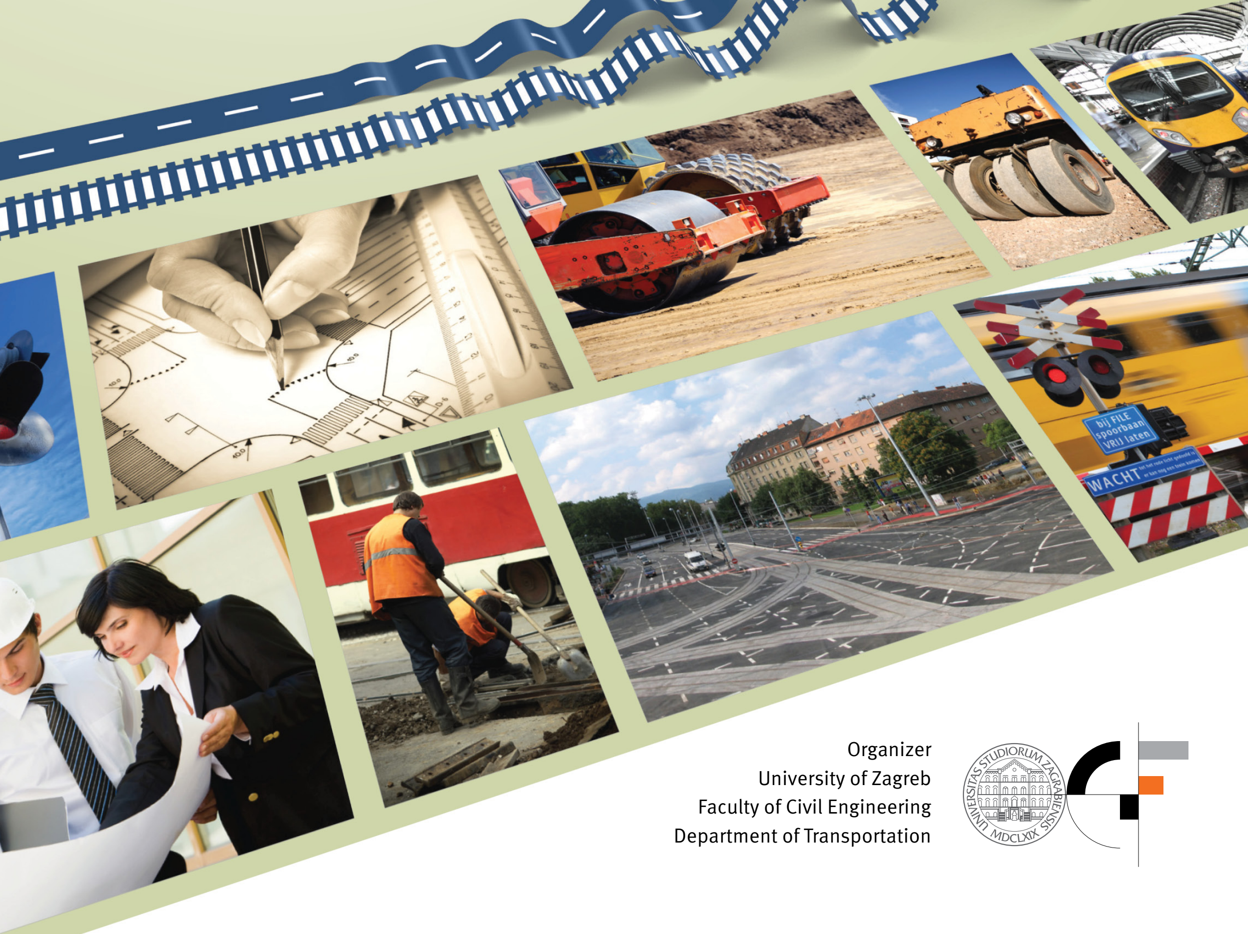
CETRA[2012]

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

# Road and Rail Infrastructure II


**Stjepan Lakušić – EDITOR**



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# Road and Rail Infrastructure II

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# LABORATORY TESTS CONCERNING FATIGUE BEHAVIOR OF ASPHALT MIXTURES

**Carmen Răcănel, Adrian Burlacu**
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## Abstract

The study of fatigue behaviour on asphalt mixtures has a particular importance, both to estimate the degradation that can occur during service period in the asphalt layer under external loads (traffic, climate) and to consider the fatigue laws that should be taken into account in asphalt pavement design.
The European Standard adopted in our country, SR EN 13108:20 stipulates some tests for determining fatigue resistance of asphalt mixtures, including the 4PB–PR test (four–point bending test on prismatic samples).
The goal of this paper is to emphasize the results (fatigue resistance and stiffness) obtained in the Road Laboratory of Technical University of Civil Engineering. The results were obtained using some types of asphalt mixtures with the PMB binder (asphalt mixtures used in Romania). Conclusions will be presented in the form of comparative charts.

