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Research Article

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Study on the relationship between clay block particle size distribution and its shear strength of "Ripping up the riverbed" reach in the Yellow River

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ABSTRACT

The riverbed condition of "Ripping up the riverbed" is existence of clay block in the stratification siltation structure riverbed. The simulation test of "Ripping up the riverbed" validated that the mechanical properties of clay block being an important affecting factor. But the particle size distribution of clay block that formed through flocculation deposition is a key indicator of affecting clay block mechanical properties. Making use of particle size analysis test and shear strength test data of clay block of "Ripping up the riverbed" reach in the Yellow River, and using BP neural network to establish the relationship model between the clay block particle size distribution and its shear strength and solving it. The results validated the model is correct and has good generalization ability. The research result provide a studying method for analyzing the relationship between the particle size distribution of clay block and its mechanical properties and also provides condition for enriching research theory of "Ripping up the riverbed".

Keywords: "Ripping up the riverbed", Clay block, Particle size distribution, Shear strength, BP neural network

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INTRODUCTION

"Ripping up the riverbed" scouring is a special phenomenon of sediment transporting and channel adjustment reaction under complex flow state and boundary condition. "Ripping up the riverbed" often results strong riverbed scoured, sometimes a flood peak can washed riverbed several meters deep, causing the riverbed and the water level dropped significantly, while scouring action often result the main channel migrated, serious damage the hydraulic engineering along river bank. Seventies of last century, the question of "Ripping up the riverbed" has aroused great concern of water conservancy workers in home and abroad and has conducted research on this issue, also obtained some study results. Whether riverbed sludge can be ripped up, depending on combined effect of a variety of conditions, including pre-silting patterns and adjustments of riverbed, sludge density and relative roughness, sludge formed and bulk layer thickness, sludge block boundary conditions, mechanical strength of the siltation, peak flow and quantity of sediment, flood duration, channel morphology parameters, pulsating pressure along layer vertical direction. Analysis of the current research results, due to study means, methods, objects, and research emphases of this issue are different, causing the criterion and discriminate index of occurring "Ripping up the riverbed" is still lack of a unified understanding, and there is not currently the research literature that considering the mechanical properties of clay block. A key factor of affecting the mechanical properties of clay block is its sediment particle size distribution [6]. Using the soil sample of "Ripping up the riverbed" in mainstream of Yumenkou-Tongguan reach and the Weihe River branch of the Yellow River, according to clay layer formation mechanism and reshape clay block. For the reshaping different particle size distribution clay sample, doing particle analysis test and the shear strength test, according to the test data, using BP neural network, build the relationship model between particle size distribution and shear strength and solving. The research result provide a research method for the analysis of the relationship between the particle size distribution of clay block and its mechanical properties and also provides condition for enriching research theory of "Ripping up the riverbed".

1 Sediment particle analysis test and shear strength test

1.1 Particle analysis test

Using the soil sample of “Ripping up the riverbed” in mainstream of Yumenkou-Tongguan reach and the Weihe River branch of the Yellow River, according clay layer formed mechanism, reshape clay block. In the experiment, through coarse sand and fine sand blending mode, reshape 50 groups different particle size distribution clay sample. According to "Test method of soils" (SL237-1999) and "Standard for test methods of earthworks" (GB 123-1999), for each sample, doing particle analysis test.

1.2 Direct shear test

Using ZJ Strain controlled direct shear apparatus for direct shear tests, to shear clay sample at 1.2mm/min shear rate, making the sample shear damage within 3-5 minute. Getting cohesive force C and the internal friction angle φ of sample. Respectively, for 50 groups of different particle size distribution sample make direct shear test under 4 kinds of vertical pressure force as shown in Table 1, obtaining corresponding shear strength τ_i (kPa)， $i=1,2,3,4$。

Table1 Saturated soil samples naturally fast shear test (sample No. 6)

