

Research Article

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Study and prediction analysis on road performance of basalt fiber permeable concrete

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Abstract: To analyze the influence of basalt fiber on the performance of permeable concrete for road applications, this study focuses on two key performance indicators: compressive strength and permeability coefficient of basalt fiber permeable concrete. Based on orthogonal experimental data, regression prediction equations were established using SPSS software to assess the effects of different fiber parameters on the compressive strength and permeability coefficient. The predicted results were then compared with experimental data. The findings indicate that the average relative error of the predicted values for both performance indicators is within a manageable range of 5%, demonstrating a high prediction accuracy. Using these regression equations, we can examine the variations in the road performance of basalt fiber permeable concrete under different fiber parameter conditions, thereby overcoming the limitations of conducting numerous parameter analysis experiments.

Keywords: basalt fiber, pervious concrete, orthogonal experiment, prediction research

1 Introduction

Pervious concrete, also known as sandless concrete, is composed of coarse aggregate, cement, reinforcements, and water [1–4]. Unlike traditional concrete, pervious concrete does not contain fine aggregates in its production process.

This results in significant internal pores within the concrete, where pressure is primarily distributed among the contact points between aggregates. As a consequence, pervious concrete generally has lower strength compared to traditional concrete. Due to these characteristics, pervious concrete is commonly used in areas such as parks and sidewalks, which experience lighter loads [5–7].

Fiber-reinforced pervious concrete is a type of composite material that uses randomly dispersed fibers with specific geometric shapes to enhance the mechanical properties of pervious concrete [8]. This unique combination between fiber and pervious concrete effectively bonds aggregates, thereby improving its mechanical strength [9–11]. Additionally, the presence of fibers facilitates the formation of interconnected pores, significantly enhancing water permeability [12–15].

Basalt fiber, an environmentally friendly material, possesses several advantages, including corrosion resistance, high temperature resistance, aging resistance, and high tensile strength [16,17]. This makes it an ideal choice for reinforcement in concrete. Basalt fiber has been widely used in reinforcement tests for concretes due to its good dispersion in the mixing process and excellent workability when combined with concrete materials [18,19]. In fact, as early as 1922, Dhe [20] first applied basalt fiber to concrete and discovered its strong affinity with cement.

In 2021, Liang [21] conducted a study on the effects of basalt fiber and polypropylene fiber on the mechanical properties of pervious concrete. The results indicate that the group with a basalt fiber content of 0.6% achieved a peak compressive stress of 31.62 MPa, while the group with a polypropylene fiber content of 0.6% achieved a peak compressive stress of 30.34 MPa. A study by Bright and Madasamy [22] investigated the impact of carbon fiber and basalt fiber, ranging from 0 to 0.4%, on the mechanical properties of pervious concrete. The results indicate that compared to plain pervious concrete, the addition of 0.3% basalt fiber increased the peak stress for compressive strength by 3.76%, and the addition of 0.2% carbon fiber increased it by 11.59%. Similarly, for splitting tensile strength, the addition of 0.3% basalt fiber increased the peak stress by 15.26%, and the addition of 0.2% carbon fiber increased it by 32.7%.

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In 2021, Li et al. [23] conducted tests on the compressive strength and splitting tensile strength of pervious concrete using different lengths and contents of basalt fibers. Their findings suggest that the specimens exhibited optimal compressive and splitting tensile properties when the fiber content was at a level of 0.07% and the fiber length was 12 mm. Wu et al. [24] studied the mechanical properties of pervious concrete through laboratory testing using five different levels of basalt fiber content. Their results show an initial increase in both flexural strength and compressive strength with the addition of fiber content, followed by a decrease upon further increase in fiber content.

