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Low-Carbon Road Reconstruction Design —— Empirical Research Based on Road Cost Management Software

Ke Wang[1, a]

[1]CCCC HIGHWAY CONSULTANTS CO.,LTD., Beijing, China

[a] Corresponding author e-mail: 339232370@qq.com

Abstract. Driven By the Low Carbon Policy, low-carbon road infrastructure construction is greatly concerned. The lack of standardized quantification of energy consumption and carbon emissions limits the universality of Low Carbon road construction practice. Based on the national road cost management software and China's life cycle core database, the standardized quantification method of energy consumption and carbon emissions is established. Empirical project data are used to check the Effectiveness of the method. The method is to screen out the design measure with better energy conservation and lower carbon emission.

Keywords: low carbon road; conserve energy, reduce carbon emissions; Road engineering consumption.

1. Preface

In recent years, people have reached a consensus on the issue of global warming, and human behavior is considered to have played an essential role in global warming[1]. With the deepening and refinement of energy conservation and carbon carbon emission reduction, road industry tend to focus on technical improvement in the design stage beside the operation state[2]. T he designed measure including the use of new materials, methods, and processes to achieve resource conservation and environmental friendliness.

With the development of information technology, the cost management of road projects has adopted an integrated software, which provides a basis for embedding energy conservation and carbon emission reduction accounting modules. Huang has studied the life-cycle carbon emissions of asphalt paving and believes that incorporating the waste phase into the life-cycle considerations is of great importance for reducing the actual environmental impacts of highway construction .Combining the carbon emission accounting with the cost document at the design stage is an effective measure that can not only realize the accounting of total carbon emissions but also achieve the detailed comparison and selection of specific measures[3], thus providing an evaluation basis for the optimization design and realizing "low carbon road " design[4]. In 1999, Piantanakulchai took the lead in accounting for carbon emissions from a single full-scale highway construction project, including an assessment of the effectiveness of technical measures to reduce emissions[5]. Through the empirical study of a provincial road reconstruction and expansion project in Hainan Province, it provides an example for the calculation and comparison of energy conservation and carbon carbon emission reduction of design measures, provides information for optimizing energy conservation and carbon emission reduction management in the road construction industry.

2. Evaluation Method of Energy Conservation and Carbon Emission Reduction

The energy conservation and carbon emission reduction accounting and evaluation system is the basis for optimal design[6]. Generally, the ISO14040 life cycle evaluation standard is adopted from cradle to grave evaluation perspective, including raw materials, construction, maintenance, and abandonment stages.The project is an asphalt pavement, and the scrapping period is considered to be full recycling. There is no concrete slab to be scrapped, so the scrapping period is not considered. The evaluation period is asphalt design life,12 years . The original road abandonment stage is

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calculated separately to analyze the utilization rate of the original road resources.The content of energy conservation and emission reduction accounting is carbon emissions and primary energy consumption.

The energy consumption index mainly refers to the primary energy consumption (PED) of coal, oil, etc. as the accounting benchmark, and the unit is MJ/kg. The carbon emission index (GWP) measures greenhouse gas emissions, including carbon dioxide, methane, etc., with carbon dioxide as the accounting benchmark, and the unit is kg CO2 eq/kg. The accounting method for carbon emissions and the primary energy consumption is

$$\sum_{i=1}^{n} GWP = Q_i \times f_i \quad (1)$$

$$\sum_{i=1}^{n} PED = Q_i \times p_i \quad (2)$$

GWP is the carbon emissions. Q_i is the inventory quantity of i materials. f_i is the carbon emission coefficient of i materials. p_i is the primary energy consumption coefficient of i materials.

