Extended bitumen testing in Germany

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ABSTRACT

In Germany conventional bitumen and polymer modified binder are mainly identified through parameters that do not allow conclusions on its behaviour regarding temperature or detailed rheological characteristics. Would these parameters be available (or specified), a more targeted evaluation of the appropriate materials for each situation could be done and eventually would lead to a better end product, i.e. road.
In 2013 the German federal ministry of Transport and Digital Infrastructure extended the bitumen testing with this objective as follows:
• Resistance to hardening under the influence of heat and air according to DIN EN 12607-1 at 163°C (penetration at 25°C and softening point)
• Resistance to hardening under the influence of heat and air according to DIN EN 12607-1 at 163°C plus an accelerated long term aging according to DIN EN 14769 (penetration at 25°C and softening point)
• Rheological properties using dynamic shear rheometer (temperature sweep and multiple stress recovery test) and bending beam rheometer
Bitumen manufacturer perform these testings quarterly with the conventional bitumen 30/40, 50/70, 70/100 and 160/220 and with the polymer modified binder 25/55-55, 10/40-65 and 40/100-65, asphalt mixture manufacturer via an extended in-house production control and contracting entity through an extended verification audit.
Around 3000 records yearly are collected by the Ruhr-Universität Bochum with the help of a specifically developed internet-based database. The statistical evaluation yields a very extensive overview of the rheological characteristics of bituminous binder and may serve for specifications in future sets of rules.

Keywords: Quality assurance, Standardisation

1. Introduction

In the recent years, the durability of roads wasn´t as long as expected. Different factors influenced the loss of durability, which were mainly located in asphalt wearing course, although in asphalt binder course. One result of causal research was that the required qualities of asphalt and bitumen complied with German specifications. Nevertheless, the production process of asphalt itself and the paving process as well as the influences of weather and traffic increase the stiffness of the asphalt pavement. This is mainly due to aging of the bitumen in correspondence with an increase of viscosity.
Based on this experience the German federal ministry of Transport and Digital Infrastructure extended the bitumen testing. Since 2013 additional testing is required for producers of bitumen and bituminous binder, producers of asphalt and public contracting authority. Ruhr-University Bochum collects the data of these testing results. An internet-based database was developed therefor.
All the testing are still running and the data analysis have started in 2015. This paper reports preliminary results.

Analysis of the test data will allow a detailed and extensive evaluation and interpretation of the development of bitumen viscosity during the lifetime of the asphalt pavement. With these results, new asphalt concepts could finally be designed (Figure 1).

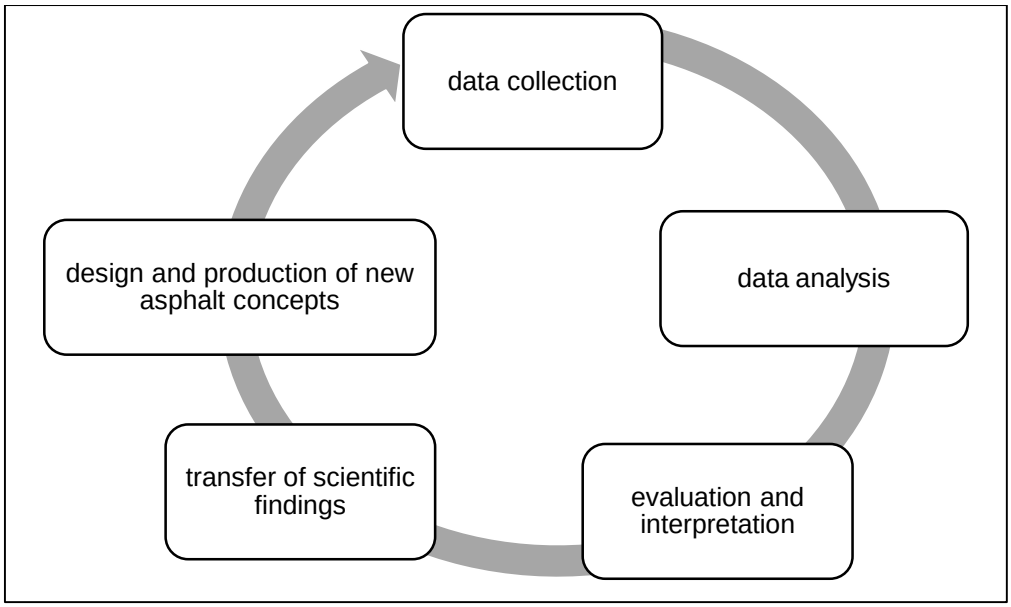

Figure 1: Score of the project

2. Bitumen testing

Data collection of four non-modified bitumen 30/45, 50/70, 70/100 and 160/220 and three polymer modified bitumen 25/55-55, 10/40-65 and 40/100-65 is structured as follows:
Producers of bitumen and bituminous binder extend their bitumen testing in line with their in-house production control and deliver testing results three times a year. Producer of asphalt also extend their in-house production control. They deliver the testing results in dependence of their product quantity. Public contracting authorities test bitumen characteristics after delivery as well as on extracted bitumen. They deliver testing results for each layer every 6000 m². Table 1 gives an overview of the extended bitumen testing program.

