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Simulation Analysis of FRP- Strengthened RC Slab using ODLN-SSO Approach

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ABSTRACT: In recent times, research endeavors have been made to explore the structural behavior of Reinforced Concrete (RC) slabs. The traditional RC slabs are exposed to a colossal reiteration of moving loads. In this manner, they are experiencing more fatigue damage. These damages are noted than that of slabs reinforced with deformed bars. To increase the strength of the slabs, an appropriate reinforcing procedure is required, for example, structures are developed with fiber reinforced polymers. In the proposed work, the Fiber Reinforced Polymers (FRPs) have been utilized as retrofitting materials to strengthen Reinforced Concrete (RC) structures. The considered FRP materials are Carbon Fiber Reinforced Polymer (CFRP), Glass Fiber Reinforced Polymer (GFRP), Basalt Fiber Reinforced Polymer (BFRP) and Sisal Fiber Reinforced Polymer (SFRP). Also, to improve the execution of RC slabs, a hybrid mix of these fibers are used as the retrofitting material. The structural behavior of FRP-strengthened RC slab is researched by the experimental as well as numerical examination by estimating the parameters, for example, compressive strength, ductility and slab deflection. Here, we utilized the Optimal Deep Learning Network (ODLN) along with Salp Swarm Optimization (SSO) Algorithm to test the FRP-RC slab. At the point, when compared with existing work, the proposed ODLN-SSO algorithm accomplishes maximum strength regarding deflection and compressive strength for the hybridized FRP-RC slabs under various loaded condition.

Keywords: FRP-strengthened RC slab, CFRP, GFRP, BFRP and SFRP, Structural Behavior Analysis, ODLN-SSO, Compressive Strength, Ductility and Deflection.

I. INTRODUCTION

Over the most recent couple of decades, the utilization of FRP bars as an inner support for concrete structures was driven by their rival of destructive properties, lightweight, and high rigidity [1]. Their wide-spread was supported up by various investigations that provided details regarding their adequacy in strengthening RC structures [2]. In the part of a building framework, concrete slabs structure an essential part and are required to give high load bearing limit under certain conditions [3-5]. In certain examples, concrete slabs are strengthened to expand their load conveying capacity attributable to the adjustments in occupancy type, or to fix the harm brought about by outrageous occasions [6], or because of decay of steel rebars from consumption as well as chloride presentation [7]. As of late, strengthening of concrete individuals is being completed utilizing FRPs, since FRPs offer different points of interest, for example, high strength, solidness, consumption obstruction, high strength-to-weight proportion and simplicity of use, over other strengthening frameworks [8, 9].

Theoretical, as well as exploratory researches have been directed to examine the dynamic reactions of ordinary concrete extensions under transient moving loads [10]. Nonetheless, a large portion of the papers analyzed on the structural behavior of FRP-strengthened RC slabs is exposed to static loading [11]. The computational outcomes demonstrate that the expansion of fibers to concrete permits diminishing its brittle nature and prompts an outstanding increment in energy absorption capacity [12]. The attributes of certain fibers are delineated as pursues: [13] completed some pliable tests on CFRP composites at various temperatures. Additionally, the temperature based tensile strength and stiffness of unidirectional FRP composites demonstrated that the composite's strength basically relies upon the fiber properties [14]. What's more, other than carbon fibers, glass fibers are additionally normal fiber fortifications. GFRPs are also an FRP material made of a plastic framework reinforced by fine fibers of glass [15]. Glass fiber is a lightweight, and strong material utilized in various ventures because of their superb properties [16]. The utilization of short sisal fibers for the fortification of cement-based materials can increment altogether its application since the customary technique for concrete generation can be utilized in the execution of these composites [17]. In view of weakening of the concrete because of increasing years, consumption of the reinforced steel, and expanded loads that were already unaccounted for, structural members may require reinforcing in the wake of being developed. So as to expand the load conveying capacity of a current RC slab, the measure of tensile capacity or compressive capacity must be expanded.

FRP composites are lightweight, non-destructive, exhibit high explicit strength and explicit solidness, are effectively built, and can be custom-made to fulfill execution prerequisites. Because of these beneficial qualities, FRP composites have been incorporated into new development and recovery of structures through its utilization as support in concrete, connecting bridge, particular structures, formwork, and outer fortification for strengthening and seismic redesign. Here, four distinct fibers are utilized to strengthen the RC slab even it is exposed to a different loaded condition. A moderately new technique that has gotten acknowledged for reinforcing existing structures is using fiber reinforced polymer. The high solidarity to-weight proportion, protection from erosion, simplicity of use, the capacity to introduce FRP without upsetting utilization of the structure, and moderately low maintenance of FRP make it an appealing composite to be utilized for reinforcing. In any case, for all intents and purposes, execution of steady quality examinations is very unpredictable in light of the fact that the optimization issue to manage be a high-dimensional one and the segments (or factors) of the breaking point state work essentially may develop during time or with geometrical as well as material non-linearity. Over the previous decade, meta-heuristic strategies have turned out to be extremely admired for the forecast investigation of FRP composite material [28-30]. This notoriety is because of a few primary reasons [18]: adaptability, inclination free component, and neighborhood optima shirking of these algorithms. The initial two points of interest starting from the way that meta-heuristics consider and tackle optimization issues by just taking a gander at the sources of info as well as outputs [19]. The test results are compared with those anticipated utilizing the current models and code conditions to survey their precision in predicting the general execution and the flexural limits of the tried samples. In the present study focused to strength the reinforced concrete slabs by using various fibers [31-33]. A real time experiment and the simulation modeling are used to find the compressive strength, deflection and ductility of the proposed specimen. In the experimental investigation six types of slabs are prepared on account of fiber types. After experimentation, the algorithms are used to validate the experimental data. The algorithms are used to predict the performance of the study. By reducing the computational burden, an effective simulation modeling depend son deep learning neural network with salp swarm optimization is developed. The algorithms reduce the computational time and gives minimum error when compared to existing techniques.

The outline of the paper is depicted as followed by this introduction section, a survey of recent literature related to FRP composites along with machine learning algorithms is discussed in section II along with its problems. Section III depicts the background of the research work algorithms. Section IV explains the FRP-RC slab experimentation and prediction models of the proposed study and then the subsection elaborates the algorithm procedure. Section V discusses the result of simulation modeling and finally, the conclusion part is clearly discussed in section VI with a future scope.

