Study on properties of permeable brick

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Abstract: The performance research and preparation methods of different kinds of permeable brick are analyzed and summarized, which shows the wide application prospect of permeable brick.

1. Introduction
Since the reform and opening up, with the acceleration of urbanization, the scope of human activities has gradually expanded, buildings and cement pavement gradually cover the urban ground, the area of soil, vegetation and open area has greatly reduced, and the original water storage function of the ground has basically lost. Since the 18th National Congress of the Communist Party of China, it is a very ordinary era in the process of China's development. With the rapid development of economy, China's national economy has made remarkable achievements in the world. At the same time, the construction of ecological civilization has achieved remarkable results. Green water and green mountains are the golden mountains and silver mountains, and the concept is deeply rooted in the hearts of the people [1]. Therefore, China advocates promoting the sponge city plan [2]. Based on this concept, more and more cities use permeable bricks to pave sidewalks, parking lots and other places, so as to enhance the urban permeability. In 2014, the Ministry of housing and urban rural development of the people's Republic of China determined the first batch of pilot projects for the construction of sponge cities, including Zhenjiang, Xiamen, Jinan, Chongqing, etc; In April 2016, the central government determined the second batch of sponge city construction pilot projects in 14 cities, including Beijing and Tianjin. In China, permeable concrete is mainly used in sidewalks, parks, scenic spots, parking lots and other places. The wide application of permeable concrete products plays a very positive and effective role in improving urban waterlogging and reducing urban heat island effect [1,3].

2. Concept and classification of permeable brick
The development and preparation of permeable brick is based on the idea of building a sponge city with natural accumulation, natural infiltration and natural purification. At the same time, it can also bring significant social and environmental benefits. Permeable brick is made of special graded aggregate, cementitious material, cementing agent and mixing water by special process. Due to the special gradation of aggregate, there are a lot of connected pores in permeable brick. When it rains or the road area is full of water, the water can smoothly penetrate into the underground or exist in the subgrade along these connected "lines". Permeable brick is mainly used in tunnel engineering, especially permeable pavement brick.

According to the permeable way and structural characteristics, permeable brick is usually divided into front permeable brick and side permeable brick. The front permeable brick can reduce the runoff in rainy days, prevent the water in the road area and the reflection at night, reduce the sliding force of the road, improve the visibility, and improve the comfort and safety of vehicles and pedestrians.
Permeable pavement materials have large porosity. Groundwater evaporates through the pores, which is conducive to adjusting the temperature and humidity of urban surface and air, and alleviates the phenomenon of heat island. Permeable pavement can not only reduce the heavy burden of road drainage facilities due to rainfall, especially in the case of short-term concentrated rainfall, but also prevent urban river flooding and public water pollution. At the same time, the rough road surface can absorb the noise generated by vehicles, reduce the glare interference at night, and create a quiet and comfortable traffic environment. A large number of pores can absorb urban pollutants such as dust and reduce dust pollution. The front permeable brick and the side permeable brick have their own characteristics and can be used in different fields. From the perspective of permeable brick, the front permeable brick has good comprehensive performance, especially the permeable brick with composite layer structure. Pervious concrete and its products have many ecological advantages, which can effectively solve the problem of rainwater loss caused by impervious pavement, make rainwater quickly infiltrate into the surface, reduce to groundwater, replenish groundwater resources in time, maintain the water level of underground soil and protect water resources. Its good water permeability and air permeability improves the living conditions of plants and soil microorganisms on the urban surface, solves the problems such as the organisms under the paving layer can not grow normally and the biodiversity is destroyed, and enhances the water purification function in the process of soil water filtration, so the ecological effect is very superior.

3. Performance of permeable brick

3.1 performance of resin based permeable brick
Resin based permeable brick is mainly made of epoxy resin and curing agent, the curing product is binder and river sand aggregate, which is cured by vibration and pressure. There are many factors affecting the performance of resin based permeable brick, including the influence of aggregate size, binder content and other factors. Through the research of Yang Sanqiang, Huang Shizhou \(^4\) and hang Deliang \(^5\), The results show that the thickness of binder and the grain size of river sand have great influence on the permeability, porosity and compressive strength of resin based permeable brick. With the increase of the thickness of the binder, the permeability and porosity of the resin based permeable brick gradually decrease, and the compressive strength increases. When the thickness of the binder is 0.035mm, the water permeability reaches the maximum value of 9.585×10^{-2}cm/s. With the increase of river sand particle size, the permeability and porosity of resin based permeable brick increase.

Yu Mingkai and others \(^6\) found that the compressive strength of permeable brick with resin content of 2% is lower when the resin output is in the range of 2% - 10%. With the increase of resin content, the compressive strength of permeable brick increases in a quadratic curve. When the epoxy resin content increases from 6% to 8%, the strength increases the fastest. When the epoxy resin content is 8%, the strength increases significantly. Increasing the amount of epoxy resin may have little effect on the strength increase. At the same time, it is found that there is a linear relationship between the amount of epoxy resin and the flexural strength, and the flexural strength increases with the increase of the amount of epoxy resin. The experimental results are shown in Figure 1.

