Analysis of Construction-specific Environmental Load Characteristics in the Road Paving Work Maintenance & Management Phase

J G Im¹, D H Kim¹, J N Liu¹, J Y Park² and B S Kim¹

¹ Department of Civil Engineering, Kyungpook National University, 80 daehakro Bukgu, Daegu, Korea
² Department of Civil Engineering, Gyeongbuk Provincial College, 114 Doripdaehakgil, Yecheon-eup, Yecheon-gun, Gyeongsangbuk-do, Korea

zakoim88@gmail.com

Abstract. In accordance with the Paris Agreement that was signed to cope with recent climate change, the Republic of Korea has presented its greenhouse gas reduction goal as 37% compared to BAU. Accordingly, construction industry that occupies 40% of total industrial energy consumption also needs to make efforts to reduce greenhouse gas. In particular, studies are needed on the effort to reduce emission amount of environmental pollutants that occur during road constructions. In the case of road construction project, which is the subject of this study, large amounts of environmental pollutants are discharged during not only construction process but also operation and maintenance & management process. For analyzing the characteristics of environmental load occurring during the road maintenance & management phase, this study conducted life cycle assessment (LCA) for 10 cases of maintenance & repair projects for local roads that have been constructed in Korea to analyze environmental load characteristics according to construction types. As for the distribution of weighted values, TET and GW showed significant results with respectively 42.45% and 27.65%, followed by ARD (13.67%) and HT (11.00%).

1. Introduction

1.1. Background

According to the Paris Agreement signed on recent climate change, Korea has presented greenhouse gas reduction goal as 37% compared to BAU by 2030. The energy consumption of construction industry occupied 40% of total industrial energy consumption, and greenhouse gas emission in construction industry is 2.67 million tons as of 2010 [1]. In addition, it mainly occurs from construction site and construction equipment fuel combustion and production of materials used during construction phase. As the scale of public works has become large, many areas are being performed through mechanization, thereby resulting in large amounts of environmental pollutant emission during construction phase.

In the case of road construction project, in particular, large amounts of environmental pollutants are being discharged not only during construction process but also operation and maintenance & management process [2]. Accordingly, it is necessary to actively respond to estimate and alleviate environmental load occurring not only during construction phase but also during maintenance and repair phase to reduce environmental load [3]. If the characteristics of construction-specific environmental load emission can be identified, environmental load reduction plan can be established
based on the information and resource implementation plan can be accordingly established and implemented for materials and equipment [4]. Accordingly, this study was conducted to provide basic information in establishing environmental load reduction plan by analyzing the characteristics of maintenance & repair project-specific environmental load upon estimating environmental load occurring during the road maintenance & repair phase by conducting life cycle assessment (LCA).

1.2. Scope & Method
To analyze the characteristics of environmental load emission during the road maintenance & repair phase, 10 local road construction project cases performed domestically were used. In this study, road paving project of road maintenance & repair phase was exclusively targeted. Based on the analysis of design documents (quantity statement, volume estimation, unit cost estimation and breakdown cost) of each project, materials, and equipment used for each project and amount of energy usage were identified to identify the amount of resources used. For calculating environmental load, LCA method was applied. Fig.1 represents the method and process of the research. The figure illustrates the procedure for computing carbon emission which is divided into three phases of case project selection, construction type analysis, and environmental load computation. These three were combined for further analysis by classifying them into construction-specific environmental load characteristic analysis and after which correlation analysis of environmental load and design information & utilized resources was performed. As for the related database, data that has been established by Ministry of Trade, Industry, and Energy and Ministry of Environment, and international DB were referred to a study conducted by [5].

![Method and Process of the Research](image)

2. Project collection & construction type analysis

2.1. Project collection
As for the cases collected to analyze maintenance & repair cases, 10 cases of projects implemented for road maintenance construction (except for bridge and tunnel repair) in Milyang, Gyeongsangnam-do during 2015-2016, and the overview was classified into construction period, repair width, repair length, repair area and repair construction type.