II. SURVEY OF RECENT LITERATURE

To date, researchers have effectively utilized numerical ways to study the deflection behavior of different steel or concrete structures. The plan of a 10-m long without steel precast fiber-RC slab, pre- stressed with BFRP bars and shear-reinforced with GFRP bars was discussed by Dal Lago *et al.*, [20]. The arrangement of Glass/Ramie fibers reinforced epoxy hybrid composites are inspected by Giridharan [21]. The hybrid composites are hybridized at various arrangements. The properties, for example, elasticity, flexural strength, impact strength are analyzed for the prepared or developed samples. Also, the morphological features of composites were considered by Scanning Electron Microscope (SEM). The outcome inferred that the hybrid composited yield preferred properties over the separate fiber composite. The basalt texture reinforced shotcrete framework was proposed by Gao *et al.*, [22] for the flexural strengthening of fire-damaged RC slabs. Test outcomes showed that the flexural limit of the fire-damaged RC slabs strengthened with the basalt texture reinforced shotcrete frameworks were expanded by 68.9– 193.4% contrasted with their un-strengthened discharge harmed partners. Concrete slabs strengthened with basalt fibers – trial tests results are talked about by Wlodarczyk and Jedrzejewski [23]. Ray *et al.*, [24] assessed the dynamic mechanical as well as thermal investigation of vinyl ester – gum grid composites reinforced with untreated and antacid treated jute fibers. The outcomes demonstrated that the composites storage modulus decline with increment in temperature. Nair *et al.*, [25] clarified the thermal as well as dynamic mechanical investigation of polystyrene composites reinforced with short sisal fibers. The outcomes recommended that the capacity modulus diminishes with increment in temperature for all composites. Some simulation examination strategies like Artificial Neural Networks (ANN) model, Fuzzy Inference System (FIS), Harmony Search (HS) algorithm, genetic algorithm (GA), and so on are talked about by Karataş and Gökkaya [26] for the composite material CFRP and GFRP.

From the reviewed literature, different researchers have been investigated the non-linear structural behavior of RC slab by both experimental and simulation methods. But still, the effect of non-linear behavior analysis is not satisfactory by the researchers. Hence, we enhance the prediction analysis by an innovative deep learning network called RBF along with a training algorithm. The traditional optimization algorithm easily encounters the local search optimism, which causes a decrease of exact at the control of its speed and the heading. It can't work out the issues of scattering and optimization. The algorithms can't work out the issues of the non-arrange systems, for instance, the solution for the energy field and the moving guidelines of the particles in the imperativeness field. Genetic Algorithm based framework is found direct, rich and logically less perplexing, which can work even without the right learning of the issue space. The amount of search in solution space extends the computational expense due to lull, various cycles and memory limit required.

This will effectively analyze the structural behavior of RC slab with different fiber layered structure.

In the event that the separating between aggregates used as a part of the strengthened concrete won't be proper, by then, the deflection are increased in the center of steel and concrete; if the steel or concrete comes up short, at that point whole structure will be failed.

In the traditional Finite Element (FE) examination of strengthened concrete structures can have consolidating issues in models that have a gigantic degree of non-linearity and moreover in the diversion. The frameworks won't work outstandingly or make it increasingly trapped, so as to beat these issues paid the course to the proposed method.

III. EXPERIMENTAL INVESTIGATION: FRP-STRENGTHENED RC SLAB

An experimental study was done to examine the strength of slabs with fiber reinforced polymer laminates with different courses of action. A rectangular FRP-strengthened RC slab (1250 mm × 1250 mm × 100 mm) is developed with the four different layers, and it is modeled in one single component with the perfect bond between the FRP, concrete and reinforcement assumed. Based on the above dimension, six different slabs are developed by varying the fiber material. The six different specimens are illustrated in Table 1.

Table 1. FRP-RC Slab Designation.

FRP- strengthened RC slab : 1250 mm × 1250 mm × 100 mm	
Specimen	**Fiber Material Used**
S1 (CFRP)	Carbon Fiber Reinforced Polymer
S2 (GFRP)	Glass Fiber Reinforced Polymer
S3 (BFRP)	Basalt Fiber Reinforced Polymer
S4 (SFRP)	Sisal Fiber Reinforced Polymer
S5 (HFRP (G/S))	Hybrid Fiber Reinforced Polymer (Glass/Sisal)
S6 (HFRP (B/S))	Hybrid Fiber Reinforced Polymer (Basalt/Sisal)

The specimens S5 and S6 are the hybrid combination of two fibers Glass/Sisal and Basalt/Sisal respectively. The nonlinear structural behavior of these specimens with different types and width of FRPs, and various spacing between FRPs is investigated and it is tested and cured with 28, 56 days in the parametric examinations utilizing the created component after approval.

A. Layer Structure of FRP- RC Slab

The proposed fiber based rectangular plate component CPE appears in Fig. 1. The cross-area of the component comprises of concrete layers, steel layers of the smeared steel support, FRP layer of the smeared FRP and an adhesive layer; layer structure shows up in Fig. 2. It is expected that each layer is in a condition of plane pressure, that similarity exists and immaculate bond is accepted between the steel, FRP and concrete layers.

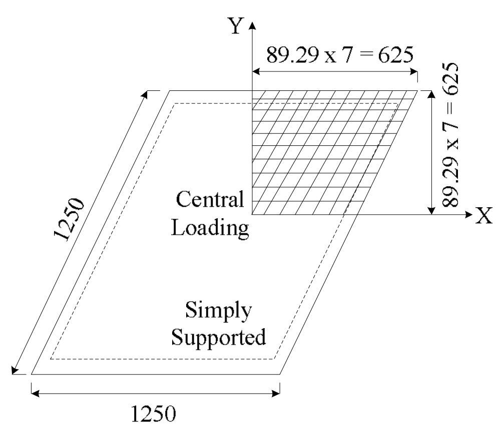


Fig. 1. Composite Material.

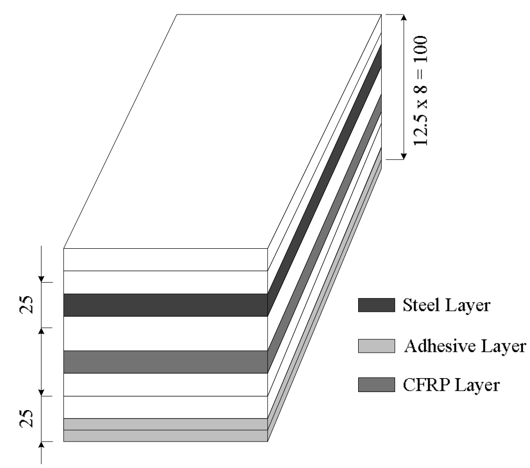


Fig. 2. Layer Structure of FRP- RC Slab.

