Maintenance and Rehabilitation of Pavements and Technological Control

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Edited by

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Preface

The sustainable maintenance and rehabilitation of pavements is becoming a key challenge in many countries in 21st century. It is well known that road and airfield pavement is the backbone of the economic prosperity and public welfare. But, the sustainability challenges pavement builders and managers to respond creatively to new and dynamic problems of rehabilitating and maintaining pavements in the most environmentally friendly manner by lowering energy cost, reducing traffic noise, and minimizing air and water pollution.

With sustainability as the main theme the **MAIREPAV5** (**MAI**ntenance and **RE**habilitation of **PAV**ements and Technological Control) conference was organized at the Canyons Resort in Park City, Utah, USA by the University of Iowa, from August 8-10, 2007. This is the **5**th International Conference in the series of conferences organized to allow researchers, government agencies, consultants and contractors to exchange technological advancements and innovations of building and maintaining longer-lasting road and airfield pavement. The first conference was held in São Paulo, Brazil by Mackenzie University in 1999, the second in Auburn, USA by the University of Mississippi in 2001, the third in Guimarães, Portugal by University of Minho in 2003, and the fourth in Belfast, Northern Ireland by the University of Ulster in 2005.

This book consists of papers presented at the MAIREPAV5 conference. The book includes two keynote papers on FHWA pavement and materials program and importance of good construction on reducing maintenance costs and eighty-eight peer-reviewed papers. Each paper was reviewed by at least two experts from the International Organizing and Scientific Committee. The final revised manuscripts were then reviewed by the editors to ensure compliance with the recommendations and suggestion made by the reviewers. The book is organized into fifteen sections based on the order of the technical sessions presented at the conference: asphalt pavement materials, concrete pavement materials, pavement construction, asphalt pavement performance modeling, concrete pavement performance modeling, pavement economic analysis, asphalt pavement rehabilitation, concrete pavement rehabilitation and recycling, pavement evaluation, asphalt pavement recycling I, pavement noise and safety, pavement management, asphalt pavement recycling II, sustainable pavement materials, and pavement preservation.

We would like to recognize the co-sponsors of MAIREPAV5: International Society for Maintenance and Rehabilitation of Transportation Infrastructure (iSMARTi), Federal Highway Administration (FHWA), Transportation and Development Institute (T&DI) of American Society of Civil Engineers (ASCE), Transportation Research Board (TRB), Korean Society of Road Engineers (KSRE), and Public Policy Center (PPC) and Civil & Environmental Engineering Department of the University of Iowa. We would like to record our indebtedness to distinguished members of International Organizing and Scientific Committee who have peer-reviewed papers and guided us to the success of this conference. Finally, we would like to thank authors who convened in Park City, Utah from all over the world to share their knowledge and experiences in building and maintaining pavements and their invaluable contributions to this book.

It was our honor and privilege to host MAIREPAV5 and edit this book.

Hosin "David" Lee / M. Asghar Bhatti

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STUDY OF AGGREGATE-MASTIC BOND PROPERTIES IN BITUMINOUS MIXTURES

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Abstract: The durability of bituminous mixtures in the pavement depends on their characteristics (particularly, the voids content) and on weather conditions. In fact, the premature distress of pavements usually occurs in poorly compacted mixtures, especially in the presence of water. The intrusion of water in the bituminous mixtures strips the mastic binder from the aggregates, thus leading to the rupture of the aggregate-mastic bonds, which in the most severe cases is manifested by the disaggregation of the mixture in the surface layer of the pavement. Consequently, the main objective of this work is the study of the aggregate-mastic bond strength of different mixtures and the evaluation of the influence of water and aging on that bond strength. The bond between the mastic and the aggregates is evaluated by using two monotonic tests (tensile and shear). The influence of water and aging is evaluated by comparing the strength of conditioned and unconditioned samples. The main conclusions of this work result from the analysis of the aggregate-mastic bond strength under different test conditions. The influence of the mixtures composition, water and aging conditioning on the bonding properties is observed, as well as the main causes of the aggregate-mastic stripping in dense mixtures, usually applied *in situ*.