The physical characterization consists of classical bitumen tests – softening point ring and ball [1] and needle penetration [2]. It was tested fresh, short time aged in Rolling Thin Film Oven (RTFOT) [3] and long-time aged in Pressure Aging Vessel (PAV) [4].
In the rheological bitumen tests using the dynamic shear rheometer (DSR), parameters complex shear modulus and phase angles between 30°C and 90°C are determined according to DIN EN 14770 [5] and the German standards AL DSR-Prüfung (T-Sweep) [6]. In addition, the Multiple Stress and Creep and Recovery Test (MSCRT) is performed in accordance to German AL MSCR-Prüfung (DSR) [7].
Regarding the cold-temperature properties rheological parameter are detected with the bending beam rheometer (BBR) according to DIN EN 14771 [8]. Parameters of stiffness and m-value are mostly measured at -10°C, -16°C and -25 °C.

Table 1: extended bitumen testing

<table>
<tr><th></th><th>Non-modified bitumen
30/45, 50/70, 70/100, 160/220</th><th>Polymer modified bitumen
25/55-55, 10/40-65, 40/100-65</th></tr>
<tr><td>Producer of bitumen
Three times a year</td><td colspan="2">- Softening point ring and ball of fresh and aged bitumen
- Needle penetration of fresh and aged bitumen
- Complex shear modulus and phase angle as result of DSR measurement of fresh bitumen
- MSCRT of fresh bitumen
- BBR measurement of fresh bitumen</td></tr>
<tr><td rowspan="2">In-house production control
1) every 300 tons
2) every 900 t / minimum once per year, starting at product quantity of 50 t
3) each 1.500 t / minimum once per year, starting at product quantity of 50 t</td><td colspan="2">- Softening point ring and ball of fresh[1)] and aged[2)] bitumen
- Needle penetration of fresh[1)] and aged[2)] bitumen</td></tr>
<tr><td></td><td>- Complex shear modulus and phase angle as result of DSR measurement of fresh bitumen[3)]
- MSCRT of fresh bitumen
- BBR measurement of fresh bitumen[3)]</td></tr>
<tr><td rowspan="2">Verification audit of public contraction authorities</td><td colspan="2">- Softening point ring and ball of fresh and aged bitumen
- Needle penetration of fresh and aged bitumen
- Complex shear modulus and phase angle as result of DSR measurement of fresh bitumen
- MSCRT of fresh bitumen
- BRR measurement of fresh bitumen</td></tr>
<tr><td colspan="2">- Softening point ring and ball of extracted bitumen
- Needle penetration of extracted bitumen
- Complex shear modulus and phase angle as result of DSR measurement of extracted bitumen
- MSCRT of extracted bitumen
- BBR measurement of extracted bitumen</td></tr>
</table>

3. Development and design of the Database (ICT-IMPLEMENTATION)

A centralized database was designed for the collection and management of the bitumen data supplied by the users. As the data will be uploaded from several different locations all over Germany/Europe, it needs to be connected to the Internet. However, several restrictions are necessary to guarantee data security. The decision was to use the Model-View-Controller (MVC) architecture to manage the information flow through the system. This separates the data management (model) from information visible to the user and the controller directs the flow through the application. The logic handling of user requests is processed by the Symfony2-framework, which is a PHP set of libraries to design MVC-applications for the web. It contains a database object relational mapper (ORM) "Doctrine", which manages the persistence of data according to previous modeled classes and provides a convenience Application-Programming Interface (API) to the developer. Figure 2 shows the system overview.