Description of Layers:

Concrete Layer: The impact of the number of concrete layers utilized in the RC slab is dissected with a different number of concrete layers, for example, 4, 6, 8, 10 and 20. For computational productivity, one-fourth of the slab is demonstrated with the composite cross segment of 8 layers of concrete, 2 layers of steel support, 1 layer of CFRP and 1 adhesive layer.

Steel layer: The strengthening steel is thought to be elastic– impeccably plastic in pressure and pressure, with axial stiffness in just the bar heading.

Adhesive Layer: The adhesive layer is viewed as elastic– consummately plastic in strain. Ordinarily, the examples with the standard concrete layer carry on flexibly until a definitive shear compel is come to. At this stage, the chemical adhesion, as well as transverse ribs, gives common execution to the concrete layer and the steel sheeting joint.

B. Proposed Fiber Materials

FRPs are thought to be linear flexible until the pressure achieves its definitive strength which makes a weak break and after that diminishes to zero. With the aim of strengthening the RC slab, we incorporate fiber layer into the layer structure. The presented fibers are CFRP, GFRP, BFRP, and SFRP. Fig. 3 shows the proposed fiber materials.

–**Glass Fiber:** The mechanical behavior of a fiber-reinforced composite essentially relies upon the fiber strength as well as modulus, the substance stability, lattice strength and the interface holding between the fiber/framework to empower pressure exchange.

–**Carbon Fiber:** The utilization of CFRP composites is to build the flexural capacity of components in the concrete structure was distinguished as a conceivable option in contrast to other strengthening techniques.

–**Basalt Fiber:** Basalt fibers are for all intents and purposes profoundly aggressive with glass ones by primary mechanical attributes and outperforms them by some of them, specifically, by water-opposition as well as chemical stability.

–**Sisal Fiber:** Sisal fibers for the support of cement based concrete materials can increment compressive strength since the conventional technique for concrete creation can be utilized in the execution of these composites.

(a) Carbon (b) Glass (c) Basalt (d) Sisal

Fig. 3. Fiber Materials.

C. Behavior Analysis of FRP-Strengthened RC Slab using ODLN

The structural behavior analysis of developed components is investigated by utilizing Optimal Deep Learning Network (ODLN) system and Salp Swarm Optimization (SSO) Algorithm. The proposed SSO algorithm is roused from the swarming behavior of salps and this will advances the network structure successfully by accomplishing better movement utilizing fast planned changes and scavenging action of salps. When contrasted with existing work, the proposed ODLN-SSO algorithm accomplishes maximum execution as far as deflection property and compressive strength for the hybridized FRP-RC slabs under various loaded condition. The detailed description of the proposed model is clarified in underneath segment. The prediction analysis of FRP-RC slab is modeled by deep learning algorithms. Here, at the first, the background of the proposed approach is deeply discussed. Thereafter comprehensive descriptions of these algorithms are elegantly offered.

(i) Basics of Deep Learning Network: Deep learning (otherwise called deep organized learning or various leveled learning) is a division of a more extensive group of Artificial Intelligence strategies dependent on learning information portrayals, instead of the task -explicit techniques.

Radial Basis Function: In the proposed work, the RBF neural network model is considered for the prediction investigation of FRP-strengthened RC slab. In this model, the node is portrayed by its middle, which is a vector with measurement equivalent to the number of contributions to the node. The connection between info vector and the RBF node center is assessed by the Euclidean distance equation.

$$Dis(PQ) = \left|P_{lk} - Q_{lk}\right| = \sum_{l=1}^{L}(P_{lk} - Q_{lk})^2 \quad (1)$$

where the parameter P and Q are explained as: $P_l = P_1, P_2, P_3....P_L$ is the input vector, $Q_k = Q_1, Q_2, Q_3....Q_K$ indicates the center of k^{th} node.

The principle of RBF Network: A RBF neural network can be considered as an exceptional three-layer network that is straight as for the output parameters in the wake of fixing all the RBF centers and nonlinearities in the middle or hidden layer [27]. The essential structure of a regular RBF network appears in Fig. 4. In this manner, the middle layer plays out a nonlinear change and maps the info space onto another space. The last layer at that point actualizes a straight combiner on this space, where the main customizable parameters are loads of the direct combiner.

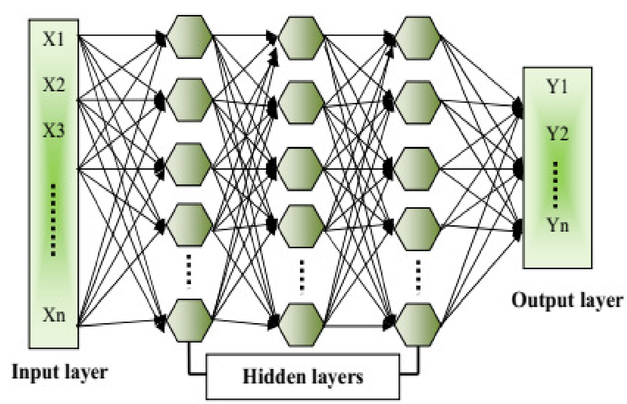


Fig 4. Basic Structure of DLN.

(ii) Salp Swarm Optimization: SSO is motivated by the swarming behavior of salps when exploring and scrounging in seas. SSO is an as of late swam insight algorithm created in 2017 by Mirjalili *et al*., [18] Salps have a place with the group of Salpidae and have a straightforward barrel-molded body. Their tissues are very like jelly fishes. They likewise move fundamentally the same as jellyfish, in which the water is siphoned through the body as an impetus to push ahead. In deep seas, salps regularly form a swarm called salp chain. The fundamental reason for this behavior isn't clear yet, but a few scientists trust this is improved by motion utilizing fast planned changes as well as scrounging. The salp chain attempts to locate the best area of food by means of seeking process with the assistance of a pioneer salp, with the others as followers. The situation of all salps is stored in a two-dimensional network called *M*. It is additionally expected that there is a food source called f_s in the pursuit space as the swarm's objective.

(iii) Proposed Prediction Model: ODLN with SSO: The utilization of optimal DLN structure is to accomplish the best arrangement and the parameters (for example slab measurements) are represented as the issue of optimization of an exhibition file. An ODLN has the features of an RBF neural network.

