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Retraction

Retracted: Response Surface Methodology Approach to Predict the Flexural Moment of Ferrocement Composites with Weld Mesh and Steel Slag as Partial Replacement for Fine Aggregate

Advances in Materials Science and Engineering

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1].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.

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[1] J. Sridhar, G. B. Shinde, D. Vivek et al., "Response Surface Methodology Approach to Predict the Flexural Moment of Ferrocement Composites with Weld Mesh and Steel Slag as Partial Replacement for Fine Aggregate," *Advances in Materials Science and Engineering*, vol. 2022, Article ID 9179480, 9 pages, 2022.

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Research Article

Response Surface Methodology Approach to Predict the Flexural Moment of Ferrocement Composites with Weld Mesh and Steel Slag as Partial Replacement for Fine Aggregate

Jayaprakash Sridhar,[1] Ganesh Bhausaheb Shinde,[2] D Vivek,[3] Khalida Naseem,[4] Piyush Gaur,[5] Pravin P Patil,[6] and Misganaw Tesfaye Tesema[7]

[1]*Department of Civil Engineering, GMR Institute of Technology, Rajam, Srikakulam, Andhra Pradesh, India*
[2]*Department of Chemical Engineering, Sir Visvesvaraya Institute of Technology, Nashik 422101, India*
[3]*Department of Civil Engineering, KPR Institute of Engineering and Technology, Coimbatore, Tamil Nadu, India*
[4]*Department of Basic and Applied Chemistry, Faculty of Science and Technology, University of Central Punjab, Lahore, Pakistan*
[5]*Mechanical Engineering Cluster, School of Engineering, University of Petroluem and Energy Studies, Bidholi Campus Via Premnagar, Dehradun, Uttarakhand 248002, India*
[6]*Department of Mechanical Engineering, Graphic Era Deemed to Be University, Bell Road, Clement Town 248002, Dehradun, Uttarakhand, India*
[7]*Department of Chemical Engineering, College of Biological and Chemical Engineering, Addis Ababa Science and Technology University, Addis Ababa, Ethiopia*

Correspondence should be addressed to Misganaw Tesfaye Tesema; misganaw.tesfaye@aastustudent.edu.et

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Design of Experiment-Response surface methodology approach is adopted to obtain the optimal flexural moment of ferrocement composites comprising galvanised square weld mesh with weight fraction of fine aggregate by steel slag. To get the optimal combination of progression variables on a flexural moment of ferrocement composites, the central composite design of response surface methodology was adopted. Regression models for responses were justified using analysis of variance and the Pareto chart. The test results show that a maximum ultimate load of 3.30 kN and moment capacity of 220 kNm was obtained for ferrocement with a volume fraction of 2.733% and steel slag of 25% replacement. From the analysis of variance, it is evident that the p value is less than 0.005, the predicted R^2 and the adjustable R^2 are less than 20%, and the predicted values go in hand with the experimental result which indicates that the proposed models are highly suitable. Moreover, the volume fraction of galvanised square weld mesh has a higher significance on a flexural moment of ferrocement composites. Surface plot, Pareto chart, and regression analysis outcomes show that the most substantial and influential factor for a flexural moment is the volume fraction of galvanised square weld mesh.

1. Introduction

Ferrocement is a special form of composite with 90% of its total volume occupied by cement mortar and the rest by galvanised weld mesh or chicken mesh etc. The composites may contain discontinuous fibres also [1, 2]. As it contains uniform mesh reinforcement spread throughout its surface, the crack arresting mechanism of ferrocement is high when compared to concrete structures [3]. Ferrocement reinforced with galvanised square weld mesh shows higher load carrying capacity and moment capacity when compared with ferrocement with GI mesh. Increase in the volume fraction of mesh reinforcement increases the moment capacity [4]. The ultimate moment capacity of ferrocement prediction by group method of data handling (GMDH) has higher accuracy when compared to other models [5]. Ferrocement with a chicken mesh having a volume fraction of 3.77% and 30% partial replacement of fine aggregate by steel slag has a greater first crack load and ultimate load when related to other specimens [6]. Predicted moment capacity of ferrocement with self-evolving network model has higher accuracy when compared with plastic analysis and mechanism approach method [7]. Ferrocement with 2 and 4 layers of weld mesh increases axial stress by 61% and 31%, respectively, with rich mortar containing silica fumes and metakaolin [8]. To learn the influence of the autonomous variables on the outcomes with the least experiments, statistical and mathematical method of Design of Experiments (DOE) preferably Response Surface Methodology can be adopted [9–12]. The test variables can be optimised with DOE which provides a relationship between the empirical model and independent variables and finally delivers optimal response for experimental data [13]. The predicted moment capacity of ferrocement composites with artificial neural network has more accuracy when compared to other methods like GMDH and ANFIs [14]. Ferrocement laminates characterised using digital image correlation reveal that as mesh volume fraction increases, flexural capacity, ductility index, energy absorption, and number of cracks by length increase, whereas the width of the crack decreases [15]. Ferrocement slabs reinforced with chicken mesh having skeleton reinforcement with bamboo and mortar mix of 1 : 3 have higher mechanical properties, and predicted theoretical results support the experimental results [16]. Ferrocement with 2 and 4 layers of weld mesh increases axial stress by 61% and 31%, respectively, with rich mortar containing silica fumes and metakaolin [8]. When the number of layers of wire mesh increased in ferrocement for strengthening of reinforced concrete better yield loads, ultimate loads and stiffnesses are obtained [17].