Project Name: Direct shear test of clay block					Test date：2011.8.2		
Sample No. 6					Test method：quick shear test		
Wet density (g/cm^3)		Dry density (g/cm^3)	Water content (%)		Test-force ring coefficient (kN/0.01mm)	C (kPa)	φ°
1.86		1.47	26.4		1.85	12.0	32.1
Centesimal meter readings (0.01mm)				Vertical load readings (kg)			
37	78	105	139	1	2	3	4
Shear strength (kPa)				Vertical pressure force(kPa)			
68.5	144	194	257	98.1	196.2	294.3	392.4

To facilitate the analysis, in this paper, the introduction of the concept of average friction coefficient represents shear behavior of clay block; the calculation formula of average friction coefficient is as formula (1):

$$F=\frac{1}{4}\sum_{i=1}^{4}\frac{\tau_i}{\sigma_i} \tag{1}$$

Where, σ_i is normal stress of soil sample in the cutting ring, its calculation formula is $\sigma_i = \frac{P_i}{A}$, P_i is vertical pressure force, A is the area of cutting ring.

2 The relationship model between clay block particle size distribution and its shear strength based on BP neural network

To study the relationship between particle size distribution and shear strength of clay block, using curve fitting method to fit particle size distribution curve of each sample, using fitting equation parameter of particle size distribution curve to indicate the particle size distribution of the sample.

2.1 Particle size distribution curve fitting of clay block sample

Particle size distribution curve fitting of clay block sample:

Reference [3] studied sediment particle size distribution curve on the double logarithmic coordinates, and proposed particle size distribution curve fitting equation as formula (2):

$$p = \left| \left|\frac{d_*}{d}\right|^{m/n} + 1 \right|^{-n} \tag{2}$$

Where, d_* is gradients particle size, mm; d sediment particle size, mm; p is the percentage of sediment that’s less than a particle size sediment; m is intermediate segment slope of sediment particle size distribution curve in dual-logarithm coordinates system; n is the gradient coefficient. In the formula (2), the calculation method of each parameter is as follow：

m value calculation: In dual-logarithm coordinates system, the small particle size point was similar to linear distribution on the particle size distribution curve, the slope of line is m .

d_* value calculation: In dual-logarithm coordinates system, extending the main trend line of sediment particle size distribution curve, intersecting with the p=100% line, the point of intersection abscissa is d_*.

p_* value calculation: In the particle size distribution curve, d_* corresponding to p-value is p_*.

n value calculation: When taking $p = p_*$, $d = d_*$, equation (1) can be written as: $p_*^{-\frac{1}{n}} = \left|\frac{d_*}{d_*}\right|^{\frac{m}{n}} + 1 = 2$, $n = -\frac{\ln p_*}{\ln 2}$.

Each parameter calculation results into equation (2), we can obtain the fitting equation of particle size distribution curve.

Particle size distribution curve fitting equation evaluating:
To verify the fitting degree of sediment particle size distribution curve fitting equation, in this paper, using mean square method to calculate fitting degree of fitting equation. Table 2 shows the actual data, fitting data and calculated mean square error of particle size distribution of the selected sample. In the table 2, y is the percentage that is less than a sediment particle size, x_1 is the actual particle size of selected sediment sample, x_2 is calculated particle size according to fitting equation, Δx is the error between the actual particle size and calculated particle size, s is the mean square error, MSE is calculated as follows:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_1 - x_2)^2}{n}} \tag{3}$$

The calculation results of the selected sample in Table 2.

Table 2 The calculation of particle size mean square error

y	x_1	x_2	x_2	Δx^2	s
5	0.0013	0.0011	0.0002	4E-08	
10	0.0024	0.0029	-0.0005	2.5E-07	
30	0.0143	0.0134	0.0009	8.1E-07	
40	0.0211	0.0198	0.0013	1.69E-06	
50	0.0284	0.0269	0.0015	2.25E-06	0.001462
60	0.0335	0.0349	-0.0014	1.96E-06	
70	0.0421	0.0438	-0.0017	2.89E-06	
80	0.0567	0.055	0.0017	2.89E-06	
90	0.0731	0.0711	0.002	4E-06	
95	0.0893	0.0868	0.0025	6.25E-06	

By above method, calculated mean square error of 50 groups of samples is in 0.001-0.0016 interval, precision to meet the requirements.

