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Effect of ecological concrete applied to water pollution control of urban river

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ABSTRACT

In view of the increasingly serious problem of urban river water pollution, the feasibility of applying ecological concrete to the urban river water pollution control and the purification effect of water quality are studied. Through the combination of theoretical exploration and model test, the physical, mechanical properties and mix proportion of ecological concrete are planned and designed. The model test of ecological restoration of urban rivers and ecological grass planting technology are carried out. Combined with the experimental results, the mechanism of water purification of ecological concrete and the ecological coagulation slope-protecting plant adapted to Handan area are discussed. Experiment of ecological concrete test block shows that the ammonia nitrogen removal efficiency of the ecological concrete block with large porosity is much better than the ecological concrete block with small porosity. In conclusion, the results of this research provide a reliable basis and method for the application of ecological concrete to the urban river wastewater remediation and have reference value for other sewage treatment projects.

Keywords: Ecological concrete; Model test; Urban river; Water purification; Slope-protecting plant

1. Introduction

The increasingly serious problem of water pollution has always been one of the major obstacles that restrict the economic development in some parts of our country, especially in the north. In 2013, the national water resources statistics report showed that the water shortage in our country is more and more serious, and some cities are suffering from serious water shortage [1]. Although the project of South-to-North Water Diversion has solved the problem of water shortage in northern cities to a certain extent, the phenomenon of water pollution is more and more serious, and water pollution incidents occur frequently [2]. About 33% of the pollutants discharged into the reservoir area of rivers, lakes and reservoirs are far beyond its capacity for pollutant discharge, resulting in serious deterioration of water quality in some of the rivers in China, which seriously affects our country's ecological environment and the daily life of residents [3].

Effectively controlling the problem of river water pollution requires not only reducing the amount of pollutants discharged into the river from the source, but also increasing the urban sewage treatment through a series of water pollution remediation technologies [4]. In other words, to solve this problem, we not only need to minimize the daily discharge of wastewater that has not been treated by the corresponding sewage treatment plant directly to the river, but also increase the sewage treatment capacity of the river itself [5]. For a long time, most of the urban banks in our country mainly adopt ordinary concrete slope protection technology. Ordinary concrete revetment has the characteristics of compact structure and high strength, which is good for the safety of revetment. However, it is not conducive to the energy exchange between river water and revetment [6]. In addition, this method cannot purify the

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water through revetment. As a result, the self-purification capacity of water body decreases [7].

In view of the above problems, taking into account the shortcomings of the traditional bank revetment technology, the revetment material is changed and the ecological concrete slope protection technology is adopted [8]. The water purification function of ecological concrete and its environmental compatibility are used in order to promote the exchange of material and energy between river body and slope protection. This not only improves the local ecological environment within the river, but also improves the river's own sewage treatment capacity [9].

2. Methodology

2.1. Cement

The cementitious material is P.O. 42.5 grade cement with a density of 3.54 g/cm^3, and all the technical indicators are in line with GB 175-2007 General Portland Cement Quality Standard. The chemical composition and physical and mechanical properties of P.O. 42.5 ordinary Portland cement are shown in Tables 1 and 2, respectively.

2.2. Coarse aggregate

The coarse aggregate used in this experiment is natural gravel, and its particle size is 5–30 mm. A series of standard sieves with pore sizes of 30, 25, 20, 15, 10 and 5 mm are selected. The particle analysis test of natural lithotripsy was carried out by sieving method. Finally, each group of gravel with different particle sizes is obtained: 5–10, 10–15, 15–20, 20–25 and 25–30 mm. According to the relevant specifications, Class I gravel should be used when making concrete with an intensity level greater than C60. Class II gravel is required when making concrete with an intensity level between C30 and C60. Class III gravel is required when making concrete with an intensity level less than C30. In this experiment, the strength of the concrete is less than C30, which can meet the requirements of the experiment. Therefore, the gravel technology of Class III is enough to meet the requirements.

According to Standard for Quality and Method of Sand and Stone for Ordinary Concrete in China, all coarse aggregates will be cleaned, dried and screened before the test.

Table 1
Chemical composition of P.O. 42.5 ordinary Portland cement (%)

SiO_2	21.87
Fe_2O_3	6.51
Al_2O_3	4.79
CaO	56.43
MgO	2.06
SO_3	2.78
Alkali content	0.7
Other content	4.86

Table 2
Physical mechanical performance index of the P.O. 42.5 Portland cement (%)

Testing item	Standard value	Measured value
Specific surface area (m^3/kg)	≥300	354
Fineness (%) (80% screen residue)	≤10	1.8
Initial setting time (min)	≥45	110
Final setting time (min)	≤60	180
Stability	Qualified	Qualified
Compressive strength (MPa)		
3 d	≥17.0	24.9
7 d	–	41.6
18 d	≥42.5	50.1

2.3. Mineral additive

2.3.1. Fly ash

According to the actual needs, Grade II fly ash with a density of 2.4 g/cm^3 is used in this test, which is mainly used to adjust the workability and durability of ecological concrete.