In the current study, an effort was made to improve the load carrying capacity and moment capacity of ferrocement with galvanised square weld mesh and steel slag. Design of experiment (DOE) is used to design the experiments. The effect of autonomous parameters on experimental results can be studied with the help of the DOE technique. To get the optimal combination of independent variables (volume fraction and steel slag) and to study the influence of independent variables on ultimate load and moment capacity, central composite method (CCM) statistical analysis was accomplished.

2. Methodology

The present experimental programme is designed by using the response surface methodology which evaluates the effect and interaction of multiple variables on a dependent variable. The experimental data were obtained from the flexural behaviour of ferrocement laminates under flexure. The appropriate regression model is chosen by the most appropriate transform due to lack of fit or by removing the extra or insignificant factors due to overfitting. The final model is obtained when the linear regression assumptions are satisfied. Optimization is done for the combined effect of volume fraction and steel slag replacement for fine aggregate to achieve maximum ultimate load and moment capacity. The step-by-step procedure to achieve response models and optimisation is shown in Figure 1.

3. Response Surface Method

The Response Methodology is a mathematical and statistical tool helpful in designing, enhancing, and developing issues where outcomes are influenced by many influencing factors [18]. In RSM, central composite design is used to determine the relationship between outcome variables and independent variables [19]. In DOE of RSM, autonomous variables, factors, and levels of variables are to be provided as shown in Table 1 for considered two responses. The required number of experiments is obtained by

$$N = 2^k + 2k + n, \quad (1)$$

where k is the number of factors, and n is the number of centre points [20]. To obtain the optimum response, following the quadratic model or second order polynomial (2) was used:

$$Y = \beta_0 + \sum_{i-1}^{n} \beta i\, x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum_{i-1}^{n} \sum_{i=n}^{n} \beta_{ij} x_i x_j; \ (i \neq j), \quad (2)$$

where β_0 is a constant; and β_{ii} and $\beta_{ij}$are the linear coefficient, quadratic coefficient, and interactive coefficient, respectively.

4. Materials and Testing

OPC 53 having a specific gravity of 3.15, an initial setting time of 35 minutes as per IS: 4031-1988 and IS: 12269-1987 was used for this investigation [21, 22]. River sand passing through 2.36 mm having a specific gravity of 2.68 as per IS: 383-1970 and ACI 549 1R-93, 1999 is used for ferrocement [23, 24]. Steel slag an effective substitute material is used as a partial replacement for river sand [25]. Steel slag passing through 2.36 mm with a specific gravity of 2.95 was used as per the recommendations of IS 228, 1987 [26] and ACI 233 R-03, 200 [27]. Galvanized square weld mesh having a yield strength of 660 N/mm^2 was used. Ferrocement of size 150 mm × 25 mm × 500 mm were cast as per the specifications in Table 2. The ferrocement composites are tested under flexure with a simply supported span of 400 mm.

5. Results and Discussion

5.1. Experimental Investigation:. From Figure 2, it is evident that an ultimate moment of 2.80 kN is obtained for ferrocement laminates with a volume fraction of 1.425% with 25% weight fraction of steel slag and 2.35% volume fraction with 0% steel slag. Similarly, a maximum ultimate load of 3.30 kN was obtained for ferrocement laminates with 2.73% of volume fraction and 25% of steel slag substitution for fine aggregate. It is observed that ultimate load reduces for specimens with 0.5% volume fraction and 50% of steel slag replacement. Moreover, it is evident that ultimate load reduces with reduce in volume fraction and an increase in steel slag substitution [28].