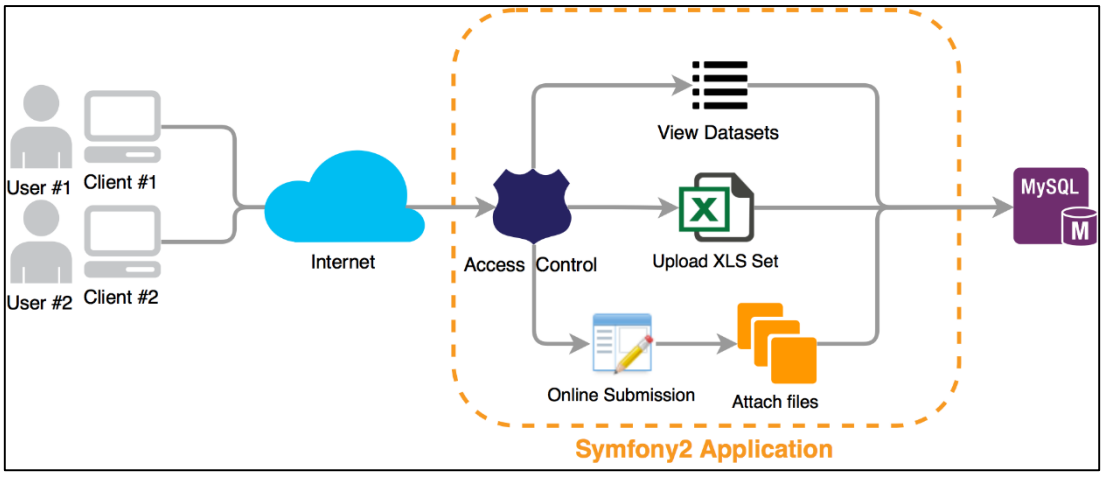

Figure 2: System Overview

Users will issue requests with their conventional web browser. They have to register and login to get past the access control mechanisms of Symfony2 and will be assigned a specialized role, which reflects their ability to interact with the system. Then it is possible to view already uploaded datasets, to upload new ones via a prepared Excel file or to use the online submission form to attach files. Online submissions are validated using dynamic and static rule sets, e.g. a field containing a numerical value should have such a value inserted by the user, but a field requiring a numerical value will not accept any character. Special combinations of values, such as descending numbers over multiple fields, are also validatable. All requests on the online submission form will be handled using asynchronous JavaScript-XMLHTTP-Requests, which enable direct validation of the values, instead of causing the application to load a new website, displaying the error information. Additional files may be attached after uploading of the main data, such as DSR/MSCR tests, initial and verification checks.

As data storage backend MariaDB, a fork of the public relational database MySQL, is used. With relational databases, it is possible to reference other data rows and create linked sets, which will not contain redundant information to minimize disk space usage. It is also possible to execute complex queries combining several data fields. The ORM-mapper Doctrine manages all operations and the system designer solely needs to create appropriate PHP classes. Convenience access to the properties of these classes is given and custom methods can be implemented. Checking several fields of the test results prevents duplicate submissions. If the system administrator runs offline, system maintenance scripts directly on the database, but other users will never have direct access to the data in the MariaDB backend. Logging is directly integrated into the logic of the application and every user action will trigger an entry into a special table, viewable only by administrators. This helps to analyze problems with the application and contains verified information about the system usage.

User objects are the most crucial part of such an application because of the contained personal information. Therefore, we decided to use the crypt-hashing algorithm of PHP to hash the passwords. Hashing is a one-way cryptography operation, normally used for file integrity checking, but special algorithms can be used to store passwords in a safe way. As the operation is not invertible, even system administrators and potential fraudsters do not have access to them. To increase the safety a “salt”-value, which is an additional, user specific string, consisting of random numbers and characters, is attached to the password and considered when hashing. In contrast to other hashing algorithms, crypt is slow and performance can be tuned using a special parameter, to make breaking of the hash-values uneconomical.

Special PHP libraries will enable an automatic evaluation of the uploaded data with graph components, so that a person maintaining the system can easily see the user-uploaded datasets. However, this has to be done after an initial testing phase of all the available parameters, to see, which evaluations will be beneficial. As the system is designed upon a plugin structure, it should be easy to maintain and extend, when needed. Nevertheless, vendor specific core updates to the underlying framework are a must and have to be scheduled by the administrative personnel.

4. Preliminary data analysis

In 2013 data collection has started. During that year, the testing program counted around 3.000 records. At present the records of testing data 2014 counts 1200 and 2015 less than 200. Various laboratories deliver these results. Almost 99% are located in Germany and the other ones all over Europe.

Figure 3 and figure 4 show the test results of 2013 and 2014 for softening point ring and ball versus needle penetration of non-modified fresh bitumen 30/45, 50/70, 70/100 and 160/200.

