RILEM TECHNICAL COMMITTEES
COMMISSIONS TECHNIQUES DE LA RILEM

101-BAT: BITUMEN AND ASPHALT TESTING

Activity report 1987-1992

H. W. FRITZ

EMPA, Ueberlandstrasse 129, CH-8600 Dübendorf, Switzerland

CONTENTS

1. Introduction
2. Fields
3. Goals
4. Members
5. Materials
6. Work accomplished
  - 6.1 Dubrovnik seminar, September 1988
  - 6.2 Proceedings of the Dubrovnik seminar
  - 6.3 Fourth International Symposium, Budapest, October 1990
  - 6.4 Proceedings of the Budapest symposium
Volume I, September 1990: RILEM Proceedings 8
Volume II, November 1991: Moderators' reports, oral presentations, conclusions
  - 6.5 Revision of RILEM Technical Recommendation BM-1
  - 6.6 RILEM Technical Recommendation BM-5
  - 6.7 Trilingual dictionary
7. Former working groups
  - 7.1 WG 1: Significant tests for sealing and waterproofing materials
WG 2: Significant tests for polymer modified binder
  - 7.2 WG 6: Tests for bituminous emulsions
  - 7.3 WG 3: Significant tests for asphalt pavements
  - 7.4 WG 4: Significant tests to characterize the aging of bituminous binders for paving asphalts
  - 7.5 WG 5: Test methods for wax determination
8. Work in progress, active working groups
  - 8.1 WG A: Polymer-bitumens
  - 8.2 WG B: Emulsions (bitumens, polymer-bitumens)
  - 8.2 WG C (former WG 3): Fundamental and significant tests for asphalt pavement materials
    - 8.3.1 Budapest symposium, October 1990
    - 8.3.2 Interlaboratory tests
9. Conclusion
10. Proposal for a new bituminous RILEM technical committee, future work
11. Acknowledgements
12. References

1. INTRODUCTION

For millennia natural asphalts have been known and used. During the twentieth century, however, bituminous materials were mainly applied not only in building and construction, but also as sealants and waterproofing materials in tunnels, on bridges, for hydraulic structures and other purposes in civil engineering. Bituminous materials play quite an important role in building construction and an even more important role in road construction and road safety.

The first 'bituminous' RILEM technical committee was founded in 1968, the second and third ones in 1980 and 1987, respectively.

RILEM technical committee TC 101-BAT started its work with the first meeting in Madrid. BAT stands for Bitumen and Asphalt Testing. This denomination reveals that this RILEM technical committee, in fact, concentrates on bitumen and polymer-bitumens as well as on products with these organic binders. Consequently, since 1987 RILEM has abandoned the organic binder material tar and its composite products - this evidently for environmental and health reasons.

In the following, details are stated concerning the working fields, goals, members, kind of materials, working targets, the work already accomplished, i.e. seminars and symposia held, main publications, former and active working groups, the work in progress, a conclusion, necessary future work, and consequently the formation of a new 'bituminous' RILEM technical committee.

Fig. 1 Optimal bituminous pavement on a main road with separated lanes.

Fig. 2 Impermeable bituminous surfacing in the basin of a hydroelectric plant in the Swiss Alps.

2. FIELDS

The technical committee TC 101-BAT was active in the fields of road construction and waterproofing. Within these fields, most important are bitumens, polymer-bitumens, and the materials produced with these organic binders.

The main fields include especially the pavement and the waterproofing materials (see Figs 1 to 3) and their behaviour *in situ*. These materials and their optimal behaviour are vital factors, for instance for urbanization, trade, industry, or – in other words – for the economical development and prosperity of a country or region.

3. GOALS

The technical committee TC 101-BAT had, amongst others, the following main goals:

(i) to evaluate fundamental and significant tests for polymer-bitumens, bitumens, bitumen emulsions and their composite materials; and

Fig. 3 Waterproofing of a prestressed concrete bridge deck with polymer-bitumen membranes.

Fig. 4 Excessive rutting of a heavily trafficked bituminous pavement. The cross-section through one wheel path of a pavement slab shows clearly the main reason for the failure: an inadequate concept of the bituminous pavement structure; with too many courses in the top 150 mm with too-small aggregates in these courses, and insufficient mix design procedures for these layers.