Similarly, from Figure 3 it is observed that maximum moment capacity is obtained for ferrocement laminates with a volume fraction of 2.73% with 25% of steel slag for fine

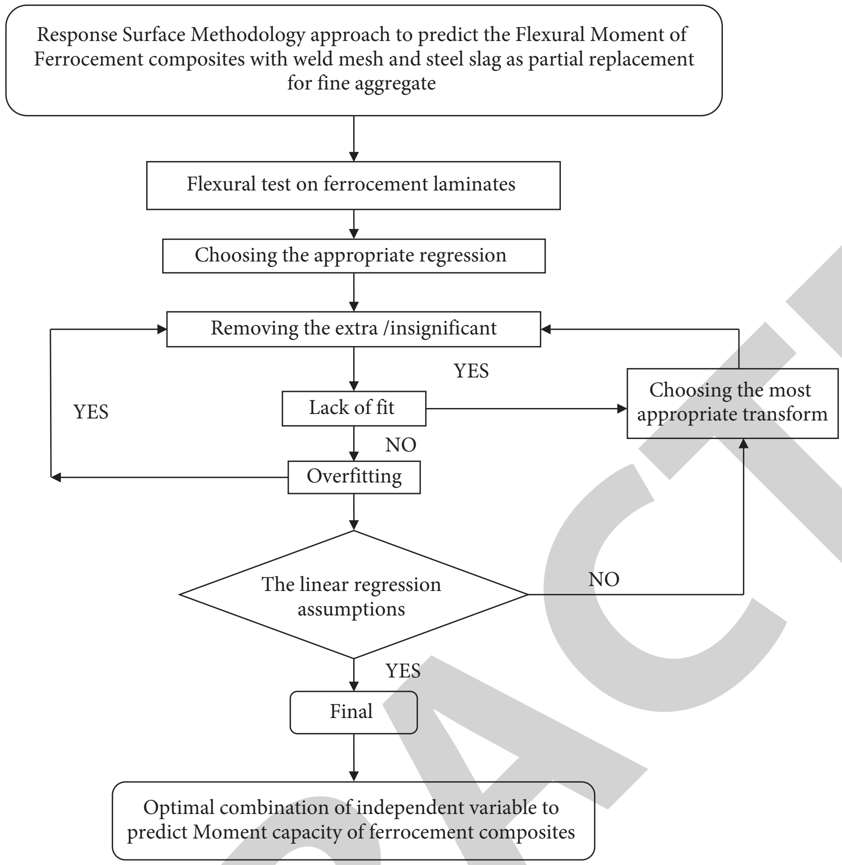

Figure 1: Step-by-step approach to achieve response models and optimisation.

Table 1: Levels of variables.

Variables	Low level (–1)	Intermediate level (0)	High level (+1)
Ferrocement volume fraction	≤ 0.01	1.425	2.35
Steel slag	≤ 0.01	25	50

aggregate. It is evident that for the lower volume fraction of galvanised square weld mesh, ultimate load and moment capacity reduces. On the other hand, for higher volume fraction, ultimate load and moment capacity increases. It is clear from the graph that for the increase in volume fraction moment capacity increases because of increased moment arm distance and increased passive confining pressure. Moreover, the diameter of weld mesh and mesh opening provides good anchorage between cement matrix and weld mesh which indirectly increases moment carrying capacity [29, 30]. The galvanised square weld mesh wires were found to be more effective in increasing the ultimate load.

5.2. RSM Modelling: Observations and Discussions. In this study, central composite design (CCD) is used to know the impact of independent parameters of volume fraction and steel slag on the ultimate load and moment capacity of ferrocement laminates. As shown in Table 3 experiments were considered to determine the response on ultimate load and moment capacity. The estimated responses are given in (3) and (4):

$$\text{ULFC} = 0.203 + 1.865(X_1) + 0.0516(X_2) - 0.320(X_1)^*(X_1) - 0.000879(X_2)^*(X_2) - 0.00486(X_2)^*(X_2), \quad (3)$$

$$\text{Moment capacity} = 13.5 + 124.3(X_1) + 3.44(X_2) - 21.33(X_1)^*(X_1) - 0.0586(X_2)^*(X_2) - 0.324(X_1)^*(X_2). \quad (4)$$

The normal probability of ultimate load and moment capacity responses are shown in Figure 4. From the figure, it is clear that all the responses fall near the straight line, which confirms that errors are evenly distributed. Analysis of variance is useful to know the relationship between autonomous variables and responses to a collection of

Table 2: Details of test specimen with galvanised square weld mesh for flexure test.

