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Evaluating Skid Resistance of Different Asphalt Concrete Mixes

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Abstract: ***Road traffic accident results in the death of over 1.2 million people, each year and 50 million more are injured. One of the main reasons for increase in traffic accidents is attributed to the low skid resistance of the highway surfaces which is a measure of the resistance of the pavement surface to sliding or skidding of the vehicle. Studying the effect that different asphalt concrete mixes have on skid resistance is very essential in order to provide the general public with safer roads and to help relevant authorities select best materials for pavement surfaces. The objective of the study is to compare the skid resistance of six different asphalt concrete mixes(i) asphalt concrete mix using local aggregate at the optimum Marshall asphalt content, ii) mixes with 0.5% and iii)1.0% asphalt contents higher than Marshall optimum asphalt content, iv) a mix designed using Superpave design procedure, v) a mix with steel slag to replace 30% of limestone aggregate, vi) and a mix with stone matrix aggregate gradation) and recommend the best mix that will provide higher skid resistance. The Skid resistance of the asphalt concrete mixes were determined in terms of their Skid resistance numberusing a modified British Pendulum skid resistance tester. The mixture with high skid number was the mixture with 30% slag followed by superpave. Increasing bitumen content for Marshall mix by 1% has the least skid number with about 12.8% decrease in skid resistance compared to the optimum binder content. Addition of steel slag in asphalt concrete mixes and using SMA mixes can be implemented to improve skidresistance of road surfaces, especially at highway intersections.***

Keywords: ***Skid Resistance; British Pendulum; Skid Number; Superpave; Stone Matrix Aggregate; Slag; Micro Texture.***

I. INTRODUCTION

According to the world health organization, road traffic accident results in the death of over 1.2 million people, each year and 50 million more are injured. The figures are on the increase in many countries, and if proper measures are not taken, by the year 2030, road traffic accidents will be listed as the fifth cause of death in the world, resulting in the death of about 2.4 million people annually [1]. The factors affecting the road traffic accident are Drivers, vehicle and the road. Therefore, highways have great effect on traffic accidents. A number of studies show that precipitation in the form of rain and snow generally results in more accidents compared with dry conditions [2]. One of the main reasons for increase in traffic accidents is attributed to the low skid resistance of the highway surfaces.

Wet road skid resistance is an important functional property of road pavements. Pavements are designed to offer a safe ride to the road users under different climatic conditions and over a long service life. In order to maintain a sufficient level of skid resistance pavement monitoring is performed at regular intervals [3].

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The coefficient of friction is significantly affected by the grading of aggregates used in the production of bituminous mixtures [4]. The extent to which the pavement surface will provide adequate skid resistance depend largely on the aggregate polishing properties [5]. Especially, as the micro texture plays a key role in the development of tire-pavement friction and it is mainly governed by aggregate properties. Asphalt binder may have some measure of influence on micro texture soon after placement. Nevertheless, aggregates make up the bulk of asphalt mixtures and serve as the primary contact medium with vehicle tires [6]. Hence, for adequate frictional performance of the pavement surface, the coarse aggregates for asphalt mixtures must be carefully selected.

Skid-resistance has been considered as one of the important factors affecting traffic safety [7,8.9] Low skid-resistance means poor friction and could increase the risk of accidents. Skid resistance mainly depends on the macro- and micro-texture of the road surface [10,11] Skidding resistance of roads can be improved by mechanical methods of retexturing using high pressured water jets which is analogous to sand blasting. It can also be improved by milling and resurfacing. In addition, road surface can be roughened or dressed by chip seal, overlay, slurry seal or micro surface, or by making grooves in it [12,13].

The characteristics of coarse aggregates have been extensively researched since coarse aggregates determine surface texture [14,15,16]. Shah et al. [17] evaluated the effects of coarse aggregates on skid-resistance and showed that the HMA with angular aggregates has better skid-resistance. Wang et al. [18] investigated the influence of mineral composition and crystal size on skid resistance by using a high-resolution optical metrology system and established a relationship between skid-resistance and the mineralogical parameters.

Asi [19] evaluated the skid resistance of asphalt pavements using the British Pendulum Number (BPN) for a number of mixes. The variability in the mixes included mix design method (Marshall and Superpave) and asphalt content (optimum and 0.5% and 1% higher). Other variables were HMA mix type (dense and SMA mixes) and aggregate type (limestone and steel slag). The results showed skid numbers in the order, mix with 30% limestone replacement with steel slag (99.6) > Superpave mix (95.7) > SMA mix (92.4) > Marshall dense mixes in the order of increasing asphalt content (87.2, 81.3 and 73.9). The unusually high skid numbers in the study are probably due to the fact that testing was done on non-trafficked laboratory prepared samples. However, the results highlight the importance of aggregate quality over mix design method for good frictional performance.