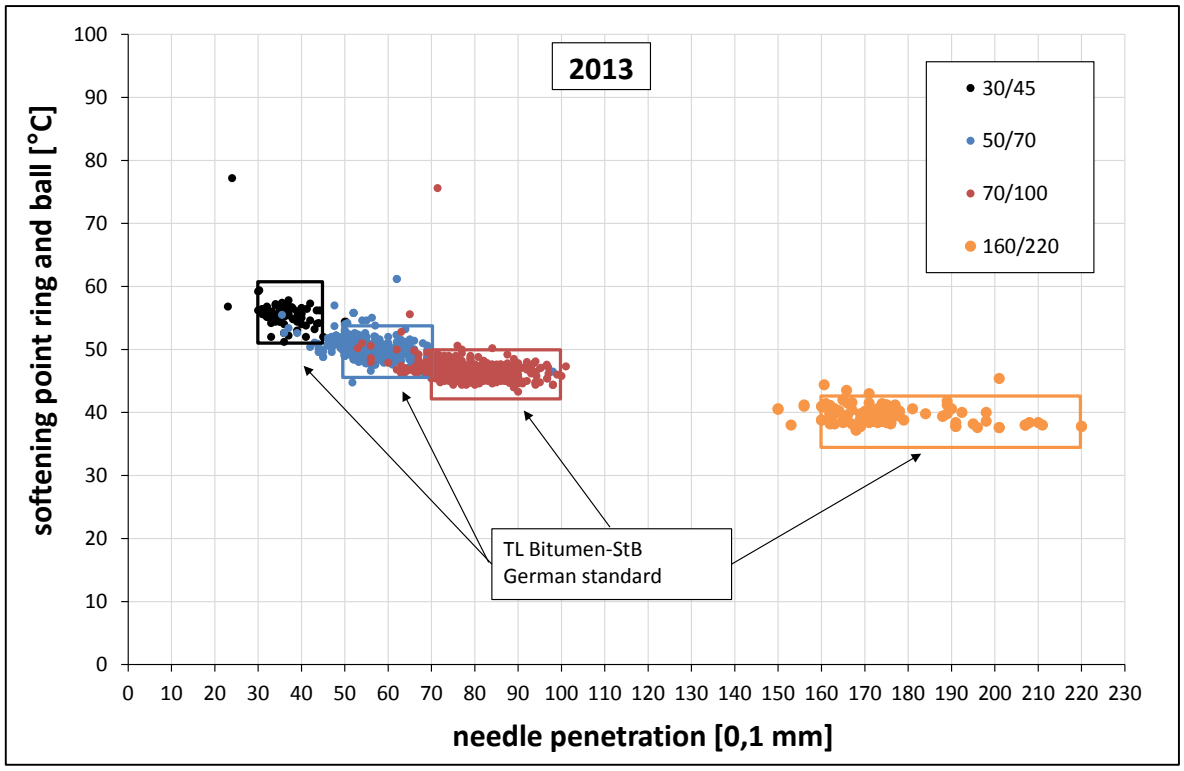

Figure 3: physical characteristics of fresh non-modified bitumen in 2013

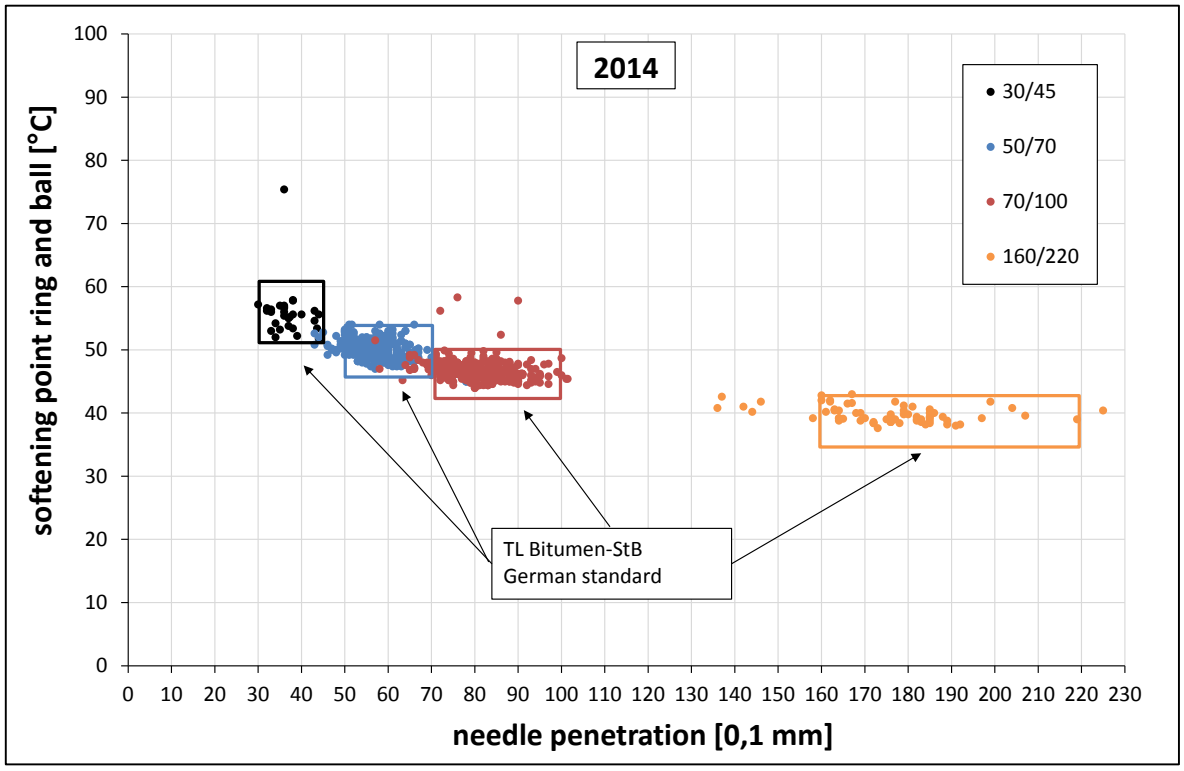

Figure 4: physical characteristics of fresh non-modified bitumen in 2014

Most of the data adhere to German guidelines TL Bitumen-StB [9]. Compared to the data of 2013 it seems that the testing quality has improved in 2014. Less spikes can be seen.
Significant in both years is the push across allocation of bitumen 160/220 testing results. Needle penetration ranges from 140 1/10mm to 220 1/10mm, but softening point ring and ball only ranges to a small amplitude from 38°C to 43 °C.
Table 2 summerize mean value, standard deviation, minimum and maximum of needle penetration test per year of fresh non-modified bitumen, table 3 the same analysis for softening point ring and ball.

