Transactions on Engineering and Technology Research
ISSN: 2960-1797, eISSN: 2960-2246 | Volume 4
ACEGE 2024

Application of Green Asphalt Pavement Technology in Modern Road Engineering

Jianwei Yang

College of Highway Engineering, Chang'an University, Xi'an, China

2022903279@chd.edu.cn

Abstract. There are environmental problems in the construction and maintenance of traditional asphalt pavement, which consumes a lot of resources and produces a variety of pollutants, especially in large and medium-sized cities, posing a threat to residents' life and urban ecology. The traditional asphalt pavement industry is facing the test, and it is urgent to explore the environmentally sustainable road construction scheme. The key path is to change the concept and study and apply green and environment-friendly asphalt pavement technology. Firstly, this paper comprehensively analyzes and summarizes the carbon emission of asphalt in the whole life cycle, and then systematically introduces three kinds of asphalt green pavement engineering technologies, namely: warm mixing asphalt mixture technology, rubber powder modified asphalt mixture technology and asphalt mixture regeneration technology. Finally, the application of the construction technology of warm mixed asphalt pavement is explained in detail. The results show that green asphalt pavement technology has great environmental, economic and social significance. In the future, the innovation of asphalt pavement technology should focus on reducing resource consumption, reducing environmental pollution and improving the recycling rate of materials during the whole life cycle.

Keywords: Traditional asphalt pavement; Environmental problems; Green pavement technology; Carbon emission.

1. Introduction

Asphalt pavement is the mainstream choice of highway and municipal road pavement in China, and its wide application has undoubtedly greatly promoted the construction and development of transportation infrastructure. However, the construction and maintenance process of traditional asphalt pavement is also accompanied by environmental problems that cannot be ignored. In this process, a large amount of fuel, mineral resources such as minerals and petrochemical products are consumed, and a variety of environmental pollutants including dust pollution, asphalt smoke and construction noise are generated. Especially in large and medium-sized cities with dense population and frequent economic activities, these environmental problems are more significant, posing a direct threat to residents' quality of life and urban ecological environment [1]. Obviously, the sustainable development of the traditional asphalt pavement industry is facing an unprecedented test, and it is urgent to explore a more environmentally friendly and sustainable road construction program. Therefore, changing the concept, actively studying and applying green and environment-friendly asphalt pavement technology has become the key path to promote the technological innovation of asphalt pavement, accelerate the development of asphalt pavement project and broaden its living space.

In the highway industry, Life Cycle Assessment (LCA) has become a widely adopted method for in-depth analysis of energy consumption and gas carbon emissions of highway engineering projects [2]. As an advanced environmental assessment tool, LCA accurately quantifies the energy consumption and emissions during the entire life cycle of a product from birth to waste, and aims to assist decision makers to select the most outstanding environmental benefits from multiple alternatives on the basis of meeting the basic performance requirements of a project. In turn, efforts are made to reduce the cumulative environmental impact of products throughout their life cycle. Therefore, the use of LCA can not only clearly understand the environmental load of each stage of highway engineering, but

also put forward more comprehensive and targeted energy-saving and emission reduction strategies and suggestions, promote the green and low-carbon process of highway construction, and contribute to the realization of sustainable development goals.

This paper introduces, analyzes and summarizes the life cycle carbon emission of asphalt, and discusses the new materials, new processes and new technologies to realize the green and sustainable development of asphalt pavement, so as to effectively control and reduce carbon emission.

2. Life Cycle Carbon Emissions of Asphalt Pavement

The life cycle carbon emission of asphalt pavement covers design, production and transportation of raw materials, construction, maintenance and end-of-life stage. It is mainly derived from the whole life cycle of construction materials, including the production, transportation, use and disposal of raw materials. Carbon emission of asphalt pavement is not only related to asphalt production process, but also involves pavement design, construction methods and maintenance measures. It is of great significance to comprehensively understand and evaluate the life cycle carbon emissions of asphalt pavement for promoting green and low-carbon development.