2.3.2. Calx

The slag used in this experiment is the black fine powder pyrite slag, which is the industrial waste residue produced by the production of sulfuric acid. After a certain process of crushing, grinding and magnetic separation, the size of the particle size below 4.75 mm is left by the screening method. The aim is to improve its cohesive force and to adjust the workability and acidity of the ecological concrete.

The main chemical components of calx are Fe_2S, FeO, Fe_2O_3 and Fe_3O_4. By correlation detection, the sulfur content is 52.7%, which is acid slag.

2.4. Ferrous sulfate

Ferrous sulfate is commonly known as copperas. It is a transparent, light green crystal, and it is very easy to dissolve in water. In humid air, it is easily oxidized to yellow-brown Fe^{3+}, but plants can only absorb Fe^{2+}. If ferrous sulfate is oxidized to Fe^{3+}, it will be difficult to be absorbed and utilized by plants, so it needs to be sealed and preserved. As one of the cement additives, the main mechanism of water quality purification by ferrous sulfate is as follows.

First, ferrous sulfate can react with $Ca(OH)_2$ produced by C_3S hydrolysis in cement composition. A large number of colloidal precipitates are formed between $Fe(OH)_2$ and $Fe(OH)_3$. The colloidal precipitate can be adsorbed on the surface of the cement particles to form a hindrance layer. By adjusting the coagulation rate of cement and the dense strengthening of its own, the later strength of the ecological concrete is improved.

Second, ferrous sulfate can react with some pollutants in sewage and produce precipitation, so as to achieve the purification effect of water quality, such as phosphate removal.

Third, ferrous sulfate can provide nutrients for microorganism in the pore of ecological concrete, improve the activity of microorganism and strengthen the purifying effect of microorganism. On the other hand, when applied to plant ecological concrete, ferrous sulfate can provide necessary nutrients for plant growth and promote plant growth. When ferrous sulfate is used with decomposed organic fertilizer, its effect is better. The decomposition products of organic matter can greatly increase the solubility of iron and promote plant growth to a certain extent. In addition to the above effects, the strong acidity of ferrous sulfate was also used in this experiment. By adjusting its concentration, the purpose of reducing the alkalinity of the ecological concrete is achieved. Determination of the concentration of ferrous sulfate and its acidity are shown in Table 3 and Fig. 1.

As shown in Fig. 1, the relationship between the acidity of ferrous sulfate and its concentration can be expressed as follows:

$$y = 0.678x^{-0.106} \quad (1)$$

where y represents the concentration of ferrous sulfate and x represents the pH value of ferrous sulfate solution.

Table 3
Ferrous sulfate acidity measurement (%)

Concentration of ferrous sulfate	pH value of solution
50.00	1.79
25.00	1.82
5.00	2.38
2.50	2.53
1.00	2.76
0.50	3.11
0.25	3.11
0.17	3.24
0.13	3.34
0.10	3.4
0.05	3.85
0.03	3.94
0.02	4.22

3. Results and discussion

3.1. Experimental study on static adsorption of water pollution of ecological concrete

In order to simulate the water purification experiment of the ecological concrete slope protection in urban river, taking into account the different flow velocities, two representative water regimes are selected for further study: the flow velocity of the river is zero and the water flow of the river flow rate is not zero. Based on this, the static adsorption test and the dynamic cross-over test of ecological concrete are designed [10].

The experiment uses the static adsorption test of ecological concrete to simulate the purifying effect of ecological concrete slope protection on the river water when the flow velocity of the river is zero [11].

3.1.1. The specific design scheme of static adsorption test

The blank control group and the experimental group are compared. The design of the mix proportion of the ecological concrete blocks in the experimental group is shown in Table 4. According to the four kinds of mix proportion in the table, four groups of ecological concrete blocks are made, respectively, and the size of all the ecological concrete blocks are 150 mm × 150 mm × 150 mm. For the convenience of description, four groups of ecological concrete are represented by 1#, 2#, 3# and 4#, respectively.

Before carrying out the static adsorption test of ecological concrete, the above four groups of ecological concrete blocks were soaked in a certain volume of tap water. After 24 h, they were removed and put into the electric heating and drying oven for drying. In addition, five plastic drums are prepared and each drum has 10 L sewage. Four pieces of samples are placed in four drums, and the one remainder drum is used as control.

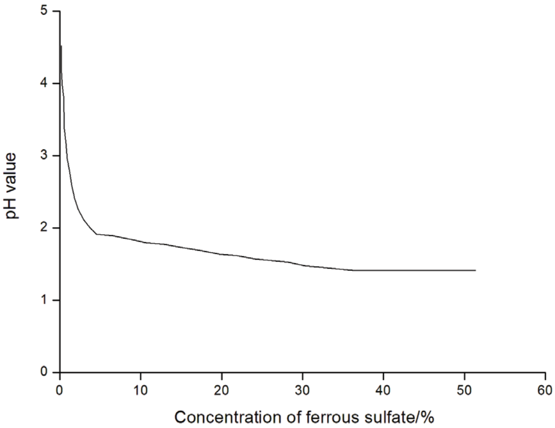

Fig. 1. Determination of ferrous sulfate concentration.

