trained neural network will contain sufficient information about the material's behavior to qualify a material for new values. Such a trained neural network not only could reproduce the experimental results but also could approximate the results in other experiments through its generalization capability [37].

The present study adopts a feed-forward supervised ANN model for the prediction of compression and split tensile strength values of different weight contents of PP-embedded concrete. The training parameters are the number of iterations (epoch), learning rate, error goal, and the number of hidden layers. These parameters are varied until a good convergence of ANN training is obtained and thereby fixes the optimal training parameters. These optimal parameters are used for the testing and validation process. The general computational ANN model is always represented by the term topology which represents the number of neurons in the input layer, hidden layer, and output layer. However, the number of neurons in the input and output layers is determined based on the problem domain depending upon the number of input variables and the number of output or target variables. The number of hidden layers and neurons in the hidden layer is fixed during the training process.

Table 5: Weibull parameters for compressive strength.

Curing age days	Plastic waste addition (%)	Scale parameter (α) (MPa)	Shape parameter (β)	Coefficient of determination (R^2)	$\Gamma(1/(\beta)+1)$
3	0	11.75	19.58	0.77	0.97
	20	11.26	61.21	0.92	0.98
	40	10.91	48.5	0.99	0.98
	60	9.35	97	0.99	0.99
14	0	25.96	23.43	0.95	0.97
	20	24.74	23.42	0.94	0.97
	40	24.33	30.61	0.92	0.98
	60	22.44	27.31	0.97	0.98
28	0	28.05	63.5	0.99	0.99
	20	27.13	61.22	0.92	0.98
	40	26.10	61.21	0.92	0.98
	60	24.90	97	0.99	0.99

Table 6: Weibull parameters for split tensile strength.

Curing age days	Plastic waste addition (%)	Scale parameter (α) (MPa)	Shape parameter (β)	Coefficient of determination (R^2)	$\Gamma(1/(\beta)+1)$
3	0	4.12	6.19	0.79	0.93
	20	3.83	21.26	0.90	0.97
	40	3.19	71.57	0.94	0.99
	60	3.12	22.75	0.78	0.97
14	0	5.16	11.17	0.83	0.96
	20	4.97	29.19	0.93	0.98
	40	4.96	24.62	0.91	0.97
	60	4.64	13.36	0.98	0.96
28	0	5.92	31.75	0.99	0.98
	20	5.69	16.95	0.94	0.97
	40	5.03	97	0.99	0.99
	60	4.62	17.17	0.76	0.97

Table 7: Comparison of experimental and predicted strength values.

Curing age days	Plastic waste addition (%)	*Compressive strength (MPa)*		% Error	*Split tensile strength (MPa)*		% Error
		Experiment	Prediction		Experiment	Prediction	
3	0	11.50	11.40	0.88	3.85	3.83	0.52
	20	11.20	11.03	1.54	3.75	3.72	0.81
	40	10.85	10.69	1.50	3.17	3.16	0.32
	60	9.32	9.26	0.65	3.06	3.03	0.99
14	0	25.48	25.18	1.19	4.97	4.95	0.40
	20	24.32	24.00	1.33	4.90	4.87	0.62
	40	23.95	23.84	0.46	4.89	4.81	1.66
	60	22.10	21.99	0.50	4.49	4.45	0.90
28	0	27.88	27.77	0.40	5.85	5.80	0.86
	20	26.95	26.59	1.35	5.56	5.52	0.72
	40	25.90	25.58	1.25	5.02	4.98	0.80
	60	24.76	24.65	0.45	4.52	4.48	0.89

Figure 8 depicts the ANN model adopted in this study to predict the compression and split tensile strength values for different weight contents of PP-embedded concrete specimens. Here, the Levenberg–Marquardt (LM) algorithm and the Log-Sigmoid transfer function are adopted for predicting the mechanical properties. Figure 9 shows the graphical representation of ANN predicted and experimental values. Here, all the data are convergent to the equity line. The correlation coefficient between the experimental and predicted data is 0.99. Table 8 shows the comparison of experimental and ANN predicted compressive and split tensile strength values and their respective percentage of errors. It is observed Table 8 that the deviation between the experimental and predicted results is less than 10%.