Table 2: preliminary statistical analysis for needle penetration of fresh bitumen

Non-modified bitumen	Requirements [0,1 mm]	Mean value [0,1 mm]	Standard deviation [0,1 mm]	Minimum [0,1 mm]	Maximum [0,1 mm]	Number of records [-]
2013						
30/45	30-45	36,58	4,87	*23,0*	*51,0*	93
50/70	50-70	55,27	6,22	*35,5*	*98,0*	519
70/100	70-100	78,34	7,48	*53,0*	101,0	578
160/220	160-220	175,74	14,40	*150,0*	220,0	110
2014						
30/45	30-45	36,59	3,24	30,0	44,0	56
50/70	50-70	56,61	5,65	*42,2*	*78,0*	390
70/100	70-100	79,71	7,48	*57,0*	*101,4*	412
160/220	160-220	174,99	15,76	*136,0*	*225,0*	92

Table 3: preliminary statistical analysis for softening point ring and ball of fresh bitumen

Non-modified bitumen	Requirements [°C]	Mean value [°C]	Standard deviation [°C]	Minimum [°C]	Maximum [°C]	Number of records [-]
2013						
30/45	52-60	55,77	2,57	*51,0*	*77,2*	93
50/70	46-54	50,22	1,61	*44,8*	*61,2*	519
70/100	43-51	46,64	1,72	43,3	*75,6*	578
160/220	35-43	39,66	1,48	37,2	*45,4*	110
2014						
30/45	52-60	55,22	3,27	51,8	*75,4*	56
50/70	46-54	50,18	1,51	*45,0*	*55,7*	390
70/100	43-51	46,72	1,51	44,0	*58,3*	412
160/220	35-43	39,72	1,23	37,6	43,0	92

Figure 5 and figure 6 show the testing results of 2013 and 2014 for softening point ring and ball versus needle penetration of polymer modified bitumen 10/40-65, 25/55-55 and 40/100-65. A lot of the delivered data of bitumen 25/55-55 were labeled instead of "A" with "RC" in addition. Therefore, this cluster is split into two categories for the analysis. Bitumen producer recommend "RC" labeled products for layers with reclaimed asphalt pavement.

Overall testing results of bitumen 25/55-55 range from 55 °C to 70 °C and from 30 1/10mm to 50 1/10mm. In 2013 Bitumen 25/55-55 RC seems to be harder than 25/55-55 A. This needs to be confirmed with more testing results of 2014.
Test results of needle penetration and softening point ring and ball of bitumen 10/40-65 and bitumen 40/100-65 show a wide range.

Table 4 and 5 summerize mean value, standard deviation, minimum and maximum of needle penetration test and softening point ring and ball per year of fresh polymer-modified bitumen.