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It also showed the superior performance of the SMA over the dense HMA mix type. The superior performance of the SMA over the dense mixes is probably due to its coarser surface texture. The Superpave mix design method performed better than the Marshall method for limestone aggregates. However, different studies have also shown that OGFC and SMA mixes show more consistent performance than Superpave mixes [20,21]. It all depends on the quality and type of aggregate used. This is supported by the observation that there was no statistical evidence of texture change with Superpave and Marshall mix design methods. The nominal maximum size of aggregate seemed to be the key factor that changes macrotexture [22].

Several studies have studied different aspects of, and some parameters influencing tire-pavement friction and skid resistance[23-30]. However, very few have considered in depth the influence of several of the aforementioned parameters in a single work. Skid resistance is a measure of the resistance of the pavement surface to sliding or skidding of the vehicle. The texture of the pavement surface and its ability to resist the polishing effect of traffic is of prime importance in providing skidding resistance. It is therefore necessary to study effect that different asphalt concrete mixes have on skid resistance in order to provide the general public with safer roads and to select best materials for pavement surfaces. The study will also help identify best methods to be used for different geographic zones to satisfy the required skid resistance. In this research, different asphalt concrete mix will be evaluated hence giving deep insight on how skid resistance is influenced by different aggregate mix and methods. The research will consider both effect of microtexture and macrotexture simultaneously. This will make the research unique from other previous researches by been the one that will consider the effect of the maximum aggregate size, coarse and fine aggregate types, mix binder content, mix gradation and mix air content by changing the asphalt concrete mix.

The aim of the research is to determine the asphalt concrete mix with higher skid resistance value. This was achieved by deteremining the skid resistance value of different asphalt concrete mixes in order to figure out the one with high skid resistance value. Skid resistance of pavement surface is affected by so many factors which includes aggregate polishing after first two years, weather (wet or dry), temperature, pavement surface's micro texture and macrotexture. In this research the skid resistance will be considered as a factor of asphalt concrete mix which only deals with the microscopic texture and macrotexture of the pavement. The research does not incorporate the seasonal effect. The skid resistance of a pavement surface mainly refers to the contribution of the pavement surface to tire-pavement interaction and the resulting friction force [23]. Such forces cause a reaction (called friction) between the tire and pavement that facilitates vehicular movements. The skid resistances largely depend on two properties of the pavement surface, vis-à-vis, macrotexture and microtexture. These depend on the materials comprising a pavement, vis-à-vis, aggregate, binder and asphalt mix properties as well as postplacement treatment. The main factors that affect the macrotexture and micro texture are listed as follows. The macrotexture is affected by the maximum aggregate size, coarse and fine aggregate types, mix binder content and viscosity, mix gradation and mix air content. While the micro texture is mainly affected by the coarse aggregate type [6].

II. MATERIAL AND METHODS

Three different samples having a height of 15cm and a diameter of 7cm for each concrete mix were prepared in order study the effect of asphalt content and asphalt concrete mix type on the skid resistance properties. The samples were compacted using Superpave Gyratory compactor. The gyratory compactor was used because it can simulate field compaction, and compact samples of 15 cm diameter,the sample height was controlled. 15 cm samples were used since the recommended contact path for the British Pendulum shoe on the asphalt concrete surface is between 124 and 127mm [8]. The British Pendulum was designed to test field asphalt concrete surfaces and not designed to test asphalt concrete laboratory samples, therefore its base was adjusted to accept 15 cm samples as by constructing a special fixture to hold the samples firmly in place. In addition, the height of the adjusting screws of the pendulum was replaced by longer ones to accept the 7 cm height samples.

The skid resistance of the six different mixes were evaluated in accordance of ASTM E303-93 test procedure. Thefirst mix is of an asphalt concrete mix using local limestoneaggregate compacted at the required optimum Marshallasphalt content, mixes with 0.5% and 1.0% asphalt contents higher than Marshall optimum asphalt content, a mix designed using Superpave design procedure, a mix with steel slag to replace 30% of limestone aggregate, and a mix with stone matrix aggregate gradation.Three samples from each mix were tested for skid resistance evaluation. On each sample, the test was repeated five times. The average value of each mix was considered as skid numbers for that mix.

