**Opinion Article**

**Research progress of comprehensive solid waste in asphalt and asphalt mixture**

**Abstract：**Solid waste has great application prospects in the road field. Solid waste can be used as a modifier to improve the performance of asphalt. Adding solid waste to asphalt mixture can change the road performance of the mixture, reduce the cost of asphalt mixture, and have high economic and social benefits. At present, the academic circles at home and abroad have carried out extensive research in the field of solid waste used in modified asphalt and its mixture, and have achieved some remarkable results. These research results have shown important application value in engineering practice, indicating that this field has broad development potential and prospects. From the perspective of environmental protection, promoting sustainable development and accelerating urbanization, these research work has positive significance that cannot be ignored.

**Keywords:** solid waste ; industrial solid waste ; modified asphalt ; asphalt mixture

# 1.Introduction

Whether it is the shadow of the ancient Silk Road, or the wind and waves of the navigation era, or the interconnection of modern transportation networks, transportation undoubtedly promotes economic integration and people-to-people exchanges. As an important part of transportation, highway construction plays a key role in building a perfect transportation network. In the field of road construction and maintenance, asphalt mixture is the most important road material. Asphalt pavement has the characteristics of good driving comfort, low noise, short construction period and convenient maintenance, which makes it the most common type of high-quality highway pavement[1].With the rapid growth of the production of asphalt and asphalt mixture, the demand for asphalt, stone, mineral powder and other building materials is increasing, which also accelerates the consumption of a large number of natural stone, which is bound to cause the lack of natural resources and the destruction of the natural environment. The use of solid waste as a modifier in asphalt, or as aggregate or filler in asphalt mixture can not only improve the performance of asphalt and asphalt mixture, but also reuse solid waste, improve the utilization rate of solid waste, and reduce its pollution to the environment. The academic community has extensively and deeply discussed the potential of solid waste in the application of road building materials, focusing in particular on its specific impact on the performance of asphalt materials. At present, industrial wastes such as steel slag, slag and fly ash have been widely incorporated into the preparation of asphalt mixtures. Through the scientific and rational use of these industrial waste residues in asphalt mixture, it is expected to open up a new way for the utilization of industrial waste resources, which shows positive and important value for promoting environmental protection and promoting the sustainable development of urbanization.

# 2.Research progress of solid waste in asphalt

The recycling of waste tires has always been a worldwide problem. In some developing countries, a large number of waste tires are still stored, burned and landfilled in the open air. Waste tires can be made into rubber powder or particles with different morphology and particle size by physical crushing and chemical treatment, which can be used for modified asphalt. Rubber modified asphalt is an ideal environmentally friendly pavement material with high temperature stability, low temperature flexibility, aging resistance, fatigue resistance, water damage resistance and other properties. It is mainly used in the stress absorbing layer and surface layer of road structure.Zhang Lu et al[2].adopted the design concept of full-high-content rubber asphalt pavement structure, and designed three kinds of dense-graded high-content rubber asphalt mixtures ARHM-13, ARHM-20, and ARHM-25 for different structural layers. The road performance of high content rubber asphalt mixture in high and low temperature environment was analyzed and evaluated by dynamic stability, low temperature bending failure strain, freeze-thaw splitting strength, residual stability, four-point bending fatigue test and constrained specimen temperature stress test. The results show that ; the high-volume rubber asphalt mixture with 30 % rubber powder content has good high temperature, fatigue performance and excellent low temperature performance.

Waste plastic is a common solid waste, commonly used waste plastics are PE, PP, PVC, PET, EPS, PA, ABS. Waste plastics can be used as modifiers for asphalt alone or in combination with other materials, which can improve the high and temperature stability, fatigue resistance and water damage resistance of asphalt. Punith V S[3]recycled polyethylene was extracted from the low-density PE handbag collected from domestic waste, and it was used as a modifier to prepare modified asphalt and used in asphalt mixture. Through its performance test, it was found that compared with the traditional mixture, the performance of PE modified asphalt mixture was better. Adding PE to the asphalt mixture can reduce the possibility of rutting and temperature sensitivity. It is recommended that the 5 % weight of asphalt PE content be used to improve the performance of the asphalt concrete mixture. Wang Yong et al[4].prepared waste PE/PPA composite modified asphalt with waste PE plastic and polyphosphoric acid ( PPA ) as modifiers. The compatibility, rheological properties, adhesion properties and water resistance of waste PE modified asphalt with different contents of PPA were studied. The results show that PPA can promote the uniform dispersion of waste PE in asphalt and improve the compatibility between waste PE and asphalt. With the increase of PPA content, the penetration and ductility of composite modified asphalt decreased, and the softening point and viscosity increased significantly. The dynamic shear rheological test proves that PPA can improve the high temperature elastic recovery rate and low temperature fatigue resistance of composite modified asphalt. With the increase of PPA content, the pull-out strength and immersion resistance of composite modified asphalt gradually increased.

