Green Energy, Environment and Sustainable Development
C. Wang et al. (Eds.)

doi:10.3233/ATDE230358

Monitoring of Energy Saving and Emission Reduction (ESER) of Expressway Pavement During the Construction Period

Fuhai WANG[a,1], Chenguang KONG[b] and Zijian WANG[a]
[a] *Innovation Research Institute of Shandong Hi-speed Group Co., Ltd., Jinan250000, Shandong, China*
[b] *Shandong Hi-speed Group Co., Ltd., Jinan250000, Shandong, China*

Abstract. The energy consumption of expressway construction is so huge that it is important to strengthen the management of energy saving and emission reduction (ESER) of expressway construction. In this study, the latest literature on monitoring of energy saving and emission reduction of expressway pavement are reviewed from the following three aspects: the technology of energy saving statistical monitoring, research on benefit accounting of ESER, and research on application of energy consumption statistical monitoring. The purpose of this paper is to help establish a green highway pavement environmental protection evaluation system and a green low carbon construction technology system to promote the scientific development and green development of highway construction.

Keywords. Freeway, energy consumption, asphalt pavement, construction period, energy saving and emission reduction (ESER), life cycle assessment (LCA)

1. Introduction

To carry out the research and application of highway energy consumption monitoring and monitoring is an important part of China's in-depth exploration of green highway energy saving and emission reduction (ESER) efficiency assessment, and scientific evaluation of green highway construction results. As a high-grade highway, it is necessary to take the lead in conducting research on energy consumption and emission reduction monitoring and detection. Monitoring and monitoring of road ESER includes two aspects: construction period and operation period. At present, relevant research and application have been conducted on monitoring ESER during the operation period of highways [1-2]. The research on ESER monitoring during highway construction started relatively late, but recently, many research results have emerged. It is necessary to sort out the application results of ESER monitoring during highway construction, achieve energy consumption reduction through technological innovation, and promote green development of highway construction.

[1] Corresponding Author, Fuhai WANG, Innovation Research Institute of Shandong Hi-speed Group Co., Ltd., Jinan 250000, Shandong, China; Email: 15963119666@139.com.

2. Energy Consumption Monitoring Technology

2.1. Research on Energy Consumption Monitoring System

The construction of highways consumes a lot of energy, and it is important to strengthen ESER management during the construction process. Monitoring the energy consumption and scientifically evaluating the progress space of ESER, can provide reference for the improvement of low-carbon construction and highway construction management, reliable information for formulating policies related to ESER and a basis for the highway industry to enter the carbon emission market. Conducting energy consumption monitoring on highways is of such great significance that domestic and foreign scholars attach great importance to the research of energy consumption monitoring systems on highways.

Shen et al. [3] studied the energy consumption of a reconstruction project, calculated the energy consumption of different mixture per unit mass in reconstruction project, and pointed out that mixing asphalt mixture is the key link to reduce energy consumption. Wang et al. [4] analyzed the CO_2 emissions during the construction and provided the proportion of CO_2 emissions from road engineering. Qian et al. [5] established an evaluation index system for ESER of asphalt pavement, selected typical asphalt pavement structures, and monitored and calculated the ESER during its construction period. Cass et al. [6] designed a calculation method for gas emissions, stating that CO_2 generated by materials, fuels and processing processes accounts for over 90% of the total emissions. White et al. [7] designed a similar solution.

2.2. Development of Energy Consumption Monitoring (ECM) and Management Information System

By utilizing the energy consumption monitoring management information system, remote monitoring, data uploading and information management of energy consumption monitoring (ECM) can be achieved, and information management of ECM can be accomplished, which can better enable the constructed ECM system. Yang [8] established an evaluation index system for ESER of asphalt pavement and developed an analysis and evaluation system E3SAP. The software system of Zheng [9] consists of three modules, each of which is with clear functional positioning and can compare the green degree of different road materials.

Nathman's team [10] developed the PaLATE system by considering energy consumption and gas emissions at all stages for road construction. Sodedund [11] established a quantitative evaluation model which is the predecessor of the Greenroads evaluation index system. Gang [12] designed an energy consumption monitoring system during the construction of green highways, which records all energy consumption with real data, providing a basis for implementing ESER measures.

2.3. Application of Life Cycle Method

More and more researchers [13] are using life cycle analysis methods to study ESER of asphalt pavement on highways, and have achieved fruitful results. Establishing a model for ESER benefits of highways relied on LCA technology, and establishing a green

evaluation system for highway construction projects, is conducive to abandoning the extensive production technology of high energy consumption, and achieving the utilization of true ESER, quality improvement and efficiency enhancement technologies.