INTRODUCTION

In this work, two test methods were developed to study the aggregate-mastic bond strength – a property of bituminous mixtures which influences their behaviour in service. According to Scholz (1995), the primary effects of lower bond strength between the mastic and the aggregates are a higher propensity of the mixture for disaggregation, a reduced stiffness modulus of the mixture and a smaller capability to resist to tensions caused by traffic (increasing rutting and cracking in pavements). Furthermore, the observation of several specimens showed that the trajectory of the cracks usually evolves in the bonding areas between the binder and the aggregates. This fact, as well as other studies (Scholz, 1995; Curtis et al., 1993), confirms that distresses in bituminous mixtures often occurs in areas of reduced mechanical strength of the aggregate-binder bond. So, the main objective of this study is to prevent failure in pavements due to weak aggregate-mastic bond strength, by evaluating the main parameters which influence that property of the bituminous mixtures, including ageing and water sensitivity procedures.

KEY FACTORS IN THE BEHAVIOR OF THE AGGREGATE-MASTIC BOND

In order to define the conditions to be used in laboratorial tests to study the aggregate-mastic bond, the following factors were considered:

- The loss of aggregate-mastic bond mainly occurs due to tensile and shear stresses;

- The tests to be carried out should represent, in a high degree, the in-service conditions in the pavement, since the aggregate-mastic bond must be evaluated when the bituminous mixtures are submitted to the traffic loads;
- These tests should be fast and easily carried out and have low operation costs;
- The bitumen is not isolated in a bituminous mixture, but it is associated with fine aggregates, thus forming a mastic which serves as a binder to the coarser aggregates (Curtis et al., 1993).

Therefore, two tests were implemented, which, together, allow the characterization of the aggregate-mastic bond of bituminous mixtures: i) tensile test; ii) shear test. As the tests should be rapid and easy to perform, a direct and monotonic loading, by imposing a growing deformation until rupture occurs was used.

EXPERIMENTAL METHOD TO EVALUATE THE AGGREGATE-MASTIC BOND

The eight mastics used in the preparation of specimens to study the aggregate-mastic bond (Silva, 2006) and their respective characteristics are presented in Table 1. The main variables in study are: binder penetration grade and content, aggregate gradation, filler source and ageing.

Table 1. Composition of the studied bituminous mastics and the objectives under study

Bituminous mastic	Mastic 1	Mastic 2	Mastic 3	Mastic 4	Mastic 5	Mastic 6	Mastic 7	Mastic 8
% Passing #10	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
% Passing #20	73.8	73.8	73.8	73.8	73.8	83.0	52.3	73.8
% Passing #40	52.1	52.1	52.1	52.1	52.1	68.8	26.0	52.1
% Passing #80	28.9	28.9	28.9	28.9	28.9	40.9	15.1	28.9
% Passing #200	16.2	16.2	16.2	16.2	16.2	23.3	9.2	16.2
Binder content	15.9 %	13.6 %	18.2 %	15.9 %	15.9 %	19.9 %	9.8%	15.9 %
Binder pen grade	35/50	35/50	35/50	50/70	35/50	35/50	35/50	35/50
Filler source	Limestone	Limestone	Limestone	Limestone	Granite	Limestone	Limestone	Limestone
Aging	No	No	No	No	No	No	No	Yes
Objective of the study	Base composit.	Lower BC	Higher BC	Binder Pen grade	Filler source	Finer gradation	Coarser gradation	Aging

The short term ageing method (Von Quintus et al., 1991), to which the mastic 8 was submitted, tried to simulate that phenomenon in the pavement, and it involved heating the loose mastic, for 24 hours, in a ventilated oven at 135 ºC.

To study the aggregate-mastic bond, specimens with 5×5×8 cm^3 were prepared with two mastic layers and one with coarse aggregates (with dimensions between 9.5 and 12.5 mm), in which it is easy to identify the bond area between aggregates and mastic. The apparent density of the specimens varied between 1.98 and 2.20 g/cm^3. The use of granitic filler and a coarser mastic with a reduced binder content hindered the bond between the mastic and coarse aggregates and reduced the density of the specimens.

The monotonic shear and tensile tests, which allowed the determination of the required parameters for a constitutive model of the behaviour of the aggregate-mastic bond, and that were used in this phase of the work, are presented in Figure 1.