Song and Zhu [2] conducted a detailed analysis of the energy consumption and carbon emission of asphalt pavement in different life cycle stages through the whole life cycle assessment (LCA) method. This study reveals the characteristics of the environmental impact of asphalt pavement in the whole life cycle, the most significant of which is that the environmental load in the use stage is much higher than that in other stages. Specifically, the energy consumption and carbon emissions of asphalt pavement in the use stage are more than 90%, which highlights the importance of this stage for the overall environmental impact. In contrast, the energy consumption and carbon emissions of the design stage, the construction stage, the maintenance stage and the final waste treatment stage are relatively low, each accounting for less than 5%. Liu et al [3] revealed the significant advantages of permanent asphalt pavement structure in energy saving and emission reduction. By comparing and analyzing the energy consumption and carbon emissions of the two typical permanent asphalt pavement structures and the traditional semi-rigid base asphalt pavement structures in the whole life cycle, they concluded that the energy consumption and carbon emissions of the traditional semi-rigid base asphalt pavement structures in the whole life cycle are at a higher level. This is mainly due to its high material consumption and frequent maintenance needs. In contrast, although the energy consumption of the two typical permanent asphalt pavement structures is relatively large in the construction phase, the investment in this phase has brought long-term benefits. In the subsequent maintenance period, these permanent asphalt pavements almost achieved "zero maintenance" and reduced energy consumption and carbon emissions in the whole life cycle by about 80% compared with the traditional asphalt pavement structure, achieving the purpose of saving energy and reducing carbon emissions.

Therefore, the problem of carbon emissions in the whole life cycle of asphalt pavement cannot be ignored, which is directly related to the green and sustainable development of the transportation industry, and is also one of the key links to the effective implementation of China's "dual carbon" policy. In order to actively respond to this policy objective, effective measures must be taken to control and reduce the carbon emissions of asphalt pavement, and promote its development in a more environmentally friendly and sustainable direction.

3. Asphalt Green Pavement Engineering Technology

Asphalt green pavement engineering technology is mainly: warm mixing asphalt mixture technology, rubber powder modified asphalt mixture technology and asphalt mixture regeneration technology.

The construction technology of warm mixing modified asphalt mixture shows its unique feature in reducing the mixing and laying temperature of asphalt mixture. This technology reduces the viscosity of asphalt by adding warm mixing agent or other technical means, so that the mixture has good fluidity at a lower temperature, so as to achieve mixing and spreading [4]. The application of this technology

not only effectively inhibits energy consumption in the production process, but also significantly reduces the emissions of greenhouse gases such as carbon dioxide and dust. At the same time, this technology ensures that the road performance of the warm-mixed asphalt mixture is equal to that of the hot-mixed asphalt mixture, and even superior in some aspects, including better construction convenience and ease of use [5]. Compared with hot mix asphalt mixture, when the production temperature is reduced by 40℃, asphalt smoke emission is reduced by 33.6%, sulfur dioxide by 43.2%, smoke by 41.3%, carbon monoxide by 20.8%, etc., indicating that the adoption of warm mix technology can greatly reduce emissions of waste gas, sulfur dioxide, smoke and other gases [6].

The rubber powder modified asphalt mixing technology is an environmentally friendly pavement material technology, which aims to improve the performance of asphalt by adding the rubber powder processed from waste tires into asphalt. At present, China's annual output of used tires has exceeded 20 million metric tons, which ranks first in the world. However, compared with the recycling rate of more than 90% in developed countries, China's recycling of waste tires is still insufficient, and there is still significant room for improvement [7]. Waste rubber, as a kind of flammable and difficult to decompose naturally polymer elastic material, its large accumulation not only occupies valuable land resources, but also may become a breeding ground for mosquitoes and bacteria, aggravate environmental pollution, and even cause fire. Therefore, actively carrying out the recycling of waste tires can not only reduce the environmental burden and pollution, but also realize the resource utilization of solid waste and contribute to the cause of environmental protection [8]. Because of its excellent elastic and viscous properties, coupled with the rich polymer content, these polymers have a significant effect on improving the quality of asphalt. Therefore, the waste tires are processed into rubber powder of specific specifications and applied in the modification process of road petroleum asphalt, which not only realizes the recycling of waste resources, but also greatly enhances a number of key properties of asphalt pavement, including low temperature crack resistance, high temperature stability and durability, thus improving the overall service quality of roads [9-10]. According to relevant analysis, using waste rubber powder modified asphalt to lay a two-way high-grade highway can consume about 10,000 waste rubber powder made of waste tires per kilometer of road surface, which is both practical and environmentally friendly [1]. In addition, this practice also effectively reduces the production cost of modified asphalt, and has a positive impact on promoting the sustainable development of society, improving economic benefits and protecting the ecological environment, showing significant social, economic and environmental benefits.

