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Composite Property of Polymer Composites for Municipal Sewer Pipes

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Abstract. The composite properties of polymer composites for municipal sewer pipes are studied. Firstly, the research background is introduced, and then the definition and classification of polymer grouting materials are expounded. The environmental stability and safety properties of polymer composites are analyzed, and the conclusions are drawn as follows: first, polymer composites are safe and non-toxic, and even if they are buried underground for a long time, they will not be harmful to the environment because of the long-term immersion of groundwater and the release of toxic and harmful substances; second, polymer composites will not lose their stability and thus affects their effectiveness due to the chemical corrosion of normal ground environment.

1. Research background

Urban drainage system is an important part of urban rainwater discharge, water pollution control and water ecological environment protection system. It is an important infrastructure to ensure the survival and sustainable development of the city. It is also the life guarantee for the city to "open up the old and accept the new" [1]. In recent years, some of the pipes laid are easy to be damaged because of the nonstandard construction operations, such as the thickness of soil, insufficient compactness and improper selection of pipe interface, resulting in sewage leakage affecting the pipeline foundation and uneven settlement of the pipeline. In addition, besides the damage of sewage pipeline caused by excavation around the pipeline, the acid and alkaline soil through the pipeline will also cause corrosion damage to the sewage pipeline, seriously affecting the safe operation of urban drainage system [2]. Polymer grouting technology is a rapid maintenance technology for infrastructure projects developed in the 1970s [3]. It is internationally widely used in the following fields: highway, urban road and airport pavement maintenance, as well as foundation reinforcement of industrial and civil buildings. The core of this technology is to inject the two-component polyurethane polymer into the foundation under the action of foaming agent, catalyst, flame retardant and other additives, according to a certain mixing ratio, through special equipment mixing [4]. The material expands rapidly after chemical reaction and solidifies as a polymer, eventually playing the role of strengthening the foundation. In the process of expansion, polymer materials can not only fill the pores of the surrounding soil and compact the soil near the grouting mouth, but also improve the bearing capacity of the foundation and uplift the soil layer above the grouting point.

2. Literature review

2.1. Introduction to polymer grouting material

Polymer is a kind of polymer material which is made up of many simple structural units linked repeatedly by covalent bonds. The polymer grouting material used here is a kind of non-aqueous reactive polymer composite material, which belongs to polyurethane polymer material. After being developed in 1937, through continuous research and improvement, its products have been widely used in many fields, such as chemical industry, light industry, electronics, textile, construction and so on [5].

Polyurethane polymer composites are classified into the following categories:

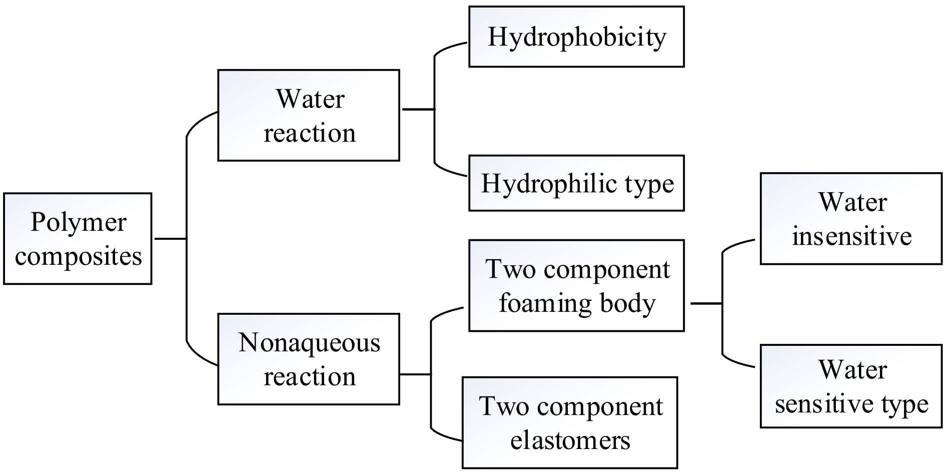

Figure 1. Classification diagram of polymer composites.

