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Application of Coal Liquefaction Residue Replacing Polyurethane Waterproof Coating in Building Waterproof

Lingzhi Zhang

Chongqing College of Electronic Engineering, Chongqing 401331, China
lzzhangedu293@163.com

This paper sets to analyze the application of coal liquefaction residue for the purpose of building waterproof replacing polyurethane waterproof coating. We adopt the method of using coal liquefaction residue 01, 05 and 07 to replace the group B in polyurethane waterproof coating. When mixed in certain ratios, we conducted analysis on the waterproof performance. It is our finding that replacing group B in waterproof coating with coal liquefaction residue improves the performance of the coating when applied for building waterproof. In conclusion, in terms of building waterproof, substituting coal liquefaction residue for group B in water proof coating improves the building waterproof performance.

1. Introduction

Polyurethane waterproof coating is a material widely used for building waterproof. Due to that there is limited variety of polyurethane waterproof coatings in China, and that many manufacturers cannot launch large scale production making it necessary to import the materials so that the industrial demands in building waterproof can be met, the coating material has impeded development in China. During the manufacturing process of polyurethane waterproof coating, some manufacturers may opt to use coal tar for lower coasts, but since aliphatic substance and aromatics in the coal tar are highly irritant, when volatized, they pose hazards to the environment as well as humans. Therefore, it is important to find a substitute for polyurethane waterproof coating that can both meet the building waterproof requirements, and can relieve the environmental pollutions caused by the production. Out of this purpose, we set to explore substituting coal liquefaction residue for polyurethane waterproof coating.

In detailed research of the application, it is necessary to analyze the method of substituting coal liquefaction residue for polyurethane waterproof coating, and the method of analyzing the waterproof performance when applied. The materials required include coal liquefaction residue, talc, calcium carbonate light, and group A of waterproof coating. Waterproof coating was prepared via mixing the materials in certain ratios. When the coating material was prepared, we conducted performance analysis on the impact of replacing group B of polyurethane waterproof coating with coal liquefaction residue on its waterproof performance. Waterborne polyurethane is a polyurethane binary collagen system with water as the dispersion medium. It has the advantages of environmental protection, strong adhesion, high hardness, good flexibility, good air permeability and non-flammable. Therefore, waterborne polyurethanes can be used in the fields of coatings, leather, ink, textile, adhesives and building materials. In addition, it can also be used for special functional materials. However, compared with solvent-based polyurethane, water-based polyurethane has many shortcomings, such as water resistance, mechanical properties and heat resistance are not very good. Therefore, in order to improve the overall performance of waterborne polyurethane, new water-based polyurethane was synthesized.

2. State of the art

Coal liquefaction residue is referred to as polystyrene foam. It is a kind of general thermoplastic, with a very low density, closed cell structure, low water absorption (hydrophobic), high strength, insulation, anti-mold, low thermal conductivity and a series of excellent physical properties. It has the characteristics of stable chemical

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properties, aging resistance and corrosion resistance (Duan et al., 2017). Waste coal liquefaction residue is a kind of closed cell and light insulation material. In the case of proper construction and waterproofing, it has the advantages of energy saving, good long-term R (thermal resistance) value, water resistance and dimensional stability, and can be used to produce all kinds of insulation building materials, such as building insulation mortar, insulation board and various commercial roof systems. The water absorption of coal liquefaction residue is very low, and the surface is hydrophobic, so it is necessary to solve the problem of compatibility between polystyrene particles and cement mortar by coal liquefaction residue. The use of waste polystyrene foam can meet the requirements of wettability of cement mortar by physical modification (Remesar et al., 2017; Zhang et al., 2016).

The earliest product of polyurethane was a two-component polyurethane waterproof coating produced by American Rubber Co., Ltd. In 1962, Germany developed a waterproof coating that can be used as a protective outer layer of cement and a waterproof layer. It has the characteristics of low solvent, and Germany has also developed a bituminous waterproof coating. After introducing the waterproofing coating technology of the DuPont Co in the United States, the waterproof coating industry in Japan has developed rapidly, and the standard of waterproof coating and the construction standard have been set up one after another. At present, foreign waterproof materials are mainly waterproof coatings. Many companies have also developed a number of additional high-performance waterproof coatings. It also includes a variety of wear-resistant and non-abrasion-resistant, flame-retardant and other varieties. In recent years, quick-setting and ultra-fast solid polyurethane waterproof coatings have also been developed. The United States invented a spray-type waterproof coating. This waterproof coating has the dual functions of waterproofing and moisturizing. Spray-type waterproof coatings account for 3% of roofing waterproof materials. It accounts for 2% of the repaired waterproof coating. This waterproof coating has proven its good performance in the project. The UK studied a quick-drying waterproof coating that can withstand light rain after a few minutes of construction. Since the late 1970s, the rapid development of the Chinese economy and construction industry has promoted the development of the waterproof coating industry. By 2010, the amount of polyurethane waterproof coating in China has reached 70,000 tons.