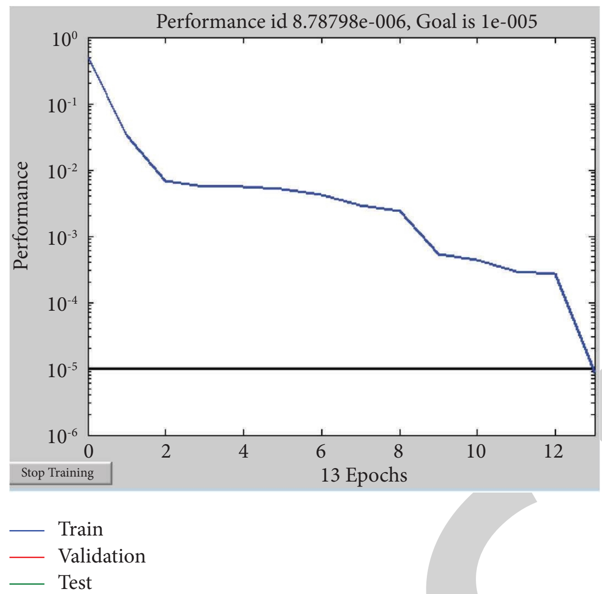

Figure 8: ANN training performance curve.

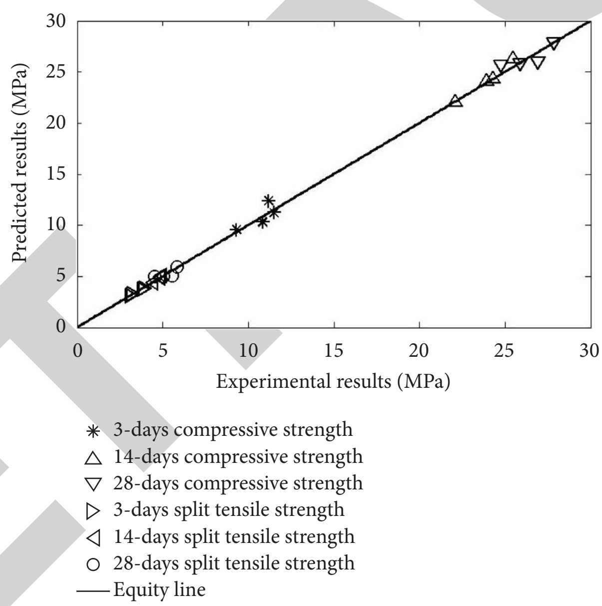

Figure 9: Predicted vs. experimental strength values using the ANN model.

Table 8: Comparison of experimental and ANN predicted strength values.

Curing age days	Plastic waste addition (%)	*Compressive strength (MPa)*		% Error	*Split tensile strength (MPa)*		% Error
		Experiment	Prediction		Experiment	Prediction	
3	0	11.50	11.24	2.28	3.85	3.83	0.41
	20	11.20	12.40	10.75	3.75	3.70	1.35
	40	10.85	10.31	4.97	3.17	3.27	3.08
	60	9.32	9.57	2.72	3.06	3.06	0.17

Table 8: Continued.

Curing age days	Plastic waste addition (%)	Compressive strength (MPa)		% Error	Split tensile strength (MPa)		% Error
		Experiment	Prediction		Experiment	Prediction	
14	0	25.48	26.28	3.12	4.97	5.05	1.63
	20	24.32	24.32	0.00	4.9	4.87	0.53
	40	23.95	24.03	0.35	4.89	4.82	1.51
	60	22.10	22.02	0.35	4.49	4.39	2.17
28	0	27.88	27.93	0.19	5.85	5.94	1.63
	20	26.95	26.01	3.48	5.56	5.05	9.10
	40	25.90	25.90	0.00	5.02	5.00	0.28
	60	24.76	25.71	3.82	4.52	4.97	9.87