In this paper, using curve fitting method to fit particle size distribution curve of 50 groups of samples, calculate respectively parameter of particle size distribution curve fitting equation (d_*^i, m^i, n^i), $i = 1, 2, \cdots, 50$ is sample No.

2.2 BP network model
Network Input: Using 50 groups of parameters of particle size distribution curve fitting equation as the network input (d_*^i, m^i, n^i), $i = 1, 2, \cdots, 50$.

Network output: The average friction coefficient F^i calculated according to shear strength test data is as network output

Training samples is shown in Table 3.

Table 3 Network training sample

Sample	Network input			Target output	sample	Network input			Target output
code	m	n	d_*	F	code	m	n	d_*	F
1	0.8	0.13	0.05	0.9014	26	0.95	0.18	0.061	0.8122
2	1	0.22	0.06	0.7211	27	0.95	0.12	0.04	0.9722
3	1.173	0.194	0.068	0.9621	28	1.3	0.23	0.057	0.8834
4	1.3	0.2	0.05	0.9254	29	1.05	0.16	0.07	0.9763
5	1.2	0.19	0.041	0.8599	30	0.7	0.12	0.07	0.8357
6	0.95	0.2	0.067	0.7572	31	1.04	0.162	0.06	0.9671
7	0.95	0.19	0.063	0.7732	32	0.95	0.13	0.045	0.9685
8	0.8	0.14	0.054	0.8511	33	1.14	0.187	0.064	0.9554
9	1.3	0.2	0.053	0.9519	34	0.9	0.14	0.048	0.9205
10	0.9	0.15	0.05	0.8898	35	1.13	0.2	0.07	0.9222
11	0.7	0.14	0.07	0.7916	36	0.8	0.15	0.065	0.8458
12	1.4	0.2	0.052	0.9697	37	0.8	0.11	0.05	0.9749
13	0.7	0.13	0.06	0.8215	38	0.7	0.12	0.05	0.9356
14	0.89	0.153	0.052	0.8743	39	0.95	0.14	0.05	0.9592
15	0.7	0.15	0.06	0.7248	40	0.95	0.17	0.059	0.8657
16	0.8	0.15	0.06	0.7988	41	0.95	0.15	0.053	0.9302
17	0.8	0.16	0.065	0.7843	42	1.1	0.16	0.053	0.9713
18	0.95	0.16	0.056	0.8977	43	0.9	0.168	0.05	0.7661
19	1.2	0.154	0.043	0.9731	44	1.12	0.184	0.054	0.9133
20	1.2	0.22	0.058	0.8294	45	0.9	0.2	0.063	0.7141
21	1.1	0.14	0.043	0.9742	46	0.85	0.155	0.057	0.8179
22	0.8	0.13	0.06	0.9427	47	0.95	0.21	0.07	0.7412
23	0.9	0.18	0.05	0.7375	48	0.9	0.17	0.045	0.7503
24	1.4	0.19	0.05	0.9755	49	1.18	0.156	0.04	0.9654
25	0.8	0.12	0.05	0.9485	50	1	0.14	0.053	0.9739

BP Network parameter setting: By experiment, the network parameters are set as follows: the maximum number of learning is controlled to 20000, and the mean square error is controlled to 0.00018, the transfer function of two hidden layers use tansig function, the transfer function of the output layer use purelin function, taking 0.03 learning rate. Using neural network function of MATLAB function Box to program and train network.

Network training process shown in Figure 1, it can be seen from Figure 1: when the number of training times close to 10,000, the error reaches the required value.

