EFFECT OF AGGREGATE ARRANGEMENT ON INCREASING FRICTIONAL RESISTANCE THROUGH BLENDING OF STONE MATERIALS

Ameri Mahmoud, Iran University of Science and Technology, Tehran, Iran

Shabani Shahin, Transportation Research Institute, Ministry of Road & Transportation, Iran

Shafiepour Abouzar, Iran University of Science and Technology, Iran

ABSTRACT

Reduced of pavement friction is one of the prominent factors which enhance the possibilities of occurrence of wet skidding accidents. Application of aggregates with high resistance to polishing will increase the skid resistance. In recognition of the fact that most of the stone materials being applied on roads are lime stones which are not sufficiently resistant against polishing. Usually the method of blending of aggregates is being applied for compensating of such a problem in this respect. In this research it has been attempted to make a study on the best arrangement of two aggregates for achieving the maximum skidding resistance in the laboratory scale. A sample of limestone (PSV=30) and a sample of basalt (PSV=50) were prepared for devising of the PSV specimens. The PSV specimens with the weight percentage of 50 percent lime stone and 50 percent basalt were manufactured in six different arrangement forms, which were then tested by application of the standard BSEN10987-8 method. Results show that the arrangement of the aggregates inside the specimens proved to be effective in the extent of the skid resistance, which may increase the skid resistance by about 20 percent.

INTRODUCTION

At all stages of pavement life, the highway surface should have some sort of aggregate surface roughness or microtexture to facilitate friction between car tyres and pavement surface. The friction between the rubber tyre and the pavement surface is also dependent on the two materials in contact: the type of tyre and type of aggregates. The microtexture of aggregates and its ability to improved polishing resistance under traffic action is of prime importance in providing skidding resistance. Polishing of the aggregate is the reduction in skid resistance, resulting in smoothing and rounding of the exposed aggregates. This process is caused by particle wear on a microscopic scale. The degree of aggregate wear is inversely affected by its hardness. Several studies have been conducted to investigate the relationship between aggregate polish characteristics and skid resistance when road surface becomes polished by vehicles tyres, microtexture gets smoothed and polished and the skid resistance decreases. This contributes to accidents especially in wet weather (Khasawneh, 2008). Skid resistance by itself will never cause accidents, but it may be one of many factors contributing to a crash.

In designing friction resistance of asphalt pavements, it is usual that the aggregates be tested in the laboratory before they are used in the mix. Some aggregates, like limestone, lack the required resistance and hence they are blended with high resistance aggregates. One method of improving the skid resistance of low skid resistance aggregates and bringing them to acceptable skid levels was to blend them with high-skid resistant aggregates (Liang, 2003).

In this connection there is no information about the effect of aggregate arrangement on friction resistance of the blended aggregates and this research was conducted to study this issue in the laboratory. Measurement of friction resistance has been carried out with the help of British

Pendulum, and abrasion due to traffic has been created by accelerated polishing machine (APM).

Resistance to Polish Action

According to a study (Beaton, 1976), four characteristics should be evaluated in the selection of aggregates for skid-resistant asphalt pavements. These are: texture, shape, size, and resistance to polish-wear action.

The ability of an aggregate to resist the polish-wear action of traffic has long been recognized as the most important characteristic for use in pavement construction. When an aggregate becomes smooth, it will have poor skid resistance. Also, if it polishes and wears too rapidly, the pavement will be slippery under wet conditions (Hosking, 1976).

A study (Sherwood, 1970) showed that coarse grain sizes and differences in grain hardness appear to combine to lead to differential wear and plucking out or shearing of grains that result in a constantly renewed abrasive surface.

According to Shupe (1958), certain minerals are associated with good skid resistance qualities. For example, the superior performances of dolomitic limestone over relatively pure carbonate limestone. For a good skid resistance, using basalt is preferred than using limestone. The least acceptable (standard) PSV depends on the road type and traffic volume; for the wearing surface, this least value is 45. Resistance against polishing has been found according to EN BS1097-8 code.

