Skid Resistance evaluation of Aggregates from Pakistan and Afghanistan

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Abstract— Mineral aggregates are the basic material of highway pavement construction as they are not only required to resist the internal stresses induced in the pavement due to traffic load, but also the wear due to abrasion by the traffic and adverse weather conditions. The pavement throughout its life should have some friction to facilitate the car wheels on pavement surface. In Pakistan there are large number of quarries/sources of aggregates for highways construction and this research is intended to study the skid resistance and polishing value of aggregates from various quarries of Pakistan and compared with the quarries of Afghanistan using the standard test procedure BS 812: Part 114: 1989. The results show that the aggregate from the Margalla source has more resistance to Polishing and high skid resistance. Marshall Samples were also prepared at different Bitumen Content and gradations and their surface skid resistance is tested using British Pendulum Skid Resistance tester, and it was found that Skid resistance values of National Highway Authority NHA class B gradation (Coarser) is more as compared to class A (Finer).

Index Terms— Aggregates, pavement, quarries, skid resistance, gradation, polishing, Bitumen Content

1 INTRODUCTION

Production of aggregates for building and road construction is one of the world major industries. Aggregates are particles of rocks, which when combined in a bound or unbound condition, form part or whole of road or building structure. Rock aggregates represent large portion of material used in construction industry and consideration of potential sources is commonly made during the preconstruction investigations for major projects.

In order to meet the requirement of globalization, Pakistan is taking initiatives to develop its infrastructure. In the construction of highways, motorways, power projects the provision of colossal quantities of aggregates is a major prerequisite. Beside other factors in service performance of these civil structures, it also depends on the engineering properties being used. These properties determine the performance of aggregates in mortar, concrete, unbound and bound pavement and rip rap.

Mineral Aggregates are the basic material of highway pavement construction in that they are not only required to support the main stresses occurring in the pavements, but in addition these aggregates in road surface must resist wear due to abrasion by the traffic as well as the direct weathering effects of the natural elements. This depends on their inherent properties and qualities of the individual particles and on means by which they are held together.

During the life of a pavement, the wearing course must offer desirable roughness between tire and road surface. PSV (Polishing Stone Value) is a measure of the skid resistance which a pavement surface offers to tire of vehicle. It depends upon the horizontal and vertical forces developed due to the motion of the vehicle on road. The pavement surface texture and its ability to resist the polishing effect of traffic are of great importance for desirable slip resistance.

When a flexible pavement is opened for traffic, normally after some duration different types of distresses are observed. Polishing of aggragates are one of the distresses that usually occurrs in flexible pavements. Polished aggregate is defined as "certain portion of flexible pavements in which either there is very small portion of aggregates extending above the road surface or there is a low percentage of rough or angular aggregate particles" which lead to a decrease skid resistance.

This could be due to the fact that the pavement surface is expected to continuous application of repeated load, due to which angular particles became polished. Consequently, the process aggravates, if the aggregates are susceptible abrasion or due to excessive studded tire wear. Figure 1. Show the road surface having polished aggregates.

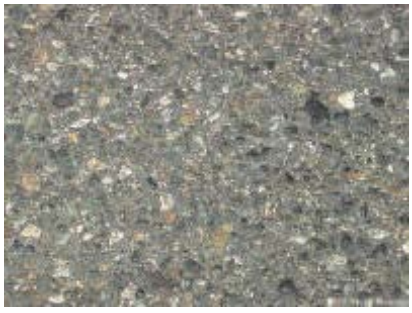

Figure 1: Road surface showing polished aggregates

The polishing of the aggregate is the reduction in micro texture, resulting in the smoothing and rounding of exposed aggregates. This happens due to wear particles at the microscopic level. It is a common fact that the lower part of the PSV value, the higher the percentage of traffic accidents, particularly during the rainy season.

A low PSV value at an asphaltic wearing surface might be due to one or more of the following reasons;

1. Use of higher asphalt content than the designed.
2. The quality of aggregates.

The quality of aggregate is one of the important factors. With the advent of modern equipments and machines, the quality of aggrgates can be judged prior to its use in construction. Hence to judge the Skiding and Polsihing of aggregates, Accelerating Polishing Machine and British Pendulum Tester (Skid Resistance tester) are used.

The principle objectives of this research were;

1. To investigate the skid resistance value change for aggregates from different aggregates sources before and after their polishing.
2. To characterize the aggregate quarries of Pakistan and Afghanistan according to their polished value and skid resistance.
3. And to study the effect of gradation and binder conent on the skid resistance values using marshal moulds.

