Cost Compression between Asphaltic Concrete and Stone Mastic Asphalt Pavements

Hosni Abdulruhman Saleh[1], Musbah Guma Musbah Faraj[2], Ali Mohamed Albeddal[3], Fathei Ramadan Saleh lamein[4], Khaled Omar Mohamed Oraibi[5]

[1, 2, 3, 4]College of Technical Science BaniWalied Libya

[5]Engineering and Information Technology Research Center, Bani Walid, Libya

*Corresponding Author Email: *alamalallam8[at]gmail.com*

Abstract: ***Many pavements and surfacing types are available for road engineers to choose from. The selection of pavement structure, either flexible or rigid, should be based mainly on construction and life cycle cost analysis. However, a number of factors should be considered such as past performance, materials and machinery availability, and contractor's capability. In the selection of road surfacing, many new and conventional mixes are available to choose from; such as stone mastic asphalt (SMA), porous asphalt, and polymer modified asphalt asphaltic concrete (A, C), and conventional asphalt. The factors such as technical factors or economic factors will be used to decide which pavement type to be constructed. It is the aim of this project to study the cost factors affecting choosing between two types of pavements, asphaltic concrete pavement and SMA pavement. The study was done by collecting information through a questionnaire that was distributed to highway companies in Selangor, Malaysia, the study shows that the initial cost for asphaltic concrete pavement is higher than the initial cost for SMA pavement. However, for long life, a comparison of the cost shows that the asphaltic concrete pavement has a low compared with the SMA pavement***

Keywords: Questionnaire Design, Data Collection, Modeling

1. Introduction

The roads and highways that connected Malaysian states and regions together provide an important infrastructure for commerce, travel, and recreation as well as a sign of civilization and development. Malaysia has increased in traffic and number of the vehicle [1]. This increment needs more road capacity to ease the vehicle's movements. The wearing course or pavements of the highway are the most affected layer of the highway. This affects comes from direct contact between vehicles and pavements. Road pricing is controlled by the wearing of course materials that are connected to fluctuating international economics [2]. In previous study conducted by UPM's Road Safety Research Center 2000 which revealed that the cost of SMA is 10% to 15% less than the cost of asphaltic concrete.

Highways are vitally important to a country's economic development. The construction of a high - quality road network directly increases a nation's economic output by reducing journey times and costs, making a region more attractive economically. The actual construction process will have the added effect of stimulating the construction market [3].

Many pavements and surfacing types are available for road engineers to choose from. The selection of pavement structure, either flexible or rigid, should be based mainly on construction and life cycle cost analysis [4]. However, a number of factors should be considered such as past performance, materials and machinery availability, and contractor's capability. In the selection of road surfacing, many new and conventional mixes are available to choose from; such as stone mastic asphalt (SMA) [5]. These reasons and other reasons lead to maintenance of the roads which is considered road's cost. However, asphaltic concrete roads have less affected by these parameters and accordingly have maintenance – free throughout their long cycle life [5]. On the other hand, the construction cost of asphaltic concrete is higher than that of stone mastic asphalt. Some of the advantages of asphaltic concrete roads over stone mastic asphalt are durability and maintenance - free life that concrete roads have a long service life and during this service life concrete roads do not require frequent repair or patching work like asphaltic concrete; Vehicles when run over an asphaltic concrete road consumes 15 to 20% less fuel than that on asphaltic concrete this is because of the fact that a concrete road does not get deflected under the wheels of loaded trucks. Unlike asphalt roads, concrete roads do not get damaged by the leaking oils from the vehicles or by extreme weather conditions like excess rain or extreme heat; Unlike asphalt roads, asphaltic concrete is less pollution, asphalt (bitumen) produces lots of highly polluting gases at the time of melting it for paving; and saving of natural resources because that concrete is produced from abundantly available limestone while asphalt bitumen is produced from imported petroleum, the reserve of which is becoming reduced drastically [6]. The main disadvantage of asphaltic concrete is paving cost, the paving cost of the concrete road is a little higher compared to asphalt paving on the other hand asphalt is still less costly compared to concrete [7]. Moreover, it takes less time to build an asphalt road than a concrete road because asphalt dries faster. In terms of initial cost, asphalt is a cheaper surface to use than asphaltic concrete but the maintenance involved raises the overall cost. Asphalt roads and driveways can last for anywhere from 10 to 30 years if well - maintained. Asphaltic concrete roads and driveways can last for 20 to 60 years if maintained properly [8].