4. Conclusion

In the present work, mechanical properties for different weight percentages of polypropylene plastic wastes embedded in concrete specimens were studied. The mechanical properties were studied at different age intervals such as 3, 14, and 28 days. The compressive and split tensile strength values were predicted using two different theoretical models, the two-parameter Weibull distribution and ANN. The decrease in compressive and split tensile strengths was found in both predicted and experimental results, with the increase in polypropylene weight contents in the concrete specimens. However, the strength values for the specimens of 20% PP-embedded concrete specimens are closer to 0% PP-embedded concrete specimens. The mechanical properties were found to be increasing with the increase in the age duration from 3 to 28 days. This can be attributed to an increase in the bonding of the microstructure of the concrete specimen, which strengthens the specimen. However, the increase in mechanical properties is relatively less between 14 and 28 days compared to between 3 and 28 days, which indicate that the post-cure of the concrete specimen for a minimum of two weeks is essential. An excellent correlation is obtained between the predicted and experimental values. It can be concluded from this study that specimens of 20% PP-embedded concrete specimens can be used for primary load-bearing applications. This contributes to reduce the unit weight of the concrete.

Data Availability

This manuscript includes raw data recorded from the apparatus and processed data derived from raw data.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] P. O. Awoyera and A. Adesina, "Plastic wastes to construction products: status, limitations and future perspective," *Case Studies in Construction Materials*, vol. 12, Article ID e00330, 2020.

[2] R. Sundarakannan, V. Arumugaprabu, V. Manikandan, K. Arun Prasath, S. Vigneshwaran, and K. Naresh, "Effect of polyethylene terephthalate char on impact and erosion properties of polyester matrix composites," *Advances in Materials and Processing Technologies*, pp. 1–14, 2022.

[3] S. Arun Karthick, T. Ragavi, K. Naresh, and P. Rama Sreekanth, "A study on collagen-PVA and chitosan-PVA nanofibrous matrix for wound dressing application," *Materials Today Proceedings*, vol. 56, pp. 1347–1350, 2022.

[4] M. Selva Priya, K. Naresh, R. Jayaganthan, and R. Velmurugan, "A comparative study between in-house 3D printed and injection molded ABS and PLA polymers for low-frequency applications," *Materials Research Express*, vol. 6, no. 8, Article ID 085345, 2019.

[5] A. Babafemi, B. Šavija, S. Paul, and V. Anggraini, "Engineering properties of concrete with waste recycled plastic: a review," *Sustainability*, vol. 10, no. 11, Article ID 3875, 2018.

[6] R. Olayil, V. Arumuga Prabu, S. DayaPrasad, K. Naresh, and P. S. Rama Sreekanth, "A review on the application of bio-nanocomposites for food packaging," *Materials Today Proceedings*, vol. 56, pp. 1302–1306, 2022.

[7] B. Jaivignesh and A. Sofi, "Study on mechanical properties of concrete using plastic waste as an aggregate," *IOP Conference Series: Earth and Environmental Science*, vol. 80, Article ID 012016, 2017.

[8] A. Serier and D. Aoufi, "Development of new biodegradable packaging," *Advances in Materials and Processing Technologies*, vol. 3, no. 2, pp. 155–163, 2017.

[9] L. Gu and T. Ozbakkaloglu, "Use of recycled plastics in concrete: a critical review," *Waste Management*, vol. 51, pp. 19–42, 2016.

[10] S. Moorthi and M. Megaraj, "Indigenous development of single screw conveying machine for pyrolysis of waste plastics using nano zeolite particles in fixed bed reactor," *Advances in Materials and Processing Technologies*, pp. 1–13, 2021.

[11] F. Colangelo, R. Cioffi, B. Liguori, and F. Iucolano, "Recycled polyolefins waste as aggregates for lightweight concrete," *Composites Part B: Engineering*, vol. 106, pp. 234–241, 2016.