(ii) to elaborate RILEM recommendations concerning the materials mentioned for the following purposes: pavements, roofing, waterproofing and other seals.

One of the main targets was to sufficiently determine and describe the essential characteristics of chosen materials in laboratory tests to facilitate correct prediction of their behaviour *in situ*. This is a very important goal, for sometimes pavements permanently deformed by heavy traffic cause severe problems. In the near future the goal must be to avoid such damage and failure as shown for example in Fig. 4. Such damage mostly occurred because the traditional or

routine tests on asphaltic mixes too often do not allow a realistic prediction of the behaviour of the pavement *in situ*. In contrast to these tests, fundamental tests are carried out under a wide range of temperatures and loading conditions. Consequently, one of the main goals was to initiate as quickly as possible the adoption of fundamental and significant tests.

Traditional or routine tests are usually carried out at one temperature and under one loading condition only. Therefore, traditional or routine tests reveal only one singular point in the wide range of temperature and loading conditions occurring *in situ*. Furthermore, the standardization of such routine tests or traditional tests on bitumens and polymer-bitumens and their composites are and will be carried out efficiently on an international scale by the corresponding technical committees, for example in Europe by the Comité Européen de Normalisation (CEN). Consequently, another main goal since 1989 was to stop dealing with routine tests.

4. MEMBERS

Since 1992, TC 101-BAT had 23 active members, one corresponding member, and three additional experts who were active only in Working Groups (so-called WG). Initially, when starting in 1987, this TC had eighteen active members. Due to retirement and job rotation, seven members had to quit TC 101-BAT. Due to this fact and due to a slight increase of the total number of participants, we were fortunate to have representatives in this technical committee from almost all over the world. In fact, sixteen countries were represented, mainly from Europe, but also from overseas and the Near East. This means that specialists originating from countries in Northern, Eastern, Southern, and Western Europe as well as from Canada and Israel collaborated actively.

5. MATERIALS

The materials dealt with are bitumens and polymer-bitumens as binders or essential components for construction and building materials, as well as for waterproofing materials for bridge decks or for roofing. Fig. 3 shows an example of the waterproofing of bridge decks with polymer-bitumen membranes. The main materials the TC dealt with are asphalt pavements and structures for roads, airfields, and for waterproofing in hydraulic structures.

This is an opportunity to repeat the definition of asphalt as it is understood in Europe: every mixture consisting of bitumen and mineral aggregates is called asphalt. However, our North American colleagues use the term 'asphalt cements' (instead of 'bitumens'), which means the organic binder materials themselves. These binders are thermoplastic materials without an exact melting point, but with a wide softening range. From elastic behaviour at temperatures below 0°C

Fig. 5 Cracks in a heavily trafficked bituminous pavement due to insufficient mix design procedure.

these binders soften to a viscous fluid consistency at relatively high temperatures. Depending on the quality of bitumens and polymer-bitumens, they are viscous at temperatures above 100°C. For this reason, asphalt pavements which are not adequately chosen are not resistant enough to heavy loads. In this case, excessive permanent deformations are the result (see Fig. 4). The choice of the binder bitumen (grade and quantity) is in many cases difficult, and frequently done in an empirical manner. If the resulting asphalt pavement is not ductile enough during hard winter conditions, cracks may occur in the pavement (Fig. 5).

As shown above, the behaviour of bitumens and polymer-bitumens and their composites is strongly influenced by environmental conditions, loading time, and load intensity. Consequently, the essential properties have to be determined over wide temperature and frequency ranges.

6. WORK ACCOMPLISHED

6.1 Dubrovnik seminar, September 1988

In September 1988, a seminar was held at Dubrovnik under the title 'Formulation, Control and Behaviour of Polymer Modified Bitumens either for Waterproofing or Road Construction'. More than 100 invited participants contributed to the success of this seminar. The place and time for this event seemed to be well chosen and everyone obviously enjoyed the seminar. Since then the tragic and fatal civil war has destroyed many of the historical places in this beautiful mediaeval city and port, which were at that time still sound and were very much admired indeed.