The higher initial cost for asphaltic concrete leads to less use for this type of pavement. Nowadays high global oil prices have made the cost of constructing and maintaining asphaltic concrete more expensive and this has led to budget shortfalls for government road and highway agencies. Increases in highway tolls, stalled projects, and loss of profits for private road owners and contractors [9]. The traffic capacity of asphalt pavement or any transportation facility is its ability to accommodate vehicles, whether moving or stationary. It is a measure of the supply side of a transportation facility [10]. Pavement design requires a prediction of the amount of loading a pavement will receive. This loading is usually in the form of vehicular traffic. Vehicular traffic can be any mixture of passenger cars and trucks [11]. The primary concern in designing the asphalt pavements is the number of and weight of axle loads expected to be applied to the pavement during a given period of time. These axle loads can vary significantly depending on the type of vehicle. The method of simplifying this variability is to equate all the axle weights to one common or equivalent axle. When designing the thickness of asphalt pavement, most designers concentrate on the truck traffic for controlling the thickness with automobile traffic loading having just a slight impact [12].

To meet the objectives of this study a questionnaire survey was distributed to highway construction companies in Selangor state, Malaysia.

2. Methodology

The survey strategy is a popular and common strategy in business research that is usually associated with the deductive approach. A survey allows the collection of large amounts of data from a sample of the population in a highly economical way. Questionnaires, structured observation, and structured interviews often fall into this strategy.

2.1 Questionnaire Design

The questionnaire was divided into three Sections. The First Section aims to measure the respondent's demographic data regarding size, capital, years of working in the field, and the number of kilometers conducted. A five - point Likert Scale ranging from 1 to 5 was used for measuring in section one. Sections two and three of the questionnaires focus on the construction and maintenance costs of the two pavement types.

2.2 Sample Selection

The basic idea of sampling is that by selecting some of the elements in a population, the researcher may draw conclusions about the entire population. There are several compelling reasons for sampling, including lower cost, greater accuracy of the result, greater speed of data collection, and availability of population selection. For this study, the sample was selected from the pavement construction companies in Selangor state, Malaysia. The sample contained more than 80% of the construction companies in Selangor state, Malaysia.

2.3 Data Collection

A survey is a procedure used to collect primary data from individuals. Surveys are used when the research involves collecting information from a sample of individuals. The data collection procedure in qualitative research involves four basic types: Observations, Interviews, documents, and audio - visual materials. In this study quantitative survey was used as a data collection method. A questionnaire was prepared to get an idea about the cost of two pavement types. The questionnaire was distributed to a sample of pavement construction companies in Selangor state, Malaysia.

2.4Data Analysis Techniques

The instrument used for data collection was a questionnaire. Descriptive research design and statistical analysis methodology will be used to address the research questions. Descriptive research involves the collection of data to answer questions concerning the current status of a given subject. To summarize and rearrange the data several interrelated procedures are performed during the data analysis stage [13]. The data was collected through a questionnaire. For quantitative data analysis, statistical tools of Microsoft Excel and SPSS will be used for data input and analysis. The statistics results were presented in graphical form with detailed descriptions. SPSS version 16 was used analysis the data, and preliminary tests for checking wrong data entry, reliability, normality, and transformation were done.

3. Analysis Result

From the result of the data analysis, the significance of the cost between the two pavement types was determined. Moreover, recommendations were extracted from the results to improve the implementation of the superior pavement type.

