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Life Cycle Assessment on Cement Treated Recycling Base (CTRB) Construction

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ABSTRACT- LCA is one of the few environmental management techniques that are used to perform a risk assessment, environmental performance evaluation, environmental auditing, and environmental impact assessment and must be applied to the construction CTRB. The purpose of this study was to determine the amount of energy consumption is used and determine the amount of emissions (CO_2) in the implementation of the Foundation Layer Top (base course) with the former asphalt pavement aggregate blended cement / Recycling Cement Treated Base (CTRB). This study uses: (i) Compilation and data inventory of relevant inputs and outputs of a product system; (ii) Evaluating the potential environmental impacts associated with the data input and output; (iii) Interpret the results of the inventory analysis and impact assessment in relation to the research objectives. The results showed that Energy consumption in the implementation of recycling pavement (CTRB) is 225.46 MJ / km of roads and the resulting GHG emissions 17,43Ton CO_2 / km of roads. Previous researchers to calculate the energy consumption of road works on the implementation of conventional (hotmix) is 383.46 MJ / km of roads and the resulting GHG emissions 28.24 Ton CO_2 / km of roads. If the calculated difference between a job and Hotmix CTRB and then a comparison is made CTRB energy consumption is 158 MJ / km of road, this happens 70.07% savings and GHG emissions resulting difference is 10.81 tons of CO2 / km of road, resulting in a decrease in 62,02%.

Keywords - *CTRB; CO_2; energy; LCA*

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INTRODUCTION

The world community is aware to the importance of environmental conservation since 1962 in conjunction with the publication of *Silent Spring* novel by Rachel Carson telling the effect of pesticides on the incidence of cancer.

This movement was followed by the American society in 1969 by conducting conference in Seattle initiated by Gaylord Nelson and then Earth Day was set for first time by the United States Environmental Protection Agency (USEPA) on April 22, 1970 and on June 5, 1972 by the United Nations in the Stockholm City State conference in Sweden designated as World Environment Day, this brings the impact of environmental conservation movement in developing countries especially Indonesia (Ervianto, 2012).

The growing of global awareness to the environmental protection related to the impact of production and consumption activities generate interest to develop a method to reduce these impacts. One technique that is developed for this purpose is the Life Cycle Assessment (LCA) in road pavement CTRB construction.

The field of transportation sector affects much to the economic and social environment sectors represents 10% of world gross domestic product. Effect of road and airport construction, including

the depletion of natural resources and energy, temperature rise, air pollution, lowering of ground water and drinking water scarcity. Overall in the world, the

transportation sector has been absorbing energy 22% of global energy consumption, burning 25% of the burning of fossil fuels and contributing to donate 30% of global air pollution and greenhouse gases.

Ongoing road construction supported by the concept of the three pillars covering of economic growth, environmental protection and social progress is the present transportation demands present without compromising the ability to meet future needs (Resmi, 2011).

Dongxin (2010), explains that the strength of recycled pavement material depends on the content of dry weight. The results of the study explained laboriumnya recycled pavement material requires relatively little water, compressive strength and tensile strength of recycled material versus exponential mixture with dry bulk density and directly proportional to the period of treatment. The most effective mix for the recycling of construction work of road pavement with a ratio of 65% aggregate / new materials and 35% use of recycled materials. Al-Oraimi (2009), explains that the recycled asphalt material has a certain strength characteristics when blended with additives such as water and cement. Factors affect the strength of the cement water mix recycling, the greater the water factor, the strength of cement in the mixture decreases. Effective mix of recycled water cement designed with a factor between 0.45 to 0.5 produces compressive strength 33 to 50 MPa in a 28-day treatment period. To increase the strength of recycled mixture with water cement factor is far but will have trouble in the mixing process.

Job recycled pavement construction can reduce the use of new materials, thus saving the cost of road construction, energy-efficient, the elevation can be maintained roads increase the economic value scratching asphalt materials and rapid in its execution (Widjayat, 2009). Use of Reclaimed Asphalt Pavement (RAP) can reduce waste of raw materials for road construction. Estimated use of RAP in the United States in 1996 about 30%, after 30 years of using it in the future RAP no longer be an alternative material but it is a requirement for road construction (Widjayat, 2010).