It is the most important in this experiment to find a suitable modifier to modify coal liquefaction residue. Polystyrene foam is a kind of high molecular compound. According to the principle of similarity compatibility, the reagents used for modification must be an organic solvent. In order to make the modified waste polystyrene foam play the role of insulation components, and the modified waste polystyrene foam on the cement mortar is only a simple physical adsorption, the selected modifier must be adapted to the wettability, dispersibility, pH, electrical, and weather resistance of the cement mortar. The selected modifier should be nonionic surfactant. In the cement mortar system, it is not an ionic state, and its stability is high. It is not easy to be influenced by inorganic salts and acids (Ferrándiz-Mas et al., 2014). It has good compatibility with other types of surfactants and has good solubility in water and organic solvents. Although this kind of surface modifier is not ionized in water, it has hydrophilic (-CH_2CHO-, -OH, etc.) and oil (hydrocarbyl-R). At the same time, the selected modifier must meet the following principles. First, the agent is non-irritating odor and non-toxic. Second, the reagent can be mass produced and will not affect production due to out of stock. Third, the reagent is cheap and easy to buy. Energy issues are the concerns of the world today, and building energy conservation is one of the most important tasks in energy conservation (Dissanayake et al., 2017). Building energy conservation is conducive to the protection of energy resources, energy security and the development of national economy. With the development of economy in our country, the production of coal liquefaction residue is increasing year by year. Therefore, turning waste into treasure and the comprehensive utilization of resources have a very positive effect on environmental protection (Briga-Sa et al., 2013).

In recent years, with the development of modern concrete technology and the deepening of the understanding of the potential effects of fly ash, high volume fly ash cement concrete is more and more widely used in hydraulic engineering (Han et al., 2015). However, some studies have shown that the early strength of concrete mixed with fly ash is too low (Posi et al., 2015). Through the appropriate technical approach, the early activity of fly ash is stimulated. Therefore, the early strength of fly ash concrete is improved. This is of great practical significance (Sanz-Pont et al., 2016). In this paper, the experimental study on the new type of insulation material modified by fly ash was carried out. Lime and gypsum are used to stimulate the potential activity of fly ash and cement. It can make up for the loss of the strength of insulation mortar caused by fly ash and modified coal liquefaction residue. According to GB / T10294 thermal conductivity standard and JTG E30-2005-concrete frost resistance test (rapid method) (T0565-2005), GB GB82-85, the workability of the modified insulation mortar on the coal liquefaction residue surface is good. Coal liquefaction residue insulation mortar bonding strength is much higher than the expansion of perlite insulation mortar. The strength of the 28 day is 51MPa. It can be compared with the best polyurethane insulation performance on the current market. Fly ash and modified coal liquefaction residue insulation mortar and the base layer has a good bond, and the dust is less at the time of construction. Coal liquefaction residue insulation mortar water absorption rate is 12.3%, it is less than 30% of expanded perlite, which creates favorable conditions for the improvement of weather resistance. The loss of strength of freezing and thawing cycle and drying and watering cycle of coal liquefaction residue thermal insulation mortar is only about half of the expansion of perlite insulation mortar. It has little difference with the best insulation material polyurethane.

3. Methods

3.1 Method to replace polyurethane waterproof coating with coal liquefaction residue

In the process of coal liquefaction, coal cannot be turned into oil at a 100% transformation rate. No matter what industrial or separation method is adopted, we will end up with around 30% residue when liquefaction is completed. If the residue is not properly utilized, the economy of turning coal into oil is undermined. With development and wide usage of coal liquefaction technique, the amount of residue will rise up to a problematic level in terms of inventory. It will be an extra burden to the environment if the residue of coal liquefaction is not properly treated. As a result, from the perspectives of the economy of coal liquefaction projects and environment protections, it is an emerging issue facing the industry to properly utilize the residue of coal liquefaction. Now the residue utilization mainly focuses on three areas, gasification, coking and combustion. Our method is to utilize the residue in high value-added carbon materials. We powdered the residue to 300 mesh and above, mixed the pre-measured plasticizer with the materials, mixed them well using a high-speed blender. When observing there was no powder-like substance noticeable, pour out the group B and grind repeatedly on the three-role grinder until all the substance was dissolved into the plasticizer. This was the way to prepare the uniform group B of polyurethane waterproof coating. Then pour the group B into clean container for sealed preservation and further use.