6.2 Proceedings of the Dubrovnik seminar

The proceedings published of the Dubrovnik seminar [1] comprise 330 pages and serve for a state-of-the-art report of Working Group A.

6.3 Fourth International Symposium in Budapest, October 1990

The Fourth International RILEM Symposium was held in Budapest from October 24 to 26, 1990. The subject was 'The Role of Mechanical Tests for Characterization, Design and Quality Control of Bituminous Mixes'. These subjects are still of vital interest. Fig. 5 clearly illustrates the difficulties some specialists have in optimizing bituminous pavement materials. The pavement shown was too brittle during the winter periods. Therefore, more and more cracks occurred. In this case the main reasons for the damage were the low binder content and the hard binder. Consequently, the mix design results did not lead to optimal quality of the pavement.

6.4 Proceedings of the Budapest symposium

The first volume of the proceedings was sent to the participants one month before the symposium. At that time, more than 200 participants were already registered and received this first volume, which was printed and distributed by Chapman & Hall in September 1990. This book, RILEM Proceedings 8 [2], comprises 650 pages. The second volume of the Budapest symposium proceedings [3] was published and distributed by Hungarian colleagues at the end of 1991. The second volume contains all the oral contributions of the Budapest symposium and is available from the Hungarian Chemical Society in Budapest.

6.5 Revision of RILEM Technical Recommendation BM-1

RILEM Technical Recommendation BM-1 'Terminology of hydrocarbon binders' [4] was revised in 1988 and published in 1989.

6.6 RILEM Technical Recommendation BM-5

RILEM Recommendation BM-5 'Recovery method with rotary evaporator of the soluble binder from bituminous mixes' was published as a Draft Recommendation 1988 in *Materials and Structures* and was published as final RILEM Technical Recommendation BM-5 [5] early in 1993.

6.7 Trilingual dictionary

The trilingual English-French-German dictionary of technical terms is related to hydrocarbon binders,

hydrocarbon composite materials, processes for removing pavement materials, and for the rehabilitation of asphalt pavements. This trilingual dictionary was published in *Materials and Structures* in May 1992 [6].

7. FORMER WORKING GROUPS

On the occasion of the first meeting in Madrid in 1987 six working groups (WG 1 to 6) were founded in order to cover the main topics. Three of the initially six working groups ceased their activities by 1989 and were dissolved at the Brussels Committee Meeting in 1990.

7.1 WG 1: Significant tests for sealing and waterproofing materials; WG 2: Significant tests for polymer modified binder

These two working groups were important for the preparation of the Dubrovnik seminar in 1988. Due to the leave of members in these working groups, the work was interrupted for certain intervals. For polymer-modified binders the corresponding new working group WG A was founded in 1990 (see section 8.1 below).

7.2 WG 6: Tests for bituminous emulsions

Due to the lack of specialists, this working group was not really active until the formation of the new working group B in 1990 (see section 8.2).

7.3 WG 3: Significant tests for asphalt pavements

Working group 3 was active without any interruption and is still active as WG C (see section 8.3).

7.4 WG 4: Significant tests to characterize the ageing of bituminous binders for paving asphalt

This working group dealt with the subject of ageing of bitumens for paving asphalts. It finished its work by giving brief statements. The main reason for abandoning this topic was that a CEN technical committee already worked in the same field quite efficiently and, furthermore, had initiated additional interlaboratory tests.

7.5 WG 5: Test methods for wax determination

The target of this working group was the elaboration of a new method for wax determination. This is still an important topic, because an excessive amount of waxy components in bituminous binders is frequently deleterious. Unfortunately, the leader of this working group retired in 1989 rather unexpectedly and at the same time another member of the small working group

Fig. 6 Detail of a heavily trafficked bituminous pavement with an additional optimal surface treatment with a polymer-bitumen as a binder.

changed his job and had to give up his activities. As a consequence, this working group ceased its work. As a matter of fact, RILEM TC 101-BAT lacked specialists in this field to activate the work. After such adversities this working group was dissolved.

