GREEN & QUALITY RURAL ROADS IN MALAYSIA

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ABSTRACT

In some developing countries in ASEAN, rural roads infrastructure has not yet been developed appropriately as vital transportation system rather than main roads because of they carry lower volume of motorized traffic. But nowadays, a good network of roads links which connecting rural villages to main road will be an essential development strategy in order to promote better national economic and social development. Malaysia in 2010, as mentioned on Prime Minister's budgetary speech 2009, will allocate of RM2.3billion in 2010 to construct and upgrade infrastructure in rural areas, the priority will be given to the use of soil stabilizers in the construction of rural roads. Refer to NKRA (National Key Result Area) agenda and initiative, Malaysia government plan is to build 1500 km of rural roads in the next 3 years as "connecting roads". By using conventional road construction method, these number will need huge amount of suitable quarry materials to be mined which will increase the carbon footprint emission to the environment, in order not to increase the burden of environment, green approach – Chemilink soil stabilization method is required as alternative on rural roads construction. In this paper, through few projects as reference which done by using Chemilink soil stabilization method, will study the effectiveness of this new green approach including quality (engineering properties), durability and carbon footprint emission estimation (CO_2) on rural road construction in Malaysia. As the results, by using Chemilink soil stabilization was found to be able to reduce CO_2 4-6 times with providing better technical performances.

KEY WORDS

Green & Quality, Rural Road, Carbon Footprint, Chemilink Soil Stabilization, In-situ Recycling

1. IMPORTANCE OF RURAL ROADS DEVELOPMENT

1.1 Road infrastructure (rural road accessibility) development and poverty reduction

In some developing countries in ASEAN region, rural roads infrastructure has not yet been properly developed as vital transportation system. As a result, negative impact either in social and economic on the livelihood for the rural communities, especially during the rainy season which the rural communities are often left isolated when the roads become impassable. Hence, a better development of road infrastructure in rural communities is required in order to improve:

a. Health and education of communities through better road access as this will shorten the travelling time to the health care centre and schools especially during the rainy season.
b. Business opportunities of farmers as this will increase the production and shorten the distribution time of agricultural products to markets.
c. Social welfare between family and friends by promoting better unity of life for the rural communities.

1.2 Overview of road networks development in BRIC and ASEAN countries

There is a total of 16 million kilometers of roads in the world, which can take us more than 20 times to the moon and back. It is still ever increasing especially in the developing countries, according to latest statistics of the road networks developments in BRIC countries (figure 1) **[9, 12]**, the volume of paved and unpaved road network size are 7.6million km and 5.3million km**,** respectively. For example, China in its latest 5 years plan includes building and renovating of 1.2 million kilometers of road, aiming for a road to every village. Meanwhile, the latest "ASEAN Statistical Yearbook 2008" statistics data **[1]** showed that the volume between paved and unpaved road network size are 0.5million km and 0.37million km, respectively, as illustrated in Figure 2. The definition of unpaved road can either be referred to gravel road or earthen road. Up to date, no specific information was found.

