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Application of Gene Expression Programming Model to Present a New Model for Bond Strength of Fiber Reinforced Polymer and Concrete

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ABSTRACT

In this paper, the gene expression-programming model was applied to present a novel model for the bond strength of concrete and fiber-reinforced polymer estimation. In order to do this, collected data were divided into the trained and tested ones by gene expression programming (GEP) means. The input parameters are the width of fiber-reinforced polymer, the width of concrete, thickness of fiber-reinforced polymer, the elastic modulus of fiber-reinforced polymer (FRP), concrete cylinder compressive strength, and bond length. The output parameters are the bond strength of concrete and FRP. Finally, a novel relationship was derived using the GEP to predict the bond strength of FRP -to-concrete composite joints. Results showed that the presented relationship was more convenient than the other models and that it was a powerful tool to predict the bond strength values of the FRP -to-concrete composite. For example, R-square (R2) of the present work is 0.92 compared to that (< 0.82) reported for other models. Among the models presented by other researchers, that of Dai et al. is more accurate than the other ones, and the model offered by Khalifa et al. has the lowest accuracy.

Keywords: Fiber Reinforced Polymers; Bond Strength; Gene Expression Programming; Concrete.

1. INTRODUCTION

Fiber-reinforced polymer (FRP) is built of a polymer matrix reinforced with fibers. The application of FRP is an effective method to ensure load path continuity between concrete surface and FRP. It is also used to increase the bond strength of concrete structures. Because of high strength-to-weight ratios and high corrosion resistance of FRPs, they are used to strengthen concrete structures [1-6]. For example, Singh [7] presented a new equation to estimate FRP-to-FRP bond capacity. They experimentally studied on bonded FRP-to-FRP lap joints and suggested models to calculate the bond capacity. Castillo et al. [8] presented a review of the design models of reinforced concrete structures strengthened with FRP composites. In another study, Castillo et al. [9] experimentally studied on bent FRP anchor specimens to characterize their behavior upon the occurrence of the fiber rupture failure mode. Properly designed FRP anchors can fully develop the strength of FRP strips. However, the comprehensive impact of some parameters such as the strength ratio of FRP anchor to FRP strip, the bend ratio, the spike embedment depth, and the dowel angle on the anchor strength have not been considered in existing equations. Therefore, some researchers, such as Sun et al. [10], incorporated these parameters in existing equations to improve the efficiency of current FRP anchors.

Chen et al. [11] studied the effects of FRP thickness and confining on the flexural performance of hybrid bonded FRP strengthened reinforced concrete beams. They experimentally studied some samples with and without hybrid bonded strengthening under four-point bending. They showed that when the failure mode was FRP rupture, increasing the confining effect increased the load-carrying capacity, whereas increasing the FRP thickness increased the load-carrying capacity. Externally bonded FRP system is one of the main approaches to increase the seismic capacity of reinforced concrete structures. In this regard, Castillo et al. [12] studied the seismic behavior of the reinforced concrete columns strengthened with FRP. They calculated the instant capacity of the FRP strengthened columns for the failure of the FRP sheets and FRP anchors. The authors also studied the tension-compression cyclic loading effectiveness on the capacity of the anchors and assessed its influence on column behavior with FRP transverse reinforcement.

In the past two decades, the FRP bridge deck has been a suitable alternative for the refurbishment of existing bridges because FRP has some properties such as lightweight, high strength, and high resistance. Therefore, some researchers investigated the use of FRP composites in bridges [13]. In addition to the experimental methods, some researchers used numerical approaches to simulate reinforced concrete structures anchored with FRP anchors. For example, Yang et al. [14] used the finite element method to analyze FRP-strengthened reinforced concrete test slabs anchored with FRP anchors. They also proposed a semi-empirical load-slip model for modeling the FRP anchors. Their results showed a good agreement between the numerical results and test measurements.

The bond strength between FRP composites and substrates is an important parameter in the design of FRP systems. Thus, some researchers studied the bond strength between FRP composites and substrates. For instance, Vaculik et al. [15] collated a database of some individual tests investigating the FRP-to-masonry bond strength through shear pull-tests. In their next research, Vahedian et al. [16] developed a novel theoretical model through stepwise regression analysis of some single shear FRP-to-timber joints to report the behavior of FRP externally bonded to timber. They finally presented a novel new model for the bond strength of FRP-to-timber joints determination. Their results showed a good agreement between the predicted loads and ultimate applied loads. Dai et al. [17] presented nonlinear bond stress-slip models for the FRP and concrete interface by using two parameters, namely interfacial ductility index, and interfacial fracture energy. The interfacial behaviors of bonded concrete and carbon FRP were experimentally studied by Woo and Lee [18]. New formulae were suggested for the shear bond strength estimation by Wu et al. [19]. Mashrei et al. [20] estimated the concrete-to-FRP composite joints by using the ANN method compared with available experimental data. They showed that the presented method could accurately estimate the aforementioned parameter. Zhang et al. [21] predicted the concrete-FRP bonded joints by using the model uncertainty.