Initialization: For examining the structure behavior (like deflection, ductility, and compressive strength) of the FRP-strengthened RC slab, ODLN structure initializes the input parameters as: the type of FRPs, width and thickness of FRPs and load as S_1, S_2, S_3 and S_4. The initialization is given by Eqn. (2)

$$S = \{S_1, S_2, S_3 \text{ and } S_4\} \tag{2}$$

Objective Function of RBF: The target work is to accomplish optimal results of forecast examination by the assessment of the minimum error rate. This will be achieved by the training process of RBF structure; for best, we present the Levenberg-Marquardt (LM) algorithm where the network weights are trained at every emphasis procedure.

Training Process of RBF: LM training algorithm is introduced in the RBF network, to train the test data attained from the experimental analysis.

LM Training Algorithm: The LM curve fitting technique is a blend of two minimization strategies: the gradient descent strategy and the Gauss-Newton technique. In the first strategy, the entirety of the squared errors is diminished by refreshing the parameters in the steepest-descent course. In the second technique, the sum of the squared errors is decreased by expecting the least squares function is locally quadratic, and finding the base of the quadratic. Simple steepest descent method to minimize the following error function:

$$R = \sum_{t=1}^{l} (S_t - C_t) \tag{3}$$

Where, S represents the target,C represents the actual output for the t-the pattern of the neuron, R is the error function, l is the total number of training patterns.

The weight update vector ∇W is calculated as

$$\nabla W = [J^T(W) * J(W) + \varepsilon I]^{-1} J^T(W) R \tag{4}$$

Underneath $J^T(w)$ J(w) is alluded to as the Hessian lattice. Relating to μ = 0 the algorithm utilizes the Gauss-Newton approach. Relating to extremely extensive μthe LM algorithm utilizes the steepest great or maybe the error backpropagation algorithm. The parameter is routinely changed at each emphasis to defend intermingling. The LM algorithm includes computation on the Jacobian J (w) lattice at every single cycle activity just as the reversal related with JT (w) J(w) square matrix and the R is a vector of size.

(iv) Structure Optimization using SSO: The parameter to be optimized is depicted as the optimization problem of SSO algorithm. Here, the optimized structure is achieved on the basis of error rate evaluation. The most optimal RBF structure leads to achieve maximum prediction accuracy in the structural behavior analysis of FRP-strengthened RC slab.

Initialization: Initialize the salps, here the network structure weights are assigned as the initial solution. It is represented by Eqn. (4).

Condition Evaluation: Optimize the network structure by input and hidden layer weights using SSO. The best optimal weight is attained based on the minimum Mean Square Error (MSE) rate. MSE is the capacity to minimize the errors and it is characterized as in Eqn. (3). Fitness

Updating Weights in RBF: To update the position of the leader or weights the following equation is proposed:

$$W_j^1 = \begin{cases} f_j + R_1\left[\left(U_j - L_j\right)R_2 + L_j\right] & R_3 \ge 0 \\ f_j - R_1\left[\left(U_j - L_j\right)R_2 + L_j\right] & R_3 < 0 \end{cases} \tag{5}$$

where, W_j^1 represents the position of the first salp (leader) in j^{th} dimension, the position of the food source j^{th} in dimension is depicted as f_i; the upper bound and lower bound is denoted as U_j and L_j; R_1, R_2 and R_3 indicates random number randomly generated in the interval of [0,1].

The salp leader just updates its sitting as per the food source. The coefficient R_1 is the most critical parameter in SSO since it adjusts exploration and exploitation characterized as pursues:

$$R_1 = 2e^{(-4l/L)} \tag{6}$$

where l symbolizes the current iteration and L is the maximum number of iterations. To update the position of the followers, Newton's law of motion is introduced. The discrepancy between iterations is equal to 1, and considering the initial speed as 0, this equation can be expressed as follows:

$$W_j^i = \frac{1}{2}\left[W_j^i + W_j^{i-1}\right] \tag{7}$$

where $i \ge 2$ and W_j^1 indicates the position of i^{th} follower salp in j^{th} dimension. With condition (7), the salp chains can be simulated. It ought to be noticed that the food source will be refreshed amid optimization in light of the fact that the salp chain is in all respects liable to locate a superior arrangement by exploring and exploiting the space around it. Thusly, the salp tie can possibly move towards the global optimum that changes through the span of cycles. At last, the optimal weights are resolved dependent on the optimal position of the salps by virtue of increasing iterations.

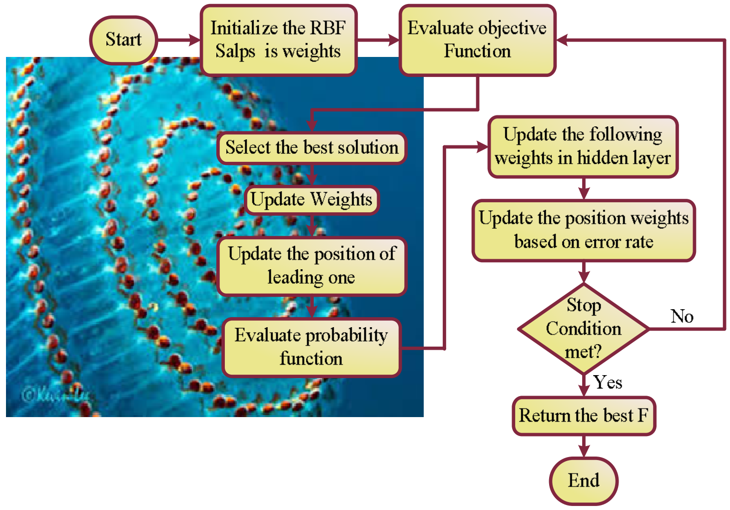


Fig. 5. Flow Chart of SSO Algorithm.

D. Optimal Solution in RBF

From the SSO optimization technique, it achieves the optimal structure by evaluating the error rate. With the help of LM training algorithm, optimal or near-optimal solutions are realized by the updating process of SSO algorithm. Based on the optimal solution, we can validate the specimen strength in terms of deflection, ductility and compressive strength behavior of the FRP-strengthened RC slab.