Mechanism of Polishing, Wearing and Skid Resistance

Polishing of aggregates is defined as the loss of small asperities of road surfaces. These asperities are called microtexture. Wearing, on the other hand, is the loss of macrotexture or surface irregularities. Most researchers agree that the principal mechanism of polishing is the abrasion of the small aggregate asperities resulted from the rubbing action under loaded tyres with the fine road detritus as the abrasive agent. The principal mechanism of wearing involves continuous abrasion resulting from loads and environmental changes such as freezing/thawing, wetting/drying, and oxidation. Polishing and wearing generally involve similar processes that vary only in the degree and the rate of material loss.

Friction, which is the force that resists the relative motion between two bodies in contact, is an essential part of the tyre-pavement interaction. Not only does friction allow a vehicle to accelerate and manoeuvre, but also it exerts a major determining factor in the ability to stop a vehicle. The factors influencing the development of friction between rubber tyres and a pavement surface include the texture of the pavement surface, vehicle speed, and the presence of water. However, pavement skid resistance is defined as the ability of a travelled surface to prevent the loss of traction with the vehicle rubber tyres.

Considering aggregates abrasion mechanism in the course of road operation, it is possible to create necessary conditions for friction resistance to be developed by arranging two different aggregates with different resistances against abrasion. This is schematically shown in figure (1). When only one type of aggregate is used in the mix, the aggregates get polishing and wearing equally due to traffic movement; but, when two types with two different polishing qualities are used there will be some space created between the aggregate due to different in their abrasion qualities. This causes height differential between aggregates types – leading to a change in skid resistance.

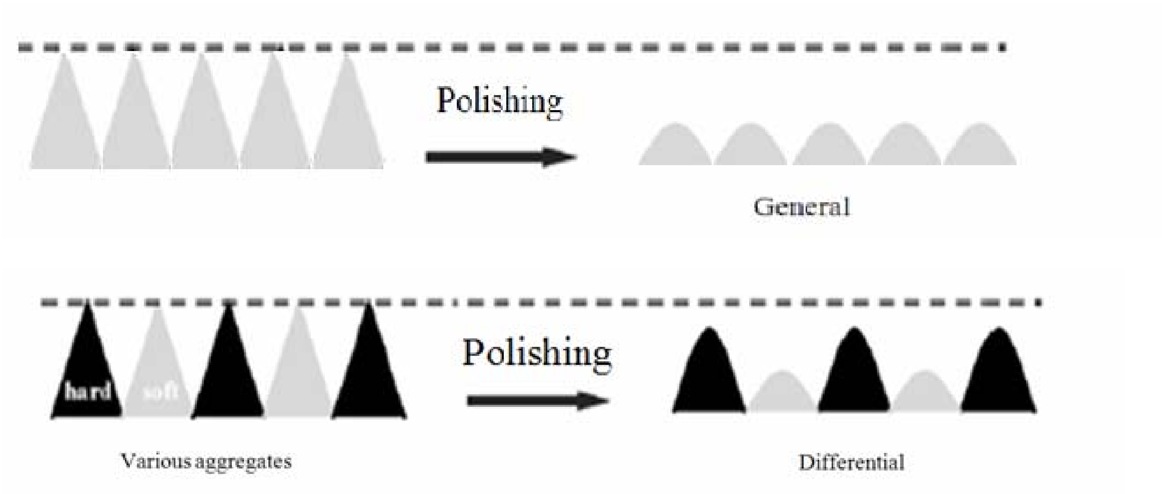

Figure 1: "General" and "differential" polishing

Selection of aggregate

Limestone

Strictly speaking, lime stones are sedimentary rocks consisting largely of calcium carbonate. However the limestone group of road aggregates can also include rocks with a substantial proportion of magnesium carbonate, examples are the Magnesium lime stones. The more recent lime stones tend to lack strength and abrasion resistance and are not resistant to damage by frost. These aggregates get easily abraded which has caused their usage to be limited in the wearing surface of asphalt pavements. It is to be mentioned that some scarce types of limestone have good resistance against abrasion, so they are used in road construction. It has been found that there is a direct relation between the amount of CaCo_3 and resistance against polishing. Gandhi (1975) showed that carbonated aggregates are among low resistance stones against polishing and their usage is limited in the wearing surface.