The growing of global awareness to the environmental protection related to the impact of production and consumption activities generate interest to develop a method to reduce these impacts. One technique that is developed for this purpose is the Life Cycle Assessment (LCA) in road pavement CTRB construction.

According to ISO 14040, LCA is a technique for assessing the environmental aspects and potential impacts associated with a product begins with the following activities: (i) Compilation and inventory of data input and output of the system relevant products; (ii) evaluating the potential environmental impacts associated with the data input and output; (iii) Interpret the results of the inventory analysis and impact assessment in relation to the research objectives. LCA is one of several environmental management techniques that are used to perform a risk assessment, environmental performance evaluation, environmental auditing, and environmental impact assessment but this technique may not be the most appropriate for use in all situations. LCA does not address the economic aspect or social aspect of a product. LCA can assist in: (i) Identify opportunities to improve the environmental aspects of a product; (ii) Decision making in industry, government organizations or non-governmental, for example at the time of planning, prioritization of product or process design and re-design the current implementation; (iii) Selection of relevant indicators of environmental performance, including measurement techniques; (iv) Marketing ie claims, environmental ecolabel or environmental product declarations. The results of the LCA study focused on issues of global and regional though not necessarily applicable to the local situation, local conditions may not be adequately represented by a regional or global conditions. The accuracy of the LCA study is determined by the accessibility or availability of the relevant data, data quality, data types, data aggregation and conditions of the study. Life cycle assessment which includes the definition of assessment, interpretation of results, scope, inventory analysis and impact as described below.

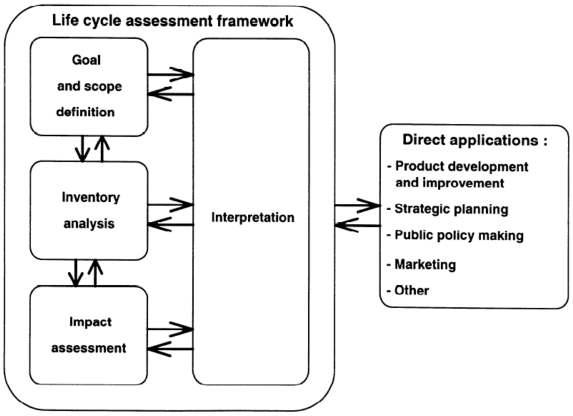

Figure 1. Phases of on LCA

Mil Lachowski (2011), analyze the environmental impact of the method of life cycle assessment (LCA) on pavement construction guided by ISO 14040 are being made to use the construction, and maintenance of toll roads per 1 km long. This study shows that the environmental impacts of highway construction, traffic operations and maintenance can be reduced. The potential environmental impact can be reduced by optimizing the production of construction materials. Reductions in fuel consumption of 0.5% during the period of service of 30 years for each 1 km highway will reduce CO2 emissions by 1154 t CO2-eq.

Gschosser F. (2011), analyze the potential environmental impacts and costs by using indicators of life cycle analysis (LCA) conducted on pavement construction in Switzerland. The results of this research encourages the field of road construction services to utilize construction materials that have a minimal impact on the environment and good technical analysis resulting in a gain in the implementation of the budget, when the traffic load, the influence of geography and climate on road construction and provide optimal service. Based on the discussions and conclusions, recommendations for future research focus on product environmental performance of road pavement materials and methodologies Life Cycle Assessment (LCA) into a pavement management system.

Nicuta (2011) analyzed the environmental impact of asphalt mixture in the perspective of life cycle assessment (LCA) states that, by adopting the recycling technology for asphalt pavement showed a significant reduction in emissions (40% in this case) of CO2e emissions that occur in activities road projects. Originality of this study was based application software on the comparative evaluation of environmental impact compared to traditional asphalt pavement due to the composition of the recycled asphalt mixture.

Wirahadikusumah (2012), analyzing the estimated energy consumption and GHG through several stages with the restriction that the study of the direct activity in the construction sector, namely: (i) Stage production of hot mix asphalt; (ii) Tahaptransportasi material; (iii) the implementation phase of the paving work. Research results revealed that the aggregate drying process requires approximately 68% of energy and emit 70-75% of the entire stage. Further research can be done various scenarios paving work methods in order to discover the optimal method to minimize the environmental impact of human harm.