Different anchorage techniques are widely applied in shear strengthened reinforced-FRP concrete systems. Therefore, some researchers evaluated the bond performance of these techniques in T-beams [22]. Lezgy-Nazargah et al. [23] studied the accuracy and reliability of available bond-slip laws for numerical modeling of FRP-concrete interfaces. A layered global-local finite element model with low degrees of freedom was also presented for the materially nonlinear analysis of reinforced concrete beams by Lezgy-Nazargah [24]. Lin et al. [25] studied the reliability of width factor models and found that plate rigidity, concrete strength, concrete width, and FRP plate width were the most important influential parameters. Cover separation, critical diagonal crack induced interfacial debonding, intermediate crack induced interfacial debonding, and plate end interfacial debonding are the different debonding failure modes in the concrete-FRP composites [26]. Kalfat and Al-Mahaidi [27] coupled the properties of bidirectional fiber patch and FRP spike anchors to make a new anchorage system with strength properties.

Gene expression programming (GEP) is a new technique for the creation of computer programs that uses character linear chromosomes composed of genes structurally organized in a head and a tail. It is a powerful tool to model the nonlinear relationships. Therefore, some researchers used GEP in different problems by estimating different parameters of concrete, such as slump, cost, and concrete strength using the GEP model [28-32]. For example, Power et al. [33] used the GEP model predict wave run up on beaches, including a wide array of beach types with varying sediment sizes and bed roughness. They showed that the presented explicit GEP model was more accurate in comparison to all other empirical models. Jafari and Mahini [34] used the GEP model to provide references for three types of lightweight concretes containing clay and natural pumice aggregates with maximum nominal sizes of 12.7 mm and 19.2 mm, respectively, and presented three equations to obtain the compressive strength of a specific mixture. Their results indicated that the proposed derivations could be a useful and practical method for engineers.

According to the literature, the external bonding of FRP composites is a popular technique for strengthening concrete structures, which is still of interest to researchers. On the other hand, GEP is a new and powerful technique for the creation of computer programs. In this paper, therefore, a novel relationship was derived using GEP to predict the bond strength of FRP and concrete composite joints.

2. METHODOLOGY

In this paper, the single-lap shear test was used to present a relationship for fundamental interface bond stress–slip and the bond strength (See Figure. 1). GEP is a new technique for the creation of computer programs that uses the character linear chromosomes composed of genes structurally organized in a head and a tail. The chromosomes function as a genome that are subjected to modification by means of mutation, transposition, root transposition, gene transposition, gene recombination, and one- and two-point recombination. The chromosomes encode expression trees, which are the object of selection. The creation of these separate entities (genome and expression trees) with distinct functions allows the algorithm to perform with high efficiency, which greatly surpasses existing adaptive techniques

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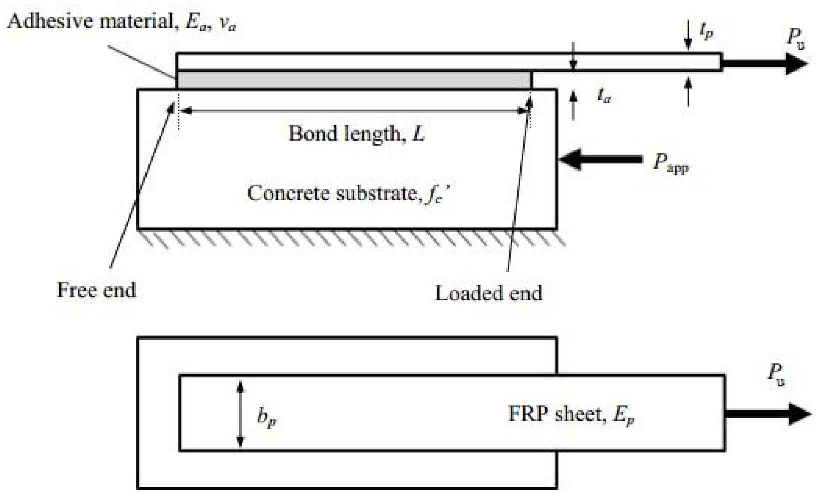


Figure 1. Single-lap shear test; a) Elevation; b) Plan form.

3. RESULTS AND DISCUSSION

In this paper, the GEP model was implemented to present a novel model for the bond strength of concrete and fiber-reinforced polymer estimation. In order do this; available data were collected from the literature, as summarized in Table 1.

Table 1. The available data collected from the literature

Reference	Bc(mm)	f'c(MPa)	Bf (mm)	tf (mm)	Ef (GPa)	L(mm)	Pu (KN)
Sharma et al. [35]	**100**	**29.7**	**50**	**1.2**	**165**	**100**	**18**
	100	**29.7**	**50**	**1.2**	**165**	**130**	**24**
	100	**29.7**	**50**	**1.2**	**165**	**150**	**28**
	100	**29.7**	**50**	**1.2**	**165**	**175**	**32**
	100	**29.7**	**50**	**1.2**	**165**	**200**	**34**
	100	**29.7**	**50**	**1.2**	**165**	**250**	**33**
	100	**29.7**	**50**	**1.2**	**165**	**300**	**34**
	100	**35.8**	**50**	**1.2**	**210**	**150**	**30**
	100	**35.8**	**50**	**1.2**	**210**	**180**	**34**
	100	**35.8**	**50**	**1.2**	**210**	**190**	**36**
	100	**35.8**	**50**	**1.2**	**210**	**200**	**36**
	100	**35.8**	**50**	**1.2**	**210**	**230**	**37**
	100	**35.8**	**50**	**1.2**	**210**	**255**	**36**
	100	**29.7**	**50**	**1.2**	**300**	**160**	**38**
	100	**29.7**	**50**	**1.2**	**300**	**180**	**41**
	100	**29.7**	**50**	**1.2**	**300**	**200**	**46**