As a kind of solid waste, red mud has the characteristics of stable chemical composition, easy breakage and rich micropores, and has the potential to replace limestone powder for asphalt mixture production. However, at present, the world is facing the problem of large accumulation of red mud and low utilization rate. How to make red mud large-scale and reduce the use of red mud is an urgent problem to be solved. Fu et al[5]. used red mud as a modifier to study its modification mechanism from a microscopic point of view. The results showed that after mixing red mud, the penetration index and 15°C ductility of asphalt decreased, and the softening point increased, thereby improving the temperature sensitivity and high temperature stability of asphalt. The energy of asphalt changing with temperature was analyzed by molecular simulation technology. It was found that the main component of hematite in red mud was adsorbed most in asphalt, followed by asphaltene and colloid, but the adsorption capacity of colloid was the highest. Molecular dynamics simulation shows that after adding base asphalt, red mud can form a uniform and stable blending system with base asphalt. Al2O3 in red mud is the main component to improve the adhesion between red mud and asphalt interface.Professor Bao Huiming et al[6]. analyzed the effect of red mud content on the temperature sensitivity of asphalt through the viscosity-temperature index under different temperature scales, and studied the compatibility of red mud modified asphalt under different storage time through segregation test. The microscopic state of red mud modified asphalt was characterized by scanning electron microscopy. The results show that when the temperature is higher than 135°C, the influence of shear rate on the viscosity of modified asphalt gradually decreases. The viscosity of modified asphalt with 5% red mud content is the largest and the temperature sensitivity is the smallest. When the content of red mud is 3%, it can reduce the viscosity to a certain extent. The main factors affecting the compatibility of red mud modified asphalt are red mud content, heat storage time and heat treatment conditions. With the increase of red mud content and the extension of storage time, the storage stability of red mud modified asphalt becomes worse, that is, the compatibility becomes worse, and the red mud calcined at high temperature is more compatible with asphalt than the original red mud.

In short, the preparation of modified asphalt by solid waste as a modifier can effectively improve the performance of asphalt mortar. By applying solid waste to asphalt, the utilization of solid waste can be greatly improved and the pollution to the environment can be reduced.

# 3.Research progress of solid waste in asphalt mixture

Coal gangue is a kind of solid waste discharged in the process of coal mining and coal washing. It is a kind of black-gray rock with low carbon content and hard than coal associated with coal seam in the process of coal formation, including tunneling gangue in the process of roadway excavation, gangue extracted from roof, floor and interlayer in the process of mining, and washing gangue picked out in the process of coal washing. It is mainly composed of Al2O3, SiO2, and also contains varying amounts of Fe2O3, CaO, MgO, Na2O, K2O, P2O5, SO3 and trace rare elements ( gallium, vanadium, titanium, cobalt ). Coal gangue powder is used in asphalt mixture to replace part of limestone powder, which can improve the stability and elastic modulus of the mixture, and can significantly reduce the damage of freeze-thaw cycle to the mixture.Wu et al[7]. also used different substitution amounts of coal gangue powder to replace mineral powder to study the variation of coal gangue powder under different freeze-thaw cycles. It was found that the content of coal gangue powder had a significant effect on the asphalt mixture, and the best substitution amount was 50%. The addition of coal gangue powder significantly reduced the damage of freeze-thaw cycles to the mixture.Through three-point bending test and microwave heating test, Lu and Li et al[8,9].found that the combination of coal gangue and functional aggregate promoted the self-healing of micro-cracks at the interface between aggregate and asphalt, and the crack resistance and healing effect were significantly improved. Zhang et al[10].combined coal gangue into powder and basalt aggregate to evaluate the adhesion, mechanical properties, low temperature crack resistance, water stability, microwave heating capacity and self-healing efficiency of coal gangue asphalt mixture. It was found that the addition of coal gangue could improve the microwave heating speed, and also showed significant advantages in water stability and self-healing, further improving the utilization rate of coal gangue.