Hakkinen and Mgkela [14] believe that asphalt content and mixture production are key factors that increase the environmental load on asphalt pavement. Stripple [15] studied the energy consumption and greenhouse gas emissions of hot mix and cold mix asphalt pavement during its lifecycle, and found that the energy consumption per kilometer of asphalt pavement construction and maintenance period after 40 years of service was 2.3×10^7 MJ, and there is no significant difference between hot mix and cold mix asphalt pavement. Park et al. [16] divided the road life cycle into four stages: manufacturing, construction, maintenance, demolition, and recycling of building materials. They compared South Korea's economic input-output model and the national energy consumption balance table, and found the energy consumption of building materials was highest during the manufacturing stage.

2.4 Energy Consumption and Emission Evaluation System and Indicators

Qi [17] put forward the evaluation system of ESER reduction during the controllable construction of asphalt surface layer, determined the ratio of each index in the evaluation system of ESER of asphalt surface layer by using the expert scoring method, and put forward the measures of ESER in pavement construction. Hanson et al. [18] provided an estimation method for greenhouse gas emissions in the production of hot, cold, and warm asphalt mixtures, suggesting that the greenhouse gas emissions of warm asphalt mixtures may be equivalent to 76% of the greenhouse gas emissions of hot asphalt mixtures. Lin [19] adopted the evaluation criteria for total greenhouse gas emissions and determined the road level coefficient.

3. Research on the Accounting of ESER Benefits

Relying on the established ECM and management information system, we can quickly obtain ECM data during the construction period of highways, objectively and realistically reflecting the energy consumption during the construction period. The calculation of ESER benefits can provide technical support for the research and establishment of calculation methods for ESER benefits.

The research results of Zapata and Gambatese [20] indicate that the energy consumption during the construction process is mainly concentrated in three stages: mixing mixture, heating aggregate, and producing asphalt. Horvath and Hendrickson [21] consider the renewable capacity of asphalt pavement and believe that the environmental friendliness of recycled resources or waste pavement is better than that of new materials. Mroueh et al. [22] analyzed the impact of material utilization on the environment and concluded that the environmental friendliness of recycled resources or waste material pavement is better than that of using new materials. Chowdhury et al. [23] compared recycled aggregates with fly ash and blast furnace bottom ash and found that recycled aggregates have lower energy consumption, lower greenhouse gas emissions, and are more environmentally friendly. Aurangzeb et al. [24] believe that increasing the use of recycled asphalt can reach ESER.

4. Research on the Application of Energy Consumption Statistical Monitoring

With the deepening of research, more and more research results have been applied to practical engineering and achieved good results. Chen et al. [25] analyzed the scope and monitoring methods of ECM, analyzed the energy consumption situation, and found that the proportion of diesel consumption during the construction process of highways is the highest. Yu et al. [26] used monitoring reports and equipment monitoring methods to analyze the energy consumption of various sections and specialties of the Dao'an Expressway, and found that the road construction energy consumption was 38804.83 tce. Tatar et al. [27] analyzed and compared the environmental impact of various additives on asphalt pavement, and selected suitable environmental additives. Wang et al. [28] evaluated the energy utilization and greenhouse gas emissions in road maintenance, and the results showed that poor construction quality may be unfavorable for ESER.

5. Conclusion

To do a good job in monitoring ESER, it is necessary to standardize the energy-saving evaluation and technical optimization of highway construction technology, so that the evaluation work has evidence to rely on. By studying the composition of energy consumption, influencing factors of energy consumption, energy consumption calculation methods, unit energy consumption of each energy consumption item, and energy consumption level, a comprehensive evaluation system and effective and feasible energy-saving measures should be proposed, and an energy-saving evaluation system should be developed to form guidelines for energy-saving evaluation of highway construction. According to the literature, the following two aspects should be further studied:

(1) The exploration of new energy-saving and environmentally-friendly materials and the research on new technologies for ESER are important directions in the research of ESER. During the research, it is necessary to continuously combine indoor experiments with construction sites to make the research results more scientific, in order to guide the construction of modern road surfaces that are environmentally friendly and energy-saving.

(2) We should actively establish a basic database for life cycle inventory analysis that is suitable for China's industry development level and industrial production level, and cannot be satisfied with utilizing energy consumption and emission data based on foreign countries. We should accelerate the establishment of a quantitative evaluation system for energy consumption and emissions throughout the entire lifecycle of the highway industry, deeply tap into the potential for ESER at all stages of the lifecycle, and actively explore the development path of Chinese style low-carbon transportation.

Acknowledgements

The authors are grateful for financial support by Science and Technology Plan of Shandong Provincial Department of Transportation—research on decarbonization planning and key technologies of carbon reduction in the transportation field of Shandong High-speed Group under carbon peaking and carbon neutrality background

(Project No. 2022BH05-05). The contributions of the manuscript reviewers are also acknowledged.