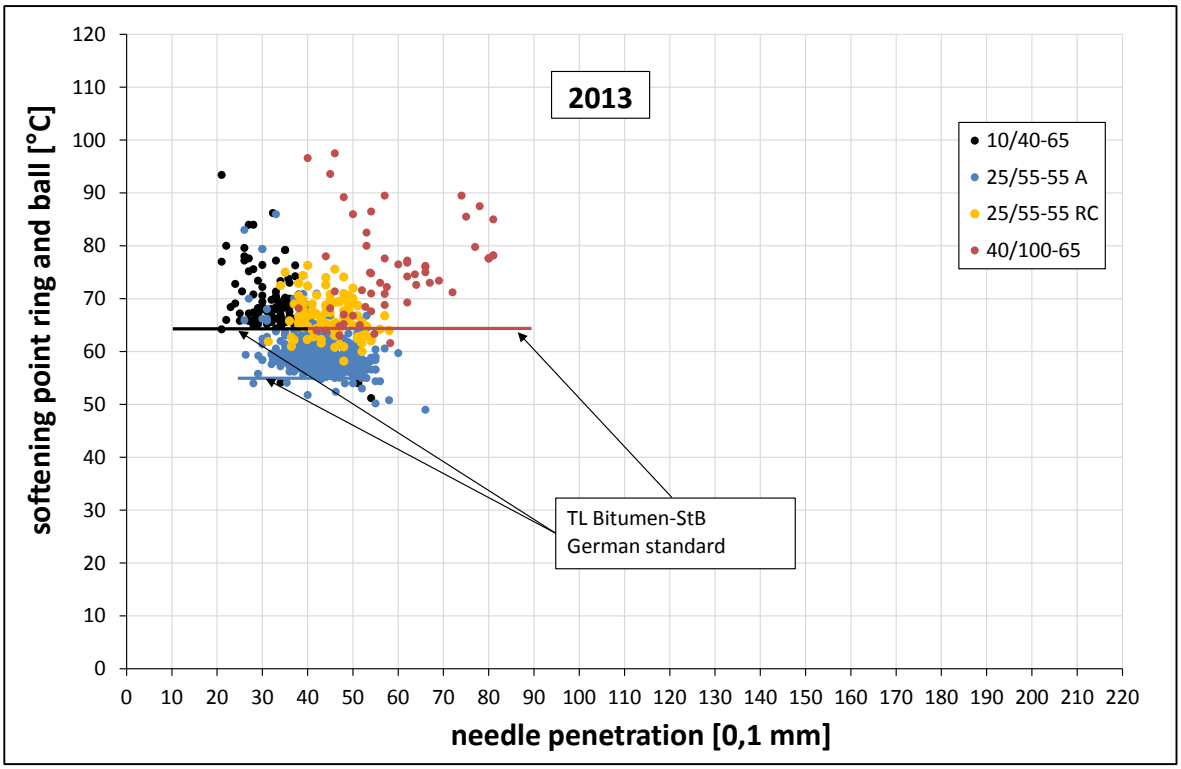

Figure 5: physical characteristics of fresh polymer modified bitumen in 2013

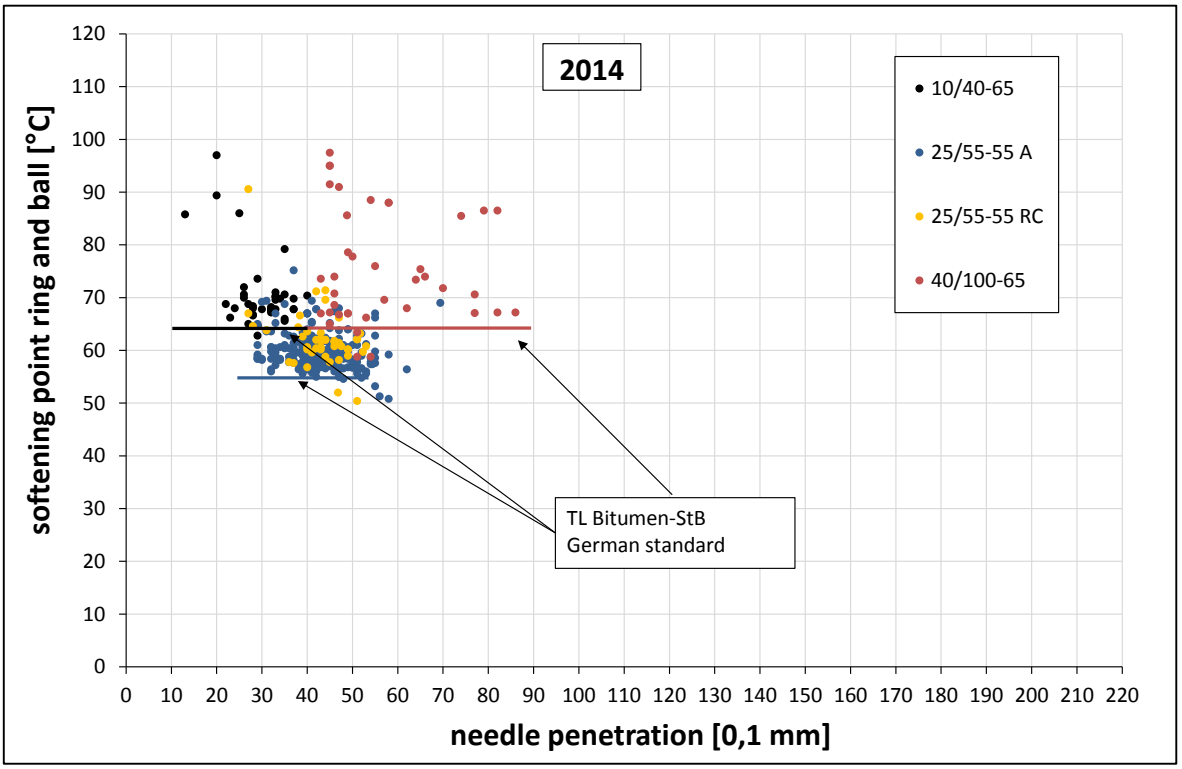

Figure 6: physical characteristics of fresh polymer modified bitumen in 2014

Table 4: preliminary statistical analysis for needle penetration of fresh bitumen

Non-modified bitumen	Requirements [0,1 mm]	Mean value [0,1 mm]	Standard deviation [0,1 mm]	Minimum [0,1 mm]	Maximum [0,1 mm]	Number of records [-]
2013						
10/40-65 A	10-40	32,45	5,41	21,0	*54,0*	109
25/55-55 A	25-55	43,19	5,34	26,0	*66,0*	629
25/55-55 RC	25-55	44,82	5,37	31,3	*58,0*	109
40/100-65 A	40-100	58,65	11,83	*38,0*	81,0	57
2014						
10/40-65 A	10-40	29,62	5,47	13,0	40,0	39
25/55-55 A	25-55	42,49	6,81	28,0	*69,4*	240
25/55-55 RC	25-55	42,80	6,25	27,0	53,0	47
40/100-65 A	40-100	56,80	12,58	43,0	86,0	40

