

Life Cycle Evaluation of the Environmental loading and Construction Cost in Paving Processes

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ABSTRACT

An optimal scheme of road paving maintenance was investigated by examining the environmental loading and cost considerations of pavement operations over a 30-year life cycle. Results indicated that the application of recycled materials in pavement construction and repair reduced the effects of environmental loading over the life cycle by approximately 40%. Furthermore, it was observed that environmental loading conditions associated with the maintenance repair stage of asphalt paving comprised 50% of the total environmental loading determined for the 30-year life cycle. Conversely, costs of the maintenance repair stage were 40% of the total life cycle costs. Finally, results suggest that environmental load and cost considerations will be improved and made more efficient over a life cycle period if a regular maintenance routine of simple asphalt repairs is established.

INTRODUCTION

The need to protect the environment is of paramount concern, particularly when a large-scale project such as a road is being undertaken. It is necessary that all aspects of construction and maintenance be monitored in relation to the environment, especially hidden factors, including the production of input materials and assembling vehicles for operational purposes. Unfortunately, very few sources exist that examine the effects of both construction materials and vehicles on the environment. Those papers that investigate both components do not evaluate the environmental issues over the whole life cycle of the road. This study investigates the environmental loading and cost parameters associated with the construction and maintenance of a road over a 30-year life cycle. The cycle includes a number of repair works as well as the optimal maintenance schedule for the road. Furthermore, the evaluation considers the impact of using recycled material in road construction and maintenance work. The Life Cycle Inventory Method is used to determine the environmental loading conditions of a road, while construction and maintenance costs are estimated using statistical tables[1-4] published in 1995 by a variety of organizations.

PAVEMENT MAINTENANCE MODELS

The costs and environmental impact associated with an asphalt road surface and a concrete road surface were evaluated over a 30-year life cycle. To estimate environmental and cost conditions associated with maintenance repair work, information on a number of

parameters was considered. Environmental loading was determined by evaluating the amount of fuel consumed by paving vehicles, the volume of resources used during maintenance procedures, and the transportation of waste material from site. The direct cost of construction was computed by combining labor expenses, material costs, and machine operating expenses. Calculations were based on a minimum traffic density of 3000 large vehicles per day in one direction (road classification ‘D’) and a unit execution area of 100m². Only one repair model was selected for the concrete surface, as concrete requires little maintenance over its life cycle. The model repair schedule included an asphalt compound coating 18 years after the road was constructed and surface treatment work 25 years following completion. Four models[5] of asphalt surface repair were evaluated in the analysis. Descriptions of each model are provided in the following section.

Asphalt paving case I: pavement is replaced every 10 years following its initial construction;

Asphalt paving case II: pavement is replaced 15 years after construction and cutting overlay occurs twice (8 and 23 years after construction);

Asphalt paving case III: 13 years following construction, pavement is replaced, surface recycling work is performed 7 years after construction, and surface treatment occurs 23 years after road completion;

Asphalt paving case IV: the pavement is not replaced; only 4 small scale repair projects are performed: cutting overlay (12 and 23 years after construction), surface recycling work (year 7) and surface treatment (year 18).

Figures 1 to 4 summarise the environmental load and cost estimates for each repair model. Carbon dioxide emissions and energy volume consumption during the repair of asphalt were estimated to be 65% of the total environmental load in case I, and 50% of the total in case II. Conversely, 70% of the total costs in case I were generated during the maintenance repair stage while repairs accounted for 40% of the total costs in case IV. Maintenance repair costs during these stages exceeded the initial construction costs calculated for cases I to III. Furthermore, the environmental load was greater than the load

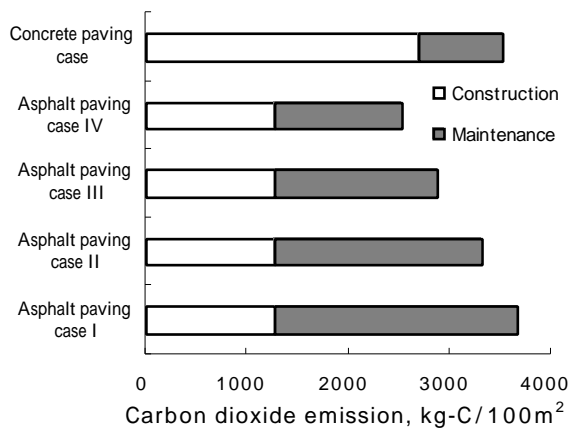


Fig.1 The life cycle carbon dioxide emission estimates for each repair model

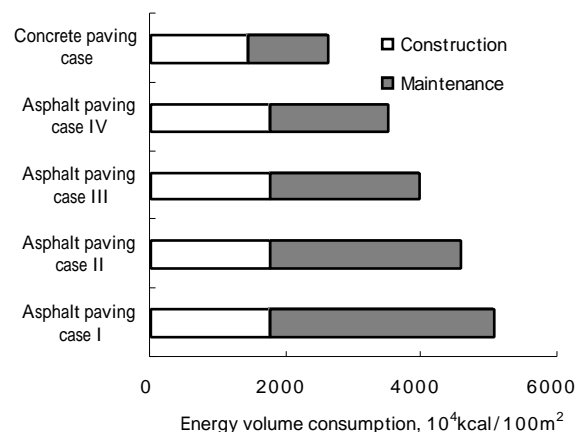


Fig.2 The life cycle energy volume consumption estimates for each repair model

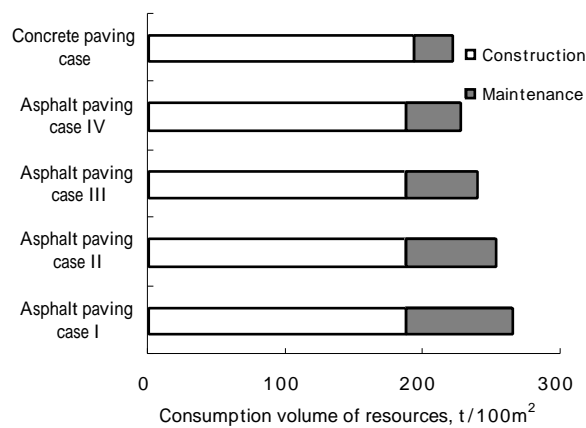


Fig.3 The life cycle consumption volume of resources estimates for each repair model

