Summary of the Grouting Material for the Void Beneath Cement Concrete Pavement Slab

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Abstract: With the increase of vehicle load and the pavement’s service life, the cement concrete pavement’s diseases are also gradually increased. Among them, the empty beneath slab is the most common disease and main safety problem. And it has seriously affected the usability and durability of the road. Press-oar is the most effective treatment means for the void bottom slab, and it has high performance requirements for grouting materials. Therefore, several common domestic and international grouting materials are analyzed and reviewed. And their advantages, disadvantages and improvement methods are pointed out. This will lay a foundation for the development of slab bottom void grouting materials in the future.

1. Introduction

At present, cement concrete pavement is the most widely used pavement in China. Although its bearing capacity is high, under the action of vehicle dynamic load and the change of humidity and temperature, the pavement base will be plastic deformed. After a long period of accumulation, the pavement will become empty which is one of the major hidden dangers of cement concrete pavement. If it is not treated in time, it may make the pavement slab break and damage. Therefore, it is necessary to treat the pavement effectively in time to avoid pavement damage. Grouting is the most effective means of repair and reinforcement at present. Grouting refers to use of special mechanical equipment to fill the slurry into the void in the bottom of the slab, and after the slurry hardening, it will form a structure layer with good stability, high strength and good compactness. And the structure layer can binds closely to the base and the bottom of the slab, thereby changing the stress state of the slab to prevent the pavement from being destroyed [1]. The effect of plate bottom removal is often related to the properties of grouting materials, so it is necessary to summarize grouting materials.

2. Grouting material

The history of grouting materials can be divided into clay slurry, cement slurry, polymer chemical slurry and cement-based composite slurry. The ideal grouting material should have the following characteristics:

- good fluidity and good irrigation.
- high initial and later strength.
- no segregation, no bleeding and no shrinkage[2].

And the commonly used grouting materials for slab bottom voids can be roughly divided into organic and inorganic grouting materials.
2.1 Organic grouting materials

Organic grouting material is mainly polymer chemical grouting material. Polymer chemical grouting prepared by monomer or oligomer and a certain amount of catalyst[3], and poured its slurry into the need to vacate treatment sites. The high polymer or macromolecule formed by a series of chemical reactions, such as polymerization or cross-linking, and then it is tightly bonded to the surrounding structure of the desired treatment site and form a whole to achieve the purpose of impermeability and reinforcement. It is widely used in road, bridge, defense, underground and restoration engineering because of its high impermeability, adhesion and easy operation. At present, the most widely used organic grain filling materials are polyurethane and epoxy resin.

2.1.1. Polyurethane grouting material

Generally, polyurethane grouting materials can be divided into two categories: aqueous and oil-soluble polyurethane. Aqueous polyurethane grouting materials are mainly based on isocyanate and water-soluble polyether as raw materials, synthesized by chemical reaction. And it has good encapsulation and impermeability[4]. The oil-soluble polyurethane grouting material has high impermeability and compression strength. It is made of polyisocyanate and polyl hydroxyl and synthesized by a series of polymerization reactions[5]. Polyurethane grouting materials can react quickly with water and produce CO₂ gas. So that, the volume is rapidly expanded and firmly bonded with the surrounding material, forming a dense consolidated body to solve the problem of the plate bottom voids to the greatest extent.

Polyurethane grouting material has the following characteristics:

- curing time is short and has certain expansion property.
- has higher early and later stage strength.
- has higher impermeability and has better bond property.

Polyurethane also has some obvious disadvantages:

- poor stability andflammability.
- high cost.

For its disadvantages, the polyurethane can be improved by means of modification or compounding.

Zhengpeng Yang[6] made of water glass, acrylamide, polyurethane, initiator and catalyst as raw materials, produced the flexible and extensible water-glass polyurethane polymer composite grouting material. And its flammability and thermal stability have been greatly improved. At the same time, it also reduces the cost. Wang Yang[7] compound nano-SiO₂, fiber materials with polyurethane. The modified polyurethane grouting material has good flame resistance and stability. Fuming Wang[8] proposed a new kind of non-water reactive two-component foamed polyurethane polymer grouting material. The comprehensive properties of the grouting material are excellent and accord with the development idea of green environmental protection.

2.1.2. Epoxy grouting material

Epoxy resin grouting material is mainly epoxy resin as a raw material, and then add a certain amount of aggregates and fillers and some catalysts (such as diluters, curing agents, accelerators, and toughening agents)[9]. Epoxy resin grouting material has been widely used due to its high strength, good mechanical properties and adhesion, low shrinkage and good thermal stability. However, its main drawbacks are:

- greater viscosity and brittleness.
- lower irrigation.

There are two main ways to solve this problems. The first is to add a large amount of organic solvents to modify it, the second is to improve its slurry. Because of the adverse effects on the environment caused by the heavy use of organic solvents. Therefore, the researchers mainly use the second way to solve this problems[10].

Dong Wang[11] used epoxy phenolic resin HY to modify epoxy resin. The epoxy resin slurry prepared by them had high impermeability and groutability. Jiaxiang Li[12] using a new type of epoxy
resin and catalyst prepared by the CW epoxy slurry, the viscosity of the epoxy resin slurry and irrigation can be improved.

Organic chemical grouting material has good comprehensive performance and can meet the filling requirements of grouting material, and is widely used in engineering. However, with the in-depth study of organic grouting materials and a large number of engineering applications, it is found that its durability is easily affected by the surrounding environment and most organic grouting materials are toxic, which has a serious impact on humans and the environment. Therefore, organic grouting materials are developing towards non-toxic environmental protection.