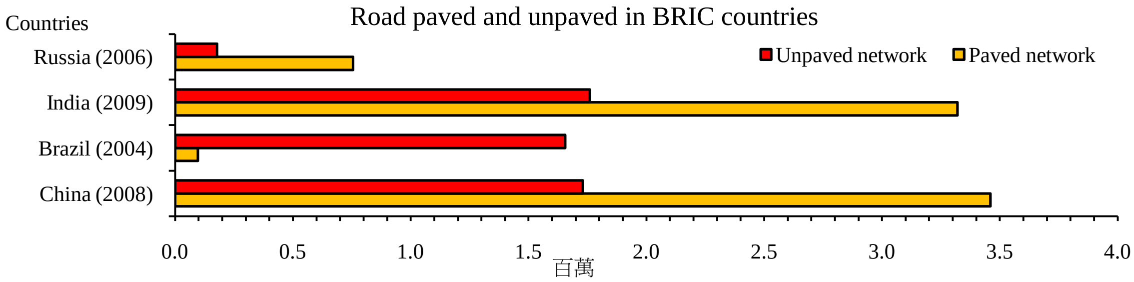
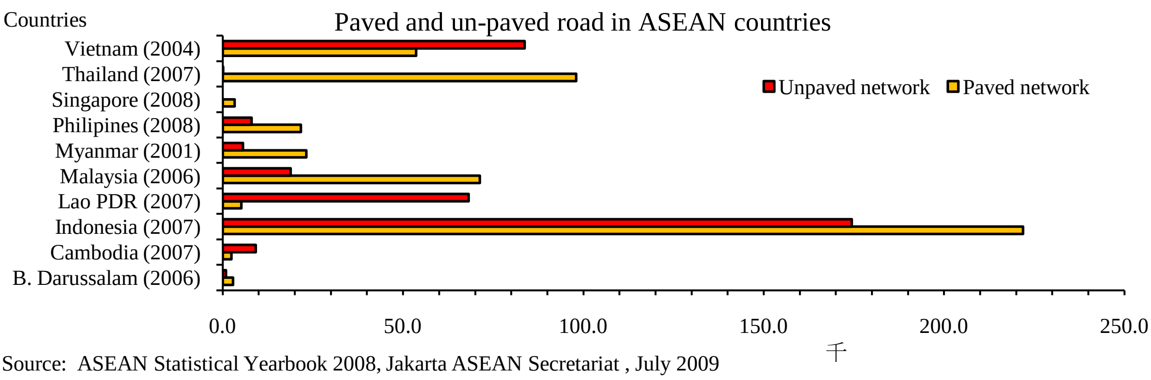


Figure 1: Road networks condition in BRIC countries



Source: ASEAN Statistical Yearbook 2008, Jakarta ASEAN Secretariat , July 2009

Figure 2: Road networks condition in ASEAN countries

Malaysia has allocated a substantial fund for soil stabilization in its last budget, which a green approach will be applied for building of rural roads. It was mentioned in Prime Minister's budgetary speech 2009 a sum of RM2.3 billion will be allocated to construct and upgrade infrastructures in rural areas in 2010. Priority will be given to the use of soil stabilizers in the construction of rural roads, where appropriate. This is due to its lower cost of construction and maintenance **[8]**. Under its NKRA (National Key Result Area) agenda and initiative, it focuses on its rural initiative in "Connecting roads" where the plan is to build 1500 km of rural roads in the next 3 years, to connect the villages as well as the resources.

1.3 Road construction by conventional method (Gravel road)

Natural gravel (crusher run) is generally used as base layer materials to replace unsuitable in-situ material for rural roads construction, but however, high intense and volume of rainfall during rainy season in some regions of South East Asia may cause severe erosion of the gravel roads and impassable to traffic. Meanwhile, the binding properties of fines gravel particles are reduced in dry season due to the moisture loss will form dust and caused negative effect to the human health **[2, 6]**.

From the construction view of rural roads, conventional construction method needs a huge demand of gravel, asphalt, etc, which lead to over mining of natural resources. The logistics of transporting these materials hundreds of kilometers to the jobsite will also known to be expensive and increasing of CO_2 emissions to environmental. Hence the green road approach is proving to be a sustainable way of constructing rural roads. Environment friendly construction techniques, participatory and decentralization approach, optimum utilization of local resources, simple technology, and self help efforts justified the Green road approach as a best way of constructing rural roads in developing countries. In this paper, a green road approach – Chemilink Soil Stabilization method is studied and compared with conventional road building method, in terms of environmental impact as well as other civil engineering implications.