2.2. Construction type analysis & application scope
The construction type in the road paving maintenance & repair phase can be classified into asphalt concrete pavement overlaying, asphalt concrete pavement cutting and overlaying, asphalt pavement overlaying and cutting and overlaying mixture.
As for its scope of application, overlaying will be performed in the service index (PSI) 2 – 1.1 section according to the PSI-specific construction type application scope specified in AASHTO Road Pavement Structure Design Guideline, and in the service index (PSI) below 1.0 section for cutting and overlaying [6].

3. Environmental load estimation & analysis

3.1. Environmental load estimation & analysis

Environmental load was estimated by linking each resource used that has been aggregated with LCI DB (Life Cycle Inventory Data Base). Table 1 provides the total environmental load estimation of maintenance and repair cases. The average percentage values are provided as weighted values.

| Case | ARD | AD | EU | GW | OD | POD | TET | HT | Sum |
|------|-----|----|----|----|----|-----|-----|----|-----|
|      | Eco-Point | Eco-Point | Eco-Point | Eco-Point | Eco-Point | Eco-Point | Eco-Point | Eco-Point | Eco-Point |
| Sum  | 1.09E+01 | 8.15E-01 | 1.02E+00 | 2.23E+01 | 2.29E-01 | 1.82E+00 | 3.81E+01 | 9.46E+00 | 8.46E+01 |
| Average (%) | 13.67% | 0.99% | 1.18% | 27.65% | 0.29% | 2.77% | 42.45% | 11.00% | 100% |

Environmental load occurring during pavement repair work was divided into 8 major impact categories to analyse the characteristics, and the result revealed that TET showed the higher distribution of weighted value with 42.45%, followed by GW with 27.65%, ARD with 13.67%, HT with 11.00%, POC with 2.77%, EU with 1.18% and AD with 0.99%.

Fig. 2 is the graphical representation of environmental load according to 8 major categories and environmental characteristics distribution according to materials and construction type. The right side figure represents the environmental load according to 8 major categories while the left figure represents the environmental characteristics distribution according to materials and construction type. Meanwhile, in regards to the environmental load distribution according to the 8 major impact categories of road construction projects, ARD and GW show the highest environmental load distributions with respectively 37.15% and 31.34% [2].

As for its reason, it is thought that environmental load of GW and ARD was significantly assessed from fossil fuel consumption since environmental load occurring in each construction type consisting road construction project such as earthwork, slope stabilization, drainage works, pavement work, traffic safety facility work and subsidiary work is mainly determined by the consumption amount of oil used for construction equipment.

In regards to the characteristics of environmental load caused by major processes and materials that consist of pavement repair work, on the other hand, 80.82% of environmental load occurring from entire pavement repair work is caused by asphalt concrete material, while 11.26% and 6.40% were caused respectively by RMC material and paint for lane repainting.

![Figure 2](image-url) Environmental load distribution according to 8 major impact categories; environmental load characteristics distribution according to materials & construction types.
In regards to the percentage of environmental load occurring from asphalt concrete, RMC and paint materials, it was 98.48% of total environmental load occurring from pavement repair work. In addition, the amount of environmental load of pavement repair work that occurs from construction work was found to be extremely insignificant and it was also found to be occurring from main materials used.

As shown in Table 2 that displays the sum of eco-point of material-specific pollutant for the degree of material-specific pollutant, the result showed TET 54.70% and GW 23.81% for ASCON, GW 47.41% and ARD 28.74% for RMC and ARD 49.55% and GW 41.35% for lane painting paint, thereby showing significant percentages of TET, GW and ARD among the 8 major impact categories.

Since measurement unit of environmental load measured through each impact category varies, environmental impact assessment index was assessed in this study through eco-point unit that converted characteristic value into weighted value.

