TRIAXIAL CYCLIC COMPRESSION TEST – SUITABLE TEST PARAMETERS FOR MEANINGFUL RESULTS

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ABSTRACT

The uniaxial cyclic compression test (EN 12697-25) was in Switzerland introduced many years ago and has since then been extensively applied both for type testing as well as quality control. This long-time experience allowed establishing requirements. However, the uniaxial test has theoretical drawbacks (no confining pressure) and its application in practice is limited (for instance in the case of porous asphalt). In this regard, the triaxial cyclic compression test according to EN 12697-25 / 13108-20 is a significant improvement, although there is at present still a lack of experience and requirements.

In the present work, it is shown how experience from the uniaxial test can be transferred to the triaxial test. Effects of laboratory compaction procedures on mechanical properties and degree of compaction are considered. With the bituminous mixtures most commonly used in Switzerland, different laboratory compaction procedures were studied at various degrees of compaction, namely by using a gyratory compactor (EN 12697-31), a roller compactor using pneumatic tyre (EN 12697-33), a roller compactor using steel roller simulating a segment roller (EN 12697-33), and an impact compactor (EN 12697-30). In addition, drilled cores from field asphalt pavements (compacted under field conditions) were studied for comparative purposes.

Based on the results, a laboratory compaction procedure was selected and requirements concerning the triaxial cyclic compression test are suggested for the bituminous mixtures most commonly used in Switzerland.

Keywords: Triaxial cycling test, rutting, resistance to permanent deformation, creep characteristic

1. INTRODUCTION

In German speaking regions, in the 1980's Schellenberg made fundamental studies for the uniaxial cyclic compression test. His studies were made within the framework of a research project. The triaxial cyclic compression test, already known from geotechnics, was also evaluated [1].
On the basis of Schellenbergs studies, in the year 1999 a technical test instruction for the uniaxial cyclic compression test was published by the Deutsche Forschungsgesellschaft für Strassen und Verkehr (German Research Organization for Roads and Traffic) [2]. The reason why the uniaxial cyclic compression test gained such an acceptance and has been so successful is that the test method is easy to apply.
In Switzerland this test method has been used often; for type testing, for optimizing the sample mixture, and to clear up cases of damages. Although the use of this test method is limited (for example it cannot be used for testing porous asphalt) and there have been objections to the theory because of the confinement, well founded knowledge, obtained in years of experience, is available. In order to make it possible to use these experiences furtheron, and at the same time to dispel the disadvantages and the objections, a research work for the introduction of the triaxial cyclic compression test was carried out.
Up to now two principle methods are described in EN 12697-25 [3], the test parameters for initial type testing are given in EN 13108-20 [4], and requirement categories are listed in EN 13108-1 [5]. The test conditions in EN 13108-20 were chosen from a broad choice of different national Standards.
With regard to the test standard specification there is a wide range of possibilities how to carry out the test. Remarkable differences are the axial load and the frequency of the haversinusoidal pulse. This study examines the selection of the categories which shall get part of the Swiss Standard.
Many different types of asphalt concrete were tested, either with standardized or with alternative test methods.

2. BASIS

2.1 Test conditions

The standard for the initial type testing EN 13108-20 specifies, that the resistance to permanent deformation due to triaxial compression has to be determined in accordance to EN 12697-25, test method B.
The confining stress σc in the triaxial cell has to be 150 kPa for surface courses and 50 kPa for binder and base courses.
The amplitude of the axial load is 300 kPa for surface courses and 200 kPa for binder and base layers.
For the cyclic haversinusoidal stress there is no rest period; the test is run at a frequency of 3 Hz.
Asphalt mixtures for surface layers are tested at 50 °C, whereas the deeper layers have to be tested at 40 °C.
The test conditions are summarized in table 1.
The maximum axial pressure becomes 750 kPa for surface courses and 450 kPa for binder and base layers, basis is the definition of the total axial pressure.

Table 1 : Triaxial compression test conditions according to EN 13108-20

Course	**Temperature [°C]**	**σ_C [kPa]**	**σ_V [kPa]**	**Frequency [Hz]**	**σ_A max [kPa]**
Surface	50	150	300	3	750
Binder & Base	40	50	200	3	450

According to EN 13108-20 it is allowed to use the haversinusoidal stress as well at the block-pulse loading. Both pulse and rest period are 1s, which means a frequency of 0,5 Hz.
The maximum block-pulse loading $_{\sigma B}$ was set to σ_V. In each case all other test conditions such as temperature etc. remain the same. No investigations on the block-pulse alternative were made because experiences with the dynamic indentation test for mastic asphalts revealed that haversinusoidal stresses are much more favorable [6].
One of the reasons for that is, that testing apparatuses in principle are not able to carry out block-pulse loading cycles without overloading peaks
Secondly, the loading curve of a rolling tire is not similar to a block-pulse, rather the loading gets continuously build up and is constantly relieved.
Some changes of the standard test conditions became necessary during the course of the investigations.