In 2018, Chen [25] established regression equations to investigate the relationship between different fiber contents and the permeability coefficient and porosity of permeable concrete. The study revealed that the porosity and permeability coefficient of fiber permeable concrete are linearly correlated with the fiber content. The best fitting accuracy was observed when the fiber length was 24 mm, with the respective values of 0.98 and 0.97. In 2018, Xue [26] examined the influence of varying basalt fiber contents (0.1, 0.2, 0.3%) on the permeability coefficient of permeable concrete. The findings indicated that the highest permeability coefficient of 6.86 mm/s was achieved when the fiber content was 0.3%. In 2020, Wang [27] studied the impact of different basalt fiber diameters, lengths, and contents on the permeability coefficient of permeable concrete. The research results demonstrated that within a certain parameter range, fiber diameter and length exhibited a positive correlation with the permeability coefficient. Additionally, the permeability coefficient decreased as the fiber content increased, with the maximum value of 5.32 mm/s occurring at a fiber content of 2 kg/m³. The influence of different basalt fiber diameter, length, and content on the pervious performance of pervious concrete was investigated by Liu [28] in 2021 using an orthogonal test. The results show that the order of influence of different material parameters on the permeability coefficient of pervious concrete is as follows: the fiber content is greater than the fiber length, which is greater than the fiber diameter. When the fiber content is 2 kg/m³, the fiber length is 24 mm, and the fiber diameter is 20 μ m, the permeability coefficient of fiber pervious concrete reaches the maximum.

In general, there has been a considerable amount of research focused on indoor testing of fiber permeable concrete pavement performance. However, there is comparatively limited research when it comes to predicting pavement performance. It has been observed that many scholars have turned to the linear regression method to predict material properties by considering different material parameters [29–35]. In this study, the multiple linear regression analysis method was used to establish regression equations for the compressive strength and permeability coefficient of basalt fiber pervious concrete. These equations were developed based on the outcomes of indoor orthogonal tests, taking into account the influence of various fiber parameters. The accuracy of the equations was then confirmed by comparing the experimental results with the predicted values. Overall, the research findings have significant implications for both the theoretical exploration and practical application of basalt fiber permeable concrete materials.

2 Experimental materials and methods

2.1 Experimental materials

The coarse aggregates used in this study were 5–10 mm uniformly sized crushed stones, with specific performance parameters outlined in Table 1. These aggregates comply with the requirements of Class II crushed stones for construction, as stated in “Aggregates for Construction” (GB/T14685). The cement used was Wanxia brand P.O42.5 ordinary Portland cement, with technical specifications detailed in Table 2. Basalt fibers were chosen in nine different specifications: diameters of 13, 14, and 15 μ m and lengths of 12, 15, and 18 mm. The physical and mechanical properties of these basalt fibers are provided in Table 3. To enhance the fiber-reinforced pervious concrete, a high-performance water-reducing agent with a reduction rate of 37% and silica fume were used. In the experiments, water from the laboratory was used.

Table 1: Performance index of coarse aggregate

Aggregate size (mm)	Flake particle content (%)	Apparent density (kg/m ³)	Packing density (kg/m ³)	Accumulation porosity (%)
5–10	6	2,990	1,670	44.15

Table 2: Technical specifications of cement

Species	Density (g/cm ³)	Compressive strength		Flexural strength	
		3 day	28 day	3 day	28 day
P.O 42.5	3.13	25.8 MPa	46.5 MPa	5.2 MPa	8.1 MPa

Table 3: Physical and mechanical properties index table of basalt fiber

Diameter (μm)	Length (mm)	Density (g/m ³)	Elastic modulus (GPa)	Tensile strength (MPa)	Elongation at break (%)
13, 14, 15	12, 15, 18	2.65	95–115	3,300–4,500	2.4–3.0

2.2 Design of mix proportion

The proportion of materials is of utmost importance as it significantly influences the performance of the permeable concrete pavement. This study refers to previous works [12,27,28] and determines a water-to-cement ratio of 0.3 for the permeable concrete. According to the “Technical Specification for Permeable Cement Concrete Pavement” (CJJ/T135-2009), the porosity of the permeable concrete should be controlled within the range of 15–30%. To ensure the strength of the permeable concrete, a target porosity of 15% is set, with a silica ash content of 5% and a water-reducing agent content of 0.5%. The proportions of the permeable concrete mixture are outlined in Table 4.