Studies carried out on limestone aggregates in Iran (Shabani et al., 2010) have revealed that their resistance against abrasion is not at the standard level. Test results have shown that the PSV for sedimentary- chemical rocks (carbonated and limestone) ranges between 35 to 46, so their use in the wearing surface is not suggested. Also, the highest decrease in the pendulum number belongs to the limestone group and the lowest to sandstones. In this research used limestone with a polish stone of 30.

Basalt

Aggregates used in the asphalt concrete surface layers should be stronger than aggregates in the lower layers. Surface layers are subjected to high stresses due to traffic loading, and aggregates are exposed at the surface, therefore, they require special properties that are quite unnecessary in the underlying pavement layers. These properties include resistance to polishing and abrasion by traffic, and resistance to weathering and chemical attack. To these should be added the more general qualities of adequate strength.

Basalt is an igneous rock that has cooled down gradually as it was formed. Its natural colour is gray to dark gray. Based on the studies carried out by Trembloy et al, 1995 and Vincent it was shown that igneous rocks are among basalt quarries in the northern and north western parts of Iran that contain a lot of silicon. Results of the tests carried out in Iran (Shabani et al., 2010) have shown that igneous rock's PSVs are between 52 and 66. In this research used Basalt with a polish stone of 50.

Experimental Program

To determine the effect of aggregate arrangement on friction resistance, six different arrangements with a blending of 50 percent limestone – 50 percent basalt were prepared. Table 1 and figure (2) show the schematic view of different arrangement along with the specific coding for each specimen. Flowchart in figure (3) depicts the complete experimental program starting with aggregates selection and continue with determination of PSVs of these aggregates. Then materials were prepared for PSV specimens according to EN BS 1097-8. The steps include sieving, washing and drying of the materials. After material preparation, PSV specimens were made in different weight percents and arrangement. Some specimens were also made of control stone to measure PSV. After specimens were made, their friction resistance was measured by British Pendulum before and after polishing tests. Finally, the results were analysed and suggestions made.

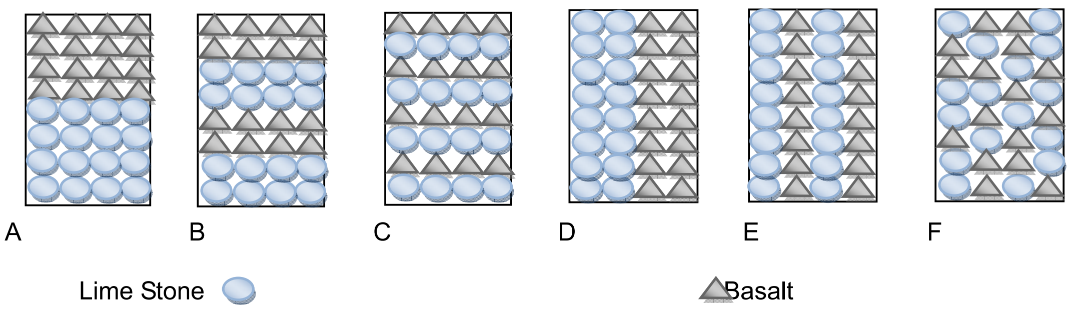

Figure 2: Six different arrangements of two aggregates

Table 1: Designation Table

Designation	Description	Designation	Description
A	Transverse Group Regular arrangement	D	Longitudinal Group Regular arrangement
B	Transverse Alternate Non group Regular arrangement	E	Longitudinal Non group Regular arrangement
C	Transverse Alternate Non group Regular arrangement	F	Irregular Random

- **Each group just consist of two parts not more**
- **Alternate sample is non group and transverse**