IV. SIMULATION RESULTS

The simulation results of created FRP-strengthened RC slab is examined in this segment with four distinct fibers like CFRP, GFRP, BFRP and SFRP. This simulation process is actualized by MATLAB 2015a with 4GB RAM and i5 processor. The performance measures, for example, deflection, ductility and compressive strength are analyzed for every sample under various loaded condition. The validation tests between the predicted and the actual results are exhibited by correlation analysis.

A. Parameters for Prediction Analysis

Deflection: The deflection distance of a member under a load is specifically connected to the slope of the deflected shape of the member under the relative load.

Ductility: Ductility is a state where extensive addition in strain happens at low (unimportant) augmentation of stress. So flexibility is a critical stage where external energy is changed into inside work energy by giving high strain.

Compressive Strength (CS): The compressive strength of concrete slabs is controlled by applying constant load over the readied specimen until failure happens. The test is led by a compression testing machine. The compressive strength of any material is characterized as the resistance to failure under the activity of compressive powers.

Table 2 describes the deflection value of developed six different specimens such as S1 (CFRP), S2 (GFRP), S3 (BFRP), S4 (SFRP), S5 (HFRP (G/S)) and S6 (HFRP (B/S)). In the proposed work, the structural behavior of developed FRP-strengthened RC slab is tested by the ODLN-SSO algorithm. Table 2 illustrates the actual and predicted (ODLN-SSO) values of six specimens.

From the analysis, the deflection gets lower in the hybrid specimens which are illustrated in Fig. 6.

For the comparison of six slabs, the specimens S5 and S6 reduce the deflection rate if the load is higher. FRP reduces the compression, improves strength of slab.

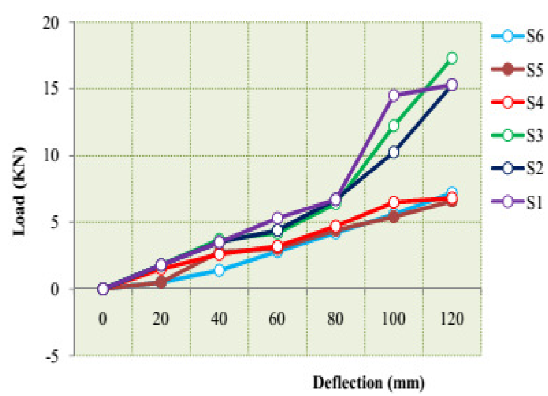
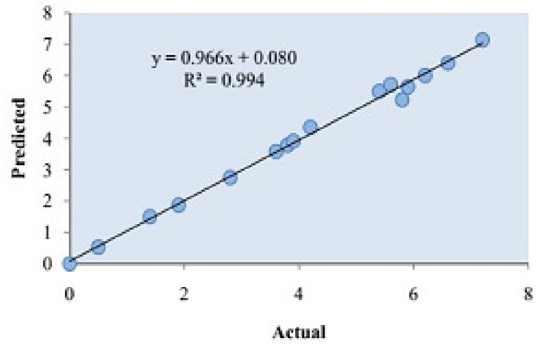


Fig. 6. Load vs. Deflection.

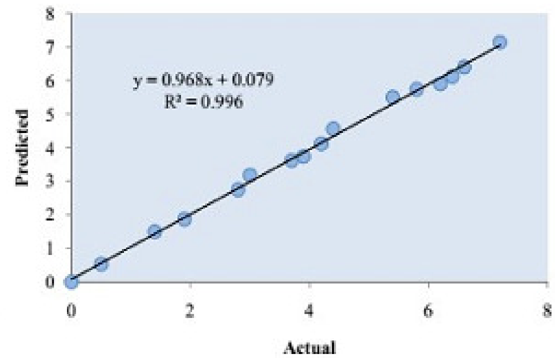
Table 2: Deflection Analysis of Prepared Specimens.

Input (Load)	Deflection											
	S6-HFRP (B/S)		S5-HFRP (G/S)		S4-SFRP		S3-BFRP		S2-GFRP		S1-CFRP	
	Actual	ODLN-SSO	Actual	ODLN-SSO	Actual	ODLN-SSO	Actual	ODLN-SSO	Actual	ODLN-SSO	Actual	ODLN-SSO
0	0	0	0	0	0	0	0	0	0	0	0	0
20	0.5	0.53	0.5	0.53	1.5	1.2	1.8	1.75	1.8	1.79	1.8	1.81
40	1.4	1.5	2.8	2.75	2.6	2.32	3.7	3.82	3.5	3.58	3.5	3.52
60	2.8	2.75	3	3.18	3.2	3.1	4.2	4.45	4.4	4.45	5.3	5.35
80	4.2	4.35	4.4	4.56	4.7	4.8	6.4	6.3	6.7	6.72	6.4	6.42
100	5.6	5.71	5.4	5.5	6.5	6.78	12.23	12.58	10.25	10.3	14.5	14.6
120	7.2	7.14	6.6	6.4	6.8	7.14	17.3	17.37	15.3	15.25	15.3	15.4

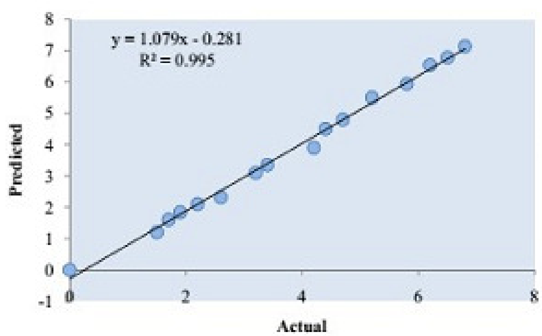
Fig. 7 explains the correlation analysis of the deflection parameter for the actual and predicted values. Fig. 7 (a) CFRP explains the carbon fiber-based RC slab material, (b) GFRP describes the glass fiber based RC slab material, (c) BFRP depicts basalt fiber based RC slab material, (d) SFRP depicts sisal fiber based RC slab material, (e) HFRP (G/S) explains the hybrid combination of glass and sisal fiber based RC slab material, (f) HFRP (B/S) explains the hybrid combination of basalt and sisal fiber based RC slab material. By comparing this correlation value, we can quantify the slab material. That means which type of fiber material is suitable for developing the RC slabs with more efficient. The correlation between the experimental and the simulation modeling is clearly predicted in graph (Fig. 7). The variation between both the analyses has attained minimum error.