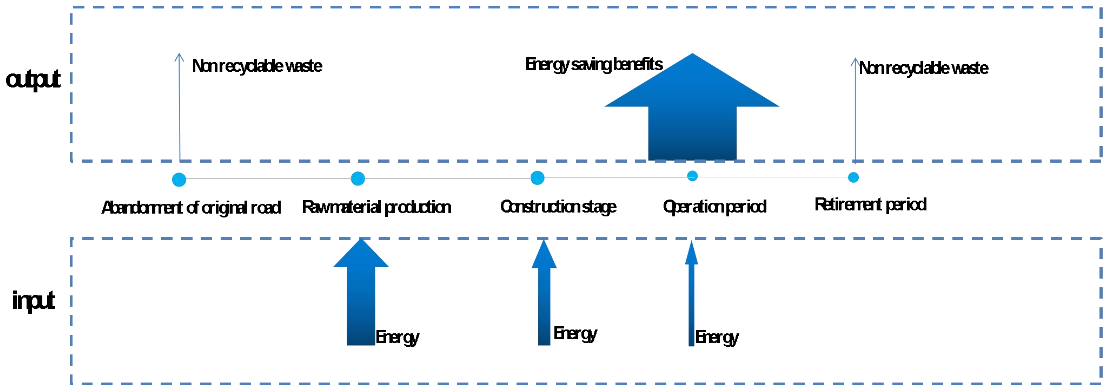

Figure 1 Carbon emission accounting content of road reconstruction

In the case study of carbon emission accounting based on the life cycle, establishing the unified quantitative standards for emission factors and the bill of materials data are always the difficulties in research. The application of recognized local databases is the key to ensuring the applicability and comparability of the evaluation results. Foreign mature carbon emission software tools and databases differ significantly from the construction of road projects in China in terms of material types, construction processes, and mechanical tools. Some research shows an error rate of 25% in environmental impact conclusions drawn from different databases[7]. In order to use the locally recognized emission coefficient data as much as possible, the carbon emission and energy consumption data of raw material production use the CLCD China Life Cycle Core Database of Sichuan University,General Principles for the Calculation of Comprehensive Energy Consumption (GB/T 2589-2008) and the Guidelines for the Preparation of Provincial Greenhouse Gas Inventory (FGBG [2011] No. 1041).The 18 bills of materials are selected to represent the project, covering 99.2% of the material of the project.

The bill of materials data of the project use the China's general road quota-based cost management software. Based on the road quota standard, the automatic quantification could be realized by software to avoid in-depth analysis and discussion of the material and energy flow at the practical level. The list data in the operation period is converted according to the actual maintenance input consumption of the road teams along the project (riverside, Donghe No.1 and Donghe No.2 road teams) in 2017, and the maintenance period is calculated by the design life of 12 years. The data is basically based on raw materials, with good independence and sensitivity.

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3. Application of optimized design