Table 5: preliminary statistical analysis for softening point ring and ball of fresh bitumen

Non-modified bitumen	Requirements [°C]	Mean value [°C]	Standard deviation [°C]	Minimum [°C]	Maximum [°C]	Number of records [-]
2013						
10/40-65 A	≥ 65	68,78	5,61	*51,2*	86,2	109
25/55-55 A	≥ 55	59,27	3,42	*49,0*	86,0	629
25/55-55 RC	≥ 55	61,59	4,06	*56,0*	76,0	109
40/100-65 A	≥ 65	75,53	8,59	61,6	97,5	57
2014						
10/40-65 A	≥ 65	70,71	7,08	*62,8*	97,0	39
25/55-55 A	≥ 55	66,52	3,16	57,4	80,4	240
25/55-55 RC	≥ 55	62,02	5,76	*50,4*	90,6	47
40/100-65 A	≥ 65	75,57	10,45	*58,8*	97,5	40

Figure 7 shows the delivered testing results of bitumen 50/70 for complex shear modulus versus temperature in 2013 and 2014. The improvement of the test results within these two years is significant.
For all types of non-modified bitumen in Germany the complex shear modulus of 15.000 Pa corresponds to the softening point ring and ball [10]. At the distinctive point of 15.000 Pa the temperature ranges around 3,5 K, which is less than the range of softening point ring and ball of German standards.

