Study on Application of oil shale waste residue reinforced by interfacial bonding in permeable asphalt pavement

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Abstract: Based on the bonding effect of silane coupling agent, the application of enhanced oil shale waste residue in permeable asphalt pavement was deeply studied through road performance, water permeability and mechanism analysis tests, and the pavement work of the test section was carried out in Siping City. The research shows that the high temperature, low temperature and anti spalling performance of permeable asphalt pavement can be effectively enhanced by replacing fine aggregate with oil shale waste residue in equal proportion, and the comprehensive increase rate is about 25%. The water loss performance test showed that after the oil shale waste residue replaced the fine aggregate in equal proportion, the immersion residual stability was 70.2%, which was less than the specification requirements. Silane coupling agent could effectively improve its water stability. After modification, the immersion Marshall stability and spring thaw Marshall stability increased by 36% and 20% respectively.

Key words: industrial solid waste; Oil shale residue; Silane coupling agent; Permeable asphalt pavement; Bonding modification

Introduction

Oil shale is a kind of solid combustible organic sedimentary rock with high mineral content. As an unconventional oil and gas resource, China's total proved resources are about 133.8 billion tons, ranking second in the world. Its development and utilization can change China's energy structure rich in coal, poor in oil and less gas, and has important strategic significance. At present, the development technology of domestic oil shale is mainly based on remote processing, which will produce a large amount of waste residue after processing. About 0.7-0.9 tons of semi coke will be produced after 1 ton of raw ore is retorted, and about 0.6-0.7 tons of waste residue will be produced after combustion and power generation. Due to incomplete recycling of waste residue, it needs to occupy a large amount of land for open stacking, resulting in secondary pollution such as dust and water. At the 2021 shale oil exploration and development promotion meeting, the national energy administration clearly required that oil shale resource evaluation and efficient development technology be included in the subtask of the national major scientific and technological project of "deep earth exploration". At present, the research on the comprehensive utilization of oil shale waste has covered many fields, such as architecture, chemical industry, transportation, agriculture, environment and so on. The application of oil shale waste residue in road engineering is mainly concentrated in subgrade and base. By adding a certain amount of oil shale waste residue, clay and fly ash as subgrade filling materials, or developing base course materials with cold resistance function. The research on the application of oil shale waste residue in pavement materials is less. The oil shale waste residue has the activity and porous characteristics, which can replace some mineral powder as filler to improve the rheological properties of asphalt mortar, and can also be used as asphalt modifier after grinding to improve the temperature sensitivity of asphalt. Whether used as filler or asphalt modifier, although it can improve the road performance of pavement materials, the amount of mineral powder and asphalt in the surface layer is less, and the utilization rate of oil shale waste residue is low.

Sponge City, as a new generation of urban stormwater management concept, can realize the natural accumulation, natural infiltration and natural evolution of precipitation through the design of structural water permeability function. In order to accelerate the construction of sponge cities, repair urban water ecology, conserve water resources, and enhance urban waterlogging prevention capacity, the general office of the State Council issued the guidance of the general office of the State Council on promoting the construction of sponge cities in 2015. As a kind of high permeability ecological pavement, permeable asphalt pavement is an important part of urban sponge. Due to the large void ratio of permeable asphalt pavement, the contact area between aggregates is small, and the thickness of asphalt film is insufficient. It is necessary to use high viscosity and high cost modified asphalt to improve the stiffness and strength of permeable asphalt pavement, which is bound to increase the engineering cost of the practical application of permeable asphalt pavement

Based on the national dual strategy of "efficient development of oil shale resources" and "sponge city construction", aiming at the common problem of low industrialization of comprehensive utilization technology of oil shale waste residue, and combining with some problems of permeable asphalt pavement in sponge City, this paper, based on the bonding effect of silane coupling agent, through road performance test, water permeability test and mechanism analysis test, The application of enhanced oil shale waste residue in permeable asphalt pavement was studied.

1 Test material

1. Oil shale residue

The oil shale waste residue used in this paper is the waste residue produced by the combustion and power generation of Huadian Longteng power plant in Jilin Province.

The oil shale waste residue is grayish brown, with shale lamellar joint structure and high content of lamellar particles. After amplification, it can be observed that the corrosion pores and intergranular pores are relatively developed, and the micro fractures run

through and distribute along the bedding, and connect with other types of pores to form a sponge micro pore network system, which has good reservoir and seepage capacity.

2. Silane coupling agent

Silane coupling agent is a new type of coupling agent, which contains two groups: organic functional group and silyloxy group. Silyloxy groups can react with inorganic substances, while organic functional groups have reactivity or compatibility with organic substances. The silane coupling agent selected in this paper is KH550 produced by Shanghai Yiyan company.

3. Bitumen

The base asphalt selected in this paper is Panjin ah-90# asphalt, which can be used as the raw material of emulsified asphalt, cutback asphalt and modified asphalt.

4. Aggregate and sample preparation

Due to the low strength of oil shale waste residue, in order to improve the utilization rate of oil shale waste residue in permeable pavement, the research group adopted pfc50 discrete element software carried out numerical analysis on the mechanical characteristics of aggregates in permeable asphalt mixture. The study found that the aggregates with particle size greater than 4.75mm in permeable asphalt pavement are the skeleton, which are the main bearing particle size, and bear more than 85% of the external load.