2.2. Inorganic grouting material
Inorganic grouting material is a kind of grouting material with certain fluidity, dilatability and strength, which is formed by mixing cement with raw materials, adding proper amount of fine aggregate and admixture, and it mainly refers to cement-based grouting materials. The common cement-based grouting materials include ordinary Portland cement and aluminum sulfate cement, but because of their larger particle diameter, they can not repair small cracks and has a certain degree of shrinkage after curing. So researcher turned their research direction to organic grouting materials[13]. However, organic grouting material have high cost, poor durability and toxicity. While, the characteristics of inorganic grouting materials such as environmental protection, low cost, convenient material drawing, simple operation, high durability and strength make the researchers re-focus their research on inorganic grouting materials and begin to study their modification, such as DSP Modified cement-based grouting materials and in-depth study of ultra-fine cement.

2.2.1. DSP modified cement-based grouting material
DSP refers to the uniform distribution of ultra fine particles system. DSP technology refers to the use of particle theory, according to the theoretical model of dense stacking, to achieve the most compact stacking state of materials through reasonable particle stacking, then get high density material by chemical reaction[14]. DSP modified cement-based grouting material is the use of DSP technology to modify the cement slurry, mainly by adding fine quartz powder, nano-SiO2 and silica fume into cement mortar to improve its mixture ratio, make its particle distribution more uniform, improve the consistency of the slurry and improve the internal structure of the pulp, so that high performance grouting material can be obtained.

DSP modified cement-based grouting material has the following characteristics compared with ordinary grout:
- lower water-cement ratio and better groutability and fluidity.
- higher durability, higher compression and higher flexural strength.
- no bleeding, no segregation and no shrinkage.
- good thermal stability.
- higher early and late strength.

2.2.2. Superfine cement grouting material
Superfine cement refers to a cement with a small particle size prepared from ordinary cement slurry by using special mechanical equipment. There is no single standard for the definition of superfine cements, generally referring to cements with a maximum particle size of less than 20 μm or a specific surface area of more than 800 m²/kg[13,15].

The properties of ultra-fine cement grouting materials are shown in Table 1, such as high compression strength, greater shrinkage, poor fluidity and stability. In addition, it has been shown that the groutability of ultra-fine cement grouting materials is about the same as that of chemical grouting materials[16]. Its disadvantages can be solved by adding appropriate amount of fly ash, ore powder or industrial waste slag and catalyst to the superfine cement slurry to prepare a new type of ultra-fine cement grouting material for mining. There has research shown that the shrinkage rate of the new mine ultra-fine grout is obviously reduced, the fluidity and the stability are improved, and the development
concept of "green environmental protection" is also met. In addition, due to the high cost and complex preparation process of the ultra-fine cement grouting material, it is not widely been applied in the engineering. Therefore, low cost and high performance are the main development directions of ultra-fine cement grouting materials.

Table 1. Properties of ultra-fine cement grouting material.

| Viscosity (mPa.s) | Fluidity (mm) | Compression strength (MPa) | Shrinking ratio (%) | Time (s) |
|------------------|--------------|---------------------------|---------------------|----------|
| 681.5            | 92           | 30                        | 63                  | 0.025    |
|                  |              | 48                        | 63                  | 0.075    |
|                  |              | 28                        | 0.25                | 0.25     |
|                  |              | 28                        | 260                 | 380      |

Compared with organic grouting materials, inorganic grouting materials are more in line with the development concept of "green environmental protection and sustainable development", but their comprehensive properties are poor. Therefore, inorganic grouting materials should be developed in the direction of how to improve their performance.

3. New grouting material

3.1. Rubber mortar grouting material

At present, how to treat and apply waste rubber has become a global issue. In China, the use of waste rubber to prepare rubber powder concrete and rubber powder mortar has become a hot research topic, while there are few reports on the research of rubber powder mortar grouting material. Yanchun Li[17] used rubber powder, cement, mortar, water reducer, swelling agent to prepare rubber powder grouting materials that are superior to ordinary cement mortars in terms of dry shrinkage and frost resistance, better water retention, and the loss rate of strength and quality has been reduced, as shown in Table 2.

Table 2. Properties of rubber cement mortar grouting material.

| Type of grouting material | Shrinking ratio (%) | Strength loss rate (%) | Mass loss rate (%) |
|--------------------------|---------------------|------------------------|--------------------|
| Ordinary cement mortar   | 0.125               | 0.25                   | 0.265              |
| Rubber cement mortar     | 0.1                 | 0.18                   | 0.25               |

3.2. Industrial waste grouting material

China is a big mining country. More than 80% of the energy and raw materials come from mineral resources. And the research and development of industrial waste grouting materials can make full use of industrial waste, make it become a treasure, and prevent secondary pollution. To some extent, the problem of accumulation and environmental pollution of solid raw materials in mining industry is alleviated, and the cost of raw materials is relatively low and the materials are convenient to be obtained. Qingjun Ding[18] used water glass as alkali stimulant, industrial solid waste (slag, fly ash, steel slag) as raw materials to prepare a new type of industrial clinker without liquid clinker double liquid grouting material. The grouting material has the advantages of adjustable setting time, high compression strength and durability, and better filling property.
In addition, because these two new grouting materials are recently emerging grouting materials, they have not been applied in the treatment of slab bottom void removal, so the treatment effect and application technology of these two new grouting materials need to be further studied.

4. Conclusion and Outlook
With the increasing awareness of environmental protection in our country, the material is gradually developing along the direction of green environmental protection. For grouting materials with slab bottom gap, green environmental protection and high performance are one of the main development directions at present. The author believes that both organic, inorganic and some new grouting materials should be developed towards the direction of environmental protection and improving their comprehensive performance. In addition, emphasis should be placed on the development of some secondary energy sources to achieve waste and sustainable development of the ecological concept.

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