2.2 Sample preparations

The cylindrical test specimens were prepared in the laboratory with the help of the gyratory compaction [7].
They all have a diameter equal to 100 mm. The height is either 60 mm for maximum aggregate size ≤ 16 mm or 80 mm for maximum aggregate size ≥ 16 mm. Silicon grease was used to limit the friction between the loading plate and the sample.

2.3 Requirement categories

Within the context of the initial type testing, the standard EN 13108-1 defines 16 requirement categories for the evaluation of the resistance towards deformation.
The creep rate corresponds to the slope in the linear part of the creep curve (deformation as a function of the number of cycles), and it is described in micro-strain/loading pulse.
Table 2 shows the 16 categories with the according maximum permissible creep rate.

Table 2 : **Categories $f_{\mathrm{cmax}\ 0.2}$ to $f_{\mathrm{cmax}\ 16}$**

Maximum creep rate f_{cmax} in µm/m/n															
0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	2	4	6	8	10	12	14	16

3. ASPHALT CONCRETE MIXTURES

3.1 Base courses

The tested hot mixtures for base courses belong to the type AC EME 22 and AC T 16. The type EME corresponds to the French concept of high modulus asphalt, called "Enrobé à Module Elevé".
The list of the mixtures is shown in table 3.

Table 3 : **List of AC mixes for base courses**

Identification	Type	Binder type	RAP [m-%]	Binder content [m-%]	Void content [vol-%]
1	AC EME 22 C2	15/20	40	5.33	1.9
2		10/20	-	5.23	1.6
3		15/20	-	5.32	2.0
4		15/20	40	5.37	2.0
5		15/20	30	5.05	2.4
6	AC T 16 S	50/70	30	4.92	5.5

3.2 Surface courses

The tested hot-mixtures for surface courses belong to type AC 11. The list of the mixtures is shown in table 4.

Table 4 : **List of AC 11 mixes**

Identification	Type	Binder type	Binder content [m-%]	Void content [vol-%]
7	L	70/100	5.93	3.1
8	N	70/100	5.82	5.1
9	N	100/150	6.08	3.0
10	S	70/100	5.90	5.5
11	S	50/70	5.67	3.0
12	S	50/70	6.16	3.4
13	S	PmB C 45/80-50	5.56	3.6
14	N	70/100	5.82	5.1
15	S	PmB C 45/80-50	5.29	5.2

4. RESULTS

The test of high modulus AC EME specimens were made at a specified temperature of 40°C and with a stress equal to that defined for base courses (see table 1).
The aim of this measurement was, on the one hand to work out data for the creep rate in connection with the chosen type of mixture, and on the other hand to get knowledge about the sensitivity of the test method.
The susceptibility to deformation of all AC EME mixtures was examined by measuring the rut depth in a "large size device wheel tracking apparatus", as described in EN 12697-22 [8].
While four out of five AC EME asphalts, which were used for the test series, showed an adequate proportional rut depth < 6%, the fifth AC EME showed a disastrous resistance to rutting (with a proportional rut depth of 27 %). This was an easy way to examine the meaningfulness and the sensitivity of the triaxial test.
The result (see figure 1) shows, that an usual AC EME can be assigned to the strictest category f cmax 0.2.
The disastrous AC EME mixture #1 shows a creep rate which has the same order of magnitude as the other four mixtures which achieved good values in the rutting test.
Many years of experience with the Rutting Test support its meaningfulness. This test method is scarcely able to distinguish between a good and a very good resistance to deformation, but it is known as well, that asphalt which does bad in the Rutting Test, in practice - in correlation to the volume of traffic - shows deformations. That the test conditions of the EN 13108-20 are not able to convey this decisive and central difference is disappointing.

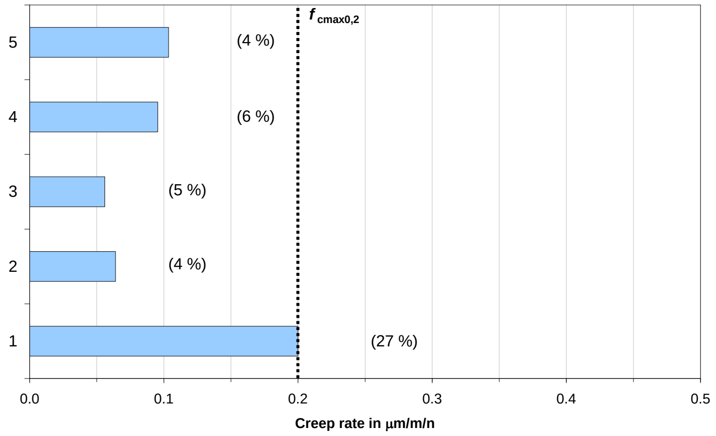

Figure 1: Creep rate of five different AC EME 22 mixtures; value in brackets show the proportional rut depth from a Wheel tracking test according to EN 12697-22.