The scope of the research covered the collection of aggregates from eight (08) different quarries of Pakistan.

- Thor Valley (DIAMIR)
- RAWLAKOT
- Hub Nadi (KARACHI)
- Chak Dolat (JHELUM)
- Margalla (ISLAMABAD)
- KABUL
- KHANDAHAR
- QUETTA

Test were performed on accelerated polishing machine and then on friction tester as recommended in Standard Code of Practice BS 812 to determine the mechanical properties of aggregate.

2 Literature Review

Studies are conducted by X.H. Chan and D.W. Wang, they investigated the phenomena of aggregate surface texture by adopting spectral and fractal approaches. Wheel polishing action is simulated by W/S Polishing Machine. Surface Profile texture and dynamic friction coefficient were taken in account during Polishing process. Fractal analysis shows that the contributing factors in the loss of friction are "changes of amplitude" & "Profile curve lengths". It can be concluded that micro texture changes result due to the differential elimination of mineral components, plays an effective role in the loss of friction. [1]

José M. Pardillo Mayora and Rafael Jurado Pina measured skid resistance using SCRIM. They analyzed the data from over 1750km of two-lane rural roads in the Spanish National Road System and checked the skid resistance depending upon the frictional resistance of the facility. They also saw the impacts of both wet and dry condition on the Skid resistance. Crash rates decreases as the skid resistance value increases both in dry and wet condition. After the analysis it was concluded that adequate level of skid resistance should be present every time on the facility to avoid accidents and safety breaks. [2]

For better understanding of the phenomena of skid resistance, M. Kane, Z. Tang, F. de Larrard developed a model predicting road skid-resistance variations. Influential factors such as polishing of aggregates, removal of binder and aging of binder has been taken and presented in the form of simple mathematical functions. Data obtained from laboratory test has been taken as model parameters. [3]

Z. Tang, M. Kane, F. de Larrard, conducted research to have a better understanding of the change in the road-surface texture due to polishing action of traffic. Examples are shown for two aggregates having respectively low and high - polishing-resistances. Surface profiles measured at different polishing stages are analyzed. Roughness parameters characterizing roughness height and sharpness are calculated and their fruition is compared with the friction fruition. [4]

Different test were conducted by Asi using British pendulum tester. Skid resistance of Marshall Moulds has been checked with different proportions of asphaltic content i.e. 0.5% & 1.0% more than the optimum asphaltic content. He also conducted testing on samples based on superpave design and SMA gradation. It was concluded that highest skid resistance has been shown by Superpave followed by SMA and Marshall Mixes and also as the asphaltic content increases skid resistance decreases. [5]

3 Methodology

The test was conducted in three parts:

1. Samples of stone are subjected to a polishing action in an accelerating polishing machine.
2. The state of polish reached by each sample is measured by means of a friction test and expressed as laboratory determined PSV.
3. Marshall samples are prepared at various bitumen content and different gradations and they are tested for skid resistance.

3.1 Testing

Samples were prepared from the material taken from different quarries in accordance to standard BS 812. Texture depth and skid resistance of road surface, BS Pendulum Skid Resistance Tester is used and to estimate the vulnerability of an aggregate to polishing under traffic, its Polished Stone Value (PSV) is determined.

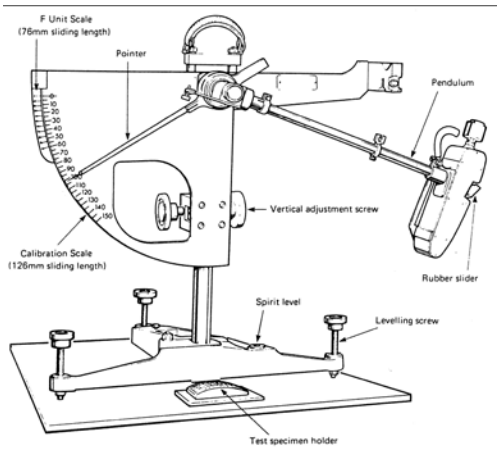

Figure 2: Pendulum Skid Resistance Tester (BSI, 1990)

Figure 3. Accelerated polishing Machine

The sample preparation is shown in figures 4-6. Fourteenspecimens were clamped on PSV machine, and subjected to two stages of polishing by a loaded rubber tire, first by corn emery and secondly by emery flour following BS 812 Pt 114: 1989, EN 1097-8, ASTM E303. The PSV of each sample was then calculated from the following equation;

PSV = S + 52.5 – C

Where

1. S is (Skid Resistance Number) of the recorded values of the three test specimens of each quarry.

2. C is (Skid Resistance of the Control Stone) of the recorded values of the four control specimens.

Note: The equation is valid only for values of C between 49.5 and 55.5. In our case the C value was 51.5.