Designation	Volume fraction (X_1)	Steel slag (X_2)
FCWM01	1.425	0.0000
FCWM02	1.425	25.0000
FCWM03	2.350	0.0000
FCWM04	1.425	25.0000
FCWM05	2.350	50.0000
FCWM06	1.425	25.0000
FCWM07	0.116	25.0000
FCWM08	1.425	60.3553
FCWM09	1.425	25.0000
FCWM10	0.500	50.0000
FCWM11	0.500	0.0000
FCWM12	2.733	25.0000
FCWM13	1.425	25.0000

statistical models and it is arrayed in Table 4. From Table 4, it is evident that p value is less than 0.005 which indicates that models are highly suitable. From Table 5, it is seen that variation of predicted R^2 and the adjustable R^2 are less than 20%. Moreover, the R^2 value of ultimate load and moment capacity is 93.14%. From Figures 5 and 6, it is clear that the model arrived can be used to predict the ultimate load and moment capacity of ferrocement laminates as the predicted values go in hand with experimental results. Moreover, the models can be validated based on the F value.

5.3. Pareto Analysis and Lack of Fit (p Value). The independent variables can be considered as important and extremely important if the p value of the progression variable is < 0.005 and < 0.001, respectively. If the p value of the independent variable is more than 0.005, then it is considered as insignificant. From ANNOVA Table 4, it is clear that the p value of the linear and quadratic X_1 is less than 0.005, but the p values of the linear and quadratic X_2were higher than 0.005. So, it clearly indicates that volume fraction is highly significant for ultimate load and moment capacity. Moreover, as steel slag is higher than 0.005, the significance of steel slag is less for volume fraction and moment capacity. From the Pareto chart as shown in Figures 7(a) and 7(b), the value of linear (A) was higher when compared to linear AA, AB, and BB which shows that volume fraction is more significant than steel slag for ultimate load and moment capacity. Similarly, from ANOVA Table 4 the p value of linear $X_1$is higher when compared to X_2, which means the volume fraction is the most substantial factor in evaluating the ultimate load and moment capacity. The observations agree with previous literature which clearly states that volume fraction may enhance the ultimate load and moment capacity significantly.

5.4. Surface Plot Analysis, Contour Plot Analysis, and Optimisation of Progression Variables. Three-dimensional (3D) surface plots were plotted in Figures 8(a) and 8(b) to comprehend the effect of independent variables on the responses. In the surface plot, the independent variables volume fraction and steel slag were plotted in the "x" and "y" direction and the

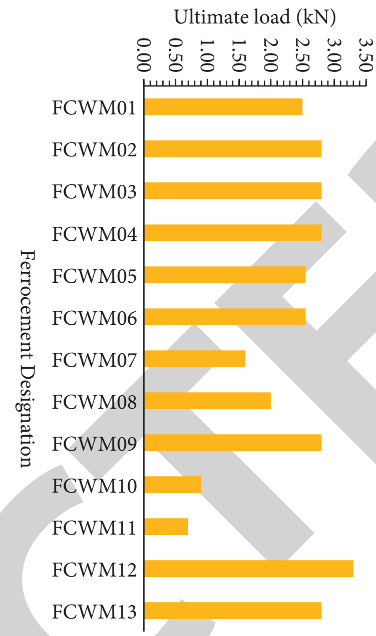

Figure 2: Ultimate load for different steel slag replacement and volume fraction of weld mesh ferrocement laminates.

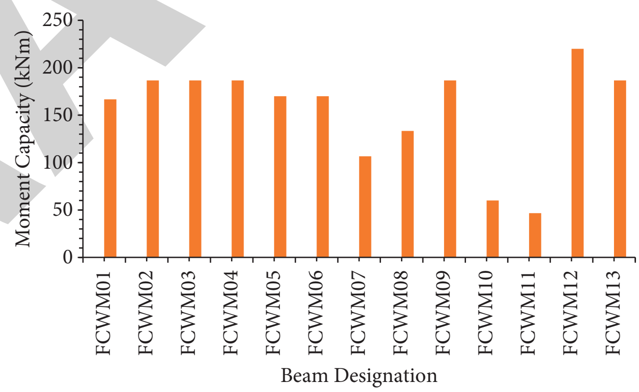

Figure 3: Moment capacity for different steel slag replacement and volume fraction of weld mesh ferrocement laminates.

Table 3: Comparison of experimental and predicted results.