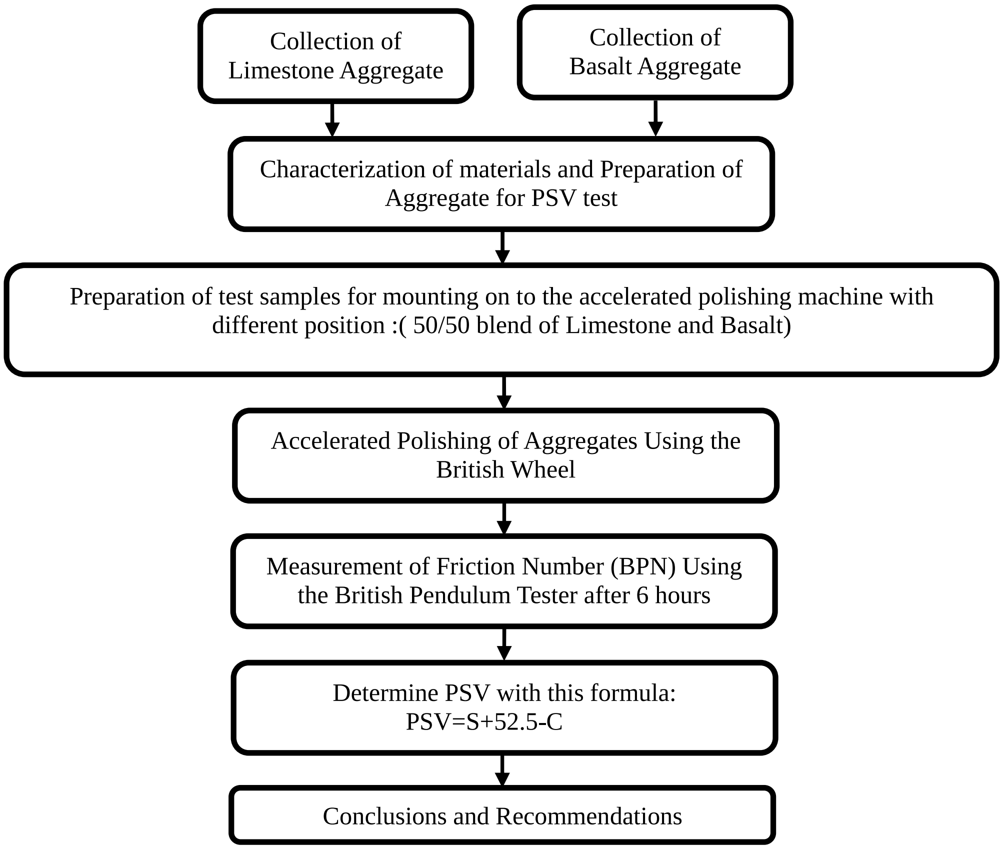

Figure 3: Flow chart of experimental program

Results and Analysis

Table 2 shows PSV for different specimens with a blending of 50 percent limestone and 50 percent basalt. Specimen B had the highest PSV and specimen F had the lowest. PSV increase in the best state of B with respect to the worst state of F was seven units which is about 17 percent increase in the magnitude of PSV.

To study friction decrease due to traffic action throughout the test period, the pendulum number at the beginning of the test has been deducted from that at the end and the result has been considered as friction decrease during the test. Column 3 in table 2 shows friction decrease for each specimen. Considering the decrease values of friction, specimen C has had the least and specimen A the most decrease in friction.

With considering both PSV and friction decrease parameters for different specimens in this blending, it can be concluded that specimens with regular arrangement (A, B, C, D, E) has had more skid resistance than the specimen with an irregular arrangement F. Specimens in which there have been transversal and alternative arrangement, have had more skid resistance than the others. Specimen B has had more skid resistance than specimen C, but the difference is not much. Comparing grouped and non grouped regular longitudinal specimens in this blending, it can be observed that the grouped basalt aggregates act more properly in developing friction resistance.

Table 2: Polish values and friction decrease for different specimens

Code *(1)*	**PSV** *(2)*	$BPN_6 - BPN_0$ *(3)*
A	47	25
B	49	21
C	46	20
D	48	21
E	44	22
F	42	23

- **Pendulum Number at the beginning of the test has been deducted from that at the end and the result has been considered as friction decrease during the test (Column 3)**

Fig.4 shows PSVs for different arrangement. Considering the least PSV (equal to 45), it can be suggested that all arrangements above the black line in fig.4 may be used in the wearing surface. Comparing of the PSVs of different specimens, it may be concluded that instead of adding more basalt to limestone, less basalt with a regular and proper aggregate arrangement can lead to the required PSV. Although how to achieve this effect on the road is difficult and requires more research.