![Fig. 1 Effect of additive amount on strength](image)
3.2 Performance of Recycled Aggregate Permeable Brick

Recycled aggregate permeable brick is mainly made of construction waste, ceramic waste, industrial waste, biomass waste and so on. Because there are a lot of pores in recycled aggregate permeable concrete, it is of great significance to control the mechanical properties and permeability of recycled aggregate permeable brick. However, it is well known that the strength and permeability of permeable concrete are two mutually restricting indexes. Yuan Zhuoyi\(^7\) and Song Zhbin\(^8\) have studied by using the orthogonal test method. The test results show that the water cement ratio has the greatest influence on the properties of recycled aggregate permeable brick. When the water cement ratio is 0.3, the bone cement ratio is 4.0, and the aggregate particle size is 2.5~10.0 mm, the compressive strength and water permeability coefficient of the specimens reach 58.28 MPa and 0.289 mm/s respectively, which are higher than the requirements for strength and water permeability coefficient in CJ/T400-2012 recycled aggregate floor tiles and water permeability bricks\(^9\). He Naifu et al.\(^{10}\) prepared permeable brick with waste sintered clay brick as aggregate, and selected the optimal replacement rate of recycled aggregate through test. The test data showed that when the replacement rate of recycled aggregate was 20%, the indexes of recycled aggregate permeable brick met the standard requirements. Wang Ping et al.\(^{11}\) prepared recycled aggregate permeable brick with desert aeolian sand and refractory clay materials, and explored the relationship between desert sand content and wear resistance of permeable brick. The test data showed that with the increase of desert sand content, the length of grinding pit increased gradually, but the permeability coefficient increased. After optimization, the optimal desert sand content was 50%, and the grinding pit length of permeable brick was 26.6 mm. Meet the specification requirements. A large number of test data show that the permeability, strength and durability of permeable brick can be improved by optimizing aggregate, adding admixtures and improving the form and quantity of internal pores on the premise of ensuring water permeability. The test results are shown in Table 1.

| Group number | Target porosity(%) | Permeability coefficient(cm/s) | Effective porosity(%) | Compressive strength(MPa) |
|--------------|-------------------|-------------------------------|----------------------|--------------------------|
| A1           | 10                | 0.001                         | 2.8                  | 45.24                    |
| A2           | 15                | 0.013                         | 4.9                  | 48.76                    |
| A3           | 20                | 0.022                         | 9.3                  | 51.28                    |
| A4           | 25                | 0.043                         | 12.3                 | 55.66                    |

3.3 Properties of Sand Based Permeable Brick

Sand based permeable brick is made of sand and extruded by sintering free process, which has the function of water filtration, energy saving and environmental protection; By changing the surface tension and density of water surface, the contradiction between strength and permeability is solved, which makes the sand based permeable material have high strength and fast water permeability; It is not easy to be blocked by dust and has long-term water permeability. It can be achieved that the shoes are rain and wet, snow and ice free. Through changing the water cement ratio, ash collection ratio\(^{12,13}\), aggregate grading and other optimized mix ratios of sand based permeable bricks, the best mix ratio is 5% of cement quality, 0.34 and 0.25 respectively. The aggregate grading is: the particle size is 0.6-2.36mm, accounting for 70% of the aggregate total mass, the particle size is 2.36-4.75mm, accounting for 30% of the aggregate total mass. The strength of the sand-based permeable concrete brick is 35.6mpa, and the permeability coefficient is 3.5×10\(^{-2}\)cm/s.

In his research, Cai Runze\(^{13}\) introduced and analyzed the preparation and road performance of sand based concrete pavement brick. The research results show that through comparing the common sand based concrete molding methods vibration molding and manual compaction molding process, it is considered that a molding method vibration / compaction composite molding method can be adopted, which combines mechanical vibration and manual compaction, The strength and water permeability of the permeable brick are improved. It is considered that the water cement ratio is 0.34,
the cement aggregate ratio is 0.25, the aggregate gradation is: the particle size is 0.6~2.36mm, accounting for 70% of the total mass of the aggregate, the particle size is 2.36~4.75mm, accounting for 30% of the total mass of the aggregate, the strength of the sand based permeable concrete brick is 35.6Mpa, and the permeability coefficient is $3.5 \times 10^{-2} \text{cm/s}$. In the experiment, the pavement performance of sand based permeable concrete pavement brick was tested, including water retention and wear resistance. The results show that the length of grinding pit is 15mm, which is far less than the requirement of 35 mm in the code, and the wear resistance is good. The water holding capacity is 1.1g/cm$^2$, which is higher than 0.6g/cm$^2$. Through the durability test, it is considered that after 25 freeze-thaw cycles, the compressive strength loss rate of permeable brick is 7.5%, which is less than 20% of the requirements of the specification, while the compressive strength corrosion resistance coefficient of sand based permeable concrete pavement brick is 87%, which is still more than 75% after 90 sulfate drying and wetting cycles, and the sulfate resistance grade can reach Ks90. The test results are shown in Table 2.

| Group number | Freeze-thaw cycles (Times) | Compressive strength (MPa) | Strength stop loss rate (%) |
|--------------|----------------------------|----------------------------|----------------------------|
| B1           | 10                         | 27.8                       | 4.5                        |
| B2           | 15                         | 29.4                       | 5.3                        |
| B3           | 20                         | 32.7                       | 6.4                        |
| B4           | 25                         | 35.6                       | 7.5                        |

4. Conclusion

Through consulting a large number of literature, the research on permeable brick at home and abroad mainly focuses on the optimization of preparation process and the improvement of its performance, but there is still a lack of data support for the durability and adaptability of permeable materials in special environments such as high altitude and cold. At the same time, the comprehensive utilization of permeable brick and solid waste is combined to reduce the environmental load. The team will continue to focus on the application of agricultural biomass waste in permeable brick for further research.

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