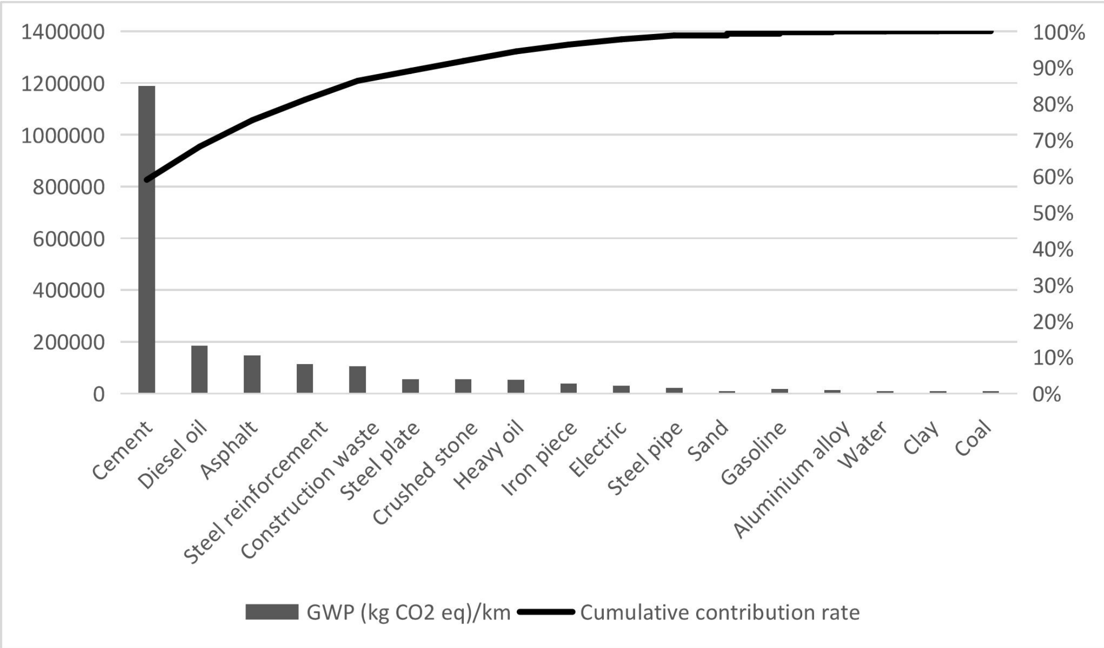

Figure 2 Cumulative contribution of carbon emissions Figure

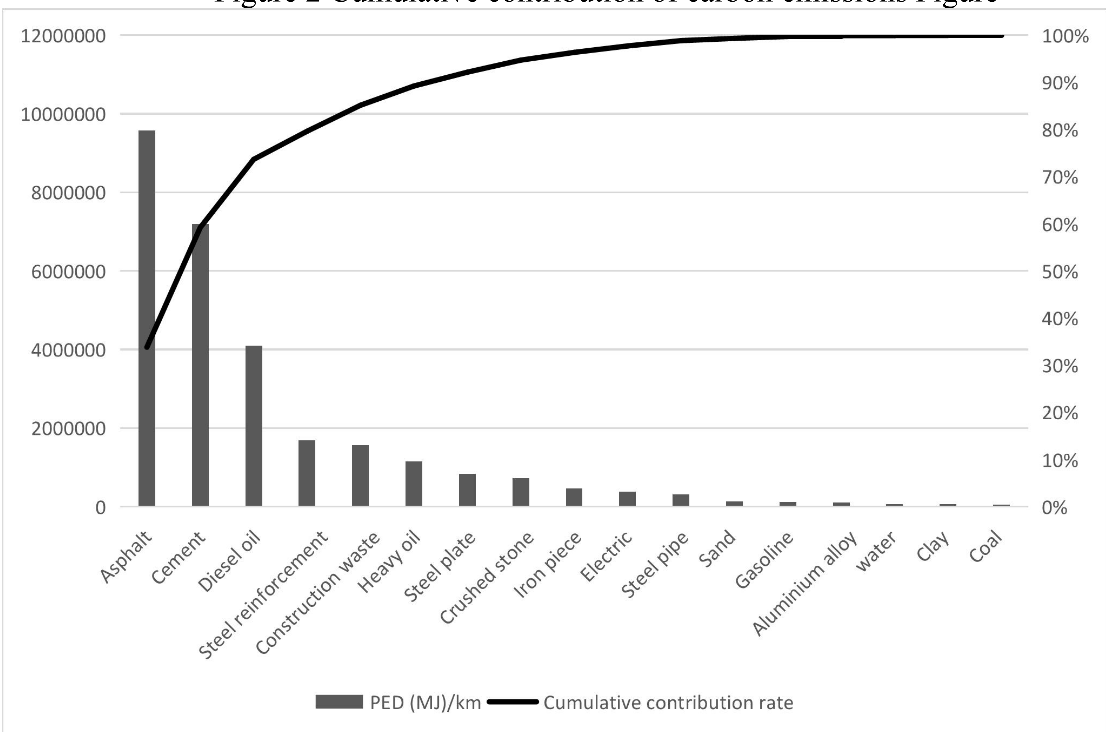

Figure3 Cumulative contribution of primary energy consumption

Through the verification of the analogy project, the selection of road construction materials has a great impact on carbon emissions and energy consumption. Zhabang Line is a similar provincial road reconstructed, with a total length of 90.177km.secondary road, asphalt concrete pavement,and 8.5m wide. The reconstruction project is designed to be widened to 12m, similar to Tianxin Line. The carbon emission in the construction drawing design is 1.26e6kg CO2 eq/km, the primary energy consumption is 2.09E+07MJ/km, the carbon emission of Tianxin Line is 1.82e6kg CO2 eq/km, and the primary energy consumption is 2.58E+07MJ/km, which is significantly reduced, mainly because the drainage protection of Zhabang Line is of masonry structure. The project consumes 880kg/km of cement and 1259m3/km of rubble. The Tianxin Line consumes

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1586.2kg/km of cement and 790.7m3/km of rubble. The results of scenario analysis and analogy analysis show that the energy conservation and emission reduction accounting and benefit evaluation system plays a guiding role in promoting the sustainable development of road reconstruction.