Asphalt pavement has been widely used in urban roads and expressways because of its excellent driving performance and convenient maintenance. However, with the continuous growth of traffic, it brings a serious burden to the asphalt pavement, leading to a large number of diseases on the road, which greatly shortens the actual service life of the asphalt pavement. Large-scale maintenance and milling reconstruction of roads is not only costly, so it is particularly important to use asphalt mixture regeneration technology to save costs. The recycling of asphalt mixture is a series of fine processes, such as digging, recycling, crushing and screening, to mix the old asphalt pavement materials to be repaired or abandoned with regenerating agents, new aggregates and new asphalt raw materials in a precise ratio to create a recycled asphalt mixture with necessary road performance [1]. At present, one of the commonly used regeneration technologies is plant mix hot regeneration, which restores part of its properties by adding certain regeneration agents to the waste asphalt mixture obtained after milling [11]. This process not only realizes the maximum utilization of waste resources, but also reduces the demand for new materials and mining, which is conducive to protecting the environment, saving resources, and promoting the development of green transportation construction.

The comparative analysis of engineering technologies of warm mixing asphalt mixture technology, rubber powder modified asphalt mixture technology and asphalt mixture regeneration technology is shown in Table 1.

Table 1. Engineering technology comparison of asphalt green pavement

Name	Advantage	Shortcoming	Application
Warm mixing asphalt mixture technology	Energy saving and environmental protection can extend the construction season, improve pavement performance	The water sensitivity and rutting resistance of the mixture are affected. Research on low temperature performance is limited.	Highways, urban roads, airport runways, etc.; areas with high environmental requirements and limited construction conditions.
Domain rubber powder modified asphalt mixture technology	Significant environmental benefits, improve road performance, reduce road noise	Large viscosity, high energy consumption, large equipment footprint, high cost, difficult quality control, storage stability still needs to be improved.	Highways, urban roads, airport runways, etc.; areas with high environmental protection requirements, large traffic volume and complex climatic conditions;
Asphalt mixture regeneration technology	Save resources, environmental protection, improve pavement performance, shorten the construction period	The performance of used materials is unstable, the quality control of each link is difficult, and the equipment investment is large.	Highways, urban roads, rural roads, etc.; the road surface damage is more serious; in need of extensive maintenance.

4. Application of Warm Mixed Asphalt Pavement Construction Technology

4.1. Preparation Before Construction

Before the construction of warm mixed asphalt concrete, it is necessary to optimize the construction personnel and mechanical equipment according to the characteristics of the construction project. It is necessary to carry out technical exchanges with technical workers, so that relevant personnel can grasp the technical specifications and quality points, organize management personnel to develop quality and safety management measures, and lay the foundation for the implementation of the project. Secondly, it is necessary to rationally select raw materials, design the mix ratio of warm mixed asphalt mixture, the optimal ratio of oil stone and the optimal dosage of warm mixed modifier, and apply it to specific engineering cases, so that the overall application effect of the project is good [12]. In addition, it is equipment inspection and debugging. Conduct comprehensive inspection of mixing equipment, paving equipment, compaction equipment, etc., to ensure that they are in good working condition. Adjust the parameters of the equipment to meet the special requirements of the construction of warm mixed asphalt.

4.2. Construction Technical Points

4.2.1. Addition of warm mixing agent.

Organic chemical warm mixing modifier is white solid granule, can improve the flow of asphalt, melting point of about 105℃, over 120℃ dissolved into a flowing state. The addition of warm mixing agent at high temperature can reduce the bonding force between asphalt and aggregate, thus reducing the production temperature of asphalt mixture [13]. In order to meet the requirements of the construction of warm mixing asphalt pavement, the automatic adding device of warm mixing agent is set up in the asphalt mixing building. The warm mixing agent was sprayed into the asphalt for 3s after asphalt spraying, and the time and spraying range were consistent. The mixing pot should open an exhaust port with a diameter of more than 30cm to discharge water vapor, and the height of the

exhaust port should be higher than the mixing area. In order to prevent steam from taking away the powder, after mixing the warm mixing mixture, the mineral powder is added. After spraying the warm mixing agent and dispersing the soft water 6s, the mineral powder is added [14]. The addition process must strictly follow the specifications. Special adding equipment can be used to evenly add the warm mixing agent to the asphalt or asphalt mixture to ensure that the warm mixing agent is fully dispersed to avoid agglomeration or uneven distribution.