Designation	Ultimate load (kN)		Moment capacity (kNm)	
	Exp	RSM	Exp	RSM
FCWM01	2.50	2.25	166.67	147.31
FCWM02	2.80	2.81	186.67	185.15
FCWM03	2.80	2.92	186.67	187.81
FCWM04	2.80	2.81	186.67	185.15
FCWM05	2.55	2.73	170.00	175.24
FCWM06	2.55	2.81	170.00	185.15
FCWM07	1.60	1.14	106.67	76.07
FCWM08	2.00	1.74	133.34	113.60
FCWM09	2.80	2.81	186.67	185.15
FCWM10	0.90	1.32	60.00	87.72
FCWM11	0.70	1.06	46.67	70.32
FCWM12	3.30	3.45	220.00	221.13
FCWM13	2.80	2.81	186.67	185.15

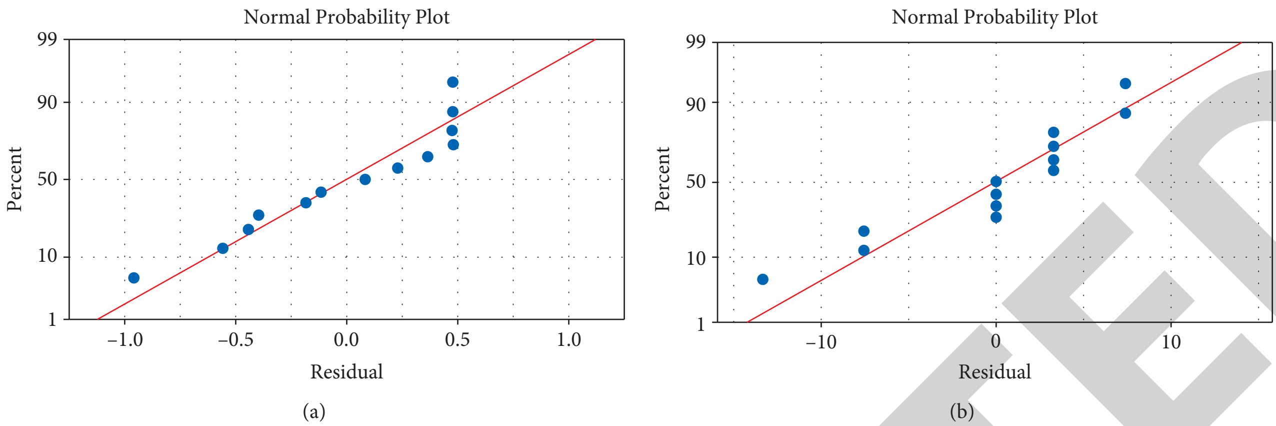

Figure 4: Normality graph of (a) ultimate load; (b) moment capacity.

Table 4: ANOVA for ultimate load and moment capacity.

Source	Ultimate load			Moment capacity		
	DF	*F*-value	*p* value	DF	*F* value	*p* value
Model	5	12.81	0.002	5	12.81	0.002
Linear	2	22.39	0.001	2	22.39	0.001
X_1	1	44.76	≤ 0.01	1	44.76	≤ 0.01
X_2	1	0.02	0.887	1	0.02	0.887
Square	2	9.08	0.011	2	9.08	0.011
X_1^2	1	5.00	0.060	1	5.00	0.060
X_2^2	1	13.83	0.007	1	13.83	0.007
Two-way interaction	1	0.48	0.511	1	0.48	0.511
$X_1 * X_2$	1	0.48	0.511	1	0.48	0.511

Table 5: proportion of variance (R^2) of the regression model.

Responses	R^2 (%)	Adjusted R^2 (%)	Predicted R^2 (%)	Difference between adjusted R^2 and predicted R^2 (%)
Ultimate load	93.14	90.10	87.23	2.87
Moment capacity	93.14	90.10	87.23	2.87

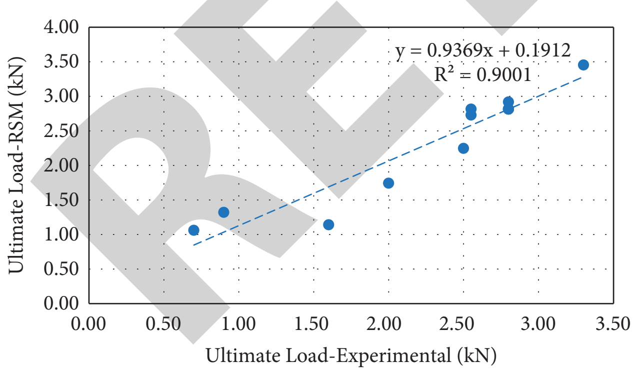

Figure 5: Predicted and actual values of ultimate load.