2.3 Experimental program

2.3.1 Mechanical property test

The compressive strength test in this case was conducted using non-standard specimens with dimensions of 100 mm × 100 mm × 100 mm. After curing the specimens for 28 days in a curing room, the surface moisture was wiped dry. The specimens were then placed in the center of the platen of a hydraulic pressure testing machine, and the parameters of the machine were adjusted for the compressive strength test. According to the “Standard Test Methods for Mechanical Properties of Ordinary Concrete” (GB/T50081-2002), when using non-standard specimens of

100 mm × 100 mm × 100 mm to determine the compressive strength, the results need to be multiplied by a conversion coefficient of 0.95 to obtain the standard compressive strength measurement, accounting for the size difference. For concrete strength grades lower than C60, a continuous load of 0.5 MPa per second was applied until the specimen was crushed, and the maximum compressive strength of the pervious concrete was recorded. The equipment used in the test process was a computer-controlled electro-hydraulic servo hydraulic pressure testing machine, as shown in Figure 1. Figure 2 depicts the appearance of the specimen after the compressive strength test and its subsequent destruction.

2.3.2 Determination of water permeability coefficient

The water permeability coefficient is measured using a laboratory-developed water permeability coefficient tester, as shown in Figure 3. The measurement is conducted using the traditional fixed head method [4]. To ensure that only one side of the test block is permeable, the surrounding area is sealed with cement slurry, as depicted in Figure 4. Subsequently, the test block is dried and soaked in water for a period of 24 h. Once the test block is fully saturated, it is placed at position 4 in Figure 3 and securely sealed with plasticine to prevent any water leakage from the sides. The water supply system is then activated, and the water flow rate is maintained constant. Once the water output from the overflow port and the water outlet stabilize, the amount of water, denoted as Q , is measured during

Table 4: Mixture ratio table of permeable concrete

Coarse aggregate (kg/m ³)	Cement (kg/m ³)	Water (kg/m ³)	Silica fume (kg/m ³)	Water-reducing agent (kg/m ³)
1685.4	396.66	125.26	20.9	2.09



Figure 1: Microcomputer-controlled electro under-hydraulic servo hydraulic press.

a specified time interval, denoted as t . The water permeability coefficient is calculated using the following equation [27]:

$$K = \frac{Q \times L}{A \times h \times t}, \quad (1)$$



Figure 2: The specimen is damaged pressure.

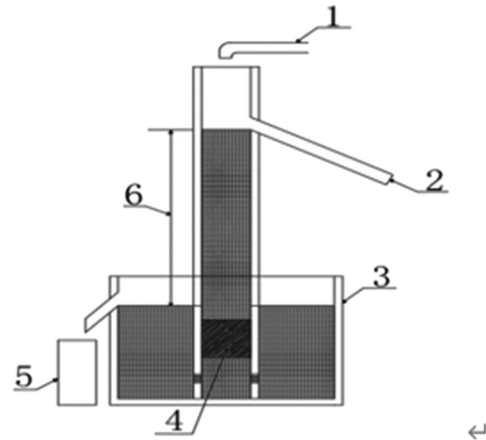


Figure 3: Water permeability coefficient tester.

where K is the water permeability coefficient of permeable concrete, Q is the amount of water flowing through the permeable concrete specimen in t minutes, L is the permeable concrete specimen height, A is the cross-sectional area of the pervious concrete specimen, h is the water head difference (6 in Figure 3), t is the time measured.

3 Orthogonal experimental design

By studying the impact of various factors on the performance of permeable concrete, it has been found that studying the influence of single factors is not comprehensive enough,



Figure 4: Surrounding with cement.

Table 5: Orthogonal test factors and level table

Level	Diameter (μm)	Length (mm)	Content (kg/m ³)	Stirring method
Level 1	13	12	2	—
Level 2	14	15	4	二
Level 3	15	18	6	三

while studying the impact of multiple factors requires a large number of experiments. Consequently, research suggests that the use of orthogonal experimental design can yield favorable results while reducing the number of experiments required [16]. Therefore, this study adopts an orthogonal experimental design for the experimental plan.