4.2.2. Mixing construction.

When mixing asphalt mixture, the mixing parameters should be set according to the mixing station and engineering design requirements to control the quality. Classification of fine and coarse aggregates and sampling testing to ensure that the material technical indicators meet the standard and the mix ratio is accurate. The mixing time should be above 52s and the temperature should be well controlled [15]. During the mixing process, asphalt materials can be processed with LB3000 equipment and additives can be added. Additive measurement should meet the accuracy and automatic adjustment, the amount of feed should meet the technical standards. Under the known mixing rate parameters, the charging steps are determined after mixing the hot material, and the warm mix asphalt is sprayed first, delayed for 3-6s, and then continued to spray. The suitable injection time is 8-10s. After spraying, the concentrated liquid is sprayed again, which is the main measure to ensure the working performance of the road surface and improve the road quality [16]. In the mixing process, pay close attention to the state of the mixture, such as color, uniformity, etc. If problems are found, the mixing parameters should be adjusted in time or the quality of raw materials should be checked.

4.2.3. The transportation, spreading and rolling of the mixture.

Using dump truck to pull mixed feeding construction work surface. According to the actual situation of the site, the stacking distance of each car is calculated accurately. When the mixture is used, it is necessary to ensure that the amount is accurate, and at the same time, to avoid segregation, flowers and other situations. Before and after material transportation, it is necessary to clean the dump truck to ensure that the interior is clean and without excess impurities. Subsequently, anti-stick agent is applied around and at the bottom of the carriage to avoid the adhesion of the mixture and the carriage and affect the quality of the mixture. In addition, during the loading process, it should be completed several times to ensure uniform loading [15].

If the climate is low and the distance is far during construction, it is necessary to cover the roof with tarpaulins and add insulation materials on the wall to keep heat, so as to prevent the temperature of the mixed materials transported to the site from being too low. Check the cleanliness of the car to avoid residue before loading, and brush the release agent on the bottom and side panels of the car. The tracking and detection of the transport truck found that the temperature of warm-mixed asphalt mixture dropped only 10℃ during transportation, which was slower than the 30℃ drop of hot-mixed asphalt mixture, and was more adaptable during long-distance transportation [14].

In the paving technology of warm mix asphalt mixture, the mixing temperature of warm mix asphalt mixture should be between 120℃ and 130℃, and the paving should be implemented according to the requirements of hot mix asphalt mixture in the "Technical Specifications for Highway Asphalt Pavement Construction". Before asphalt mixture paving, it is necessary to preheat the paver, especially in low temperature construction, preheating is particularly critical [17]. Before the construction of hot mix asphalt pavement, it is necessary to comprehensively test the quality, geometric size, elevation, etc., to ensure that it is consistent with the construction needs. Before the paving operation, preheat with the ironing machine to 80℃ ~ 100℃. After spreading to the site, install the backing plate on the flat bottom surface to ensure the height is consistent and calibrated. The thickness and flatness are checked by contactless double-plane measurement, and various methods are used to ensure that the components comply with the regulations and have the process parameters. A plurality of pavement before paving, measuring record data. During the paving stage, each section is re-measured, the thickness of the false paving is recorded and compacted. If there is a problem, adjust the control in time, and the paving speed cannot be changed at will. The horizontal

scale method is used to measure the reference elevation on both sides. The elevation of each component and the thickness of the virtual paving shall be in accordance with the standard requirements, and the reference elevation shall not exceed 15 ~ 20cm to ensure that the paving elevation meets the requirements [16].

After finishing the spread, it is necessary to roll to improve the density and stability of the warm mix layer. Rolling is very important to make the coarse and fine aggregate dense. The test section adopts impact rolling technology, and the rolling forming rules are "light before heavy, slow before fast, both sides before middle" [13]. Select the appropriate roller according to the situation of the warm mixing layer, determine the rolling sequence and path, generally from the inside out, from the bottom to the top. Control the number and speed of rolling to avoid excessive rolling. Operators should check regularly and test with tools such as density tester to ensure that the warm mixing layer reaches the designed density [18].

5. Conclusion

In this paper, three kinds of green asphalt pavement engineering technologies are deeply studied, and the following conclusions are drawn:

(1) The life-cycle carbon emission of asphalt pavement is extremely critical, which is closely related to the green and sustainable development of the transportation industry and the implementation of China's "two-carbon" policy. Effective measures must be taken to control and reduce carbon emissions in order to promote their continuous development in the direction of environmental protection and sustainability. This is not only responsible for the environment, but also an important guarantee for the future long-term development of the transportation industry.

(2) Asphalt green pavement engineering technology has brought new opportunities and challenges for modern road construction because of its outstanding characteristics of environmental protection, high efficiency and sustainability. With the increasing requirements of society for environmental protection and sustainable development, this technology will surely occupy an increasingly important position in the future transportation construction, and become an important force to promote the high-quality development of road construction.