Table 1: Materials and models

The raw material	Specifications
MOCA	The secondary
Talcum powder	More than 325 eyes, half 0.5% water
Light calcium	More than 325 eyes, half 0.5% water
Coarse whiting	More than 325 eyes, half 0.5% water
Calcium oxide	More than 325 eyes, half 0.5% water
Coal liquefaction residue	More than 325 eyes, half 0.5% water
Waterproof coating a group	NCO content of 3.14%

Considering the fillers of group B of polyurethane waterproof coating are inorganic, and the group A is organic, the compatibility of inorganic group B and organic group A determines the final performance of the waterproofing. Given that the coal liquefaction residue contains much organic components, including alkyl chain and aromatic compounds, it is similar to the group A of the waterproof coating to a great extent. Therefore, the coal liquefaction residue has good compatibility with group A of the coating, and can improve the waterproof performance. We used the residue to replace calcium carbonate light, calcium carbonate heavy and eventually the talc, mixed it evenly with group A and applied the mixture coating, and conducted tests on the performance in line with GB/T19250.2003 standards.

Table 2: The classic formula of waterproof coating group B

The raw material	Specifications	Formula/copy of
MOCA	The secondary	16.30
Oxidation of paraffin	40#	200.00
Talcum powder	More than 325 eyes, half 0.5% water	45.00
Light calcium	More than 325 eyes, half 0.5% water	15.00
Coarse whiting	More than 325 eyes, half 0.5% water	7.50
Calcium oxide	More than 325 eyes, half 0.5% water	5.00
Di-n-butyltin dilaurate	industrial-grade	1.30

3.2 Performance analysis method

Generally, the polyurethane is produced by mixing polyether glycol and polyisocyanate in certain proportions. Based on the macro-molecular structure after completion of the chemical reaction, polyurethane has two structures, the linear structure and bodily structure. Polyether diols and diisocyanate, after chemical reaction, make a linear-structure polyurethane, while the polyether glycol and polyisocyanate create bodily-structure polyurethane. With different materials mixed at different ratios, the polyurethane created can have varied performance. As a result, for waterproof material of different types, such as coating, plastics, rubber, fiber, and adhesive, that are made with different materials in varied mixing ratios, the surface drying time is an important indicator of waterproof performance. The surface drying time stands for the curing speed of the material. To be eligible for construction use, the waterproof material must have a proper curing speed. The curing speed should not be too high, otherwise the waterproof material dries up before the construction is completed. On the other hand, the waterproof material should also be able to cure soon enough after the completion of construction. When group A and group B are mixed evenly, we applied the film of thickness 3.0±0.2 mill to its surface. Sometime after formation of the film, a layer of polyethylene film was applied on the surface of the elastomer, onto which a metal plate (weight 40g, size 19 mm ×38 toni) was placed and pressed for about 30 seconds. Then peel the polyethylene film off from the surface and observe if any material was attached to the film. The process was repeated until no material was attached to the film by observation. The time it takes from film application to non-material attachment is the surface drying time. Fracture elongation and tensile strength are mechanical properties of waterproof materials. In line with the GB/T528 standards, we prepared samples from the well-preserved polyurethane waterproof coating. The samples were prepared in the shape of dumbbell. The tensile strength and fracture elongation were tested using the universal testing machine. The polyurethane waterproof coating samples were kept in a -40℃ low-temperature test box for 8 hours and then wrapped around a cylinder of 6 mm diameter under low-temperature. We then observed if there was any breaking of the coating under a magnifier.

4. Results and analysis

4.1 Content of coal liquefaction residue 01 and its influence on waterproof coating

Adopting the material ratios in a classic formula, we replaced all the calcium carbonate light and calcium carbonate heavy in the formula, and gradually replaced the talc by 5.5 portions each time in the tests with coal liquefaction residue 01. In this way, we set to analyze the influence on the tensile strength and fracture elongation on the waterproof coating material.