### Table 2. Sum of Material-specific Pollutant Eco-Point (Weighted).

| Material         | ARD  | AD  | EU  | GW  | OD  | POC | TET  | HT  | Sum  |
|------------------|------|-----|-----|-----|-----|-----|------|-----|------|
|                  | Eco-Point | Eco-Point | Eco-Point | Eco-Point | Eco-Point | Eco-Point | Eco-Point | Eco-Point | Eco-Point |
| ASCON            | 4.07E+00 | 5.53E-01 | 8.64E-01 | 1.64E+01 | 1.68E-01 | 5.71E-01 | 3.78E+01 | 8.62E+00 | 6.91E+01 |
|                  | 5.89% | 0.80% | 1.25% | 23.81% | 0.24% | 0.83% | 54.70% | 12.48% | 100.00% |
| RMC              | 2.59E+00 | 1.22E-01 | 4.54E-02 | 4.27E-00 | 5.24E-02 | 1.13E+00 | 3.97E-02 | 7.34E-01 | 9.60E+00 |
|                  | 28.74% | 1.35% | 0.50% | 47.41% | 0.58% | 12.83% | 0.44% | 8.15% | 100.00% |
| Lane painting    | 1.31E+00 | 1.20E-01 | 4.96E-02 | 1.10E+00 | 1.10E-03 | 2.44E-02 | 1.21E-03 | 4.45E-02 | 2.65E+00 |
| paint            | 49.55% | 4.54% | 1.87% | 41.35% | 0.04% | 0.92% | 0.05% | 1.68% | 100.00% |

#### 3.2. Environmental load design info. & resources utilized correlation analysis

Table 3 shows the correlation analysis result between environmental load and pavement repair work construction period, repair width, repair length, repair area, repair material, repair construction type.

### Table 3. Correlation Analysis.

| Division          | Coefficient of determination (R²) | Pearson correlation coefficient |
|-------------------|-----------------------------------|--------------------------------|
| Pavement repair length | 0.794                             | 0.891                          |
| Pavement repair area       | 0.976                             | 0.976                          |
| Asphalt concrete amount   | 0.924                             | 0.961                          |

The correlation between pavement repair length and environmental load showed 0.794 coefficient of determination (R²) and 0.891 Pearson correlation coefficient. Next, correlation between pavement repair area and environmental load showed 0.952 coefficient of determination (R²), which is an improvement by 20% compared to pavement length, and 0.976 Pearson correlation coefficient, which is an improvement by 10% compared to pavement length. Accordingly, increase in the pavement repair area was found to have significantly contributed in linearly increasing environmental load of pavement repair work. Lastly, correlation between asphalt concrete amount and environmental load showed 0.924 coefficient of determination (R²) and 0.961 Pearson correlation coefficient. Upon collecting cases on overlaying, cutting and overlaying and mixed constructions of pavement repair construction works, environmental load was estimated and correlation of case-specific characteristics & main attribution information and environmental load was analyzed. The result showed that environmental load occurring as a result of asphalt concrete material quantity was dominant for pavement repair work, along with high correlation between repair length and repair area.

### 4. Conclusion

This study examined the construction type-specific environmental load characteristics of road maintenance & repair for 10 cases of domestic local roads, and the result of environmental load
distribution according to 8 major environmental impact categories showed a concentrated result of TET and GW with respectively 42.45% and 27.65%.
In regards to the characteristics of environmental load caused by main processes and materials consisting of pavement repair work, 80.82% of environmental load occurring in the entire pavement repair work was from asphalt concrete material, while 11.26% and 6.40% were respectively from RMC and lane painting paint.
Compared to existing road construction, it is shown that environmental load occurs in the majority of material items in road maintenance & repair work, along with an extremely insignificant amount of environmental load caused by construction work. In addition, it was found that there is a close correlation between environmental load and pavement repair length, pavement repair area and asphalt concrete amount.

5. References

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