response ultimate load and moment capacity were plotted in the "z" axis. From Figures 8(a) and 8(b), it is understood that the increase in volume fraction from 0.5% to 2.35% increases the ultimate load and moment capacity for the ferrocement laminates, which clearly depicts volume fraction has a high significance in ultimate load and moment capacity. Although the volume fraction is the significant factor for ultimate load and moment capacity, the addition of steel slag also increases the load carrying capacity up to 25% replacement of fine aggregate by steel slag, beyond which ultimate load and moment capacity reduces. From the surface plot, it is understood that maximum ultimate load and moment capacity was obtained for the volume fraction of 2.73% and steel slag of 25% by weight of fine aggregate. From Figures 9(a) and 9(b), the contour plot which is plotted for independent variables volume fraction and steel slag shows the range of distribution of ultimate load and moment capacity. The response of the graph confirms with results obtained from 3D surface plots. The optimised ultimate load and moment capacity of ferrocement laminates are shown in Figures 9(a) and 9(b). The notations "y" and "d" plotted in Figure 9 refer to the maximum ultimate load and moment capacity value and appeal of the independent variables from zero to one, where zero indicates the undesirable variable and one represents the desirable variable. From Figures 10(a) and 10(b), it can be seen that to attain the maximum ultimate load and moment capacity, the optimal value of volume fraction and steel slag was found to be 2.73% and 21.95% of weight fraction, respectively. The validation test was executed to confirm the outcomes as shown in Table 6.

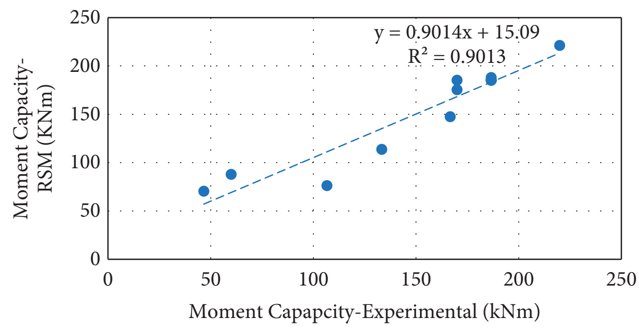

Figure 6: Predicted and actual values of moment capacity.

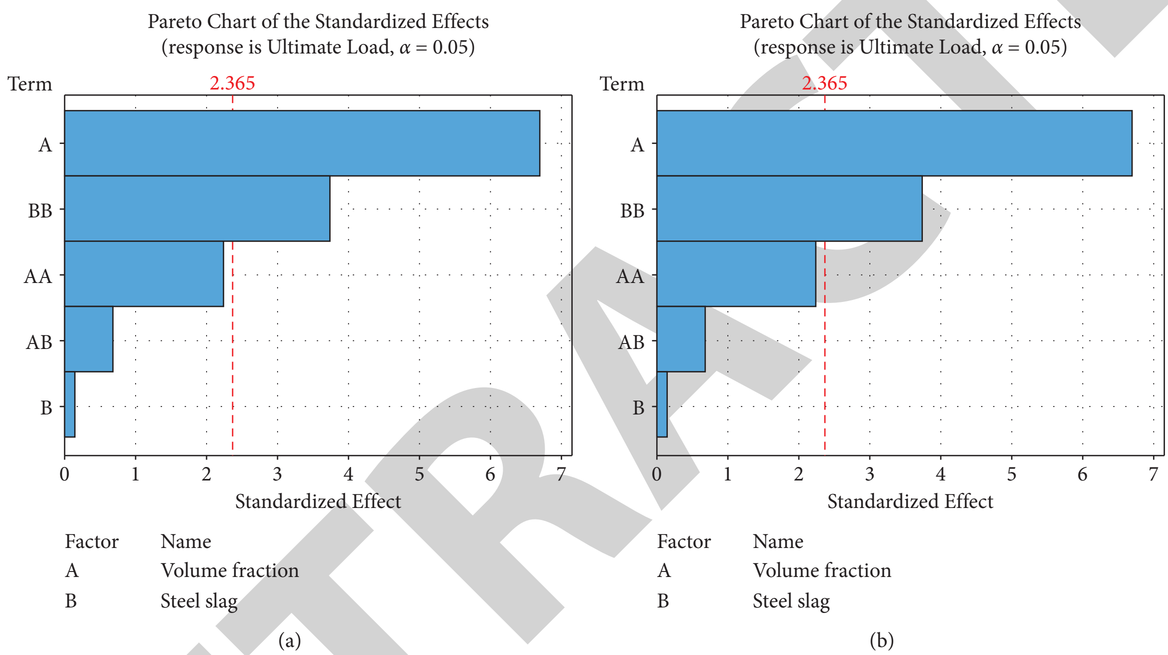

Figure 7: Pareto chart. (a) Ultimate load; (b) moment capacity.