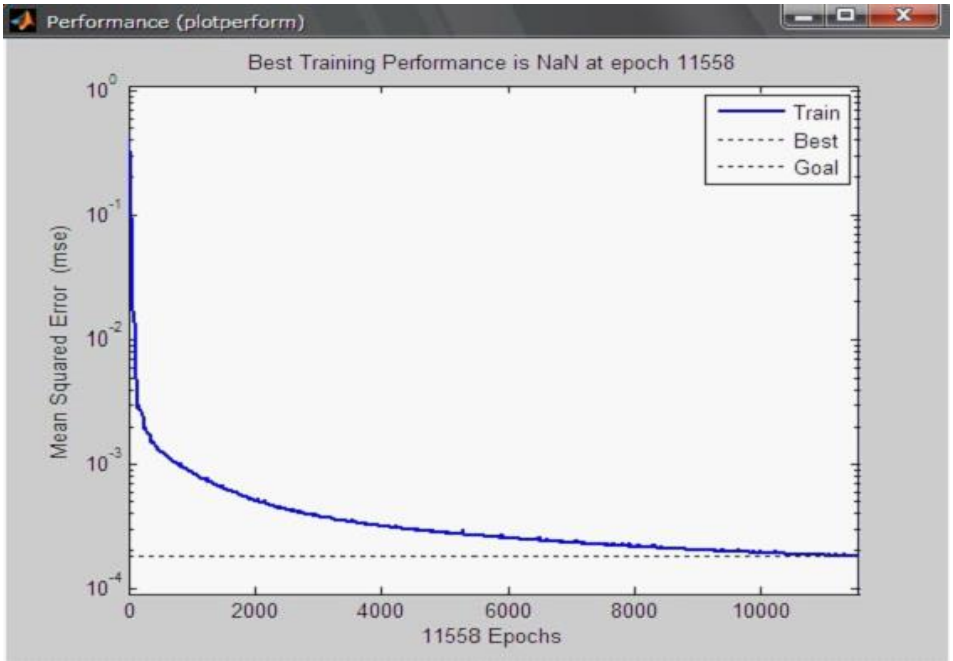

Fig.1 The training results of BP network

The computing results of test sample: Table 4 lists calculated results by network model, the actual results of some sample and relative error of the both.

Table 4. The target output of average friction coefficient and computing output

Sample No.	Network output	Target output	Relative error (%)	Sample No.	Network output	Target output	Relative error (%)
1	0.9044	0.9014	0.3317	26	0.8088	0.8122	-0.4204
7	0.776	0.7732	0.3608	32	0.9684	0.9685	-0.0103
11	0.7903	0.7916	-0.1645	36	0.8429	0.8458	-0.3441
15	0.7242	0.7248	-0.0829	40	0.869	0.8657	0.3797
19	0.9743	0.9731	0.1232	44	0.912	0.9133	-0.1425
25	0.949	0.9485	0.0527	50	0.9733	0.9739	-0.0616

By Table 4 shows that the computing results by BP neural network model are very close to the actual results, the error is at control in ±1%.

CONCLUSION

This paper established BP network model of relationship between clay block average friction coefficient (shear strength of clay block) and sediment particle size distribution from "Ripping up the riverbed" prototype river, and using neural network function in MATLAB programming to achieve model solution. The computing results of test sample shown, the paper established network model has better generalization ability and higher calculation accuracy. The results provide a research method for the analysis of the relationship between particle size distribution of clay block and its mechanical properties.

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REFERENCES

[1] Cheng Longyuan, Zhang Cheng, Liu Yaner. **2005**, *Journal of Sediment Research*, 4, pp: 21～29.
[2] Dong Wensheng. **2012**, *Applied Mechanicals and materials*, Vols: 212-213, pp: 108~112.
[3] Dai Qing, Han Qiwei, Hu Jian. **2009**, *Yellow River*, 31(10), pp: 69～70.
[4] Han Qiwei. **2005**, *Journal of Sediment Research*, 4, pp:5～28.
[5] Jiang Enhui, Cao Yongtao, Zhang Qing. **2004**, *Yellow River*, 26(7), pp: 6～11.
[6] Jiang Enhui, Li Junhua, Zhao Lianjun. **2010**, *Journal of hydraulic Engineering*, 41(6), pp:727~731.