	100	29.7	50	1.2	300	250	45
Yao et al. [36]	100	29.7	50	1.2	300	300	45
	150	23	25	0.17	256	75	5.2
	150	23	25	0.17	256	85	5.8
	150	23	25	0.17	256	95	6
	150	23	25	0.17	256	115	6
	150	23	25	0.17	256	145	6.1
	150	23	25	0.17	256	190	6.6
	150	27.1	25	0.17	256	100	5.9
	150	27.1	50	0.17	256	100	11
	150	27.1	75	0.17	256	100	14
	150	27.1	100	0.17	256	100	19
	150	18.9	25	0.17	256	95	5.6
	150	19.8	25	0.17	256	95	6.1
	150	21.1	15	0.17	256	95	4.1
	150	21.1	25	0.17	256	95	6.2
	150	21.1	50	0.17	256	95	12
	150	21.1	75	0.17	256	95	14
	150	21.1	100	0.17	256	95	15
	150	24.9	25	0.17	256	95	6.7
	150	24.9	25	0.17	256	145	6.91
	150	24.9	25	0.17	256	190	7.26
	150	24.9	25	0.17	256	240	6.7
Takeo et al. [37]	100	28.88	40	0.17	230	100	8.75
	100	26.66	40	0.17	230	100	8.85
	100	28.88	40	0.17	230	200	9.3
	100	26.66	40	0.17	230	200	8.5
	100	28.88	40	0.17	230	300	9.3
	100	26.66	40	0.17	230	300	8.3
	100	24.99	40	0.17	230	100	8.8
	100	26.17	40	0.17	230	100	8.41
	100	24.4	40	0.17	230	100	7.89
	100	24.99	40	0.33	230	100	11.4
	100	24.99	40	0.5	230	100	13.5
	100	24.4	40	0.17	230	100	11.23
	100	49.97	40	0.17	230	100	7.9
	100	24.99	40	0.11	230	100	7.7
	100	26.17	40	0.11	230	100	6.95
Toutanji et al. [38]	200	17	50	0.42	110	100	7.56
	200	17	50	0.66	110	100	9.29
Woo and Yun [39]	200	30	10	1.4	152.2	50	5.15
	200	30	10	1.4	152.2	100	7.55
	200	30	10	1.4	152.2	150	7.7
	200	30	10	1.4	152.2	200	7.9
	200	30	10	1.4	152.2	250	6.25
	200	30	10	1.4	152.2	300	7.58

	200	40	10	1.4	152.2	50	5.1
	200	40	10	1.4	152.2	100	6.85
	200	40	10	1.4	152.2	150	6.35
	200	40	10	1.4	152.2	200	6.95
	200	40	10	1.4	152.2	250	6.8
	200	40	10	1.4	152.2	300	6.4
	200	50	10	1.4	152.2	50	4.55
	200	50	10	1.4	152.2	100	7.1
	200	50	10	1.4	152.2	150	7.78
	200	50	10	1.4	152.2	200	7.65
	200	50	10	1.4	152.2	250	6.8
	200	50	10	1.4	152.2	300	7.25
	200	30	30	1.4	152.2	50	9.3
	200	30	30	1.4	152.2	100	16.25
	200	30	30	1.4	152.2	150	16.2
	200	30	30	1.4	152.2	200	22.1
	200	30	30	1.4	152.2	250	15.6
	200	30	30	1.4	152.2	300	15.85
	200	40	30	1.4	152.2	50	9.15
	200	40	30	1.4	152.2	100	14.9
	200	40	30	1.4	152.2	150	16.05
	200	40	30	1.4	152.2	200	16.15
	200	40	30	1.4	152.2	250	16.11
	200	40	30	1.4	152.2	300	16.9
	200	50	30	1.4	152.2	50	9.2
	200	50	30	1.4	152.2	100	17.8
	200	50	30	1.4	152.2	150	15.22
	200	50	30	1.4	152.2	200	18.5
	200	50	30	1.4	152.2	250	19
	200	50	30	1.4	152.2	300	17.73
	200	30	50	1.4	152.2	50	13.3
	200	30	50	1.4	152.2	100	26
	200	30	50	1.4	152.2	150	27.8
	200	30	50	1.4	152.2	200	27.2
	200	30	50	1.4	152.2	250	24.84
	200	30	50	1.4	152.2	300	23
	200	40	50	1.4	152.2	50	10.7
	200	40	50	1.4	152.2	100	24.5
	200	40	50	1.4	152.2	150	27.45
	200	40	50	1.4	152.2	200	19.3
	200	40	50	1.4	152.2	250	21.9
	200	40	50	1.4	152.2	300	27.3
	200	50	50	1.4	152.2	50	10.8
	200	50	50	1.4	152.2	100	16
	200	50	50	1.4	152.2	150	21.25
	200	50	50	1.4	152.2	200	25

