The Influence of Mixture Composition on the Skidding Resistance of Asphalt Wearing Courses

With Particular Reference to the Arterial and Distributor Roads in Malta

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ABSTRACT:

Road engineers and users are concerned with the safe passage of vehicles that operate over them. One aspect of this safety is that there be adequate traction or friction between tyre and road surface to sustain driving forces and to allow stopping within safe limits. This aspect of safety is tackled under the general designation of skid resistance. The skid resistance of the surface of a pavement is one of the major factors in determining the overall safety of a road. Slippery pavements are known to be the cause of many road accidents and fatalities. The critical aspect of skid resistance is when the pavement is wet, since almost all pavements have more than adequate friction for safe vehicle maneuvering in dry conditions.

The phenomenon of pavement surface friction or skid resistance involves the complex interaction of pavement, vehicle, and environmental factors. The problem for those who design, build, and maintain roads is to know enough the factors that contribute to skid resistance to allow the latter to be maintained at an adequate level under all conditions of traffic and environment.

The study of skid resistance has been scrutinised for many years abroad, but increases in traffic density, vehicle speed, and the rapid rise in accidents, has placed added emphasis on this subject in more recent years. Awareness in this field has, however been lacking completely the local scene until very recent years. It has been only within very recent years that concern in this field has been given. There is an obvious awareness of the problems of poor skid resistance in Malta as illustrated by the cautious driver behaviour when the road surfacings are wet.

It has been pointed out in the “Masterplan for the Roads of Malta and Gozo - Volume 2” published in 1999 by Professors Müller and Semar, that the local networks suffer from insufficient wet skidding resistance, adversely affecting the overall traffic safety. An important aspect referred to in this Report is the issue regarding the relation between skid resistance and the mixture composition of bituminous surface courses. The question of whether the loss of skid resistance experienced locally could be reduced by an improved surface texture was specifically addressed. All these aspects form part of a thorough study of this dissertation.

1 INTRODUCTION

1.1 *Definitions:*

Skid resistance is the force developed when a tyre that is prevented from rotating slides along the pavement surface. More commonly, skid resistance is thought of as a pavement property; it is the antonym of slipperiness. It is in this sense that skid resistance is used in this study. It refers to the influence which the road surface has on the magnitude of the maximum driving, braking or side forces between tyre and road.

Friction force is the resistance measured or experienced when one body in contact with another is being moved or is to be moved. It is dependent on the contact area and is, therefore, not suited for describing the character of a friction pairing.

1.2 *Objective:*

Following a comprehensive study of past research carried out in the field of skid resistance, with particular emphasis on the area of surface-course mixture composition, the following were determined to be the primary objectives of the study:

1. Review of the nature of skid resistance, with particular reference to the fundamentals of the tyre-pavement friction mechanism and pavement skid behaviour.

2. Review of the factors influencing the skid resistance of pavements, giving particular emphasis to the pavement parameters.

3. Review of presently accepted and widely used principles and facts on highway and pavement design in this field, practiced by foreign highway departments.

4. To investigate the importance of pavement surface texture on the skidding resistance.

5. To investigate the local situation in this field, focusing on the causes of deterioration of skid resistance.

6. To investigate the relation between mixture composition and skid resistance, focusing on what improvements in local bituminous surface compositions are possible to yield safe, skid-resistant pavements.

7. To provide experimental results to determine the relation between mixture composition and skid resistance, and whether the improvements presented in this study yield to higher skid resistance values.

The research reported herein is part of a broad effort to treat the problem of designing for and maintaining an adequate level of skid resistance. This research effort is part of a program to determine whether the loss of skid resistance can be diminished by changes in local mixture compositions whilst utilizing local limestone aggregates, which as a rule are known to have low polishing values.

2 CHARACTERISTICS OF SKID-RESISTANT SURFACES

The ideal pavement surface has the following characteristics, which, however, are not necessarily all compatible with one another:

- High skid resistance – ideally the skid resistance when wet would be as high as that of the dry pavement.
- Little or no decrease of the skid resistance with increasing speed – the skid resistance of dry pavements is nearly independent of speed, but this is not the case on wet pavements.
- No reduction of skid resistance with time, as from polishing or other causes.
- Resistance to wear – by abrasion of aggregate, attrition of binder and loss of particles.
- Structural durability – resistance to compaction, ravelling and break-up.
- Low noise generation.
- Low cost – not necessarily low first cost, but cost per year of service with acceptable skid resistance.
- Low tyre wear and rolling resistance.

3 SKID RESISTANCE STUDY ANALYSIS

It has been clear at the outset that skid resistance is influenced by many variable factors and therefore its value is sensitive to changes in all these factors. Moreover, this implies that it is very difficult to achieve a direct marked relationship (that is a high correlation coefficient) between skid resistance and any one particular factor. Thus as expected, skid resistance studies were complicated by the influence of many variable aspects affecting pavement-tyre friction. In this study more significance has been attributed to the primary and secondary factors associated with the pavement surface, so as to derive correlation tendencies between the pavement-surface mixture composition and skid resistance.