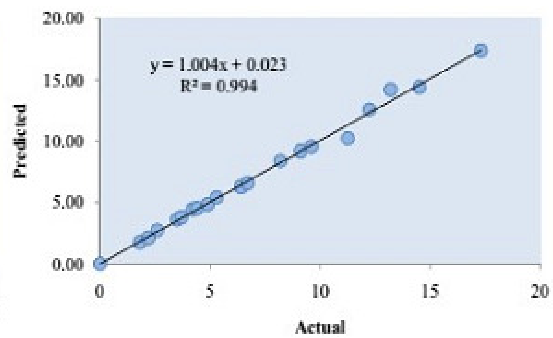
(a) CFRP



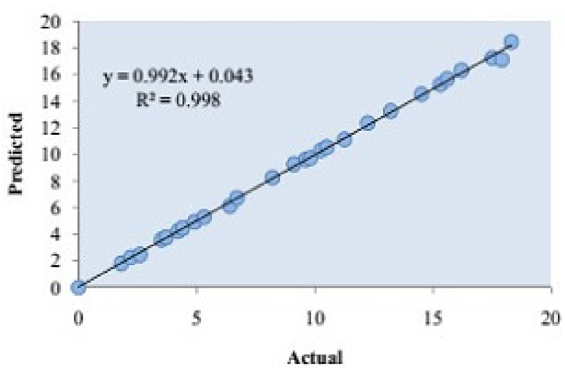
(b) GFRP



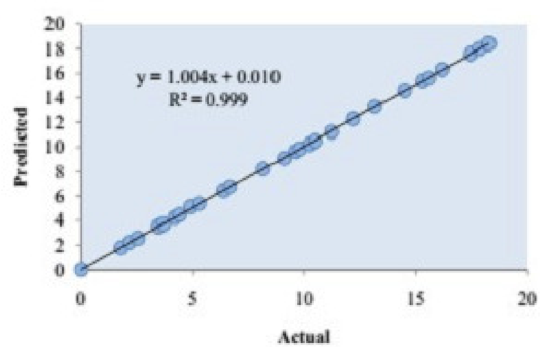
(c) BFRP



(d) SFRP



(e) HFRP (G/S)



(f) HFRP (B/S)

Fig. 7. Correlation Analysis-Deflection of FRP-RC Slab Under Loaded Condition; (a) CFRP, (b) GFRP, (c) BFRP, (d) SFRP, (e) HFRP (G/S), (f) HFRP (B/S).

Table 3: Compressive strength.

Specimen	Compressive strength											
	Actual			ODLN-SSO (proposed)			ODLN			FNN-ODA		
	14 days	28 days	56 days	14 days	28 days	56 days	14 days	28 days	56 days	14 days	28 days	56 days
S1	24.15	44.96	55.35	28.96	53.9	65.43	28.89	57.86	64.29	27.89	47.86	64.64
S2	27.09	46.86	59.8	29.39	51.12	63.77	30.84	48.57	60.84	26.84	45.57	60.34
S3	28.54	50.65	59.35	27.79	51.64	65.43	28.53	50.23	64.29	25.53	48.23	62.32
S4	29.63	52.05	62.26	27.15	52.33	62.93	29.78	52.89	59.12	24.78	49.49	60.12
S5	31.72	52.78	68.09	30.03	53.73	68.58	29.59	54.92	69.19	28.59	54.12	68.18
S6	32.91	56.96	73.27	28.85	54.72	70.25	30.91	57.19	72.64	31.21	53.19	70.44

Table 3 describes the compressive strength analysis of six specimens for curing days 14, 24 and 56. The actual and predicted values are tabulated in Table 3. The proposed ODLN-SSO is compared with ODLN and FNN-ODA. The hybrid specimen S5 and S6 achieve high compressive strength compared to separated fiber based RC slab. The comparative analysis of CS based on specimen curing days for the proposed model ODLN-SSO algorithm is illustrated in Fig. 8. For 7, 14, 28 and 56 days, the CS of FRP-strengthened RC slab is examined and the values are plotted in the line graph. On comparing the actual and predicted values, ODLN-SSO gives nearly equal to actual values. Here, the graph concludes that the hybrid specimen achieves high compressive strength when the slab is subjected to a compressive test.

Fig. 9 shows the validated result of proposed FRP-RC Slab. Figure 9 explains the ductility value of proposed examination. The ductility of six slabs is analyzed for 14 and 28 days. The results demonstrate that hybrid fiber based RC slab has high strength and ductility when compared to normal RC slab. Concrete slabs generally have little flexural reinforcement proportions and are viewed as pliable structural members. Despite that, this isn't valid for slabs that containing low-malleability tensile reinforcement. These sections flop in a brittle way by rupture of the fortification at generally little distortions. This is on the grounds that a significant number of the suspicions certain in the plan of fiber strengthened slabs. Here, the HFRP improves the ductility rate and the individual fiber specimens minimize the ductility value i.e. CFRP, GFRP, SFRP and BFRP. In the investigation of the structural behavior of FRP-strengthened RC slab, the accuracy analysis of different prediction algorithms is illustrated in Fig. 10. The analyzed techniques are DA, FNN-ODA, ODLN and the proposed ODLN-SSO. For validation purpose, we use soft computing techniques to predict the model. If the minimum error achieved in the algorithm, that algorithm is referred as optimal algorithm. Compared to existing algorithms, the ODLN-SSO attains the maximum accuracy in the evaluation of performance measures and quantifying the slab material.

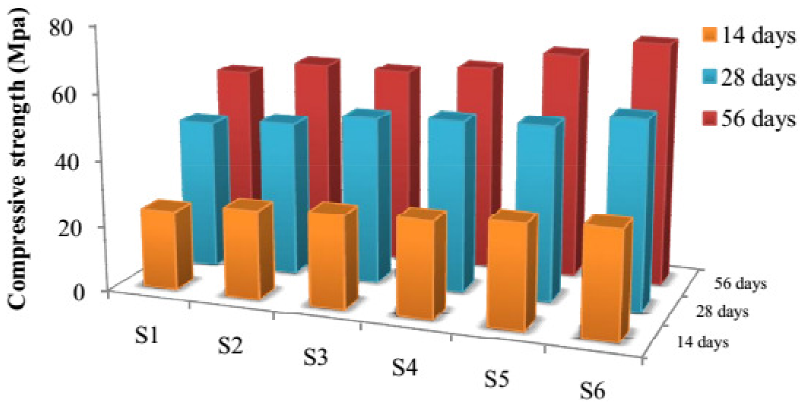


Fig. 8. Comparative Analysis of CS.