	200	50	50	1.4	152.2	250	24.9
	200	50	50	1.4	152.2	300	34
Chajes et al. [40]	228.2	36.1	25.4	1.02	106	76.2	8.46
	228.2	47.1	25.4	1.02	106	76.2	10.4
	228.2	43.6	25.4	1.02	106	76.2	10.62
	228.2	24.1	25.4	1.02	106	76.2	9.87
	228.2	28.9	25.4	1.02	106	76.2	9.34
	228.2	36.4	25.4	1.02	106	50.8	8.09
	228.2	36.4	25.4	1.02	106	101.6	12.81
	152.4	36.4	25.4	1.02	106	152.4	11.92
	152.4	36.4	25.4	1.02	106	203.2	11.57
Zhao et al. [41]	150	16	100	0.08	240	100	11
	150	16	100	0.08	240	150	11.25
	150	28.63	100	0.08	240	100	12.5
	150	28.63	100	0.08	240	150	12.5
Ren [42]	150	22.39	20	0.51	83.03	150	5.81
	150	22.39	50	0.51	83.03	150	10.6
	150	22.39	80	0.51	83.03	150	18.23
	150	35.33	20	0.51	83.03	100	4.63
	150	35.33	20	0.51	83.03	150	5.77
	150	35.33	50	0.51	83.03	60	9.42
	150	35.33	50	0.51	83.03	100	11.03
	150	35.33	50	0.51	83.03	150	11.8
	150	35.33	80	0.51	83.03	100	14.65
	150	35.33	80	0.51	83.03	150	16.44
	150	43.29	20	0.51	83.03	100	5.99
	150	43.29	20	0.51	83.03	150	5.9
	150	43.29	50	0.51	83.03	100	9.84
	150	43.29	50	0.51	83.03	150	12.28
	150	43.29	80	0.51	83.03	100	14.02
	150	43.29	80	0.51	83.03	150	16.71
	150	22.39	20	0.33	207	150	5.48
	150	22.39	50	0.33	207	150	10.02
	150	22.39	80	0.33	207	150	19.27
	150	35.33	20	0.33	207	100	5.54
	150	35.33	20	0.33	207	150	4.61
	150	35.33	50	0.33	207	100	11.08
	150	43.29	20	0.33	207	100	5.78
	150	43.29	50	0.33	207	100	12.95
	150	43.29	50	0.33	207	150	16.72
	150	43.29	80	0.33	207	100	16.24
	150	43.29	80	0.33	207	150	22.8

In this step, available data were evaluated by their statistical characteristics summarized in Table 2 and Fig. 2.

Table 2. The statistical characteristics of data

Statistical Index	Bc(mm)	f'c(MPa)	Bf (mm)	tf (mm)	Ef (GPa)	L(mm)	Pu (KN)
Mean	**161.35**	**33.68**	**39.89**	**0.84**	**178.00**	**150.59**	**14.73**
Median	**150**	**3.**	**40**	**1.02**	**152.2**	**150**	**11.16**
Mode	**200**	**3.**	**50**	**1.4**	**152.2**	**100**	**34**
Standard deviation	**40.63**	**9.3**	**21.54**	**0.53**	**58.55**	**70.92**	**9.80**
Range	**128.2**	**34**	**90**	**1.32**	**216.97**	**250**	**41.9**
Minimum	**100**	**16**	**10**	**0.08**	**83.03**	**50**	**4.1**
Maximum	**228.2**	**50**	**100**	**1.4**	**300**	**300**	**46**
Sum	**24202.2**	**5051.58**	**5984**	**126.06**	**26699**	**22589**	**2210**
Count	**150**	**150**	**150**	**150**	**150**	**150**	**150**