Table 4
Material composition of ecological concrete block (kg/m^3)

Mix proportion										
Sample	Cementing material	Cement (%)	Fly ash (%)	Calx (%)	Water–binder ratio	Water	Water reducer (%)	$FeSO_4$ (%)	Amount of gravel	Glue size of gravel (mm)
1#	306.50	75.00	25.00	0	0.3	91.95	1.2	12	1,600	15–20
2#	291.50	75.00	25.00	0	0.3	87.45	1.2	12	1,600	20–25
3#	200.63	71.00	25.00	4.00	0.3	60.19	1.2	12	1,600	25–31
4#	228.46	71.00	25.00	4.00	0.3	68.54	1.2	12	1,600	20–25

3.2. Measurement results of corresponding performance indexes of ecological concrete

The test results of physical and mechanical properties of 1#, 2#, 3# and 4# ecological concrete block are shown in Table 5.

According to the experimental data of Table 5, the relation curves of 28 d compressive strength and porosity of different ecological concrete blocks with different ratio are shown in Fig. 2. The relation curve of 28 d compressive strength and porosity is shown in Fig. 3.

As shown in Table 5, the pH values of the ecological concrete blocks with different mix ratios are different. The pH value of 4# ecological concrete block is the smallest, which is 9.85. Second, the pH of the 3# and 2# ecological concrete specimens was 9.96 and 10.17, respectively. The pH value of 1# ecological concrete block is the largest, and its value is 10.25. The pH value of the four groups of ecological concrete blocks is lower than that of ordinary concrete, which can basically meet the requirements of plant growth. This shows that the alkalinity of the ecological concrete is reduced to a certain extent by reducing the amount of cementitious materials and adding the admixtures of ferrous sulfate. By comparing 1#, 2#, 3#, 4# porosity and pH data, it is found that the lesser the amount of cementitious material is, the smaller the pH value is. This shows that the pH value of ecological concrete can be reduced to a certain extent by reducing the amount of cementitious material. The porosity of the four ecological concrete blocks with different mix ratios is more than 19%, which can meet the needs of plant roots. The permeability coefficient is greater than 1.9 cm/s, showing that the permeability is good. It is beneficial for the water around the ecological concrete test block to enter the concrete through the connected pores and provide the favorable conditions for the plant to grow and root. On the other hand, the permeability coefficient is less than 3 cm/s, which indicates that the moisture of the ecological concrete is not easy to drain, and is conducive to the storage of water. The permeability coefficient is inversely proportional to the 28 d compressive strength of the ecological concrete test block. By comparing the strength of each eco-concrete test block, it is known that except for 3#, the 28 d compressive strength of 1#, 2# and 4# eco-concrete blocks is greater than 8 MPa, which the compressive strength requirements of ecological concrete used in river bank protection projects. The 28 d compressive strength of 3# ecological concrete block is 7.6 MPa, which is slightly less than 8 MPa. Generally speaking, the engineering design will consider a corresponding safety factor, so the 3# ecological concrete test block can also be applied to the river bank protection project.

Table 5
The test results of physical and mechanical performance index of ecological concrete block

Test block	pH value	Porosity (%)	Osmotic coefficient (cm/s)	28 d compressive strength (MPa)
1#	10.25	19.50	1.99	11.40
2#	10.17	22.96	2.17	10.00
3#	9.85	29.48	2.63	7.60
4#	9.96	27.70	2.40	9.45

As shown in Figs. 2 and 3, with the increase of porosity, the compressive strength of concrete decreases. There is an inverse relationship between strength and porosity, which is similar to ordinary concrete. The ecological concrete design is the process to deal with the relationship between the compressive strength of concrete and the permeability of the concrete.

Compared with the relationship between concrete mix proportion, 28 d compressive strength and porosity, it can be found that the larger the coarse aggregate size is, the less material the cementitious material is. In addition, the greater the porosity is, and the lower the 28 d compressive strength is, which is consistent with the previous research results. By comparing the results of the physical and mechanical properties of ecological concrete, it is found that 3# and 4# are most suitable for making plant concrete [12].

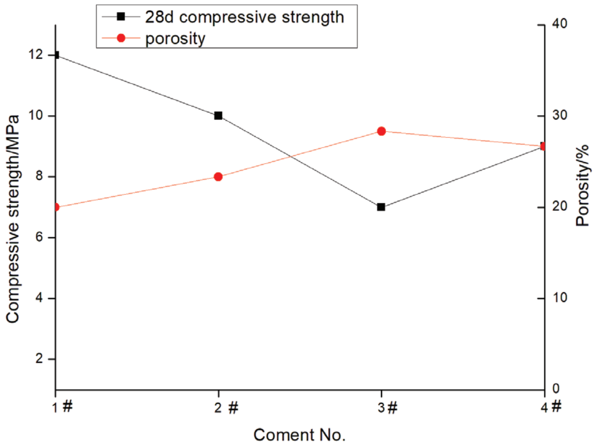

Fig. 2. Relationship between different mixture ratio and the compressive strength and porosity.