*Keywords: asphalt mixture, fatigue, stiffness, four point bending test*

## 1 Introduction

### 1.1 Context

Knowing that stiffness and asphalt mixtures response to fatigue is an important issue, those two paramaters need to be taken into consideration when designing a pavement structure for a specific traffic calculation.
The stiffness modulus of asphalt mixtures is a fundamental property that gives information about how much the material deforms under a given load. It is closely related with fatigue cracking and permanent deformation because of time and temperature dependence. The stiffness modulus of asphalt mixture is useful for: quality evaluation of the asphalt mixture, asphalt mix design, pavement design and asphalt mixture damage.
In the calculus of a pavement structure, estimating the life duration of an asphalt mixture under fatigue is necessary so that possible re–dimensioning would enable the pavement to resist the heavier traffic.
In the asphalt mixtures fatigue study, two types of controlled load can be applied: constant (controlled) stress and constant (controlled) strain. Under constant stress testing, the effort (stress) remains constant, but the deformation increases with the increasement of applied load, while under the constant deformation (strain) test the deformation is maintained constant and the effort decreases with the number of applied load.
The first test type has the advantage of a quick failure so itcan be easily defined, while for the constant deformation testing arbitrary failure criteria is frequently used.
For asphalt mixtures stiffness and for their fatigue behaviour, our country adopted a European norm SR EN 13108:20, which requires a conduct of specific laboratory testing. Among the tests

recommended by European norms, the four point bending test (4PB–PR) can be found. It is performed at constant strain (controlled), on prismatic asphalt mixture samples made in the laboratory, using the roller compactor or cores extracted from the asphalt of a road structure.

### 1.2 Objectives

In Romania, concomitant with the European norm SR EN 13108-20 is the Romanian norm SR174 which establishes the requirements regarding the performance of asphalt mixture. So, when we refer to stiffness and fatigue resistance, the Romanian norm imposes the IT–CY test (indirect tensile test performed on cylindrical samples, SR EN 12697-26 annex C and SR EN 12697-24, annex E).
The Roads Laboratory of the Faculty of Railways, Roads and Bridges from Technical University of Civil Engineering of Bucharest, in accordance with the European norms: 2PB-TR, 4PB-PR and IT-CY, is equipped with all of the equipment required for dynamic testing (stiffness and fatigue test) and has years of experience in the conduct of these tests.
The objective of this paper is to present the results (fatigue resistance and stiffness)obtained in the Road Laboratory of Technical University of Civil Engineering on some types of asphalt mixtures used in Romania, most of them containing PMB binder, using the the 4PB-PR test. Therefore, our Romanian asphalt mixtures will be characterised from the stiffness and fatigue resistance point of view, according to European norms SR EN 13108-1 and 13108-5.

## 2 Stiffness and Fatigue test

### 2.1 investigated asphalt mixtures

This study was carried out in the Roads Laboratory of Faculty of Railways, Roads and Bridges (Technical University of Civil Engineering of Bucharest).

**Table 1** The used materials in asphalt mixtures and recipes of the used asphalt mixtures

| Asphalt Mixtures | Source / Type and % | Crushed Rock | | | | Filler | Fiber by mix | Bitumen by mix |
|---|---|---|---|---|---|---|---|---|
| | | 0–4 | 4–8 | 8–16 | 16–25 | | | |
| MAMR16 | Source / Type | Revarsarea | | | | Limestone Holcim | - | 25/55-65 PMB |
| | % | 25 | 29 | 35 | - | 11 | - | 4.12 |
| MASF16m-T | Source / Type | Turcoaia | | | | Limestone Holcim | Topcel | 25/55-65 PMB |
| | % | 13 | 25 | 45 | - | 11 | 0.3 | 5.7 |
| MASF16m-P | Source / Type | Turcoaia | | | | Limestone Holcim | Poly-propylene | 25/55-65 PMB |
| | % | 13 | 25 | 45 | - | 11 | 0.3 | 5.7 |
| MASF16m-T-wm | Source / Type | Turcoaia | | | | Limestone Holcim | Topcel | 25/55-65 PMB+ additive |
| | % | 13 | 25 | 45 | - | 11 | 0.3 | 5.7 |
| BA16 | Source / Type | Cerna | | | | Limestone Holcim | - | 50/70 |
| | % | 32 | 22 | 30 | - | 9.4 | - | 6.6 |
| BAD25 | Source / Type | Turcoaia | | | | Limestone Holcim | - | 25/55-65 PMB |
| | % | 31 | 17 | 20 | 23 | 4.5 | - | 4.5 |