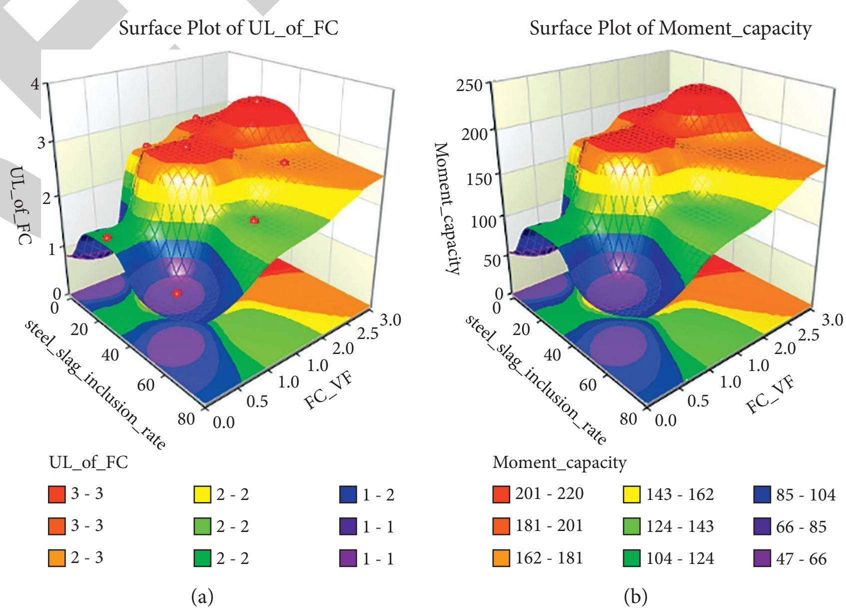

Figure 8: 3D Surface plot for: (a) ultimate load; (b) moment capacity.

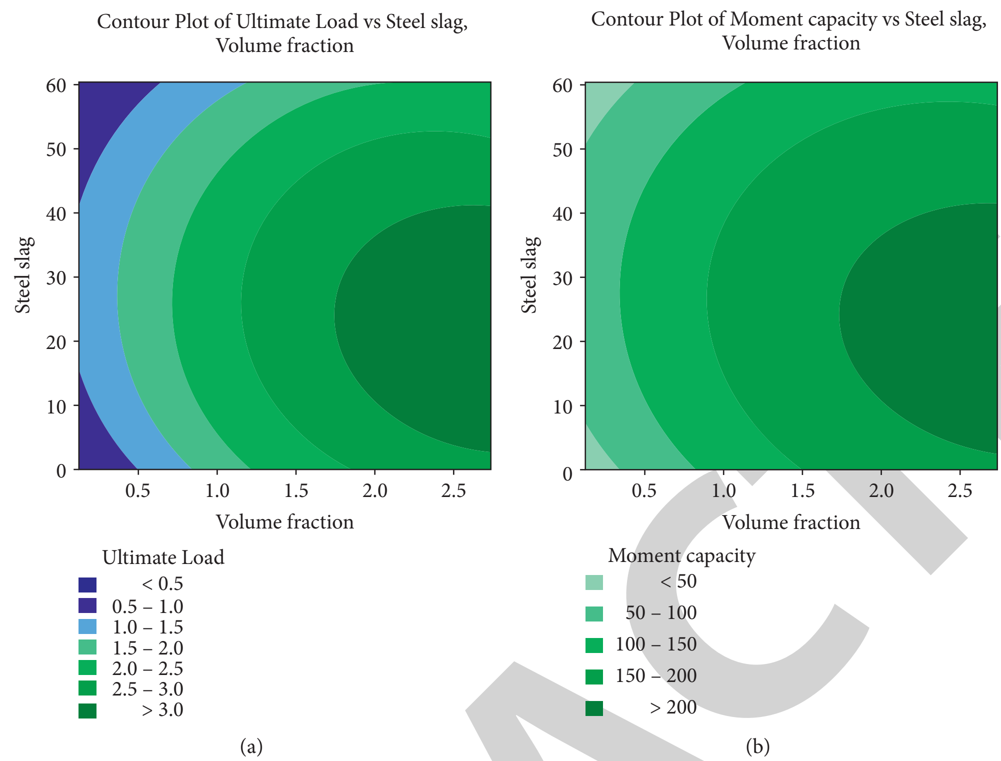

Figure 9: Contour Plot: (a) ultimate load; (b) moment capacity.