Table 3: Fracture elongation

Coal liquefaction residues 1/ part	Tensile strength (MPa)
20	2.05
30	2.67
40	3.21
50	3.63
60	1.76
70	0.84

Table 4: Tensile strength

Coal liquefaction residues 1/ part	Elongation at break (%)
20	450
30	485
40	578
50	630
60	492
70	421

Both the fracture elongation and tensile strength improved in the first place. When the talc was at 55.5 portions, the highest fracture elongation and tensile strength were achieved. The components in the coal liquefaction residue, such as asphaltene and heavy oil, formed reticular structure thanks to the hydrogen bond, π-7c bond, and abundant functional groups. When the inorganic component was replaced with certain amount of residue, its compatibility was improved compared to the inorganic component. At this stage, the reticular structure formed can fixate the macro-molecular of the group A, thereby enhancing the fracture elongation and tensile strength. However, when the amount of residue added exceeded a certain level, it started to absorb the oil and plasticizers in the waterproof coatings. At this time the system fluidity became deteriorated and both the fracture elongation and tensile strength drastically declined.

4.2 Content of coal liquefaction residue 05 and its influence on waterproof coating

Adopting the material ratios in a classic formula, we replaced all the calcium carbonate light and calcium carbonate heavy in the formula, and gradually replaced the talc by 5.5 portions each time in the tests with coal liquefaction residue 05. Based on the performance of residue 01, the tests started with 45 proportions. Its results on the fracture elongation and tensile strength are listed as below.

At first, the fracture elongation improved but the tensile strength deteriorated. When the proportion of talc was 72, both the fracture elongation and tensile strength met the industrial standards. The waterproof coating modified with residue 05 has the same working principle with the residue 01 modified material. However, the residue 05 modification displayed lower level of association ability than residue 01 modification, hence it has less impediment to the fluidity of the coating material. Using residue 05, more inorganic filler can be replaced, and the fracture elongation and tensile strength both improved. The best performance was achieved when 72 proportions of residue 05 was added, the components of group B of the coating material are listed as below:

Table 5: The proportion of material in group B

The raw material	Specifications	Formula/copy of
Oxidation of paraffin	40#	200.00
MOCA	The secondary	16.30
Coal liquefaction residue	300 mesh	72.00
Calcium oxide	More than 325 eyes, half 0.5% water	5.00
February silicate dibutyltin	industrial-grade	1.30

4.3 Content of coal liquefaction residue 07 and its influence on waterproof coating

Adopting the material ratios in a classic formula, we replaced all the calcium carbonate light and calcium carbonate heavy in the formula, and gradually replaced the talc by 5.5 portions each time in the tests with coal liquefaction residue 07. Based on the performance of residue 01, the tests started with 45 proportions. Its results on the fracture elongation and tensile strength were listed as below.

At first, the fracture elongation improved but the tensile strength deteriorated. When the proportion of talc was 72, both the fracture elongation and tensile strength met the industrial standards (The waterproof coating modified with residue 07 has the same working principle with the residue 01 modified material). However, the residue 07 modification displayed lower level of association ability than residue 01 but a similar level with residue 05, hence it has similar performance as residue 05. Using residue 07, more inorganic filler could be replaced, and the fracture elongation and tensile strength both improved. Then group A and group B of the polyurethane waterproof coating material were mixed by ratio 1:2 and applied with film. Maintained in line with standard requirements, we tested the performance of the material.

Table 6: Performance test data

Test project	The test data
Elastic recovery rate/%	522.46
The tensile strength/MPa	3.40
Low temperature flexible/^{0}C	-40.00
Table dry time/h	6.50
Work time/h	15.00
Solid content/%	98.4
Impervious 0.3MPa, 30min	impervious

5. Conclusion

This paper successfully filled the coal liquefaction residue 01, 05 and 07 into the group B of polyurethane waterproof coatings, and mixed the content with group A by ratio of 1:2 for film application. Based on national standards GB/T19250.2003, the performance of the mixture was tested and the results met the national requirements. Since the coal liquefaction residue has replaced the inorganic component of group B, and therefore has improved compatibility with group A, the performance of the coating material improves. In addition, China has high demand for waterproof coating every year, therefore a great amount of coal liquefaction residue can be consumed. The economy of coal liquefaction projects can also be improved.

The polyurethane waterproof coating, when filled with coal liquefaction residue, achieves higher performance as well. Inorganic components can serve as fillers for not only polyurethane waterproof coating, but also other categories of coatings and sealants. The coal liquefaction residue can also be used in other types of coatings and sealants.

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