References

[1] Wang H, Zhu X, Wang Z, et al. Research on online monitoring technology system of green expressway during operation period—Environmental, meteorological and energy consumption monitoring. Transport Energy Conservation & Environmental Protection. 2022;18(1):139-144.
[2] Li D, Fu Z. Comparison of two energy consumption evaluation methods for expressway operation period. Journal of China & Foreign Highway. 2017;(6):310-316.
[3] Shen Y. Energy Consumption and Emission Evaluation Model and Method for Highway Maintenance and Renovation Projects. (Hefei: Hefei University of Technology). Master's Thesis. 2017.
[4] Wang X, Wu L, Yang D. Carbon dioxide emissions from highway construction: Case study in southwest China. Transportation Research Board 93rd Annual Meeting. 2014.
[5] Qian L, Jing J, Liu Q. Research on the calculation of energy consumption and carbon emission quota during the construction period of typical asphalt pavements. Shanghai Highways. 2016;(1):1-5.
[6] Cass D, Mukherjee A. Calculation of greenhouse gas emissions for highway construction operations by using a hybrid life-cycle assessment approach: Case study for pavement operations. Journal of Construction Engineering & Management. 2011;137(11):1015-1025.
[7] White P, Golden JS, Biligiri PK, et al. Modeling climate change impacts of pavement production and construction. Resources, Conservation and Recycling. 2010;54(11):776-782.
[8] Yang B. Quantitative Analysis Method and Evaluation System for Energy Conservation and Emission Reduction of Asphalt Pavement. (Xi'an: Chang'an University). Doctor's Thesis. 2012.
[9] Zheng L. Road Material LCA and Its Informationization Development. (Changsha: Changsha University of Technology). Master's Thesis. 2007.
[10] Nathman RK. Palate User Guide, Example Exercise, and Contextual Discussion. (Newark: University of Delaware). Master's Thesis. 2008.
[11] Soderlund M. Sustainable Roadway Design—A Model for an Environmental Rating System. (Washington D. C.: University of Washington). 2007.
[12] Gang H. Design of energy consumption monitoring system for green highway construction period. Electronic World. 2016;(20):110-112.
[13] Xie J, Wang Z, Wang F, et al. The life cycle energy consumption and emissions of asphalt pavement incorporating basic oxygen furnace slag by comparative study. Sustainability. 2021;13.
[14] Hakkinen T, Makela K. Environmental impact of concrete and asphalt pavements, in environmental adaption of concrete. Technical Research Center of Finland. Research Notes. 1752. 1996.
[15] Stripple H. Life cycle assessment of road. IVL Report. IVL Swedish Environmental Research Institulte, 2001;03:22-50.
[16] Park K, Hwang Y, Seo S, et al. Quantitative assessment of environmental impacts on life cycle of highways. Journal of Construction Engineering & Management. 2003;129(1):25-31.
[17] Qi L. Research on Evaluation Indicators and Evaluation System for Energy Conservation and Emission Reduction of Asphalt Pavement. (Xi'an: Chang'an University). 2015.
[18] Hanson C, Noland RB, Cavale KR. Life-cycle greenhouse gas emissions of materials used in road construction. Transportation Research Record Journal of the Transportation Research Board. 2012;2287(2287):174-181.
[19] Lin R. Research on the Greenhouse Gas Emission Evaluation System during the Construction Process of Asphalt Pavement. (Xi'an: Chang'an University). 2014.
[20] Zapata P, Gambatese JA. Energy consumption of asphalt and reinforced concrete pavement materials and construction. Journal of Infrastructure Systems. 2005;11(1):9-20.
[21] Horvath A, Hendrickson C. Comparison of environmental implications of asphalt and steel-reinforced concrete pavements. Transportation Research Record Journal of the Transportation Research Board. 1998;1626(1):105-113.
[22] Mroueh UM, Eskola P, Laine-Ylijoki J, et al. Life cycle assessment of road construction. Roads. 2000;51(3):656-9.
[23] Chowdhury R, Apul D, Fry T. A life cycle based environmental impacts assessment of construction materials used in road construction. Resources Conservation & Recycling. 2010;54(4):250-255.
[24] Aurangzeb Q, Al-Qadi IL, Ozer H, et al. Hybrid life cycle assessment for asphalt mixtures with high RAP content. Resources Conservation & Recycling. 2014;83(1):77-86.

[25] Chen S, Cao Z, Zhang Y, et al. Energy consumption monitoring technology and empirical research during the construction period of green highways. Highway. 2017;(9):211-215.
[26] Yu K, Cheng D, Yang F, et al. Monitoring and analysis of energy consumption and emissions during the construction period of Dao'an expressway. Shanghai Highways. 2017;(3):17-20.
[27] Tatari O, Nazzal M, Kucukvar M. Comparative sustainability assessment of warm-mix asphalts: A thermodynamic based hybrid life cycle analysis. Resources Conservation & Recycling. 2012; 58(1):18-24.
[28] Wang T, Lee IS, Kendall A, et al. Life cycle energy consumption and GHG emission from pavement rehabilitation with different rolling resistance. Journal ofeaner Production. 2012;33(5):86-96.