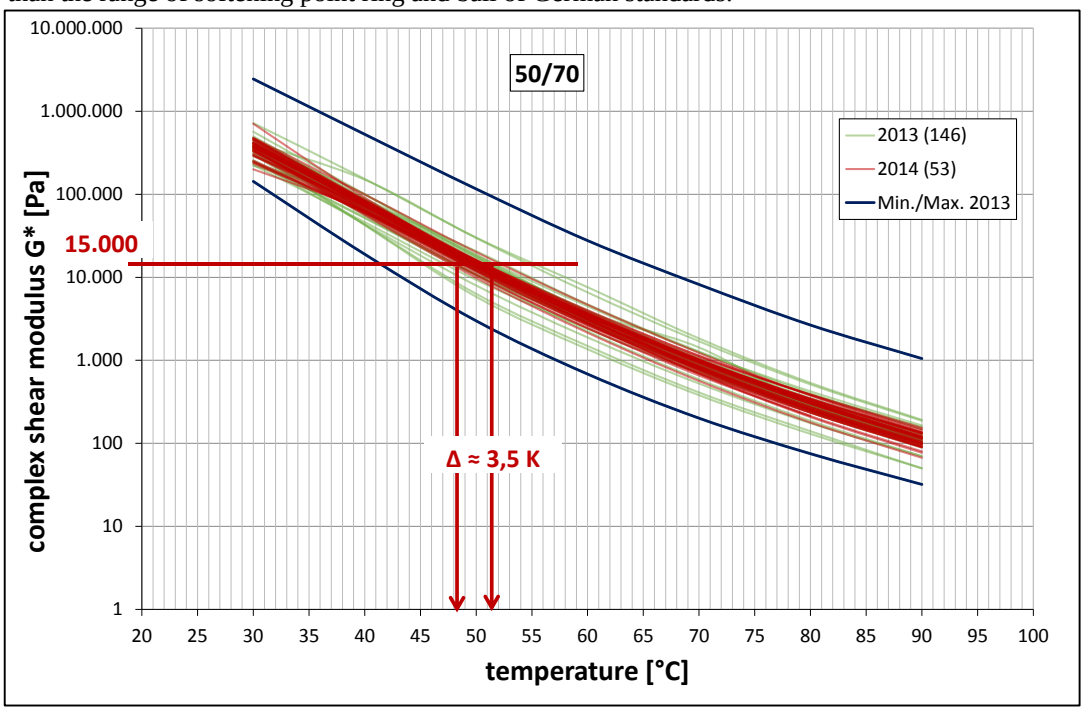

Figure 7: rheological properties of fresh non-modified bitumen 50/70

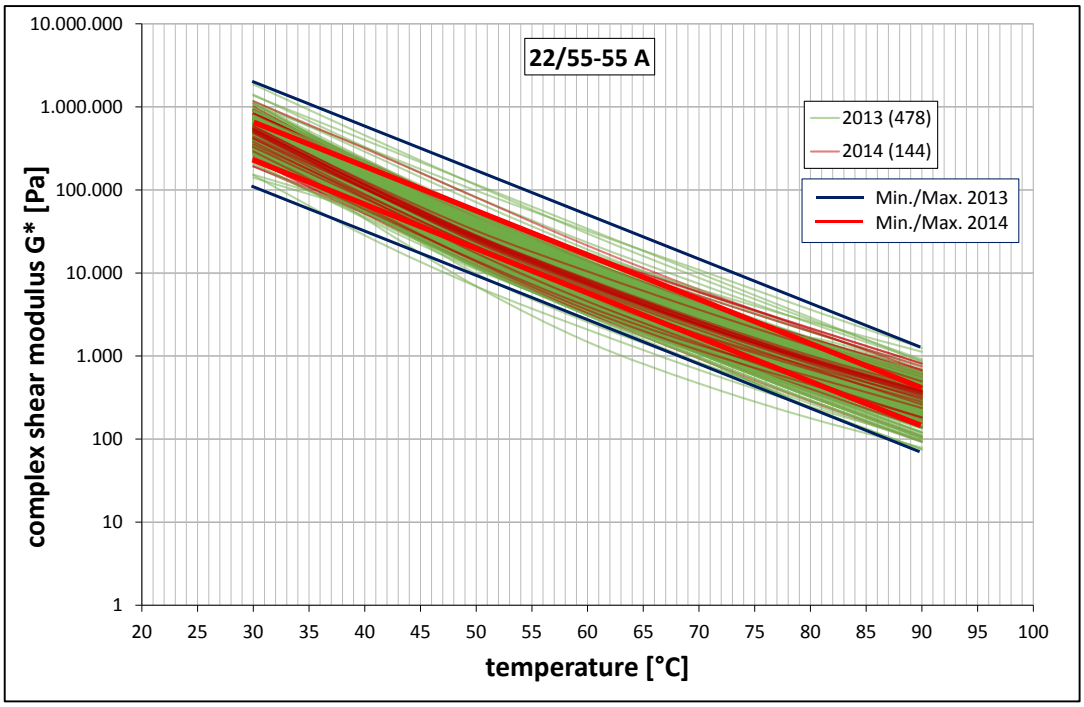

Figure 8: rheological properties of fresh polymer modified bitumen 25/55-55 A

Figure 8 shows the complex shear modulus versus temperature in 2013 and 2014 of polymer modified bitumen 25/55-55 A and figure 9 of bitumen 25/55-55 RC. The test results also improved in comparison to non-modified results, but the range of temperature is still high. When the delivery rate of test results will rise in 2014, the analysis could be refined.

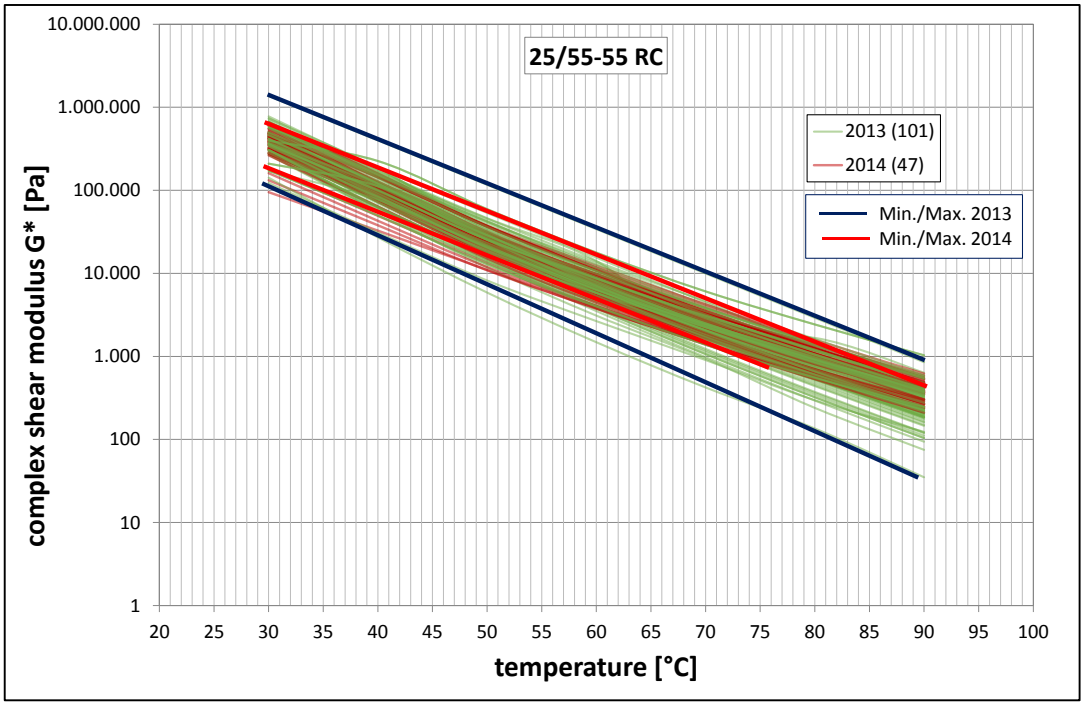

Figure 9: rheological properties of fresh polymer modified bitumen 25/55-55 RC

5. Perspective

Data collection started in 2013 and was established in 2014. All laboratories updated their testing routine and in consequence, the range of testing results improved significantly.

For the statistical evaluation and interpretation of bitumen´s behavior over a pavement lifetime testing data of 2014 and 2015 will be analyzed. This will give an overview of rheological characteristics of fresh, short-time and long-time aged bitumen. Future specifications may benefit from the conclusions of this comprehensive data collection.

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