Four types of asphalt mixtures frequently used in our country (table 1) were examined: a classic asphalt mixture–type BA16 for wearing course; a classic asphalt mixture – type BAD25 for a binder course, a high modulus asphalt mixture – type MAMR16 and an asphalt mixture with fibre – type MASF16. For the last mixture, two types of fibre were used: topcel and polypropylene as well as two technologies: a hot mix (MASF16m-T) and a warm mix (MASF16m-T-wm). The recipes for studied asphalt mixtures correspond to Romanian norm but are also in accordance with the European norms SR EN 13108-1 and 13108-5.

## 2.2 Sample preparation

The prismatic samples for the 4PB-PR test were manufactured by cutting the required dimensions (50 x 50 x 405 mm) from slabs compacted with roller compactor.

## 2.3 Four Point Bending Test

The four–point bending test 4PB-PR is used to determine the asphalt mixtures stiffness and to evaluate the asphalt mixtures fatigue behaviour and it is performed at constant strain (controlled) in time. The test was made on prismatic asphalt mixture samples submitted to a sinusoidal load. The prismatic beam was subjected to four–point periodic bending, with free rotation and translation at all load and reaction points. During the test, the load bent the sample. The deflection and the phase angle were measured as a function of time. The test is considered finished when the force reaches half of its initial value (Fig. 1). In order to establish the stiffness modulus and the fatigue resistance of asphalt mixtures presented above, the laboratory test was conducted according to the SR EN 13108-20 (table 2 and 3).

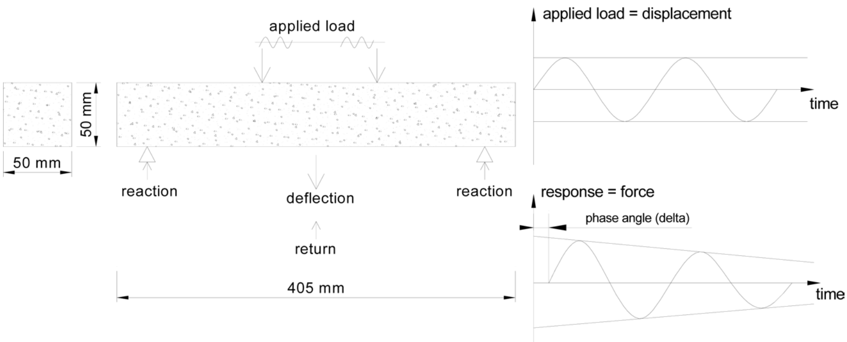


**Figure 1** The four points bending test and the load and response in the case of fatigue apparatus for four points bending test

**Table 2** Requirements regarding determination of asphalt mixture stiffness according to SR EN 13108-20

| Type of loading | Temperature | Frequency | Test method |
|---|---|---|---|
| 4PB-PR | 20oC | 8Hz | SR EN 12697-26, annex B |

**Table 3** Requirements for measurement of asphalt mixture fatigue according to SR EN 13108-20

| Type of loading | Temperature | Frequency | Test method |
|---|---|---|---|
| 4PB-PR | 30°C | 30Hz | SR EN 12697-24, annex D |

# 3 Stiffness and fatigue test results

## 3.1 Stiffness test results

The obtained results for stiffness modulus of the tested asphalt mixtures are presented in Fig. 2. According to the SR EN 13108-1, the stiffness category of these asphalt mixtures is as presented in the table 4.