2.1.1. Classification and characteristics of water responsive polymer composites. Water responsive polymer composites belong to single component materials. They are mixed with water (or ground water) and have chemical reaction to form foam / paste polymer. It can be divided into two types: hydrophilic type and hydrophobic type. Water responsive hydrophilic polymer composites: Water responsive hydrophilic polymer composites are characterized by water absorption after completion of reaction with water. According to the mixed water quantity and water quality, the flexible polymer will form foam or gel. This kind of material is easy to be dispersed and dissolved in water, emulsified, and polymerized. It has the dual function of elastic water stopping and swelling water stopping [6]. Water responsive hydrophobic polymer composites: Unlike hydrophilic polymers, water responsive hydrophobic polymer composites will not absorb water after chemical reaction with water. Hydrophobic polymer composites have low water content, and no drying shrinkage will occur. They have good resistance to chemical media and they can be used for water plugging and foundation reinforcement.

2.1.2. Classification and characteristics of non-water responsive polymer composites. Non-water responsive polymer composites have been widely applied in Europe since the 1980s. Non-water responsive polymer composites (NWRPs) can be used as bi-component materials instead of water responsive polymer composites to participate in curing reaction. When the bi-components are contacted, chemical reactions can take place and solidify. Bi-components elastomer polymer composites: Bi-components elastomer polymer composites consist mainly of polyols and isocyanates. The material can still maintain good flexibility at low temperature, and because it does not foam during the curing process, the volume expansion rate after reaction is very small. Bi-components foam polymer composites: When the foaming agent is added to the bi-components elastomer polymer composites, it becomes the bi-components foam polymer composites. By adding different components, foam materials with different properties can be obtained. Therefore, materials can be adapted according to the specific requirements of the project. The material generally has a fast reaction rate and a large expansion rate. It only takes 6-

10s to expand to 20-30 times the original volume. Bi-component foamed polymer composites have the characteristics of rapid reaction, adjustable reaction time, high expansion rate, waterproof and impermeability, and good durability. They are polymer composites with better comprehensive properties. It is noteworthy that the strength of polymer composites formed by mixing the bi-components in different states is quite different. The strength of polymer formed in water is less than 30% of that in dry state. The bi-component foamed polymer composites become water-sensitive materials.

2.2. Performance analysis of polymer materials

The properties of polymer grouting materials mainly include the following six aspects:

High expansion rate: when the two main raw materials are mixed, the volume expands rapidly, resulting in the expansive force between 500kPa and 1000kPa. And the free expansion ratio of polymer materials can reach 20:1.

Lightweight: since the material is porous after reactive molding, the solid material formed is lighter in weight, the volume of the specimen is $3375cm^3$, the mass is 160.8g, and the density is $47.6kg/m^3$.

High strength: under suitable reaction conditions, the material can reach 90% of its strength within 15 minutes. The material also has high tensile strength.

Durability: the properties of grouting materials are stable and durable, and can be more than 100 years underground.

Waterproof: because the rigid polyurethane foam is a compact micro-porous material, the closed porosity is as high as 92%. Except for the cracked pores, there will be no seepage, which can eliminate the water accumulation in the disease.

Environmental protection: grouting materials have been recognized by many national environmental protection departments as neutral in the environment and do not pollute soil and water.

