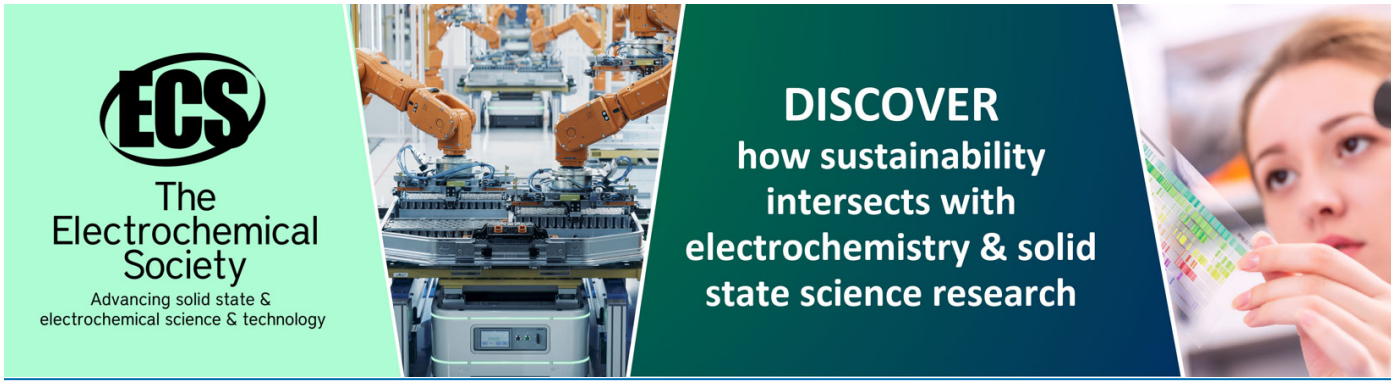
Assessment Ranking for Green Pavement Material Elements



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Assessment Ranking for Green Pavement Material Elements

W N A Wan Azahar[1], R P Jaya[2] , M Bujang[3] , N Kasim[1], N N Ismail[1], N M Husain[1], N K Basri[1], N A A M Hasazli[4]

[1] Assistant Professor, Department of Civil Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia.
[2] Associate Professor, Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, Gambang, Pahang, Malaysia.
[3] Lecturer, School of Engineering and Technology, University College of Technology Sarawak, No 1, Jalan Universiti, Sibu, Sarawak.
[4] Department of Civil Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia.

Email : aifa@iium.edu.my

Abstract. The development of green roadway in Malaysia is one of the contributions to accomplish Malaysia Go Green Campaign. Hence, sustainable materials are widely used in road construction recently because people are more aware about its implications towards environments. However, people keep trying to find the most suitable sustainable materials to be used in designing road pavement. Hence, a new method is introduced which assessment ranking for green pavement material element and research is developed by finding and adding more green material used in designing pavements in Malaysia. They are then been categorized and analysed in order to identify which will become the most preferred material. Development of questionnaire survey is one of the steps involved as well as analysis of factor and ranking method for all the green material elements used in roads. About 25 respondents including teams from Public Work Department (JKR) and consultant company are chosen to answer the questionnaire survey according to their specialisation in road construction area. The agreement level which is the output from survey will be transferred into Minitab Software and measured using factor analysis. The factor score which is product from factor loading and mean values being restructure and becomes the weightage factor. Thus, all the material elements are ranked based on their weighted factor value. From the analysis of questionnaire survey, alternative binder become the most preferable material to be used for green pavement for it has the largest weighted factor.