MATERIAL AND METHODS

a. Compilating and inventory of input and output data which relevants to the product system.

Data collected through. a survey to the construction contractor company CTRB road construction, data obtained includes data on CTRB implementation mechanisms associated with fuel consumption in the company, consisting of data on the use of cement, fuel (diesel), the use of oil, water tank trucks used in conjunction with a recycling machine (CTRB recycler), goat foot roller, the roller (road roller). The data is compiled every 1km on roads done starts from laying cement, scratching pavement (milling), scarifying with a mixture of water, compacting and resurfacing CTRB construction.

Thus it can be seen the use of materials and energy each 1km in the CTRB construction.

Table 1. Energy conversion factor and fuels emission factor (IPCC, 2006)

Fuel type	Density	Calorofic Value		Emission Factor	
	(kg/ltr)	(GJ/Mg)	(MJ/ltr)	($kgCO_2$/GJ)	($kgCO_2$/ltr)
Crude Oil	0.847	42.30	35.83	73.30	2.63
Diesel fuel	0.837	43.00	35.99	74.10	2.67
Bituminous Coal		25.80		94.60	

b. Evaluating the potential environmental impacts associated with the input and output data.

In the second stage, the analysis of environmental impacts is done associated with construction work especially CTRB starting from transportation phase and use of materials, fuel and energy consumption by using the guidelines of the IPCC 2006 are as follows:

GHG emissions (kgCO2/ton) = Energy Consumption (MJ) x Emission Factor (kgCO2 / MJ)/ Total production (1)

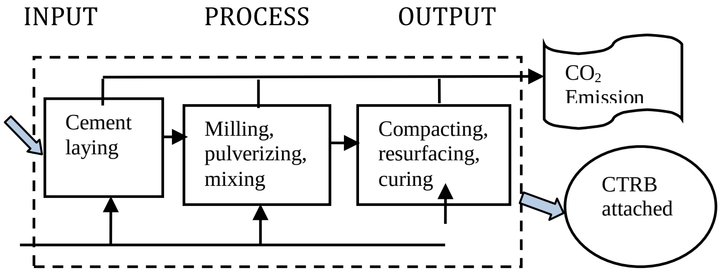

Figure 1. Emissions of greenhouse gases (CO2) on the implementation of the CTRB.

c. Interpreting the results of the inventory analysis and assessment impact in relation to the research objectives.

At this third stage, resource inventory analysis and assessment impact of the use of resources and energy expended during the implementation of construction works CTRB are done by using the following formula:

Energy Consumption (MJ / ton) = Fuel consumption (liters) x Colorafic Value (MJ/liter)/ Total production (2)

The basis of calculation is a compilation of data that has been mentioned above and also conducted field observations according to the model shown below.

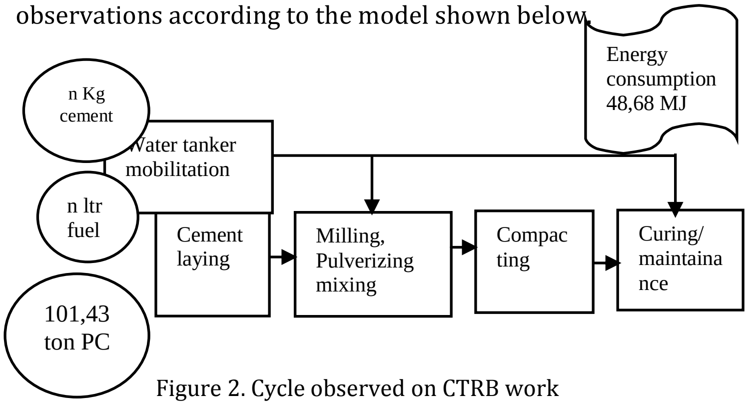

Figure 2. Cycle observed on CTRB work

RESULTS AND DISCUSSION

a. Compilating and inventory of input and output data which relevants to the product system.

The collection of data calculates the estimated energy usage and greenhouse gas emissions of recycling work of CTRB pavement construction by conducting a survey to several technical institutions that are to the Department of Highways Central Java Province and to the Center of the National Road Implementation in Sidoarjo, East Java Province.