[12] A. M. Hameed and B. A. Fatah Ahmed, "Employment the plastic waste to produce the light weight concrete," *Energy Procedia*, vol. 157, pp. 30–38, 2019.

[13] I. Mercante, C. Alejandrino, J. P. Ojeda, J. Chini, C. Maroto, and N. Fajardo, "Mortar and concrete composites with recycled plastic: a review," *Science and Technology of Materials*, vol. 30, pp. 69–79, 2018.

[14] I. Almeshal, B. A. Tayeh, R. Alyousef, H. Alabduljabbar, and A. M. Mohamed, "Eco-friendly concrete containing recycled plastic as partial replacement for sand," *Journal of Materials Research and Technology*, vol. 9, no. 3, pp. 4631–4643, 2020.

[15] E. A. Ohemeng and S. O. Ekolu, "Strength prediction model for cement mortar made with waste LDPE plastic as fine

aggregate," *Journal of Sustainable Cement-Based Materials*, vol. 8, no. 4, pp. 228–243, 2019.

[16] N. Saikia and J. d. Brito, "Waste polyethylene terephthalate as an aggregate in concrete," *Mathematical Research*, vol. 16, no. 2, pp. 341–350, 2013.

[17] Y. Adela, "Plastic Wastes as a Raw Material in the Concrete Mix," *An Alternative Approach to Manage Plastic Wastes in Developing Countries*, vol. 382, p. 7, 2020.

[18] J. Wight, *Reinforced concrete: mechanics and design*, Pearson Education, England, 2016.

[19] B. S. K. Keerthi Gowda and M. S. Dakshayini, "Application of FOSM and Chebyshev's theorem concept to predict compressive strength attributes of corncob ash embedded cement concrete," *Computational Engineering and Physical Modeling*, vol. 3, no. 1, pp. 16–24, 2020.

[20] B. S. K. Keerthi Gowda and G. L. Easwara Prasad, "Prognostication of concrete mix proportion by ANN approach," *Advanced Materials Research*, vol. 261–263, pp. 426–430, 2011.

[21] A. Bardhan, R. Biswas, N. Kardani et al., "A novel integrated approach of augmented grey wolf optimizer and ANN for estimating axial load carrying-capacity of concrete-filled steel tube columns," *Construction and Building Materials*, vol. 337, Article ID 127454, 2022.

[22] Y. Mater, M. Kamel, A. Karam, and E. Bakhoum, "ANN-Python Prediction Model for the Compressive Strength of green concrete," *Construction Innovation*, 2022.

[23] K. C. Onyelowe, D. P. N. Kontoni, A. M. Ebid et al., "Multi-objective optimization of sustainable concrete containing fly ash based on environmental and mechanical considerations," *Buildings*, vol. 12, no. 7, p. 948, 2022.

[24] D. Rezazadeh Eidgahee, H. Jahangir, N. Solatifar, P. Fakharian, and M. Rezaeemanesh, "Data-driven estimation models of asphalt mixtures dynamic modulus using ANN, GP and combinatorial GMDH approaches," *Neural Computing & Applications*, vol. 34, no. 20, pp. 17289–17314, 2022.

[25] K. Naresh, K. Shankar, and R. Velmurugan, "Reliability analysis of tensile strengths using Weibull distribution in glass/epoxy and carbon/epoxy composites," *Composites Part B: Engineering*, vol. 133, pp. 129–144, 2018.

[26] K. Naresh, K. Shankar, R. Velmurugan, and N. K. Gupta, "Statistical analysis of the tensile strength of GFRP, CFRP and hybrid composites," *Thin-Walled Structures*, vol. 126, pp. 150–161, 2018.

[27] M. Shariati, M. S. Mafipour, P. Mehrabi et al., "Prediction of concrete strength in presence of furnace slag and fly ash using hybrid ANN-GA (artificial neural network-genetic algorithm)," *Smart Structures and Systems*, vol. 25, no. 2, pp. 183–195, 2020.