1. Introduction

A lack of research for highway industry has led to the increasing of energy wastage and non-systematic system. Therefore, some of energy conservation system have been developed to promote the environmental safety in Malaysia including the green highway. A green highway is developed by using sustainable material that are harmless to environment. Previously, transformation of highway technology study neglects the awareness on the environmental impact which causes harm on the surrounding ecosystem. Thus, an effective assessment ranking had been introduced as a part of the

sustainable development practices. Sustainable development is a system that was formed on technologies and non-technologies by considering political, economic, social and technological as the principles [1]. However, assessment ranking system is not quite familiar assessment in Malaysia. This is because, some of the road developers continuously practicing the traditional system in road industry. Assessment ranking helps in identifying the preferred sustainable material from a ranking method determined by the road expertise. This practice benefits the road developer in finding the best material that minimizes environmental impact.

1.1. Material verification

The development of green pavement comprises of six categories which are ecology, landscaping, waste reduction, materials, water conservation and energy efficiency. Based on these six elements, the road will be classified as green road pavement if it follows the elements conditions [2]. The designing of road is based on user capacity which leads to various pavement material used. Each pavement material has its own characteristic and strength which it affects the pavement performance and lifetime. In order to reduce the destruction towards environment and maintain the road resources, material efficiency and the circular economy are important. Thus, some pavement materials are identified and their characteristics meet the environmental health requirements.

The pavement material plays a big role in road construction hence the application of sustainable material in pavement aims not only to reduce environmental problem but also decreasing the gas emissions and hazard substance [2]. Some pavement materials such as waste material, regional material and recycled material can reduce the gas emission that released from the production of new road material and can be used as soil stabilization. Furthermore, reusing and recycling by-products materials can minimize the producing cost that benefits the industrial management where their properties are partially have the same values and usage with the invented material. The implementation and reuse of by-products material in industries can prevent them from being dumped into the landfill as well as saving the landfill space [3]. Hence, to avoid any increasing of wastage in landfill and industries, it is advised to maximize the reuse of by-products materials in all industries such as manufacturing industries, construction and rehabilitation.

Although asphalt is very important in developing the flexible pavement, it consists of hazardous compound that can affect human health and environment. The main reason why asphalt is more hazardous because it will release bitumen fumes that will cause respiratory problems and eye and throat irritation to the workers [4]. Thus, the alternative binders were used to save the natural resources and reduce the energy consumption while maintaining and improving the pavement performances [5]. It is proven that some of the alternative binders such as fossil fuel, bio-binder, palm oil and engine oil residue have similar chemical compositions to the conventional asphalt material. Furthermore, the replacement of aggregates with polymers which is high-density polyethylene (HDPE) results to higher stiffness changes [6]. Pavement with higher stiffness will reduce the pavement cracking when receiving the heavy load and reduce road maintenance.

The mixing of asphalt, cement and emulsifier will produce asphalt emulsions which it can reduce asphalt viscosity for lower temperature. The production of asphalt emulsion is ecological and energy saving because its production does not need heating process that might release gas emissions. Some of the asphalt emulsions reduce energy needs and fume production and the emulsion mix overlays improve structural capacity of roads [7]. The table shows the summary of six sustainable material.

Table 1. Sustainable material determination

Elements	Element Description
Waste material	Reduce wastage at dumpsite and being used as soil stabilization.
Regional material	Reduce the transportation, energy consumption, cost of project, and gas emission.
Recycled and reused material	Reduce the transportation, energy consumption, and gas emission.
Alternative binder	Help to save natural resources and reduce energy consumption while

	maintaining.
Chemical-based material	Reduce road maintenance and allow the rehabilitation of asphalt pavement.
Emulsions	Reduce asphalt viscosity for lower temperature

2. Methodology

The objectives of this research can be achieved by dividing the methodology phases into four phase. The first phase was about revision of existing literature review in previous studies then identifying the related problems in the research. Figure 1 showed the flowchart that explain the whole research's methodology.