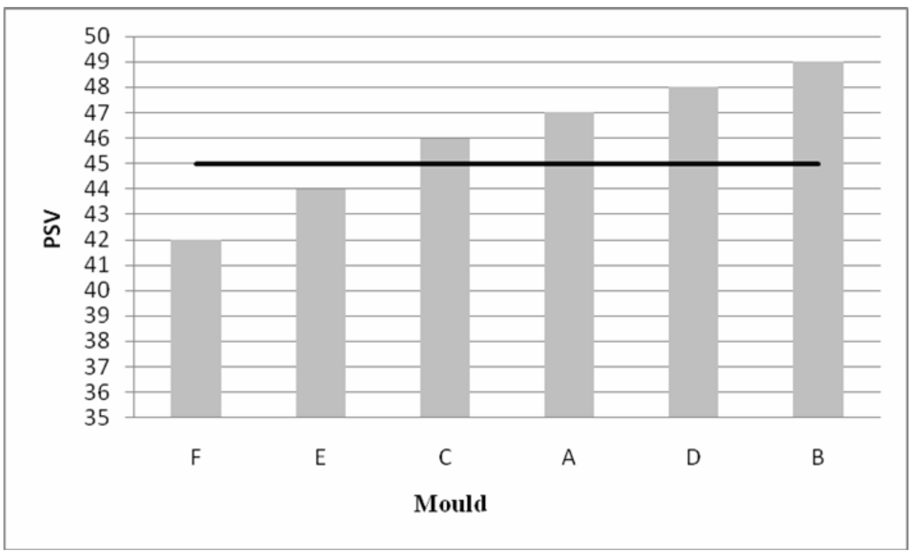

Figure 4: Polished stone values for different specimens

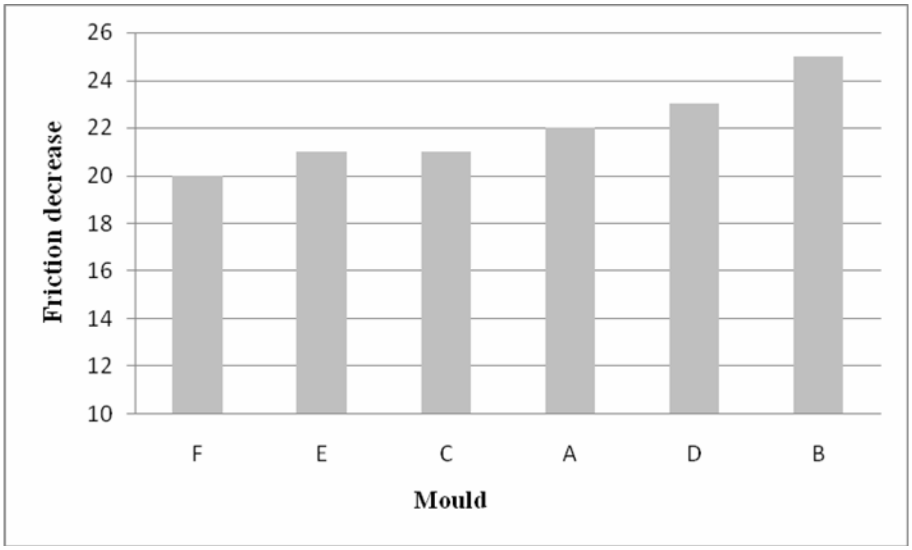

Figure 5: Friction decrease for different specimens

Conclusions

This research has been conducted with the objective of finding, in laboratory, the effect of aggregate arrangement in aggregates blending. To do this, two different aggregates in blending of 50-50 limestone – basalt were selected and, for this blending, 6 different aggregate arrangements were considered in PSV specimens. Although how to achieve this effect on the road is difficult and requires more research.