Figure 4. Aggregates placement in Mould

Figure 5. Sample preparation

Figure 6. prepared samples

4. RESULTS

The Skid Resistance values obtained before and after the PSV test along with PSV values comparison of the Skid Resistance values are shown in the tabular form below. For the results please refer Table 1, 2.and Figures 7, 8.

Table 1: Skid resistance values of Aggregates of Different Quarries.

SR. NO	SOURCE	SAM-PLE NO	Skid resistance value Before Pol-ishing					Skid resistance value after Pol-ishing				
			TRI-AL 1	TRI-AL 2	TRI AL 3	MEAN		TRI AL 1	TRI-AL 2	TRI AL 3	MEAN	
1	THOR VALLEY DIAMER	1	41	41	44	**42**	**45**	31	33	35	**33**	**34**
		2	47	49	48	**48**		32	34	33	**33**	
		3	45	46	43	**45**		37	36	35	**36**	
2	RAWALA-KOT	1	45	44	45	**45**	**46**	26	28	30	**28**	**30**
		2	42	43	43	**43**		30	31	31	**31**	
		3	48	51	50	**50**		31	32	31	**31**	
3	CHAK DOLAT JEHLUM	1	43	44	41	**43**	**41**	34	33	31	**33**	**32**
		2	40	41	40	**40**		30	32	31	**31**	
		3	40	42	40	**41**		32	31	32	**32**	
4	HUB NADI KARACHI	1	37	39	39	**38**	**42**	29	30	29	**29**	**32**
		2	41	42	44	**42**		32	34	32	**33**	
		3	45	46	46	**46**		34	33	33	**33**	
5	MARGALLA	1	65	64	63	**64**	**66**	56	54	53	**54**	**54**
		2	66	64	68	**66**		52	53	55	**53**	
		3	69	68	67	**68**		54	55	56	**55**	
6	KANDAHAR	1	40	35	40	**38**	**37**	25	30	25	**26**	**29**
		2	30	38	37	**35**		25	33	34	**30**	
		3	41	36	41	**39**		32	30	35	**32**	
7	KABUL	1	40	45	42	**42**	**49**	30	35	32	**32**	**36**
		2	50	53	50	**51**		35	38	35	**36**	
		3	56	55	59	**56**		40	39	43	**40**	
8	QUETTA	1	40	50	40	**43**	**44**	28	38	28	**31**	**33**
		2	45	44	42	**43**		35	36	35	**35**	
		3	47	48	50	**48**		32	33	35	**33**	

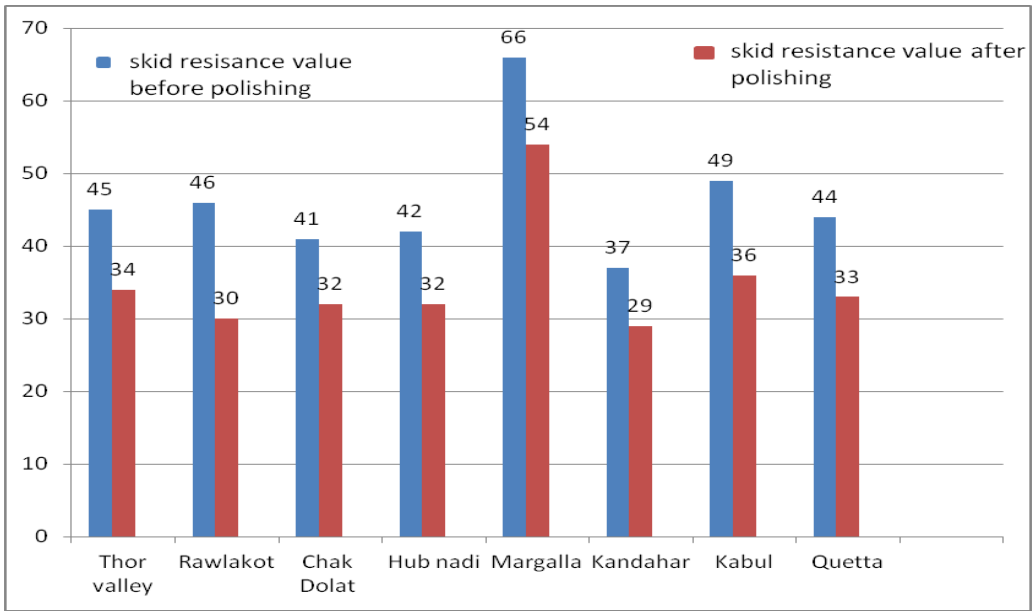

Figure 7: Comparison of Skid Resistance values before and after Polsihing.