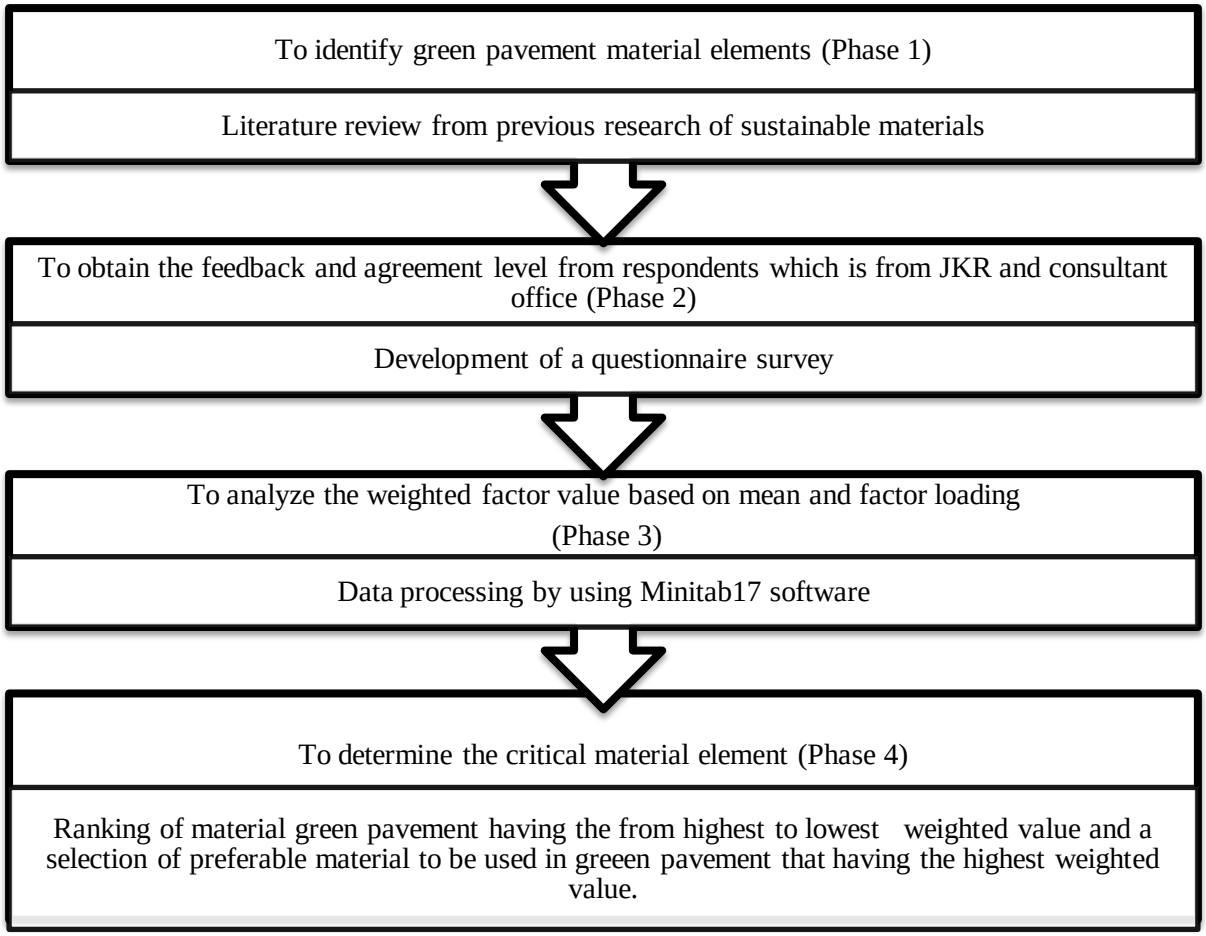

Figure 1. Methodology flowchart

2.1 Questionnaire survey

A survey of analysis and determination of preferable green pavement material was developed and distributed among 25 respondents in Jabatan Kerja Raya (JKR) office and consultant company around Kuala Lumpur and Selangor. The respondents justified their opinion on each of the material specifications in terms of agreement level. Furthermore, there are two parts in this survey which first part consist of demographic information of respondent while second part is an analysis on the agreement level of questionnaire survey. Their agreement level data was inserted in Minitab Software and being analysed.