In this paper, the crushed and screened oil shale waste residue is used to replace the aggregate with particle size less than 4.75mm in permeable asphalt mixture, so as to meet the large consumption of oil shale waste residue and ensure the strength of permeable asphalt pavement. In this paper, silane coupling agent is used to enhance the consolidation strength of the oilstone interface and improve its water damage problem. Previous studies have shown that there are two main technical methods for treating oil shale waste residue with silane coupling agent: surface treatment method and modified asphalt method.

2 Experimental method

1. Road performance test

In order to systematically and comprehensively evaluate the road performance of five kinds of asphalt mixtures, this paper evaluates the high temperature performance, low temperature performance, water stability performance and loose performance. According to the regulations gb/t0709-2011 and gb/t0719-2011, the high temperature performance test is evaluated by Marshall stability test and rutting test. Both Marshall stability test and rutting test are tested in a standard environment of 60 ° C.

2. Permeability test

Permeability is the most important characteristic of permeable asphalt pavement. The indoor test of permeability is divided into constant head permeability test and variable head permeability test. The former is suitable for permeable materials with greater permeability, and the latter is suitable for permeable materials with smaller permeability. In this paper, the constant head permeability test is selected to test the permeability of permeable asphalt mixture.

3 Test results and analysis

1. Road performance test results and analysis

According to the Marshall test data of five groups of permeable asphalt mixture, the Marshall stability of orf-pac is up to 30% higher than that of PAC, which indicates that the high-temperature stability of permeable asphalt mixture can be effectively improved by replacing fine aggregate with oil shale waste residue, because the porous morphology of oil shale waste residue enhances the anchoring and consolidation strength with asphalt, Further, the gripping force of asphalt mortar on aggregate is improved.

According to the rutting test data of five groups of permeable asphalt mixture, the dynamic stability of sm-orf-pac and orf-pac are almost the same, while the dynamic stability of dm-orf-pac is 9.59% higher than that of sm-orf-pac, which also shows that the modified asphalt method can improve the dynamic stability of permeable asphalt mixture more effectively than the surface treatment method.

According to the low-temperature splitting test data of five groups of samples, the splitting tensile strength of orf-pac is 24.82% higher than that of PAC, which can reach 88.37% of that of sbs-ogfc, indicating that the low-temperature cracking resistance of permeable asphalt mixture can be effectively improved by replacing fine aggregate with oil shale waste residue.

According to the immersion Marshall test data of five groups of permeable asphalt mixture, the Marshall stability of orf-pac after immersion decreases very fast, and its immersion residual stability is 70.2%, which does not meet the specification requirements, indicating that the water stability of permeable asphalt mixture cannot be improved after oil shale waste residue replacing fine aggregate, which is closely related to the high water absorption of oil shale waste residue.

According to the water immersion Marshall test data of five groups of permeable asphalt mixture, the spring thaw Marshall stability of dm-orf-pac and sm-orf-pac is increased by 34.36% and 20.42% respectively compared with orf-pac, and the silane coupling agent assisted modification effect is obvious.

According to the Kentucky dispersion test data of five groups of permeable asphalt mixture, the dispersion losses of dm-orf-pac and sm-orf-pac are 12.8% and 13.7%, respectively, which are 11.7% and 5.5% lower than those of orf-pac, indicating that the addition of silane coupling agent can improve the anti stripping performance of asphalt mixture.

2. Water permeability test results and analysis

According to the constant head seepage test data of five groups of permeable asphalt mixtures, the permeability coefficients of dm-

orf-pac and sm-orf-pac are the same, which may be due to the close oil stone ratio of the two permeable asphalt mixtures. The permeability coefficient of dm-orf-pac is 0.04cm/s higher than that of orf-pac, which is due to the low oil stone ratio of dm-orf-pac compared with orf-pac.

3. Paving of test section

In this paper, based on the above research, relying on the sponge city construction project in Siping City, Jilin Province, the silane coupling agent modified asphalt method is selected to carry out the pavement work of the test section of Qingnian Road in Guoguang community. The construction section is 3.3m wide, 10.5m long and 0.05m thick. It is paved manually and compacted by small rollers.

After paving, the pavement is flat, the structural depth is uniform, the water permeability is good, and all indicators meet the requirements. Compared with the conventional permeable asphalt pavement, the oil shale waste residue permeable asphalt pavement has darker color, more sufficient oil adhesion, and less local oil bleeding and segregation.

4 Conclusion

Based on the bonding effect of silane coupling agent, through road performance test, water permeability test and mechanism analysis test, the application of enhanced oil shale waste residue in permeable asphalt pavement was deeply studied, and the pavement work of the test section was carried out in Siping City. The specific conclusions are as follows:

(1) The high temperature, low temperature and anti spalling performance of permeable asphalt pavement can be effectively enhanced by replacing fine aggregate with oil shale waste residue in the same proportion, with a comprehensive increase of about 25%.

(2) After the fine aggregate is replaced by oil shale waste residue in equal proportion, the immersion residual stability is 70.2%, which does not meet the specification requirements.

(3) Silane coupling agent can effectively improve the water loss stability of oil shale waste residue used in permeable asphalt pavement, and the immersion Marshall stability and spring thaw Marshall stability are increased by 36% and 20% respectively.

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