By using the formulae given in the Code, mentioned above the Polsihed Stone values of the quarries under consideration are given below.

Table 2: Polished Stone Values

Quarry	S	C	PSV=S+52.5-C
THOR VALLEY DIA MIR	34	51.5	35
RAWLAKOT	30	51.5	31
CHAK DOLAT JEHLUM	32	51.5	32.8
HUB NADI KARACHI	32	51.5	32.8
MARGALA	54	52.5	54
KANDAHAR	29	51.5	30
KABUL	36	51.5	37
QUETTA	33	51.5	34

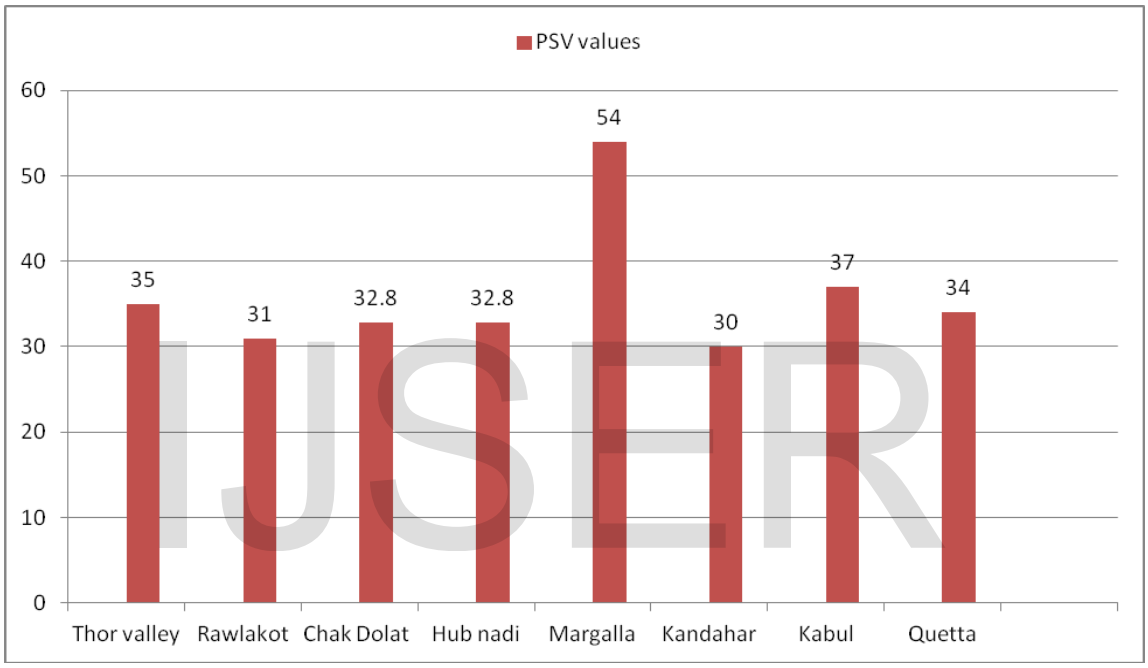

Figure 8: Polsihed Stone Values

4.1. Investigation skid resistance using Marshall moulds

Skid resistance values for marshal moulds were also investigated. The gradation adopted is for wearing course gradation as described by NHA specification. NHA Class A and Class B gradations are used. The amount of bitumen used is 4%, 4.5% and 5%. Skid resistance value of Marshall Samples based on SMA gradation have also been investigated.

Table 3: Skid Resistance Values for Class B Gradation of Wearing Course

NHA GRADATION	amont of bitumen (percentage)	skid resistance value				final mean values
		trial1	trial2	trial3	mean	
CLASS A	4%=48 grams	22	19	19	20	22
		23	25	24	24	
CLASS A	4.5%=54 grams	26	25	30	27	27
		29	25	27	27	
CLASS A	5%=60 grams	38	36	37	37	37
		36	38	40	38	

The Class A gradation has more proportion of coarser aggregates. It has been shown from table 3 that as the asphalt content increases skid resistance value increases.