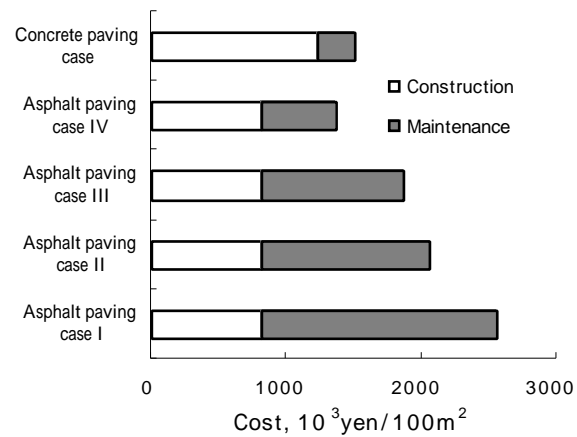


Fig.4 The life cycle cost estimates for each repair model

estimated for the initial construction stage, except for the volume of consumed resources. In order to improve the range of results for asphalt repair, the analysis should include maintenance details over the entire life cycle of the road.

Carbon dioxide emissions generated from the maintenance repair stage of concrete were less than the initial construction phase. Furthermore, approximately 25% of the total carbon dioxide emissions computed for the project originated from the repair stage. It is important to note that this percentage includes the carbon dioxide that is naturally emitted from limestone, an important component of concrete. Asphalt compound is regularly used for concrete pavement repair. As such, the energy consumption volume does not greatly differ between the initial construction stage and the maintenance repair stage. However, the initial construction stage of concrete paving contributes greatly to the overall environmental load of the project, while the maintenance repair stage contributes fewer loads. In asphalt paving, the relationship is reversed: the maintenance repair stage generates greater load on the environment compared to the initial construction phase. It is important to note that repeated large-scale repairs on asphalt are less economical and more detrimental to the environment than the construction and minimal maintenance of concrete roads.

ENVIRONMENTAL LOAD OF RECYCLED MATERIALS IN ASPHALT ROAD CONSTRUCTION

The environmental effects of using recycled materials in pavement construction and repair were investigated. Asphalt paving case IV was used as the test model, and the carbon dioxide emissions and consumption volume of resources from the model were monitored. Results of the emission analysis are presented in Figure 5, while the consumption volume data are displayed in Figure 6.

As illustrated in the figures, recycled pavement at the maintenance repair stage reduced carbon dioxide emissions and resource consumption by 20% and 5% respectively. A 40-50% reduction in both environmental parameters was ultimately anticipated assuming significant portions of recycled materials were used during the construction and repair of asphalt pavement. Nonetheless, results suggest that the use of recycled materials in paving

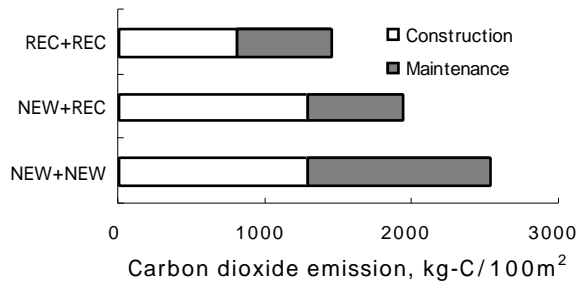


Fig.5 The emission analysis for the carbon dioxide emission effects of using recycled materials in pavement construction and repair (NEW: using new materials, REC: using recycled materials)

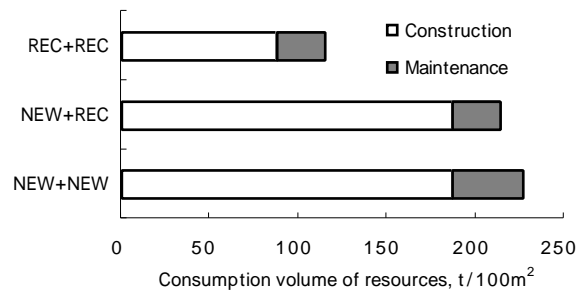


Fig.6 The emission analysis for the resource consumption effects of using recycled materials in pavement construction and repair (NEW: using new materials, REC: using recycled materials)

activities can help minimize impact on the environment. Further research in this area is recommended, including a more detailed examination of the types of recycled material available for paving projects.

CONCLUSION

Two important parameters that must be considered during any road construction and maintenance project are the costs and the impact on the environment. Research results indicate that large-scale repair or replacement of asphalt pavement is less cost efficient and more harmful to the environment than any other maintenance method investigated. The environmental load and cost implications associated with maintenance repair projects can be mainly attributed to the asphalt compound in pavement. Environmental loading can be reduced by approximately 40% if recycled materials are incorporated in road maintenance projects. Results also suggest that the maintenance stage contributes greatly to the environmental load and cost parameters associated with a road. Specifically, the repair stage generated 50% of the total environmental load for a 30-year life cycle project and approximately 40% of the total cost. To achieve the most desirable environmental and cost conditions for road paving projects, it is recommended that a maintenance program of regular small-scale repair jobs be established.

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