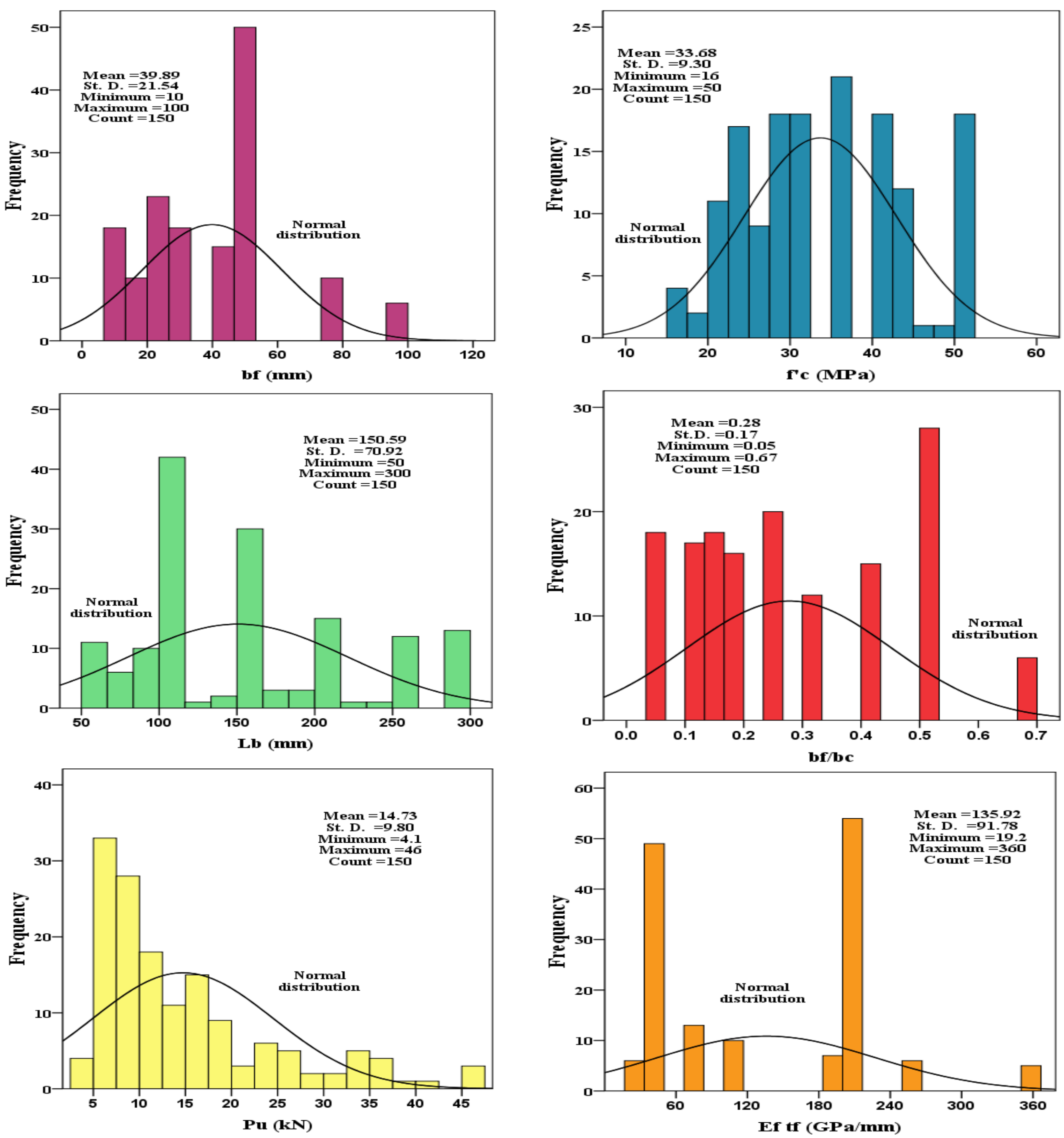


Figure 2. The statistical characteristics of the data

Based on the input parameters, the bond strength of concrete and *FRP* was defined as follows:

$$P_u = f\,(f'_c\,, b_f\,, \frac{b_f}{b_c}\,, L_b\,, E_f\,, t_f\,) \tag{1}$$

In the next step, 150 data were randomly divided into 120 and 30 sets to train and test by GEP means, respectively. Different LGP models were evaluated, and the best model was adopted in this paper, the results of which as a C++ program are shown in Figure 3. The parameters v [0], v [1], v [2], v [3], v [4], and v [5] are f'c, Bf, Bf/ Bc, L, tf, and Ef, respectively. f [0] is the output of the program.

```
float DiscipulusCFunction(float v[])
{
  long double f[8];
  long double tmp = 0;
  int cflag = 0;
  f[0]=f[1]=f[2]=f[3]=f[4]=f[5]=f[6]=f[7]=0;
  L0:      f[0]+=v[3];
  L1:      f[0]*=v[3];
  L2:      f[0]*=v[0];
  L3:      f[0]*=v[3];
  L4:      f[0]=sqrt(f[0]);
  L5:      f[0]*=v[2];
  L6:      f[0]=sqrt(f[0]);
  L7:      f[0]=sqrt(f[0]);
  L8:      f[0]*=v[4];
  L9:      f[0]*=v[5];
  L10:     f[0]+=v[1];
  L11:     f[0]*=v[2];
  L12:     f[0]=sqrt(f[0]);
  L13:
  if (!_finite(f[0])) f[0]=0;
  return f[0];
}
```

Figure 3. The best model of LGP to predict the bond strength of concrete and FRP

The derived equation using the model shown in Figure 2 was derived as follows:

$$\mathrm{P_u} = \sqrt{\frac{b_f}{b_c}(b_f + t_f E_f)\sqrt[4]{\frac{b_f}{b_c} L\sqrt{f'_c\, L}}} \tag{2}$$

To validate the presented model in this step, it was implemented to predict the bond strength of concrete and *FRP* using available data summarized in Table 1. The results (Figure 4) indicate a good agreement between the literature data and the results of the present model.