2. SOIL STABILIZATION BY CHEMILINK METHOD (GREEN CONSTRUCTION) [10, 11]

2.1 Background of Chemilink soil stabilization

Generally in road construction, the unsuitable in-situ soft soils need to be replaced by imported gravel (crusher run) materials as unbound base layer, but due to some limitations, the gravel materials are difficult and expensive to procure in certain regions, moreover, over exploration of natural materials would cause negative effect to the natural environment. Recently, the alternative solutions that are fulfilling technical requirements have been studied intensively to address these environmental issues. Among of these alternatives, soil stabilization method is one of the options. With soil stabilization, limited fresh natural materials and much less waste disposals are required.

By mixing adequate proportion of stabilizers with in-situ soils, the stabilizers will improve the properties of soils such as the volume stability, strengths, stress-strain, permeability and durability. After strengthening the properties of the in-situ soils, it can be act like sub-base or base layer of the road as bound platform.

2.2 Process of in-situ soil stabilization application

A mechanical spreader is used to evenly spread the stabilizing agents onto the surface of in-situ soils that need to be stabilized, followed by using an advanced self-running mixer called Stabilizer or Recycler be used for in-situ mixing of local soil or solid construction waste with the stabilizing agents. Finally, the mixture is compacted by rollers with higher capacity (Figure 3). Meanwhile, the construction methodology of the in-situ soil stabilization was modified for rural road construction, in view of possible unavailability and inaccessibility of the sophisticated machineries. This is necessary to cater for the working condition in rural areas, as well as using machines available as an alternative.

Spreading of stabilizing agent can be done manually, which not only effectively lower the construction cost, but also provides more job opportunities to the local residents. Besides, the widely available agricultural rotovator can replace the specialize stabilizer. Construction procedures of such simple method are shown in figure 4.

Mechanical Spreading In-situ Mixing (Stabilizer) Compaction

Figure 3: Soil stabilization process with higher grade of machineries

Manual Spreading In-situ Mixing (Rotovator) Compaction

Figure 4: Soil stabilization process with lower grade of machineries

2.3 Technical justification of Chemilink soil stabilization

Chemilink soil stabilization concept is to replace the conventional gravel (stone aggregate) by the same thickness of stabilized layer as a road base layer. Instead of design requirement of California Bearing Ratio (CBR) by conventional design is equal or greater than 80%, in order to provide equal or better technical performances in terms of stress bearing capacity and vertical stress reduction, the CBR design criteria for Chemilink stabilized soil layer is also set to be equal or even better than design requirement.

To verify the sufficiency of Chemilink design, which at least having equivalent strength compared with conventional design, mechanistic design by Elastic Layer Programs which specify by pavement design authority of Malaysia (JKR) is used as pavement design tools **[3, 4]**. The program was used to predict the stresses and strains condition of different structural component of the pavement layers. From the prediction obtained, the effectiveness in load bearing, distribution and reduction in each layer can estimated and the maximum vertical stress impose on existing sub-grade layer can be anticipated.

3. GREEN CONSTRUCTION REDUCED CARBON FOOTPRINT ON RURAL ROAD CONSTRUCTION

3.1 Outline of estimation CO_2 emission on rural road construction

In this study, CO_2 emissions by two different types of constructions method was analyzed, these methods include conventional replacement method which uses natural gravel (or crusher run) as base layer material and bituminous concrete as surface layer material, and Chemilink soil stabilization method which uses soil stabilization agent (stabilizers) to improve the engineering properties of in-situ material as base of the road with chip seal layer as surface layer.

Generally, for both methods, construction work involved in rural roads construction is divided into 4 stages as shown in Figure 5. Energy consumed and CO_2 emitted in rural road construction were calculated based on the following scope of works **[6]**:

a) Material production: Total quantities of materials, including road base and surface layer, machines and disposal of any waste.
b) Material and machineries transportation: Fuel consumption to deliver all materials and machineries to work site, and to dispose any construction waste generated away from site.
c) Road construction: Fuel consumption for machineries used for rural road paving construction.
d) Waste disposal: Logistics of disposal of waste materials