Table 4: Skid Resistance Values for Class B Gradation of Wearing Course

NHA GRADATION	amont of bitumen (percentage)	skid resistance value				final mean values
		trial1	trial2	trial3	mean	
CLASS B	4%=48 grams	25	26	27	26	25
		26	24	22	24	
CLASS B	4.5%=54 grams	37	36	35	36	34
		35	30	31	32	
CLASS B	5%=60 grams	44	45	43	44	46
		46	48	50	48	

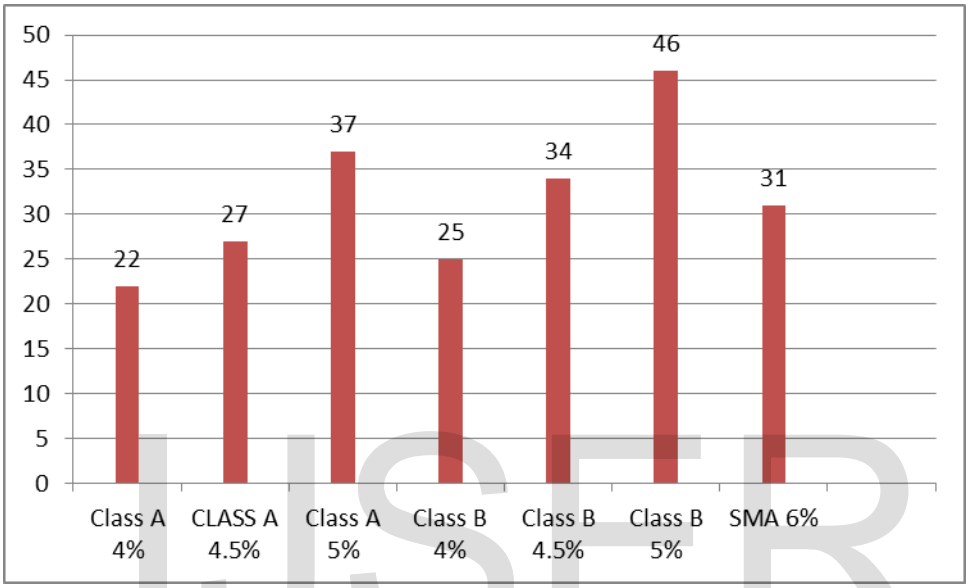

Figure 11: Graph showing skid resisance values for marshall moulds

After comparing the skid resistance values of class A and class B samples it has been seen that skid resistance value of class B is more than class A at each percentage of binder content.
For same gradation with increase in binder content skid resistance values increases.

5. CONCLUSIONS:

1. The results of PSV have shown that the Margalla quarry has values higher than all the other quarries and it is equal to 54, which shows that the aggregates of margalla Quarry offer sufficient resistance to polishing. They also provide suitable resistance to skidding and can be efficiently used in roads constructions even in critical situations.
2. Results of the BPN values show that the BPN of aggregates ranges between 30 and 54 after PSV test and the aggregates of Margalla Quarry are suitable to be used for difficult site such as Roundabouts, sharp curves and gradients.
3. The values obtained after the test were lesser than those obtained prior to the test and concluded that "as aggregates get polished their friction resistance reduces"
4. This test will help to minimize the accidents by choosing sources that provide aggregates having sufficient skid resistance and resistance to the polishing effect.
5. After the Margalla Quarry the Aggregates from Kabul and Quetta have the higher values than the rest of the quarries.
6. Skid resistance values of NHA class B gradation is more as compared to class A. so for better skid resistant behavior of pavements class B is used in mix design.

6. RECOMMENDATIONS

1. This test should be conducted all over Pakistan to find out the best possible source of aggregate for the road construction.
2. Aggregates having PSV greater than 60 are regarded as High Skid resistant aggregate.
3. The higher the PSV, the greater is the resistance of aggregate against polishing.
4. In Pakistan the Aggregates use for roads typically have PSV which range from 51 to 65.
5. The Margalla quarry has the highest resistance against skidding and polishing so it is recommended to use its aggregates for the construction of highways in Pakistan.
6. The coarser the gradation more will be the skid resistance vales hence coarse gradations for wearing course are helpful in maintaining skid resistance values.

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