In order to make further investigations concerning the sensitivity of the test method, a similar test serie with some AC 11 asphalt mixtures was carried out. With the choice of an asphalt for surface courses, a higher temperature and a higher confining stress was chosen too. This was done in the hope that the test method would now show a better sensitivity under these test conditions. The resistance to permanent deformation of the mixture was varied by using different kinds of binder (unmodified and polymer-modified) as well as using different paving grades (from B 50/70 to B 100/150).

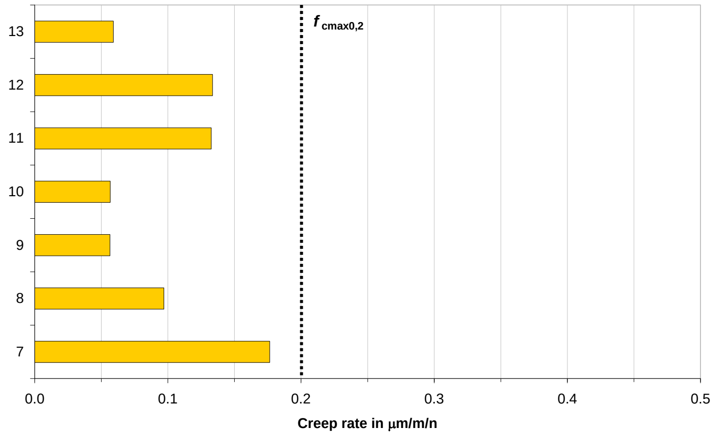

Figure 2: Creep rate of different AC 11 types with different grades of bitumen; σ_c = 150 kPa and σ_V = 300 kPa, T = 50°C.

The results, shown in figure 2, shows the mean value from at least two tests per asphalt type. All variants of the AC 11, with no consideration for binder viscosity, belong to the strictest category fc max 0.2. Even an AC 11, mixed with a very soft bitumen B 100/150, fulfills the strictest demands fc max 0.2. That a surface course with such a soft bitumen is going to fail in practice is obvious; that the Triaxial Test assigned this asphalt to the best category is kind of strange.
In order to be able to answer the question whether the absence of meaningfulness is due to the confining stress, the axial load or the temperature, further test were made with varying test conditions. The temperature was increased from 50°C to 60°C and at the same time the confining stress was reduced from 150 kPa to 50 kPa and finally to 0 kPa.

A survey of the different stress levels is given in figure 3. In order to get larger creep rates a type of mixture was chosen where an average resistance to permanent deformation was expected. The mixture AC 11 N was produced with a B 70/100 bitumen. The results of this test series are shown in figure 4.
Although the effect of the temperature is small it cannot be ignored. A rise in temperature of 10° C leads to a doubling of the creep rate. But, the doubling happens at a deep level; the relatively soft mixture, even at a higher temperature, fulfills the requirements of the highest category (fc max < 0.2).
In comparison, the confining stress has a much bigger influence on the creep rate. Between 150 kPa and 50 kPa the AC mixture changes from category fc max 0.2 to category fc max 0.6. A further reduction of the confining stress leads to a disproportionately large increase of the creep rate, which, in the end, without confining stress reaches more than 2 µm/m/n.
Two further test series with AC 11 S and AC 16 S were made in order to emphasize these observations. The observations concerning the connection between creep rate and confining stress are summarized in figure 5.

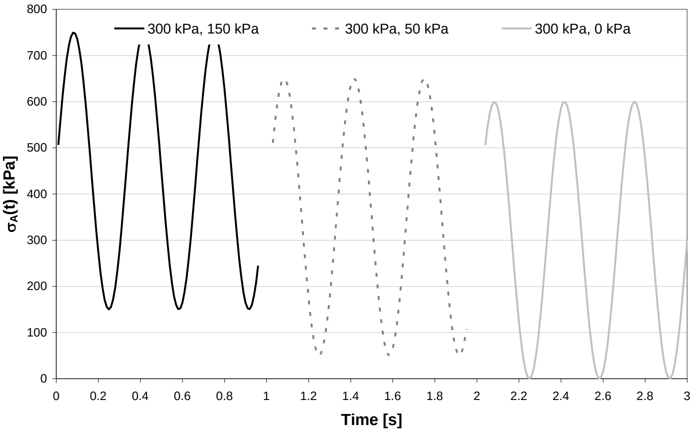

Figure 3: Stress curves of 3 pressure configurations; amplitude of the axial stress σ_V is always 300 kPa, confining pressure varies from 150 kPa to 50 kPa and 0 kPa.