3.1 Sample and Response Rate

Eight out of Thirteen companies (62%) were positively responding to the questionnaires. It took almost twenty days to collect back the forms from the companies since the sending date. However, there are still some forms not collected but, due to the time limit of the semester, only the received form was analyzed.

3.2 Questionnaire Analysis

Section A has four questions, A1, A2, A3, and A4. All 8 respondent companies were working in the construction field as displayed in Table 1 and all of the companies have an annual turnover for the year 2009 of more than RM millionshowed in Table 2.

Table 1: Company main field of work

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	construction	8	100.0	100.0	100.0

Table 2: Company annual turnover

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	more than 25 million	8	100.0	100.0	100.0

None of the respondent companies has experienced less than 5 years. Most of the companies have experienced between 15 to 20 years (50% of the respondents' companies) while 25% of the respondent companies have experienced more than 20 years, and 25% of the respondent companies have experienced between 10 - and 15 – years as presented in Table3.

Table 3: Company working experience

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	between 10 and 15 years	2	25	25	25
	between 15 and 20 years	4	50	50	75
	more than 20 years	2	25	25	100
	Total	8	100	100	

3.3. Construction and maintenance information for asphaltic concrete pavement

Section B contains 5 questions B1, B2, B3, B4, B5, and B6. The questions aim to get some information about the construction and maintenance of asphaltic concrete pavements, namely the material cost per ton, material transportation per ton, construction labor cost per ton, maintenance material cost per ton, maintenance transportation cost per ton, and maintenance labor cost per ton for the asphaltic concrete pavements. The cost of construction materials for asphaltic concrete pavements is more than RM 50 as presented in Table 4.

Table 4: Asphaltic concrete construction material range cost per ton

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	more than RM 50	8	100.0	100.0	100.0

Table 5presents the asphaltic concrete construction pavement materials transportation cost, it is observed that the trends of the cost are not dependent on the material only, it mainly depended on the distance from the material source to the project area. The labor cost of construction of the asphaltic concrete pavement is shown in Table 4.8, the labor cost is more than RM50 (50% of respondent companies) while it is between RM 30 and RM 50 for 50% of the respondent companies.

Table 5: Asphaltic concrete pavement construction materials transportation cost per ton

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	between RM 10 and RM 20	2	25	25	25
	between RM 20 and RM 30	3	37.5	37.5	62.5
	between RM 30 and RM 50	3	37.5	37.5	100
	Total	8	100	100	

3.4 Observations

The objectives of this project are to compare the cost of asphaltic concrete and SMA pavements and to find out the significant difference between the two pavement types. However, this study does not include the base and sub - grade cost; it only focuses on the pavement material cost, transportation of the pavement material, pavement maintenance material cost, and maintenance material transportation cost. The comparison of the material cost shows that the construction material cost of the asphaltic concrete pavement is lower than the construction material cost per ton of the SMA pavement. All companies supplied that the cost of material for the asphaltic concrete and SMA pavement is more than RM 50. The mean of the material cost per ton for the asphaltic concrete pavement is RM 73, with a standard deviation of 6.125 and the mean of the material cost per ton is RM 174 with a standard deviation of 10.198 as shown in Table 6. Material transportation costs per ton for construction and maintenance for the two pavement types varied from RM 10 to more than RM 50, noting that the material transportation cost is strongly dependent on the distance between the source of the pavement to the project area. The labor cost for asphaltic concrete is higher than the labor cost for SMA. This is due to a mechanism that is used in SMA pavement which reduces the number of laborers, while asphaltic concrete pavement it needs more labor for construction and maintenance as shown in Table 4.8. The study recommended that an economic construction cost of SMA is achievable if the cost of material and thickness of the laid surfacing are properly managed.