For studying basalt fiber different indicators (length, diameter, content) and the way of mixing of basalt fiber waterproof concrete compressive strength and the influence law of permeable coefficient, this study uses the four factors and three levels of L9(3⁴) orthogonal table, a total of nine groups of test plan, test factors, and levels, as shown in Table 5. According to the literature [27,28], there are

mainly three kinds of mixing methods as shown in Table 6, among which 1) one-time feeding method: first add coarse aggregate and basalt fiber to the machine for 30 s, then add cement and silica for 25 s, then add 50% of the total water for 35 s, and finally add the remaining water and water-reducing agent for 120 s; 2) premixed cement slurry method: first add cement and silica fume into the mixer, then add water and water-reducing agent for mixing for 60 s, and finally add coarse aggregate and basalt fiber for mixing for 150 s; and 3) cement-wrapped stone method: the first coarse aggregate and basalt fiber into the mixer for 30 s, then add the total water 20% of the water for 30 s, finally, add silica, cement, water-reducing agent for mixing for 150 s. The process of stirring method is shown in Figure 5. The corresponding four-factor three-level design table is shown in Table 7.

The compressive strength for each group is determined by conducting three tests, and the average value of the compressive strength of the three specimens is used as the value for that group. If the difference between the median value and either the maximum or minimum value exceeds 15%, the median value is considered as the

Table 6: Mixing modes of pervious concrete

Stirring method	—	二	三
Stir name	One-time addition method	Ready-mixed cement paste method	Cement-wrapped stone method

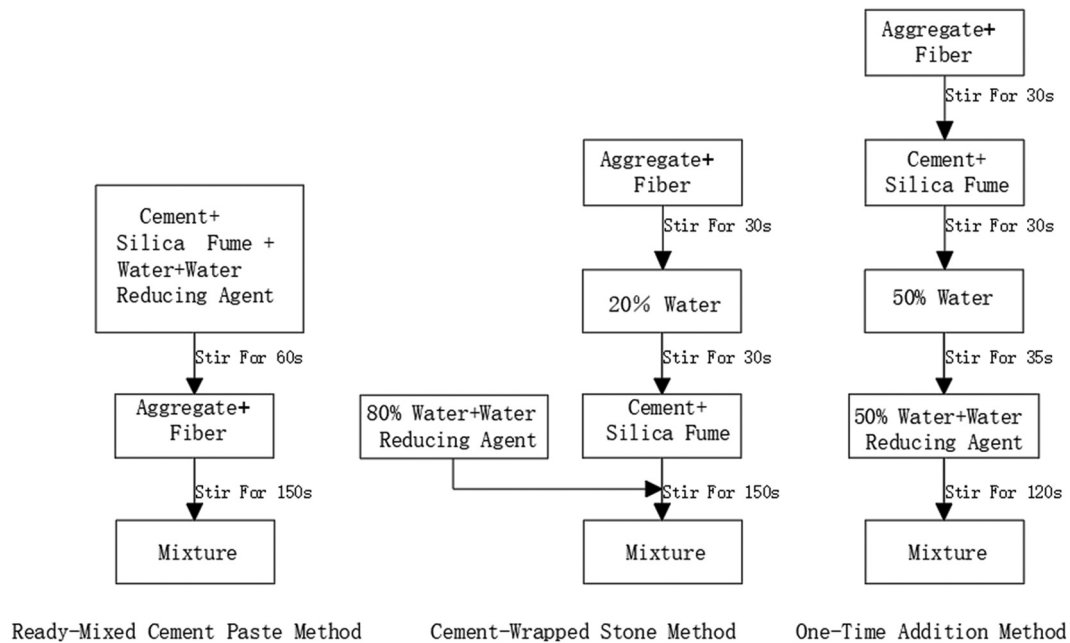
**Figure 5:** Flow chart of mixing method.

Table 7: Four-factor three-level orthogonal design table

Group number	Factor one	Factor two	Factor three	Factor four
Group 1	1	1	1	1
Group 2	1	2	2	2
Group 3	1	3	3	3
Group 4	2	1	2	3
Group 5	2	2	3	1
Group 6	2	3	1	2
Group 7	3	1	3	2
Group 8	3	2	1	3
Group 9	3	3	2	1

compressive strength value for that group. If both the maximum and minimum values differ from the median value by more than 15%, the data for that group are discarded. For the permeability coefficient, three tests are conducted for each group, and the final result is obtained by averaging the three permeability coefficient values. Based on the orthogonal experiment results in Table 8, the values of compressive strength and permeability coefficient for each group can be observed.