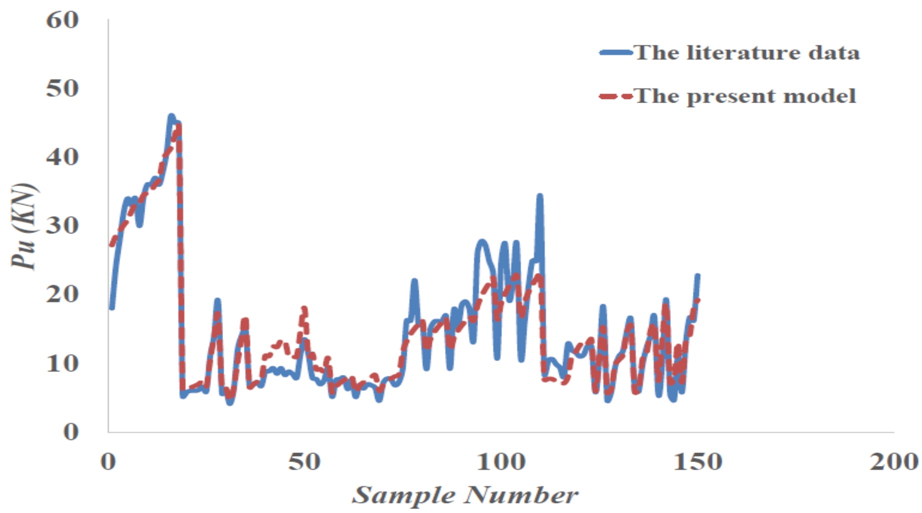


Figure 4. Comparison of the literature data and the results obtained from the present model for the bond strength of concrete and FRP.

Some models suggested by researchers for the bond strength of concrete and FRP estimation are summarized in Table 3.

Table 3. Relations for estimation of the bond strength of concrete and FRP suggested by some researchers

Researcher	Equations	
Maeda et al. [43]	$P_u = b_f L_e (110.2 \times 10^{-6} E_f t_f)$	$L_e = e^{6.13-0.58 \ln E_f t_f}$
Khalifa et al. [44]	$P_u = b_f L_e \left[\frac{110.2}{10^6} \left(\frac{f'_c}{42} \right)^{2/3} E_f t_f \right]$	
Chen and Teng [45]	$P_u = 0.315 \beta_w \beta_1 b_f L_e \sqrt{f'_c}$	$\beta_w = \sqrt{\frac{2 - b_f / b_c}{1 + b_f / b_c}}$ $\beta_1 = \begin{cases} 1 & \text{if } L \geq L_e \\ \sin \frac{\pi}{2} \frac{L}{L_e} & \text{if } L < L_e \end{cases}$ $L_e = \sqrt{\frac{E_f t_f}{\sqrt{f'_c}}}$
Dai et al. [17]	$P_u = (b_f + 2\Delta b_f)\sqrt{2 E_f t_f G_f}$	$G_f = 0.254 (f_c^{'})^{0.236}\ N/mm$ $\Delta b_f = 3.77$ mm

In this step, these models were employed to predict the bond strength of concrete and *FRP* using available data summarized in Table 1. The results are shown in Figure 5.

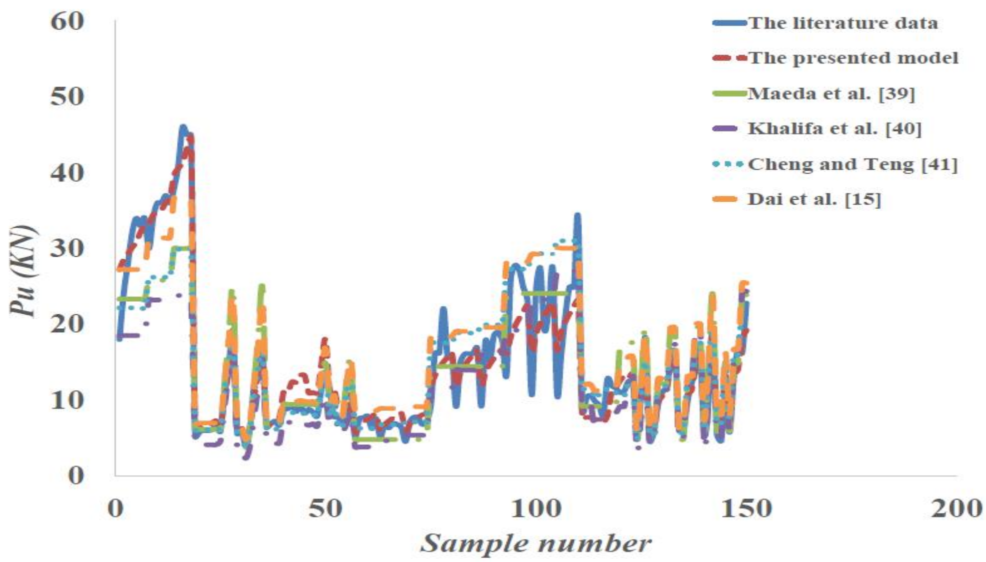


Figure 5. Comparison of the literature data and the results obtained from the existing models for the bond strength of concrete and FRP

In this step, Relative Error (RE) was estimated for different methods, and the results are shown in Figure 6.