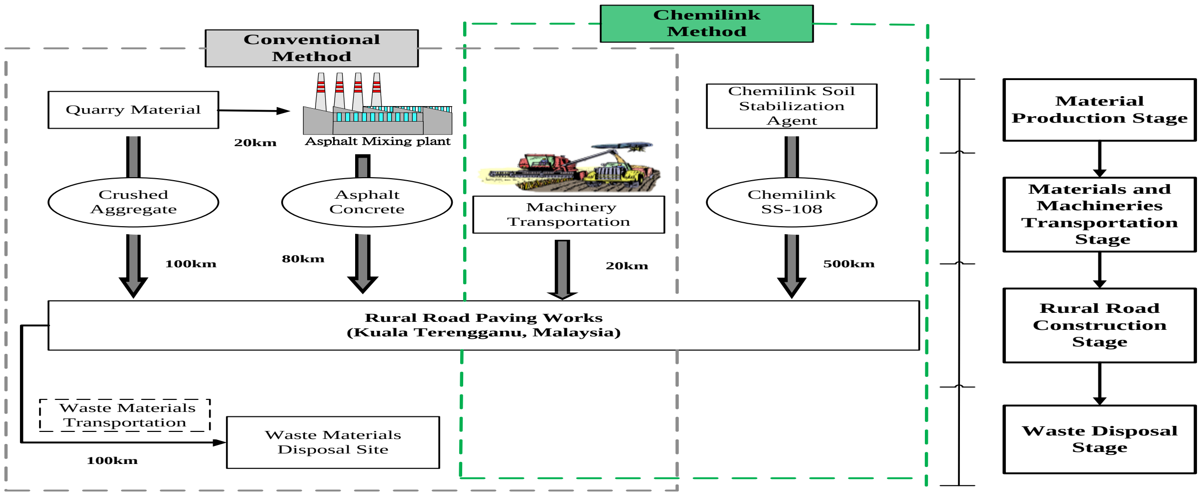


Figure 5: Range for Determine the Environmental Loads of Rural Road Construction
(By West Malaysia Project)

3.2 Case Study – Estimation and Comparison on CO_2 Emission

Two rural road construction projects were used to compare the carbon footprint emission for 2 different construction methods, the projects completed by using green approach- Chemilink soil stabilization method are:

a. West Malaysia project, completed in December 2009, the main function of the road is to connect village to the main road to the cities.

b. Oil and timber plantation road project in East Malaysia, completed in September 2010, the function of the road is connecting the villages inside plantation to the main road, and also as service road for oil and timber plantation vehicles. The type of commercial vehicles using the road is up to 5 axles which the total loading load is ranging from 20-40tons.

   The existing road condition before stabilized with soil stabilization layer is impassable during the wet season which it will be affecting the operation of oil and timber production.

Following project information were extracted and used for the estimation and comparison on CO_2 emission as shown in Table 1.

Table 1: Projects information for CO_2 estimation and comparison

Items		West Malaysia	East Malaysia
1. Road structural design by Green method	Base layer	200mm	250mm
	Surface layer	Chip seal	
Conventional gravel road design [a]	Base layer	200mm	250mm
	Surface layer	50mm of Asphalt concrete	
2. Logistic movement to job site (Conventional and Green construction methods) [b]			
a. Gravel and Asphalt concrete (from nearest source location)		100km	60km
b. Soil stabilizers (from Singapore)		500km	1700km
c. Construction machineries		20km	60km
3. Dimension for calculation		1km x 4m	1km x 6m

Notes: [a] Typical rural road design by conventional road design
[b] Distances assumption from nearest sources to the job-site for movement logistic of materials and machineries

Meanwhile, other assumptions for the machineries used and respective fuel consumption **[5]** are demonstrated in Table 2. The basic unit of Environmental Loads of materials used for rural road paving construction is as shown in Table 3 **[7]**.