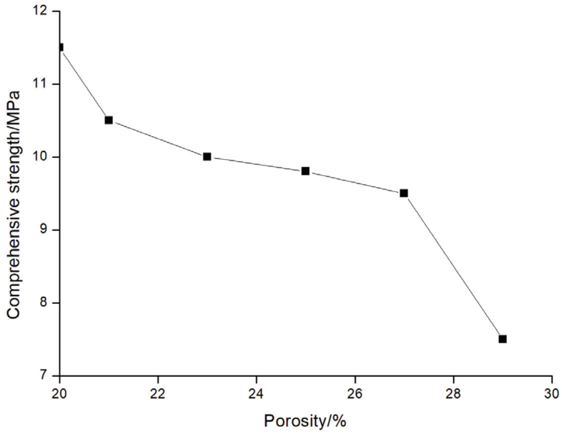

Fig. 3. Relationship between the compressive strength and porosity.

3.3. Change of water temperature and pH value

In order to verify the feasibility of ecological concrete applied to sewage treatment and its impact on water environment, the changes of water temperature and pH value of water body during a period of time are tested.

3.3.1. Water temperature

Fig. 4 is the change regulation chart of the temperature of the test water body with the soaking time of the ecological concrete block [13]. As shown in the figure, the temperature change of the water body in the experimental group is basically the same as that in the blank control group. It shows that the soaking ecological concrete block has no effect on the temperature of the water body. Observing the whole test process, the temperature of water body has been fluctuating, but its range of change has been kept at 26°C–28°C, which can meet the normal temperature requirement of microorganism growth.

Fig. 5 is the change regulation chart of the pH value of the test body with the immersion time of the test block. As shown in the figure, compared with the blank control group, the pH value of each test barrel is higher than 8, and all of them decreases gradually with the increase of soaking time, and finally tends to be smooth. Finally, it is almost equal to the pH value of blank control group. The effect of different test blocks on water quality is different. Compared with 1# and 2# test block, 3# and 4# have little effect on the pH value of test water. In the whole test process, the pH value of 1# and 2# presents a certain fluctuation. This indicates that there is a phenomenon of alkali release in the experiment of eco-concrete block. As the soaking time goes on, it gradually tends to be stable, reaching a balance without alkali release reaction. Therefore, the influence of ecological concrete blocks on the pH value of water only exists in a short period of time. After stable operation, it will no longer affect the pH value of water body, and will not affect the survival of aquatic plants and aquatic animals.

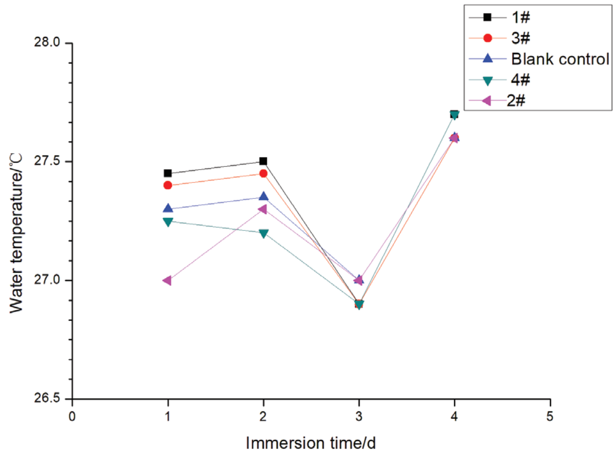

Fig. 4. The temperature of test water variation with immersion time pH value.

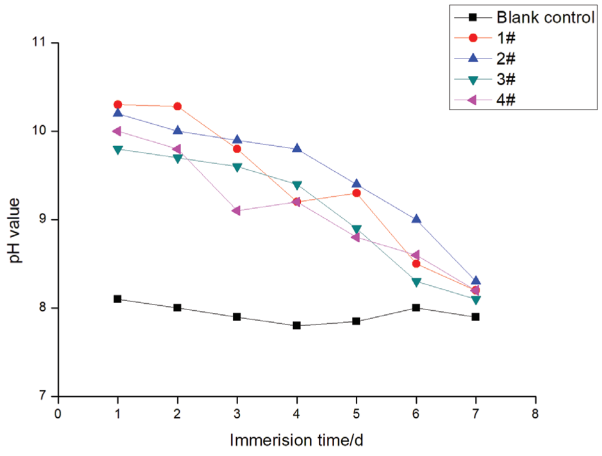

Fig. 5. The pH of the test water variation with immersion time.