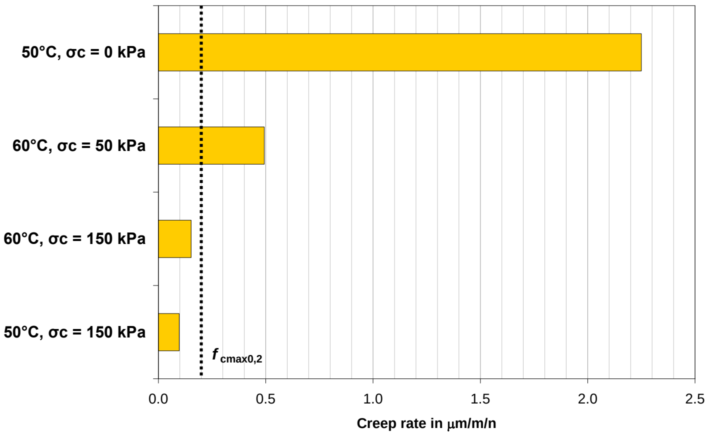

Figure 4: Creep rate of an AC 11 N (14) with binder type 70/100 in dependance to temperature and confining stress; the axial stress was constantly kept at 300 kPa.

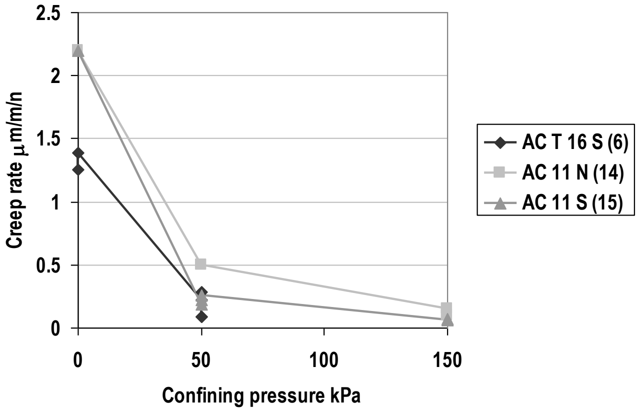

Figure 5: Creep rate as a function of confining stress; data is shown despite the fact that the temperature can be 40, 50 or 60 °C.

5. DISCUSSION

An extensive analysis of the test conditions of the triaxial compression test, as specified in EN 13108-20, was made in order to investigate the meaningfulness and sensitivity of the test method.
As shown in fig. 1, the creep rate of high modulus base courses, tested according to the test conditions of EN 13108-20, fulfilled the requirements of the strictest test category f cmax 0.2. This absolutely meets our expectations.
But nonetheless, when taking into consideration the proportional rut depth of each AC EME mixture, it is noticeable that the triaxial test was not able to recognize the mixture with a bad resistance to permanent deformation.
This lack of sensitivity has to be seen as a serious disadvantage of the standardized test conditions. A further test series was made at a temperature of 50 ° C and a confining stress of 150 kPa. This test series came to nearly the same result, which means that the creep rate doesn't reflect the variety of the binder viscosity (see figure 2).
The AC 11 asphalt with a PmB 45/80-50 is classified in the same category as another AC 11 asphalt with a very soft binder 100/150. This difficulty is maybe related to the confining stress.
As recently shown by Renken and Buechler [9], the axial deformation increases only if the confining stress falls below a threshold value. At higher confining stresses the axial deformation nearly stays the same. In case that the confining stress is above 50 kPa, the axial deformation practically doesn't change. This corresponds to our results as shown in figure 5. These observations emphasize that the confining stress does play an important part concerning the triaxial creeping, and a high confining stress has a negative effect on the sensitivity of the test method. As a consequence, the author suggests, to reduce the confining stress to a maximum of 50 kPa.
With the context of the continuation of this work, it is intended to make further tests with a temperature of 50 ° C, a confining stress of 50 kPa and an axial amplitude of 300 kPa for surface- , binder- and base courses.

6. CONCLUSIONS

When the test conditions - specified in EN 13108-20 - are applied, it is not possible to distinguish between extremely different asphalt qualities.
Also asphalts with provable different resistance to deformation, are assigned to the same category. The test conditions should be adjusted in the way, that a differentiated classification according to EN 13108-1 is possible.
The influence of the confining stress on the creep rate follows an exponential running. Confining stress from more than 50 kPa hinders the sensitivity of the test method. The author suggests a reduction of the confining stress to a value equal or below 50 kPa.
Compared to the confining stress, the temperature and the axial load only have a minor effect on the creep rate. Nonetheless the author suggests, that the test temperature for binder- and base- courses should be increased from 40 ° C to 50 ° C, and the amplitude of the axial deformation should be raised from 200 kPa to 300 kPa.

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