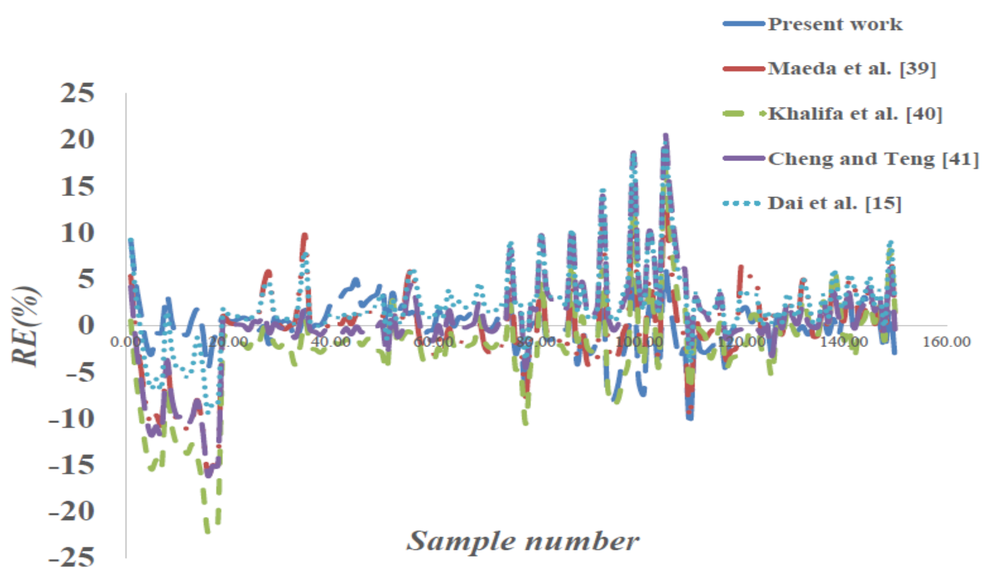


Figure 6. Comparison of the Relative Error (RE) of different models

Furthermore, some criteria between the experimental and predicted values were used as follows:

$$R = \frac{\sum_{i=1}^{n}(h_i - \bar{h}_i)(t_i - \bar{t}_i)}{\sum_{i=1}^{n}(h_i - \bar{h}_i)^2 \sum_{i=1}^{n}(t_i - \bar{t}_i)^2} \tag{3}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(h_i - t_i)^2}{n}} \tag{4}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|h_i - t_i| \tag{5}$$

Herein, the statistical characteristics of the present model and other reported models are summarized in Table 4.

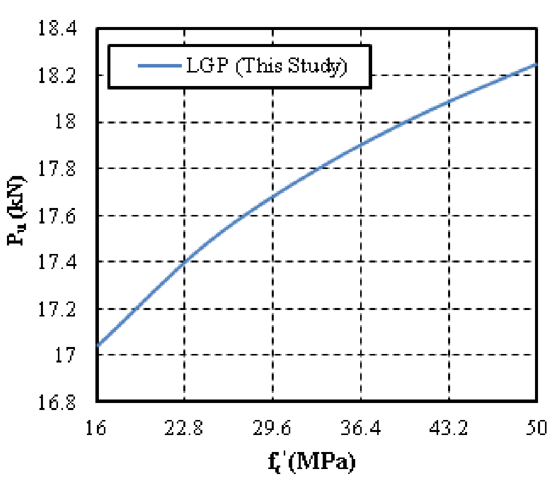
Table 4. Comparison of the statistical characteristics of the present model and other reported models

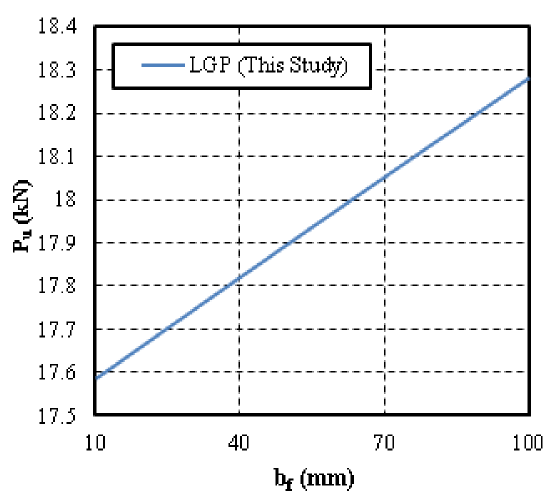
Statistical Characteristic	R	R2	RMSE	MAE	Max |RE|
Saghi et al. (Present work)	**0.96**	**0.92**	**2.73**	**1.92**	**10.89**
Maeda et al. [43]	**0.87**	**0.76**	**4.85**	**3.30**	**16.01**
Khalifa et al. [44]	**0.83**	**0.68**	**6.08**	**4.03**	**22.19**
Chen and Teng [45]	**0.84**	**0.71**	**5.28**	**3.14**	**20.21**
Dai et al. [17]	**0.91**	**0.82**	**4.65**	**3.31**	**19.24**

The results show that the suggested relationship is more accurate than other reported models. For example, R-square (R2) of the present work is 0.92, while this parameter is less than 0.82 for other reported models. Based on the RMSE criterion, the current study, Dai et al. [5], Maeda et al. [43], Chen and Teng [45], and Khalifa et al. [44] are the highest accuracy, respectively. But, based on the MAE criterion, the current study, Maeda et al. [43], Dai et al. [5], Chen and Teng [45], and Khalifa et al. [44] are the highest accuracy, respectively. By considering the Max |RE |criterion, we can see that the current study, Maeda et al. [43], Dai et al. [5], Chen and Teng [45], and Khalifa et al. [44] are the highest accuracy, respectively. So, among the models presented by other researchers, that of Dai et al. [5] is more accurate than the others, and the model offered by Khalifa et al. [2] has the lowest accuracy.