4 Multiple linear regression equation establishment

4.1 Introduction

Multiple linear regression analysis is a statistical analysis method that determines the linear or non-linear relationship between a dependent variable and multiple independent variables. The general form of the multiple linear regression equation [31] is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \mu, \quad (2)$$

where n is the number of explanatory variables, β_i ($i = 1, 2, \dots, n$) is the regression coefficient, and μ is the random error.

After the parameters of the sample regression equation are determined, the regression equation needs to be tested for goodness of fit (R^2), equation significance test, and significance test between variables [32] to judge the reliability of the equation.

- 1) Goodness-of-fit (R^2) test: The R -squared is a statistical measure used to evaluate how well a regression model fits the observed values of a sample. R -squared is a value between 0 and 1, where a lower R -squared indicates a weaker fit and an R -squared closer to 1 indicates a better fit.
- 2) Test of overall linear significance of the equation: The t -value and significance (sig) value are both used to assess the overall linear significance of the equation. The sig value is the key factor in determining whether there is a significant impact of at least one independent variable (X) on the dependent variable (Y) in the regression equation. The sig value is used to conduct a significance test, where a sig value between 0.01 and 0.05 indicates significance and a sig value less than 0.01 indicates high significance. The t -value, on the other hand, is used to assess the individual significance of parameters in the regression equation. Generally, a t -value greater than 3 suggests a significant influence of the variable on the regression equation.
- 3) Diagnosis of collinearity between variables: Collinearity between variables can be assessed using the variance inflation factor (VIF). A VIF value between 5 and 10 suggests a moderate level of collinearity, while a VIF exceeding 10 indicates a severe collinearity issue. When collinearity is present, it may lead to regression coefficients showing the opposite sign from the actual relationship, causing significant variables to become insignificant, and *vice versa*. A

Table 8: Summary table of orthogonal experiment results

Group	Diameter (μm)	Length (mm)	Content (kg/m^3)	Stirring method	Compressive strength (MPa)	Water permeability coefficient (mm/s)
①	13	12	2	—	18.98	2.77
②	13	15	4	二	19.16	3.67
③	13	18	6	三	20.91	5.01
④	14	12	4	三	17.8	4.23
⑤	14	15	6	—	18.82	4.63
⑥	14	18	2	二	19.5	5.01
⑦	15	12	6	二	17.5	4.76
⑧	15	15	2	三	18.22	5.01
⑨	15	18	4	—	18.89	5.32

positive regression coefficient indicates a positive correlation between two variables, with a higher coefficient indicating a stronger relationship. Conversely, a negative coefficient suggests a negative correlation, with a smaller coefficient value representing a stronger association.

4.2 Regression equation of compressive strength and water permeability coefficient

The sample data used for the regression equation in this text are obtained from experimental data generated using orthogonal experiments in Section 3. The regression equation is selected as follows: the dependent variables are the compressive strength (Y_1) and permeability coefficient (Y_2) of basalt fiber pervious concrete. The independent variables include the diameter of basalt fiber (X_1), the length of basalt fiber (X_2), the content of basalt fiber (X_3), and the mixing method (X_4).

Use the stepwise regression algorithm in the SPSS software to establish a multiple linear regression equation for the compressive strength and permeability coefficient of basalt fiber pervious concrete in relation to the diameter, length, content, and mixing method variables of basalt fiber. It is suggested to eliminate the dependent variables from the fitted results if their significance levels are less than 0.05 [33].

4.2.1 Compressive strength regression equation

Based on the SPSS output, it is evident that the mixing method and fiber content have shown relatively weaker

Table 9: Summary table of compressive strength regression equation

Regression equation	R	R^2	Adjusted R^2	F change
1	0.961	0.924	0.899	36.459

Table 10: Coefficient of compressive strength regression equation

Regression equation	Non-standardized coefficient		Standardization factor	t	Sig	Collinearity statistics	
	B	Standard error	Beta			Tolerance	VIF
Constant	25.041	1.947		12.858	0.001		
Diameter	-0.74	0.131	-0.637	-5.657	0.001	1.00	1.00
Length	0.279	0.044	0.720	6.396	0.001	1.00	1.00

significance in terms of their influence on the compressive strength of pervious concrete. Therefore, these two factors were excluded from the process of creating the regression equation for compressive strength. The summarized table (Table 9) and coefficient table (Table 10) for the compressive strength regression equation provide further details.