(3) As a new road construction technology, the construction technology of warm mixed asphalt pavement is gradually being widely used in modern road engineering. Its application process includes careful preparation before construction, such as meticulous planning of construction site and materials. The accurate addition of warm mixing agent to ensure the performance of asphalt mixture. Strict control of the mixing construction process to ensure the uniformity of the mixture. The standard operation of the subsequent processes such as transportation, spreading and rolling of the mixture.

(4) There are still some problems in the construction of green pavement technology. For example, in terms of energy conservation, energy consumption may be too high because the equipment technology is not advanced enough or the construction process is unreasonable. The lack of mechanization affects the stability of construction efficiency and quality. Brand construction lags, making the market's recognition and recognition of green road technology is not high.The modular construction is not perfect, which increases the construction cost and management difficulty. At the same time, the construction quality is difficult to control effectively, and may be affected by many factors such as the technical level of construction personnel and the fluctuation of material quality.

(5) In the future, the technological innovation of green asphalt pavement should focus on the whole life cycle, and be committed to reducing resource consumption, reducing environmental pollution and construction costs, while constantly optimizing construction quality. Through the efforts of technological innovation and management optimization, the continuous development and improvement of green asphalt pavement technology will be promoted to provide solid technical support for the green and sustainable development of transportation construction.

References

[1] K. Yao. Research progress and application of green technology of asphalt pavement, Journal of urban road and bridge and the flood prevention 4 (2016) 25- 28 + 6-7.

[2] Z.Z. Song, H.Z. Zhu. Whole life cycle energy conservation and emissions reduction strategies of asphalt pavement case study, Grandpa in the road 40. 5 (2020) 36-42.

[3] J.R. Liu, X.Y. Wang, W.G. Yang, et al. Analysis of Energy consumption and carbon Emission during the life cycle of permanent asphalt Pavement Structure, Highway Transportation Science and Technology (Applied Technology Edition) 15.06 (2019) 111-113+117.

[4] Z.F. Liu, S.P. Wu, M.Z. Chen, et al. Current situation and existing problems of warm mixing asphalt mixture, Journal of Wuhan University of Technology 4 (2009).

[5] J. Ge, S. Chen, Z.W. Gao, et al. Evaluation status and prospect of low-carbon emission reduction technology effect of asphalt mixture, Road Construction Machinery and Construction Mechanization 32.11 (2015) 38-44.

[6] K.H. Tan, Y.L. Gao, EC120 temperature mixing modified asphalt mixture effect analysis, Energy Saving and Emission Reduction in Road 35. 02 (2015) 258-260.

[7] H.Y. Yue, Y.F. Bi, R. Xu, et al. Scrap tires in the road engineering application research progress, Materials guide, 16.4 (2022) 72-82.

[8] Q.B. Lu, W.Q. Ni, Q.Q. Lu, et al. Research Progress on green sustainable Development of asphalt pavement under the background of "double carbon", Municipal Technology 41.5 (2019) 42-51.

[9] A.S. Mohammad, S. Javad, P. Pooneh, et al., Fatigue properties of crumb rubber asphalt mixtures used in railways, Construction and Building Materials 184 (2018) 248-257.

[10] X.H. Ding, T. Ma, W.G. Zhang, et al. Experimental study of stable crumb rubber asphalt and asphalt mixture, Construction and Building Materials 157 (2017) 975-981.

[11] J.B. Guo. Application of asphalt mixture regeneration technology in highway engineering, Transportation World (Junten-Issue) 3 (2022) 31-32.

[12] Z.N. Wang. Application of warm mixed asphalt in expressway construction, Transportation World (Xiexunning) 4 (2020) 148-149.

[13] Z. Bu, Application of warm mix asphalt technology in asphalt pavement construction, China Highway 2 (2022) 87-88.

[14] Y.Y. Wang. Application of construction Technology of warm mixed asphalt concrete pavement in Highway engineering, China New Technology and New Products 18 (2018) 114-115.

[15] S. Li. Research on the application of warm mixed asphalt technology in asphalt pavement construction, Model World 16 (2024) 107-109.

[16] X. Meng. Construction preparation of warm mixed asphalt technology and its application in high-speed construction, Sichuan Building Materials 50. 2 (2024) 100-102.

[17] P.Z. Bai. Research on the application of warm mixed asphalt technology in asphalt pavement construction, Architecture and Decoration 32 (2020) 87-88.

[18] Y.S. Lv. Discussion on application and quality control of warm mixed asphalt Technology in Bridge and tunnel pavement construction, Juye 2 2024 58-60.