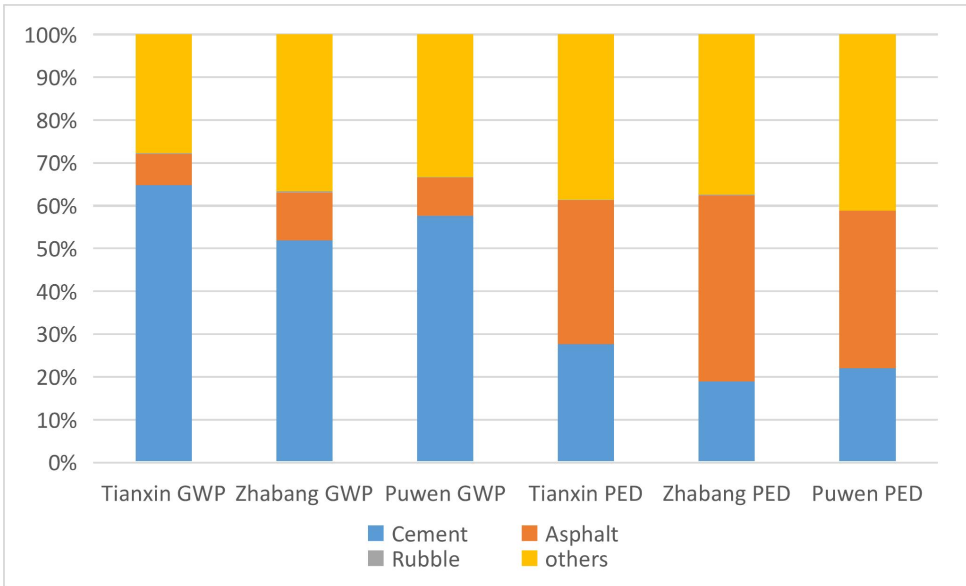

Figure 6 Carbon emissions and energy consumption analogy analysis

3.1 limitation and discussion

The main function of energy conservation and emission reduction accounting is to save social resources.Energy conservation and carbon emission reduction are environmental indicators that reflects the consumption of environmental resources by the whole society through road construction from a material point of view. They cannot fully reflect the impact of roads on the original ecological environment, such as ecological damage and land property change caused by rock excavation. The significance of energy conservation and emission reduction accounting is to guide the engineering using old road resources, replacing concrete with rubbles, warm mixing of asphalt and so on. It could reduce consumption on the material level.

Including energy consumption and carbon emissions into the cost management system software can achieve full coverage during the construction period, but it is difficult to cover the full life cycle. It is possible to include the maintenance and waste stages by multiplying the consumption coefficient. However, the accuracy and applicability are relatively low, especially since the consumption coefficient is not unified. The next step is to study the integrated software of construction and maintenance quota to realize the life cycle data collection, analysis, and accounting of road reconstruction projects.

4. Conclusion

Low carbon road optimization design based on the road cost management software applies to the road reconstruction practice in China for carbon emission management. By building a standardized accounting software, basic information is provided on energy consumption and carbon emissions for the comparison and selection of design measures, and thus promote the recycling of old road resources.

From the perspective of energy conservation and emission reduction,de-concrete and reducing mixing temperature are essential measures that play a decisive role in reducing energy consumption and carbon emissions throughout the life cycle of the road. In addition, the refined design has strong

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operability, including the use of new energy, the comprehensive utilization of old road waste resources, and the optimization of material transportation and allocation, which is also an essential part of the optimization design.

According to the implementation of the project, 10% carbon emission reduction and 10% energy consumption can be achieved. Based on existing engineering technology, replacing cement structures with high-quality rubble structures, 17-22% carbon emissions and 13-16% energy consumption may be further reduced. With the wide application of warm mix asphalt and plant mix hot recycling, it is expected to reduce emissions by 35-38% and save energy by 31-50%.In specific practice, the site characteristics and construction conditions are often considered in the measures comparison and selection. To improve the application of the optimal measure for energy conservation and emission reduction, it is necessary to increase the policy pressure, improve and innovate the application of construction technology.

References

[1] White J C, Petry W H, Wagner W R. United Nations Framework Convention on Climate Change (1992)[J]. Educational Testing, 1996, 17(4):8.

[2] Yue Huang, Bachar Hakim, Susanna Zammataro. Measuring the carbon footprint of road construction using CHANGER[J]. International Journal of Pavement Engineering, 2013, 14(6):1-11.

[3] Huang Y, Bird R, Heidrich O. Development of a life cycle assessment tool for construction and maintenance ofasphalt pavements[J]. Journal of Cleaner Production, 2009, 17(2):283-296.

[4] Fernández-Sánchez G, Álvaro Berzosa, Barandica J M, et al. Opportunities for GHG emissions reduction in road projects: a comparative evaluation of emissions scenarios using CO 2 NSTRUCT[J]. Journal of Cleaner Production, 2015, 104:156-167.

[5] Piantanakulchai M, Inamura H, Takeyama Y. A life cycle inventory analysis of carbon dioxide for a highway construction project using input-output scheme a case study of the Tohoku expressway construction works[J]. Doboku Gakkai Ronbunshuu D, 2010, 16.

[6] White P, Golden J S, Biligiri K P, et al. Modeling climate change impacts of pavement production and construction[J]. Resources Conservation & Recycling, 2010, 54(11):776-782.

[7] Azarijafari H, Yahia A, Amor M B. Life cycle assessment of pavements: reviewing research challenges and opportunities[J].Journal of Cleaner Production 2016, 112:2187-2197.