It is found that the higher the porosity is, the faster the pH decline speed is, which has a little effect on water pH. The pH value of the ecological concrete block with the porosity of 29.48% decreases quickly. The pH of the water body decreases from 9.85 to 8 after the test block is socked for 6 d, and the decreasing rate is 18.78%. The main reason is that the large porosity ecological concrete has larger specific surface area compared with the small porosity ecological concrete. Therefore, the contact area with the experimental water is larger. The effect of alkali release and the rate of pH descending are faster.

According to the test data, when carrying out tests such as eco-concrete planting, which require a high alkaline content of eco-concrete, the eco-concrete test should be soaked for a certain period of time. The alkalinity is reduced to a certain degree and then dried for the next step test. To a certain extent, the effect of concrete alkalinity on the test can be eliminated. Of course, this method is only feasible in theory. In the actual operation process, influenced by various factors, the alkaline removal effect may not be ideal. For the ecological concrete block, the process of its alkali release is also the process of its strength decline. Therefore, in general, the ecological concrete is soaked for 1–2 d.

3.4. Test results and analysis

3.4.1. Purification effect of total nitrogen

According to the amount of the nitrogen dissolved in water, nitrogen can be divided into two categories including soluble nitrogen and insoluble nitrogen. In addition, it can be divided into organic nitrogen and inorganic nitrogen according to its material form. In the experiment of ecological concrete sewage remediation, the removal of pollutant nitrogen is mainly through the adsorption and filtration of the pores of ecological concrete, the nitrification and denitrification of microorganisms and the absorption of the roots of the plants. Four groups of ecological concrete samples with different mix ratios are compared with the purification effect of total nitrogen in blank control group to determine the influencing factors of total nitrogen purification efficiency in the static adsorption test of ecological concrete [14]. The specific test results are shown in Fig. 6.

As shown in Fig. 6, generally, the total nitrogen concentration in 1#, 2#, 3# and 4# experimental devices decreased with the increase of immersion time. It has a rapid decline in the early period, a slow decline in the middle period and then tends to be stable. The total nitrogen concentration

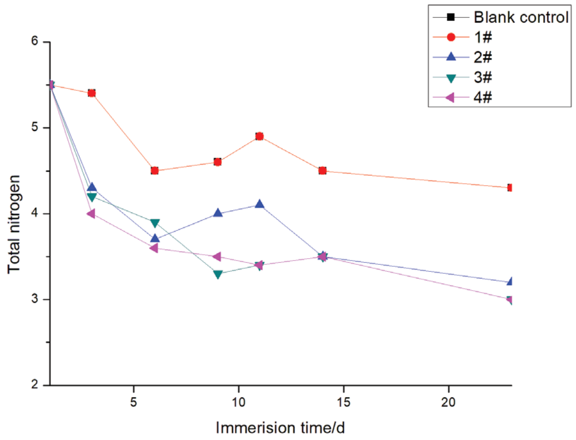

Fig. 6. The total nitrogen variation with time of the static adsorption experiment (blank control is the same as 1#).

in the blank control group decreased with the increase of time, then increased slightly and then slowed down slowly. The cause of the decrease of total nitrogen concentration in the blank control group is that partial insoluble nitrogen precipitation results in the decrease of total nitrogen concentration in the water body. Compared with the experimental data of 1#, 2#, 3# and 4#, it is found that the ecological concrete has a good removal effect on total nitrogen. The total nitrogen removal efficiency of 3# is the best, and the removal rate is up to 47.4%. The second is 4# and 2#, and the total nitrogen removal rate of 4# is 45.9%. The total nitrogen removal rate of 2# is 42.4%. The total nitrogen removal efficiency of 1# is the weakest, which is 39.4%. According to the porosity of ecological concrete, the higher the porosity is, the higher the total nitrogen removal rate is, which is related to the purification mechanism of nitrogen. In the experiment of ecological concrete wastewater remediation, the removal of nitrogen pollutants is mainly through the adsorption and filtration of the pores of ecological concrete and the degradation of microorganisms. Organic nitrogen can be adsorbed in the pores of ecological concrete through adsorption effect. On the one hand, it can be used as a nutrient for microbiological growth. On the other hand, aerobic microorganisms can oxidize part of the organic nitrogen into NH_3 by microbiological action, and then hydrolyze them into ions step by step. By nitrification and denitrification, microbes convert ammonium ions into gaseous N_2 and N_2O, so as to complete the removal of nitrogen in sewage by ecological concrete block.

3.4.2. Purification effect of nitrate nitrogen and nitrite nitrogen

In the static adsorption test of ecological concrete, the variation of nitrate nitrogen and its concentration with time are shown in Figs. 7 and 8.

As shown in Fig. 7, in the static adsorption test of ecological concrete, the concentration of nitrate nitrogen first decreases and then increases with time. At last, it gradually changes slowly, and the final concentration is less than the initial concentration. In the experimental devices of 1#, 2#, 3# and 4#, the removal rates of nitrate nitrogen are 3.8%, 9.8%, 27.2% and 26.3%, namely, 3# > 4# > 2# > 1#, respectively.