1) Goodness-of-fit test of compressive strength

It can be seen from Table 9 that the goodness of fit is $R = 0.961$, and $R^2 = 0.924$ is close to 1, the regression equation has a high degree of fit, and the independent variable can explain 92.4% of the change in the dependent variable.

2) Overall linearity test of compressive strength equation

The results indicate that the significance values for the fiber content (X_3) and mixing method (X_4) are 0.796 and 0.550, respectively, both of which are greater than the significance level of 0.05. Therefore, the significance is poor. Consequently, these two factors are excluded. The regression results, as shown in Table 8, reveal that the significance values for the basalt fiber diameter (X_1) and basalt fiber length (X_2) are 0.01, which are below the significance level of 0.05. This suggests a significant linear relationship between the independent variables and the dependent variable.

3) Compressive strength collinearity diagnosis

Based on the information given in Table 10, the VIF for variables X_1 and X_2 is 1, which is below the threshold of 5. This indicates that there is no problem of multicollinearity between X_1 and X_2 .

The B column in the table represents the non-standardized coefficients, and the standardized coefficient column represents the regression coefficients of the equation. The standardized regression coefficients are obtained by standardizing the data (subtracting the mean and dividing by the standard deviation), which removes the influence of measurement units. These coefficients measure the importance of the independent variables in relation to the dependent variable. By standardizing the data, we can compare the importance of different variables, and the magnitude of the coefficients indicates the extent of the

independent variables' impact on the dependent variable. On the other hand, the non-standardized coefficients explore the change in the dependent variable when the independent variable changes by one unit. In this article, the equation composed of standardized coefficients is referred to as the "regression equation," which allows for comparing the importance of variables. The equation composed of non-standardized coefficients is defined as the "regression prediction equation," which is used for making actual predictions.

According to the standardized coefficient column, the regression equation of compressive strength and fiber diameter and length is as follows:

$$Y_1 = -0.637X_1 + 0.72X_2. \quad (3)$$

According to Table 10, it is evident that the absolute value of the fiber diameter coefficient is 0.637 and the absolute value of the fiber length coefficient is 0.72. This indicates that the length of the fiber has a greater influence on the compressive strength of permeable concrete. The fiber diameter coefficient has a negative value, while the fiber length coefficient is positive. Hence, there exists a negative correlation between fiber diameter and compressive strength, whereas a positive correlation exists between fiber length and compressive strength. This can be attributed to the fact that a larger fiber diameter requires more cementitious material to encapsulate the fiber, which consequently results in a thinner cement paste covering the aggregate and leads to a decrease in compressive strength of permeable concrete. Conversely, an increase in the length of basalt fiber allows it to provide restraint against the failure of permeable concrete, thus enhancing its compressive strength.

The regression prediction equation for the compressive strength of basalt permeable concrete with respect

to the fiber diameter and length can be determined based on the non-standardized coefficients:

$$Y_1 = 25.041 - 0.74X_1 + 0.279X_2. \quad (4)$$

4.2.2 Water permeability coefficient regression equation

Similar to the examination of the regression equation for compressive strength, a stepwise regression analysis was conducted to determine the factors influencing the permeability coefficient. It was observed that the significance value for mixing method X_4 was 0.56, which exceeds the predetermined significance level of 0.05. As a result, X_4 was considered insignificant and excluded from the equation. The summarized table and regression coefficient table after excluding X_4 can be seen in Tables 11 and 12, respectively.

1) Water permeability coefficient goodness-of-fit test

Based on the information presented in Table 11, the regression equation demonstrates a high level of fit with a goodness-of-fit (R^2) value of 0.988 and an R -squared (R^2) value of 0.976. These values, which are close to 1, indicate a strong fit of the regression model. The independent variables are capable of explaining approximately 97.6% of the variation observed in the dependent variable.