The British Skid Resistance Pendulum Tester

4 EXPERIMENTAL PROGRAM

The research reported herein was part of a broad effort to treat the problem of designing for an adequate level of skid resistance. This research effort was part of a program for determining improvements in wearing-course mix composition in an attempt to attain higher levels of skid resistance, under utilisation of the available local limestone aggregates.

The objectives investigated and reported on were the following:

1. To review the nature of skid resistance, with particular reference to the fundamentals of the tyre-pavement friction mechanism and pavement skid behaviour.

2. To investigate the factors influencing the skid resistance of pavements, with particular importance to the pavement parameters.

3. To determine the relation between mix composition and skid resistance, focusing on those improvements that yield to higher skid resistance values without however disregarding the other pavement requirements.

To accomplish the first and second objectives, a comprehensive and exhaustive review of literature was carried out so as to determine presently accepted and functional principles in this field, which until recent times were virtually unknown locally. It was clear that even though the skidding resistance of pavements has been studied abroad for many years, various questions concerning the true nature of the interaction of rubber and pavement surface remain unanswered due to the extent and complexity of variables affecting pavement slipperiness. The factors affecting skid resistance were identified and grouped under three categories: Pavement, Rubber and Operational Factors. Special consideration has been given to the pavement factors since these constitute the basis of this study.

To accomplish the third objective, three sets of data were collected and analysed. The first two sets of results were used in producing a tendency of correlation between the mix composition and skid resistance, while the third data set was exploited to confirm or disapprove these trends. A series of factorial experiments were performed for study of initial surface friction of bituminous surfaces as a function of mix composition variables: in particular the bitumen content and the aggregate gradation. In all cases, the instrument used to measure the frictional resistance of the pavement surfaces was the British Portable Tester, giving values in skid number (SN) and measured in accordance with ASTM Method E-274. Measurements of pavement surface texture were carried out using the Sand Patch Method in accordance with ASTM Method E-956.

Test results for skid resistance were consistent in showing correlations between skid resistance and the mixture composition. Correlation coefficients of up to 0.70 were attained. It was clear at the outset that the skid resistance study analysis would be complicated due to the quantity and complexity of the variables affecting the pavement-tyre interface. This large number of variables played a significant influence on the values of correlation coefficients attained. One main difficulty encountered in the analysis was that upon comparison between different mix compositions, more than one factor was different so direct judgment was further complicated. However, by applying different approaches to analyse the results, it has been possible to understand the effect and tendencies that each constituent in a wearing-course mixture has on the skid resistance performance. Attempts made to find what correlations existed between skid resistance and other technological properties proved successful, and some remarkable results have been achieved.

5 SUMMARY OF CONCLUSIONS

These were the findings:

1. A consistent and highly influential tendency was found between skid resistance and the bitumen content in a wearing course mixture: the higher the bitumen content, the lower the skid resistance. The bitumen content played a dominant role on the surface texture and on the Marshall Stability of the bituminous surfacing. The tolerance from the upper to the lower limit of the optimum bitumen content resulted in a 5-point reduction in the skid number. This result suggested that the bitumen content might be the major factor in the mix composition affecting the skid resistance of a wearing course mixture.

2. The findings indicate that pavement texture is the controlling factor in the skid-resistance level of roadway surfaces. Skid resistance has been observed to be first and foremost a function of the micro- and macro-roughness of the pavement surface. The mixture composition determines the micro- and macroscopic geometric properties of the surface.

3. A general positive relationship was observed between the skid resistance and the chipping content: the higher the chipping content, the higher the skid resistance. The chipping content determined the degree of macro-roughness of a pavement surface, which facilitates the drainage of water.

4. A consistent trend has been observed between the skid resistance and the sand content in a surface-course mixture: the higher the sand content, the higher the skid resistance. The sand content governed the extent of micro-

roughness of a pavement surface. Micro-roughness refers to fine-scale grittiness on the pavement's surface. The importance of the fine aggregate size fractions stood out clearly in all experimental results.

5. The results suggest that among the characteristics of the road surface, the micro-roughness has most considerable influence on the skid resistance. It has been observed that low resistance to skidding is caused primarily by a lack of micro-texture rather than a lack of macro-texture.

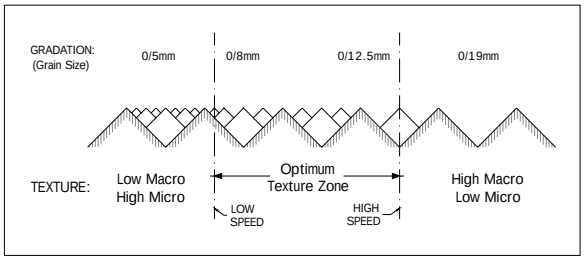
6. A correlation was established between the skid resistance and filler content: the higher the filler content, the lower the skid resistance. This suggested that the skid resistance is adversely affected by the filler content. A high correlation has been observed between the filler and the bitumen content, which indicates that the bitumen content had a direct influence on the correlations obtained with the filler content.