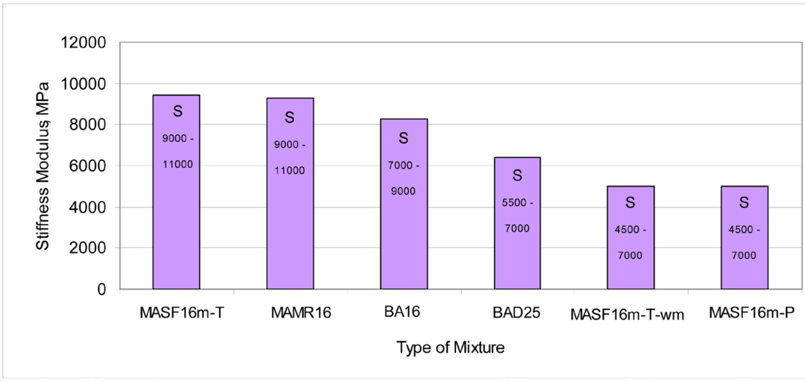


**Figure 2** Stiffness modulus values for different asphalt mixtures gotten from the four point bending test. Temperature: 20°C, frequency: 8Hz

**Table 4** Minimum and Maximum Stiffness, according to the SR EN 13108-1

| Type of mixture | Stiffness values, MPa | Stiffness category | |
|---|---|---|---|
| | | $S_{min}$ | Smax |
| MAMR16 | 9274 | 9000 | 11000 |
| MASF16m-T | 9452 | 9000 | 11000 |
| MASF16m-P | 4975 | 4500 | 7000 |
| MASF16m-T-wm | 4990 | 4500 | 7000 |
| BA16 | 8256 | 7000 | 9000 |
| BAD25 | 6424 | 5500 | 7000 |

## 3.2 Fatigue test results

The obtained results for fatigue lines of MAMR16, MASF16m, BA16 and BAD25 asphalt mixture are presented in Fig. 3.
The fatigue line has the following shape:

$$\ln N = A_0 + A_1 \ln \varepsilon \qquad (1)$$

where:
N is the fatigue life for the chosen failure criteria (number of load cycles);
ε – the initial strain amplitude measured at the 100th load cycle, με;
$A_o$ and $A_1$ – material constants.

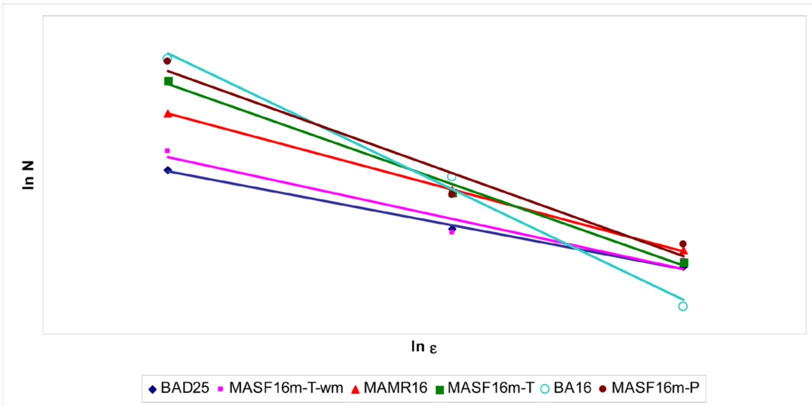


**Figure 3** Fatigue lines from the four point bending test. Temperature: 30°C, frequency: 30Hz

Table 5 gives an overview of material constants, as well as the estimation of the initial deformation for the fracture criteria chosen. For the given testing conditions ($\varepsilon_6$), the expected fatigue life is $10^6$ cycles. The resistance to fatigue category of these asphalt mixtures, concerning the SR EN 13108-1, is also presented in table 5. A comparison of asphalt mixtures from the category $\varepsilon_6$ (resistance to fatigue) is given in Fig. 4.
In Fig. 5 and Fig. 6 the fatigue lines are plotted together, for fatique resistance comparison between $\varepsilon_6$ specific asphalt mixtures.

**Table 5** Fatigue line characteristics and estimation for $\varepsilon_6$

| Type of mixture | $A_0$ | $A_1$ or slope 'p' of fatigue line | Correlation coefficient of the regression $R^2$ | $\varepsilon_6$, με | Resistance to fatigue category $\varepsilon_6$ |
|---|---|---|---|---|---|
| MAMR16 | 59.657 | -8.5154 | 0.9997 | 217 | $\varepsilon_{6\text{-}190}$ |
| MASF16m-T | 75.117 | -11.293 | 0.9937 | 227 | $\varepsilon_{6\text{-}220}$ |
| MASF16m-P | 76.268 | -11.451 | 0.9593 | 233 | $\varepsilon_{6\text{-}220}$ |
| MASF16m-T-wm | 49.986 | -6.8977 | 0.9578 | 189 | $\varepsilon_{6\text{-}160}$ |
| BA16 | 96.827 | -15.248 | 0.9921 | 231 | $\varepsilon_{6\text{-}220}$ |
| BAD25 | 45.032 | -6.0302 | 0.9961 | 177 | $\varepsilon_{6\text{-}160}$ |