8. WORK IN PROGRESS, ACTIVE WORKING GROUPS

8.1 WG A: Polymer-bitumens

Working group A dealt with the very important subject of performance-orientated test methods for polymer-bitumens. For this reason, this working group was relaunched at the Brussels meeting in 1990. Based on the valuable Dubrovnik seminar Proceedings published early in 1989, the task of the WG was to present a state-of-the-art report in 1993. Based on this state-of-the-art report, necessary future activities will be planned and proposed. Polymer-bitumens play more and more an important role in surface treatments (see Fig. 6) and polymer-asphalts for road construction.

8.2 WG B: Emulsions (bitumens, polymer-bitumens)

Working group B searched for significant tests for emulsions in the field of breaking and adhesion of binders. Due to the difficulties of not having enough experts in the working group, it was only possible to

relaunch this working group at the Amsterdam meeting in 1991. The state-of-the-art report has to be published in 1993. Based on this state-of-the-art report, the necessary future activities have to be proposed at that 1993 meeting. Emulsions are still important binders, for example for surface treatments of roads (see Fig. 7).

8.3 WG C (former WG 3): Fundamental and significant tests for asphalt pavement materials

8.3.1 Budapest symposium, October 1990

WG C – which was identical to the former WG 3 – was formed in Madrid in 1987 and continuously worked hard and effectively. It successfully co-operated with our Hungarian colleagues to organize the Budapest symposium in October 1990. This fact and the Budapest symposium proceedings Volumes I and II establish a good basis for the work of the technical committee and the working group in the near future and the nineties.

As far as asphalt materials for all purposes are concerned, a lot of work is still to be done. In the future this working group's main task will be to elaborate a RILEM Recommendation on fundamental tests on pavement materials, as for instance a recommendation concerning the determination of moduli or the fatigue behaviour of these materials for pavement purposes.

Fig. 7 Inadequate execution of surface treatment with an emulsion as a binder.

8.3.2 Interlaboratory tests

In order to achieve the outlined goals within a couple of years, this working group organized interlaboratory tests in collaboration with an OECD Project. The OECD FORCE Project (FORCE stands for First OECD Road Common Experiment) was mainly based on the tests on the LCPC's circular pavement test track in Nantes. This project was completed and the report was published in Spring 1991 [7]. Altogether 23 laboratories in 17 countries – from North America, Israel, and mainly Europe – promised their participation in the interlaboratory tests. Not all laboratories participated in both parts, but each of these two parts was supported by seventeen laboratories.

Excessive permanent deformation as shown before in Fig. 5 and inadmissible cracking (see Fig. 6) should not occur any more in the near future. This explains the great need to improve the so-called mix design of asphalt pavement materials. Designing asphalt paving mixes, as with other engineering materials designs, is largely a matter of selecting and proportioning materials to adequately obtain the desired qualities and properties in the finished construction. The overall objective is to determine an optimum blend and gradation of aggregates and an optimum asphalt content.

To compare the different optimum mixes designed

by the participating laboratories and to improve the mix design procedures it was decided to organize the interlaboratory tests in two parts. Furthermore an important objective was to link the different traditional mix design procedures to fundamental tests on pavement materials by carrying out Parts 1 and 2 of these interlaboratory tests as described below.

Part 1 consisted of the so-called mix design. The laboratories had to evaluate a certain optimum mix for a specific asphalt pavement mixture with specific traffic loads and climatic conditions. For the purpose, the same materials had been sent to 17 of the 23 participants.

In Part 2 the laboratories had to carry out fundamental tests on pavement slabs taken from the LCPC's circular test track in Nantes. Seventeen of the 23 laboratories promised to determine moduli and the fatigue behaviour of the pavements. For this purpose, forced vibration tests have to be carried out. The principle of forced vibration tests is to apply either repeated equal loads or repeated forced displacements on a test specimen (see Fig. 8). Tests on bituminous materials have to be carried out under various precisely maintained temperatures.