2.3. Research status

2.3.1. Research status of polymer materials property. Dai Shimei et al. studied the water absorption of rigid polyurethane foam, and added γ-aminopropyl triethoxysilane (KH-550) in the material to achieve the purpose of delaying the diffusion of water in the material. The results showed that the surface tension of the material decreased, the water absorption of the material decreased from 10.18% to 1.91%, the water absorption of the material decreased from 10.18% to 1.91%, and the effect of water prevention was obvious. Abdel-Hamid I Mourad et al. discussed the effects of sea water and temperature on the structure and properties of glass/epoxy resin and glass/polyurethane composites. The soaking time ranges from 3 months to 1 year, and the temperature includes room temperature and 65 degrees Celsius. The absorption of seawater increases with soaking time and temperature, and the tensile strength decreases by 19%. Zhang Tiancai used NaCl tracer technology to observe the diffusion of water on the surface of polyurethane foam with optical microscope [7]. Meanwhile, the distribution of moisture in polyurethane foam materials was observed by electron microscope. In order to analyze the diffusion process of water in detail, the diffusion of water on the surface is divided into the surface diffusion without defect matrix and the surface diffusion of gel micropores. Wang Yan measured and compared the volumetric water absorption of different types of polyurethane by international law and simple method for many times. The results showed that the simple method was feasible, and it was simple and convenient in practical application and saved a lot of test time. Cai Zhengyin et al. knew the physical and mechanical properties of sulfate saline soil under various conditions and the influence of dry density and sodium sulfate content on compressive strength through uniaxial test.

2.3.2. Research status of polymer conformance materials. On the basis of Darcy's law and spherical diffusion theory, Yang Xiuzhu et al. studied Bingham body in non-Newtonian fluid. The formula for calculating the diffusive radius of Bingham body's slurry was obtained, and the feasibility of the formula was verified in practical construction. Xu Tao prepared polyurethane materials, analyzed the effect of solution concentration and humidity on its appearance, and then studied the adhesion of water and ice on the surface of polyurethane materials, and chose adhesion work as an index to evaluate the adhesion force. Huang Hongjun et al. tested the adhesive force of polyurethane materials through experiments, and calculated the adhesive strength of the materials. The influence of the content of epoxy resin on the adhesion of epoxy resin was studied. Modified polyurethane materials were prepared by DMP-30. The reaction process and adhesion properties of the modified materials were analyzed by infrared spectroscopy. Jiang Lei et al. developed a method for measuring the adhesion of sodium polyacrylate based on the probe method. The effects of initial pressure, water absorption and separation rate on the adhesion of the probe were also analyzed. Samal et al. introduced the relationship between microstructure and mechanical properties such as bending strength and bending modulus of fiber reinforced geocomposites after high temperature. Banea et al. discussed the tensile and thermal conductivity of polyurethane adhesives modified by thermal expansion particles, and used scanning electron microscopy to study the fracture surface morphology of the samples. Reis et al. studied the tensile strength of polyurethane reinforced by glass fiber at variable strain rates and proposed a viscoelastic damage model.

3. Analysis of environmental stability and safety performance of polymer composites

With the enhancement of people's awareness of safety and environmental protection, more and more attention has been paid to the impact of engineering materials on the environment and human health. Polymer materials are mainly affected by both internal sewage and external soil. In order to analyze the impact on the surrounding soil and groundwater after construction, it is necessary to analyze the environmental impact of non-water responsive polymer grouting materials.

Analysis of water soluble matter: Experimental objective: When the polymer composite material is injected into the pipeline to be repaired, the polymer composite materials act as the isolation layer to isolate the soil outside the pipeline from the groundwater and the sewage inside the pipeline, and the pipeline is immersed in the groundwater and the sewage inside the pipeline for a long time. In order to investigate whether the toxic substances in the polymer composites will diffuse due to de-polymerization during long-term immersion, the immersion test of the polymer composites was carried out. Experimental method: The bi-component foam polymer composites formed in the air were ground and crushed. The polymer materials under 50g and 100 mesh sieve were taken and immersed in deionized water at a solid-liquid ratio of 1:100 for 24h and 48h. When the soaking time reached, the filtrate was filtered according to the Standard Test Method for Drinking Water Hygienic Standards GB5750-2006, Water and Wastewater Monitoring and Analysis (Fourth Edition) and other standards. IICPIRIS Intrepid Spectrometer, ICS-2000 Ion Chromatography, AFS-8130 Dual-channel Atomic Fluorescence Spectrometer, PHS-3C Meter, and M6 Graphite Furnace Atomic Absorption Spectrometer and other instruments were used to analyze the water quality of polymer composite material. Experimental results and analysis: The test results are shown in Table 1:

From Table 1, it can be seen that the substances of polymer materials immersed in purified water for 24h and 48h have little difference. All the test results are lower than the standard limit of drinking water, and some indexes are even lower than the detection limit. The experiments show that polymer composites are safe and non-toxic. Even if they are buried underground for a long time, they will not be harmful to the environment because of the long-term immersion of groundwater.

Chemical corrosion resistance analysis: Experimental objective: Due to the chemical characteristics of polymer materials, their strong acid, alkali and organic solvent corrosion resistance is generally poor. As a kind of polymer material, the anti-corrosive effect of polymer composites on strengthening chemical needs to be verified, which provides factual basis for practical application. Experimental method: The non-water responsive polymer grouting material was cut into rectangular bottoms with sides of 30mm and 50mm high. The grouting material was put into a wide-mouth stopper medicament bottle, and hydrochloric acid, sulfuric acid, sodium hydroxide, ethanol and other reagents were added to the medicament bottle. After soaking for 30 days, the sample was taken out and the volume of the sample was measured by drainage method. Experimental results and analysis: The test results are shown in Table 2:

Table 1. Comparison of water quality test results of polymers and sanitary standards of drinking water.

Test terms	Immersion result (mg/L)			Standard limits for drinking water (mg/L)	Experimental result
	Pure water	Immersion toxicity test 24h	Immersion toxicity test 48h		
pH	6.2	6.3	6.2		Neutral
cr6	<0.05	<0.05	<0.05	0.05	Conforming to standard
As	<0.005	<0.005	<0.005	0.05	Conforming to standard
Cd	<0.0001	<0.0001	<0.0001	0.005	Conforming to standard
Cu	<0.001	<0.007	<0.006	1.0	Conforming to standard
Hg	<0.00005	<0.00005	<0.00005	0.001	Conforming to standard
Pb	<0.005	<0.005	<0.005	0.01	Conforming to standard
Cr	<0.005	<0.005	<0.005	.	.
Se	<0.01	<0.01	<0.01	0.01	Conforming to standard
Fe	<0.001	<0.004	<0.004	0.3	Conforming to standard
Mn	<0.001	<0.007	<0.005	0.2	Conforming to standard
Al	<0.001	<0.005	<0.005	0.2	Conforming to standard
Zn	<0.001	<0.002	<0.002	1.0	Conforming to standard

Table 2. Experimental results of chemical corrosion resistance

Solution name	Volume loss rate (%)
Water	0
Sulphuric acid (10%)	5.6
Hydrochloric acid (10%)	4.2
Sodium hydroxide (10%)	1.1
Engine oil	2.3
Gasoline	3.6
Methanol	4.1
Ethanol	3.9
Propanol	21.4

The results showed that, except acetone, the acid, alkali conditions and common organic solvents could not dissolve the polymer composites, and the volume of the composites was greatly reduced. Therefore, in the underground environment, polymer composites will not lose their stability and thus their effectiveness due to chemical corrosion in the normal ground environment.

4. Conclusion

The polymer composites studied here refer to the difference between bi-component foamed polymer composites and other polyurethane polymers. Based on the experimental results and analysis of physical and mechanical properties of this kind of material, it is concluded that the material can meet the requirements of trenchless repair technology. The water solubility and chemical corrosion resistance of the polymer composites studied here are investigated by experiments. The results show that the polymer composites cannot dissolve metal substances and pollute the sewage in the pipe and the soil environment outside the pipe. The results of chemical corrosion resistance test show that the solubility of other common acids, alkalis and organic solvents is lower than that of acetone. It is inferred that the material will not be damaged by chemical corrosion in normal ground environment.

Acknowledgments

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