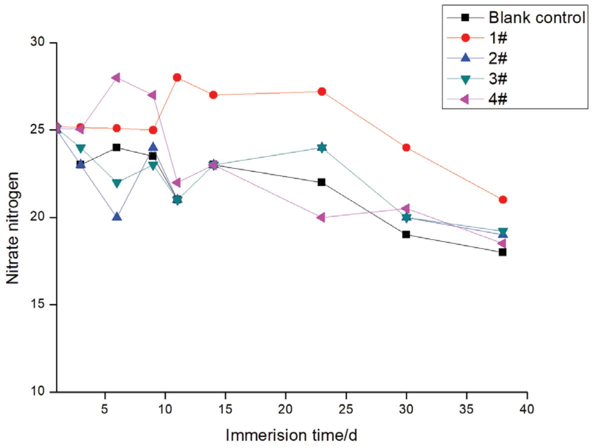

Fig. 7. The nitrate nitrogen variation with time of the static adsorption experiment.

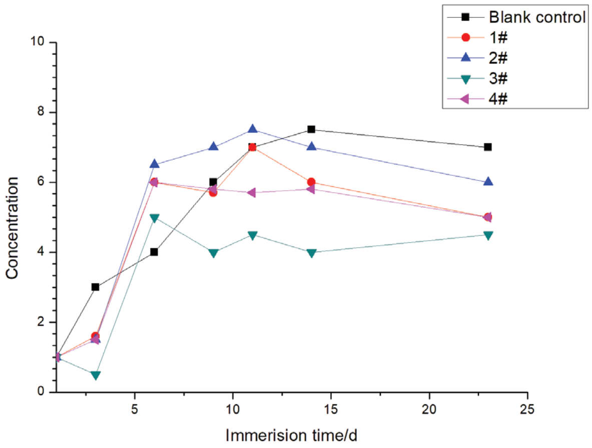

Fig. 8. The nitrite nitrogen variation with time of the static adsorption experiment.

As shown in Fig. 8, in the static adsorption test of ecological concrete, the concentration of nitrite nitrogen increases slowly with time and gradually tends to be gentle. Because of the removal of nitrogen from sewage by ecological concrete, nitrification and denitrification are needed. Therefore, these processes need to take place under the participation of specific microorganisms. During the experiment, nitrification and denitrification cannot be carried out effectively because of the limited number of microorganisms in the water body and the small number of specific nitrifying and denitrifying bacteria. Therefore, nitrite nitrogen cannot be quickly converted to nitrate nitrogen. However, with the increase of nitrite nitrogen concentration, the number of nitrite-oxidizing bacteria increases rapidly. In addition, the oxidation rate of nitrite nitrogen increases. Until 11 d, the accumulation of nitrite nitrogen reaches the maximum, and the rate of ammonia nitrogen oxidation is equal to the rate of nitrite nitrogen at this time. After that, the oxidation rate of nitrite nitrogen is greater than ammonia nitrogen, and the accumulation of nitrite nitrogen tends to decrease. However, the oxidation rate of nitrite nitrogen cannot be greatly improved due to the limitation of the test device, and the content of nitrite nitrogen does not show a significant downward trend. As nitrification and denitrification tended to stabilize, the accumulation of nitrogen and nitro nitrogen reaches a stable state [15].

3.4.3. Purification effect of ammonia nitrogen

In the static adsorption test of ecological concrete, the change rule of ammonia nitrogen with the soaking time of water body is shown in Fig. 9.

As shown in Fig. 9, in the static adsorption test of ecological concrete, the ammonia nitrogen concentration in the water body decreases first, then increases and then decreases. In the early stage of the experiment, there is no microbial attachment in the ecological concrete, but it has some ammonia nitrogen removal efficiency. The main reason is that the ecological concrete block has a larger specific surface area, and has a certain adsorption capacity for ammonia nitrogen.

Compared with the change rule of ammonia nitrogen concentration in 1#, 2#, 3# and 4#, the change trend of ammonia nitrogen of eco-concrete block with different mix ratio is basically the same, and ammonia nitrogen removal effect is slightly different. The 3# ecological concrete block has the most obvious removal effect on ammonia nitrogen, and the removal rate of ammonia nitrogen is 28.2%. The second is 4# and 2#, and the removal rate of ammonia nitrogen is 26.1% and 24.2%, respectively. The removal effect of 1# ammonia is the worst, and the removal rate of ammonia nitrogen is 22.5%. The experimental results show that the ammonia nitrogen removal efficiency of the ecological concrete block with large porosity is much better than the ecological concrete block with small porosity. The main reason for this phenomenon may be that the ecological concrete block with large porosity has a larger specific surface area, and its adsorption is stronger. The microbial biomass attached to the ecological concrete test block is more, then it is beneficial to the removal of ammonia nitrogen in the sewage.