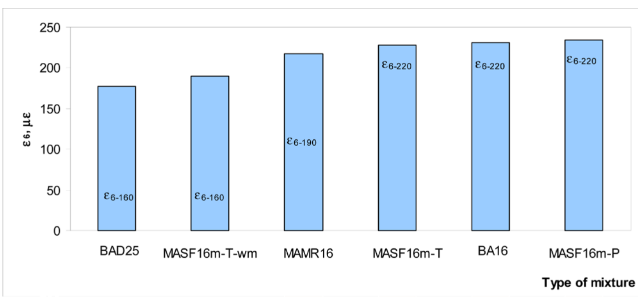


**Figure 4** Category $\varepsilon_6$ for different asphalt mixtures

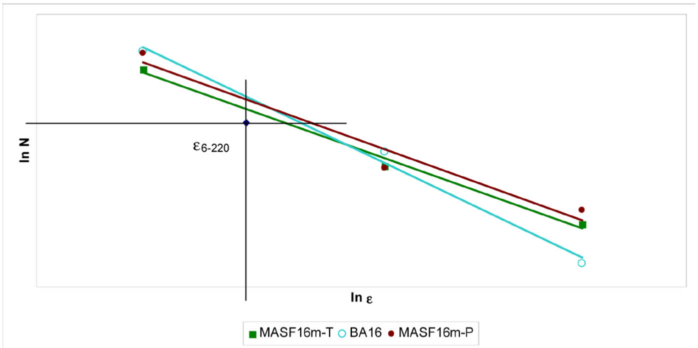


**Figure 5** Fatigue lines and fatigue resistance $\varepsilon_6$ for MASF16m-T, MASF16-P and BA16 asphalt mixture

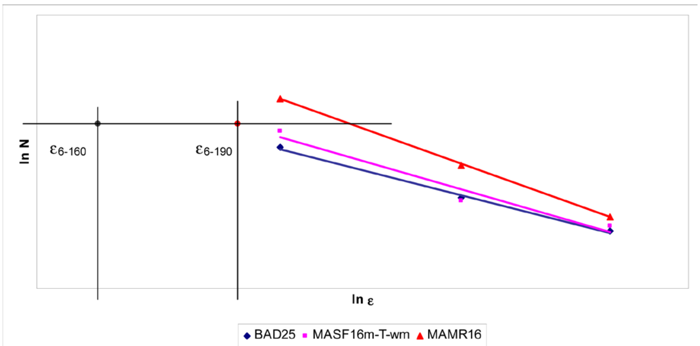


**Figure 6** Fatigue lines and fatigue resistance $\varepsilon_6$ for BAD25, MASF16m-T-wm and MAMR16 asphalt mixture

## 4 Conclusions

The study presented above leads to certain conclusions regarding the performance of asphalt mixtures, in terms of category, according to the European norm. The study of asphalt mixture stiffness highlights the fact that different values can be obtained depending on asphalt mixture type. Using a polymer modified bitumen (PMB) and a strong aggregate skeleton (MAMR16 and MASF16m-T mix) results in better asphalt mixture stiffness for mixtures studied ($S_{9000\text{-}11000}$ category). Using an additive in asphalt mixture MASF16m-T-wm we achieved smaller values of stiffness then asphalt concrete MASF16m-T. The same conclusion is valid for polypropylene fibre in asphalt mixture, MASF16m-P ($S_{4500\text{-}7000}$ category).
Regarding the study of fatigue behaviour it can be said that asphalt mixture with fibre - MASF16m-T has a specific strain corresponding to one million cycles $\varepsilon_6$, which is superior to other studied mixtures. The studied asphalt mixtures are classified in three categories, based on the fatigue resistance : $\varepsilon_{6\text{-}220}$, $\varepsilon_{6\text{-}190}$ and $\varepsilon_{6\text{-}160}$. Mixtures with high stiffnes are in the first category, like MASF16-m-T along with mixtures with low stiffness, like MASF16m-P. The asphalt mixture stiffness affects the slope and the position of the fatigue line. The number of cycles necessary to reach fatigue decreases with the increasement of stiffness modulus.
From all the studied asphalt mixtures, MASF16m-T-wm mix type has the worst fatique behaviour, which is in correlation with its low stiffness. Since this is a warm mixture, the benefits for asphalt industry must be taken into account: helping the compaction of stiff mixes, prolonging the paving season (in cold weather), allowing longer transport distances and reducing emissions and odour in limited urban areas.

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