The data obtained in the form of CTRB production per day, the use of heavy equipment and fuel consumption during execution of the recycling work such as road pavement as in the table below.

Table 2. Specifications of equipment on the CTRB implementation.

Stage	Process	Equipment's name	Specification
	Cement laying	*Dump truck*	ELF 120 PS, capacity $3m^3$, power 120 HP, TP. 2009.
	Milling Pulverizing Mixing	*Cold recycler machine*	Wirtgen WR 2500, capacity 2,6m, power 670 HP, TP. 2009.
CTRB Executions	Compacting	*Motor grader*	Mitsubishi MG 330, capacity 4000 mm, power 125 HP, TP. 2008.
		Water tanker	Isuzu-71, capacity 5000liter, power 121 HP, TP. 2009.
		Pad foot compactor	Hamm 3620 P, capacity 20 ton, power 197 HP, TP. 2009.
		Vibro roller	Sakai SV 500, capacity 8mm, power 135 HP, TP. 2009.
CTRB Executions	Flattening Curing	*Pneumatic tire roller*	Sakai TS 2000, capacity 15 ton, power 80 HP, TP. 2009.
		Water tanker	Mitsubishi FN 517 ML 2, capacity 16000liter, power 220HP, TP. 2009

Source : Department of Highway Central Java Province, 2014

Table 3. Data of fuel consumption on CTRB implementation per day.

Volume CTRB per day (7 hours)	Equipment's name	Fuel type	Fuel consumption per day (liter)
	Dump truck	Diesel fuel	70
	Cold recycler machine	Diesel fuel	1000
Length : 300m;	*Motor grader*	Diesel fuel	160
Width : 7m	*Water tanker* 5000lt	Diesel fuel	40
Thickness : 30cm	*Pad foot compactor*	Diesel fuel	500
	Vibro roller	Diesel fuel	80
	Pneumatic tire roller	Diesel fuel	60
	*Water tanker 16*000lt	Diesel fuel	50
	Total		1960

Source : Department of Highway Central Java Province, 2014

b. Evaluating the potential environmental impacts associated with the input and output data.

CTRB product attached per day with a length of 300 meters and a width of 7 meters wide is 2,100 m2. Thickness is 30 cm, then the volume of CTRB is 630 m3, weight volume average of 2.3 ton/m3, so the CTRB weight = 1,449 tons.

Consumption of diesel per ton CTRB installed: *1.960 liter/1.449 ton* = 1, 35 liters per ton.

To calculate the estimated energy requirements and GHG emissions per km used field data that CTRB work for each side of road width is 7 m with a thickness of 30 cm, the number of attached CTRB per km is 1000m x 7m x 0,3 m x 2,3 ton/m3 = 4,830 tons per kilo-meters long.

Consumption of diesel fuel is 1960 liters per day.

Diesel emission factor: 2.67 kg CO2/liter;

Calorific value of diesel: 35.99 MJ / liter;

The use of cement 7 percent of the weight of the attached CTRB material: *(7/100) x 1.449 ton = 101,43 ton.*

Energy and emissions per day occured on CTRB implementation can be estimated as follows:

Energy requirements (MJ/tonne) = (*1.960 lt x 35,99 MJ/liter)/1.449ton = 48.68 MJ / ton*

GHG emissions (kg CO2/ton) = (*1.960 lt x 2,67 kg)/ CO_2/liter = 3.61 kg CO2/ton.*

While the energy and emissions per 1 km on CTRB implementation can be estimated as follows:

Energy requirements (MJ / ton) *= 48.68 MJ / ton x 4,830 ton / km x (1GJ/1000 MJ)= 225, 46 GJ / km*.