Table 6: Cost comparing between SMA and asphaltic concrete pavement

Cost	SMA	Asphaltic Concrete	Remarks
Construction materials cost/ton	More than RM 50 (mean RM 174)	More than RM 50 (mean RM 73)	
Construction pavement materials transportation cost	Between RM 10 to RM 50	Between RM 10 to RM 50	Depending on the distance,
Labor cost of construction of the pavement	Mostly between RM 30 to RM 50	Mostly more than RM 50	
Material cost for maintenance of pavement	Mostly more than RM 30	Mostly between RM 30 to RM 50	
Yearly maintenance transportation cost pavement	Vary from RM 10 to more than RM 50	Vary from RM 10 to more than RM 50	Depends on the distance.
Maintenance labor cost for pavement	Mostly between RM 30 to RM 50	Vary between RM 10 to RM 50	

Moreover, the price of SMA bitumen materials is depending on the oil price which is getting higher and higher. These facts and others, made the Malaysian government encourage the use of concrete pavement in Malaysian highways, as result at least 30% of the North - South Expressway is built using asphaltic concrete and there are plans to use asphaltic concrete on the East - Coast Expressway.

3.5 Modelling of SMA Pavement Cost

Regression analysis was conducted on the questionnaire used in this study; Table 7 shows the result of the Regression for SMA cost. The result shows that there is a significant variant of selected independent variables that contribute to pavement cost as the dependent variable, with the value F = 128.557, Sig = 0.003 < 0.05.

Table 7: ANOVA table for SMA cost model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	684.879	4	171.220	128.557	.003
	Residual	3.996	3	1.332		
	Total	688.875	7			

Based on the regression analysis conducted, it is found that the dependent variables of materials transportation for construction and maintenance were not contributing to the model due to that these variables depended mainly on the distance. This means that there are four predictors that contributed to the SMA pavement cost. The predictors are material cost per ton and labor cost per ton for construction and maintenance.

The regression equation with the predictors is:

$Y=9.526+1.004x_1 - 0.076x_2+0.99x_3+1.008x_4$

Y= SMA pavement total cost (RM/ton)

x_1= SMA construction material cost (RM/ton)

x_2= SMA construction labor cost (RM/ton)

x3=SMA maintenance materials cost (RM/ton)

x4= SMA maintenance labor cost (RM/ton)

Constant= 9.526

3.6 Modelling of Asphaltic Concrete Pavement Cost

To model the cost of the asphaltic concrete pavement a regression analysis was conducted on the questionnaire data. Table 8presents the result of the regression for asphaltic concrete pavement cost. The result shows that there is a significant variant of selected independent variables that contribute to pavement cost as the dependent variable, with the value F = 11.577, Sig = 0.036< 0.05.

Table 8: ANOA table for the asphaltic concrete cost model

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	66.563	4	16.641	11.577	.036
	Residual	4.312	3	1.437		
	Total	70.875	7			

Based on the regression analysis conducted, it is found that the dependent variables of materials transportation for construction and maintenance were not contributing to the model due to that these variables depended mainly on the distance between the sources of the materials to the project area. This means that there are four predictors that contributed to the asphaltic concrete pavement cost. The predictors are material cost per ton and labor cost per ton for construction and maintenance.

The regression equation with the predictors is:

$=0.035+1.088x_1+0.835x_2+0.661x_3+1.301x_4$

Y= Asphaltic concrete pavement total cost (RM/ton)

x_1= Asphaltic concrete pavement construction material cost (RM/ton)

x_2= Asphaltic concrete pavement construction labor cost (RM/ton)

x_3= Asphaltic concrete pavement maintenance materials cost (RM/ton)

x_4= Asphaltic concrete pavement maintenance labor cost (RM/ton)

Constant= 9.526

3.7 Model Validation

In statistics, model validation is possibly the most important step in the model building sequence. It is also one of the most overlooked. Often the validation of a model seems to consist of nothing more than quoting the R^2 statistic from the fit (which measures the fraction of the total variability in the response that is accounted for by the model). The residuals from a fitted model are the differences between the responses observed at each combination value of the explanatory variables and the corresponding prediction of the response computed using the regression function.

Graphical analysis of residuals: There are many statistical tools for model validation, but the primary tool for most modeling applications is graphical residual analysis. Different types of plots of the residuals from a fitted model provide information on the adequacy of different aspects of the model. In this study, the validation of the model using the plot of observed data versus the expected from the model as in figures 1 and 2 for the SMA total cost model and asphaltic concrete model respectively. The plot showed that the model of the regression fit the data successfully.