3.4.4. Purification effect of total phosphorus

Fig. 10 is the purification effect of the ecological concrete block on the total phosphorus in the static adsorption test. As shown in the figure, the ecological concrete block has a good effect of total phosphorus purification. The change of total phosphorus in the blank control group is very little, and the concentration is almost constant. However, the concentration of total phosphorus in the water of 1#, 2#, 3# and 4# continues to decline as time goes on. Until 14 d, the concentration of total phosphorus in the water body of each test group reaches the minimum. The four kinds of ecological concrete test block with different mix ratio are compared and analyzed, it is found that the purification effect of 1# ecological concrete block on total phosphorus is the worst, and the total phosphorus removal rate is 42.1%. The purification effect of 3# and 4# ecological concrete blocks on total phosphorus is the best, and the total phosphorus removal rate is 69.4% and 70.3%, respectively. The total phosphorus removal rate of 2# ecological concrete block is 62.2%. In general, the effect of ecological concrete block on total phosphorus removal is good, and the concentration of total phosphorus can be reduced to less than 0.02 mg/L. This is mainly related to the removal mechanism of the total phosphorus. The total phosphorus concentration is mainly reduced by pore adsorption and filtration. There are many tiny pores in the eco-concrete block, which play a key role.

3.4.5. Purification effect of permanganate index

Permanganate index refers to the amount of potassium permanganate consumed during the treatment of a water sample by utilizing the acidity and alkalinity of the solution and the corresponding oxidation reaction with potassium permanganate as the oxidant. Therefore, the permanganate index is often used as a comprehensive indicator of the degree of pollutant contamination by water bodies.

Under the condition of static concrete adsorption test, the change rule of potassium permanganate index with time is shown in Fig. 11.

As shown in Fig. 11, in the static adsorption test of ecological concrete, potassium permanganate index continues to decline with the immersion time, but there is some fluctuation. Potassium permanganate index is a comprehensive index that affected by many factors,

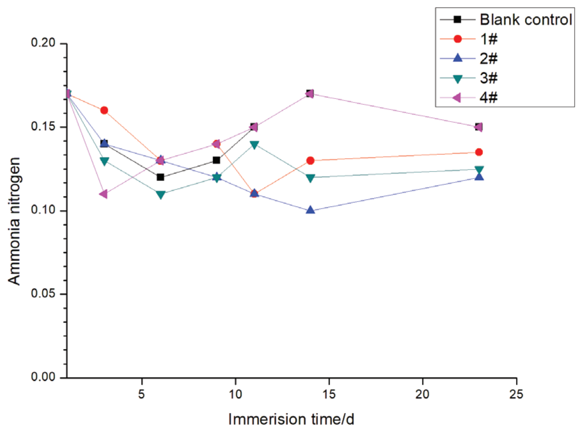

Fig. 9. The ammonia nitrogen variation with time of the static adsorption experiment.

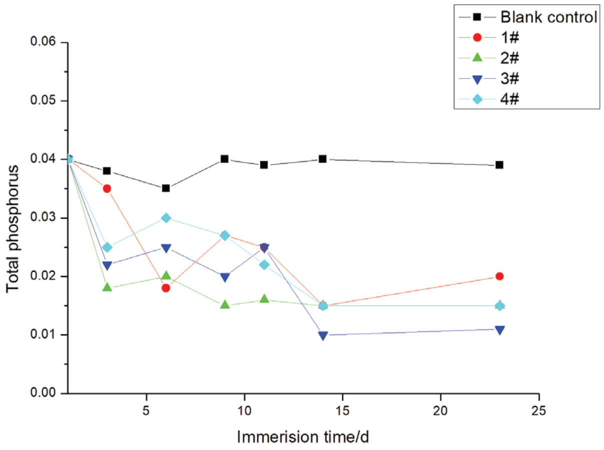

Fig. 10. The total phosphorus variation with time of the static adsorption experiment.

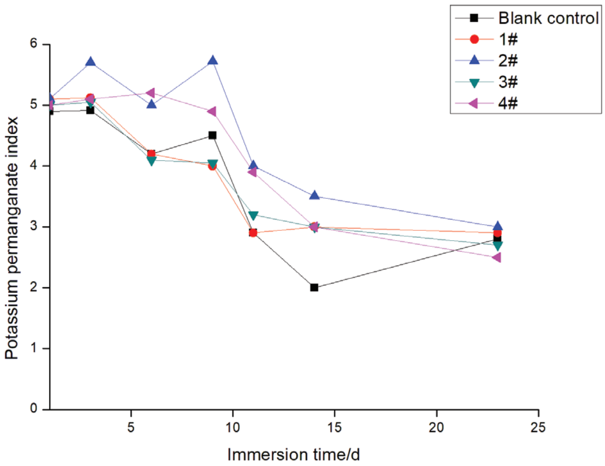

Fig. 11. The potassium permanganate index variation with time of the static adsorption experiment.

so there are some instabilities. 1#, 2#, 3# and 4# ecological concrete blocks have a purifying effect on potassium permanganate index, and the purification effect is obvious. In the ecological concrete blocks of each group, the decline rate of potassium permanganate index is above 45%. In the 1#, 2#, 3# and 4# ecological concrete, the decline rates of potassium permanganate index are 45.8%, 46.9%, 51.6% and 48.9%.