GHG emissions (kg CO2/ton) = *3.61 kg CO2/ton x 4,830 ton / km x m x* (*1ton/1000*) *= 17.43 tons of CO2/km.*

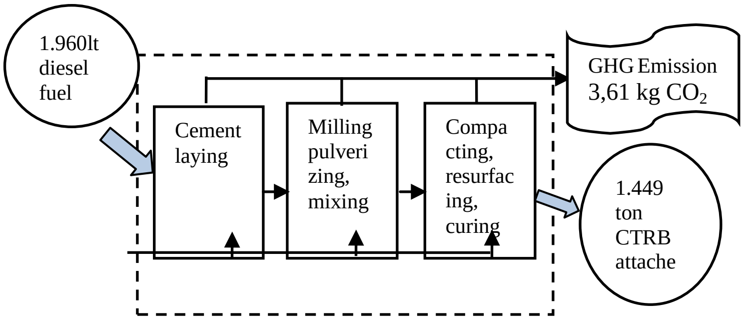

Figure 3. Energy consumption and GHG emissions (CO2) on the CTRB implementation

c. Interpreting the results of the inventory analysis and assessment impact in relation to the research objectives.

Table 4. Estimated energy consumption and GHG emissions on the CTRB implementation

Process	Main Tool	Energy consumpt		GHG Emission	
		MJ/ton CTRB	GJ/km run	kg CO_2/ton CTRB	ton CO_2/km
Cement laying	*Dump truck*	1,738	8,39	0,128	0,618
Milling Pulverizing Mixing	*Cold recycler machine*	**24,83**	**119,9**	**1,84**	**8,887**
Compacting	*Water tanker160 0 lt*	1,24	5,989	0,092	0,444
	Motor grader	3,97	19,17	0,294	1,420
	Pad foot compctor	12,41	59,97	0,921	4,448
	Vibro roller	1,987	9,597	0,147	0,710
Flattening	*Pneumatic tire roller*	1,49	7,196	0,11	0,531
Curing	*Water tanker 5000 ltr*	0,993	4796	0,073	0,352
	Total	**48,68**	**235,1**	**3,61**	**17,43**

Table 5. Comparison of energy consumption and emissions of road pavement.

Types of pavement construction	Energy consumption (MJ/ton)	GHG Emission (Kg CO_2/ton)	Information
Hot Mix Asphalt (HMA)	494,62	36,43	Wirahadikusumah, 2012.
Cement Treated Recycling Base (CTRB)	48,68	3,61	Research result, 2014

Table 6. Comparison of energy consumption and emissions of road pavement per-km

Types of pavement construction	Energy consumption (MJ/ton)	GHG Emission (Kg CO_2/ton)	Infor-mation
Hot Mix Asphalt (HMA)	383,46	28,24	Wirahadikusumah, 2012.
Cement Treated Recycling Base (CTRB)	225,46	17,43	Research result, 2014

From the calculation results as shown in Table 4, it can be said that the implementation of CTRB jobs that require attention during the process of dredging, tilling and mixing engine that uses recycler, because fuel consumption is high enough so that the energy that it takes about 51% and emissions generated around 51%. For energy efficiency and reduce greenhouse gas emissions in the execution of the work effort required CTRB modification of equipment that uses fuel more efficiently with the same capacity. The construction of the road pavement recycling methods consume more energy efficient and produce less greenhouse gases compared to conventional methods (hot mix).

The results of calculation of the estimated energy consumption and greenhouse gas emissions in the execution of the CTRB work in this study can contribute as the information to support government policy in an energy efficiency effort and decreasing of greenhouse gas emissions nationally according to PERPRES No. 5 of 2006 and the commitment of the Government of the Republic of Indonesia in international conferences.

CONCLUSION

1. Development of road infrastructure has a very important role to enhance national development, but along with that role, pavement road construction requires energy and produces emissions of greenhouse gases that affects global warming.
2. Energy consumption in the implementation of recycling pavement (CTRB) is 225.46 MJ / km of roads and the resulting GHG emissions 17,43Ton CO2 / km of roads. Previous researchers to calculate the energy consumption of road works on the implementation of conventional (hot mix) is 383.46
3. MJ / km of roads and the resulting GHG emissions 43Ton 28.24 CO2 / km of roads. If the calculated difference between a job and Hotmix CTRB and then a comparison is made CTRB energy consumption is 158 MJ / km of road, this happens 70.07% savings and GHG emissions resulting difference is 10.81 tons of CO2 / km of road, resulting in a decrease in 62,02%.
4. The construction of road pavement implementation by using recycling processes uses energy more efficiently and produces less greenhouse gas than conventional method (hot mix).

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