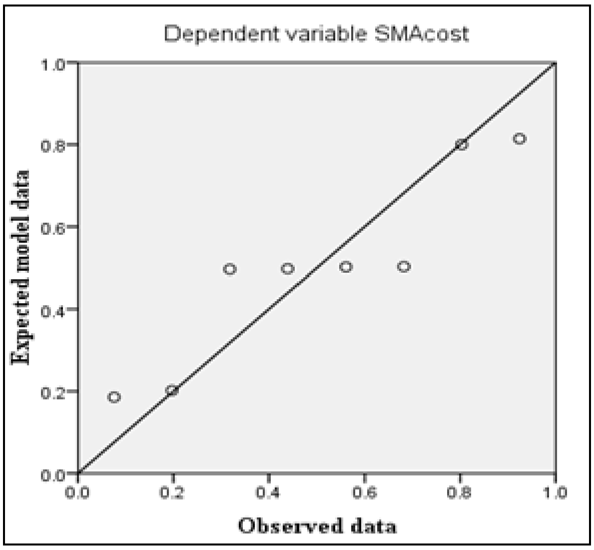

Figure 1: SMA pavement cost model validation

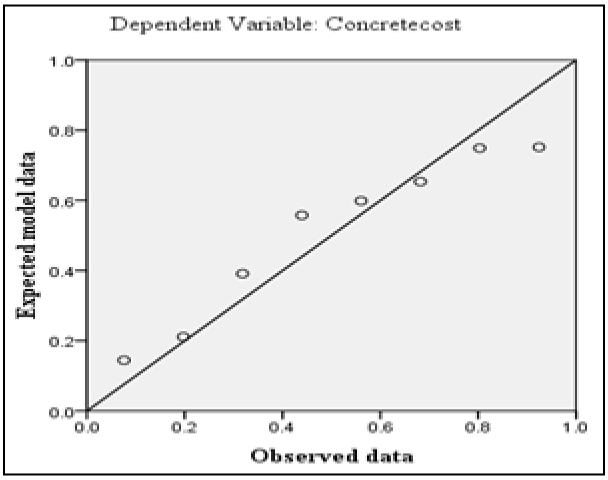

Figure 2: Asphaltic concrete pavement cost model validation

4. Conclusions

In this study, a questionnaire was distributed to highway companies in Selangor state, Malaysia. The aim is to find out the cost differences between SMA pavements and asphaltic concrete pavement. The questionnaire covered the cost of pavement construction cost as well as the maintenance cost. The cost of material pavement construction cost per ton, material transportation cost per ton, labor cost per ton, and maintenance cost for material, transportation, and labor cost per ton were covered in this work. This study revealed that the cost of SMA is higher than the cost of asphaltic concrete. This result is different than the study conducted by UPM's Road Safety Research Center, 2000 which revealed that the cost of SMA is 10% to 15% less than the cost of asphaltic concrete.

Recently, the cost of SMA is more expensive than the asphaltic concrete cost, this is due to the change in the oil price which is rising and reaches more than the US $ 90 per barrel. The relation between the SMA cost and oil price is that: bitumen is produced from oil and is used in SMA pavements. The quantity of bitumen used in SMA pavement is more than the quantity used in asphaltic concrete pavements. Thus, the cost of SMA pavement in 2009 is higher than the cost of asphaltic concrete pavements. It is clear that oil price is controlling HMA pavement by controlling the bitumen price. This is clear by comparing the cost of SMA pavement to asphaltic concrete pavement cost in the year 2000 it found that SMA cost is lower than the cost of asphaltic concrete. This is due to the oil price in the year 2000 being less than the oil price inthe year 2009.

Linear regression was conducted on the data; the result is two models for SMA and asphaltic concrete pavement cost, the models considered the material cost per ton and labor cost per ton for construction and maintenance.

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