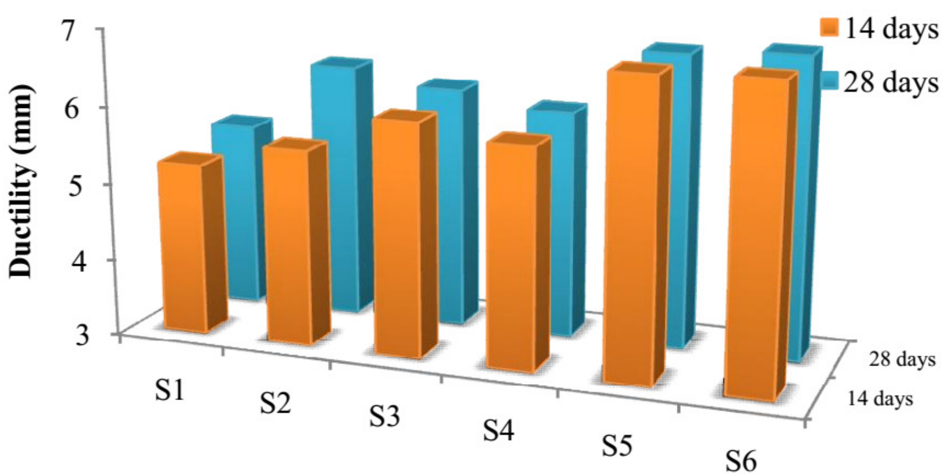


Fig. 9. Ductility of FRP-RC Slabs.

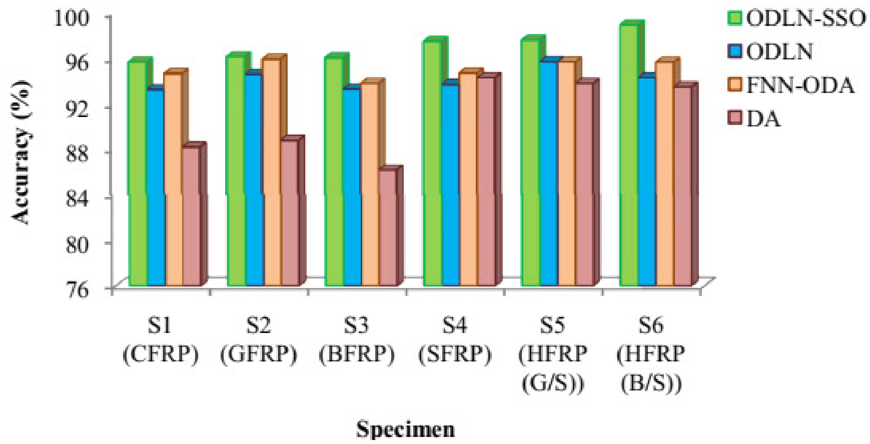


Fig. 10. Accuracy analysis.

V. CONCLUSION

In this paper, a rectangular composite layered component (RC slab) was developed for nonlinear structural behavior examination of FRP-strengthened RC slabs. The impacts of various types, widths and thicknesses of FRPs on the flexural response of FRP-strengthened RC slabs were additionally considered utilizing the proposed component. Further, the deflection behavior for all specimens like CFRP, GFRP, BFRP, SFRP and the hybridized fiber RC slab were inspected by the proposed ODLN-SSO algorithm. The deflection performed in HFRP slab achieves 0.5 mm, 7.2 mm which is less than that of GFRP, CFRP, SFRP and BFRP. The deflection that can be attained in central area of the RC slab strengthened with hybrid fiber reinforced polymer. Similarly, the compressive strength and ductility increased in HFRP slabs than other specimens. The most optimal solution is obtained by the swarming behavior of salps and this will improve the network structure successfully by accomplishing better locomotion using rapid coordinated changes along with scavenging action of salps. The persuading output results are seen to be almost equivalent to the experimental data set with a minimum error value. The proposed ODLN-SSO prediction model accomplishes high accuracy in the FRP-RC slab strengthening when compared with existing models. In future research on the strengthening of FRP-RC slab, the hybrid mix of natural fibers is considered along with training algorithms. In further research work, the high performance concrete with different proportions of nature fibers is added to increase the strength of the concrete. Moreover, different structures like beams, cylinders, cubes etc. are used to enhance our research study.

Conflict of Interest. The authors declare that we have no conflict of interest.

REFERENCES

[1]. Attia, K., Alnahhal, W., Elrefai, A., & Rihan, Y. (2019). Flexural behavior of basalt fiber-reinforced concrete slab strips reinforced with BFRP and GFRP bars. *Composite Structures*, *211*, 1-12.
[2]. McMahon, J. A., & Birely, A. C. (2018). Service performance of steel fiber reinforced concrete (SFRC) slabs. *Engineering Structures*, *168*, 58-68.
[3]. Luccioni, B., Isla, F., Codina, R., Ambrosini, D., Zerbino, R., Giaccio, G., & Torrijos, M. C. (2018). Experimental and numerical analysis of blast response of High Strength Fiber Reinforced Concrete slabs. *Engineering Structures*, *175*, 113-122.
[4]. Wang, W., & Chouw, N. (2018). Experimental and theoretical studies of flax FRP strengthened coconut fibre reinforced concrete slabs under impact loadings. *Construction & Building Materials*, *171*, 546-557.
[5]. Mousavi, T., & Shafei, E. (2019). Impact response of hybrid FRP-steel reinforced concrete slabs. In *Structures*, *19*, 436-448. Elsevier.
[6]. Hajiloo, H., & Green, M. F. (2019). GFRP reinforced concrete slabs in fire: Finite element modelling. *Engineering Structures*, *183*, 1109-1120.
[7]. Kodur, V. K. R., & Bhatt, P. P. (2018). A numerical approach for modeling response of fiber reinforced polymer strengthened concrete slabs exposed to fire. *Composite Structures*, *187*, 226-240.
[8]. Gholamhoseini, A., Khanlou, A., MacRae, G., Scott, A., Hicks, S., & Leon, R. (2016). An experimental study on strength and serviceability of reinforced and steel fibre reinforced concrete (SFRC) continuous composite slabs. *Engineering Structures*, *114*, 171-180.
[9]. Sermet, F., & Ozdemir, A. (2016). Investigation of Punching Behaviour of Steel and Polypropylene Fibre Reinforced Concrete Slabs Under Normal Load. *Procedia engineering*, *161*, 458-465.
[10]. Ramnath, B. V., Kokan, S. J., Raja, R. N., Sathyanarayanan, R., Elanchezhian, C., Prasad, A. R., & Manickavasagam, V. M. (2013). Evaluation of mechanical properties of abaca–jute–glass fibre reinforced epoxy composite. *Materials & Design*, *51*, 357-366.
[11]. Martin, T., Taylor, S., Robinson, D., & Cleland, D. (2019). Finite element modelling of FRP strengthened restrained concrete slabs. *Engineering Structures*, *187*, 101-119.
[12]. Li, L., Yan, L., & Zhang, Y. (2015). Experiment research of UHMWPE fiber reinforced concrete under triaxial compression. In *2015 International conference on Applied Science and Engineering Innovation,* 1847-1852. Atlantis Press.
[13]. Sen, T., & Paul, A. (2015). Confining concrete with sisal and jute FRP as alternatives for CFRP and GFRP. *International Journal of Sustainable Built Environment*, *4*(2), 248-264.