7. A consistent and significant correlation was achieved between skid resistance and the mortar content: the higher the mortar content, the lower the skid resistance. A high correlation was observed, suggesting that skid resistance is highly influenced by the mortar content in a negative manner.

8. Correlation was found between the skid resistance and the void content in a wearing course mixture: the higher the void content, the higher the skid resistance. A significant correlation was observed between the void content and the pavement surface texture.

9. A trend was observed between skid resistance and the filling degree (VFA): the higher the filling degree, the lower the skid resistance. This correlation however, was less significant than that observed for the mixture composition.

10. A general relationship between the long-term value of skid resistance and the Marshall Quotient Q (stability/ flow ratio) measured by the Marshall Method was observed: the results suggest that the higher the stability/ flow ratio, the higher the skid resistance. Individual correlations between stability and flow and the skid resistance were found, but these proved less consistent than those observed for the stability/ flow ratio. No functional correlations have been reported in the literature linking skid resistance to mix stability.



Influence of grain size on surface texture

The conclusions arrived at as a result of this investigation were the following:

A. Paramount importance is to be given to provide an adequate pavement surface texture, since this has been shown to be the governing factor in achieving an acceptable initial level of skid resistance. Skid resistance is primarily a function of the micro- and macro-roughness of the pavement surface. The micro-roughness, which is determined by the sand content in the mix, has considerable influence on the skid resistance. Adequate macro-roughness, determined by the chipping content, must also be adequately provided.

B. The influences of the surface characteristics (micro-texture and macro-texture) discussed above imply that:

   I. The composition of the wearing course must limit the binder content to a designed optimum level. This ensures that the safety and durability performance requirements of a wearing course mixture are respected. This also helps in reducing mortar concentration due to temperature increase during summer in conjunction with compaction due to traffic. This can be achieved in practice by aiming at an optimum binder content. Careful attention to adhere to the recommended range given by the Asphalt Institute Specifications is therefore essential.

   II. The composition of the wearing course must aim at the upper limit for the recommended range given by the Asphalt Institute for the void content. This reduces the tendency of bleeding due to compaction under the action of traffic and increase in temperature.

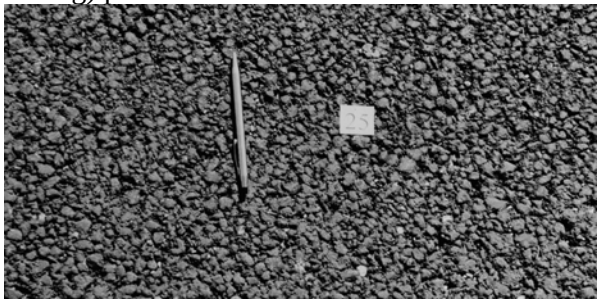
III. The composition of the wearing course, the dimensions of the aggregate chips and the laying must be such that the aggregates form sufficiently sharp projections so as to attain a gritty surface texture.

IV. The sand content should be increased but still within limits according to ASTM Standard D 3515. In this way, the micro-roughness of the pavement surface texture is ensured. However, the effect of this increase in the sand content must be checked on the other pavement performance requirements, especially the influence on compaction.

V. The aggregate must be strong enough to withstand early fragmentation or wear from traffic. The polishing influence can be further reduced by choosing mix gradations 0/ 12.5 mm instead of 0/19 mm. For a given aggregate, liability to fragmentation depends on the type of wearing course. It is less if the surface ensures laterally-gripped aggregates.

VI. A compromise between providing an adequate micro-roughness and macro-roughness may be achieved by choosing a maximum grain size of 12.5mm. This choice is based not only on the attainment of an adequate initial surface texture but also on the long-term performance of the pavement surface.

VII. The composition of the wearing course must be such that the asperities do not disappear as the result of the embedment of the aggregate into the wearing course, which means that a the mix must be designed to have a sufficient stability. Aiming at a value of a stability/ flow ratio of about 5.0 reaches a compromise between the safety (skid resistance) and durability (resistance to cracking) performance criteria.



Wearing Course with excellent skid resistance properties

6 RECOMMENDATIONS FOR FUTURE WORK

- Being the first study to be carried out locally in this field, it is recommended that further skid resistance measurements for the sites are carried out so as to verify the trends and conclusions accomplished in this study.
- The effect of the type and quality of bitumen on the skid resistance was not possible to be established in this study. It is therefore suggested that experiments are carried out to verify the effects of a harder bitumen grade having a higher softening point and a lower penetration than that currently used locally (Grade 60/70). This might reduce the tendency for bleeding under adverse climatic and traffic conditions.
- Further research is also suggested in the relation between skid resistance and the mixture stability. The results obtained in this study gave highly interesting trends, which are worth investigating in further detail.
- The influence of compaction on the skid resistance could not be studied in this dissertation. It is therefore suggested that research is carried out to analyse in detail the influence that the degree and the various types of compaction of the wearing course have on the overall skid resistance of the bituminous surfacing.