Table 2: Fuel Consumption for machineries

Equipment and machinery	Fuel consumption rate (Diesel)
Asphalt paver, Rotovator, Motor grader and Stabilizer	0.019-0.053 L/m^2
Road roller	0.015-0.030 L/m^2
Tire roller	0.018-0.036 L/m^2
Vibratory roller	0.031 L/m^2
Water tank	0.1114 L/m^2
Truck	4.90-19.72 L/hour

Table 3: Basic Environmental Loads

Items	Unit	CO_2 Emissions (kg-CO_2)
Asphalt Paver	Ton	26.2
Road roller	Ton	0.95
Tire roller	Kg	0.248
Vibratory roller	L	2.69

3.3 Results of Estimation on CO_2 Emission

Calculation steps for CO_2 emission include:

a. Based on the pavement design, estimates the quantities of materials and machines used for rural road paving construction, as well as the amounts of fuel consumption for both logistics and construction.

b. The CO_2 emission estimation was derived by multiplying the amount of material consumed by the basic units of environmental loads.

As shown in Table 4 and Figure 6, the CO_2 emitted to build 1km of rural road by using conventional method is estimated to be 129-151tons, meanwhile the CO_2 emission can be effectively reduced by up to 4-6 times (22-32tons) by using green method such as Chemilink soil stabilization method.

Table 4: CO_2 Emission Estimation Results

Emission Stage	West Malaysia (4x1000m)		East Malaysia (6x1000m)	
	Conventional Method	Green Method	Conventional Method	Green Method
Material production	16.6	16.5	25.6	25.9
Material and Machineries Transportation	61.0	3.3	65.9	3.2
Rural road construction	3.1	1.8	5.0	2.5
Waste Disposal	48.8	0.0	54.9	0.0
Total stage emissions (ton-CO_2)	129 ton	22 ton	151 ton	32 ton

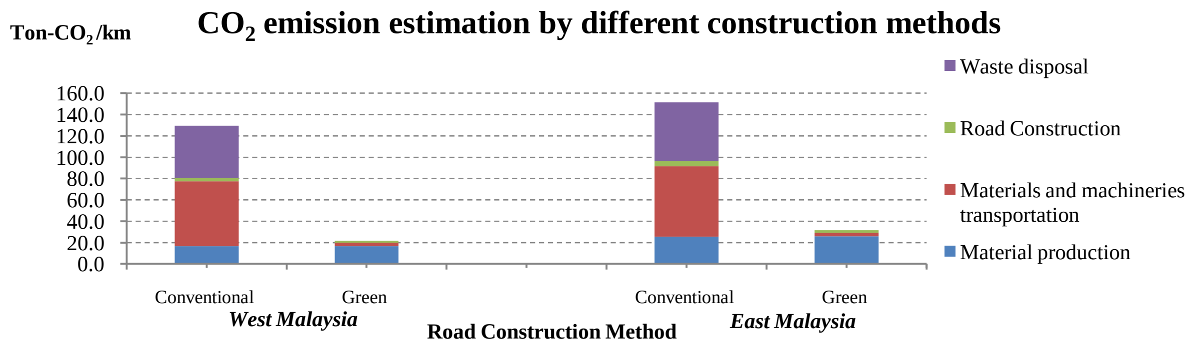


Figure 6: Results of Estimation on CO_2 Emissions

4. QUALITY GREEN ROAD CONSTRUCTION METHOD

As described in section 2.3, the design concept of Chemilink soil stabilization layer is to replace the conventional gravel with Chemilink stabilized in-situ soil layer as road base layer, the main design parameter has conform to the design parameter of the road, for example, the CBR value for base layer > 80%, mean that the quality of the Chemilink stabilized layer must equal or exceed the CBR value. The quality of rural road construction can be control by In-situ CBR measurement testing and long-term monitoring the condition of road post construction.

1. Quality of road during construction

   In order to control the construction quality, the in-situ CBR testing was applied by qualify laboratory.

   a. West Malaysia project, from 10 points of In-situ CBR testing by laboratory, the testing results showed that In-situ CBR value is range between 86- 149%. All of the In-situ CBR values were exceeded to the design CBR value (>80%).
   b. East Malaysia project, the design CBR value of this project is 50-80%. After the construction, 60-120% of CBR values were obtained from 20 points of In-situ CBR value testing.