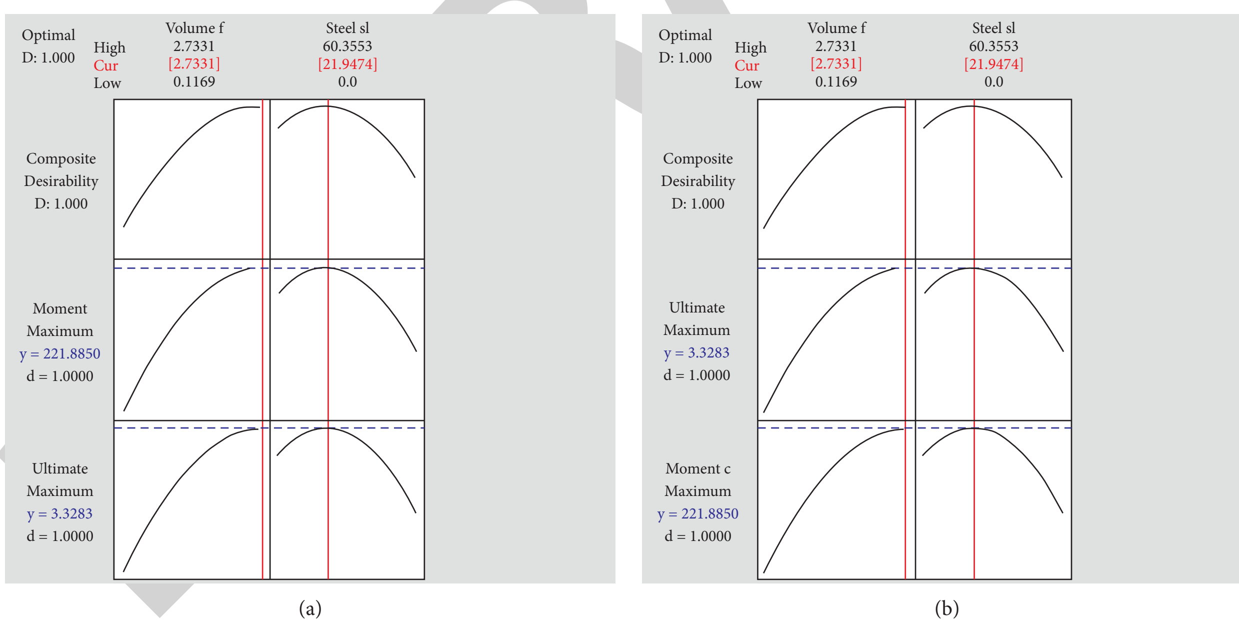

Figure 10: Response optimisation plots: (a) ultimate load; (b) moment capacity.

Table 6: Confirmation of Test results.

Properties	Volume fraction	Steel slag	Predicted result RSM	Confirmation results
Ultimate load	2.73	21.95	3.46	3.31
Moment capacity	2.73	21.95	221.73	220.56

6. Conclusions

In this present study, optimisation of ultimate load and moment capacity of ferrocement composites with different volume fractions and steel slag using the central composites method of RSM is made and the conclusions arrived are given below:

(i) The addition of steel slag has moderately enhanced the ultimate load and moment capacity of ferrocement laminates. But for higher levels of steel slag content the ultimate load and moment capacity reduces.

(ii) Ferrocement with volume fraction of 2.73% and 25% of steel slag by weight fraction of fine aggregate has improved the ultimate load and moment capacity of ferrocement laminates

(iii) A total of two responses ultimate load and moment capacity were considered in the central composite method of RSM examination, the influences and the level of each outcome were 2 and 2, respectively.

(iv) The ANNOVA results show that the most contributing factor for ultimate load and moment capacity is the volume fraction of mesh reinforcement.

(v) The model established using regression analysis to predict ultimate load and moment capacity shows that forecast values go in hand with the experimental results.

(vi) The ANOVA and Pareto chart examination showed that the regression models for ultimate load and moment capacity are highly significant. The mathematical outputs of the models are of high precision as the p value of the models was less than 0.005. The most substantial factor for ultimate load and moment capacity was found to be volume fraction (X_1).

Data Availability

The data used to support the findings of this study are included in the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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