For fatigue tests, for example forced vibration tests with imposed displacements and constant temperatures can be carried out. In these cases, the life cycle is usually defined by the numbers of cycles applied until the force registered diminishes to half of the initial values. Fig. 9 schematically shows the coaxial cylinders with a test specimen in place [8]. This kind of shear test allows the determination of the ratio of viscous and elastic moduli as components of the complex modulus in shear as follows. For the complex modulus in shear

$$\vec{G}^* = \vec{G}' + i \cdot \vec{G}''$$

where $\vec{G}^*$ = dynamic shear modulus, $\vec{G}'$ = elastic shear modulus or storage shear modulus and $\vec{G}''$ = viscous shear modulus or loss shear modulus.

Fig. 8 Forced vibration tests: sinusoidal displacements (x), recorded force (F) and phase angle (ϕ) for viscoelastic materials.

Fig. 9 Schematic view of coaxial cylinders with a test specimen in place for determining the components of the complex modulus in shear. 1, Test specimen; 2, central cylinder; 3, outer cylinder; 4, measurement of displacement; 5, repeatedly applied load.

The imaginary part of the complex modulus in shear is also called the viscous modulus G'' . This viscous modulus is then described by the relationship of its components G' and G^* :

$$G'' = G^* \cdot \sin \phi$$

where ϕ = phase angle. G'' is a measure of the lost energy, which is transformed into heat, observed in the temperature rise of the specimen during the tests at high frequencies.

The real part of the complex modulus in shear (which is the elastic modulus in shear as well) can be presented as

$$G' = G^* \cdot \cos \phi$$

G' is a degree of recoverable energy of displacement and therefore a measure of elasticity. In the plane of the complex numbers the characteristics cited can be represented as shown in Fig. 10. The phase angle ϕ results consequently in $\tan \phi = G''/G'$.

Measuring forced displacements and the forces

Fig. 10 Complex modulus in shear and its components represented in the imaginary plane.

Fig. 11 Complex modulus in shear for the frequency $f = 1 \text{ s}^{-1}$ in the temperature range from -20 to 60°C of asphalt concretes (M2-M5 differing only in the binder content: 4.7–5.9 wt%).

applied in forced vibration tests allow the characterization of the viscoelastic material behaviour. Such forced vibration tests carried out over wide temperature and frequency ranges, typically from -10°C up

Fig. 12 Cross-section through the wheel path of a slab of a heavily trafficked pavement slab. This cut reveals an ideal concept: as few courses as possible with extremely large maximum size of the crushed aggregates and correct mix design of the asphalt concretes.

to $+40^{\circ}\text{C}$ and between 0.1 and 32 Hz, allows the characterization of bituminous materials (see Fig. 11).

The results and reports from each laboratory constitute an important basis for the final reports for parts 1 and 2 of the interlaboratory tests as well as for the comments and conclusions of working group C. These publications – planned for spring 1993 – will form an important basis for improving the mix design and the necessary characterization of bituminous materials with fundamental and significant test methods in a decisive manner [9]. Consequently, for this working group these reports are essential to achieve the goals as outlined before.

9. CONCLUSION

The main activities of RILEM TC 101-BAT 'Bitumen and Asphalt Testing' brought the following findings and results:

- The Dubrovnik seminar in 1988 and the Budapest symposium in 1990 with the various proceedings and publications.
- The 1988 revision of RILEM Technical Recommendations BM-1 'Terminology of hydrocarbon binders' and its publication in 1989.
- The draft publication of RILEM Technical Recommendation BM-5 'Recovery method with rotary evaporator of the soluble binder from bituminous mixes' in 1988. The unchanged final publication of this draft as BM-5 is planned by the RILEM general secretariat in 1993.
- The publication of the trilingual dictionary in English–French–German of technical terms related

to hydrocarbon binders, hydrocarbon composite materials, processes for removing pavement materials, and for the rehabilitation of asphalt pavements has taken place in *Materials and Structures* in May 1992.

- The formation of working groups was essential and indispensable for making progress within a reasonably short period of time.
- Three main topics are under consideration in the three existing working groups: fundamental and significant tests for asphalt pavement materials, emulsions, and polymer-bitumens. In the three existing working groups decisive work will be accomplished in the near future to optimize bituminous pavements (see Figs 12 and 13), surface treatments and other asphaltic materials.