As a collection of various impurities produced in the steelmaking process, steel slag belongs to industrial solid waste, and its output is about 15 % ~ 20 % of the crude steel output. According to the steelmaking process and slag forming process, steel slag can be divided into converter steel slag, arc slag and ladle refining slag. At present, most researchers at home and abroad use it as stone instead of natural stone for secondary recycling and application in asphalt mixture[11]. Chen et al[12]. studied the asphalt mixture with alkaline oxygen furnace ( BOF ) steel slag as coarse aggregate, and found that adding steel slag to the asphalt mixture has a high resistance to permanent deformation and damage caused by moisture. Lu et al[13]. used full steel slag and partial steel slag instead of conventional gravel as aggregate to prepare AC-20 asphalt mixture. Through the analysis of its performance, the results show that the mixture is superior to the traditional gravel mixture in terms of high temperature stability, low temperature crack resistance and fatigue performance. Although its water stability is slightly inferior to that of gravel mixture, it still meets the requirements of relevant specifications.HadiGoli et al[14]. used steel slag coarse aggregate in warm mix asphalt mixture. The water sensitivity of asphalt mixture was evaluated by Marshall stability ratio, elastic modulus ratio, tensile strength ratio and fracture energy ratio. The fatigue and rutting behavior of the mixture were evaluated by 4-point beam fatigue and dynamic creep tests. The results show that the use of coarse aggregate in WMA mixture enhances the resistance of asphalt mixture to water damage and permanent deformation.

Fly ash is a powder-like fine particle discharged from a coal-fired boiler in a thermal power plant. It is usually a hollow porous spherical structure with a large specific surface area. At present, most researchers at home and abroad use it as a filler to replace natural stone in asphalt mixture. Zhang Baolong et al[15]. aimed at the interaction between fly ash and asphalt, with the help of surface modification technology, NaOH alkaline solution and KH550 coupling agent were used to treat four different sources of fly ash. The results show that the modified fly ash can reduce the elasticity of the green mortar, improve the anti-deformation ability of the green mortar, and improve the anti-rutting ability of the slurry. Jamshidi Ali et al[16]. added fly ash instead of filler to hot mix asphalt mixture and warm mix asphalt mixture respectively. The results show that the tensile strength of asphalt mixture containing fly ash not only meets the design standard, but also its tensile strength is higher than that of asphalt mixture containing cement filler. For warm mix asphalt mixture, the addition of fly ash increases the elastic modulus of asphalt mixture by 7.5%, which reduces the greenhouse gas emission in the manufacturing stage of raw materials.

Iron tailings are the waste after beneficiation and the main component of industrial solid waste. In recent years, a number of domestic and foreign studies have shown that iron tailings have a good application prospect in asphalt mixture as coarse aggregate or fine aggregate. Liu Mingyang et al[17]. prepared iron tailings-steel slag aggregate micro-surfacing mixture. Through the test of its road performance, it was found that iron tailings and steel slag had a significant enhancement effect on the wear resistance, long-term skid resistance and rutting resistance of the micro-surfacing mixture. The incorporation of iron tailings will adversely affect the cohesion and water damage resistance of the mixture, but the incorporation of steel slag can effectively improve the problem of poor adhesion caused by iron tailings. Cao et al[18]. used iron tailings to replace coarse and fine aggregates. It was found that the iron tailings asphalt mixture had better high temperature performance, but its low temperature performance and water stability were relatively poor.

Waste glass is a kind of inorganic solid waste, and its main components are silica ( SiO2 ), sodium oxide ( Na2O ), calcium oxide ( CaO ) and so on. It is found that the recycled glass asphalt mixture has the characteristics of low permeability, high friction coefficient and excellent reflective performance, and there is a high correlation between the reflective performance of glass asphalt concrete and the glass content, and the reflective performance is enhanced with the increase of the content. With the increase of road wear, the reflective intensity of glass asphalt pavement gradually becomes stronger.

In summary, researchers have applied a large number of industrial solid wastes to replace part or all of the natural aggregates in asphalt mixtures. This is also the best way to solve the problem of solid waste pollution. It not only solves the problem of large accumulation, but also saves energy and reduces consumption. It is conducive to environmental protection, giving full play to the practical value of solid waste and expanding the use of ways.

# 4. Conclusion

The engineering performance of asphalt can be effectively improved by adding solid waste into asphalt after treatment. Different solid wastes can improve the viscosity, rheological properties and durability of asphalt, and change the softening point. Using solid waste to replace aggregate or filler completely or partially in asphalt mixture can change the mechanical properties of the mixture. Different solid waste can also improve the high temperature rutting resistance, low temperature crack resistance, water damage resistance, fatigue resistance and durability of asphalt mixture. In addition, the application of solid waste in asphalt and asphalt mixture can solve many problems caused by the accumulation of solid waste. It can also reduce the high economic cost and environmental pollution caused by over-exploitation of natural stone resources, closely fit the concept of green and low-carbon development, and promote the virtuous cycle and coordinated development among society, economy and environment. It is of far-reaching and great significance to promote the sustainable development of transportation engineering construction.