2) Overall linearity test of water permeability coefficient equation

According to Table 12, it is evident that the diameter, length, and content of basalt fibers exhibit a significant linear relationship with the independent variables, as indicated by the sig values of 0.006, 0.006, and 0.034, respectively. All these sig values are below the threshold of significance set at 0.05.

3) Diagnosis of collinearity of water permeability coefficient

The VIF values for X_1 , X_2 , and X_3 are all 1, suggesting that there is no presence of multicollinearity among these variables.

According to the standardized coefficient column, the regression equation of the water permeability coefficient and the fiber diameter, length, and content is as follows:

Table 11: Summary of regression equations for water permeability coefficient

Regression equation	R	R^2	Adjusted R^2	F change
2	0.988	0.976	0.953	41.498

Table 12: Coefficients of the regression equation of the water permeability coefficient

Regression equation	Non-standardized coefficient		Standardization factor	t	Sig	Collinearity statistics	
	B	Standard error	Beta			Tolerance	VIF
Constant	-7.523	1.968		-3.824	0.012		
Diameter	0.607	0.131	0.646	4.632	0.006	1.00	1.00
Length	0.199	0.044	0.635	4.556	0.006	1.00	1.00
Content	0.134	0.065	0.286	2.049	0.034	1.00	1.00

Table 13: True value table

Group number	Diameter (μm)	Length (mm)	Content (kg/m ³)	Compressive strength (MPa)	Water permeability coefficient (mm/s)
Group 10	13	18	4	20.69	4.32
Group 11	15	12	4	16.63	4.43
Group 12	15	15	6	17.98	5.07
Group 13	15	18	2	18.82	5.56

Table 14: Comparison of predicted and true value of compressive strength

Group number	Regression prediction value (MPa)	True value (MPa)	Relative error (%)
Group 10	20.443	20.69	1.21
Group 11	17.289	16.63	3.82
Group 12	18.126	17.98	0.81
Group 13	18.963	18.82	0.75

Table 15: Comparison table of predicted and true values of water permeability coefficient

Group number	Regression prediction value (mm/s)	True value (mm/s)	Relative error (%)
Group 10	4.486	4.32	3.70
Group 11	4.506	4.43	1.69
Group 12	5.371	5.07	5.60
Group 13	5.432	5.56	2.36

$$Y_2 = -0.646X_1 + 0.635X_2 + 0.286X_3. \quad (5)$$

Based on the information provided in Table 12, it can be observed that the absolute values of the coefficients for the diameter, length, and content of basalt fibers are 0.646,

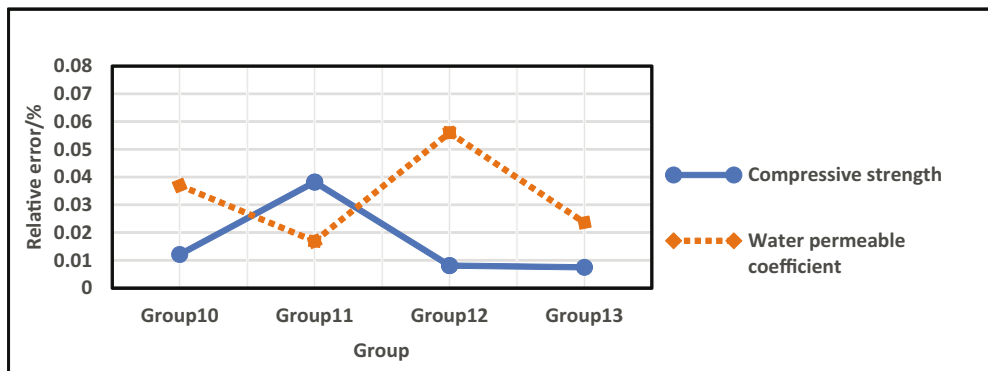
0.635, and 0.286, respectively. This indicates that the diameter of the fiber has the greatest impact on the permeability coefficient, followed by fiber length and then fiber content. Furthermore, since all coefficients are positive, it can be concluded that there is a positive correlation between the permeability coefficient and the diameter, length, and content of basalt fibers. This means that as the fiber diameter increases, more cement slurry is required on the fiber surface, resulting in a thinner cement slurry thickness on the aggregate surface, larger inter-aggregate voids, and an increased permeability coefficient. Similarly, an increase in fiber length promotes the formation of a network structure within the pervious concrete, which further enhances its permeability [26].