4. Conclusion

Through the static adsorption test of ecological concrete, it is feasible to simulate the effect of sewage treatment of ecological concrete revetment under the condition of different flow velocity of urban river, and the effect of water purification is obvious. In static adsorption test, 3# ecological concrete has the best water purification effect. In addition, the cumulative removal rate of total nitrogen, nitrate nitrogen, ammonia nitrogen and total phosphorus is 47.4%, 27.2%, 28.2%, 69.4% and 51.6%, respectively. By optimizing the mix ratio of ecological concrete, the effect of water purification is effectively improved. When a single coarse aggregate is used, the aggregate size is 20–25 mm, and the ratio of water to glue is 0.3. The amount of ferrous sulfate is 12%. When the optimal dosage of ash is 4%, the remediation effect of ecological concrete on water pollution is the best.

Because of the limited test time and test conditions, the purification mechanism of the water quality of ecological concrete is not combined with the microtechnology. At the same time, the study of ecological concrete slope protection only considers the single purification effect of the ecological concrete structure on the river sewage under the condition of ecological concrete slope protection. Therefore, further exploration can be carried out in the research of planting type concrete slope protection technology.

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References

[1] H.H. Kim, C.G. Park, Performance evaluation and field application of porous vegetation concrete made with by-product materials for ecological restoration projects, Sustainability, 8 (2016) 294.
[2] S. Ido, P.F. Shimrit, Blue is the new green—ecological enhancement of concrete based coastal and marine infrastructure, Ecol. Eng., 84 (2015) 260–272.
[3] S. Mundra, P.R. Sindhi, V. Chandwani, R. Nagar, V. Agrawal, Crushed rock sand—an economical and ecological alternative to natural sand to optimize concrete mix, Perspect. Sci., 8 (2016) 345–347.
[4] H.H. Kim, S.K. Lee, C.G. Park, Carbon dioxide emission evaluation of porous vegetation concrete blocks for ecological restoration projects, Sustainability, 9 (2017) 318.
[5] K. Deng, X. Wang, Treatments to control urban river pollution in water source city of south to north water diversion project, Polish J. Environ. Stud., 24 (2015) 379–385.
[6] W. Cai, Y. Li, P. Wang, L. Niu, W. Zhang, C. Wang, Revealing the relationship between microbial community structure in natural biofilms and the pollution level in urban rivers: a case study in the Qinhuai River basin, Yangtze River delta, Water Sci. Technol., 74 (2016) 1163.
[7] H. Li, P.K. Hopke, X. Liu, X. Du, F. Li, Application of positive matrix factorization to source apportionment of surface water quality of the Daliao River basin, northeast China, Environ. Monit. Assess., 187 (2015) 80.
[8] M.S. Islam, M.K. Ahmed, M. Raknuzzaman, M. Habibullah-Al-Mamun, M.K. Islam, Heavy metal pollution in surface water and sediment: a preliminary assessment of an urban river in a developing country, Ecol. Indic., 48 (2015) 282–291.
[9] J. Liu, Y.P. Li, G.H. Huang, S. Nie, Development of a fuzzy-boundary interval programming method for water quality management under uncertainty, Water Resour. Manage., 29 (2015) 1169–1191.
[10] A. Shrivastava, S.A. Tandon, R. Kumar, Water quality management plan for Patalganga River for drinking purpose and human health safety, Int. J. Sci. Res. Environ. Sci., 3 (2015) 71–87.
[11] X. Ji, R.A. Dahlgren, M. Zhang, Comparison of seven water quality assessment methods for the characterization and management of highly impaired river systems, Environ. Monit. Assess., 188 (2016) 15.
[12] H.M. Zakir, M.A. Sattar, Q.F. Quadir, Cadmium pollution and irrigation water quality assessment of an urban river: a case study of the Mayur river, Khulna, Bangladesh, J. Chem. Biol. Phys. Sci., 55 (2015) 2133–2149.
[13] N. Brion, M.A. Verbanck, W. Bauwens, M. Elskens, M. Chen, P. Servais, Assessing the impacts of wastewater treatment implementation on the water quality of a small urban river over the past 40 years, Environ. Sci. Pollut. Res. Int., 22 (2015) 12720–12736.
[14] F. Othman, S.A. Muhammad, S.A.H. Azahar, M.E.A. Eldin, A. Mahazar, M.S. Othman, Impairment of the water quality status in a tropical urban river, Desal. Wat. Treat., 57 (2016) 88–94.
[15] A. Ivanovsky, J. Criquet, D. Dumoulin, C. Alary, J. Prygiel, L. Duponchel, G.Billon, Water quality assessment of a small peri-urban river using low and high frequency monitoring, Environ. Sci. Processes Impacts, 18 (2016) 624–637.