Test results are as follows:

- Aggregate arrangement affects friction resistance; the highest change in PSV (about 7 units) has been obtained in this blending.
- Transversal alternative arrangement of aggregates provides a better condition for the creation of a new texture.
- The least friction is obtained when aggregates are placed in the specimens irregularly and randomly; this is usually the case.
- The best aggregate blending arrangement, with a different abrasion property, is achieved when aggregates are arranged regularly and also the conditions have been provided for the creation of a new texture.
- Longer tyre interaction with high PSV aggregates means more friction, but a new texture can increase friction more.
- The least friction decrease, during the test period, has been found from specimens with alternative non group regular arrangements.

REFERENCES

Robert Y. Liang, August 2003,"Blending Proportions of High Skid and Low Skid Aggregate" Department of Civil Engineering The University of Akron

Hosking, R,1992 "Road Aggregates and Skidding" .State-of-the-Art Review 4, HMSO, London

Shabani, SH., Ahmadinejad M., Ameri, M., 2010, "Assessment of Polished Stone Value of Road Aggregates in Iran", Transportation Research Institute, Journal of Transportation Research, Vol. 7, No.2, Summer.

M.-T. Do, Z. Tang, M. Kane, F. de Larrard” Evolution of road-surface skid-resistance and texture due to polishing” 2008

Won, Moon C., and Fu, Chein N. “Evaluation of Laboratory Procedures for Aggregate Polish Test”. Transportation Research Record 1547, TRB, National Research Council, Washington, D.C. pp. 23-28, (1996)

Khasawneh ,Mohammad Ali, August, 2008” THE DEVELOPMENT AND ERIFICATION OF A NEW ACCELERATED POLISHING MACHINE”

81. Sherwood, W. C., and Mahone, D. C. (1970) “Predetermining the Polish Resistance of Limestone Aggregates” Highway Research Board 341, HRB, National Research Council, Washington, D. C.

Shupe, J. W. (1958) “A Laboratory Investigation of factors Affecting the Slipperiness of Bituminous Paving Mixtures” JHRP report, Project No. C-36-53D. Purdue University.

Beaton, J. L. (1976) “Providing Skid Resistance Pavement” Transportation Research Record 622, TRB, National Research Council, Washington, D. C., pp.39-50

Dahir, S.H. and J.J. Henry. 1978. Alternatives for the Optimization of Aggregate and Pavement Properties Related to Friction and Wear Resistance, Report No. FHWA-RD-78-209, Federal Highway dministration (FHWA), Washington, D.C.

BS EN 1097-8 (2000) “Test for mechanical and physical of aggregates”, part 8: Determination of the polished stone value (PSV).

ASTM (1983) "ASTM Designation: E303-83, Standard Method for measuring surface frictional properties using British Pendulum Tester (BPT).

Wessex Skid Tester S885 (2000) Operating manual, version 2.0. Wessex Engineering Ltd

AUTHOR BIOGRAPHIES

Dr. Ameri, Mahmoud

Position: Associate Professor, Department of Civil Engineering, Iran University of Science and Technology, Tehran, Iran

Program Area: Highway Engineering

Phone: (+98-21) 77240399 Ex: 3104

Fax: (+98-21) 7724-0398

Email: Ameri@iust.ac.ir

Mailing Address: Iran University of Science and Technology, College of Civil Engineering, Narmak, Tehran, Iran

Dr. Shabani, Shahin

PhD on Road and Transportation Engineering from Iran University of Science and Technology. Research Faculty and Head of Road Safety Department in Transportation Research Institute (TRI) related to Ministry of Road and Transportation. Managing and Supervising Projects on Road and Transportation.

Work Address: No. 65, Kalantary st, gharahny st.Taleghani Ave.Tehran – Iran

Postcode: 1598846611

TEL: +98-21-88933521/30

Fax: +98-21-88933536

Email: shabani@iust.ac.ir

Mr. Shafiepour, Abouzar

Phone: (+98-21) 88898000

Fax: (+98-21) 88906361

Email: Shafiepour@civileng.iust.ac.ir

Mailing Address:

Iran University of Science and Technology, College of Civil Engineering, Narmak, Tehran, Iran