3.1. Parametric study of the presented model

In this step, a parametric study was conducted on the terms of the proposed model, and the results are shown in Figure 7. As expected, there is a logical relationship between the bond strength of concrete and *FRP* with the independent variables (width of *FRP* (b_f), width of concrete (b_c), thickness of *FRP* (t_f), elastic modulus of *FRP* (E_f), concrete cylinder compressive strength (f'_c), and Bond length (L)).





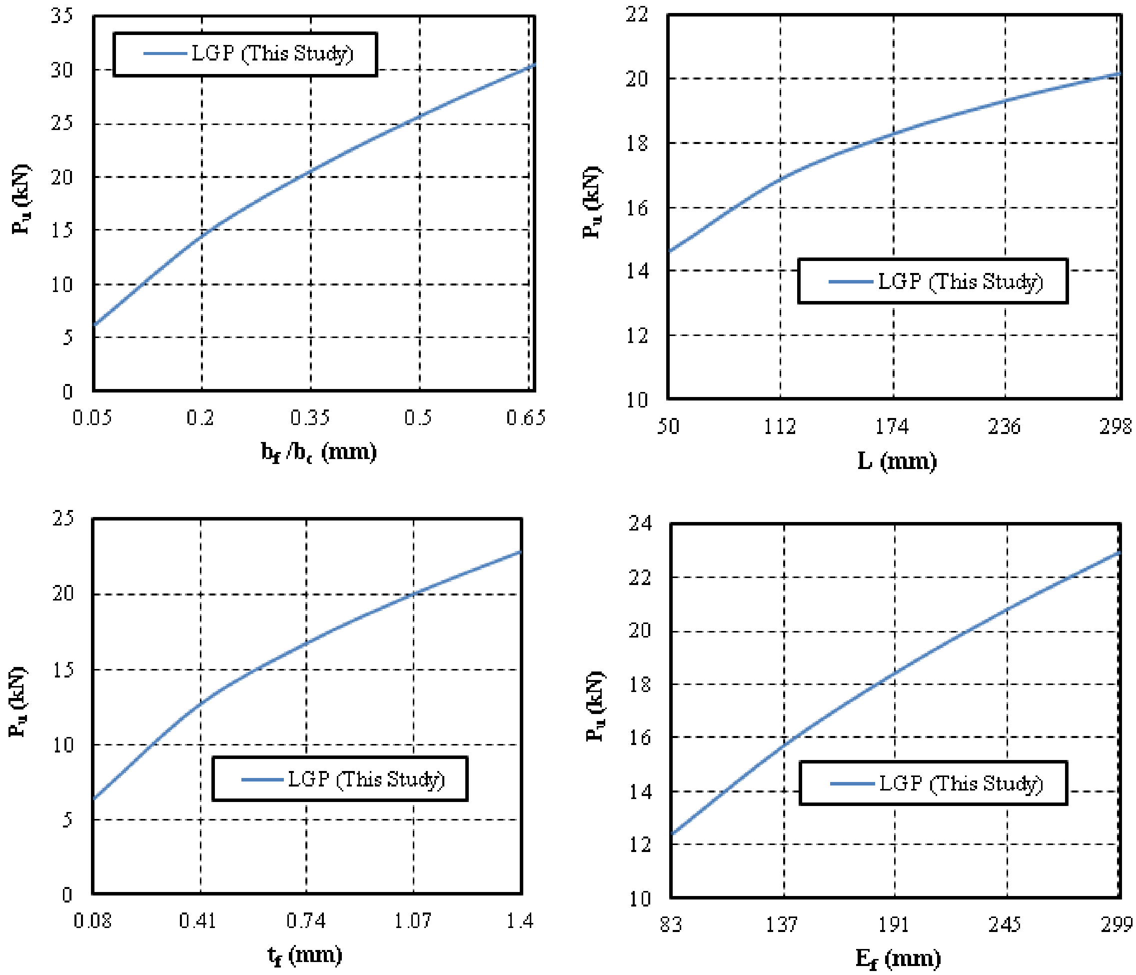


Figure 7. Parametric study of the independent terms in the present model

4. CONCLUSION

In this paper, *GEP* was used to present a novel relationship to predict the bond strength of *FRP* and concrete composite joints. In order to do this, available data were divided into trained and tested ones. The input parameters, including the width of *FRP*, the width of concrete, the thickness of *FRP*, the elastic modulus of *FRP*, concrete cylinder compressive strength, and bond length, were used as input parameters. These parameters were applied in the *GEP* model to present a novel relationship. According to the results, the suggested relationship is more accurate than the other models. For example, R-square (R^2) of the present work is 0.92 compared to that (< 0.82) reported for other models. Among the models presented by other researchers, that of Dai et al. is more accurate than the other ones, and the model offered by Khalifa et al. has the lowest accuracy.

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AUTHORS CONTRIBUTION

The authors declare that they have no conflict of interest.

CONFLICT OF INTEREST

The author (s) declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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