Fig. 13 Optimal bituminous pavement in the Swiss Alps. Ideal concept of the asphalt pavement and correct mix design.

- Regarding waterproofing materials, a working group has not yet been founded. The new bituminous RILEM TC (see below) will decide if a working group in this field will be founded and which topics are to be treated.

10. PROPOSAL FOR A NEW RILEM TECHNICAL COMMITTEE AND FUTURE WORK

In the large field of bituminous materials the permanent involvement of RILEM is appropriate. Technical Committee TC 101-BAT was dissolved by the end of 1992 and for the continuation of its work in the field of bituminous materials a new RILEM Technical Committee TC 152-PBM was formed, and approved by the RILEM General Council in October 1992.

The bituminous RILEM technical committee should not duplicate international standardization work efficiently done for example by CEN, ASTM or ISO. If possible, or if it seems necessary for certain reasons, possible assistance to such organizations will be given, but it is certainly not intended to repeat work which is already in progress within CEN. In order to enable decisive progress in the bituminous field in the near future, the bituminous RILEM technical committee and its working groups have to elaborate fundamental and significant test methods in its fields – this for sufficient characterization of the materials in the laboratories and the optimization of the materials' behaviour *in situ*. This has to be ensured by selecting significant laboratory tests to facilitate reliable prediction of materials' behaviour *in situ*. Such innovative RILEM Technical Recommendations (RTRs) enable international standardization organizations to elaborate new specifications and test methods more quickly.

11. ACKNOWLEDGEMENTS

In closing, the writer as former chairman expresses his thanks to the following members and experts for their co-operative attitude in the tremendous amount of work they have done up to now hoping, at the same

time, for a fruitful, effective continuation of the necessary work. The members were: C. D. M. Beverwijk (Netherlands), K. E. Cooper (Great Britain), E. Eustacchio (Austria), L. Francken (Belgium), A. Gómez Saiz (Spain), U. Isacsson (Sweden), I. Ishai (Israel), M. Luminari (Italy), L. Nagy (Hungary), A. Paez (Spain), I. Pallos (Hungary), S. Pallotta (Italy), M. Partl (Switzerland), G. Peroni (Italy), G. Ramond (France, Secretary), O. Ruud (Norway), A. Solc (Croatia), M. Smiljanic (Serbia), O. J. Svec (Canada), G. Svechinsky (Israel), D. Sybilski (Poland), S. Toth (Hungary), R. Urban (Germany), J. Verstraeten (Belgium). The experts were F. Choquet (Belgium), J. Sanchez Caba (Spain), A. Verhasselt (Belgium).

12. REFERENCES

1. Proceedings of RILEM seminar, Dubrovnik, 1988: 'Formulation, Control and Behaviour of Polymer Modified Bitumens Either for Waterproofing or for Road Construction' (The Highway Institute, Kumodraska 257, Belgrade, 1989).
2. RILEM Proceedings 8, Budapest symposium, 'Mechanical Tests for Bituminous Mixes, Characterization, Design and Quality Control', Vol. I (Chapman and Hall, London, 1990).
3. *Ibid.*, Vol. II (Hungarian Chemical Society, Budapest, 1991).
4. RILEM Technical Recommendation BM-1, 'Terminology of hydrocarbon binders' (1989) 237–239.
5. RILEM Technical Recommendation BM-5 (1992), 'Recovery method with rotary evaporator of the soluble binder from bituminous mixes'; Draft Recommendation, *Mater. Struct.* **21** (1988) 151–160.
6. 'English–French–German dictionary of technical terms related to hydrocarbon binders, hydrocarbon composite materials, processes for removing pavement material and for the rehabilitation of asphalt pavements', *Mater. Struct.* **25** (1992) 171–185.
7. 'OECD full-scale pavement test' (Road Transport Research, OECD, Paris, 1991).
8. 'Entwicklungen zur Bestimmung mechanischer Materialkennwerte an bituminösen Baustoffen, insbesondere an Asphalt', Report No. 215 (EMPA, Dübendorf, 1987).
9. 'Interlaboratory Tests...', publication foreseen Spring 1993.