2.2 Factor score

A selection of interpreted data will be done by using refined method based on the loading factors which resulted to factor score values. Factor score values will be calculated by multiplying mean score and factor loading. Factor loading and mean values data were will be developed and obtained from Minitab statistical package software.

$$factor\ score\ =\ factor\ loading\ \times\ mean \tag{1}$$

2.3 Weightage factor

Weighting numbers are applicable in giving priority for one number over another. In this research, the proportions of overall variables are different so weighting values are used to generate a new type of proportions so homogenous sampling ratio can be designed. To design a weighting value for each element, their factor score must be divided by total factor score for all elements. Then, a new weighting value can be obtained and each value will be ranked to find the most critical green material elements.

$$weighting\ factor = \frac{factor\ score\ for\ each\ elements}{total\ factor\ score} \tag{2}$$

The highest value of weightage factor will become most agreed material by respondents and being ranked first out of six elements.

3. Green pavement material elements

Six pavement materials that involved in the study was examined using factor analysis. Table 2 showed the eigenvalues obtained from the data analysis using Minitab which is it was based on the agreement level. Meanwhile, the scree plot explained the number of components that must be extracted in order to find the factor loadings.

Table 2. Eigenvalues for each material that were calculated from survey result.

Variable	Eigenvalues
Waste material	3.4706
Recycled and reused material	1.1251
Regional material	0.7064
Chemical-based material	0.4104
Emulsions	0.1841
Alternative binder	0.1034

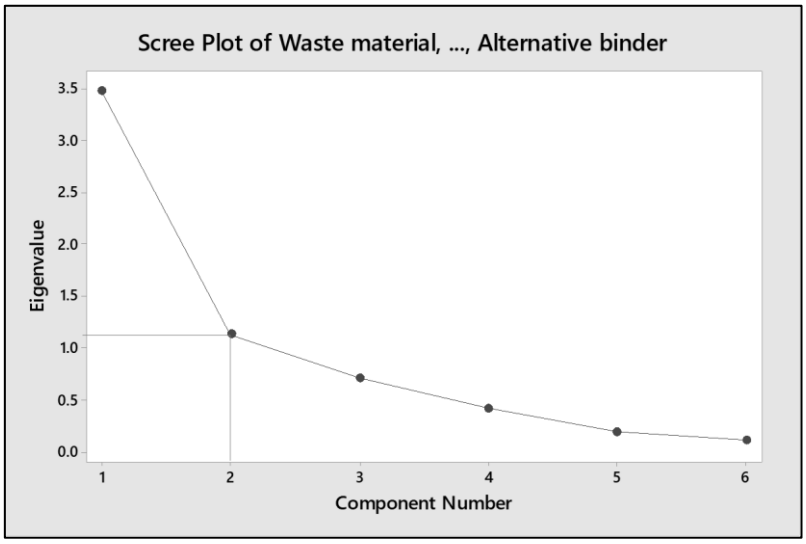

Figure 2. There are two components had the eigenvalues more than 1. Thus, the factor extraction analysis required only two factors to be considered.

3.1 Factor analysis

Factor analysis in the survey was used to identify common factors that correlate or uncorrelated with each other. By using maximum likelihood method of extraction, two factors were extracted in order to find the factor loadings. Factor loadings explained the relationship between the elements and the factor. In a case of allowing the factor loadings to interpreted easily, the factor loading usually rotated or re-oriented. Varimax rotation is commonly used to prevent the factors correlated with each other. Varimax rotation is an orthogonal rotation where it preserves simple structure and focusing to a single column only. Benefits of varimax rotation is that it maximizes the differences between high loading and low loadings. The table showed two factor loadings for each element. The group then be named reflecting all the elements criteria. The value of factor loading for each element explained the relationship between the elements and the factor. Higher factor loading showed it correlation between material and its factor. Meanwhile, Table 3 showed the category and sorted factor loadings.