[14]. Konapure, C.G. & Kalyankar, P.T. (2015). Effect of Basalt Fiber and Polypropylene Fiber on Hybrid Fiber Reinforced Concrete. *Journal of Current Engineering and Technology*, *5*(4), 2787-2790.
[15]. Gupta, M. K., & Srivastava, R. K. (2015). Effect of sisal fibre loading on dynamic mechanical analysis and water absorption behaviour of jute fibre epoxy composite. *Materials Today: Proceedings*, *2*(4-5), 2909-2917.
[16]. Ramakrishna, G., & Sundararajan, T. (2019). Long-term strength and durability evaluation of sisal fiber composites. In *Durability and Life Prediction in Biocomposites, Fibre-Reinforced Composites and Hybrid Composites* (pp. 211-255). Woodhead Publishing.
[17]. Lima, P. R., Barros, J. A., Roque, A. B., Fontes, C. M., & Lima, J. M. (2018). Short sisal fiber reinforced recycled concrete block for one-way precast concrete slabs. *Construction and Building Materials*, *187*, 620-634.
[18]. Mirjalili, S., Gandomi, A. H., Mirjalili, S. Z., Saremi, S., Faris, H., & Mirjalili, S. M. (2017). Salp Swarm Algorithm: A bio-inspired optimizer for engineering design problems. *Advances in Engineering Software*, *114*, 163-191.
[19]. Mohd. Abdul Rehman, Subodh kumar V. Dhoke & Snehal R. Shirbhate, (2018). Experimental Study on Strengthening of RCC Slab by using CFRP & GFRP Sheets. *Journal of Engineering Development and Research*, *6*(2), 60-68.
[20]. Dal Lago, B., Taylor, S. E., Deegan, P., Ferrara, L., Sonebi, M., Crosset, P., & Pattarini, A. (2017). Full-scale testing and numerical analysis of a precast fibre reinforced self-compacting concrete slab pre-stressed with basalt fibre reinforced polymer bars. *Composites Part B: Engineering*, *128*, 120-133.
[21]. Giridharan, R. (2019). Preparation and property evaluation of Glass/Ramie fibers reinforced epoxy hybrid composites. *Composites Part B: Engineering*, *167*, 342-345.
[22]. Gao, W. Y., Hu, K. X., Dai, J. G., Dong, K., Yu, K. Q., & Fang, L. J. (2018). Repair of fire-damaged RC slabs with basalt fabric-reinforced shotcrete. *Construction and Building Materials*, *185*, 79-92.
[23]. Wlodarczyk, M., & Jedrzejewski, I., (2016). Concrete slabs strengthened with basalt fibres–experimental tests results. *Procedia Engineering*, *153*, 866-873.
[24]. Ray, D., Sarkar, B. K., Das, S., & Rana, A. K. (2002). Dynamic mechanical and thermal analysis of vinylester-resin-matrix composites reinforced with untreated and alkali-treated jute fibres. *Composites Science and Technology*, *62*(7-8), 911-917.
[25]. Nair, K. M., Thomas, S., & Groeninckx, G. (2001). Thermal and dynamic mechanical analysis of polystyrene composites reinforced with short sisal fibres. *Composites Science and Technology*, *61*(16), 2519-2529.
[26]. Karataş, M. A., & Gökkaya, H. (2018). A review on machinability of carbon fiber reinforced polymer (CFRP) and glass fiber reinforced polymer (GFRP) composite materials. *Defence Technology*, *14*(4), 318-326.
[27]. Maglogiannis, I., Sarimveis, H., Kiranoudis, C. T., Chatziioannou, A. A., Oikonomou, N., & Aidinis, V. (2008). Radial basis function neural networks classification for the recognition of idiopathic pulmonary fibrosis in microscopic images. *IEEE Transactions on Information Technology in Biomedicine*, *12*(1), 42-54.
[28]. Bolandi, H., Banzhaf, W., Lajnef, N., Barri, K., & Alavi, A. H. (2019). Bond strength prediction of FRP-bar reinforced concrete: a multi-gene genetic programming approach. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion* (pp. 364-364). ACM.
[29]. Cogurcu, M. T., Donduren, M. S., Saritas, I., Kamanli, M., Altin, M., & Kaltakci, M. Y. (2008). Artificial neural network design for behaviours of reinforced concrete column under axial load and comparison of experimental study. In *Proceedings of the 9th International Conference on Computer Systems and Technologies and Workshop for PhD Students in Computing* (p. 42). ACM.
[30]. Wang, F., Liu, J., Wang, X., Bao, X., & Li, S. (2019). Finite Element Analyses on the Soft Projectile Impact Testing of a Wall-floor-wall Reinforced Concrete Structure. In *Proceedings of the 2019 International Conference on Artificial Intelligence and Advanced Manufacturing* (p. 47). ACM.
[31]. Yang, J. Q., Smith, S. T., Wang, Z., & Lim, Y. Y. (2018). Numerical simulation of FRP-strengthened RC slabs anchored with FRP anchors. *Construction and Building Materials*, *172*, 735-750.
[32]. Kong, X., Qi, X., Gu, Y., Lawan, I. A., & Qu, Y. (2018). Numerical evaluation of blast resistance of RC slab strengthened with AFRP. *Construction and Building Materials*, *178*, 244-253.
[33]. Amran, Y. M., Alyousef, R., Rashid, R. S., Alabduljabbar, H., & Hung, C. C. (2018). Properties and applications of FRP in strengthening RC structures: A review. In *Structures*, *16*, 208-238. Elsevier.

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