2. Quality of road by periodically monitoring (after construction)

   A. West Malaysia project (Completed at December 2009)

(a) Existing road condition (muddy during wet season)

(b) Road condition after 7 months with minor chip seal defects (photos taken at August 2010)

Figure 7: Road condition of West Malaysia project

   B. East Malaysia project (completed at September 2009)

(a) Existing road condition (Muddy and Shrinkage cracking)

(b) Road in services (photos taken at January 2011)

Figure 8: Road condition of East Malaysia project

5. CONCLUSIONS

From the CO_2 emission prediction results, about 129-151 tons of CO_2 is emitted for every kilometer of rural road when constructed by using conventional method. In the future, If we used 5.3million and 0.37million km volume of unpaved road to be build in BRIC and ASEAN countries, it will results hundred million tons of CO_2 emission is emitted, this will cause a huge impact to environment in the term of CO_2 emission, and the most important consequence is over exploration of natural resources (gravel) as main construction material. Therefore, soil stabilization method should be considered as the alternative construction method as long as the quality achieved equal or even better than conventional method. Beside of quality during construction, the quality of rural road which constructed by soil stabilization method shall also be control by long-term monitoring of the road conditions during the service life.

6. REFERENCES

[1] ASEAN Statistic Yearbook 2008 (2009) Chapter VII Transport and Communication, pp 146-147, **The ASEAN Secretariat**, Jakarta, Indonesia.

[2] Gourley, C., Greening, A., Jones, D. and Petts, R. (2002) Paving the way for the rural development & poverty reduction, **20th Conference of ASEAN Federation of Engineering Organizations**. Phnom Penh, Cambodia.

[3] Harun, M.H. **The New JKR Manual on Pavement Design, Jabatan Kerja Rakyat (JKR),** Kuala Lumpur, Malaysia.

[4] Jabatan Kerja Rakyat (JKR) Malaysia (2008) **Standard Specification for Road Works Section 4: Flexible Pavement, Final Report JKR 20601-LK-0156-KP-05,** Kuala Lumpur, Malaysia.

[5] Kawakami, A., Nitta, H., Kanou, T. and Kubo, K. (2009) Study on CO_2 emissions of pavement recycling methods, **13th Conference of the Road Engineering Association of Asia and Australasia**. Incheon, Korea.

[6] Lee, M., Tan, P.C., Daud D. and Wu, D.Q. (2010) Green approach to rural roads construction-Stabilization of in-situ soils and construction wastes, **7th Asia Pacific Conference on Transportation and the Environment**, Semarang, Indonesia.

[7] Nitta, H. and Nishizaki, I. (2008) LCA evaluation of recycle pavement using scrap tire and waste plastic, **Journal of Pavement Engineering, Japan Society of Civil Engineers**, pp 79-86, Japan.

[8] The 2010 Budget Speech-Introducing the Supply Bill (2009) in Dewan Rakyat Malaysia, pp. 45-46.

[9] Postigo, A. (2008) Financing road infrastructure in China and India: current trends and future options, **Journal of Asian Public Policy, Vol. 1**, pp. 71-89, Routledge, London, UK.

[10] Wu, D.Q,, and Tan, P.C. (2008) Chemilink Stabilization Technologies for Roads and Airfileds, Seminar on Soil Subgrade Stabilization, **Public Works Department (JKR) of Malaysia and Road Engineering Association of Malaysia**, Legend Hotel, Kuala Lumpur, Malaysia.

[11] Wu, D.Q., and Tan, P.C. (2009) Recycling of Unsuitable In-Situ Soils and Construction Wastes by Chemilink Soil Stabilization, **2nd World Roads Conference – Sustainable Urban Transport Development**, Suntec Singapore, Singapore.

[12] **2008 Statistical Bulletin of Highway and Water Transportation Industry in China (2009)**, Ministry of Transport of the People’s Republic of China, China. (in Chinese)