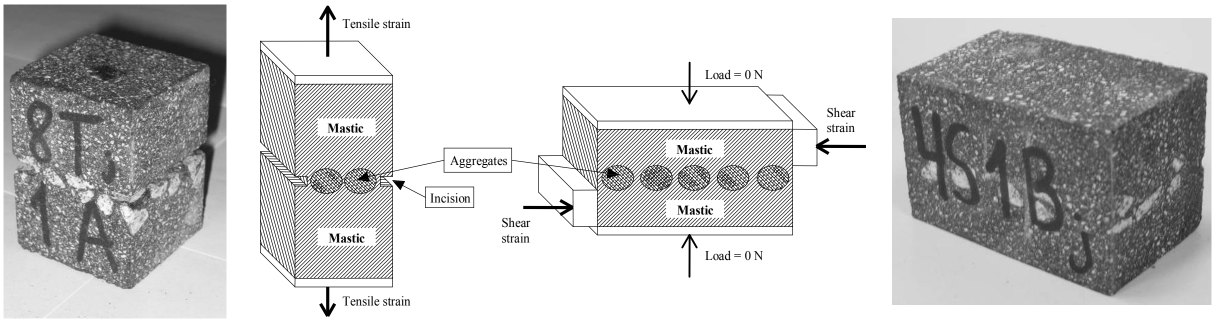

Figure 1. Configuration of the tensile and shear tests to characterize the aggregate-mastic bond

Five different test configurations (Airey et al., 2002) and 3 repetitions for every one of them were performed (to find a mean value). These tests were carried out in strain control. The "base temperature" selected was 15 ºC, although other tests were performed at 25 ºC. A "base strain rate" of 0.001 s^{-1} was selected, as well as a higher (0.01 s^{-1}) and lower strain rate (0.0001 s^{-1}).

Finally, tests were carried out on specimens under a previous water conditioning (1 hour under water with partial vacuum, followed by a period of 3 days immersed in water at 15 ºC), by trying to simulate the specimens sensibility to the presence of water. This conditioning, which is based on the "short term ratios" of Lottman (1982), was modified due to the high sensibility of the mastic to high temperatures. To sum up, five test configurations were used: i) Strain Rate (SR)= 0.01 s^{-1}, Temperature (T)= 15 ºC, without Water Conditioning (WC); ii) SR= 0.001 s^{-1}, T= 15 ºC, without WC; iii) SR= 0.0001 s^{-1}, T= 15 ºC, without WC; iv) SR= 0.001 s^{-1}, T= 25 ºC, without WC; v) SR= 0.001 s^{-1}, T= 15 ºC, with WC.

BEHAVIOR OF AGGREGATE-MASTIC BOND IN SHEAR AND TENSILE TESTS

Next, the results of the monotonic shear and tensile tests are presented. The main results were the shear and the tensile strength, the strain in the rupture and the tangent modulus of the bond between aggregates and the different mastics in the several test configurations.

In Figures 2 and 3, the results of the monotonic tests for the five used test configurations (left) and the results obtained in the base configuration for all the bituminous mastics (right) are presented, in the shear test and in the tensile respectively.

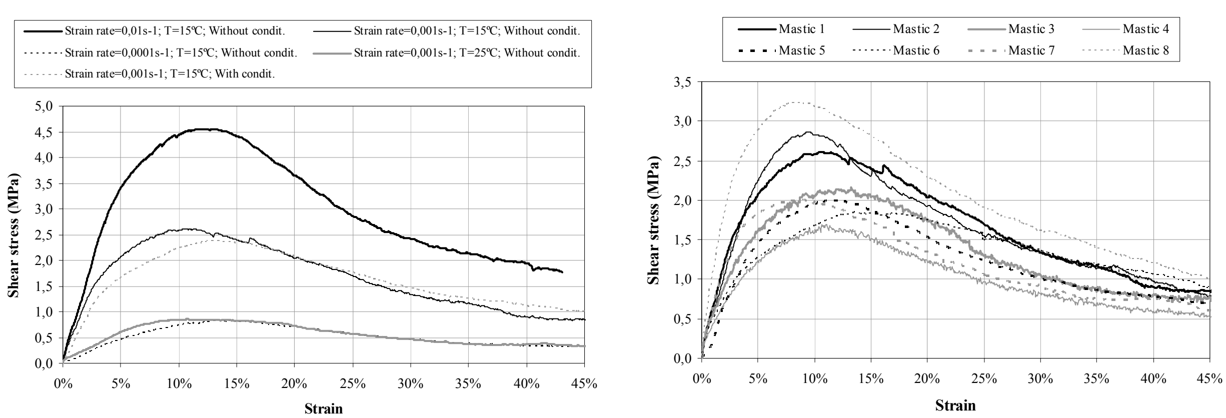

Figure 2. Stress-strain curves of the mastic-aggregate bond in monotonic shear tests