# 5.References

1. Yu Huayang, Ma Tao, Wang Dawei, et al. Summary of academic research on pavement engineering in China 2020 [ J ].China Journal of Highway, 2020,33 (10):1-66.
2. Zhang Lu, Meng Huilin, Li Yanwei, etc. Experimental study on the performance of engineering high content rubber asphalt [J].Highway Transportation Science and Technology, 2024,41 (09):71-78.
3. Punith V S , Veeraragavan A . Behavior of Asphalt Concrete Mixtures with Reclaimed Polyethylene as Additive[J]. Journal of Materials in Civil Engineering, 2007, 19(6): 500-507.
4. Wang Yong, Jiang Bo, Zhang Fuyou, et al. Study on the effect of PPA on the road performance of waste plastic modified asphalt and its mixture [J]. New chemical materials, 2022,50 (07):229-234 + 240.DOI :10.19817 / j.cnki.issn1006-3536.2022.07.0477.
5. Fu T, Wei J H, Bao H, et al. Multiscale Study on the Modification Mechanism ofRed Mud Modified Asphalt [J]. Advances in Materials Science and Engineering. 2020.
6. Bao Huiming, Lyu Zongwei, Zhang Yimin.Analysis of viscosity-temperature characteristics of red mud modified asphalt [J].Road construction machinery and construction mechanization, 2019,36 (08) :64-68 + 75.
7. Wu J R, Zhao W Z, Cui S C, et al. Study on flexural properties of coal gangue powder asphalt mixture under freeze-thaw cycles[J]. Materials Research Express, 2022, 9(5): 055103.
8. Lu D, Jiang X, Leng Z, et al. Dual responsive microwave heating-healing system in asphalt concrete incorporating coal gangue and functional aggregate[J]. Journal of Cleaner Production, 2023, 422: 138648.
9. Li J R, Cao Y S, Sha A M, et al. Prospective application of coal gangue as filler in fracture-healing behavior of asphalt mixture[J]. Journal of Cleaner Production, 2022, 373: 133738.
10. Zhang B, Gao X, Xu S, et al. Microwave heating healing of asphalt mixture with coal gangue powder and basalt aggregate[J]. Sustainability, 2023, 15(17) : 12986.
11. Li, Zhang, Ding et al. Study on the adhesion characteristics of steel slag-asphalt interface [J]. Journal of Dalian University of Technology, 2022,62 (3) : 254-262.
12. CHENJ, WEIS. Engineering properties and performance of asphalt mixtures in corporating steelslag[J]. ConstructionandBuildingMaterials, 2016,128:148-153.
13. LUFL, LIJ. Research on Performance of Road Application of Converter Bituminous Steel-Slag Mixture of Jigang Group Co. Ltd[J]. Applied Mechanics and Materials, 2012,1802(178-181).
14. LUFL, LIJ. Research on Performance of Road Application of Converter Bituminous Steel-Slag Mixture of Jigang Group Co. Ltd[J]. Applied Mechanics and Materials, 2012,1802(178-181).
15. Zhang Baolong, Wu Ping, Yan Xinyong, et al. The effect of surface modified fly ash on the road performance of asphalt [J]. Journal of Chang 'an University ( Natural Science Edition ), 2018,38 (3) : 43-51.
16. Jamshidi Ali, Mohd Hasan Mohd Rosli, Lee Mei Ting. Comparative study on engineeringproperties and energy effciency of asphalt mixes incorporating fly ash and cement[J]. Constructionand Building Materials,2018,168:295-304.
17. Liu Mingyang, Zhou Bin, Yan Feng, et al. Experimental Study on Road Performance and Durability of Iron Tailings-Steel Slag Aggregate Micro-surfacing Mixture [J]. Silicate Bulletin, 2022,41 (09) : 3176-3189.DOI : 10.16552 / j.cnki.issn1001-1625.2022.09.027.
18. Cao L, Zhou J, Zhou T, et al. Utilization of iron tailings as aggregates in paving asphalt mixture: A sustainable and eco-friendly solution for mining waste[J]. Journal of Cleaner Production, 2022, 375: 134126.