[28] N. Saikia and J. de Brito, "Use of plastic waste as aggregate in cement mortar and concrete preparation: a review," *Construction and Building Materials*, vol. 34, pp. 385–401, 2012.

[29] M. Batayneh, I. Marie, and I. Asi, "Use of selected waste materials in concrete mixes," *Waste Management*, vol. 27, no. 12, pp. 1870–1876, 2007.

[30] R. Siddique, J. Khatib, and I. Kaur, "Use of recycled plastic in concrete: a review," *Waste Management*, vol. 28, no. 10, pp. 1835–1852, 2008.

[31] B. Liguori, F. Iucolano, I. Capasso, M. Lavorgna, and L. Verdolotti, "The effect of recycled plastic aggregate on chemico-physical and functional properties of composite mortars," *Materials & Design*, vol. 57, pp. 578–584, 2014.

[32] A. Gupta, N. Gupta, and K. K. Saxena, "Experimental study of the mechanical and durability properties of Slag and Calcined Clay based geopolymer composite," *Advances in Materials and Processing Technologies*, pp. 1–15, 2021.

[33] M. Mahmoudi Nehrani, A. Abdi, M. Zarei, and F. Akbarinia, "The effect of rice husk ash and gilsonite on the properties of concrete pavement," *Advances in Materials and Processing Technologies*, pp. 1–21, 2021.

[34] S. Jadhav and R. S. Patil, "Comparison of flexural, split tensile & compressive strength of HP-SCC using magnetized water," *International Journal of Emerging Trends in Engineering Research*, vol. 4, pp. 130–135, 2016.

[35] M. A. Akinpelu, S. O. Odeyemi, O. S. Olafusi, and F. Z. Muhammed, "Evaluation of splitting tensile and compressive strength relationship of self-compacting concrete," *Journal of King Saud University - Engineering Sciences*, vol. 31, no. 1, pp. 19–25, 2019.

[36] A. Jaber, I. Gorgis, and M. Hassan, "Relationship between splitting tensile and compressive strengths for self-compacting concrete containing nano- and micro silica," *MATEC Web of Conferences*, vol. 162, Article ID 02013, 2018.

[37] G Zhang, N Hamzehkolaei, H Rashnoozadeh, and S Shahab, "Band & Amir Mosavi (2021) Reliability assessment of compressive and splitting tensile strength prediction of roller compacted concrete pavement: introducing MARS-Goa-MCS," *International Journal of Pavement Engineering*, 2021.

[38] A. Khalili and K. Kromp, "Statistical properties of Weibull estimators," *Journal of Materials Science*, vol. 26, no. 24, pp. 6741–6752, 1991.

[39] F. Wang and J. Shao, "Modified Weibull distribution for analyzing the tensile strength of bamboo fibers," *Polymers*, vol. 6, no. 12, pp. 3005–3018, 2014.

[40] L. Bazli, S. Eskandarinezhad, N. Kakur et al., "Electrical properties of polymer blend composites based on Silicone rubber/EPDM/clay for high voltage insulators," *Journal of Composites and Compounds*, vol. 2, no. 5, pp. 18–24, 2021.

[41] K. Naresh, K. Shankar, R. Velmurugan, and N. K. Gupta, "Probability-based studies on the tensile strength of GFRP, CFRP and hybrid composites," *Procedia Engineering*, vol. 173, pp. 763–770, 2017.

[42] S. Ilangovan, S. Senthil Kumaran, K. Naresh, K. Shankar, and R. Velmurugan, "Studies on glass/epoxy and basalt/epoxy thin-walled pressure vessels subjected to internal pressure using ultrasonic 'C' scan technique," *Thin-Walled Structures*, vol. 182, 2022.

[43] P. Gupta, N. Gupta, K. K. Saxena, and S. Goyal, "Multilayer perceptron modelling of geopolymer composite incorporating fly ash and GGBS for prediction of compressive strength," *Advances in Materials and Processing Technologies*, pp. 1–15, 2021.