III. RESULT AND DISCUSSSION

The result of the skid resistance for different mixture was summerised and presented in table 1. From the result obtained the mixture with 30% slag has the highest skid resistance number and least value for standard deviation than all the mixture types. The is due to to the 30% replacement of the coarse aggregate with steel slag which have more friction than the aggregates. Increasing bitumen content above the optimum value was found to be a factor decreasing the skid resitance of the pavement as can be seen that the skid number is decreasing from 85.3 for optimum content to 81.5 for 0.5 increase and finally down 74.4 which about 12.8% decrease. Figure 1 shows the average skid number for different mix type.

Table 1: Skid Resistance Evaluation Results for the Different Mixes[19]

Sample no.	Trial no.	Marshall	Marshall+0.5%	Marshall+1%	Superpave	SMA	30% slag
1	1	92	84	77	100	93	102
	2	89	80	71	110	90	97
	3	97	77	70	97	90	100
	4	100	80	73	93	96	100
	5	80	81	75	92	94	100
2	1	80	82	72	90	94	100
	2	80	83	77	90	92	99
	3	85	84	70	98	93	99
	4	82	82	77	95	92	99
	5	87	80	77	92	90	100
Average		87.2	81.3	73.9	95.7	92.4	99.6
Standard deviation		7.3	2.2	3	5.1	2	1.3

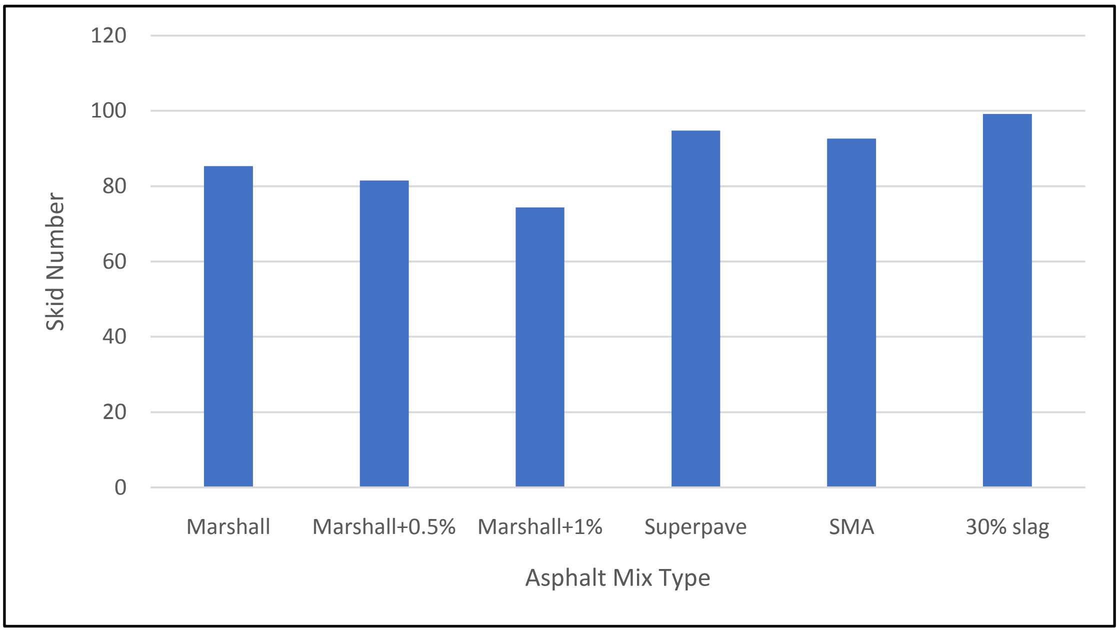

Figure 1: Average Skid Resistance for Different Mix

IV. CONCLUSION

Skid resistance of six different asphalt mixes were studied with aim of determining the asphalt mixture with highest skid resistance using a modified British pendulum tester. The following conclusions can be drawn from the result obtained. Asphalt concrete mixes containing 30% slag have the highest skid number followed by Super pave, SMA, and Marshall mixes, respectively. Increasing asphalt content above the optimal asphalt content value decreases skid resistance. Mixes designed according to Super pave mix design procedure have better skid numbers than those designed using Marshall procedure. Addition of steel slag in asphalt concrete mixes and using SMA mixes can be implemented to improve skid resistance of road surfaces.

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