Table 3. Factor loadings for each material before being sorted and categorized

Variable	Factor1	Factor2	Communality
Waste material	0.309	-0.587	0.440
Recycled and reused material	0.663	-0.534	0.725
Regional material	0.668	-0.241	0.504
Chemical-based material	-0.018	-0.666	0.444
Emulsions	0.635	-0.681	0.868
Alternative binder	0.991	0.010	0.981

3.2 Ranking method

Generating weighting factor is crucial in order to identify the importance of a material in accordance to their standard proportions. The highest weightage factor gives more impact on the components measured. Based on the Table 3, the highest weightage factor is 0.235 which is alternative binder. Most of the respondents agree on the alternative binder is the most economical and energy efficiency material that can be used for green pavement application. Alternative binder is ranked first was placed in the non-hazardous and economical category where it was used to replace the asphalt binder while improving the pavement performance. That is why, the respondents agree on the alternative binder being most preferable to replace the conventional binders. Regional material having lower weightage

factor compared to alternative binder is ranked second. Some of the respondents might agree and some might not agree on the material being economical and consume less energy. But it reduces the transportation of the material as well as reducing the energy consumption and project cost.

Furthermore, the emulsions and chemical-based material have low weightage factor which are 0.161 and 0.159. The respondents trust that these two materials are the innovative material where they were used to improve the asphalt binder performance and allowed the rehabilitation of the pavement for a long period. Same goes to reused and recycle material where it is ranked as fifth material based on the respondent's feedback. Although it helps in reducing the production of virgin material cost, but the respondents justify that these materials might fail to increase the pavement performance

Lastly, the lowest weightage factor for innovative material is waste material which is 0.133 where there is a large difference compared to the highest weightage factor. The respondent's justification on the waste material shows that waste material is partially incompatible to be used as material in green pavement. It can be concluded that, the survey provides grades for each material that can be used as an alternative solution in replacing the unsustainable materials for developing green pavement.

Table 4. Material description and ranking

Category	Elements	Mean	Factor loading	Factor score	Total factor score	Weightage factor	Ranking
Non-hazardous and economical	Alternative binder	3.88	0.991	3.845	16.394	0.235	1
	Regional material	4.04	0.668	2.699		0.165	2
Innovative material	Emulsions	3.88	0.681	2.642		0.161	3
	Chemical-based material	3.92	0.666	2.611		0.159	4
Non-hazardous and economical	Recycled and reused material	3.64	0.663	2.413		0.147	5
Innovative material	Waste material	3.72	0.587	2.184		0.133	6

4. Conclusion

Green pavement is one of the sustainable developments that has been implemented in Malaysia yet it was a new industry evolution. In conjunction with the promoting the green pavement development, the material used for constructing the system were successfully identified. The six materials are waste material, reused and recycled material, chemical-based material, emulsions, alternative binder and regional material.

In order to find the most advantageous material between the six materials, a judgement from the expertise of the road development is needed. Apart from that, the green pavement material elements must comply with the sustainable pavement category which are ecology, landscaping, waste reduction,

materials, water conservation and energy efficiency [8]. The agreement level which is the output of the survey has been analysed using factor analysis where the weightage factor for each material has been measured.

Alternative binder become the most suitable material as it has the highest weightage factor compared to the other material. The weightage factor is based on the factor score and factor loading from the factor analysis. Alternative binder improves the performance against the pavement distress where it changes the rheological properties of the asphalt binder [5]. Meanwhile, all the material being ranked from first to the last based on their weightage factor. The last ranked material is valuable as the first ranked but there might be some lacking in its performance. Hence, some improvement must be taken into consideration to make the last ranked material which is waste material being able to be in the first ranked sustainable material in the future. The assessment ranking can be used as a reference purpose for all the construction industries if they want to implement the green pavement system in the future.

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