Based on the non-standardized coefficients, the regression prediction equation for the relationship between the permeability coefficient and the diameter, length, and content of basalt fibers can be determined:

$$Y_2 = -7.523 + 0.607X_1 + 0.199X_2 + 0.134X_3. \quad (6)$$

5 Analysis of regression prediction equation results

By comparing the error results between the predicted values from the regression equation and the actual results

**Figure 6:** Relative error curve of compressive strength and water permeability coefficient.

obtained from indoor experiments, we can better assess the accuracy of the regression equation and determine its usability. This study conducted validation experiments using four groups, namely, the 10th, 11th, 12th, and 13th groups, of basalt fiber pervious concrete. The measured data from the indoor tests are presented in Table 13.

By assigning different numerical values to the fiber materials in regression equations – formulas (3) and (4), we obtained the predicted values for the compressive strength and permeability coefficient of basalt fiber pervious concrete. These predicted values were then compared to the actual measured values in order to determine the error of the multiple linear regression equation. The results of this comparison can be seen in Tables 14 and 15.

According to Tables 14 and 15, it can be observed that in the regression prediction equation with basalt fiber pervious concrete compressive strength and permeability coefficient as dependent variables, the average relative error for predicting the compressive strength of basalt fiber pervious concrete is 1.65%. Among these errors, 100% are below 5%, resulting in a prediction accuracy of 98.35%. The average relative error for predicting the permeability coefficient of basalt fiber pervious concrete is 3.34%. Among these errors, 75% of them are below 5%, resulting in a prediction accuracy of 96.66%.

According to the literature [35], predictions are considered accurate when the relative error between predicted and measured values is within 10%. The relative errors between the predicted values and measured values for the compressive strength and permeability coefficient of fiber pervious concrete are illustrated in Figure 6.

Based on Figure 6, it is evident that the predicted relative error of the compressive strength and permeability coefficient of pervious concrete remains consistently within a range of 6%, indicating a relatively high level of prediction accuracy. There are several potential factors that could contribute to this prediction error, including inherent errors in the multilinear regression equation itself and the limited number of experimental data used in the linear regression equation, as it was fitted based on only the ninth set of orthogonal experiments. This lack of sufficient training samples may have resulted in inadequate model fitting. Unavoidable factors and environmental variations during the experiments should ideally be controlled to ensure consistent conditions. The analysis solely considers the linear relationship between the independent and dependent variables, while the presence of non-linear relationships may exist.

6 Conclusion

Based on laboratory orthogonal experimental data, this study aimed to investigate the influence of different parameters of basalt fiber (diameter, length, and content) on the compressive strength and permeability coefficient of basalt fiber pervious concrete. The research used the multiple linear regression method to establish both standard and non-standard regression equations for these properties. The analysis of the standard regression equation suggested a negative correlation between fiber diameter and compressive strength, while fiber length showed a positive correlation. The absolute coefficients of fiber diameter and length indicated that fiber length had a greater impact on compressive strength than fiber diameter. The standard regression equation for water permeability coefficient and fiber parameters (diameter, length, and content) revealed a positive correlation. The standardization coefficients showed that fiber diameter had the highest coefficient value, followed by fiber length and fiber content. Therefore, the influence on the permeability coefficient of pervious concrete is as follows: the fiber diameter is greater than the fiber length, which is greater than the fiber content. The non-standard regression equation was used to predict and analyze the compressive strength and permeability coefficient of basalt fiber pervious concrete with various fiber parameters. The comparison of predicted values with actual values demonstrated a high prediction accuracy of 98.35% for compressive strength and 96.66% for permeability coefficient. This confirms the reliability of the non-standard regression equation. The research findings provide valuable insights for both the theoretical research and practical application of pervious concrete materials reinforced with basalt fibers.

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