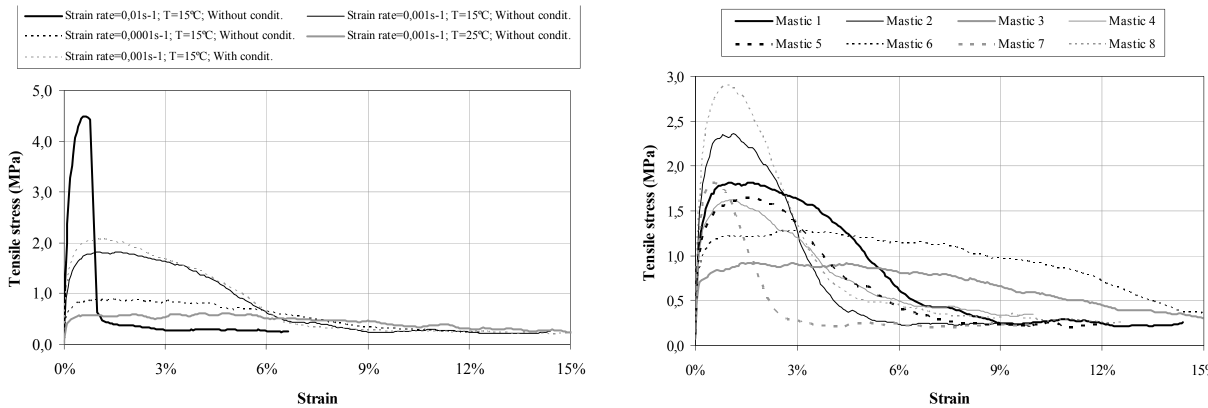

Figure 3. Stress-strain curves of the mastic-aggregate bond in monotonic tensile tests

On one hand, the shear strength of the aggregate-mastic bond is obtained for a relatively high strain (10 to 15%). This value is higher when the binder content increases. The slowest tests and the tests at 25 ºC caused smaller shear strength, while the maximum shear strength was obtained for the highest strain rate test (configuration 1).

On the other hand, the tensile strength of the aggregate-mastic bond is obtained for a very small strain (inferior to 1%). The strain in the rupture is statistically higher and the tensile strength is statistically smaller when the binder content is high or when the tests are carried out at a reduced strain rate or at 25 ºC. The highest strain rate test (configuration 1) clearly increases the mean value of the tensile strength of the aggregate-mastic bond.

Figure 4 presents examples of the rupture of specimens in the shear test (left) and in the tensile test (right). Rupture occurred in the aggregate-mastic bond area. This is an essential condition which allowed the validation of the used tests to evaluate the bond between these two materials.

Figure 4. Rupture area observed in shear tests (left) and in tensile tests (right)

The comparison between the specimens with different binder contents shows that the tensile strength frequently increases when the binder content rises, in opposition to what occurs in the shear test. This indicates that the bitumen intervention is crucial to bond the aggregates by increasing the tensile strength. However, at the same time, it is a "lubricant" between aggregates, thus reducing the shear strength. The shear and tensile strength of the aggregate-mastic bond almost always decrease by using of softer bitumen (50/70).

The use of a finer gradation of the aggregates in the mastic and of a granitic filler visibly causes a reduced shear and tensile strength of the aggregate-mastic bond.

The influence of ageing (left) and of water presence (right) in the behaviour of the aggregate-mastic bond is presented in Figures 5 (shear test) and 6 (tensile test).

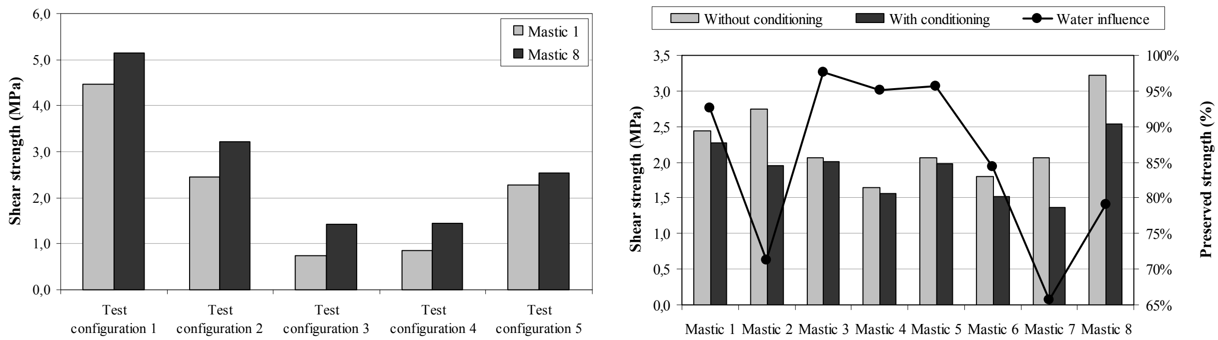

Figure 5. Influence of the mastic ageing and of the water conditioning in the shear strength of the aggregate-mastic bond

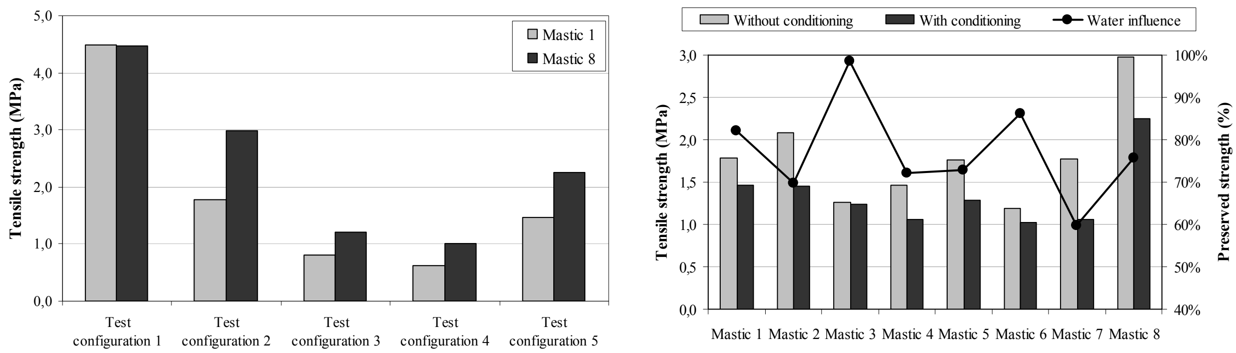

Figure 6. Influence of the mastic ageing and of the water conditioning in the tensile strength of the aggregate-mastic bond

The aged mastic statistically improves the shear and tensile strength of the aggregate-mastic bond. This result appears as the aged mastic has a higher stiffness, thus hindering the shear deformation of the mastic in its bond to the aggregates. Moreover, the ageing procedure allowed the bitumen to be deeply bonded to the aggregates, thus increasing the tensile strength of the aggregate-mastic bond.

The water influence is not very noticeable, because the specimens have a reduced porosity. However, most specimens reduced their shear and tensile strength (mean value) after water conditioning, mainly in the tensile test. The specimens with reduced binder content were the most harmed by water in both tests. The water sensibility was also slightly high, not only for the aged mastic in shear tests, but also for the mastics with granitic filler and with softer bitumen in tensile tests. In Figure 7 it is clear that water removed mastic from the surface of the coarse aggregates in some specimens. This demonstrates the influence of water in reducing the aggregate-mastic bond.

The shear and tensile strength of the aggregate-mastic bond is very susceptible to the variation of temperature as that strength at 25 ºC drops to about a half of its value at 15 ºC. Finally, an obvious increase of the shear and tensile strength of the aggregate-mastic bond was observed with the raise of strain rate, which seems to stabilize for higher strain rates.

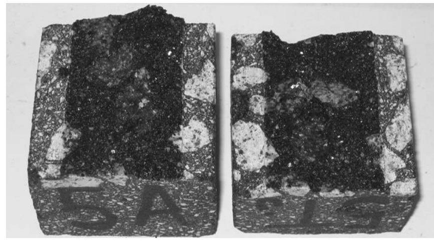

Figure 7. Stripping in the aggregate-mastic bond, due to water sensibility

CONCLUSIONS

The conditions/configurations of the shear and tensile tests performed in this study can be used to characterize the aggregate-mastic bond strength in the bituminous mixtures as they cause the rupture in the bond area under study. The results of the tests carried out to establish the influence of the composition and test parameters in the strength of the aggregate-mastic bond allowed the following conclusions and recommendations, based on statistical tendencies of the results:

- The shear strength rises when the binder content is reduced (in opposition to the tensile tests);
- The use of a softer bitumen (50/70), finer gradations of aggregates in the mastic and granitic filler (in comparison with limestone) are not recommended;
- The ageing improved the strength of the aggregate-mastic bond, due to the increase of the mastic stiffness and to a better bond between the mastic and the aggregates;
- The water conditioning of the specimens usually reduced the strength of the aggregate-mastic bond, mainly in the tensile tests and in the specimens with low binder content, in which it was evident (by observation) the stripping in the bond area between the mastic and the aggregates;
- Temperature and strain rates have a great influence in the behaviour of the aggregate-mastic bond, mainly in specimens with higher binder contents and without ageing conditioning.

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